Light my Fire

Engine Health

By Bill Hancock

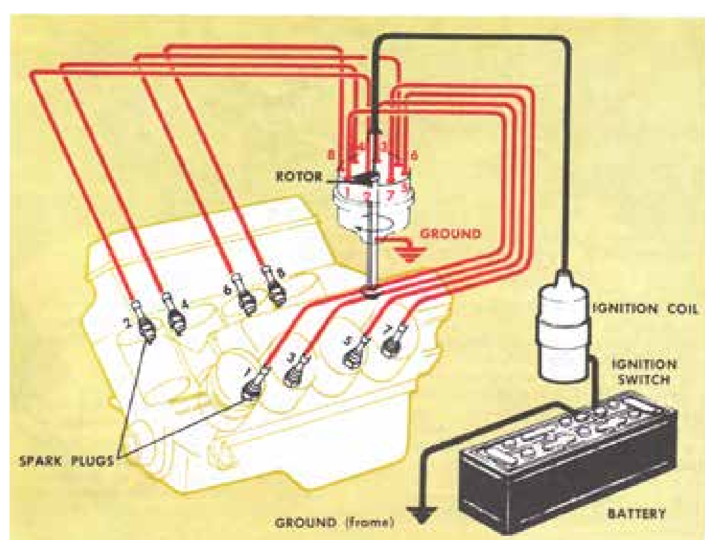
A primer on how your engine uses electricity and fuel to generate energy

Ignition systems in spark ignition internal combustion engines are constantly evolving. Since with the birth of the internal combustion engine, various methods have been used to produce a spark, which in turn serves to initiate the burn that ultimately produces the power stroke. A small nucleus of flame called a kernel ignites and then expands throughout the combustion chamber, in a process called flame propagation. Now enough of the technical stuff, how do we light the fire and what's involved in the system that creates and then controls and ultimately delivers the spark?

Early on, there were two types of ignition systems; battery and magneto. The battery system relies on a DC source of electricity, usually 6 volts and later 12 volts to provide the current necessary to saturate the primary side of the coil and ultimately produce a high voltage spark. The magneto system uses rotating magnets to produce a spark. The advantage of the magneto was that it required no battery, hence, lower total weight and one less thing to go wrong. However, the magnetos were expensive to build and maintain, so eventually, battery powered ignition systems captured the automotive market. Magnetos are still used today in many small private airplanes.

For this article, we will focus on a battery powered ignition system and explore how it works. The ignition system has two main duties: it must first be capable of producing a spark powerful enough to ignite a mixture of fuel and air which has been compressed by the engine during the compression stroke. Secondly, and just as important, it must reliably deliver this spark to the combustion chamber at precisely the instant it is required. If this spark is too early, severe damage could result, if it is too late, the engine will fail to produce adequate power and suffer from overheating.

Now for some interesting facts. The next time you have the opportunity, watch a NASCAR race on TV. Specifically, watch the in-car tachometer. When the V8 engine is running at 9000 RPM, the ignition system is producing a total of 36,000 sparks per minute to the cylinders or 600 sparks per second, for the V-8 engines. Closer to home, one of our boats out on a leisurely cruise down the lake powered with a V-8 at 2500 RPM is only required to produce 167 sparks per second. Remember, these sparks have to be delivered at 8 separate and distinct intervals separated by 90 degrees of crankshaft rotation and with an accuracy of plus or minus 1 degree; each and every time.



The Ignition System

FIG. 1 A typical point type ignition system- drawing courtesy of Revell

The whole ignition timing strategy gets more complicated when you change the load or RPM of the engine. In a well tuned engine we want peak cylinder pressure to occur at anywhere between 10 to 12 degrees after the piston passes Top Dead Center, regardless of RPM and load. This is universally true of all piston engines regardless of the number of cylinders or layout of the engine. As you can now see, the ignition system must be able to maintain both its performance and its accuracy.

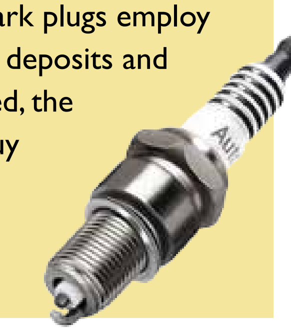
In order to have the pressure peak occur at precisely the right time when we increase the speed of the engine, we have to introduce the spark a little earlier because we have less time for the flame front to fully form and complete the task. We accomplish this by having an advance system that senses changes in engine speed and advances the spark automatically. When we are running at 2500 RPM, instead of starting the fire at 6 degrees before TDC like we do at idle, we start 35 degrees before TDC. When the fire gets initiated earlier, it arrives fully formed just in time to produce peak cylinder pressure at 10-12 degrees ATC (After TDC).

