Know your Coils - A guide to restoration and adjustment of Model T Ford ignition coils.

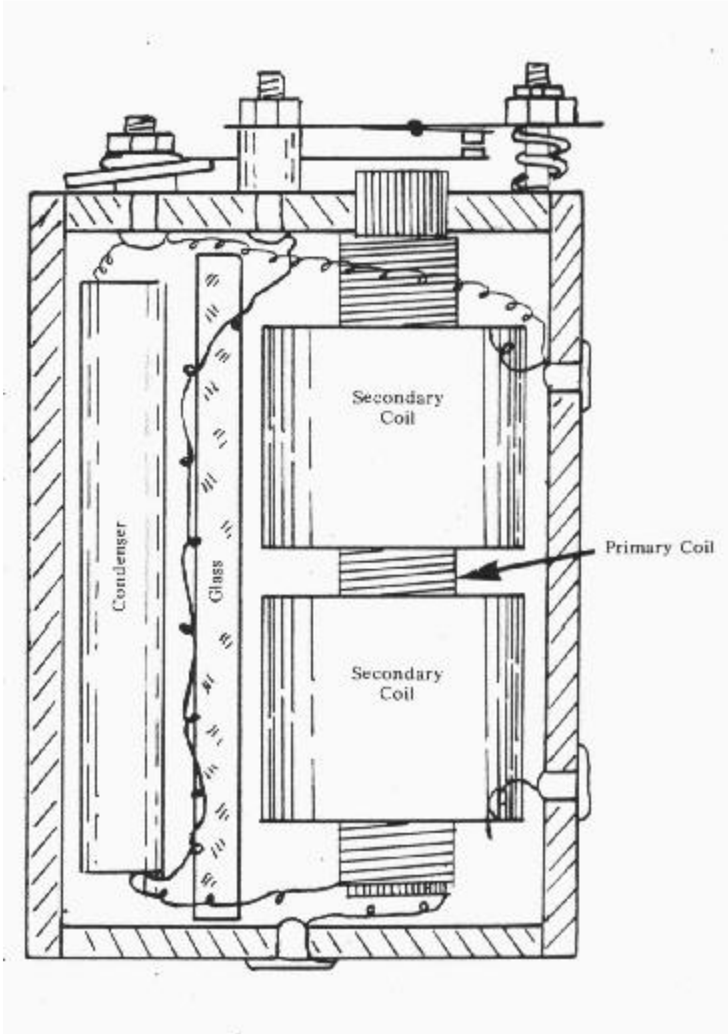
One of the most misunderstood aspects of the Model T is the ignition system.
The coils and timer system goes back to the Quadricycle with the power source being battery only, until the Models N,R,S, which had the option of an accessory dynamo, and finally the T which introduced the flywheel magneto. With nearly 16 million T's, and thousands of the preceding models using this system, one would have to be suspicious of claims of unreliability.
Being of such apparent simplicity, the method of operation and initial adjustment is a trap for the unwary. Simply assuming the coils are glorified door buzzers with a high voltage output leads so many owners into trouble. Left frustrated and unable to get good results, a more familiar ignition system then gets installed. However, with the understanding of some key points, and a methodical set up procedure, the Ford ignition system is as effective and trouble free as any other.

Coil Rebuilding.

Unless they are new reproductions, coils will need to be rebuilt before use. They may well buzz and produce a nice fat spark but this is just the start of the trap many fall into.
Firstly, the eighty plus year old internal capacitor, being of wax paper construction, will be leaky. Not necessarily leaky enough to prevent a spark being produced, but it will be leaky. This leakage may increase with temperature and voltage input to the coil, further compounding the problem. The end result is the output from the coil is not consistent and not as high as it should be. In the extreme case, the coil will buzz but be unable to produce a spark.
Secondly, the condition of the coil points and their setting is important. Incorrect settings can indeed provide a strong spark, but rough running is the likely result.
Some coils have open circuit high voltage windings. These will still often produce a spark as the high voltage jumps the break in the winding. However, not only is there a loss of high voltage for the spark plug, but the continual arcing between the broken ends of the winding will erode it away until the gap is so large that the coil fails to produce an output.
Before rebuilding a coil, the resistance of the secondary winding needs to be tested with an ohmmeter. Typically it should be around 3000 ohms. While reproduction windings are available, they are tricky to fit and unless you have a set of the rarer coil types used in the very early cars, it's easier just to find another coil with good windings.

