Ignition Systems | Catalytic Converters | Water Injection | Motor C

About Spark Plugs

Before we start to talk about ignition systems let's first have a look at what the experts have to say about sparkplugs. If you came to this page without reading the introduction to ignition systems first, we suggest you do that now to give you a fair idea about which experts we are talking, always useful to know, follow this link to come there; ignition systems introduction, otherwise just continue reading.

If you read technical car magazines and forums you may have noticed that there is a lot of confusion about spark plugs and what the different esoteric materials and designs can mean for the performance/economy of your car. "Jacobs Electronics" have researched this subject and we believe that the outcome of these tests is very clear and will help you take future decisions with confidence, moreover knowing about this could save you money..

Let's get on with what Jacobs has written about this..

SPARK PLUGS

The type of ignition system you have on your vehicle will, to a great extent, determine what kind of sparkplugs you buy. The better the system, the colder the plugs you **can**, but **don't have** to use. In the olden days B.C. (Before Camaro), ignitions, like the computer-type, and before even electronic ignitions, you had to change plugs going from street to strip because Rule No. 1 where plugs are concerned is: **THE WORSE THE IGNITION, THE MORE CRITICAL THE PLUG SELECTION**. If you've got a Bosch or Lucas system, for example, you may even be looking at buying specialty plugs (see SPECIALTY PLUGS later on in this article) to compensate for what I believe is a weak ignition.

Others, looking for a free lunch, have bought those more horsepower, make your engine last forever, double your mileage absolutely G-U-A-R-A-N-T-E-E-D neat plugs. There is such a big mark-up, retailers can afford full page ads to promote these something- for- nothing specialty plugs. I'm here to tell you to use your own good sense; obviously these plugs can do no more than your standard two-electrode plugs. That is, no more than light off the fuel in the cylinder. **Please don't get sucked into buying anything because of claims that appear to violate the laws of physics**.

The words hot or cold in reference to sparkplugs can be confusing because a hot plug is normally used in a cold smogtype engine and a cold plug in a hot performance engine. The terms refer to the plug's ability to transfer heat from the firing end into the engine cylinder head and thence into the coolant.

The nose of the plug is near the center of the combustion chamber where it is the hottest. Consequently, it absorbs the most heat. Plug tips or noses have an ideal operating temperature of about 700 degrees F (which is 371 C), regardless of engine type. If the plug nose is hotter than this (a hot plug), it will glow, and you'll get detonation that can destroy engine parts. Too hot a plug also works itself to death in a matter of a few miles. If the plugs are too cold (a cold plug), say, about 350 degrees F (which is 177 C) when running, carbon builds up on them. They make an engine cough back, load up excessively, and need frequent cleanings or changes. Also, on the street, cold plugs cost you mileage.

The length of the core nose and electrode alloy material are the factors that determine the heat range of a sparkplug. Hot plugs have relatively long insulator noses with long heat-transfer paths. Cold plugs have much shorter insulator-nose length and transfer heat more rapidly.

If ignition timing, camshaft, compression ratio or carburetion is changed, heat-range substitution may be necessary. Stock-heat- range plugs recommended in the service manual may be replaced with slightly colder ones when you modify the engine. But without an ignition upgrade to, say, a hot multispark or preferably a computer ignition (not to be confused with OEM computerized fuel management and timing computers), the ultra-cold plugs required for best all-out racing performance or high speed highway driving wilt not work for slow putting around town. Extremely cold racing plugs do give better pre-ignition protection when fired by computer ignition systems. However, plugs thermally matched to give 700 degree F, 371 C, tips are superior to too-cold plugs, regardless of the type of ignition systems you are using.

Variable magnetic coils and transistorized or computer ignition systems do not require changes in sparkplug heat range. Rather, combustion-chamber temperature conditions, not spark temperature, determine optimum spark plug heat range.

If you are not running a blower, turbo, or heavy-duty nitrous, then a really good plug is the extended-nose, which acts as a hot plug at low speeds and cools off to act as a cold plug as rpm increases.

The cooling-off process is the result of inrushing air/fuel which blows past the extended tip. The projected core-nose plug benefits from the cooling effect of the incoming charge at high engine speeds. This extended cooling on the firing end provides greater pre-igniter protection at high speed and makes it possible to increase the insulator length on a given design, improving the spark plug-temperature characteristics when the engine is running at low speed. Also an extended tip puts the spark in a better position to start the ignition process.

However, if you are running a King Kong type motor where detonation could really be severe, you'd better pull the nose out of the combat zone and use regular nose or even a recessed nose plug.

