DON'T NEGLECT THE SPARK PLUGS

If you had to name one item that has more of an effect on engine performance than anything else, it would have to be the spark plugs. The plugs are the business end of the ignition system that delivers the all-important spark needed to ignite the air/fuel mixture. No spark means no combustion, wasted energy, increased emissions, loss of performance, idle roughness, hesitation, hard starting—and possibly even a no start if all of the plugs are affected.

Consider for a moment what happens when a plug fires. The spark is created when high voltage supplied by the ignition coil jumps across a small air gap between the plug's electrodes. The high voltage surge from the coil goes down the plug's center electrode, ionizes the air between the electrodes (the air gap) and forms a spark (arc) as it jumps across the gap to the outer ground electrode. The initial voltage required to form the spark may range from 4,000 up to 28,000 volts depending on the distance between the electrodes, engine load and compression (larger distances, higher engine loads and compression all raise the firing voltage requirements). The spark only lasts about a millisecond, but it is long enough to start the burn.

The instant at which the spark occurs is timed precisely to coincide with the position of the piston as it approaches top dead center on its compression stroke. On most engines, the spark occurs a few degrees before the piston reaches top dead center. If the spark occurs too soon (over advanced timing), cylinder pressures rise too quickly and peak too early in the cycle resulting in a loss of power. This can also cause engine damaging "detonation" (spark knock or ping) to occur. If the spark occurs too late, cylinder pressures peak too late in the cycle also resulting in a loss of power. Ignition (spark) timing is controlled by the engine computer and ignition module, **not the spark plugs**, so a timing problem would indicate a sensor or module problem.

PLUG PROBLEMS

If an engine cranks but won't start, one of the first things you should check is spark. No spark at any of the plugs usually indicates an ignition problem that requires further investigation (a bad coil, ignition module, distributor pickup, crank sensor, etc.).

If the engine runs but misfires, one or more spark plugs may be worn or fouled, or there may be one or more bad spark plug wires. To diagnose this kind of problem, observe the firing pattern for each cylinder on an oscilloscope. A higher than normal firing voltage in any one cylinder may indicate excessive resistance in a plug wire, a loose plug wire, or a badly worn or misgapped spark plug (too wide). A lower than normal firing voltage in any one cylinder may indicate a shorted plug wire, or a fouled or damaged spark plug.

Fouling is the number one reason why spark plugs have to be replaced. Plugs also have to be replaced for preventive maintenance because the electrodes wear as the plugs age. This increases the distance between the electrodes, which in turn leads to a gradual increase in the firing voltage required to jump the gap. The gap on a standard spark plug grows about 0.00063 to 0.000126 inch for every 1,000 miles of normal driving, which means the firing voltage requirements creep up about 500 volts for every 10,000 to 15,000 miles of driving. Eventually the plug's firing voltage requirements under load exceed the ignition system's output resulting in a misfire. But most plugs foul out long before they're worn out. A single fouled spark plug is bad news because it can kill up to 25% of a four cylinder engine's power output. It's like riding a horse with a broken leg. A fouled plug will also cause a big increase in

fuel consumption and emissions (more than enough to cause an emissions failure and/or the check engine light to come on if the vehicle has an OBD-II system). Fouling can occur if fuel or oil deposits build upon the plug's electrodes. The ceramic insulator around the center electrode prevents voltage from finding a shortcut to the steel plug shell and ground. Deposits here may form a conductive path for the voltage to bleed off to ground, preventing it from jumping the gap and making a spark. Deposits around the outer ground electrode or between the electrodes may form a barrier or bridge that also prevents a spark from occurring. Fouling can be a problem if an engine uses oil. Worn valve guide seals and guides can allow oil to be sucked down the guides and into the combustion chamber. A heavy buildup of thick black deposits on the plug and intake valve would indicate such a problem. Worn or broken rings, or damage to the cylinder wall can also allow oil to enter the combustion chamber and form ash deposits on the plugs. Extensive idling and/or short trip stop and go driving can also lead to a rapid buildup of normal fuel deposits. This occurs because the plugs never get hot enough to burn off the deposits—something which plugs are designed to do. Powdery black deposits on the plugs can occur from "carbon fouling." The underlying cause here is a rich fuel mixture. On an older carbureted engine, the problem might be a broken or stuck choke. On a fuel injected engine, the problem might be a leaky injector, or a dead oxygen sensor or coolant sensor that prevents the engine control system from going into closed loop and leaning out the fuel mixture.