How the coil works.

The 'door buzzer' approach is only a simplistic way of looking at coil operation. There is however, much more to it. Basically, energy is stored in the soft iron core of the coil and released at a controlled rate, through the high voltage winding and into the spark plug. The capacitor controls how fast this energy is released.



The amount of energy stored in the iron core is determined by how much current flows through the low voltage primary winding, and for how long. These factors are largely determined by the points adjustment and supply voltage.

First, let us examine the low voltage side of the coil. When current from a battery or magneto is fed into the coil, current flows through the primary winding of the coil. A magnetic field thus builds up around the iron core.

This magnetic field does not reach its maximum strength immediately, but takes a finite time, which is determined by a number of things, one of which is the coil current. The higher the current, the faster the magnetic field builds up.

If current is allowed to flow beyond the time at which the maximum magnetic field has built up, the core becomes saturated, and the energy is now wasted as heat. This is why we sometimes see a coil where the pitch has oozed from the casing; chances are the current was set too high.

The iron core has a secondary purpose which is to attract the lower vibrator point, thus interrupting the circuit before the core can become saturated.

Once the current is interrupted, the point springs back, completes the circuit and the process starts again. This happens about 300 times per second. Hence, the characteristic buzz.

The capacitor.

With the sudden interruption of the current when the points open, the energy stored in the iron core is rapidly released. Because the magnetic field collapses faster than it took to build up, the primary winding actually generates something much higher than the battery or magneto voltage. In fact, it’s enough to arc across the points as they open. This is the points arcing seen on a Ford coil with an open circuit capacitor.

We can slow down the rate of magnetic field collapse by connecting a capacitor across the points. The capacitor absorbs the energy at a specific rate of time and reduces the voltage across the

opening points to a non destructive level. Typically, this may be around 300V when the coil is operating from a 6 volt battery. (Note that this figure was measured with a particularly good coil and others may differ!)
Needless to say, the value of capacitor is important as it not only affects output voltage but also point life. The capacity is 0.4 to 0.45 microfarads for KW coils and should be rated for at least 400 volts working.
Unbeknown to most T owners who have attempted to replace coil capacitors is another very important rating. This is the dv/dt rating, which is the rate of voltage change over a specified time period. Put simply, if the capacitor is forced to charge too quickly it will overheat and fail.
The Ford coil requires a capacitor of at least 600 volts per microsecond. That is, if you were to charge the capacitor up to 600 volts in less than one microsecond, the rating would be exceeded and it will eventually fail.
Ordinary polyester capacitors sold by Dick Smith, Jaycar, and the like, are rated at about 100 microvolts per second. This is why so many folk experience failed capacitors when attempting to rebuild coils, even if the correct capacity and voltage ratings have been used. Suitable replacements will be discussed later.

How is the spark plug voltage produced?

Having produced our pulses of 300 odd volts across the primary winding, simple transformer action is used to step this up. A secondary winding of many more turns is wound over the primary. The collapsing magnetic field will therefore induce a higher voltage, the value of which is determined by the ratio of the number of primary turns to the number of secondary turns. The primary winding of a typical KW coil has 212 turns and the secondary winding has 16,600 turns. Thus the turns ratio is 78:1. Now, what happens when the 300V is stepped up 78 times? The magical figure of 23,000 volts is produced; more than enough to reliably jump the gap of a spark plug under compression.
The astute reader may wonder about coils with an open circuit capacitor and why they fail to produce output. After all, with much higher voltage across the points shouldn't this in turn produce a greater spark plug voltage? In theory, yes, but when air ionises and breaks down it forms an arc at those opening points. The voltage across the points gap then drops considerably because an electrical arc is a conductor.

