The Double Spark Doctrine Paradox

By Mike Kossor January 3, 2017

The Double Spark Doctrine

The **Hand Cranked Coil Tester (HCCT)** is the time proven, trusted tool for properly testing and adjusting Model T coils. Each coil is tested by turning the HCCT crank at moderate speed while adjusting the points to produce an average coil current reading of 1.3A on its Ammeter while observing 16 individual sparks are displayed by the rotating spark gap. The 1.3A coil current reading indicates the coil fires spark at the correct time and a single spark at each of the 16 locations means all that energy is concentrated in just one hot spark to ensure good combustion. A double spark at any position indicates the coil points are misadjusted because the spark energy is divided between 2 sparks; a weak spark firing early (advanced) followed by another weak spark firing late (retarded) resulting in poor ignition timing, questionable combustion and degraded engine performance. Thus the lore of the **Double Spark Doctrine**: **Single Spark = GOOD, Double Spark = BAD.**

HCCT Model T Coil Adjustment

HCCT coil adjustment uses coil current as an indirect approximation of coil firing time. Set all 4 coils for the same average HCCT coil current and the presumption is each coil will take the same amount of time to fire spark. While this may be true for identical coils, all 4 coils are not always identical and there are other anomalies like point arcing that can skew coil firing time significantly despite being adjusted for the exact same average current. That's bad because coils that take different times to fire spark means ignition timing variation from one cylinder to the next which degrades engine performance.

Dwell Time to Fire Method of Model T Coil Adjustment

Since the end objective of adjusting Model T coils is to set them for equal firing time, why not directly measure the time it takes each coil to fire spark and set them for equal firing time? That was not possible 100 years ago but it is today thanks to modern electronics. The Electrically Cranked Coil Tester (**ECCT**) is a new coil tester specifically designed to do exactly that using what is known as the **dwell time to fire method** of coil point adjustment. This method applies a rapid pulse of electricity to the coil similar to what the coil receives during normal engine operation and accurately measures how long the coil takes to fire spark from its resting state. The ECCT also measures the coil current but it measures the coil current of the individual spark responsible for combustion at the moment of spark fires rather than an average current of a bunch of sparks so it knows exactly how hot the spark is that initiates combustion.

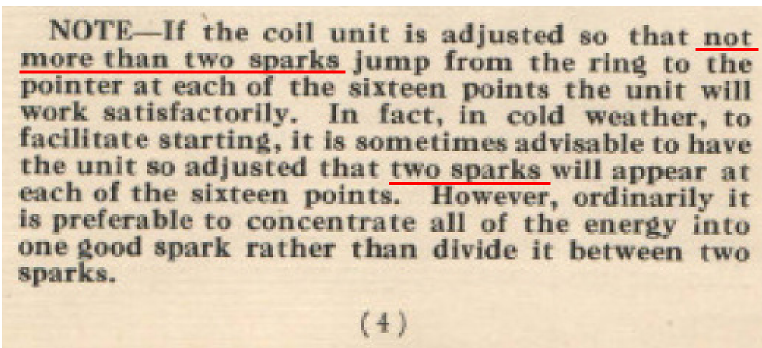
Adjusting coils using the dwell time to fire method has been growing in popularity because it is now easy for anyone to do and accurate. Excellent engine performance has widely been reported on properly maintained cars with all 4 coils adjusted for equal firing time. Several coil rebuilders with years of HCCT experience have reported superior engine performance using coils tuned with the dwell time to fire method based on actual road test results. This included qualitative observations such as smooth engine operation and strong pulling to quantitative observations like ability to climb familiar hills in high pedal easier with greater speed in less time compared with coils adjusted using the HCCT or other coil testers.

Dubious Superiority

A few HCCT users skeptical of the reported superiority of ECCT adjusted coils were quick to pop ECCT adjusted coils into their trusted HCCT and got a surprise; ECCT adjusted coils violated the Double Spark Doctrine; they produced double sparks! This immediately cast doubt about claims of superior engine performance using ECCT adjusted coils. Unless, of course, what they were really observing was a paradigm shift; a fundamental change in underlying assumptions. Could it be the Double Spark Doctrine we were all taught and lead to believe to be true is not always true?

