DISTRIBUTORS

Most of our engines have a distributor, so let's explore just what it is and how this clever device works.

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Using a football analogy, if the spark is the football, the distributor could be considered the quarterback of the engine team. Before a cylinder fires, the distributor sizes up the situation in the engine and then passes the spark at the right time and in the right place to make the most power. Before we begin our analysis, let's take a moment to suffer through another quick lesson on Internal Combustion Engine (ICE) operational theory.

By burning gasoline, our engines produce usable power by converting heat from a chemical reaction into shaft horsepower. The engine is essentially a reciprocating air pump which has 4 cycles. During the first cycle, the piston travels down the bore which creates a vacuum drawing outside air into the engine while it is being mixed with vaporized gasoline. During the second cycle, this gulp of air and fuel, called the charge, enters the combustion chamber where it is swirled and compressed by the piston, and then ignited by a spark which initiates combustion as the piston reaches the top of its travel. In the third cycle, the continuing combustion produces heat causing the charge to rapidly expand within the cylinder which pushes the piston back down the bore thus causing the crankshaft to turn. Once most of the work from the expansion has been harvested, the exhaust valve is opened as the piston nears the bottom of its travel, and then during the fourth and final cycle the rising piston forces the remaining spent gas to continue to flow into the exhaust system.

Because of its name, many think that the distributor's sole function is to distribute the spark generated by the coil to the correct cylinders in the firing order. In fact, the actual distribution of the spark is probably the simplest of the distributor's multiple functions. As

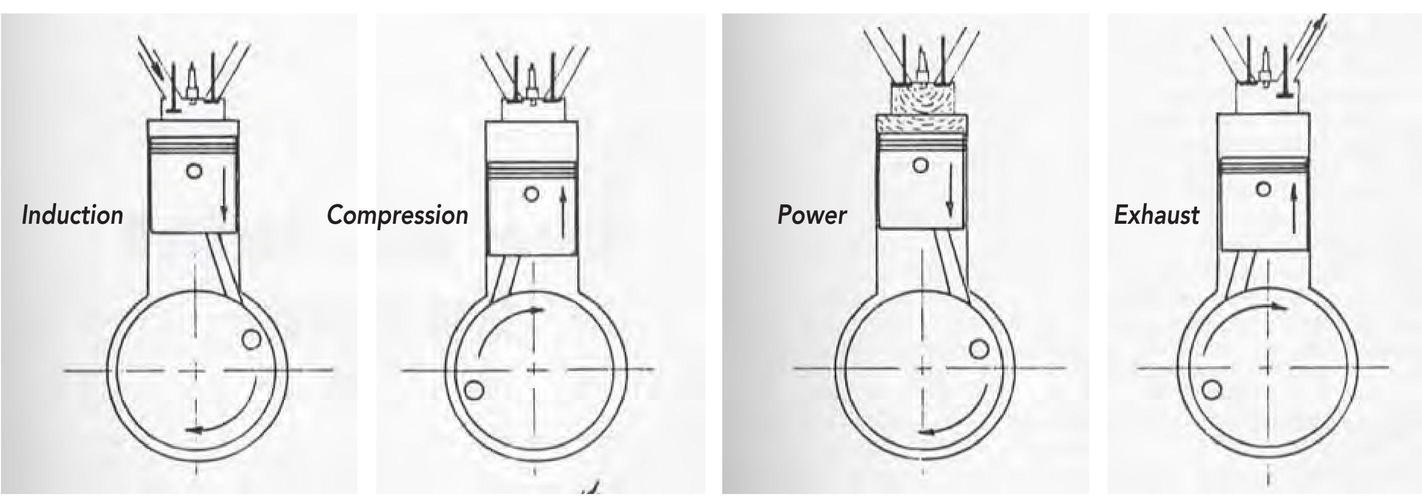

Fig. 1 – The four cycles of a typical boat engine

FIRING ORDER

The cylinders in our engines are arranged and numbered by their designers according in a variety of configurations. The firing order is a sequence listing the numerical order in which the individual cylinders fire. It is critical to not only know the firing order, but also the numbering scheme of your cylinders. Most engine specification booklets or shop manuals contain a diagram showing both the cylinder numbering scheme as well as the firing order. Finally, to ensure proper wiring, it is necessary to know the rotational direction of both the engine and the distributor so the secondary ignition wires can be sequentially installed in the distributor cap according to the firing order. Determining the firing order gets further complicated when an engine has two separate firing orders depending on its application or rotational direction. Be sure you have the correct cylinder numbering as well as the proper firing order information when attempting any work on your ignition system. A task as simple as replacing the spark plugs or secondary plug wires can turn into a nightmare if you manage to get the spark plug wires misoriented.

