Ignition Systems

Proper understanding — and operation — can prevent unpleasant surprises

by KEN GARDNER / AOPA 132319

■■ Some mechanical things perform all that is asked of them and do it well. For certain this is the case of the modern aircraft engine ignition system.

The magneto/spark plug system is simple and reliable, but it can be abused by careless operation or improper maintenance. A pilot who has a basic familiarity with his airplane's ignition system can prevent unpleasant surprises later on.

The heart of the system is its magneto. The magneto contains a small alternating current generator driven by the engine's accessory gear train. A magnet generates magnetic lines of force in a conducting iron loop (Figure 1, A). This force field alternates in direction as the magnet rotates, inducing an alternating, low-voltage electrical current in a coil of wire wrapped around the iron loop (Figure 1, B and C). This coil is the primary winding which does not produce enough voltage for the spark plug; a second coil with more windings wrapped around the primary winding—and called the secondary or high-tension winding—has high-voltage electric current induced in it by the alternating low-voltage current in the primary winding, and it is this current that is directed to the spark plugs.

A set of breaker points (Figure 2) interrupts the current flow in the primary winding just as the voltage peaks, causing a rapid collapse of the primary voltage, which produces an even greater boost in the secondary voltage. A condenser reduces arcing of the points and aids in more rapid restoration of the primary voltage build-up.

Many pilots understand the fundamentals of their automobile engines and often use this knowledge on an analogical basis in determining the behavior of their aircraft engines. While this can be a good approach, it can also be misleading. Thus far, the magneto and automotive systems would appear to be similar, and almost are.

With the automobile, primary source energy is supplied by the vehicle's electrical system; thus the voltage to the primary is relatively constant. The primary voltage in the magneto increases with engine speed and that results in a hotter or stronger spark. The higher engine speeds and loads, the greater spark intensity must be to work against increased combustion-chamber pressures.

Since the magneto provides its own primary source, the engine can be started by propping, as was once done. The automotive engine cannot be started even by hand cranking unless there is electrical power to the system's ignition coil.

The automotive ignition system incorporates an automatic spark-advance-and-retard feature. The aircraft engine has a fixed advance and is retarded only for starting purposes. Maximum power and fuel efficiency require that combustion be completed before the piston begins its power stroke descent. Gasoline burns at a relatively constant speed. As engine speed and power increase, the amount of fuel to be burned increases and the time in which to do it decreases.

To insure that combustion is always completed at the proper piston position we need to ignite the mixture earlier; that process is defined as spark advance. The automobile ignition system is designed to automatically change ignition timing to match varying speed and load conditions.

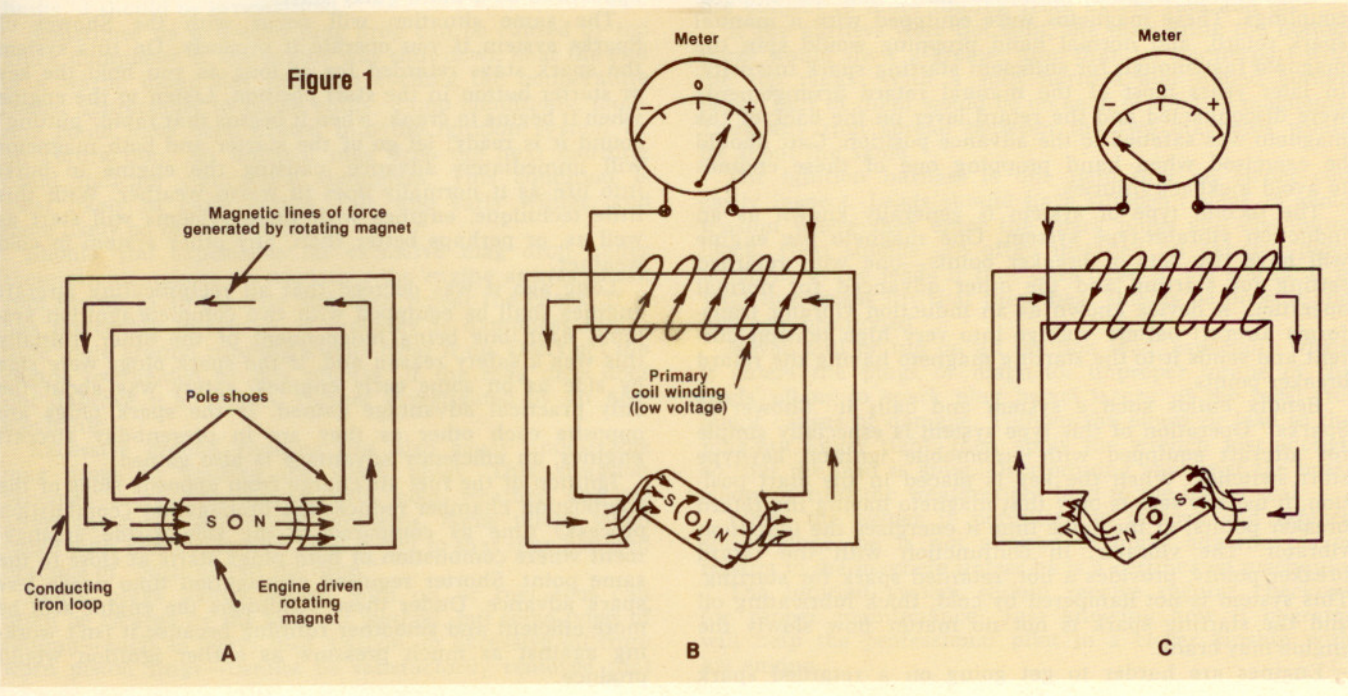
Since spark advance is fixed on the aircraft, it is usually set for maximum engine speed and power. If the spark is set for, say, 28 degrees before top dead center (BTDC), that means that ignition occurs 28 degrees of crankshaft rotation prior to the point where the piston reaches its highest position while on its compression stroke. That condition prevails at all engine speed and power conditions, whatever they might be. If you tried to start the engine with that much advance, it would kick back (attempt to run backward). For starting purposes the spark is usually retarded to a few degrees after top center. Again, this is automatically controlled on the automobile engine.