Most of those intending to rebuild their coils will be glad to know that the technical information presented so far is not actually necessary, but it does illustrate why it is necessary to rebuild original coils and with the correct capacitor.

Preparing the coil for rebuild.

To access the internals, it is first necessary to remove the two or three panel pins at the bottom of the coil box. The lid should just slide downwards, unless it has been stuck in position by the pitch inside the box. If so, gently prying will usually release it. In some cases it's necessary to break apart the box but this isn't as drastic as it sounds because it will usually come apart cleanly at the joins.
The messy part comes with removing the pitch around the capacitor. The capacitor occupies the entire length of the box on the left hand side. Immediately to its right is a strip of wood or a piece of glass used to insulate it from the actual coil windings. Both the capacitor and insulator need to be removed. Be careful not to damage the coil windings with whatever implement is being used to dig them out. In the process, pieces of pitch will fly everywhere and stick to everything. It is better to chip out the pitch cold rather than to heat it for it will come out in chunks rather than a gooey mess.
As the capacitor is extracted, cut off its two connecting wires close to the body; one at each end.
Next, remove the points assembly; this involves removing all the nuts on the top of the coil.

Capacitor replacement.

As explained previously, there are very few capacitors suitable for use in Ford coils. The original capacitor has a value of 0.4 to 0.45 microfarads. The nearest value available today is 0.47 microfarads which is well within tolerance.

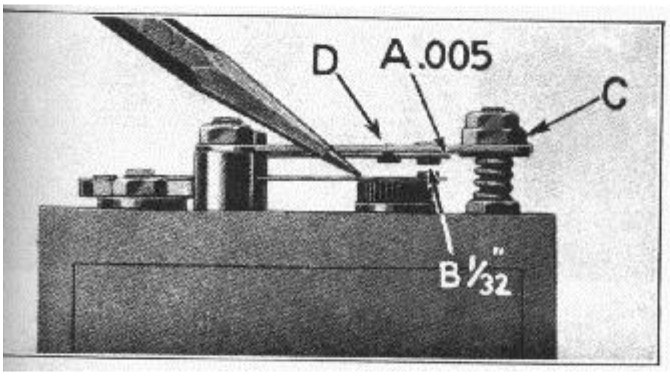
It is futile obtaining the capacitor from any of the usual electronics part suppliers because it will have insufficient dv/dt rating, and will eventually fail, no matter how high the working voltage.
While points capacitors used for distributor ignition systems may look enticing, they have inadequate dv/dt rating. Electrolytic capacitors are the worst possible type one could choose. Not only are they for DC only, but are completely unsuitable for pulse circuits and will fail immediately.
There are two kinds of capacitor which are suitable. The first is a polypropylene type available from Farnell and other specialised suppliers. However, its dimensions make it awkward to fit inside the box and it is rather expensive.
The best type of capacitor is a Sprague "Orange Drop" which is available from several Model T parts suppliers. Unfortunately, some suppliers are still selling ordinary polyester capacitors which fail. So, I always purchase direct from the original source, www.funprojects.com. Not only do these easily fit in the coil box, but they are very inexpensive; around $2.00 each.
The story of why it is essential to use the correct capacitor is described further on the Fun Projects site.
Again, I need to emphasise incorrect capacitors will end in frustration. Provided the correct type is used, the coils will happily operate from a 30V magneto for a lifetime, without the capacitor failing.
Installation is simply a matter or connecting its leads to the wires cut off the old capacitor. The joints should be twisted before soldering, given the vibration the connections will be subjected to. I don't advise re potting the capacitor until the coil is tested, just in case there are other faults. The insulating glass or wood will not fit back in the box, but fortunately it is no longer necessary with the new capacitor.