"Reading" the old plugs can reveal not only the cause of a fouling problem but other types of engine problems too such as preignition and detonation. A melted or badly eroded electrode may be the result of over advanced ignition timing, engine overheating, low octane fuel, or too hot a plug for the application.

HEAT RANGE

The "heat range" of a spark plug determines how hot the plug runs during normal operation. If the heat range is correctly matched to the engine application, the plug will run hot enough under normal driving conditions to burn off fouling deposits before they can cause problems. Likewise, the plug won't get too hot and become a source of ignition causing engine-damaging preignition and detonation. If the plug's heat range is too cool for the application, though, fouling deposits may build up faster than they're burned off.

For this reason, always follow the vehicle manufacturer or plug supplier's heat range recommendations when selecting a spark plug for a particular application. Two spark plugs may appear to be identical on the outside but have entirely different heat ranges. There are situations, though, that may require a slightly hotter or colder plug than the one normally recommended. Switching to a slightly hotter plug can help reduce fouling in an older engine that uses oil, for an engine that spends a lot of time idling or is used for short trip stop-and-go driving. But a hotter plug should not be used unless an engine is experiencing a fouling problem because of the increased risk of preignition and detonation. For performance applications (racing, or engines that are run under heavier than normal loads or at high rpm for sustained periods of time), switching to a slightly colder plug can minimize the risk of preignition and detonation. Even so, a colder plug can increase the risk of fouling with extended idling and low speed operation.

Many of today's spark plugs have a very broad heat range because the plug manufacturer uses a copper core or platinum center electrode. Copper is an excellent conductor of heat, so the insulator can be designed to run hotter and burn off fouling deposits without it getting too hot under increased load to cause preignition or

detonation. A solid platinum center electrode will also carry heat away from the tip, but not if the electrode only has a platinum tip.

PLUG REPLACEMENT OPTIONS

The recommended replacement interval for standard spark plugs has typically been every 25,000 to 45,000 miles. But most of today's extended life plugs have special wear-resistant electrodes made of platinum, gold-palladium, nickel yttrium, iridium or other exotic alloys that minimize electrode erosion. Such plugs can usually go 80,000 to 1000,000 miles plus with little or no electrode wear. **Even so, they may still be vulnerable to fouling** if an engine has an oil consumption problem or spends excessive amounts of time idling.

Extended life spark plugs are a good upgrade for many engines, but may not be the best choice for an older engine that uses oil—**or even some performance engines.** According to one plug manufacturer, platinum tipped electrodes run hotter than standard electrodes. This may increase the risk of preignition and detonation in some turbocharged and high performance engines. For such applications, a standard plug with a colder heat range might be a safer choice.

There are also a wide variety of electrode configurations from which to choose today. Each manufacturer claims certain performance benefits for their particular design. It may be reduced electrode wear, or improved ignition reliability, or both. Such plugs are often marketed as "premium" or "performance" plugs, and may command a price of up to $6 or $7 apiece.

Some of these plugs (as well as standard plugs) also have multiple electrodes (two, three or four ground electrodes). A spark plugs with more than one ground electrode will still only produce one spark per ignition cycle. But with four paths from which to choose, the likelihood of getting a good spark to at least one of the ground electrodes is multiplied for improved ignition reliability. Having more than one ground electrode also distributes the wear to minimize electrode erosion and growth of the spark gap over time. Some such plugs also experience a self-cleaning effect because the sideways path of the spark helps burn deposits off of the insulator.

Are premium plugs worth the extra money? They are if they can provide extended plug life, reduce the need for maintenance or improve overall ignition performance. The plugs in many front-wheel drive cars and minivans with V6 engines are very difficult to replace. Installing extended life plugs can almost eliminate the plug change hassle for good. Likewise, performance plugs that reduce misfires can enhance performance for a smoother running, cleaner more fuel efficient engine. No spark plug can create power out of thin air, but improved ignition reliability can minimize any horsepower loss due to misfire.