The Double Spark Doctrine Revisited

First of all, we know the dwell time to fire method of coil point adjustment results in good Model T engine performance; really good engine performance. In fact, several Montana 500 endurance car drivers used this method of coil point adjustment to achieve average speeds of nearly 55 MPH to win the Montana 500 with nearly stock engines. The topic of HCCT "double sparking" comes up periodically on the MTFCA discussion forum. One notable discussion was back in October of 2011 http://www.mtfca.com/discus/messages/179374/242895.html?1321748342 Discussion participant Jim Thode challenged the Double Spark Doctrine; he questioned if the traditional thinking that HCCT double sparking is always a bad thing. Jim pointed out that the Instructions for using the Ford Agents' Coil Unit and Magneto Test Stand (HCCT) actually states double sparking is OK and sometimes even advisable! Here is an excerpt from the manual.



NOTE—If the coil unit is adjusted so that not more than two sparks jump from the ring to the pointer at each of the sixteen points the unit will work satisfactorily. In fact, in cold weather, to facilitate starting, it is sometimes advisable to have the unit so adjusted that two sparks will appear at each of the sixteen points. However, ordinarily it is preferable to concentrate all of the energy into one good spark rather than divide it between two sparks.

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Jim then proposed theories why the Ford HCCT Operator Manual said what it said about double sparking but did not have any measured data to back up his theory. Jim's challenge of the double spark doctrine was promptly dismissed by the experts with a plea to search the forum archives for proof why Ford Engineers were mistaken and the Double Spark Doctrine is absolute; which he did but found little information. Further research was needed to get to the bottom of this.

The Double Spark

The common explanation why Ford and KW coils double spark is insufficient cushion spring tension. Weak cushion spring tension permits the lower vibrator spring contact to pull away from the upper cushion spring contact prematurely before the coil is fully energized which produces an early weak spark. The point contacts close again and current flow resumes to eventually produce a second weak spark later than needed. So a double sparking coil results in poor engine performance because of improperly timed sparks that are too weak to guarantee reliable and complete combustion. While this scenario is plausible, it's not the only reason why a coil can double spark when tested on the HCCT. Understanding the other reason why a coil can produce a double spark requires a review of HCCT operation and its magneto voltage output and detailed study on how the coil responds to generate spark.

Review of HCCT Operation

The HCCT magneto produces an AC voltage output consisting of alternating negative and positive voltage pulses as the hand crank is turned as is illustrated in Figure 1. The AC voltage is represented by the green triangle wave with amplitude change displayed on the vertical axis and time displayed on the horizontal axis. Note that the HCCT magneto voltage shown in Figure 1 produces 3 negative voltage pulses (A, C, and E) below 0 volts and 2 positive voltage pulses (B and D) above 0 volts. Any **one** of these 5 voltage pulses will make a model T coil fire spark but we will focus on what happens during just one of these magneto voltage pulses; **Pulse B**. Referring to coil pulse B in Figure 1, note that coil points can be adjusted to fire spark at different times during magneto voltage pulse B. The coil points can be adjusted to fire spark just as the magneto voltage pulse is reaching its peak value at **point 1**. The points can also be adjusted to fire spark just after the magneto voltage pulse peaks at **point 2** or the points can be adjusted to fire spark well past the peak magneto voltage pulse as it the voltage is falling in value at **point 3**. We will examine each of these possible firing locations in detail to understand the spark characteristics of each case.

