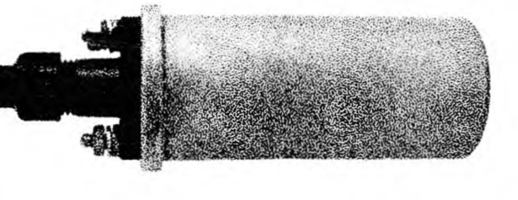
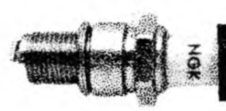
Basics



IGNITIONS



By Gordon Jennings

• Four months ago we presented a basic treatment of spark plugs that contrived to give the sparks themselves only passing mention. This narrowness of focus served to match the article's length to what we presume is the reader's attention span; it may also have tended to obscure a vitally important point: that the spark plug is but a single component in a complicated ignition *system*. That spark may become visible in the plug electrode gap; its timing, strength and form originate elsewhere—and all three of these things directly influence engine efficiency.

Before you can cope with all the intricacies of motorcycle ignition systems it is necessary that you know something about electricity and magnetism, which is unfortunate because not even degree-wielding physicists can agree on the true nature of those phenomena. On the other hand we don't have to know what electrons and magnetic force fields are; only how they behave in circumstances applicable to ignition systems. For our purposes it is enough to know that passing an electric current through a coil of wire produces a magnetic field around the coil; that a magnetic field passing through a coil of wire will induce in the wire an electric current; and that when a moving magnetic field performs its feat of induction and starts a current traveling in a coil you get a second magnetic field acting in opposition to the first—producing what is known as a "choke" effect.

All of the above are at work in the high-ratio transformer that produces the voltage to fire a motorcycle's spark plugs. This device commonly is called a "coil" but it really is *two* coils wound around a laminated soft-iron core. One of these coils is the primary winding, made up of about 200–300 turns of .024″-diameter copper wire. The secondary winding will contain between 10,000 and 20,000 turns of much finer (.003″-diameter) wire, and it is in this part of the spark coil that the voltage required to force an electrical arc between the plug electrodes is created.

The voltage produced in that secondary winding is induced by the rapid shifting of a magnetic field, and the induction phenomenon is employed in a similar manner in virtually all ignition systems. But the creation and shifting of that magnetic field can be accomplished in a variety of ways, and the method chosen has a very great effect on an ignition system's performance, cost and complexity.

Despite all the wonderful things claimed for "magic-box" ignition systems, a few of which are true, most ordinary touring type motorcycles continue to rely on the familiar and exceedingly simple battery-and-coil spark generator. In this one the motorcycle's line voltage, supplied from the battery, is valved through a spark coil by an engine-operated switch. The switch itself is a pair of contacts held closed together by a spring and bumped open by a cam rubbing against a phenolic follower. There also is a condenser, a device that acts as a kind of electrical reservoir, connected in parallel with the contacts in the circuit.

When the contacts are closed in the battery-and-coil system, current flows through the spark coil's primary windings—propelled by either 6- or 12-volts, depending on the battery used—and builds a magnetic field inside the coil. There is only a comparatively slight voltage induced on the coil's secondary side when the contacts close, because the choke effect prevents the rapid progress of either electric current or magnetic field. Eventually, however, the field does become established at full strength, as does the current, and then nothing whatever happens in the secondary winding until the contacts open. Then, with the interruption of the primary current, the magnetic field collapses extremely rapidly and induces in the coil's secondary winding a voltage (hopefully) high enough to spark across between the plug electrodes.

