Waste Spark

Why twice the sparks? Why so many ignition coils?

From the point of view of gasoline mixed in the right proportion with air, the polarity of a spark doesn't matter one bit, only the voltage. If there's enough to jump the gap between the plug electrodes and enough in reserve to hold a spark burn for a few milliseconds, there's enough to light the fire for the thermal expansion of the next power stroke. Fuel's polarity-indifference allows ignition engineers to solve several problems at one time with what is often called "waste-spark ignition." German carmakers, thriftier at least rhetorically, prefer to call the system "dual-spark" or "double-ended" ignition, but it is the same system by whatever name.

The fundamental design of this system is a coil for every two cylinders in the engine, and each of the two spark plugs fired by each one of the coils is an opposite end (and thus opposite polarity) of that coil's secondary system. While none of them look like the plug cable wound into a noose as in our photo above, in principle that's how the system works, with the secondary circuit entirely independent of the rest of the electrical system. Unlike conventional and coil-on-plug systems, the waste-spark ignition uses primary and secondary circuits electrically insulated from one another: their only connection is through the magnetic field, sown, as it were, by the primary and reaped by the secondary circuit.

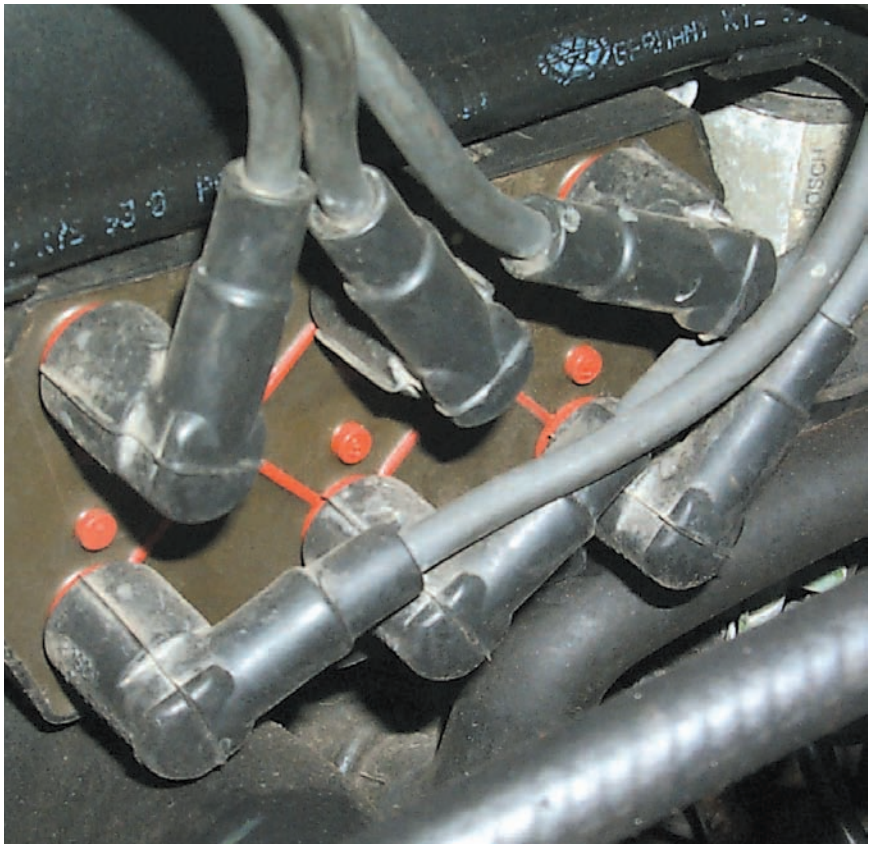
The two sparks occur almost simultaneously, with the lower resistance gap ionizing a few zillionths of a second before the higher. Since the two cylinders mated by the single coil are opposite in crankshaft rotation, the working spark occurs at the proper spark advance point in the compression stroke for the load, heat and engine rpm. The other, the 'wasted' spark occurs at the same point in the opposite cylinder's exhaust stroke. The first ignites the mixture; the second sparks in an already burned-out atmosphere.

