Shots in the Dark:

ENGINE MISFIRE DIAGNOSIS

By John Thompson

Chasing after something you can't touch, that can come and go seemingly at will, can be confusing and frustrating. That's why a systematic approach to misfire diagnosis is essential.

You can't touch a misfire, but at the same time you can "feel" a misfire. This is the sense that can get you in trouble—feeling. The reality and danger of this is that your mind will create a conception (and usually an associated mental picture) of what may be causing a misfire that's not based on fact. Notions of what a misfire is (and of what may be causing it) will be different for each of us, drawn from our own personal and professional experience.

Other factors can complicate the issue, as well. Things have certainly changed over the last 25 years with the advent of computer-controlled drivetrains. Before the advent of feedback processors to control an engine, mechanics (as we were called back then) worked on the *internal combustion engine* (ICE). Later on, they also had to deal with the engine management computer, also nicknamed the *frustrating ridiculous electronic device* (FRED).

Things might seem more complicated today, but a good diagnostic approach to driveability issues (including misfires) has not changed since the days of the Model T; it's just been largely forgotten. Like Henry's T, the modern ICE needs just three basic things for proper combustion: Engine Mechanical, A/F Ratio (Lambda) and Ignition.

It really is that simple. Get back to the basics when looking for misfires. Verify the ICE! Sure, the modern internal combustion engine could have a problem with injectors, coils or their drivers. The problem could be related to sensor inputs like MAF, MAP, TPS, ACT, CKP, CMP, etc. Or it could be an output like EGR, ICM, fuel pump, etc. But remember that all these things will fall into only one of two of the requirements for combustion—ignition or A/F ratio. But there are three things required for proper combustion, and consequently three diagnostic roads you can travel.

Almost forgotten in the world of FRED, a vacuum gauge was once used to verify the mechanical integrity of the ICE. It can't be forgotten that FRED is merely controlling a purely mechanical device. Do you know how

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5
10
ZERO
150
inHg
vac

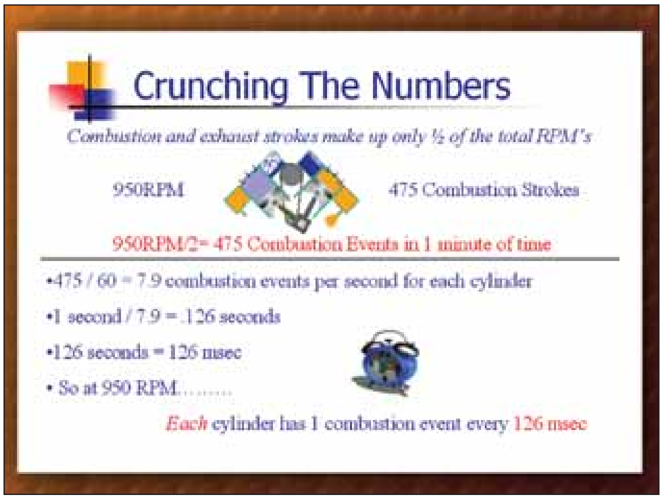

Fig. 1

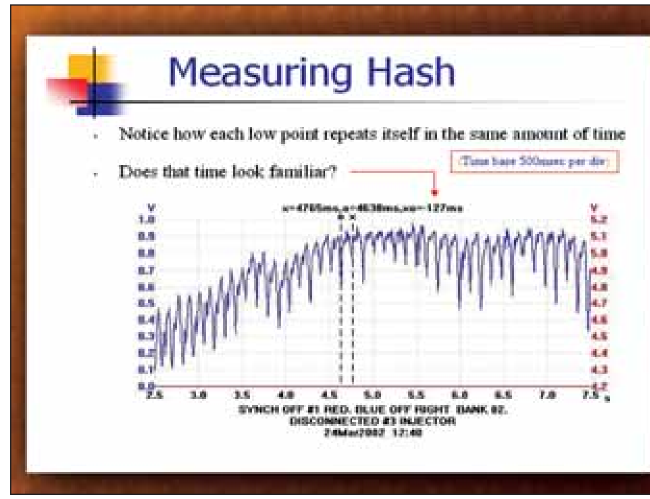

Fig. 2

Illustrations: John Thompson

to use a vacuum gauge properly? If you don't, you need to learn. If you do know, how often is it your first step in diagnosing a misfire, or any driveability issue for that matter? If the answer is not "always," your procedure is flawed.