Now imagine we are driving down the road and have to hold our speed constant at 45 mph. In order to maintain our speed when we start to climb an incline, we press down on the gas pedal which opens the carburetor to admit more air and a corresponding amount of fuel. The engine speed remains constant, but the load on the engine has increased. This new set of engine operating conditions requires a different fuel/air mixture and therefore a new spark advance. In order to manage this, the distributor utilizes a second advance system, controlled by vacuum, which measures intake manifold pressure and adjusts the spark accordingly. We use manifold pressure as an indicator of engine load. As the load goes up, the manifold pressure goes down. The engineers use this relationship as a reference to control the spark timing. So now we not only have RPM but also load determining the spark timing.

By now, you can see that the distributor which regulates and delivers or "distributes" the spark to each cylinder is a fairly ingenious electro-mechanical device. In its simplest form the distributor compensates for not only changing engine speed but also the changing load on the engine. The final feature of the device is to "distribute" or deliver the spark to each individual cylinder precisely on time.

Cleaning Spark Plugs

In the old days, mechanics would blast spark plugs with a small sand blaster to "clean" the plugs and then reinstall them to save money. While this will work for a while, todays spark plugs employ advanced coatings which inhibit deposits and once these coatings are removed, the plugs lose their effectiveness. Buy new plugs! They are not that expensive and then all you have to do is check the gap.



Early automobiles and even some of today's small aircraft have manual spark control or at least the ability for the operator to incrementally adjust the spark as needed. As more vehicles were produced, the need to automate spark control became more important. In the beginning, in order to make motoring more appealing to a broader market, many of the functions such as electric starting were added.

Today, companies are looking at essentially removing the steering and braking tasks by introducing self driving cars, thus allowing the drivers to relax and channel their energy into texting, phone calls and relaxing.

In most cases, the cars we drive today have a series of on-board computers, one of which is called the engine controller or ECU, which utilizes individual spark coils for each cylinder, hence there is no distributor. The fuel, air, and spark are all controlled for each individual cylinder by the ECU. The ECU receives a myriad of sensor inputs which it feeds into internal algorithms to calculate precisely when to produce a spark and how large a sip of fuel to inject in each cylinder. By relying on the computer, we can achieve phenomenal fuel economy, great performance while maintaining low emissions. The systems today are so efficient that they literally adjust fuel, air, and spark in between the individual cylinder firings. So as the engine in your vehicle is humming along at 2500 rpm, the computer is constantly evaluating the inputs and adjusting the upcoming fuel, air, and spark to compensate. The systems are so discrete that they can tailor the fuel, air, and spark for each individual cylinder averaged between the cylinder's last event and the current demand.

To grasp this task, let's put it in perspective: Imagine that you wanted to provide the fuel and spark manually for a 250 HP V-8 engine running down the lake at 2500 RPM. If you were given a hypodermic needle and a barbecue ignitor, you would have to click the igniter 166 times and with the other hand squeeze exactly 166 shots of gasoline, of exactly.322 cc. EVERY SECOND! If the captain wanted to speed up, you would have to quickly recalculate and things would get even busier.

This makes watching a Formula 1 Racing engine which routinely turns 18,000 RPM look like a miracle!

Now let's talk about our typical mid-sixties ignition system (Fig 1) we might find in a classic runabout with a small V-8. This system typically has a coil, a point type distributor with centrifugal advance and a single 4-Bbl carburetor. This is a plain vanilla system and, when properly maintained, can produce a reliable spark for years to come.

The coil (fig. 2) takes a low voltage current and dramatically increases the voltage so it will be able to jump the gap to produce a spark when it reaches the spark plug. When this slug of high voltage energy leaves the coil it travels through the coil wire to the center of the distributor cap where it is routed to the distributor rotor. The rotor's job is to deliver the burst of energy to the next cylinder in the firing order. The current leaves the distributor cap, and travels down the secondary ignition wire to the spark plug.

The spark plug has an air gap between the center electrode and the ground electrode, which is where the spark forms because the current has to jump the gap in order to reach the ground electrode of the spark plug.

The points in the distributor do the mechanical switching of the 12 volt current flowing to the coil. In the mid 60's, transistors were introduced to switch the current more efficiently than mechanical points. Eventually, "Hall effect" sensors, which utilize photoelectric principles, came to dominate the aftermarket as a better and more reliable way to switch the current going to the coil. Today most engines employ a crankshaft trigger wheel which produces a signal as it passes a magnetic trigger switch. This signal is then processed by the computer to fire the individual coils mounted to each cylinder.