Booster-Gap Plug

To understand a concept it is often helpful to go back in history to a simpler time and see how things were done then. A good example booster gap sparkplugs.

Called the "U" series, they have unfortunately been discontinued; however when available, they were one of Champion's best contributions to preventing plug fouling and hence the need for ultra-frequent plug replacement. Inside the porcelain of a booster-gap plug is an actual 5/16 to 3/8 in. (8 to 10 mm) gap. Before the spark reaches the electrode gap inside the combustion chamber, it must first jump the booster gap. (see picture if you can't visualise this).

How can a gap in the path of spark current help ignition? It works like this: without a booster gap, as the coil output voltage slowly reaches the center electrode of the plug, but before arc-over occurs, the coil's voltage begins to stack up on the spark plug's center electrode. The more electrons the coil can deposit on the plug's electrode, the higher the sparkplug voltage. If the coil's voltage gets high enough, a spark will occur.

The problem is that most coils put out current (current is the flow of electrons) so slowly (called rise time), that it takes a long time (about 100 microseconds) for the plug to finally reach arc-over voltage. During this rise time, when the coil needs to stack electrons up on the center electrode, there are many paths for leaking electrons off that electrode: carbon fouling, combustion chamber turbulence, and any dampness, such as moisture in the morning, gasoline or oil. It's like trying to use a slow-running garden hose to fill a small bucket with holes in the bottom.

What happens with a booster gap is that the coil has all the time it needs to slowly stack up electrons behind the booster gap. Since there is no place for the electrons to leak to, there is a bunch of them stacking up; that is, lots of voltage. When there are sufficient stacked up electrons (voltage) to arc (jump) the booster gap, this avalanche of electrons hits the center electrode with so much current, so fast, there is no time for the leaking sources to rob the electrons away. To put some numbers to this basic principle, rise time drops from 100 microseconds to about 4. This is like the coil slowly filling a big, solid bucket, then quickly pouring its contents into the smaller, leaky one mentioned above, immediately filling it to the brim, arcing over before the leaky holes get a chance to rob electrons. The **disadvantage** of a booster gap is that it reduces spark duration and energy. As the coil output starts to trail off, the booster gap shuts down the spark; that is, stops conducting sooner than a direct connection plug would have.

The need for booster gap type action has never diminished. Fortunately, electronic solutions are now available. For example, a computer ignition achieves the same result by storing tremendous energy within itself. At the proper time to generate a spark, a computer ignition directs such a healthy chunk of current to the coil, generating arc-over so fast, it's like blasting the leaking sources with a full-on fire hose. Leaky plugs don't even know what hit them.

RESISTOR PLUGS

Resistor-type plugs, in no way I've ever seen, help ignition or plug life, but on the other hand, they don't significantly hurt them either. If radio reception is important to you, it's just fine to use them. In a full-race situation I wouldn't recommend resistor plugs because I've seen resistors go away; that is, open circuit from the heat on hot-running race engines, and even on street machines, especially when using alternate fuels like propane. In my experience, Autolite, which is really my long-life favorite, does open circuit more than most. On the other hand, Champions, my plugs of choice if fouling is a problem, seem to have the most stable resistors. AC plugs are in between soft, hot electrode Champions and hard, long-lasting Autolites.

SPECIALTY PLUGS: EXOTIC, METAL AND WEIRD GEOMETRY TYPES

Specialty plugs work by reducing the amount of voltage required to jump the spark gap, thereby making it easier on a weaker ignition. The amount of voltage necessary to achieve arc-over at the electrode gap is set by the following characteristics:

- The size of the gap, where arc-over voltage is roughly proportional to the gap size.
- The air/fuel ratio within the gap, whereas the richer the air/fuel ratio (more gasoline vs. air), the lower the required arc-over voltage.
- The compression at the moment arcover is to occur, whereas the higher the compression, the higher the required arcover voltage.
- The composition of the electrode, whereas certain metals, for all conditions stated above, will require less arc-over voltage than other metals. For example, platinum requires less arc-over voltage than does steel (all other things equal).
- The shape of the electrode, whereas the sharper and more jagged the shape, the easier it is for voltage to jump.
- The amount of fouling deposits trying to remove electron flow from the arc, where with more fouling deposits, the resistance to ground is lower-, they do not raise the voltage required to achieve arcover, but make the ignition system work harder to reach that voltage.

While it may therefore seem desirable to lower the required arc-over voltage, since without arc-over there is a total misfire and no ignition, low arc-over voltage produces low spark power because **spark power is directly proportional to the square of arc-over voltage**. That is, by doubling the required arc-over voltage, you quadruple the instantaneous peak spark power and the higher the spark power, the better the ignition.