It would be convenient if the coil's collapsing magnetic field confined itself to inducing an electrical potential in the secondary winding alone, but that's not the case. When the field strength shifts it exerts an influence on both of the coil's windings, and even though the flux change will not induce the kind of kilovolt response produced in the secondary winding on the primary's relatively few turns of wire, the response is there and that's why a condenser is required. Without the condenser there would be an electric arc formed between the contact surfaces of the breaker point assembly. Most ignition contacts are set to open as much as .012″ to .016″ and primary voltage is not suf-

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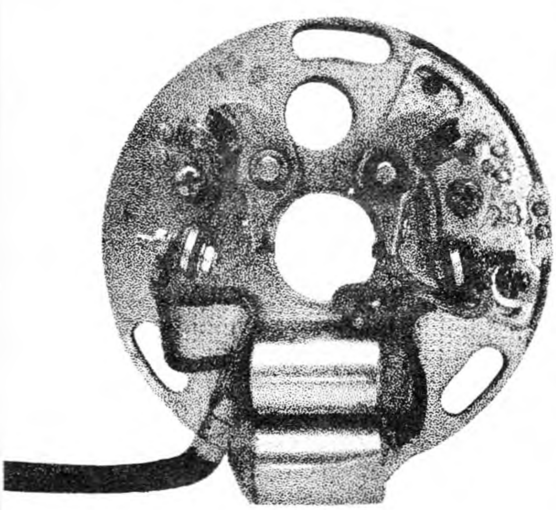
ficient to force an arc that distance. But the big voltage surge does not wait for the contacts to separate even .010"; it comes only microseconds after the contacts have ceased to touch, while the surfaces are little more than microns apart, and without the condenser in the circuit to soak up the initial surge there would be heavy arcing across this narrow gap.

Even the flickering and intermittent sparking the contacts endure when the condenser is present causes electrical erosion and eventual failure; so it may be that a no-condenser system would burn its breaker points to cinders very quickly. We'll never know, for the condenser is an indispensable element in the ignition system's primary job—which is the production of sparks. If we let that arc form between the contact surfaces, it becomes a path for the electrical potential induced



in the primary winding and current then will flow across that path. And with that current flow the primary winding promptly creates an expanding magnetic field to brake the collapse of the original field. A balance between induced current and the rate of field collapse is then established, and both dwindle slowly away—too slowly for the desired electrical potential to be induced in the coil's secondary winding. In other words, no spark, which is precisely what happens in a system with no condenser, or one in which the condenser has failed.

Condenser failures should be extremely rare, because the device itself is extremely simple. It's just a pair of metal foil strips sandwiched with a separating insulator strip, all three rolled tightly and stuffed in a small cylinder. One of the foil strips is grounded against the cylinder; the other connects with an insulated wire lead. When that big voltage surge occurs in the coil's primary, electrons pile up on one of the condenser's foil strips and are forced away from the other, which is how the condenser is able to act as an electric reservoir. Failure can be nothing more complicated than a disconnected lead wire, which still is all the failure required to stop the ignition system from producing sparks. But a far more common and sometimes diabolically insidious form of failure is internal shorting. The condenser's insulating strip is supposed to prevent direct contact between its foil elements; if the insulation fails a direct short-circuit may develop, in which case the condenser assumes the electrical properties of a straight wire.

The more diabolical aspects of condenser failure arise when the installation site has been unwisely chosen, and most failures may be traced to the same manufacturer's mistake. Condensers don't like heat, which softens their internal insulation, yet they all too frequently are installed in a compartment with the contacts as an *engine* component. They will work as well inserted into the ignition circuit near the spark coil, which usually is mounted up in a cool, protected spot under a bike's fuel tank. But some manufacturers persist in placing them where they quickly reach the same temperature as the engine's castings. Now this becomes really nasty because the internal short-circuit a condenser suffers when overheated sometimes will disappear as it cools. That kind of thing can drive you crazy, because the heat-related intermittent condenser problem lets your bike start and run fine until it gets warm, at which point it will begin misfiring and may even stop running. People mistake this problem for everything from fouled plugs to a fuel stoppage, and if they spend enough time in any attempted "cure" the condenser will cool enough to resume its functions. Bad condensers have sold a lot of spark plugs, breaker points and fuel filters.