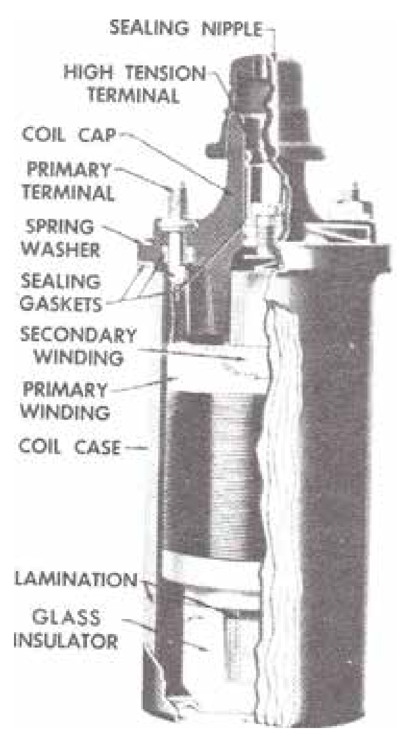


FIG. 2 A typical 12V. ignition coil- Courtesy Delco

For what we are doing today with our boats, a basic points type ignition will work quite well as long as properly set up and correctly maintained. However, you may want to improve your system and hence the power and fuel economy by upgrading your ignition system to a more modern way of producing a spark. There are numerous upgraded solutions available in the automotive aftermarket. In the end, it still comes down to the simple fact of reliability: lighting the fire precisely on time, and burning the charge completely.

As far as an ignition tune-up goes, a distributor will work quite nicely as long as you have correctly adjusted points, a good coil, cap, condenser, and rotor, followed by a strong coil, good wires, the correct firing order and clean, properly gapped spark plugs of the proper heat range.

Most tune-ups begin with removing the distributor and taking it to a shop which has a distributor machine. This device runs and analyzes the distributor to ensure it is correctly set and meets the specs for your particular engine. Once that testing is completed, reinstall your distributor and set the initial timing. It is important to note that worn distributors will not produce reliable spark or meet the complex timing requirements, so be sure to check the distributor for shaft and bushing wear. Replace the secondary wires if needed, and replace the spark plugs with new ones of the proper heat range.

Start the engine and verify your timing marks, then follow the manufacturer's specifications for the initial spark advance. Once the advance has been set, rev up the engine and hold it steady at no more than 3000 RPM, while it is out of gear and with a timing light hooked up to cylinder #1 watch what the timing is doing. The timing should remain steady. If it does not, you will need to correct the problem.

The best things you can do to ensure good ignition performance are the following:

1 Always have a strong fresh battery which has extra capacity.

2 Make sure ALL of the electrical connections are clean and tight and the cables are properly sized for the current required.

3 Make sure the starter is fresh and capably of spinning the engine without difficulty.

4 Have your ignition system at peak operating efficiency as outlined above. Make sure your distributor is the one which is designed and calibrated specifically for your particular model engine. The internal system of springs, weights and vacuum advance, if so equipped, has been carefully developed and configured to match the capabilities of your engine with your boat.

5 Make sure your fuel system including fuel pump, carburetor, lines, filters and tank are all clean and properly adjusted. Drain your old fuel from the entire system and replace it with fresh fuel in the Spring when you commission your boat for the upcoming year. Boats are notorious for getting water in the fuel. There is usually just enough water in the fuel to cause the engine to run poorly, as opposed to not at all. You will spend untold weeks and many trips to the mechanic until you eventually burn out the old fuel and the engine perks up and runs correctly. The mechanic will replace every part in the ignition and carburetor, and charge you accordingly, because that's what most mechanics do, since it is very hard to test gasoline quality in the field. If you suspect there is a problem with water in your fuel, there is a fairly simple test. Take a sample of your fuel from the very bottom of the tank. Since water is heavier than gasoline and will migrate to the bottom of the tank. Place the sample in a clear glass Mason jar and let it sit overnight. If you see a line of separation and liquids of two different colors, there is a strong chance you have water in your fuel. While you can add a product called dry gas, which absorbs the water and allows the engine to eventually burn it, the best and easiest way is to just completely drain the ENTIRE system and start with fresh fuel.

6 Have a good charging system that is operating properly; otherwise you will have just enough power to get to the most inaccessible spot on the lake whereupon the engine will die. It is important to understand that your charging system must be capable of providing slightly more current than is needed to run your engine plus power whatever accessories you may have on board such as lights and bilge pumps. The battery is merely there to provide a reservoir of power for starting when the engine is not running and hence not capable of generating the needed current. During the first few minutes of running your engine after starting, the charging system will provide the excess current necessary to replenish your battery's initial charge. Your voltage regulator plays a key role by controlling the amount of current produced by the generator or alternator.

7 If at all possible, replace your generator with an alternator since alternators are much more reliable and efficient as well as inexpensive. If you are driven to maintain the originality, there are vendors who make generators which have alternators built inside them in order to maintain the old look.

8 Now, hit the key and light the candles and let's go boating!

Today, some preservationists insist on using the original equipment generators on their restored engines, which is fine. Where this falls apart is when today's mechanics (many of whom have never seen a generator) hook up the freshly rebuilt generator to the new voltage regulator and do not know that you must polarize the regulator, or simply fail to do it correctly. If you use a generator and voltage regulator, make sure you know how to correctly polarize your system, otherwise, it will never work properly and you will have nothing but frustration. Instructions for polarizing a regulator can be found in older engine repair manuals covering your engine electrical system.