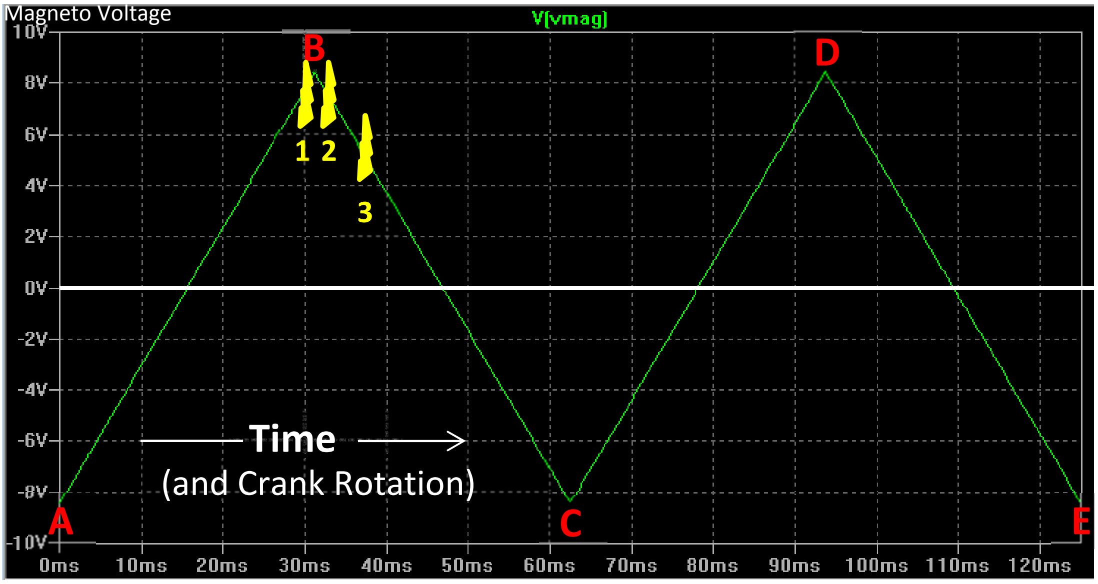


Figure 1. HCCT Magneto Voltage Output versus Time

The Dreaded Double Spark

Referring again to Figure 1, magneto voltage pulse B is just reaching its peak value at Point 1 when the coil points open and spark fires. The actual HCCT magneto voltage and current waveforms of a coil firing spark at point 1 of the HCCT magneto pulse is shown in Figure 2. The HCCT magneto voltage is shown in yellow and the coil current is shown in blue. Time is shown on the bottom scale in milliseconds (ms). The first spark fires when the coil current (blue) reaches 3A and abruptly drops to 0A just at the magneto voltage (yellow) reaches its peak value of about 6 Volts cranked at 125RPM. The coil points close almost immediately, charge up again but this time only to 2.5A before firing a second weaker spark later. Again, the points close almost immediately after the 2nd spark and coil current starts charging the coil again but by this time, the magneto voltage is now too weak to force the coil current high enough to fire so no 3rd spark.

The measurement shown in Figure 2 was made using a coil with insufficient cushion spring tension and vibrator spring adjusted to register around 1.5A average current on the HCCT Ammeter; the current reading fluctuates depending upon cranking speed due to the insufficient cushion spring tension. The spark appeared pale/weak and sounds inconsistent firing with visible single and double sparks depending upon cranking speed. This is an example of the “Dreaded Double Spark”. The key characteristic of the Dreaded Double Spark is the points close almost immediately after opening. Even if the HCCT is cranked significantly faster at 250 RPM, the Dreaded Double Spark continues to be visible. This can be seen in the oscilloscope measurement illustrated in figure 3. Despite the fact the magneto voltage now peaks at 11V and rises twice as fast, the coil current only increases slightly to 3.6A before the points open and fires the 1st spark just as the magneto voltage peaks. The points remain open for only about 0.5ms and close again to charge the coil to about 2.4A to produce a 2nd weak spark. The dreaded double spark definition still holds true; an early (advanced) weak spark followed by a late (retarded) weak spark despite the faster HCCT cranking speed, 250 RPM.