When the plugs are changed, they should not be removed on engines with aluminum cylinder heads until the engine has cooled. This will minimize the risk of damaging the threads in the head when the plugs come out.

Most threads on spark plugs designed for aluminum head applications are precoated to reduce the risk of thread damage. If you're in the habit of applying a drop of antiseize compound to the plug threads before they go in for added insurance, you might want to reconsider this practice. One vehicle manufacturer warns against this practice because antiseize acts like a lubricant and may allow the plugs to be overtightened—which can damage the threads. Their advice is to reduce the tightening torque on the plugs 40% if you decide to use antiseize on the threads. How much the plugs should be tightened depends on the size of the plugs and the type of plug seat. Spark plugs with gasket style seats require more torque than those with taper seats.

Always follow the vehicle manufacturer's torque recommendations, but as a

general rule 14 mm plugs with a gasket style seat should be tightened to 26 to 30 ft.lbs. in cast iron heads, but only 18 to 22 ft.lbs. in aluminum heads. Likewise, 18 mm plugs with gasket style seats should be tightened to 32 to 38 ft.lbs. in cast iron heads but only 28 to 34 ft.lbs. in aluminum heads. For taper seat spark plugs, 14 mm plugs should be tightened to 7 to 15 ft.lbs. in both cast iron and aluminum, while 18 mm taper seat plugs should be tightened to 15 to 20 ft.lbs. in both types of heads.

As for setting the plug gap, always follow the vehicle manufacturer's recommendations—unless you are installing a set of Bosch's new Platinum+4 spark plugs. These plugs are pregapped at the factory to a standard 1.6 mm gap. This is necessary to achieve maximum plug performance and longevity. Therefore, do not change the gap .

Finally, play close attention to the condition of the spark plug cables and boots when changing the plugs. Loose fitting boots or damaged cables can cause ignition misfire. Also, make sure the cables are properly routed and supported in their looms to avoid crossfire problems and contact with the hot exhaust manifold.

WHY SPARK PLUGS STILL NEED TO BE REPLACED

One of the leading causes of hard starting is fouled or worn spark plugs. When a fuel-injected engine that normally starts quite easily has to be coaxed to life, it often means the plugs are overdue for a change. As the electrodes wear, the voltage required to jump the gap and ignite the fuel mixture goes up. At the same time, accumulated deposits on the insulator can drain off voltage before it even has a chance to form a spark. So the engine fails to start or starts only reluctantly after prolonged cranking.

One of the reasons why plug sales take off when cold weather arrives is because many motorists put off changing the plugs until they absolutely have to. The vehicle manufacturer's recommendations to change the plugs every 30,000 miles for preventative maintenance are ignored, so the plugs continue to rack up mile after mile until they've deteriorated to the point where they're causing noticeable drivability problems.

Emission checks will catch a lot of bad plugs and force motorists to change plugs that need to be replaced. But in areas where emission checks are not required, the only incentives for changing the plugs are the drivability problems created by the plugs themselves. So many motorists today think they're saving money on maintenance by putting off a plug change until it's obvious the engine needs new plugs. Then and only then will they begrudgingly spend any money on a new set of plugs.

WHY CHANGE 'EM?

What motorists need to be told today is why the plugs should be replaced according to their vehicle manufacturer's scheduled maintenance recommendations be it every 30,000 miles, or 60,000 to 100,000 miles in the case of long life plugs. So here are three good reasons why the plugs need to be changed:

REASON #1:

New plugs maintain peak engine performance and efficiency. Every engine will misfire occasionally. But as the number of misfires per mile goes up over time, it increases exhaust emissions, wastes gas and reduces power. In the past, most motorist wouldn't notice the gradual decline in ignition performance until it reached a point where it created a steady miss, caused the engine to run rough, buck or stall, or made it hard to start. Not so today. All 1996 and newer vehicles have an OBD II onboard diagnostic system that tracks ignition misfires. When the rate of misfires

exceeds a certain limit and causes emissions to increase 50% over baseline levels, it illuminates a warning light. Too bad every vehicle doesn't have this watchdog system onboard. Since they don't, the next best thing you can do is to recommend replacing the plugs for preventative maintenance BEFORE they deteriorate to the point where misfires become a problem and create problems. A new set of plugs isn't a cure-all for drivability and emissions problems, but in many cases a plug change can make a significant improvement. Changing the plugs can reduce hydrocarbon (HC) emissions up to several hundred parts per million, which may make the difference between failing and passing an emissions test.