Sure, mechanical integrity of the ICE is probably responsible for a relatively small percentage of misfire-related issues, but it was the same small percentage back in the days when we were called "mechanics." Maybe that's where the step was lost. Somewhere back when mechanics concentrating on ICE turned into technicians obsessed with FRED, that crucial first step was largely discarded.

To check the mechanical condition of an engine, you'll need a vacuum gauge (the bigger the dial face the better) and the elevation of your shop. At idle at sea level, your vacuum gauge should read at least 18 in./Hg or higher (you might accept 17 in./Hg on a high-mileage engine). For every 1000 ft. of elevation above sea level, subtract about 1 in./Hg of vacuum. The vacuum needle should also be steady. If it flickers, look for a single-cylinder compression issue. If it's unsteady and floating, look for a vacuum leak. There are many other very valuable off-idle vacuum tests that can be performed, but this should get you started.

If the engine's mechanical condition looks good, with good idle vacuum and a steady needle, then (and only then) use a scan tool to let PIDs (specifically fuel trim PIDs) help you decide how to proceed. It would be hard to give a set-in-stone fuel trim number to rely on that would fit all makes and models. Remember what a fuel trim correction is: a percentage of correction to the processor's lookup table for the engine's operating requirements.

For misfires, I would suggest rule-of-thumb numbers to guide your diagnosis. Fuel trims of ±10% suggest ignition problems. With a fuel trim of, say, +22%, look for A/F ratio problems. Begin your diagnosis with your vacuum gauge to verify engine condition, then look at fuel trim PIDs to decide between ignition and Lambda.

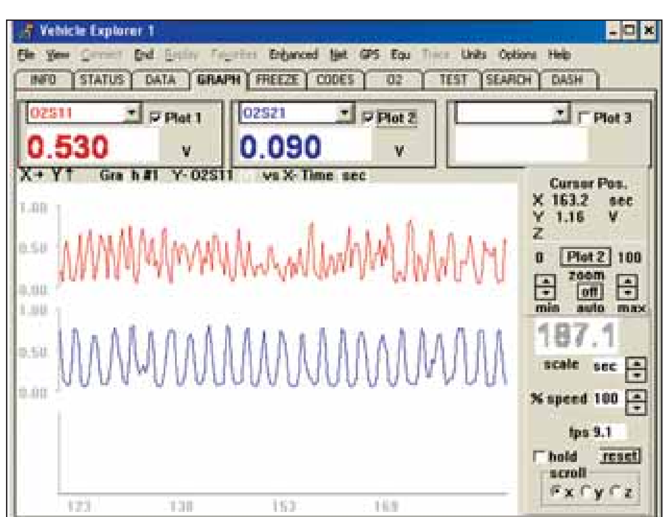

Fig. 3

Further Misfire Diagnostic Techniques

There are only a couple of methods commonly used for tracing a misfire to a specific cylinder: OBD II misfire counters and misfire codes. Most manufacturers use a method of measuring crankshaft acceleration to determine if a particular cylinder is misfiring. The problem is that crankshaft acceleration depends on torque. Would it surprise you to know that a misfire code will almost never set at idle or low load because torque is very low under these conditions?

Following are the EPA regulations concerning types of misfires and the requirements for setting a Malfunction Indicator Light:

Type A is a catalyst-damaging misfire, which will cause the MIL to flash (one-trip code).

Type B is a misfire that will cause an emissions failure but not damage the catalyst (two-trip code).

Type C causes a driveability issue that will not light the MIL or set any code.

This means that unless you

have a Type A misfire that's severe enough to damage the catalyst, you won't see a flashing MIL on the first trip. You also will not see a flashing MIL for a misfire that happens only at idle because there's not enough heat generated at idle to be potentially harmful to the converter.

Did you also know that if multiple misfires are detected, the EPA requires only that a P0300 miscellaneous misfire code be set? This is because it's almost impossible to accurately identify more than one cylinder by measuring crankshaft acceleration deficiencies when multiple misfires are present. A P0300 is almost useless information, other than giving you freeze frame parameters, because it tells you what you already know: The engine is misfiring! Use OBD II misfire detection when possible, but just don't make the mistake of thinking it's foolproof. If OBD II gives you a P0302 code and you can find nothing wrong with No. 2 cylinder, the cylinder may have been identified incorrectly.

Another tried-and-true method of detecting misfires is via ignition secondary waveform diagnostics. Long before technicians operated digital storage oscilloscopes (DSOs), mechanics were analyzing secondary ignition waveforms with analog scopes. Unfortunately, the analog ignition scope did not solve misfire issues for all mechanics, just as it will never solve misfire issues for all present-day technicians. In fact, mechanics probably had a better chance of finding a misfire and its cause using secondary ignition patterns than present-day techs. This is because they were much more familiar with the method and its limitations.