(Note CDC, elsewhere in Jacobs' book it is also described how the time lapse between the time your timing light flashes and the actual beginning of the burning of the mixture in the combustion chamber (**as a whole called ignition lag**) is delayed in 3 phases.

The 1st phase is called the **voltage rise time lag**, which is the time lapse from when the spark voltage first starts and your ignition timing light flashes till the spark **current begins.**

The 2nd phase is called the **transport lag** and is the time lapse between when the current begins and a ball of flame is initiated. This ball of flame starts at the diameter of the sparkplug gap.

The 3rd phase is the time lapse between the beginning of the ball of flame until it has grown to 0.100 inch (2.54 mm) diameter, this part of the ignition lag is called the **growth lag**, after this the flame propagates very rapidly.

Unfortunately the ignition lag as a whole is not very predictable, in which case it would be easily compensated for by additional timing advance. The lag moves in waves and the scatter is worse than any normal spark scatter, timing can vary randomly from between 2 and 12 degrees(!).

You can now see clearly that any action taken to reduce this scatter will pay back in improved power and economy. There are only 2 things we can do about reducing this, one is to improve the spark profile, which deals with how intense or long the spark is, not with timing per se, and the other is to reduce the growth lag by having a sparkplug gap as close to the magical 0.100 inch as possible with your ignition system without losing this improvement because of an increased amount of misfires because your ignition system cannot handle the larger gap consistently. Note that just having a lot of power on the ignition system **without having it controlled** would lead to punch through or cavitation, basically also misfires although not always. We can only advise you to buy Jacobs' book to to read more and get a good understanding about all of this. End of note CDC).

The essence of ignition is, therefore, a balance between the requirement to have sufficient arc-over voltage vs. increasing spark power for better, quicker ignition. It's a lot like playing Black Jack. You want to get the required arc-over voltage as close to the peak ignition voltage capability (like getting 21 points in Black Jack) as possible, but if you get the required voltage higher than the capable voltage, you bust.

The primary advantage of a specialty plug, say, platinum, especially in an OEM ignition system and particularly in an older OEM system that's not producing as much voltage as when it was new, is platinum requires less arc-over voltage. In such a weak ignition, platinum allows the spark plug gap to be jumped a higher percentage of the time.

For example, with plugs gapped at factory specifications, due to the changing engine environment and running conditions, with steel electrode plugs, it requires as much as 18,000 volts to achieve arc-over 5% of the time. If the OEM ignition only produces 17,000 volts, then it follows that 5% of the time there will be a misfire.

On the other hand, by installing platinum plugs, which may require only 13,000 volts to achieve arc-over, the 5% of misfires with steel plugs would be eliminated. Since the output on OEM ignition rolls off as RPM increases, platinum plugs, in this case of a weak OEM ignition, specialty plugs would allow the motor to reliably run at higher RPM, thereby giving an increase in performance and possibly gas mileage.

The disadvantage of this method for reducing misfires is that the higher the arc-over voltage, the better the spark when it does fire. Therefore, platinum plugs will show a performance improvement with a weak ignition, only because the benefit from reducing the percentage of misfires more than outweighs the loss from reduced spark power.

Split Fire (split or forked side electrode) plugs also reduce the amount of arc-over voltage, but they accomplish this in a different way. Rather than using a semi-precious metal, as platinum plugs do, a V is cut into the side electrode, giving three more "pointy" or jagged areas for the spark to jump from. It is the increase in the number of these "pointy" areas for the electrons, migrating from the center electrode, to "light"on (no pun intended), which lowers the arc-over voltage. All the advantages and disadvantages of platinum plugs described above are inherent with the installation of Split Fire plugs.

While certain geometry of electrode, such as splitting the side electrode, have gained in popularity, the principle behind all "unusually shaped" electrodes is virtually the same. That is, sparks like to jump from and to "pointy" objects. Therefore, the "pointier" or more jagged the object, the lower the voltage needs to be to arc-over. While not usually classified as a specialty plug, AC has a clever idea. If you look at the outside edge of their center electrode, you'll see it isn't smooth, but has protrusions like teeth on a gear. These teeth make lots of sharp points for a spark to jump from, lowering the required arc-over voltage. However, when the plug wears, the teeth go away and you're right back to the performance of smooth electrodes.

By the way, this explains why new spark plugs often increase miles per gallon and performance. That's because the center and side electrodes are cut nice and sharp on a new plug, whereas after being used for many miles, the constant flow of arcing electrons invariably tends to round them off.

