Oxygen Sensor Tips

Oxygen sensors began appearing during the 1970's to help computer-control systems achieve the best possible balance of performance, economy, and emissions. Today they are found on nearly all new gasoline powered cars and light trucks sold in this country.

Even if you are not a new car dealer, you'll be seeing more computer-equipped vehicles with oxygen sensors that need service as time goes on.

We can't ignore the importance of the oxygen sensor when we try to understand the efficiency built into computer-controlled designs. Early emission systems were patchwork quilts of add-on components. Each component had a job to do, but there was no way to keep track of how well they did that job.

As a result, early systems were less than ideal. Compared to the efficiency of current systems, they were pretty sloppy.

The oxygen sensor changed all that. Suddenly we could keep tabs on the fuel mixture. We didn't measure the amount of unburned fuel in the exhaust. Instead, we measured the amount of oxygen that had or had not been used for combustion.

To Build A Fire

Even the cavemen figured it out. If you take a combustible substance and get it hot enough in the presence of oxygen, you get fire. You get heat. You get a release of energy. Take away any one of these things, the fuel, the heat, or the oxygen, and you get zip.

Somewhere in between a good fire and no fire at all, you get a bad fire. It doesn't burn well. It doesn't go out completely either. But one of the three elements needed for a good fire just isn't strong enough to really get things cooking.

The same thing happens in an internal combustion engine. You may not have enough compression or spark to light the fuel/air mixture (heat). You may have too little fuel, or too much fuel for the heat and oxygen available. You may have too little oxygen available to keep the fire going.

The point is, you don't have things in the right combination to make a really good fire.

To Build A Bad Fire

One of the best ways to figure out whether or not a fire is good is to keep track of what's left after the burning. A good hot campfire doesn't make much smoke. But throw a few wet logs on the fire. Then stand back.

Engineers needed a way to measure what was left in the exhaust after combustion.

The oxygen sensor was the answer.

When there's a bad fire in the combustion chamber, the oxygen doesn't combine with the fuel very well. There's a lot of unconsumed oxygen left over. The more oxygen left over, the worse the fire.

So we don't need to measure the amount of unburned fuel to determine the efficiency of the fire. We can just as easily measure the amount of unburned oxygen left over to tell us how well the fire is burning.

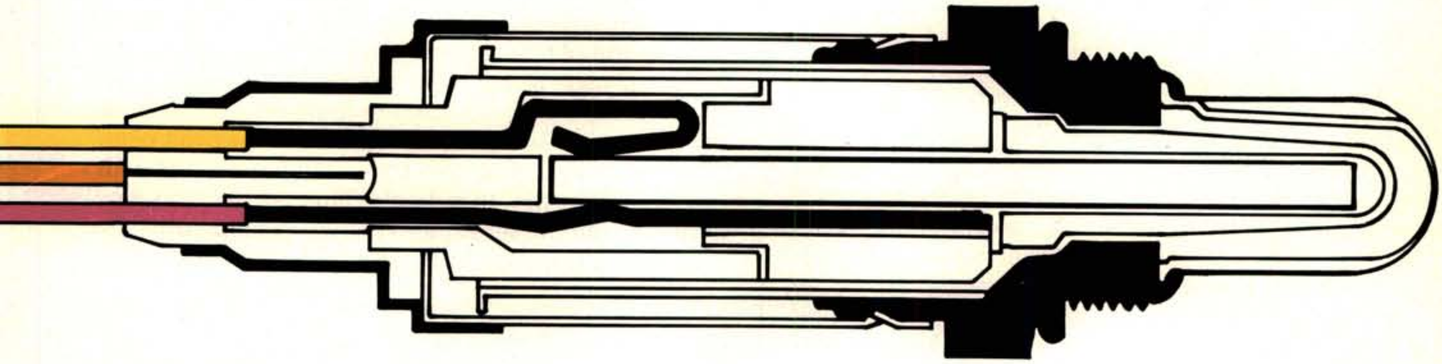
Oxygen Sensing

Two kinds of oxygen sensors are in use: zirconia and titania. The zirconia sensor is the most common, and the one you'll probably see. Each sensor contains a ceramic element made of zirconium dioxide. This element is coated with platinum. One surface of the element is exposed to exhaust gas. The other surface is exposed to outside air.

These two platinum coatings act like the opposite poles on a battery. And just like that sample battery you may have built in high school, when a difference in potential exists between those poles, an electrical current is generated.

Let's look at an example.