REASON #2:
New plugs improve cold starting. Bad plugs are often responsible for many cold weather "no start" service calls. Many times the battery has been run dead while cranking the engine because the plugs wouldn't light the fire. When the old plugs are removed and examined, they are often found to be worn or dirty. New plugs reduce the voltage requirements on the ignition system, which decreases the chance of misfire while leaving more amps for the starter and injectors.
Wet fouled plugs can also prevent an engine from starting, but in many instances the fouling problem has nothing to do with plug wear or neglect. If an engine is flooded with fuel while it is being cranked, gasoline can soak the plugs and bleed off the ignition voltage before it forms a spark. Wet fouling tends to be more common on older vehicles that have carburetors because pumping the gas pedal can easily flood the engine with too much fuel. Flooding can also occur if the choke sticks, the float is set too high or the needle valve leaks. On fuel injected engines, wet fouling is less of a problem but can happen if a cold start injector leaks or there's a fuel calibration problem that creates an overly rich startup mixture. The cure in all cases is to wait for the plugs to dry out, or to remove the plugs and clean or replace them.

REASON #3:
New plugs minimize the risk of catalytic converter failure. A single misfiring plug can dump enough raw fuel into the exhaust to overheat and damage the converter. The presence of higher than normal quantities of unburned gasoline in the exhaust will cause the operating temperature of the converter to soar, which may lead to a partial of complete meltdown of the converter's substrate. This, in turn, may form a partial restriction or complete blockage in the exhaust that creates enormous backpressure and chokes off the engine's ability to exhale. The engine may lack power, especially at higher speeds, and deliver terrible fuel economy. Or, it may stall and refuse to run after it is first started. Replacing the converter will solve the restriction problem. But unless the plugs are replaced, the new converter may soon die from the same ailment.

ABOUT PLUGS
As we've already said, the spark plugs are the business end of the ignition system. Whether an engine has a conventional distributor or a direct ignition (distributorless) system, a good set of plugs is absolutely essential for peak performance.
The typical spark plug needs anywhere from 5,000 to 25,000 volts from the ignition coil before it will fire. The exact firing voltage depends on:
· Plug gap—the wider the gap, the higher the voltage required. The gap must be set to specs for good ignition performance.
· Electrode condition—wear increase voltage requirements. Fouled electrodes may not fire at all!
· Engine load—higher load increases voltage needed. If the plugs are worn or gapped to wide, they may misfire under load.

· Resistance—electrical resistance in the plugs and wires increases voltage required. Replacing worn, damaged or loose fitting plug wires is recommended for improving ignition reliability.
· Operating temperature—a cold plug requires more voltage to fire than a hot one.

Reliable ignition, therefore, requires a hot spark from the coil, good plug wires to carry the juice, and spark plugs that are clean, in good condition and gapped properly. If any of these criteria are not met, the spark may not reach it intended destination causing the engine to misfire.
One way to tell if the plugs need changing is to look at a vehicle's odometer. If it's been more than the recommended number of miles (usually 30,000) since the plugs were last changed, it's time for a new set.

Another way to tell is to observe the secondary ignition pattern on an oscilloscope. If there's an open plug or wire, the plug won't fire causing the firing voltage to shoot up to the maximum output of the coil. Badly worn plugs or plugs that have been misgapped too wide will also increase the firing voltage dramatically (as can a bad rotor and/or ignition cables with excessive resistance). If the required voltage exceeds the maximum output of the system, the plugs won't fire. If the pattern shows initial secondary spikes approaching the upper voltage limits of the system, therefore, it's a sure sign that the plugs (and/or cap, rotor and cables) need attention.
A fouled plug (or shored ignition cable), on the other hand, will show an unusually low firing voltage.