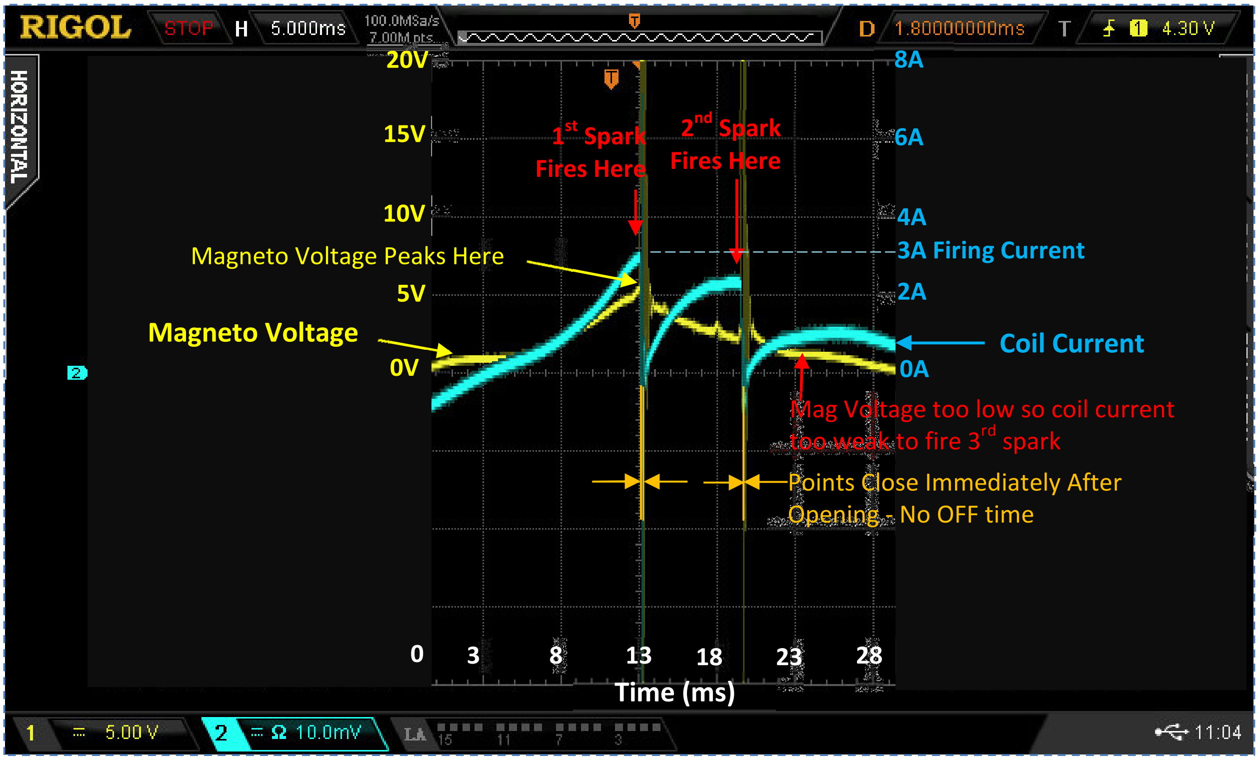


Figure 2. HCCT Coil Voltage and Current of coil with improper cushion spring tension, 125RPM