An ignition scope has been called a window into the combustion chamber. However, the view may not be entirely clear. It frustrates me to hear a technician say that he can see a bad fuel injector in a secondary waveform, or that he can see a bad plug wire in another secondary waveform. Don't believe it. An expert might be able to examine the waveform and come up with the correct analysis, but he can't see those things. All that can be seen in a secondary ignition waveform are a pattern of normal resistance, a pattern of high resistance or a pattern of low resistance...period! Again, there are many technicians whose experience will lead them down the secondary analysis road with much success. But it's time to be honest with yourself. Are you one of them? And if you are, is your analysis always correct?

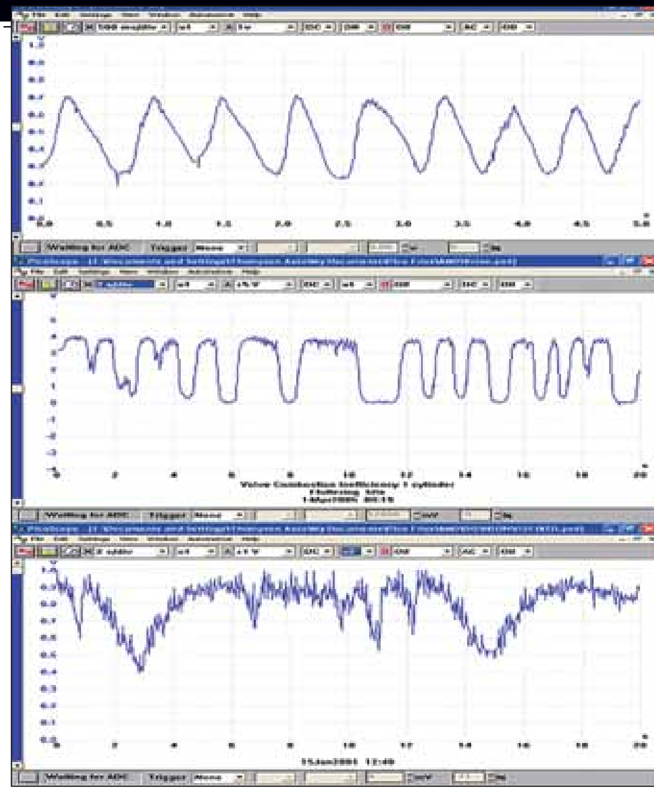

Fig. 4

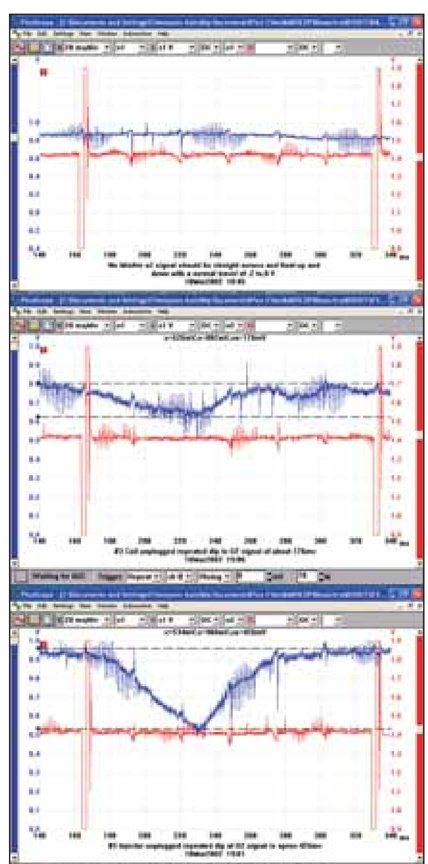

Fig. 5

If you aren't a diehard ignition scope guru, let me offer another diagnostic technique. If an ignition scope is "a window into the combustion chamber," why not open the back door and see what comes out? By back door I mean oxygen sensors. The exhaust stroke contains the result of a cylinder's combustion process. Each stroke passes right by the O_2 sensor, with good diagnostic information just waiting to be analyzed.

The combustion process requires optimal levels of compression, ignition and air/fuel ratio (Lambda). It's a pretty straightforward process as long as nothing goes wrong. The basic scenario goes like this: Air (containing oxygen) is drawn into the cylinder. Fuel is added. The mixture is compressed and then a spark is ignited in the cylinder. The spent charge subsequently exits the combustion chamber on the exhaust stroke.