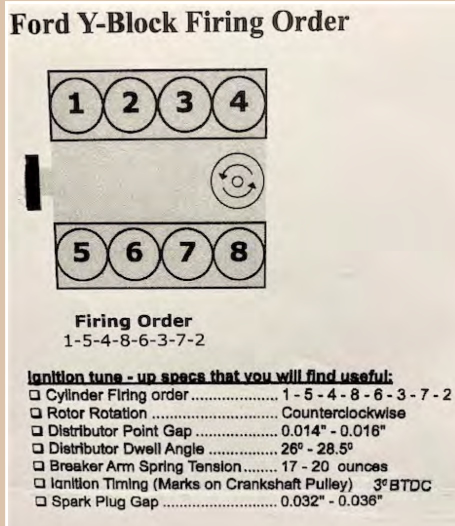

Fig. 2 – An example of timing and wiring information. This is typically avail from the manufacturer or on the internet.

each piston approaches the top of its travel on the compression stroke, the distributor sends a low voltage electrical impulse to the coil which in turn produces a very high voltage current which is immediately returned to the distributor cap where it is directed to the next cylinder in the firing order.

The primary or low voltage side of the coil, typically labeled "BAT" or +, is connected to the positive side of the battery through the ignition switch. The negative or "DIST" side of the coil is connected to the distributor. Inside the distributor is a switch comprised of a pair of contacts called the points, which open to stop the current flow to the coil. This switching action causes a sudden disruption of current to the coil which forces the secondary windings in the coil to produce a high voltage surge of current. The points are opened and closed by a spinning cam located inside the distributor.

Spark timing is accomplished by the distributor which not only synchronizes the creation and the delivery of spark with the crankshaft position, but also varies the timing, typically depending on two factors; engine speed (rpm) and in some cases the load.

Very early gasoline engines required the operator to manually adjust the spark to maximize the output while avoiding detonation. These engines were started by first retarding the spark advance and hand cranking until the engine started running, at which point the spark could be slowly advanced. If the operator failed to retard the spark before cranking, the engine could backfire causing many a broken wrist. Once the engine warmed up and the vehicle was underway, the driver would manually adjust the spark with a lever typically mounted on the steering column. The first internal combustion engines were crude at best, but bear in mind at that point in time, compared to a horse and buggy, they were considered a revolutionary breakthrough.

As the engine operating conditions such as rpm and load change, the distributor adjusts the timing of the spark's arrival at the spark plug to optimize the power. Spark timing is measured by crankshaft degrees of rotation before Top Dead Center TDC for the intended cylinder. The timing for each spark is created by using rpm and load values to provide spark timing which matches or fulfills the instantaneous requirements for the cylinder to achieve optimum performance. The correct total spark advance at any given time is determined by three factors: initial advance, rpm, and load. To better understand the subtle complexities involved, let's explore the relationship between rpm and load and their individual effects on spark advance.

To get a better understanding of load, let's use a car as an example. Suppose your car is running effortlessly down a smooth level road at 60 mph and 2000 rpm requiring a mere 20% throttle opening. Soon you reach the mountains where, to maintain 2000 rpm and 60 mph, you must open the throttle to 35%. By opening the throttle, you are allowing more air to enter the engine where it gets mixed with proportionately more fuel to produce the additional horsepower needed to climb the hill while still maintaining the same vehicle speed and engine rpm. Because more fuel and air were added due to increased throttle opening, the charge is now denser, therefore it needs to be ignited a bit earlier, to reach its peak pressure just after each piston starts down the bore. Spark timing is called spark advance, because the spark is delivered before, or in advance of the piston reaching the top of its travel at TDC.

Interestingly, all engines when properly tuned, whether found in a lawnmower, boat, or car, all have one thing in common; peak cylinder pressure typically occurs at between 8-12 de-

