"Maker Points" Instead of "Breaker Points"?
The First Generation Mercury CDI Ignition System

Phase Maker CDI.DOC W. Mohat Rev. 1.0 Dec. 11, 2020

If you repair outboards other than the really old antiques, sooner or later you will run into more modern CDI (Capacitive Discharge Ignition) systems. Modern CDI systems are extremely reliable, almost-zero-maintenance systems. However, when CDI Ignition were first being developed in the early 1970s, there were some "evolutionary half steps" as classic Magneto systems evolved toward full CDI over a few years. Some of those early 1970s "CDI Ignitions" were real evolutionary oddballs, and if you run into one of them, you're in for some real frustration, as most manufacturers didn't disclose much (if anything at all) about how they actually worked. Many times circuitry was buried in "modules", that were filled with epoxy to both preserve the circuitry from being damaged by water, and also to protect the manufacturer's design secrets. Even the Factory Service Manuals didn't describe how these systems ACTUALLY worked…...and their "Troubleshooting Guides" were often of limited usefulness. (I'm being polite here.)

And so, in the spirit of this series of "**How Ignition Systems Work**" articles, I'm going to explain how CDI Ignition systems work, over a series of articles. I'll start with the first-generation Mercury "Phase Maker" CDI system, that was the first evolutionary half-step Mercury took toward modern CDI ignition systems. This was a real odd duck, that DID have "capacitive discharge"…..***but ALSO had mechanical points.*** Worse, though, these points CLOSED to trigger the spark, as compared to all magneto systems, where the points OPEN to trigger the spark. Mercury gave this system the name: "**Phase Maker Ignition**", because the points close (MAKE CONTACT…..i.e. "maker points") instead of OPEN (BREAK CONTACT…..i.e. "breaker points"). In fact, when you look closely at this system, almost everything operates EXACTLY BACKWARDS from how Magnetos operate. Strap in, boys…..this is going to get REALLY STRANGE, really quickly!

If you don't have a good knowledge of how Magnetos operate, please go back and re-read my AOMCI technical article, called:

"**Articles_Ignition_Part3_Magic_Of_Magneto.PDF**".

You can download this article easily by going to the AOMCI Western Reserve Chapter's website, and look at the Technical Documents page. This can be found at:

https://wrcoutboards.org/magazine-articles/

You need to understand how classic Magnetos operate first, before looking into CDI Ignition. So……..assuming you have brushed up your knowledge on Magnetos, let's start looking at Mercury's evolutionary migration from Magnetos to modern CDI systems. We'll start with the first generation Mercury "Phase Maker" system, that was used from 1971 to 1972, on 4, 7.5 and 10 horsepower motors.

SO…..if you have an early 1970s small Mercury outboard, here's how to tell if it's got one of these first-generation "Phase Maker" ignition systems. Pull off your flywheel, and see if it looks like the picture below. **See Photo 1, below, for details:**

1971-1972 Mercury "Phase Maker"