But Why Do It?

What's the advantage to arranging the ignition system this way? Isn't this really wasting half the spark capacity? Couldn't that electrical power be conserved some way? Of course, it can with a coil-on-plug ignition, with one ignition coil and its required primary microcircuitry per cylinder. That obviously costs more to build or to repair if things go wrong.

But the relevant comparison to waste spark is with distributor ignition, and the advantages of the dual system are to overcome problems with the distributor. Notice that every distributor plug circuit has two sparks: one that we see at the plug and another that we don't see between the rotor tip and the distributor cap electrode.

Right: *The waste-spark system uses one coil for every pair of cylinders, so in this VW six-cylinder, numbers one and six, two and five, and three and four are paired, each set with an ignition coil firing both plugs simultaneously. Even if one plug fouls, the other will usually continue to function normally.*

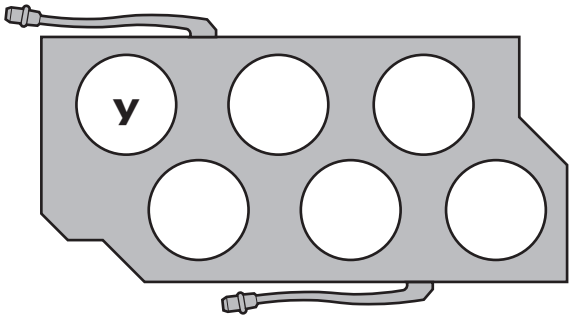


Bottom: *Looking more closely at the coil cluster, each joins a pair of spark plug secondary circuits. The primary circuits as well as the module controlling the ignition system are electrically independent of the high voltage side.*

That second spark gap consumes about the same energy as does the 'wasted' spark on the waste-spark system.

Using a coil for every pair of cylinders does mean more coils than a distributor ignition system requires, but it helps solve the 'coil-saturation' problem: At low engine speeds, there is more than enough time to build a strong magnetic field around the coil's ferrous core; in fact, the problem comes with designing a system that will reduce current or shorten on-time duty cycle ("dwell") so the coil doesn't overheat when the engine runs slowly. On the same engine, though, there must be enough electric current reserve to build a sufficiently strong magnetic field at high rpm, when there's much less time available. There are only two ways to do this: First, increase the current through the coil by reducing resistance or increasing voltage; or second, increase the number of coils, affording more time at lower current for each charge cycle. That latter is how waste spark works. This implies, of course, that you have to have an even number of cylinders on the engine — five-cylinder engines are out as far as waste spark is concerned.

On most vehicles with waste-spark systems, while the plugs fire in pairs, the injectors fire in sequence, as determined by the signal from the camshaft position sensor. Should that signal fail, thus, the engine will not start on most such cars.



Knock Sensors
Two knock sensors fit on either side of the cylinder head for this engine, allowing the computer to discern precisely which cylinder has ignition knock and to retard spark to that cylinder only (or to retard different cylinders different amounts, if that's what it takes to quiet the knock sensors). Knock sensors are piezoelectric devices, generating their own voltage oscillations if vibrations characteristic of ignition knock occur.

What Can Go Wrong?

If a plug fouls, does that shut off both cylinders on that coil? Usually not. After all, there's still a complete electrical circuit through everything, even if there's no spark at one plug. Most contemporary systems detect the misfire and shut off the fuel to the dead cylinder. More sophisticated management systems will even bias the oxygen sensor's voltage to compensate for the extra oxygen coming down the pipe through the dead hole. This keeps the mixture to the other cylinders squarely in the famous 'stoichiometric notch.'