If the exhaust mixture is rich, it will contain less oxygen than the outside air. There's more fuel available for the oxygen to combine with, so there's less oxygen left over.



Richer Mixture=Less Oxygen in Exhaust=More Voltage

Now the oxygen ions from the outside air pass from the outer platinum surface, or pole, through the ceramic to the inner platinum surface, or pole. An electrical voltage is generated. The sensor acts like a small battery.

The opposite happens with a lean exhaust. There is more oxygen left in the exhaust, since there is less fuel for it to combine with. This amount of oxygen is closer to the amount of oxygen found in the outside, or ambient air. There is a smaller differential between the platinum poles. As the differential between the poles decreases, so does the current flow.

Leaner Mixture=More Oxygen in Exhaust=Less Voltage

This voltage changes very rapidly in response to changes in the amount of oxygen in the exhaust. Most sensors operate in a range of 100 to 1000 mV (0.1 to 1.0 volts). This tiny voltage is sent to the microprocessor as a signal. The microprocessor adjusts the fuel mixture to keep the fuel mixture in an acceptable range. This is called "closed loop" operation.

Operating Temperature

The oxygen sensor must be heated to work properly. The resistance of the ceramic changes with its temperature. Since early sensors were heated only by the exhaust, they were placed very close to the engine to get them hot and working as soon as possible.

There were two problems with the unheated sensors. First, they took too long to get hot. As a result, the engine stayed in open loop too long during warm up, and emission levels were still too high during cold engine operation.

Secondly, since the sensors were so close to the engine, they were sometimes scorched when a hot engine ran at peak load for a long time.

Heated Sensors

It was only logical that someone would eventually install a small heater in the sensor. This heater gets the sensor to operating temperature a lot sooner. It also allows it to be placed farther from the hottest part of the exhaust. This combination improves the efficiency of the sensor and extends its service life.

Heated sensors have three wires. Two for the heater (one hot with the engine running and a ground) and one "signal wire" running to the microprocessor.

When It's Time, It's Time

Always refer to the manufacturer's suggested replacement interval and encourage your customer to replace the oxygen sensor at that time. Let's say your customer has 50,000 miles on his car, and the owner's manual says to replace the sensor at that time. The customer is suspicious about replacing the sensor since the car is running properly. He asks you to check the sensor to see if it's working.

So you throw a voltmeter on the sensor and see that the voltage is fluctuating. What you don't know from this test is how quickly the sensor is responding to changes in the fuel/air mixture. Even sensors that fluctuate will take longer and longer to respond as they age. Their reflex action is a little slower than it once was—just like mine.

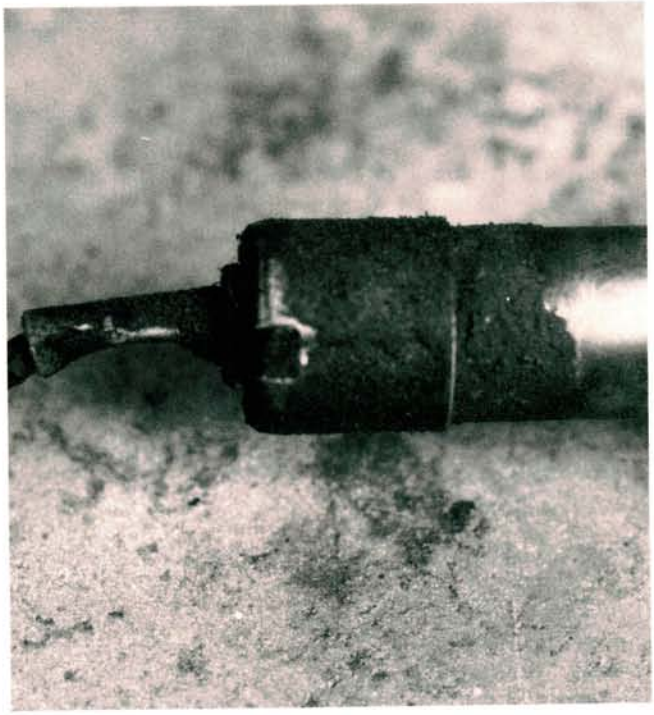
The average shop just doesn't have the sophisticated equipment to measure response times in milliseconds, and not all cars have ECU's with that capability just yet. So ignoring the replacement interval for oxygen sensors may be a false economy, at best.

—By Ralph Birnbaum

Unless an oxygen sensor is due to be replaced as part of the preventive maintenance schedule, be sure you thoroughly troubleshoot the system before changing the sensor. Simply removing the sensor and eyeballing its working end may not tell you anything. A sensor that looks good may not be working at all. Some of the uglier ones may work just fine. You could look at this group of sensors all day without knowing for sure which were good and which were bad.