Retarding the spark for starting is generally accomplished in one of two methods for aircraft engines. One is the impulse coupling. This is a mechanical device, consisting of a spring-loaded coupling with ratchet-like pawls and stop pins. At very low engine speeds—such as cranking conditions—the coupling momentarily halts the magneto until the engine reaches a retarded firing position, then rapidly spins the magneto rotor shaft to firing position.

This arrangement provides the necessary spark retard and the required magneto rotor speed essential for a hot starting spark. The loud "clacking" sound of the impulse coupling at its moment of release can be heard when hand-propping an engine.

Some airplanes have placards directing that you start the engine on just one of its magnetos. It may be left or right, but this usually indicates that only one magneto is equipped with an impulse coupling. Where this is the case, a pilot will do well to heed the instructions. Starting with the magneto switch on both could cause damaging kickback or, if hand propping, serious injuries should the unretarded magneto turn fast enough to fire in its advanced position.

Impulse couplings are reliable and seldom cause any trouble. However, they can become inoperative under the influence of thick lubricating oil and extreme cold (0°F or less). Under these circumstances the pawls tend to stick in their retracted positions. If this happens the spark does



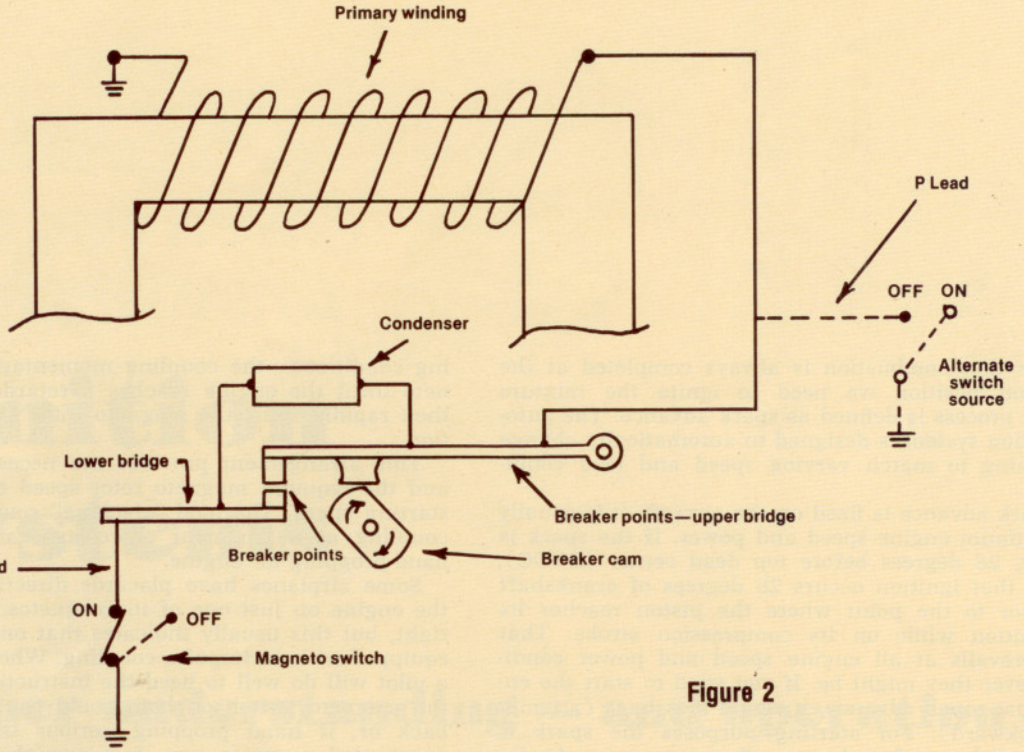


Figure 2

not retard nor will the magneto spin through fast enough to provide sufficient spark intensity to start the engine. Proper preheating will usually preclude such straits.

Some early engines, antiques now, had no impulse couplings. These magnetos were equipped with a manual spark retard, and normal hand propping would spin the magneto fast enough for sufficient starting spark intensity. In later years most of the manual retard arrangements were disconnected and the retard lever on the back of the magneto was safetied to the advance position. Care should be exercised when hand propping one of these engines to avoid kickback injuries.

The second type of system is generally known as an induction vibrator-type system. One magneto per engine will have two sets of breaker points—one with retarded setting for starting and the other advanced for normal operation. A device known as an induction vibrator transforms aircraft battery voltage into very high tension current and sends it to the starting magneto having the retard breaker points.

Bendix builds such a system and calls it "Shower of Sparks." Operation of this type system is especially simple for aircraft equipped with automobile ignition key-type start switches. When the key is placed in the start position, it usually selects only that magneto having the retard breaker points; at the same time it energizes the induction vibrator. The vibrator, in conjunction with the retard breaker points, provides a hot, retarded spark for starting. This system is not hampered by cold, thick lubricating oil and the starting spark is hot no matter how slowly the engine may crank.