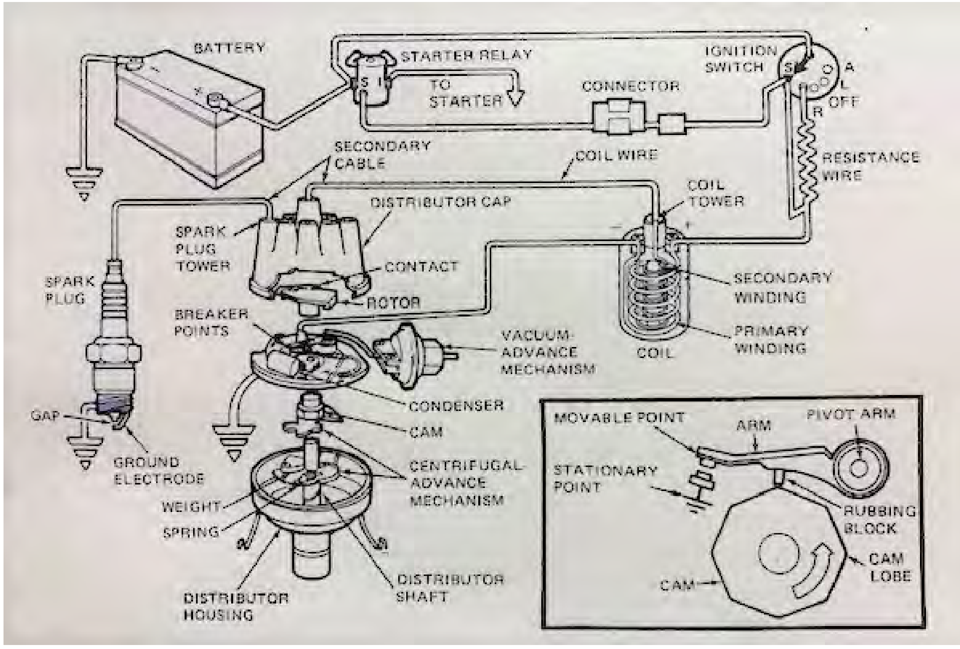

Fig. 3 – Schematic showing the ignition system components. Courtesy of Ford Motor Co.

grees after the piston passes Top Dead Center on the power stroke.

Combustion starts inside the cylinder when the spark plug produces a spark. The engine must burn the entire charge, or at least as much of it as possible within the time allowed, to be efficient and powerful. Optimum combustion takes a certain incremental amount of time depending on the charge composition and pressure. At idle the piston is traveling slowly and therefore we can get away with minimal spark advance since there is plenty of time available for combustion. As the engine rpm increases, the available amount of time for efficient combustion decreases, so to ensure complete combustion, the spark must be introduced earlier by increasing the spark advance. Logically, it would follow that the relationship between available time and time required would be linear as the rpm increases, however as the rpm increases, the mixing motion of the charge mixture inside the cylinder becomes very turbulent, which serves to promote flame propagation, thereby reducing the rate of increase for the spark advance, and in fact actually retarding it in some cases.

To meet the variability of timing requirements due to rpm, the distributors typically found in our boats have a mechanical advance system that uses a pair of weights and springs to control spark advance as a function of increasing rpm. These spinning weights attached to the distributor shaft and held in position by springs are drawn outward by centrifugal force. These weights push against the distributor cam plate to advance it relative to its initial orientation. By changing the weights and spring tensions, the advance rate, commonly called the mechanical advance curve, can be tailored to meet the spark timing requirements of the engine as it moves through the rpm range.

Meanwhile, independent of the rpm, the load is a function of the throttle opening. The load and rpm determine the amount of fuel required. The air/

Fig.4 – Showing the mechanical advance weights used to advance the distributor cam as RPM increases.

fuel ratio required to ensure efficient combustion must keep the ratio of air to fuel by weight at around 12.5 : 1. Depending on combustion chamber mixing and turbulence plus other variables, the changing load and rpm will require different spark advance settings. Fortunately, engine load can be measured by intake manifold vacuum, therefore many distributors use the intake manifold vacuum signal in addition to rpm to control the spark advance. Using a series of springs and vacuum actuators, the distributor can utilize two independent inputs (rpm & load) concurrently to initiate and deliver a spark to each cylinder just in time to match the spark timing requirements for that particular event. The next time around, conditions within the engine may have changed the spark timing requirements.

Since the duty cycle for most of our boats is at constant load and rpm, most of our antique boat engines utilize a distributor that utilizes only a simple mechanical advance system of springs and weights. Vacuum advance systems are typically found in road vehicles where load and rpm are constantly changing due to speed and load requirements.