Surface gap plugs, which provide a solid-state medium for the electrons to migrate across, generally allow electron flow, regardless of spark voltage.

However, they do not allow the fuel/air ratio 360 degrees of contact area with the migrating electrons, as is by an open gap spark plug, but rather only about 180 degrees. This is because 50% of the electron path is shrouded in the solid-state medium. Like platinum and split electrode plugs, they often mask a problem inherent in weak ignitions.

TEST CASE EXAMPLE

In Jacobs Electronics' extensive testing of assorted spark plugs, we have noticed an increase of power using specialty plugs, on some occasions, with weak ignitions. However, we have never seen an advantage to using specialty plugs with the Energy Team, Omni-Pak and especially with the Ultra Team ignition systems manufactured by Jacobs Electronics. In some cases, we have seen a slight loss of power when specialty plugs were installed in place of standard, steel electrode plugs at the same gap! On the other hand, we have seen a gain with specialty plugs when their lower arcover voltage requirement has allowed us to increase the plug gap above that possible with steel electrode plugs.

For example, we tested a 253 cu. in. V-6 engine, which was slightly modified, with the factory recommended .045" (1.14 mm) spark plug gap. With the stock ignition in place, it produced 168 horsepower. We installed platinum plugs gapped at the same .045" and the horsepower increased to 171. When we installed Split Fire plugs, the horsepower stayed at 171. With surface gap plugs, the horsepower rose to 172.5.

Next, we installed an Ultra Team (note CDC, a special coil and ignition wires package), reinstalling the original steel electrode plug gapped at .045" and the horsepower increased to 180.5. Keeping the gap a .045", we reinstalled all three sets of specialty plugs, recording an average 1.5 - 2 horsepower drop from the 180.5 recorded earlier with the steel electrode plugs. The reason for this power loss was that the specialty plugs required less arc-over voltage at the same gap; therefore, the peak spark power fell off.

Then we experimented with the plug gaps, continuing to use the Ultra Team With steel electrode plugs, the peak horsepower achieved was 186 at .063 gap. Split Fire plugs achieved 184 horse power, but required a .067" gap, causing concern about piston contact. The platinum plug peaked at just under 185 horsepower, with an optimum plug gap of .066" * The surface gap plugs were not re-tested as their gap is a fixed surface and cannot be increased.

CONCLUSION

While specialty plugs can mask the effect of an inadequate ignition system so can reducing spark plug gap in many cases. One of the true tests of a good ignition is to install a specialty plug instead a standard steel electrode plug. If the performance of the engine significant improves at the factory spark plug gap then the ignition was either inadequate or operating in its marginal range.

While all results will vary depending on engine size and driver tendency, our results are representative and show the balance between the need to lower arc over voltage requirement to assure spark actually occurred and the need raise arc-over voltage requirement to get higher peaked spark power. As a rule, the better the ignition system, the less benefit will be gained from using special plugs unless the installer is willing to go to monstrously large gaps.

If you're deciding whether special plugs are right for you, or you've already spent $50.00 for a set and want to optimize their potential, give our Technical Service department a call at (800) 627 8800. They'll be glad to help you make the most of either situation.

This is were we stop this subject's quotation by Jacobs.

Jacobs book has more, about indexing spark plugs, about reading of sparkplugs and what it all means and to whom and what it should absolutely NOT mean. Also about thread lengths, the effects of them and what to do when you have a problem in that area. Again, buy the book to know what the experts have experimented with and found to work or not work.

There are other important economy factors dependent on a controlled and powerful spark. One of the observations is that a larger sparkplug gap on a capable ignition system improves economy AND power much beyond the smaller economy gain, but resulting powerloss, achievable with a standard OEM yet marginal system, already explained a little bit by the above. Yet another point is that the leaness of the mixture is determined by the ability of the ignition system to ignite the mixture predictably, timely and consistently with regards to ignition lag.

As proven today, **once underway** Air/Fuel mixtures of 25 to 60 to one burn rapidly. Now this is achieved by for example by the popular air shrouded injectors, the preignition chamber with richer mixture and latest the new (Mitsubishi) direct injection systems making the mixture easier to ignite by manipulating the fuel droplet size, or by precombustion chambers or staged injection providing a small charge with an richer mixture for ignition start and a leaner charge to be ignited by the burning of that richer mixture. All in all **mixtures can be a lot leaner** than they are today **resulting in fuel savings**.... Think what could happen if we combined todays and future computer controlled spark quality with these fuel mixture manipulating tricks, interesting times, also for aftermarket producers researching retro fitting these technologies to yesterdays cars...

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