Engines are harder to get going on a retarded spark because of the excessive loss of power under retarded firing conditions especially in cold weather. Impulse couplings cease their operation well below normal engine idle speeds. Thus, the spark advances the moment the engine begins to pick up starting speed. The resulting increase in power under such circumstances produces what appears to be a more gutsy start.

The same situation will occur with the Shower of Sparks system if you operate it properly. On this system the spark stays retarded for as long as you hold the key or starter button in the start position. Listen to the engine when it begins to crank; when it begins that rapid "putting" sound it is ready; let go of the starter and both magnetos will immediately advance, causing the engine to burst into life as it normally does in warm weather. With this little technique, engines with these systems will start as well as, or perhaps better than, any other system in cold weather.

Long ago it was decreed that all reciprocating aircraft engines shall be equipped with two complete ignition systems, each one being independent of the other. Initially this was a safety reason and, if the spark plugs were side by side as on some early engines, safety was about the only practical advantage gained. If the spark plugs are opposite each other as they are in present-day aircraft engines, an efficiency advantage is also gained.

Ignition of the fuel air charge from opposite sides of the combustion chamber reduces the propagation (combustion process) time as compared to the side-by-side arrangement where combustion of both plugs starts at close to the same point. Shorter required propagation time needs less spark advance. Under these conditions the engine will be more efficient and smoother running because it isn't working against as much pressure as earlier ignition would produce.

There will also be a greater magneto drop when checking the mags in preflight run-up. The side-by-side setup will have a small mag drop under normal circumstances because of its small efficiency gains. A normal mag drop—that is, one within prescribed limits—is actually the observed combustion efficiency differential between single and dual ignition. It is the primary circuit of the opposite magneto that you interrupt when checking one magneto individually. Thus, if the magneto you selected was inoperative, the engine would cease firing when switched to that magneto. The primary purpose of the magneto check is to determine that both systems are operating. The amount of rpm drop is indicative of how well each system is operating.

However, this comparison check is not valid if both systems are in bad repair. For example, if the spark plugs on the right magneto system were badly fouled, but not so on the left, then there would be a noticeable mag drop difference between the two, alerting the pilot to a possible problem. If the plugs were badly fouled on both systems, there would be no significant difference.