Some visual inspections will tell what ails the sensor and the system. This sensor was the victim of a sloppy installation. Someone didn't properly secure the sensor wire. As a result, the wire sagged and rubbed against the exhaust manifold. Once the insulation was broken, the wire shorted against the manifold. Make sure you test this sensor carefully. Don't just tape the wire and let it go. It may be history by this time. If you do repair and reuse the sensor, properly secure the wire away from the manifold.

This oxygen sensor is not working. An over-zealous application of undercoating or sound deadener after body damage repair has blocked the sensor's air reference opening. No ambient (outside air) can enter the oxygen sensor. As a result, the sensor can't compare the amount of oxygen present in the exhaust with the oxygen in the outside air. This tar-like goo may have run into the sensor and ruined it. Hopefully, the sensor was the only thing ruined.



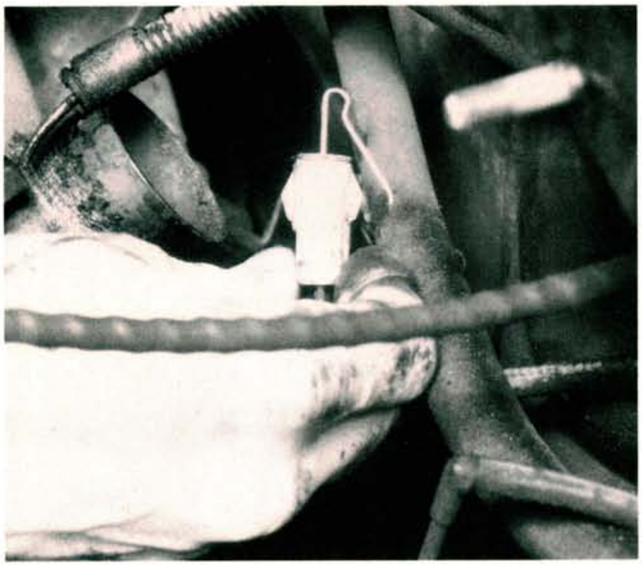
This sensor is oil fouled. The oil filler cap on the Renault Alliance from which this sensor came had a loose fitting gasket. The leak it caused allowed engine oil to run down the valve cover gasket and into the sensor. The problem may have been made worse by someone's poor aim with the oil can during an oil change. It looked like a lot of oil originally intended for the crankcase ended up on the sensor. Unlike door hinges and lock cylinders, oxygen sensors require no periodic lubrication!

You all know those color photo diagnosis charts of spark plugs that have been fouled by improper fuel mixtures or chemicals. Many of the deposits found on oxygen sensors are similar in appearance to the deposits found on spark plugs. And while you can't always tell a bad sensor by its appearance, you can get some clues about why a sensor failed by inspecting the deposits on the sensor tip. This sensor has been blackened by an over-rich fuel mixture, but may recover after being run in a lean mixture for a few minutes.

High engine oil consumption will leave these dark brown deposits on the sensor tip. Again, they look like the tip of a spark plug operating under the same conditions. These deposits may not kill the sensor right away, but they will reduce sensor efficiency, and ruin it in the end. Like the preceeding photos, this is an example of a basic problem that must be corrected before a new sensor is installed. Make it a habit to inspect every sensor you replace for clues like these.

The white chalky appearance of this sensor tip is probably caused by contamination from the improper use of an RTV sealer or even from silicone in the fuel. These deposits can accumulate on the tip of the sensor. This will result in a delayed response by the sensor to changes in the fuel air-mixture. Silicone will also cause a false message to be sent to the computer, resulting in improper fuel mixtures. Use only RTV sealers that are compatible with oxygen sensor systems.