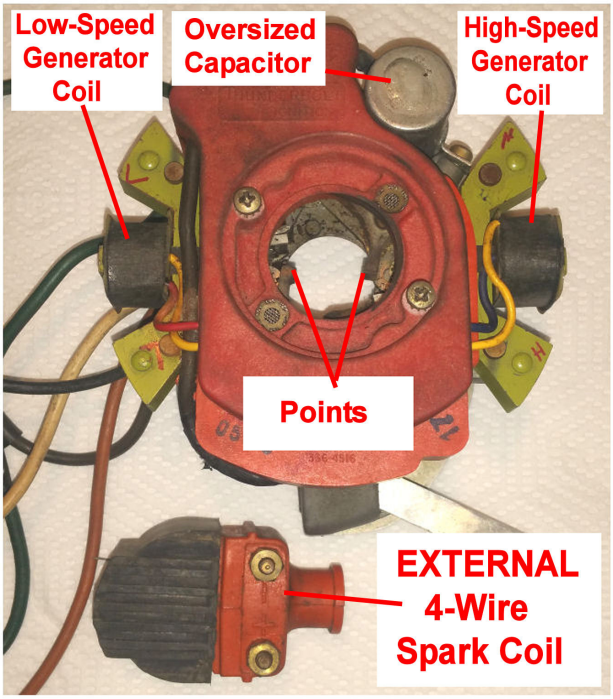


Photo 1 - Early CDI System, With Points

At first, you notice the large orange plastic block, which doesn't seem to be anything other than a terminal block that's holding down some wires. You see what LOOK LIKE standard "breaker points"…..and you see what LOOK LIKE standard spark coils, on 3-pole armatures (like any other normal magneto-based system). But then, things start to look a bit strange…..you see a condenser, (although it's about twice the size of any condenser you've seen before, and it's .5 uF instead of the standard .22uF…..and it's rated for about 1000V, instead of the typical 500V). Worse, you also find a EXTERNAL SPARK COIL, one for each cylinder…..and these spark coils have 4 wires on them (two for the Primary, one for the spark plug, and one extra one for the "ground return" for the spark wire.

"Wait a freaking minute" (you think to yourself)….."if **THIS** is my spark coil, then what the heck are those coils under the flywheel?" You just now realize you've stepped into the Twilight Zone, and suddenly nothing makes sense…...so in desperation you get your hands on either the Mercury Shop Manual for your motor, or you find the aftermarket Clymer repair manual at your local Library. (Reference for Clymer: ISBN number: 9780892873951). You get what technical documents you can, and start

reading…and you begin with looking at the Wiring Diagram they provide…...only to find that there isn't a lot of detailed information there.

SO…..I've drew up my own Wiring Diagram for you, in full color, to make it easier to understand. See Fig. 1, below, for details:

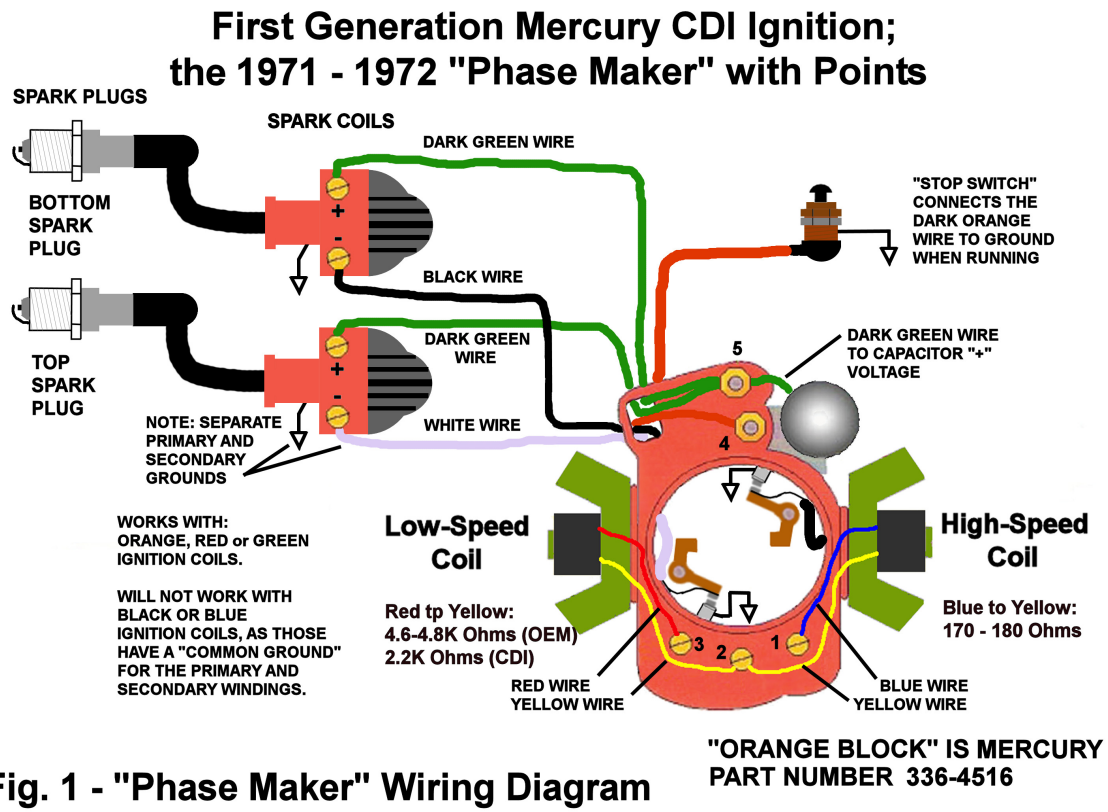


Fig. 1 - "Phase Maker" Wiring Diagram

So, armed with this wiring diagram, you start to read Mercury's (or Clymer's) description of how this works, and quickly you find out that everything works almost exactly BACKWARDS of how your familiar Magnetos operate. Specifically:

1) **In a Magneto, the "spark coil" is under the flywheel**, typically on a 3-pole armature. The magnets spinning past this coil DIRECTLY INDUCE current in the Primary of the spark coil, with the POINTS CLOSED. There is NO VOLTAGE on the capacitor (condenser), because the points are closed, shorting it out.

   When the points OPEN (BREAKER POINTS), the current in the primary is suddenly stopped, and converted into a high-voltage spike. The condenser LIMITS the peak voltage of this spike to under 400V, to protect the points, while

the quickly collapsing magnetic field in the spark coil also induces an extremely high voltage in the Secondary, causing electricity to jump across your spark plug.

TECHNICALLY, in magnetos, the "spark coil" is NOT operating as a transformer here….it's operating as a "flyback coil", creating high voltage in the secondary from the SPEED OF THE COLLAPSE of the magnetic field. As such, the "turns ratio" between the number of windings on the Primary and the number on the Secondary *really doesn't matter much at all.*

2) In this "Phase Maker" system, what LOOKS like spark coils under the flywheel….AREN'T. Instead, Mercury (and Clymer) call them "generator coils", and there's TWO of them (even if you have a single-cylinder engine). The points initially are OPEN (so the capacitor is NOT shorted out). Somehow, these "generator coils" charge up the capacitor to about 400 volts DC…….then the POINTS CLOSE ("MAKER POINTS", remember?)….and this dumps that 400V through one of the external Spark Coils' PRIMARY WINDINGS, …..which INSTANTLY (and I do mean INSTANTLY) causes a high-voltage in the Secondary winding, causing your spark plug to fire.

In this system, the capacitor STORES the charge FIRST, the points CLOSE, and the capacitor acts like a battery, powering the EXTERNAL spark coil Primary winding. **Here, the spark coil DOES act like a traditional transformer**, and the voltage across the primary winding is multiplied by the "turns ratio", causing a VERY HIGH voltage to appear on the secondary.

So….the "capacitor" HITS THE SPARK COIL with 400V, when the points close….which means there's nothing protecting the points from voltage spikes (like the "condenser" does, in your traditional Magneto). And, that's the first downside of this "Phase Maker" system….**the points DO tend to burn and pit quite a bit.** But, with 400V across them, they don't have to be all clean and polished to work well……..they can look very burned, and still operate just fine with that much voltage. Screwy.

But, this is just the tip of the iceberg. OK, you realize…..these "generator coils" are operating like a generator, to charge up the Capacitor (like traditional ignition systems charge up a 12V battery). **But, why 400 volts, and not 12?** And, noting that there are no commutators or slip rings in sight…..you KNOW that these "generator coils" are producing AC voltage, NOT DC….so technically what you have here is not a generator, but an ALTERNATOR…..and specifically a couple of alternator "stator coils". But, unlike in your traditional 12V Battery-powered ignition system, where the stator produces about 20 volts AC (peak), these coils are producing about 400 volts AC peak. Stranger and stranger yet.