Magnetos rely on the same rapid flux changes as battery-and-coil systems for producing sparks, but the manner in which those flux changes are created is completely different. There is even a major division of methods within the broad category of devices we call magnetos: there are magnetos with all their works lumped together; those with separate energizing and spark coils; and some very tricky magnetos with transistors, storage capacitors and other electronic wizardry. All of them get their name and operating power from the use of (usually) an engine-driven, multi-pole magnet sweeping its field through a coil or coils of wire.

In the old-fashioned magneto the magnetized rotor swept its field directly through the spark coil, but the coil's secondary winding did not develop its voltage just from the flux change produced by the spinning rotor. In fact, rotor speed would have to be extremely high to coax a spark out of the coil without some kind of boost. That boost is provided by the coil's primary winding, which reverses the role it plays in a battery-and-coil ignition system: in the latter the primary windings build the necessary magnetic field; the magneto's primary coil is used to hold the rotor's field away from the secondary winding until it is time to make a spark.

Here's how it works: the rotor would sweep its field right through the spark coil, but when that field begins to be felt in the coil, the primary winding responds with a current that passes through the contact points. This current produces its own field, which holds off that of the moving rotor, and you have what amounts to an electromagnetic stand-off. There is a strong magnetic pulsing as the rotor's poles swing past the coil but only a little of this is felt in the secondary winding, due to the shielding effect of the current-produced field in the primary, until the current is interrupted. Then, when the ignition breaker cam bumps the contacts apart, there no longer is any opposition to the rotor's field and it promptly flicks out to assume its undistorted form. The result is that the otherwise slow field movement speeds enormously, and in sweeping through the coil's secondary winding induces a very high electrical potential transmitted to the spark plug *via* an insulated lead. The primary winding's lesser potential is diverted into a condenser, just as in a battery-fed system.

In all but a very few instances, Harley-Davidson providing a notable exception, all modern magnetos are of the "energy-transfer" type pioneered by Triumph several years ago. This type has only an energizing coil sited next to the rotor; the spark coil is remote from the engine, like that of a battery-fed system. The energy-transfer magneto is widely assumed to be nothing more than a variant of the traditional type, but its operating principle actually is quite different. You have the same choke effect when the contacts are closed and rapid field movement when they open; that's where the resemblance ends. The E.T. magneto's energizing coil has only a single winding, and in the instant after the contacts open it is capable of kicking out an approximately 4-amp, 300 volt surge. This surge is fed into the primary winding of the system's remote mounted spark coil—a special high-ratio transformer—and it overwhelms the choke effect, triggering an immediate high-voltage response in the coil's secondary side.

Another assumption frequently made is that a spark is a spark, and if a good hot one can be made to appear between the plug electrodes, all the engine's requirements will have been satisfied. In fact, there is something called "rise time" to be considered. The term refers to the time required for spark voltage to attain full strength, and there's a big difference between the rise time characteristics of the various ignition systems. Our faithful old battery-and-coil system takes about 100 microseconds to work itself up to spark-level voltage. A good magneto will do it in less than half that time: about 35 microseconds, and it is that factor rather than any consideration of sheer voltage that makes the magneto a better igniter.

Rise time is important because spark plug insulators quickly accumulate deposits and those deposits are to some extent electrical conductors. There is a finite electrical potential available from the coil and it starts trickling away across the deposits the instant that voltage rise in the secondary winding commences. Give the process enough time and you'll have all trickle and no spark. Tests have shown that with a conventional ignition system an engine will begin to misfire noticeably when the resistance between its plugs' center electrodes and ground is still as much as 200,000 ohms. Low rise time ignition systems are capable of providing clean running when deposits have lowered the insulators' effective resistance to no more than 10,000 ohms.

So rise time is a factor not to be overlooked, and its importance accounts for the increasing application of capacitor discharge ignition (CDI) systems. The CDI system represents very nearly the ultimate in brief voltage rise times, leaping from quiescence to full potential in less than 7 microseconds. In the comparison the old battery-and-coil system is as laggardly as a Boy Scout rubbing two sticks together to make a fire.