When something goes wrong, what we refer to as a *misfire* occurs. Most of the oxygen taken into a cylinder for the purpose of combustion is consumed in the combustion process. If a cylinder misfires, the oxygen that was drawn into that cylinder is not consumed (or not totally consumed, depending on the type and severity of the misfire).

As the exhaust stroke gases from the misfiring cylinder pass the O_2 sensor, the sensor will react with a lean voltage dip, repeatedly and reliably. Exhaust gases are not a continual mixed stream of gas. They are totally independent (though theoretically identical pulses of exhaust stroke gases) that are separate and self-contained—that is, unless there's a misfire or combustion inefficiency present. In that case, a different content of unconsumed O_2 and possibly uncombusted HCs will be present in the exhaust stroke gases of the offending cylinder.

With some manufacturers, ignition system interference will be present in an O_2 signal. This is not to be confused with O_2 sensor *hash*. Ignition system interference is easily discernable from hash because it will occur with the frequency of each cylinder's ignition event. Hash from a single-cylinder misfire will not; it will occur only from one cylinder's exhaust stroke.

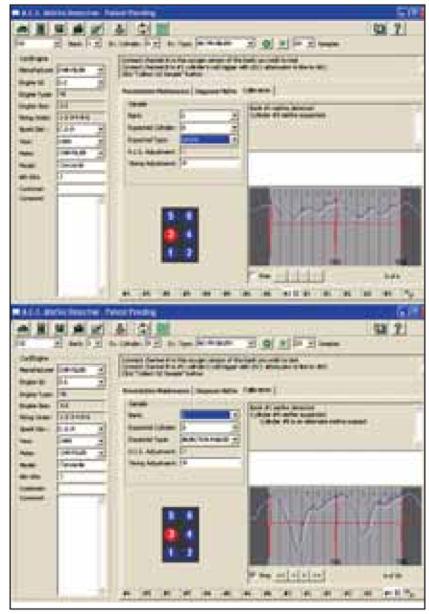

Fig. 6

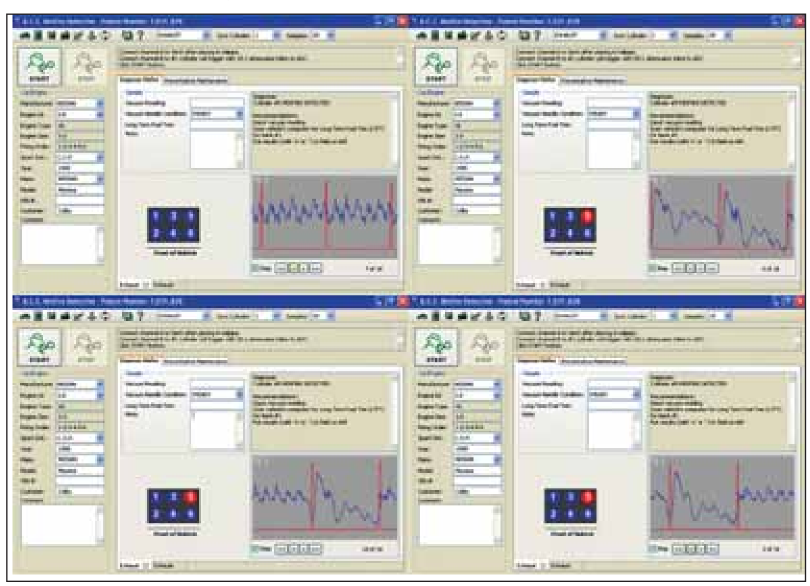

Fig. 7

The use of the word *hash* can be misleading. It has been said that it's normal for an engine to develop O_2 sensor hash as mileage increases. This is untrue and comes from the lack of understanding of what hash actually is. Hash is *always* a reflection of unconsumed oxygen from a cylinder whose combustion process is not the same as other cylinders on the same upstream O_2 bank. Some simple math is necessary to prove this point. If an engine is running at 950 rpm, how often will a combustion stroke occur on any cylinder of that engine? Refer to Fig. 1 on page 48 for further explanation.

A repeating hash spike in an upstream O_2 signal is a reflection of a single-cylinder misfire. Fig. 2 illustrates this with one cylinder's total lack of injection. Each time the exhaust stroke gases pass the O_2 sensor, the unconsumed oxygen from the offending cylinder causes the sensor to react with a lean hash spike. Does that time of 127mS look familiar? It should; this engine was running at as close to 950 rpm as possible with the No. 3 injector disconnected. Each time the exhaust stroke from the No. 3 cylinder passes the O_2 sensor, the sensor will react to that unconsumed oxygen, repeatedly and consistently.