You also know from **your traditional 12V battery-powered ignition systems, that the points CLOSE FIRST (spark is NOT generated when the points close, remember????) You then have to WAIT FOR SOME PERIOD OF TIME (about 10 or 20 degrees of turn on the camshaft) for the low 12 volts to start to build up current in the Primary of your spark coil. (Remember setting the "Dwell Angle" on your points on your pre-1970s cars? That's what you were doing!)** So, after some period of time, the Primary coil current gets up to 3 or 4 amps, and your points then OPEN UP (breaker points, get it?)….and the primary current instantly collapses, causing the big voltage spike to be generated in both the Primary and Secondary windings. Your CONDENSER, here, protects the breaker points from high-voltage damage, while the high voltage spike on your secondary fires your spark plug.

The Mercury (and Clymer) manuals claim that in Maker Phase systems, the CAPACITOR gets about a 400V charge, the points CLOSE (MAKER POINTS, remember!)….and that **this causes the spark coil to instantly fire, with NO delay at all..** So, how can this be possible?

Let's go back to basics. All inductors (chokes, coils, transformers) RESIST A CHANGE IN CURRENT. In a 12V ignition system, the VOLTAGE is LOW, and the SPARK COIL is BIG (has high "inductance", causing to STRONGLY resist the 12V that's trying to push current through the primary windings.) It takes a few milliseconds for the low 12 volts to get the current going in the spark coil Primary…...but once the current is there, you OPEN the points, and your spark plug INSTANTLY FIRES, as the FIELD COLLAPSES.

But here, in CDI systems, your "battery" is a CAPACITOR, and you're charging it with 400V (about 33 times more voltage). And, the spark coil is about 1/3 the size of your spark coil in your battery-powered ignition system (the "turns ratio" doesn't have to be as high, because you're starting with a much higher primary voltage). So, 33X the voltage, with 1/3 resistance to current change….**that's a factor of 100 reduction in the time it takes to get the current in that spark coil primary up to 3 or 4 amps.** (So, instead of it taking a few milliseconds (and maybe 20 or 30 degrees of crankshaft angle movement) to build up the primary current, here in CDI systems, it takes a FRACTION of a millisecond (and only a few tenths of a degree of crankshaft angle) for that current to build up…….and it builds up SO FREAKING FAST that it FIRES the spark plug at the same time.

The high 400V charge on the capacitor ALMOST INSTANTLY OVERWHELMS the inductance of the spark coil, INSTANTLY causes the primary current to spike (which INSTANTLY causes a big magnetic field change), which INSTANTLY fires the spark plug. And, quickly, the 400V charge on that capacitor bleeds off, causing the current in the primary winding to collapse (but, usually SLOWLY ENOUGH that you don't get other spark discharges, although it won't really matter if you did.)

See? Everything here is working BACKWARDS from your magneto. Bizarre.

OK, …...it's a bit weird, but electrically it DOES make some sense. But, you're smart enough to know the following:

1) That those "generator coils" are NOT producing DC voltage, so, there has to be a "rectifier block" and possibly a voltage regulator block SOMEWHERE…..and these are clearly alternator-type STATOR coils, not "generator coils".
2) That ALL coils generate voltage proportional to the SPEED of the magnetic field moving by it. The HIGHER the RPM, the HIGHER the voltage. SO, if you have 400V at 1,000 RPM, **you would expect 24,000V at 6,000 RPM**…….which would INCINERATE EVERYTHING….your condenser would explode, the points would burn to a crisp, and your Primary windings in your spark coils would burn up as well. (Well, most likely ONE of these items would short out and catch fire, protecting the others.) So, how the heck is this **not** happening??

Going back to your Mercury and Clymer repair manuals, they do a bit of hand-waving, and say that the "generator coils" are DIFFERENT, and that ONE of them produces power at LOW RPM (the "low speed generator coil")….and ONE of them produces power at HIGH RPM (the "high speed generator coil"). It's IMPLIED that there's some switching between these coils that's going on. And, they DO NOT EXPLAIN HOW ANY OF THIS WORKS.