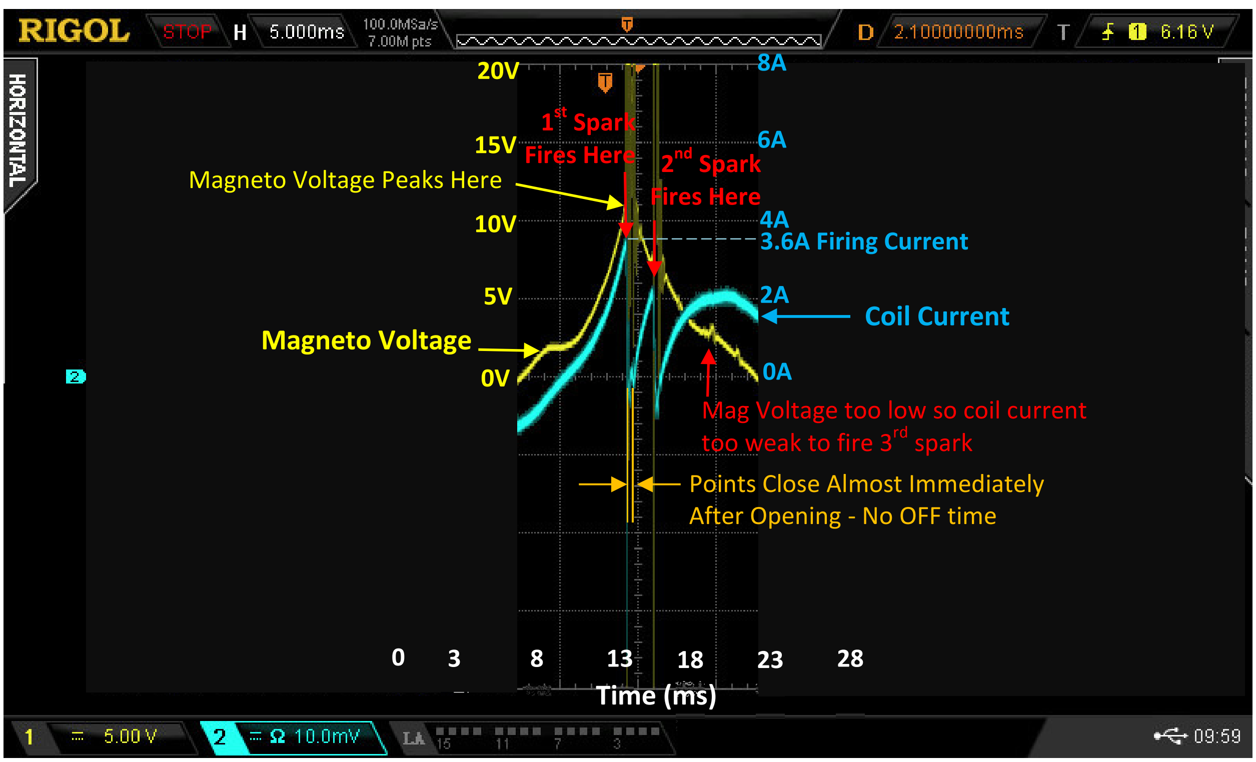


Figure 3. HCCT Coil Voltage and Current of coil with improper cushion spring tension, 250RPM

This same coil was tested on the ECCT by applying an abrupt 12V pulse of electricity to the coil similar to a magneto voltage pulse at normal engine speed except the amplitude of the voltage pulse remains constant for the duration of the pulse. The coil voltage and current was measured and displayed in figure 4. The classic double spark is clearly visible; a weak spark (coil current =3.8A) firing early (1.16ms) followed by another weak spark (coil current=3.4A) firing late (2.95ms).

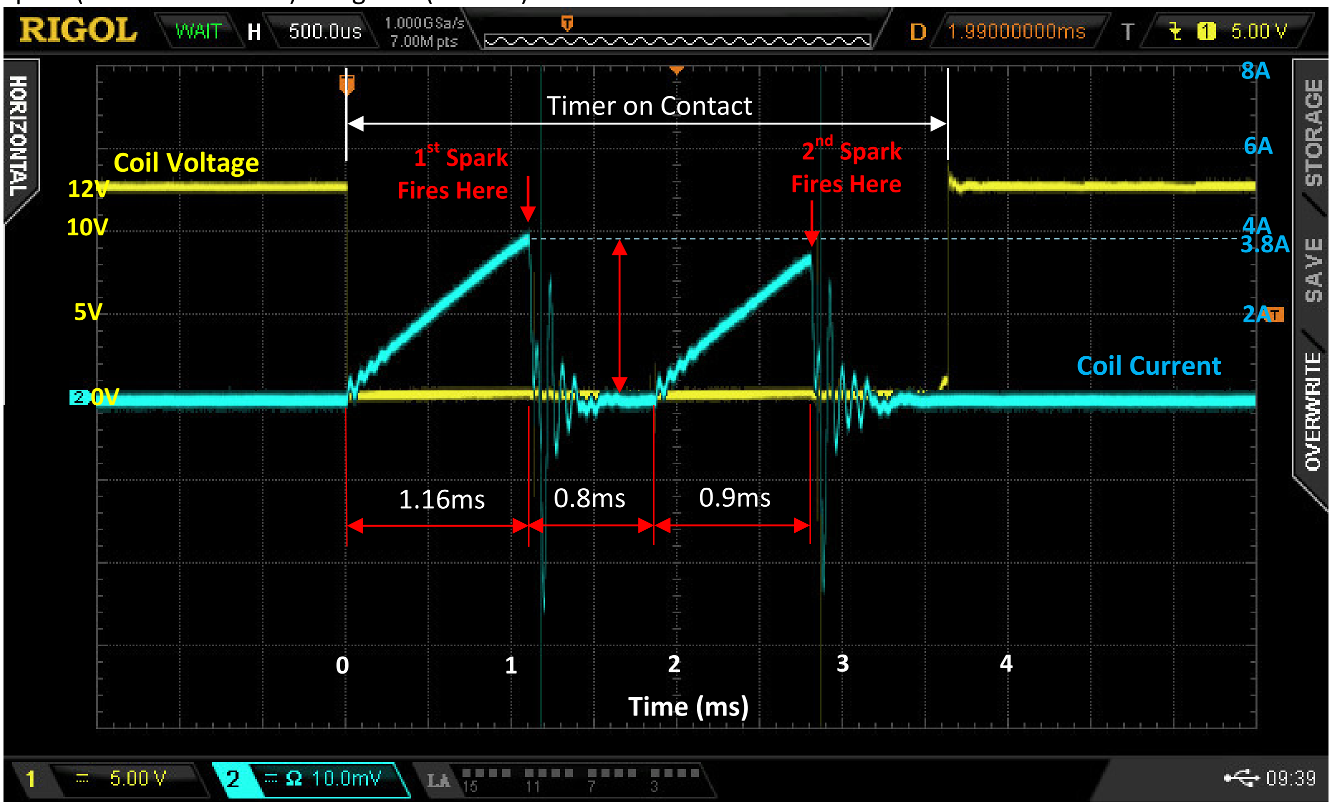


Figure 4. ECCT Coil Voltage and Current of Same coil with improper cushion spring tension