Essentially, the magneto check is a process of checking one system against the other in accordance with the manufacturer's recommendations. The engine speed at which the magnetos are checked is generally determined by a series of factors and therefore is the best compromise.

The simplest method is to switch from the *Both* position to the first mag in order on that particular switch. Note the amount of drop and compare with the manufacturer's limits. Now switch to the next magneto and note the differential between the two.

The initial drop, if within limits, reflects the combustion efficiency loss from delayed propagation. The second reading is, if any, the spread or differential between the two systems. Presuming at least one system to be good, an abnormal spread difference would indicate that one system is not as strong. If the spread is beyond allowable limits, it should be investigated.

Sometimes an excessive mag drop can be caused by too much dampness. If the engine was shut down near the end of a warm, damp day and that evening the temperature cooled appreciably to cause chilly, damp conditions, moisture could have been drawn into the ignition system by air contraction. An unusual mag drop the next morning could indicate contraction dampness. This condition is most likely in early spring, fall, and early winter, and more likely on older equipment.

Should you experience an excessive mag drop under these circumstances try operating the engine at mag check rpm for 20 to 30 seconds and then repeat the check. If it has noticeably improved, it probably is dampness and a little more ground running should clear it up. Don't get the engine overheated in this process; if the mag drop does not improve it should be further investigated by an A&P mechanic.

Excessive ground running can also cause undesirable mag drops by fouling the spark plugs. This situation becomes more pronounced with cold weather and its attendant fuel vaporization problems. Some pilots, when faced with this occurrence, will resort to that time-honored practice of "burning out the drop."

Spark plugs lightly fouled with oil or fuel soot can often be cleared by the burnout method, but some types of fouling—such as heavy lead, carbon, or excessive oil from worn piston rings—cannot be satisfactorily removed that way. If you are unable to determine which type of fouling it is, you should not attempt the cure.

There are many definitions of what constitutes "burning out" a mag drop, but the simple truth is that you must get combustion chamber temperatures high enough to actually burn such contamination off the spark plugs' core nose insulators. In flight such temperatures are normal, but on the ground that kind of heat could cause engine damage because of improper engine cooling. Most engine manufacturers take a dim view of such engine treatment and, unless instructions for this procedure are set forth in your operators manual, it isn't advisable.

Most ignition systems have one single magneto for each of the two systems. There are dual magnetos, which are essentially two complete magnetos in one case having one common drive. The dual magneto requires only one accessory drive pad, leaving the other pad for an optional accessory. There is also a weight reduction, which is always welcome.

Although the dual magneto is not new to the industry and has been proven both in combat military as well as civilian aviation, there are still some skeptics that fear it is a less reliable system due to its single drive. However, if you were to examine the magneto drive train, you would find that both of the single-magneto drive gears are usually driven from one accessory gear just as the dual magneto is.

Secondary, or spark, voltage from the magneto approximates 20,000 to 25,000 volts. The ignition leads conducting the high tension current to the spark plugs must be heavily insulated to contain such voltage, sealed to keep out moisture, and shielded to prevent interference with the airplane's avionics.

The opposed engine has a "split" harness—one magneto firing all top plugs on one cylinder bank and all bottom plugs on the other bank. This is a little more confusing than the neat arrangements for inlines and static radials, but necessary. The bottom plugs on the opposed engine are subject to more fouling from excess fuel and oil.

If the harness were not split, the mag firing the bottom plugs would show a greater drop than its counterpart with the top plugs. With a split harness and fouled bottom plugs, half of them would be on each of the two magnetos. Thus any rpm spread between the two magnetos would be about the same.

The ignition harness is one item that an owner can easily inspect. Leads should have sufficient slack to avoid tension where they enter the spark plugs and distributor block. Heat shields are often installed on exhaust pipes adjacent to the leads if they pass close to the stacks. It is vital to harness lift that these heat shields be present and properly positioned.

Never pull or tug on an ignition lead, especially where it enters the plugs or magneto. Improper torque of the leads' elbow to spark plug barrel is one of the most frequent causes of damage. Tighten the elbow or lead to the plug-nut finger tight, then apply the wrench just enough so that the lead is snug. Overtorquing can twist the brass elbow or ruin the weathertight lead to the barrel seal.

While the owner is permitted to remove and replace spark plugs, he is not allowed to make adjustments or repairs to the magneto unless he is a certificated mechanic.

The ignition system should receive regular checkups for proper maintenance. Just knowing how it operates will help the professional pilot to a closer kinship with his engine. □