The manuals DO SHOW that the two generator coils are DIFFERENT….the "low speed coil" measures about 4 K ohms, and the "high speed coil" measures about 200 ohms. Well, that makes sense….the coil producing voltage at lower RPM would have to have more windings to produce more voltage, so it WOULD have a higher resistance….but YIKES, that's got to be a LOT of windings in that "low speed coil". And, how the heck can the excess voltage be managed (that excess voltage HAS TO BE BEING PRODUCED by that low speed coil at high RPMs, right?) Mercury refuses to say.

OK, the wires from these "generator coils" DO GO to the orange plastic "ignition block". So, there HAS TO BE some rectifiers and control circuitry in there, but Mercury and Clymer are TOTALLY SILENT on what this is. You want information, but their documentation just says…."nope, you don't have a need to know".

Now, if you absolutely hate mysteries like this as badly as I do, you just will not take "no" for an answer. So, in a fit of anger…..I took one of those orange ignition blocks, and soaked it in Methyl Ethyl Keytone (a rather aggressive solvent) for a week, and dissolved all the plastic down to nothing….exposing the internal circuitry. And what did I find? Curiously, not very much at all! See Photo 2 – next page:

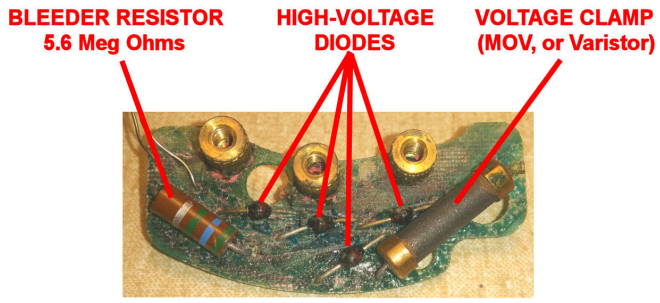


Photo 2 - Internals of Ignition Module

Hmmmmmm…. 4 diodes to rectify the AC voltage coming out of the coils….THAT was expected. A 5.6 meg ohm "bleeder resistor"? Yeah, that makes sense, because you don't want that capacitor to stay charged up to 400V when you shut the engine off, and hold that charge long enough to surprise some poor mechanic some time later. And the "voltage clamp" here is ether a Metal Oxide Varistor (or something like it)……..but **THIS makes no sense,** because **MOVs DEGRADE** with every high voltage transient that's put across them. At 6,000 RPM, if THIS was the "voltage regulator", it would burn to a crisp in just a couple of minutes. So, what the heck? How can this work?

First step, create a formal electrical schematic diagram, (which Mercury and Clymer did NOT provide). See Fig. 2, below:

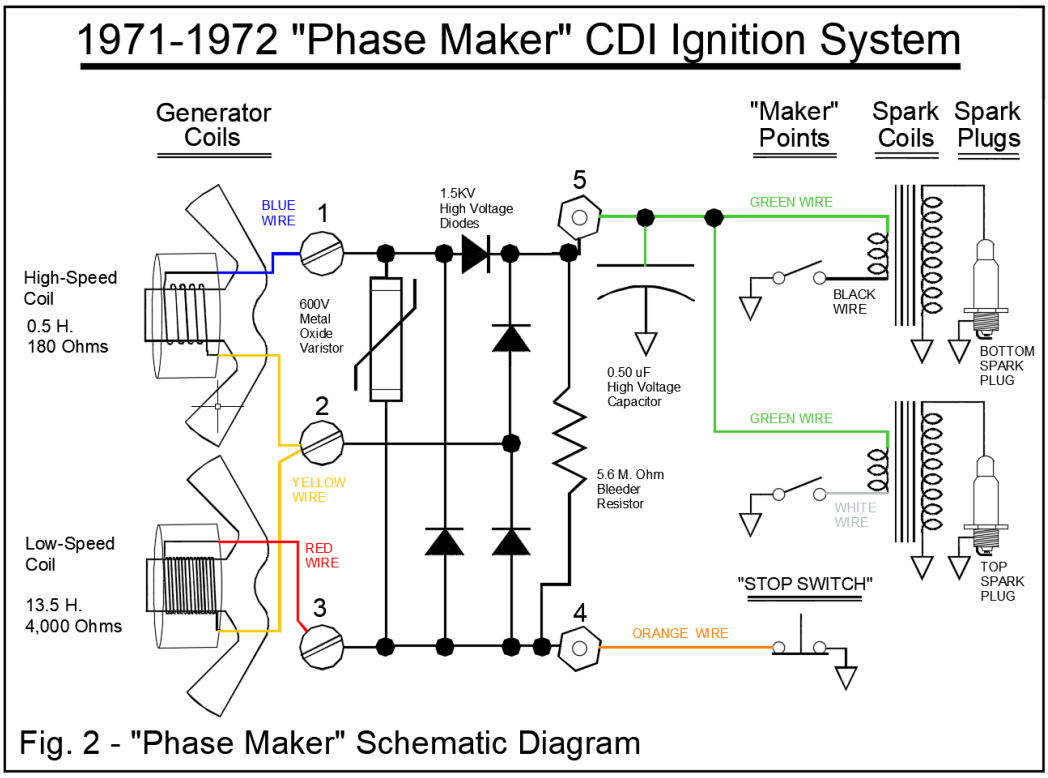


Fig. 2 - "Phase Maker" Schematic Diagram

OK, this is a bit more clear. BOTH SETS OF POINTS are open MOST of the time, allowing the capacitor to charge up to a high voltage. ONLY ONE of the points closes at a time, discharging the capacitor through ONE of the spark coils at a time.

The "stop switch" …….curiously……..this REMOVES THE "GROUND" CONNECTION from the circuitry in the ignition module. This causes the voltages inside that module to swing around wildly, which isn't a really good idea, quite frankly. It WILL cause your ignition to stop working, but……..if the engine is running at high RPM when you press this switch, the voltage spikes here are likely to damage something. Curiously, the Mercury and Clymer literature only say that you should not use this "stop switch" if you are running your outboard on "muffs" (and not in a barrel or lake)…..…..because the "lack of back pressure on the exhaust may cause the ignition module to get damaged". This makes no sense, but that's what they say. **The REALITY is that if you run your engine at high RPM, UNDER ANY CONDITIONS, and press that "stop switch", you're likely to cause damage.** So,…..if you have one of these motors, take it down to the lowest idle you can, and THEN press the STOP SWITCH. (Or, just "choke it out" to stop it). This will prevent damaging your ignition module.

BUT……...let's step back a bit…..there's one mystery left. If that "low speed coil" can produce a couple of hundred volts at low RPM, what keeps it from producing THOUSANDS OF VOLTS at 6,000 RPM, thereby also blowing the ignition module? Remember the rule of generators and alternators….the FASTER the RPM, the MORE VOLTAGE is produced by your coils. Physics is physics, after all…...and if that Metal Oxide Varistor isn't limiting the "low speed coil's voltage", then ….what the heck IS?

AHA, mystery number 2! This one had me <u>COMPLETELY</u> stumped….but fortunately for me, there was one "Outboard Troubleshooting Guide" I found on a Russian website that sort of explained it. I redrew their diagram, and straightened out their rather bad English explanation. So…..please refer to Fig. 3 (on the next page), and follow along.

First, initially I want you to ONLY look at the BLUE voltage curve on this graph. This is the voltage out on the "high-speed generator coil"….and it's EXACTLY what we would all expect to see. **Note how voltage out is related to RPM**…. (Again, refer to Fig. 3 on the next page for details).