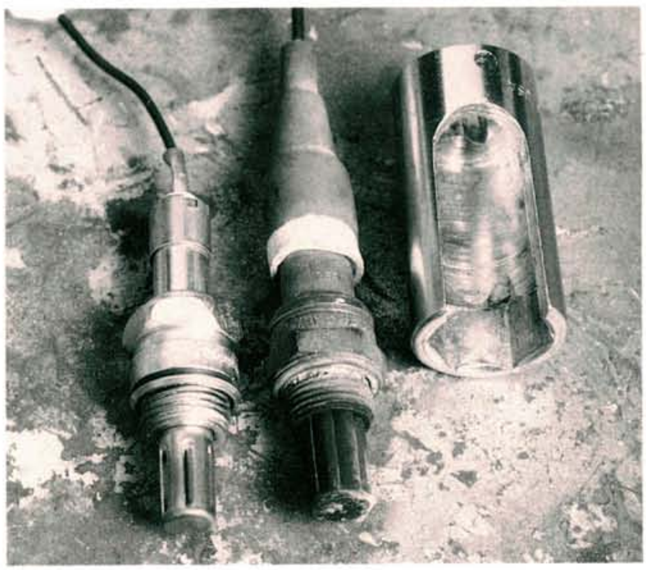
This coating on the sensor tip is similar in appearance to the one above, but has a gritty, grainy appearance. The additives in ethylene glycol have ruined this sensor. We all know that anti-freeze belongs in the cooling system and not in the combustion chamber, so if you find a dead sensor with this appearance, make sure you thoroughly check for leaks between the cooling jacket and the combustion chambers. A blown head gasket will only destroy the new sensor.



Many test procedures require you to check sensor output voltage using a digital volt-ohmmeter or DVOM. Poking through the insulation on the sensor lead wire is a bad practice. You can damage the wire itself, or allow road salt to enter the wire, causing corrosion. One way to avoid this is to disconnect the plastic connector between the sensor lead and the carside harness and gently insert a cotter pin. Then use an alligator clip to connect your DVOM.

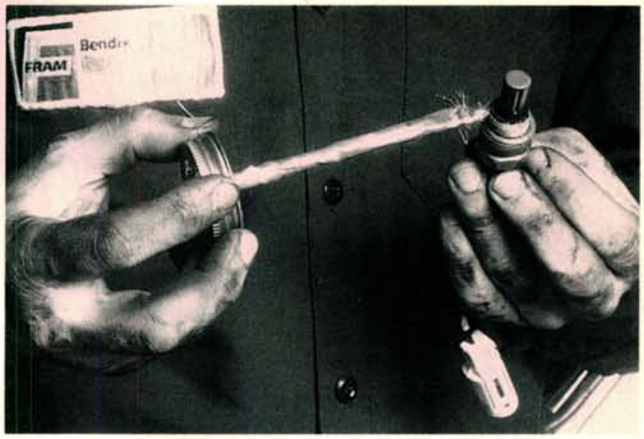
Once you've installed your cotter pin test lead in the connector from the oxygen sensor, hook up your DVOM. Make sure the DVOM is set to read voltage, not ohms, and make sure the meter has a minimum 10 megohm impedance. Checking the sensor with your ohmmeter is not only a waste of time, it may be the death of the sensor. The reference voltage generated by the DVOM in the ohmmeter mode is enough to ruin the oxygen sensor. Make sure you use a DVOM and not an analog meter. An analog VOM won't pick up the small variations in a sensor's output voltage.

If the sensor doesn't want to come out with reasonable force, don't resort to unreasonable force to remove it. If the engine is cold, start it up and run it above idle for a few minutes to warm the exhaust flange. Some really stubborn sensors may require heating with a torch. Make sure the threads in the flange are clean. Chase them with a tap if necessary. If the sensor does not seal properly in the flange, it will allow oxygen to enter the exhaust and confuse the sensor.



The best way to remove or install an oxygen sensor is with a vacuum switch/oxygen sensor socket. This is a deep socket with a slot milled in one side. Most are 22 mm (⅞ inch) six-point sockets, allowing a good grip on stuck sensors. Since the drive is concentric with the sensor, the socket gives you an accurate torque reading when you install a new sensor. The slot in these sockets, originally cut to clear the ports on a vacuum switch, gives the oxygen sensor's wire a safe place to go.

Unfortunately, one socket won't fit all when it comes to oxygen sensors. Some sensors are too long between the top of the sensor body and the hex to allow you to use the vacuum switch socket. If the original sensor is too long to be removed with the socket, you may need to use a flare nut or box-end wrench to get it out. An open-end is a poor third choice. You may even need to use a crowfoot or offset style wrench when the size and location of the sensor eliminate both the socket and the box wrench.



Do everyone a favor. When you install a new oxygen sensor, or reinstall an old one, coat the sensor threads with a high temperature anti-seize compound. Otherwise, you'd better hope you aren't the one who gets to remove it next time. Many new oxygen sensors come packaged with the anti-seize compound already applied. Without it, the sensor could wind up seized fast in the manifold. Route the sensor wire away from the manifold and secure it. Make sure the sensor wire connector is clean and tightly plugged together.