ECCT software captured the double spark event and alerts the user. Note the displayed coil firing time and current agrees closely with the oscilloscope data. Normal firing time is 2ms and normal firing current is 6A.

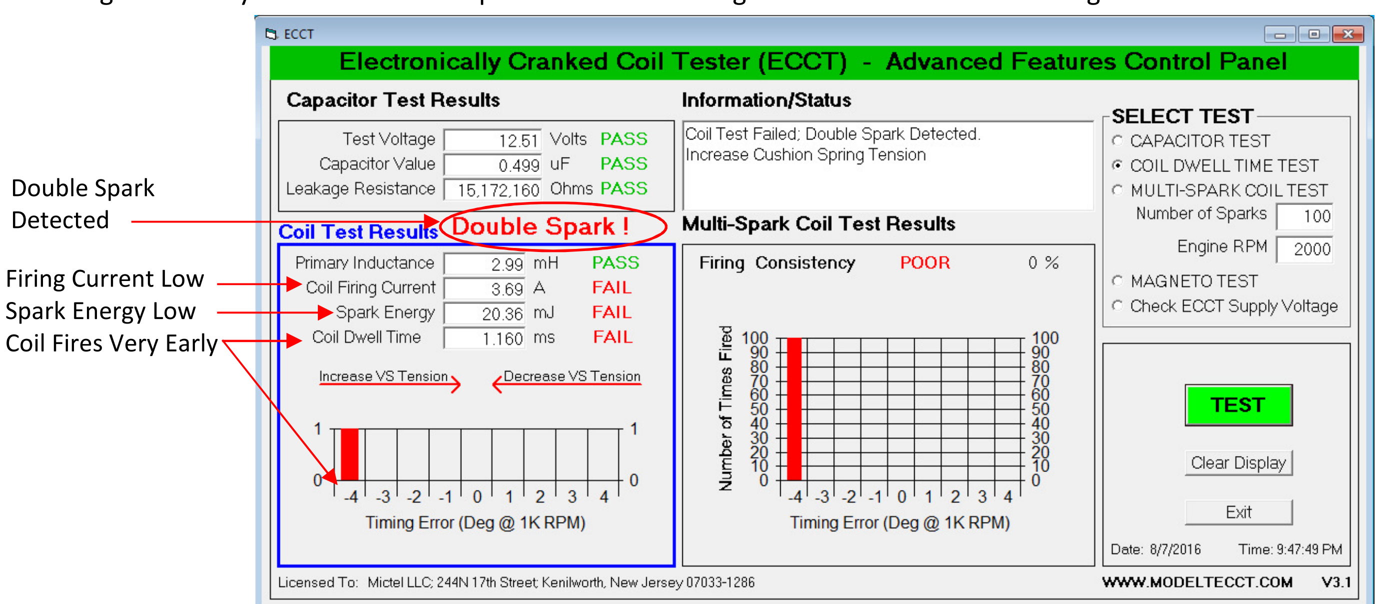


Figure 5. ECCT Advanced Features Software Showing Double Spark Detection and Early Firing

The standalone ECCT display also captures and indicates the double spark event by displaying 2 firing events on the LED display as shown in Figure 6.