"Phase Maker" Coil and Capacitor Voltages

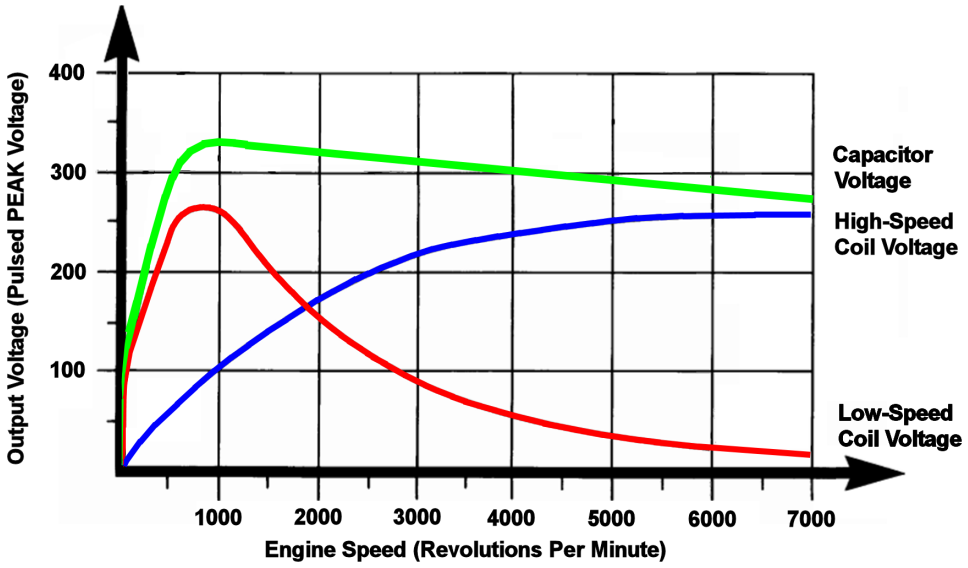


Fig. 3 - Coil and Cap Voltages

Yes, the **BLUE CURVE** is JUST what we would expect to see, because we've seen it on EVERY generator and alternator we've ever come across. BUT…..notice how this is NOT A STRAIGHT LINE, with voltage DIRECTLY proportional to RPM. **In fact, at 6,000 RPM the curve has "flattened out", and it's clear that it won't go any higher, no matter WHAT speed you spin the flywheel at. (Keep this in mind, it's important!)**

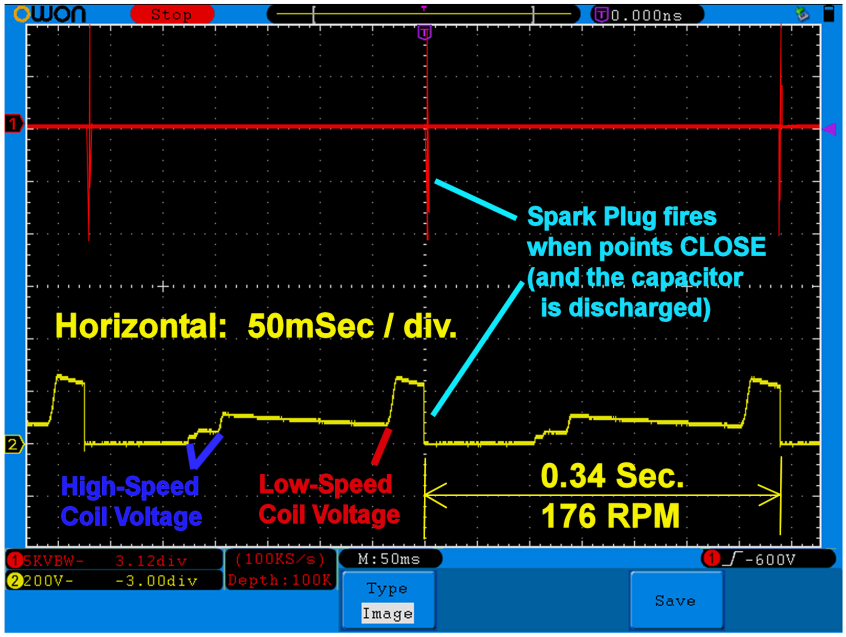
Now, take a look at the **RED curve.** This is the voltage out of our LOW SPEED "generator coil". Note that it starts to produce HIGH VOLTAGE at even 100 RPM...and the curve starts to "flatten out" at less than 1,000 RPM,…..**and the voltage actually starts to COLLAPSE as the speed of the motor is higher than 1,000 RPM**. (We'll explain this in a bit!) And, note how the GREEN curve is **approximately** the SUM of the outputs of the two separate coils (added together by the diodes in the ignition block.)

