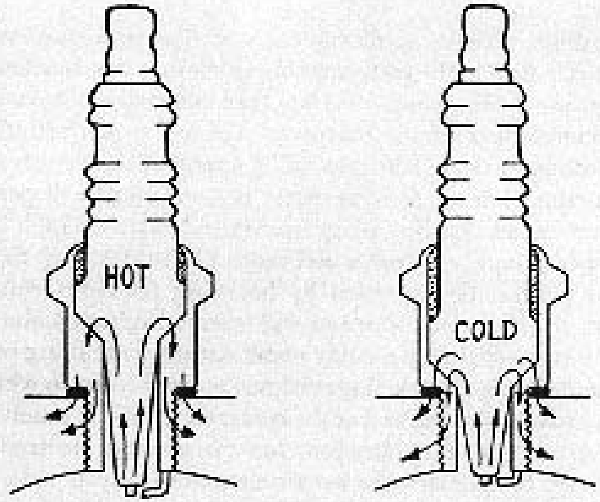
by two-stroke racing engines.

Sports/touring motorcycles, like the 750cc, 3-cylinder Kawasaki usually have a battery powering their capacitor-discharge ignition system. The battery's 12-volt potential is multiplied to the required 400-volts by a special oscillating circuit and transformer, and the capacitors dumped into the spark coils via transistors of the type called SCR (silicon controlled rectifiers). The SCRs are actuated by separate circuits, which are in turn controlled by magnetic triggers. Conventional points will also work here, but most manufacturers seem to feel that as long as they have to resort to solid-state electronics, they might as well go all the way and dispense with the breaker-points. A more suitable system, for racing, is one in which the capacitor (or condenser) is charged directly from a magneto-type rotor/stator arrangement with an appropriate generating coil. By inserting a rectifier-type transistor between the generating coil and the capacitor, voltage is trapped in the latter, to be used in activating the spark coil. With a little jiggling of circuitry, it is possible to use the same rotating magnets to charge the capacitor, and trigger an SCR into releasing the charge to the coil, and this is the arrangement you would find inside the encapsulated wiring of most current "CD magnetos" if you could get them apart. There isn't much I can tell you about these ignition systems except that when they work they work very well, and when they stop working you are obliged to start replacing magic-boxes because everything in their inner workings is A) sealed off so you can't touch the transistors, resistors, etc., and B) you have to know more about electronics to fix the things than most people have at their command. I have done some work in this area, but I wouldn't feel comfortable trying to instruct you in the intricacies of solid-state electronics even if that did not require more space than can be given the subject here – my ignorance is too great. One thing I can tell you is that all the magnetically-triggered systems should be timed using a "strobe" light, it is impossible to set them accurately by any other means, and the best of these systems, badly timed, is inferior to the conventional battery-and-coil, or magneto. Proper timing is the first requirement with *any* ignition system.

Finding the exact ignition advance yielding best results with a given engine is, as noted at the beginning of this chapter, a time-consuming chore, but one worth pursuing diligently. Actually, unless you have changed your engine very considerably from the stock specifications you probably will find that maximum performance is obtained at a setting very near that recommended by the engine's manufacturer. Generally speaking, modifications that tend to raise engine output without increasing the crank speed at which maximum power occurs will require that the spark be retarded slightly from the standard setting. Major upward relocations of the power peak usually require a more advanced spark. I would be delighted to provide you with a universally-applicable rule for predicting the exact spark timing for two-stroke engines; unfortunately no such rule exists. It is known that about 75-percent of the combustion process should be completed by the time the piston has reached TDC, and that when the average rate of flame-front travel can be found, calculating spark advance from the flame propagation rate and the distance from the spark plug to the remote end of the combustion chamber is a simple arithmetical problem. But confusion arises because flame propagation rates vary so enormously. Both the type and location of the spark plug has an influence in this, as do pre-combustion turbulence and the shape of the combustion chamber. Engine speed also has an effect, and as your modified engine probably departs from the original specifications in all of these particulars, it is essential that you do the careful testing necessary in finding that elusive optimum. Start testing with the ignition timing retarded about 5-degrees from the stock setting, and then advance the spark in two-degree increments until best results are obtained. Dynamometer testing is the best means of verifying results, but you can also use a drag strip, for it has been found that while sheer rider-technique is the determining factor in elapsed time, the motorcycle's speed at the end of the quarter-mile is almost exclusively a function of engine horsepower. Thus, if you find that maximum speed (which may be taken from an accurate tachometer) is reached with a spark advance of, say, 27-degrees BTC, then that timing will be the one providing maximum horsepower. Interestingly, the influence of mixture turbulence – which increases with engine speed – is so strong that the spark-advance optimum does not change much even over a fairly wide speed range. Indeed, from all available evidence, the ability of combustion-chamber turbulence to speed burning is so great that increases in peaking speeds frequently require a slight retarding of ignition, while advancing the spark may well give a small improvement in power at lower-than-peak engine speeds at the expense of maximum power.