Points checking and replacement.

Because the coil box wood is soft, it may have been noticed that the two cylindrical spacers used to support the upper point have sunk into the wood, likewise the attachment of the lower point bridge.
Leaving things in that condition will prevent correct point alignment, but one can simply pack up the depression in the wood with washers to restore the original level.
The screws and nuts need to be cleaned of rust because this can result in non operation of the coil.
The point gap adjustment nut (the one everyone fiddles with when they shouldn't) has fibre washers to separate the spring from the upper contact.
If they have crumbled away they will need replacement. The fibre washer is not strictly necessary with the wooden top coils, and a steel or brass one can be used instead. Brass top coils do require the fibre washers, otherwise the top of the coil will be connected to the upper point and short out.
Old points can be reused provided pitting is not severe and most of the contact surface is present. It is possible to clean them up for a new lease of life, but any filing must be done as squarely as possible, otherwise the full contact will not be made, resulting in overheating and erosion of the small part that does make contact.
Given that new points are inexpensive, it is worth replacing them when rebuilding a coil unless the old ones are in excellent condition.

Installing the points.

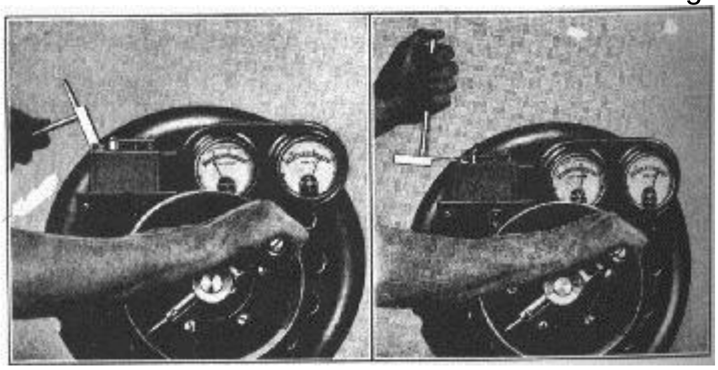
Replacing the points is straightforward enough, but if the screws securing them to the box keep turning or need replacement, now is the time to deal with it. These screws are of an obscure thread but replacement nuts are available. If authenticity is not important they can be re threaded or replaced with something more convenient.
When screwing down the nuts, see that the points are set squarely. This is done by holding down the upper contact, against the lower contact and seeing that the two contacts are fully touching.
Next, the points gap adjusting nut can be set (point C in the diagram). To do this, hold down the lower vibrator contact until it touches the iron core. Using a feeler gauge, screw down the points adjusting nut until the upper vibrator contact has a 0.031" clearance.



The cushion spring is the final static adjustment. Here, with the lower contact held against the core, there needs to be about 0.005" between the cushion spring and the upper vibrator, shown at point A. This is achieved by slightly bending the upper vibrator which can be done by gently tapping on point D.
The coil is now ready to be set with suitable apparatus to be described later.
Once the points have been statically set it is now time to set the current and check for double sparking. This is an area where many run into trouble, again resulting in frustration and discarding of the original ignition system. Suitable test apparatus is required and there is no shortcut.

Setting the current.

Ideally, one has access to a hand cranked coil tester. This is the simplest means to check for correct settings. The procedure is outlined in the Ford Service Manual, which every T owner should have, so I won't go into detail here except to say that the machine is cranked at sufficient speed to show 6 volts. Then, the current of the coil is set to draw 1.3 amps. Coil current is set by means of adjusting the tension of the lower vibrator point. One way of doing this is to use a pair of long nose pliers and bend the lower contact bridge up to increase current or down to decrease it. The service manual shows a small hammer being used for the same purpose.



Eliminating the double sparking.

There should be 16 evenly spaced individual sparks around the spark ring of the coil tester. If there are groups of multiple sparks then the cushion spring tension needs to be corrected by bending the upper vibrator point near where the cushion spring rivet is. Again, the procedure is outlined in the service manual. The important point here is that if this is not checked, rough running on magneto is a possible result.