Firing voltages should not vary by more than 3 kV cylinder to cylinder. A cylinder that shows an abnormally low firing voltage probably has a grounded spark plug (deposits bridging the electrode gap), or a shorted ignition cable. A cylinder that shows an abnormally high firing voltage compared to the others likely has an open ignition cable or a plug with a wide gap.
The plug firing time (spark firing line) portion of the secondary ignition display shows the duration of the spark in milliseconds (thousandths of a second). The average spark duration with the engine idling should be about 1.5 milliseconds.

A duration of less than 0.8 milliseconds would mean there either isn't enough voltage to keep the spark going (low coil output), or the voltage is having trouble reaching its destination (excessive resistance in the plug wires). A longer than normal spark (1.8 milliseconds or more) is an indication that the firing voltage is experiencing little resistance because a plug is fouled or grounded (or a plug wire is shorted) probably due to accumulated carbon deposits. Fouling can be a problem if a plug's heat range is too cold for the application (which can be solved by installing hotter plugs). But it may also be the result of excessive oil consumption due to worn valve guides or seals, worn rings, or even short trip stop-and-go driving.

Intermittent misfires can be caused by a variety of ignition, fuel or mechanical problems. Lean misfire occurs when there's too much air and not enough fuel, so the engine should be checked for air or vacuum leaks, dirty injectors, carburetion problems or a leaky EGR valve. If the misfire appears to "jump around" from cylinder to cylinder, a manifold vacuum leak or a leaky EGR valve may be the cause. But if the misfire is isolated to a single cylinder, a worn or fouled spark plug (or bad plug wire) is the most likely cause.

READING PLUGS

Examining the tips of the spark plugs as they are removed can reveal a great deal about the health and performance of an engine. The appearance and color of the deposits can reveal other problems that may need fixing:

· Normal deposits—light brown or tan colored.

· Fuel fouled—black fluffy carbon deposits indicate an overly rich fuel mixture or possibly a weak spark. Check for such things as a stuck choke, a heavy or misadjusted carburetor float, a leaky needle valve in the carburetor, leaky injectors, low coil output or high resistance in the plug wires.

· Wet plug—a wet plug means the plug has not been firing. If not due to engine flooding, the problem may be a bad ignition cable (excessive resistance, shorted or arcing). But wet fouling can also be caused by dirt or moisture on the outside of the plug that provides a conductive path to ground, or by an internal crack in the ceramic insulator that shorts the plug to ground.

· Oil fouled—heavy black deposits with an oily appearance. These are the result of oil entering in the combustion chamber, probably past worn valve guides, guide seals or rings. Switching to a hotter plug may help prolong plug life somewhat, but no plug will survive long under such conditions. The only permanent cure to this condition is to fix the oil consumption problem.

· Glazed plug—yellowish melted appearing deposits on the insulator tip that result from high temperature operation. The engine may be running too hot (check for cooling problems), the EGR valve may be inoperative and/or the heat range of the plug may be too hot for the application. Switching to a cooler plug may be necessary if no other problems are found.

· Damaged plug—if the electrodes have been smashed flat or broken, somebody put the wrong plug in the engine. A plug that protrudes too far into the combustion chamber may hit the piston or a valve. Always follow the plug manufacturer's application recommendations when selecting replacement plugs to prevent this kind of problem.

· Overheating—if the insulator is blistered, white and free from deposits, something is making the plug run too hot. If the plug's heat range is not too hot for the application, check for cooling problems, incorrect ignition timing or a lean fuel mixture.

· Melted electrode—a symptom of severe preignition. The plug has been running too hot for a long time (see overheating above). This can be very damaging and may burn a hole through the top of a piston!

· Detonation—if the insulator is split or chipped, detonation (spark knock) may be occurring in the engine. The underlying cause here might be an inoperative EGR valve, overadvanced ignition timing, excessive compression due to accumulated deposits in the combustion chamber, or engine overheating.

REPLACEMENT TIPS

When spark plugs are replaced, you might want to upgrade to a "performance" spark plug. These plugs typically have unique electrode configurations that increase spark exposure to the air/fuel mixture and have multiple edges to reduce the chance of misfire. Performance plugs are usually more expensive than standard or even long-life plugs, but may be a good alternative if you want the ultimate in ignition performance.

There are also spark plugs today that are specially designed for truck engines. Such plugs have increased fouling resistance and oversized electrodes for longer service life.