SPARK PLUGS

People who are relatively inexperienced in the art of tuning racing two-stroke engines seem always to fall into the trap of trying to use a spark plug that is too "cold", and/or one having the wrong nose configuration, which they then compensate with a too-lean mixture. This kind of error probably stems from a basic misunderstanding of spark plug heat-range, and the reason for having more than one type of plug. The reason? As it happens, the temperature of the burning mixture in the combustion chamber is high enough to melt the engine, and it fails to do so only because heat is carried away from the combustion chamber's walls fast enough to prevent them from reaching flame temperature. The spark plug reaches much higher temperatures than the



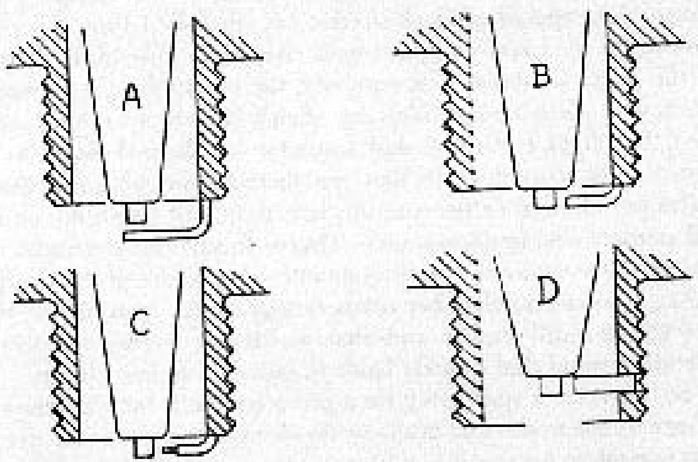
Spark plugs look the same externally, but the heat path from the insulator tip through the plug body into the cylinderhead is much longer in the "hot" plug than in the colder ranges.

cylinderhead itself, because heat moving away from the plug's nose must cross the joint formed by the threads on the plug and in the plug hole. And, of course, the exposed plug electrodes are separated from the cylinderhead's cooling fins by a very long heat-path, and in the case of the center electrode, by the plug's insulator. Consequently, the electrodes get extremely hot, and that is very much a mixed blessing: Fairly high temperatures are required to keep the plug's electrodes and insulator tip burned clean, to prevent the formation of sooty deposits that can short-circuit the spark. But if the electrodes are allowed to become too hot, they will constitute an independent and uncontrolled ignition source. That is to say, the electrodes may become hot enough to ignite the air/fuel mixture in advance of the spark. When that occurs, combustion chamber temperatures climb even higher, which causes auto-ignition still earlier and that yields yet higher temperatures in an ascending spiral that quickly leads to outright engine failure.

So, the correct spark plug for a given engine is one that stays hot enough to burn its electrodes and insulator tip clean, but does not reach temperatures high enough to cause auto-ignition (more commonly termed, "pre-ignition"). Unfortunately, all spark plugs transfer heat from their electrodes to the cylinderhead into which they are threaded at a rate fixed by their construction, while engine operating temperatures vary enormously. "Correct" selection of a spark plug is therefore a matter of choosing one having a heat-transfer

rate compatible with the application at hand. The process of selection is less exacting today than in the early days of the internal combustion engine, principally because the mica and porcelain used as insulators have been replaced by aluminum oxide ceramics that are stronger and much better conductors of heat. Other improvements in spark plug construction have further widened plug heat-range, but not to such extent that any plug will perform satisfactorily in any engine. Touring plugs have extended tips, which burn clean but have exposed ground electrodes and center electrodes, and these respond to prolonged full-throttle operation by becoming incandescent; racing plugs have short, shielded electrodes and will tolerate higher combustion chamber temperatures but foul very quickly under starting and idling conditions.