In one respect the CDI system is like an E.T. magneto: it shoots a big jolt of electricity into the primary winding of a special high-ratio spark coil. But the magneto develops the jolt through the time-consuming generative processes of its magnetized rotor and field coil, while the CDI's spark coil is energized by the almost instantaneous discharge of a stored potential. Some CDI systems can work themselves up to spark voltage in an incredibly brief 2 microseconds, and will produce a satisfactory spark even from a plug that has been dipped in dirty oil.

Various means have been found for charging the CDI's capacitor (which is a condenser with a fancy name). When the system is to be used in a touring bike the energy can be drawn from the battery. That is not to say the capacitor is charged to only 6- or 12-volts; something near 400 volts is needed to do the job, and for that a voltage converter is included in the circuit. The converter contains an oscillator on its input side, which pulses voltage from the battery into a step-up transformer. The transformer raises the voltage to the required level and its alternating-current output is rectified back into direct current to charge the capacitor. This method has been employed on some Kawasaki triples, and the faint, high-pitched singing owners hear when they switch the ignition on is the high output converter. Capacitors also can be charged with the rectified output from a field coil and magnetized rotor, as is done in the kind of system called a "CDI magneto."

Early CDI systems were triggered with conventional contact breaker points operated from an engine-driven cam. These systems delivered a spark when the contacts *closed,* and we might still be seeing them in use today but for advances in solid state electronics. Specifically, it was the large current capacity silicon controlled rectifier (SCR) that made the "pointless" CDI system possible. Ordinary transistors, especially those available a decade ago, simply do not have the internal characteristics needed to withstand the kind of voltage and amperage fed from the capacitor to the spark coil. But the better SCRs can do the job, and work very well. They are inserted in the circuit as an electrical dump valve: no current passes from the SCR's anode to its cathode until a small voltage is applied to its third terminal, or "gate." The trigger voltage can be supplied through points, of course, but the present crop of CDI magnetos use the output from a small trigger coil positioned next to the magneto rotor.

Because written discussions of transistorized ignition systems must either be so simplified as to be misleading, or so lengthy as to constitute complete articles in their own right, we will not venture further into the wonderful world of semi-conductors at this time. You can find reams of material on the subject in any public library. The only thing books on transistors may not tell you is that semi-conductors fail, when they fail, "catastrophically." That is to say, a transistorized ignition system either works or it doesn't, and failure comes without a trace of the early warnings given by the less glamorous ignitions. Also, it must be noted that although magic-box ignitions do not have the same shortcomings of the old-fashioned battery-and-coil type or a simple magneto, they are not perfect. Transistorize a conventional system's breaker points and the current across the contacts not only will be too low to burn them, it may also be too low to burn away the film of oil that tends to form there and the points may cease to conduct at all. Aftermarket CDI systems have wonderful things claimed for them, but they can shock a conventional spark coil right into failure, and unless their circuitry is arranged to yield a longer-duration spark than is their wont, they may actually give inferior performance—freedom from fouling notwithstanding.

What of the future for ignition systems? The CDI system probably will come into even wider use, but in modified form. The reason for improving on those we have today is that it is not enough to have a lot of voltage building quickly. If the spark is too brief, the hot-spot it creates inside an engine's combustion chamber may not be hot enough to establish a uniform flame front. This can give the effect of ignition timing that wanders back and forth several degrees of crank rotation. From what we are told, the name of the game these days is spark *amperage,* and we are further informed that while the spark current with a conventional magneto is about .05-amp, some of the more advanced systems—these being still in the experimental stage—produce up to 1.6-amp currents across the spark gap.