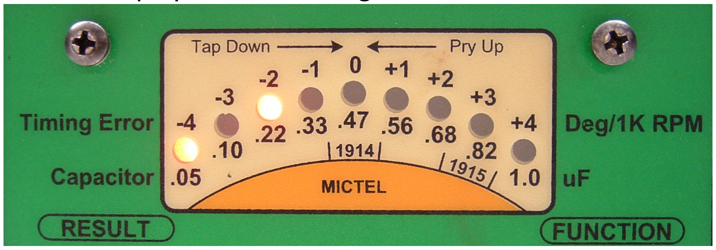


Figure 6. ECCT Display Showing Double Spark Detection

The "Advisable" Double Spark

We now know the Dreaded Double Spark occurs early in the magneto voltage pulse (Point 1) and that it doesn't go away even if the HCCT is cranked faster. Next, we examine coil points adjusted to fire spark just after the peak HCCT voltage pulse, at Point 2 of Figure 1. Such a coil was tested on the HCCT and results illustrated in Figure 7. The first spark fires when the coil current (blue) reaches 3A just after the magneto voltage (yellow) reaches its peak value of 6.5V. Note however, the coil points now remain open (0A current) for about 1ms before closing again to allow the coil current to start rising again. Another weaker spark fires later when the coil current reaches 2.3A. The average HCCT coil current of this coil registered 1.3A and relatively steady when cranked at about 130RPM. Sparks appeared bright blue and regular accompanied by consistent snapping sound as the crank was turned with occasional double spark visible. This coil behavior is typical of coils adjusted with the Dwell Time to Fire Method using the ECCT. This is likely the "Advisable" Double Spark as referenced in the Ford HCCT Operator Manual but seemingly indistinguishable from the "Dreaded Double Spark" so far; giving the impression it is improperly adjusted.