Looking back at the **BLUE curve**….what would happen if we took this up to 10,000 or 20,000 RPM? Well, just like the RED curve, the BLUE curve would start to come down and collapse, just like the RED curve did…….it just does it at HIGHER RPM.

OK……...what the heck is going on here? How are we getting voltage regulation, with no voltage regulation circuitry in sight? (Well, that's the $50,000 question, isn't it?)

To answer this question, we have to remind ourselves of the basic characteristics of INDUCTORS. Coils of wire (inductors), without any external magnetic fields applied, are called **CHOKES.** They are used to filter out (i.e. " CHOKE") voltage spikes, by NOT ALLOWING current changes. You see "chokes" in electronic filters all the time. The bigger the choke (the higher it's "inductance"), the more severe of a "choke" it is, and the LOWER the frequencies it will allow to pass. Smaller "chokes" (lower inductance) allow higher frequencies to get through….say, over 1000 cycles a second. BIGGER chokes (higher inductance) only allow lower frequencies to pass (say, UNDER 1000 cycles per second.) Do you begin to see where this is going?

With this thought in mind, I got out an impedance bridge and MEASURED the inductance of those two "generator coils". The "low speed coil" measured 4 K ohms resistance, and a whopping **13.5 HENRIES OF INDUCTANCE.** Cripes! That makes a heck of a good low-pass filter! So, while it can produce high voltages at VERY low RPM (and let them get through)…..at above 1,000 RPM, this inductance acts more like a FILTER (killing the output voltage) than it acts like a voltage generator coil. The "high speed coil", in contrast, measures 200 ohms resistance, and **0.5 Henries of inductance.** This is a much smaller inductor, producing less voltage at lower RPM (not enough to run on!)...but produces more voltage ABOVE 1000 RPM , enough to run on just fine, ….. UP TO about 6,000 RPM, where even this smaller inductor starts acting like a filter, and starts LOWERING it's output voltage. And voila' …. we get the voltage curves that we see in Fig. 3, with NO electronic controls needed at all. Yes, this screwy ignition system really does work this way. Still not convinced? OK, I got out an oscilloscope, and actually measured what going on. See Fig. 4, below!



SPARK voltage
5KV / div
25KV peak
35KV p-p

CAP voltage
200V / div
225V peak, but discharges slightly and fires at about 210V, at 176 RPM.

Fig. 4 - Oscilloscope Waveforms

As the picture shows, at low RPM, the "high speed coil" is only making about 100V, NOT QUITE ENOUGH to run on…..but then the "low speed coil" comes along and kicks up the capacitor voltage to over 200 V, even at less than 200 RPM. (We saw the low-speed coil producing over 150V at about 85 RPM, which allows a VERY LOW engine idle speed!)

So, the ADVANTAGE of this first-generation CDI system, is that it produces an insanely hot spark across the entire RPM range, even at VERY LOW (under 100 RPM) speeds. That's the "upside".

The DISADVANTAGE of this first-generation Mercury "Phase Maker" CDI system, is that it **still has mechanical points,** which ARE a wearout / maintenance item, just like in traditional "magneto" systems.

And so, the Mercury first-generation "Phase Maker" CDI ignition system is a bit of a mixed bag. Because of this, it only was only produced from 1971 to 1972. In 1973 and 1974, Mercury produced a second-generation CDI ignition system, which was very similar to the first one, but with one significant improvement. Specifically, they replaced the "maker points" with a magnetic pickup sensor, and then added an ignition "switch module" to actually do the work of discharging the capacitor through the spark coils, using a TRIAC or SCR device, instead of the old-fashioned mechanical points. This

system is very similar to most modern “breakerless” CDI ignition systems that you see today. However, while some versions of this second-generation Mercury CDI ignition system were VERY reliable, others were INFAMOUS for blowing up their (rather expensive) switch modules, and doing it fairly often. What’s in those modules, and WHY some of them were so fragile, is the topic for a future article.

Keep the blue smoke flowing!

Bill Mohat

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