Until the wonders of advanced, solid-state systems become commonplace in the automotive field they probably won't trickle down to motorcycles, so we have long years of dealing with mundane considerations ahead of us. Points will continue to pit and burn; timing will continue to shift as points blocks wear away. We can help the timing problem by resetting those mechanical contacts after they've been in operation a couple of hundred miles. There's a soft skin on the breaker points' rubbing block and it makes initial wear rather rapid. Let the points settle into their job and then re-time the engine.

An engine's ignition timing also will be more stable if you keep the points' rubbing block properly lubricated. Get a tube of the special, high melting point grease made for that purpose. One inexpensive tube of the stuff will last for years if used sparingly—which is how it is supposed to be used in any case. Too much grease on the points' block and some of it will surely coat over the contact surfaces. Those contacts must be kept clean, especially in magnetos, which experience a large loss of efficiency if anything should impede the flow of current.

Many people approach the task of setting the ignition timing with a far less serious attitude than it deserves. Most street machines have some form (usually centrifugal) of automatic advance mechanism, which is used to pull the spark timing back near TDC for starting and idle while moving it ahead to, say, 35° BTC when crank speed rises above 1500–2000 rpm. Owner's manuals often call for static adjustment of the timing, assuming that the automatic advance mechanism will pull the spark ahead exactly the right amoung when the engine is running. More often than not that isn't what happens. To put it bluntly, those automatic advancers are not to be trusted, so you should always check the timing with one of the special strobe lights made for that purpose.

If your bike seems to frazzle its ignition contacts too quickly, it's just part of the price you pay for a cost reduction on the manufacturer's part. The fact is that motorcycles' ignition systems are uniformly pretty poor, being no better than marginal in terms of spark voltage when everything is fresh and declining rapidly with service time. Short of wholesale components replacement we don't know what can be done about the problem. You should not attempt to fit trick coils or anything else without doing a lot of checking to make sure that the coil (for example) will not draw more current than the rest of the system can comfortably supply.

Replacing condensers sometimes will help ignition contact life. These contacts carry a very large electrical load and it is to be expected that there should be some erosion of their mating surfaces, but the erosion should take the form of an even grayish film. When one of the surfaces develops a spike and the other a crater, it is because (in most cases) the condenser's capacitance is wrong for the rest of the system and operating conditions. Most of today's ignition systems are grounded on their negative side, which is the fixed contact, and if this develops a crater—with a spike on the positive or moving contact—then the condenser's capacitance is too great. When the spike develops on the fixed, negative contact the capacitance needs to be increased. It should be noted here that the condenser is not always at fault. A loose connection at the coil's primary terminals can also cause problems with abnormal point erosion—as can a too-high charge rate from the alternator, or a battery very badly in need of filling.

Any of these things can upset the ignition system's balance.

Most of all, what every ignition system needs is tender care. Not daily replacement of parts or anything like that; just very careful assembly and adjustment. The most important adjustment is spark timing: it's easy to miss by more degrees than the engine will tolerate. Get the timing more than a couple of degrees off the optimum and efficiency suffers, with errors in the direction of excessive advance being a prime cause of overheating and drastically shortened piston life. This means getting the right equipment to use in timing your bike's engine, and it means not trusting automatic spark advance mechanisms. It also means applying the right kind and amount of grease on the point rubbing block, periodically checking the wiring for loose connections and broken strands, and avoiding the temptation to fine-tune the timing by bending the points' moveable contact bracket. Do everything right, by the book, and you'll get fairly good performance out of even the humble motorcycle battery-and-coil system. The same basic rules apply to magnetos, with the added warning that you should check the rotor/field-armature clearance. And unless you know a lot about leaping electrons, henrys, joules and the like, steer clear of modifications. Bad as they are, all the motorcycle ignition systems will perform at least satisfactorily if you understand how they work and take the right steps to keep them working; and the less tricky they are the less likelihood there is of a sudden failure a jillion miles from home. That attribute is worth a little Sunday morning maintenance—and may even be worth having struggled through our basic explanation. ◉