No hand cranked coil tester.

In the real world, few have a hand cranked coil tester. Despite less and less T owners using the original ignition system as time goes on, it is surprising how much they sell for. One modern alternative is the "Strobo-Spark" tester made by Fun Projects which simulates the old hand cranked tester and shows multiple sparking if it is present.
As I have neither of those, I use an oscilloscope to check the coil firing point, but the operation is too technical to explain here and few T owners would possess such an instrument.

Battery operated coil testers.

Familiar to many, these simply consist of the coil being placed into a jig which connects it to a battery via an ammeter. A spark gap is provided to load the coil and simulate a spark plug. These devices have their place and can be useful provided their limitations are understood, the most important of which is they will not show up double sparking. However, they can be used to set coil current reasonably accurately.

The meter used in the battery powered tester is a moving coil type which only measures DC. The hand cranked tester uses a moving iron meter which measures AC. Without going into the details of why, a coil set to 1.3A on a hand cranked coil tester will show something different on a DC powered tester. My tests show a 200 milliamp discrepancy with meters I have tried. This is not a serious problem, but merely one to keep in mind. The current setting of a Ford coil is not critical and 1.3 to 1.5A is satisfactory. The important thing is that all four are adjusted identically.

Note that for those who have ideas of using a 12V battery with a coil tester, the current readings are completely different, and setting to 1.3A will result in short point life as well as difficult magneto operation.

When a coil is run at more than 6V, the current automatically reduces but the power input to the coil remains roughly the same although it is not a completely linear relationship. This is one reason the 30V AC from the magneto does not overload the coil as might be first thought.

The source of 6V for the coil tester should be a battery of reasonable capacity, otherwise the voltage will drop under load and give erroneous results. For those who don't have a 6V car battery, a new 6V alkaline lantern battery (of the type that fits Dolphin or Big Jim torches) can be used providing the tests are kept short. Incidentally, such a battery has enough capacity to run Ford coils and get you home if your magneto or normal car battery has failed.

Battery only operation.

If your coils will only be operated from a 6 (or 12) volt battery due to a faulty or non existent magneto, a DC tester will get you by for setting the coils.

Operating conditions for coils are quite different on DC (battery) and AC (magneto), and the multiple sparking is less of a problem with DC. This gives rise to the 'rough running on magneto but smooth on battery' phenomenon when the coils haven't been set up correctly.

Simply set the static clearances on the vibrator points and cushion spring, and then set the current to 1.3A at 6V.

A word on battery versus magneto operation would be pertinent at this point, however the subject is an article in itself and will have to carry over to a future time. Suffice to say, with attention paid to a few points, battery operation is satisfactory and one should not feel unable to use the Ford coils if the car does not have a working magneto. Conveniently, it turns out that the ideal operating voltage on DC is between 6 and 12V. As an example of performance, 70+ km/h can often be achieved in a car with a 6 volt electrical system and no magneto.

Migration of the contact material from one point to another occurs with DC operation, the result being one point loses material to the other. My observations are that on 6V it occurs at an insignificant rate, probably on par with magneto operation, but is more prevalent on 12V. Even then, it is so gradual as to be practically irrelevant and this has been proven by a number of cars in the club.

Re potting the capacitor.

If all has gone to plan, and the coil is now working and set correctly, the capacitor needs to be secured. One can re use the old pitch by melting the pieces in a tin can over a weak blowtorch flame. However, there will not be enough to fill the entire void unless one has saved the pitch from other defective coils. My preferred method is to use expanding foam. This can easily be cut away with a knife if repairs have to be made in the future, but is quite rigid when set.

Provided the coil restoration has been done correctly, there should be no need to attend to them for many years. Using my own car as an example which has now done around 19,000km since the coil rebuild, the points have not needed adjustment, the capacitors have not failed, and the points themselves are still clean with only minor pitting.

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