When engines are initially developed by their manufacturers, part of the process involves developing then optimizing the basic spark advance curve. Hercules, an early generic engine manufacturer, produced a family of engines for a variety of applications. The engines were supplied to equipment manufacturers where they powered cranes, forklifts, and in our case, boats. In each of these unique applications, the engines are adapted and upfitted with task specific hardware, such as engine mounts and in our case, water-cooled exhaust manifolds which came with many of the engines produced for Chris-Craft. Once mounted in a hull, these engine versions then underwent a secondary development step to match the advance curve to the specific application. Within that application, there may be several variables. For example, two visually identical marine engines may each have a different camshaft and

SETTING ENGINE TIMING

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a different distributor advance curve depending on whether they were used in an 18 ft. runabout or a 35 ft cruiser. Over time, these subtle specifications disappear and years later at a swap meet both distributors look outwardly identical. Without a detailed examination of the individual internal parts, or testing, there is no way to determine the true specifications.

The smaller engine suppliers like Hercules typically purchased generic Prestolite distributors, while the major automotive manufacturers like Ford and GM produced their own unique distributors. However, Prestolite often produced distributors for Chrysler Marine engines.

Now that we have the boring part of the story out of the way, how can we ensure that our distributor will perform as designed and produce a trouble-free boating experience? Let's begin with the basics. Start by making sure your timing marks on your engine are accurate. The timing marks are found on the flywheel or crankshaft damper while the second or stationary reference mark is found on a fixed bracket or casting. When the two zero marks line up, they indicate when the #1 cylinder is precisely at TDC. Due to age or mismatched parts, it is very easy to end up with inaccurate timing even though the marks might be perfectly aligned.

Many times, the timing marks become misaligned and are therefore no longer accurate due to switched or worn parts. Depending on your engine, finding TDC can be quite simple or maddeningly complex. If in doubt, have a COMPETENT mechanic verify your marks to ensure the accuracy.

The next step involves checking the distributor for wear. Typically, the distributor shaft rides in bronze bushings which may have worn over time resulting in a fair amount of slop. This extra clearance allows the shaft to literally rattle around in the loose bore as it rotates, causing a number of timing inaccuracies. If you encounter significant wear, it will be necessary to have the bushings and possibly the shaft replaced. Next, make sure the advance cam and weights are free to rotate relative to the distributor shaft. Unless this movement is free, the distributor will not function correctly.

The distributor cam and points must be examined for wear. If the cam or points are worn, they must be replaced. The condenser should also be replaced at this time. The condenser's function is to capture the residual current flow to prevent arc erosion of the points as they open and close. Once these parts have been repaired or replaced it is time to perform a functional check of the system before it is reinstalled in the engine. A distributor machine spins the distributor at varying rpm and by applying current it measures the timing curve of the distributor as speed and vacuum are changed. The resulting curve is compared to the original specification. If changes are necessary, springs and weights can be changed to tailor the curve to meet the requirements.

Fig. 5 – If the shaft bushings are worm, they will have to be driven out and replaced with new ones using a special driver.

Fig. 6 – The components for a typical marine distributor with mechanical advance only. Note the special bronze USCG approved flame arrestor screen located in the non-vented housing required for all marine distributors.

The distributor cap and rotor should be inspected. Look for cracks, arcing, and wear on the rotor and individual terminals inside of the cap. Though not part of the distributor, the spark plug wires play a key role in delivering the spark to the plugs. Be sure to inspect the wires, terminals, and boots. Look for any signs of distress. If you are new to working on your own engine, do yourself a favor. Familiarize yourself with the cylinder numbering and the firing order before removing the wires, then, as you remove the wires, number them on both ends by using some masking tape and a ball point pen. Once the distributor is rebuilt, it should be carefully reinstalled, and re-timed. From there, be sure to perform annual maintenance such as lubricating the cam and adjusting the points.

A note of caution is necessary here. Do not use an unapproved automotive distributor in a marine engine. Since the distributors produce a continual stream of internal sparks, unless they are specially equipped with flame arrestors, they pose a great risk of explosion. Always use a USCG approved unit. Distributors switched from points to electronic operation in the early seventies which eliminated the contact points and enabled the distributor to provide a much more consistent and accurate spark. Because they eliminate the points, they also pose a far lower risk of explosion.

In the 90's mechanics were replaced by technicians, and technicians generally don't repair things, because of rising labor costs coupled with technical complexity, they simply diagnose problems and replace parts. Starting in the late nineties, distributors began to be eliminated and replaced by "distributorless ignition systems" (DIS). This resulted in shops which have the expertise as well as the equipment to test and repair distributors becoming as scarce as shoe repair shops. Be especially wary of what we like to call "Spray Can Rebuilds" where the visible parts are cleaned, polished, repainted, and readily available parts are such as distributor caps are replaced *while the worn parts such as bushings, points, and springs remain untouched.*

Happy boating