The most common spark plug configuration is the one in which the ground electrode extends over the end of the center electrode. A much better type, in any two-stroke engine application, has the ground electrode reaching in slightly lower to approach the center electrode from its side. The improvement, here, is that the ground electrode is somewhat shorter, and being shorter offers a more direct heat path to the plug body — which means that it is less likely to become white-hot. A refinement of this design has a short bit of platinum wire inserted in the tip of the ground electrode. This wire's diameter is quite small, and it is used in conjunction with a center electrode also reduced in diameter at its tip, an apparently minor difference unless you



Spark plugs commonly have the ground wire overlapping the center electrode (A) but in plugs made for two-stroke engines it approaches from the side (B). A variation of plug "B" has a short platinum wire in the end of the ground (C). Recessed-nose, side-wire racing plugs (D) are prone to fouling and should be used only when an extremely cold spark plug is an absolute necessity.

consider that much less voltage is required to form a spark between two points than between two flat surfaces. An ordinary iron ground electrode cannot be made pointed, because its tip would instantly overheat and melt, but platinum – with a melting point of 1774°C., as compared with 1535°C. for iron – is less likely to melt, has a thermal conductivity 18 times greater than iron, and will not oxidize. As a result, the platinum electrode survives its hostile environment very well even when used in small diameters, and I would not hesitate to recommend the platinum-tip plug for most racing applications. At any given heat-range, the platinum plug will provide longer life and less tendency to foul than any conventional type plug. Pure racing plugs, which have deeply recessed insulators and center electrodes, with an extremely short ground electrode bridging straight across from a hole through the side of the plug body, should be used only as a last-resort in two-stroke engines. Racing plugs of the type described are very, very prone to wet fouling, oil fouling and every other kind of fouling possible. They are a necessary evil in hyper-horsepower road-racing engines, but should never be used where extended-nose plugs will serve. Not unless there is some kind of major breakthrough in either spark plug or ignition system design, which always is a possibility. I would recommend that all who are serious about keeping ahead of the pack keep abreast of developments in these areas. All the spark plug manufacturers are working constantly to give us improved foul-resistance and reduced spark-voltage requirements, and they are very accommodating to anyone who takes the trouble to write and ask for literature.

"Reading" spark plugs, and the process of selecting correct heat-range, falls much more into the realm of art than science, and it is an art in which one becomes really proficient only after long and sometimes painful experience. But there are a few rules that may be used for guidance by those who have yet to acquire experience – or by the many whose experience has left their ignorance largely undiluted: First, you should know that it is all but impossible to read anything in the appearance of a spark plug unless the engine has been cut clean after having been brought up to operating temperature and given a long burst of wide-open throttle. Very experienced tuners will see the signs they're looking for under the layer of soot, oil and fuel that accumulates so quickly at idle, but even they vastly prefer to work with clean-cut plugs. Second, get the right heat-range before you try to read mixture strength, and my recommendation is that you always use the hottest plug the engine will tolerate. You'll know a plug is too hot when you observe signs of blistering around the insulator nose (which will also be scorched white) and on the electrodes. A too-lean mixture will also give you a whitish insulator, but will not usually produce the burned, pitted appearance of the electrodes that is characteristic of a too-hot spark plug. Also look for signs of melting along the sharp edges at the ground electrode's end – any sharp corner will get

hotter than other areas along the electrode, and trouble will first be revealed there. A plug that is too cold simply looks, and is, wet. Plugs of the correct heat-range get hot enough to burn away oil, and soot, and will have only dry, brown to tan deposits on their insulators after a hard run. As noted before, the correct mixture strength will be very slightly leaner than that which is just lean enough to keep the engine from four-stroking. How much leaner? Not very much, and until you have gained considerable experience with a particular engine you should not reduce strength below the jetting that provides clean running. To get a bit closer to the optimum, I watch the faint, almost invisible ring of soot that forms around the electrode on the insulator's nose, and the light dusting of soot over the exposed end of the plug body. There is a point at which I see "just enough" soot, and if there is more or less than that I interpret the signs to mean a mixture that is too rich or too lean, respectively. And I couldn't begin to tell you how much soot is "just enough"; that would be like trying to explain a taste, or sound, or smell. With experience, you learn to recognize what it is you're looking for, and there is no substitute for that experience. You will also learn – if you know where to look – that the faint light spot on the electrodes at the sides of the spark gap are an important clue to ignition system performance. When you have a spot of about the same diameter as the ground electrode's end showing on the center electrode, or *vice versa*, then you may be sure the magneto is doing its job. When that spot begins to fade, or become ragged around the edges and shrinking in diameter, the ignition system isn't performing as it should. Finally, with experience you'll learn to give your very close attention to *all* aspects of the mundane task of selecting jets and plugs, and spark timing, because in these things you ultimately succeed or fail as a tuner; all the rest is mere mathematics, surgery and wrench-twirling.