Hash can easily be used with either a lab scope or graphing scanner to identify the bank that a misfire is on. If you look at the graphing scan tool graph in Fig. 3, it's pretty easy to see that the misfire is on bank 1.

With hash, it's a question of how closely you want to look. Fig. 4 on page 49 shows three lab scope graphs with hash. The top is a known-good O_2 pattern. The middle waveform shows dirty injectors creating just enough inefficiency and unburned HCs to fail a tailpipe emissions test. The bottom waveform is a full-blown repeated single-cylinder misfire.

Try scoping the upstream O_2 signals on the next good-running engine with more than 100,000 miles that you see in your bay. You'll likely see some degree of hash. Why not do yourself and your customer a service and recommend fuel system cleaning as preventive maintenance. You'll be able to prove the results to your customer and yourself with a before-and-after scope comparison.

If you have a starting point from which to measure, the consistency of an O_2 sensor's dip reaction is amazing. Regardless of the cause—ignition, Lambda or compression—the dip from an offending cylinder is so consistent that it will appear in the same time-relative spot over and over again.

Fig. 5 shows an O_2 signal that has been magnified to reflect the time necessary for all six exhaust strokes on a 3.2L Chrysler engine to pass the O_2 sensor. The blue trace in the top pattern shows the engine with no misfire. No dip in the signal is expected since no misfire is present. The blue trace in the middle pattern is a complete ignition failure of No. 3 cylinder, with an obvious deflection of the O_2 sensor signal. The blue trace in the bottom pattern shows the same cylinder with a total lack of injection.

You'll notice that the dip is in the same spot in both misfire patterns, although the amplitude of the dip is greater when the injector is unplugged. The same amount of unconsumed oxygen passes the O_2 sensor during both misfires, but with an ignition misfire, unburned HCs are mixed in the exhaust stroke and dampen the severity of the O_2 sensor signal deflection.

Fig. 6 on page 50 illustrates two different types of misfire from the same cylinder on the same engine. Because unconsumed HCs are also in the mix, the amplitude of O_2 signal deflection will vary on an ignition-type misfire (vs. a total lack of HCs due to a faulty injector). But in both types of misfire, the O_2 signal deflects in the same time-relative place(s), making the cylinder from which the misfire originated easy for misfire-detecting software to identify.

Software also can be used to indirectly analyze the unconsumed oxygen contained in a misfiring cylinder's exhaust stroke by measuring the change in exhaust stroke pressure. The unconsumed oxygen will result in a difference in pressure in the misfiring cylinder's exhaust stroke (as compared to exhaust strokes from cylinders with good combustion). This pressure change is an extremely accurate and fast way to track a misfiring cylinder.

Have you ever tried to track an intermittent misfire? Take a look at the waveforms from a 1999 Nissan Maxima engine displayed in Fig. 7. The engine was misfiring very intermittently. The red lines are triggers from the No. 1 cylinder. The blue lines in between the triggers are all cylinder exhaust strokes. As you can see from the different frames, at times there was no misfire for two or more complete cycles; at other times a misfire occurred from one cycle to the next. A pressure probe was inserted into the tailpipe and a connection to an ignition coil was used for an exhaust stroke reference. This diagnosis took less than 60 seconds. The fault was the ignition coil for the No. 5 cylinder.

Identifying misfires by cylinder with this type of technology is fairly new, so if you don't have that capability yet, don't sweat it. There's still much you can do with a lab scope or graphing scan tool to use O_2 sensors for a real diagnostic advantage. If you're working on a V-configuration engine, try this method: If the engine has bank-dedicated upstream O_2 sensors, road-test the vehicle while using a graphing scan tool or lab scope feeding you the upstream O_2 sensor data. If it misfires you'll see it and, more importantly, you'll know which bank the misfire is on! Then you can use your vacuum gauge and fuel trim numbers to zoom in on the bank and the likely area from where the misfire is coming. Remember, O_2 sensors can give you a quick and easy path to misfire diagnostics by zooming in on half the engine. Then you can use your vacuum gauge and fuel trim data to identify which one of the only three (or four) cylinders from which the misfire could be coming. M

John Thompson is an ASE Master certified technician, educator, author, member of the Society of Automotive Engineers and a U.S. patent holder for enhanced engine misfire detection systems.

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