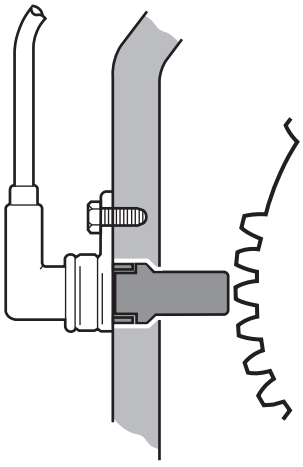
Even if one side of the ignition secondary pair burns open, there is usually a spark on the other side, because the wire and the coil itself have enough capacitance to function as a kind of electrical 'mass,' absorbing the voltage oscillations.

If the system loses the signal from the camshaft position sensor, some engines stop immediately; some keep running until they are turned off, after which they can't restart because the computer can't sequence the fuel injection (there is at least one domestic carmaker who has overcome this!). If the crankshaft sensor fails, there is no control over spark advance; most engines stop; others fall into limp-home, spark-retard mode.

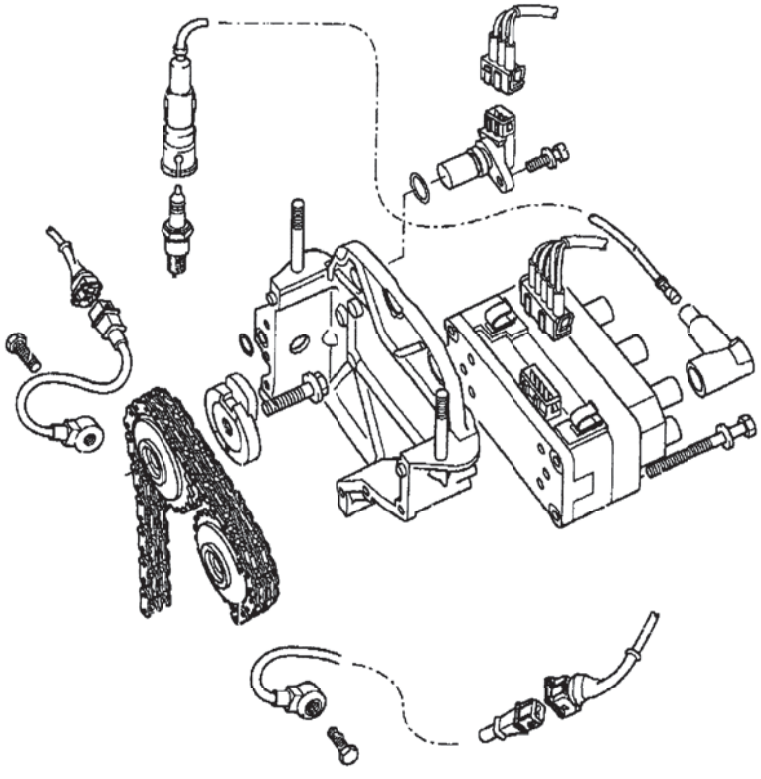
Ordinary electrical resistance tests are valid for waste-spark systems, but remember there is no continuity between the primary circuit and the secondary. Except for the cycling magnetic field they share, there is nothing between them.

Why so many sparks and coils? Turns out the number of sparks is the same, and while the number of coils increases, the number of distributors — far more difficulty-prone and expensive components — is down one. ■

—By Joe Woods



Crankshaft Position Sensor
The crankshaft position sensor for the VR6 VW engine as well as many other waste-spark systems, is an inductive pickup near a toothed wheel on the crankshaft. The signal it sends reflects the engine speed, and the system uses the information principally for calculating timing advance.



Camshaft Position Sensor
The camshaft position sensor on the VR6 is a Hall-effect unit indicating exactly where the engine is in its four-stroke cycle, information used both to sequence the fuel injection and to adjust ignition timing by individual cylinders based on information from the knock sensors. Many vehicles will continue to run if the camshaft position sensor signal is lost because the computer remembers its 'page in the book.' On many of the same cars, however, the engine cannot restart without a camshaft signal once it is shut down.