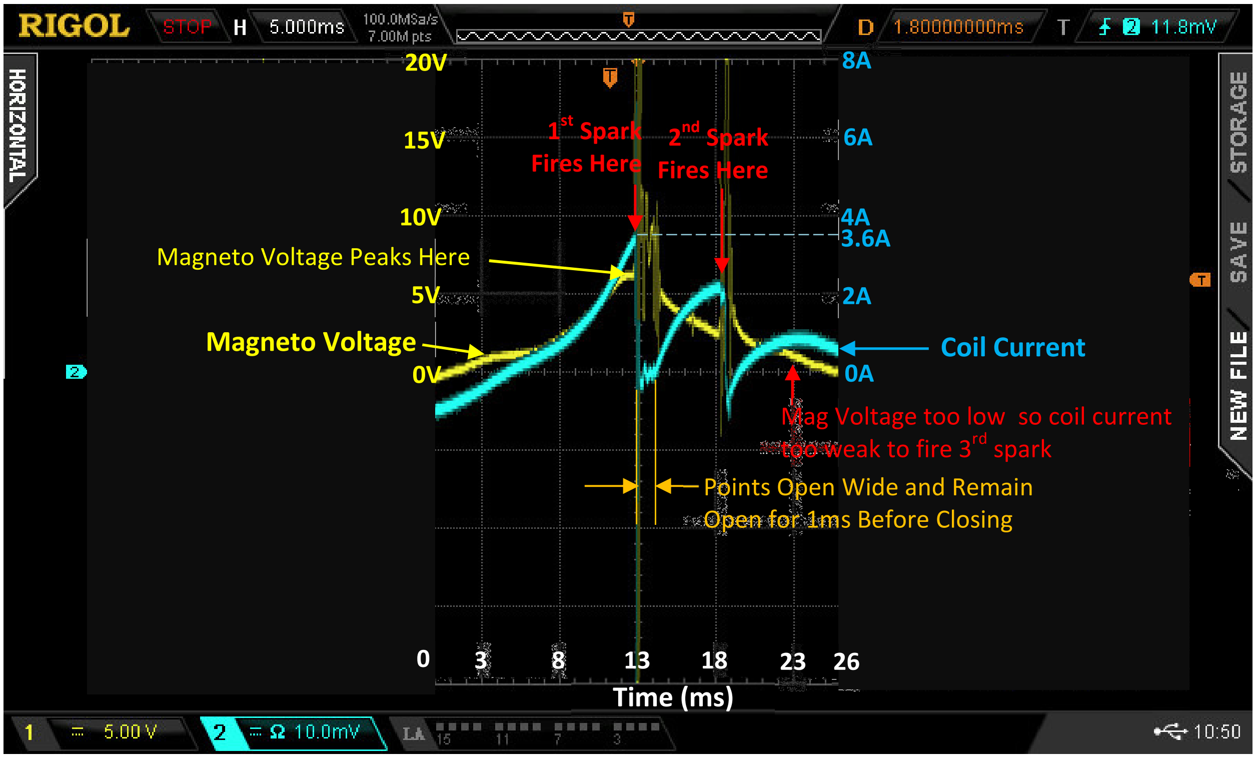


Figure 7. HCCT Coil Voltage and Current of ECCT Adjusted Coil, 130 RPM

Now let's see what happens again when we crank the HCCT significantly faster at 250RPM to apply a higher voltage pulse to the coil. This can be seen in the oscilloscope measurement illustrated in figure 8. The first and only spark fires when the coil current (blue) reaches 4.4A just after the magneto voltage (yellow) reaches its peak value of 10.5V. Also note that the coil points are now thrust open (0A current) wider because it now takes twice as long to close again, about 2ms. Coil current begins flowing again but the voltage pulse is now too weak to force enough current through the coil to make it spark a 2nd time. The key distinction is; the coil stops double sparking when the HCCT is cranked faster, closer to normal engine speed. This did not occur in the case of the misadjusted coil producing the Dreaded Double Spark. That coil continued to produce double sparks when the HCCT was cranked faster at 250 RPM.

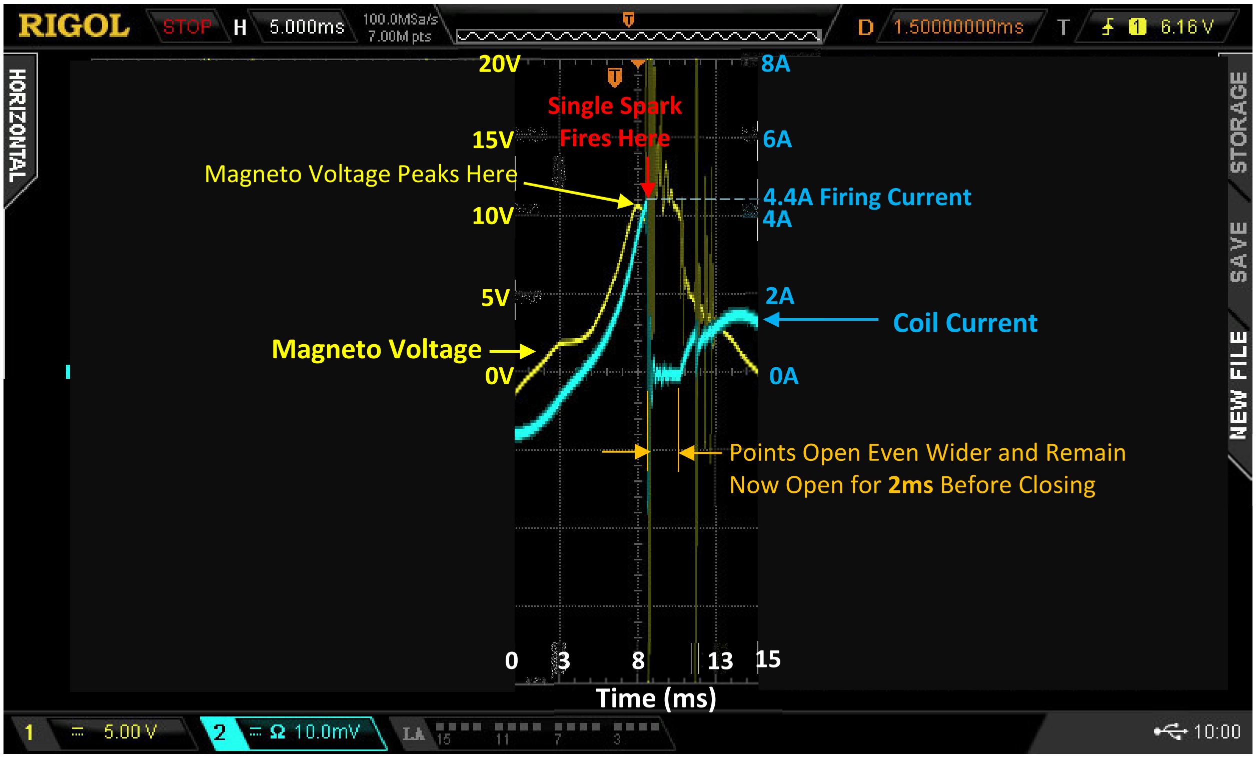


Figure 8. HCCT Coil Voltage and Current of ECCT Adjusted Coil Cranked ate 260 RPM

This coil was adjusted on the ECCT using the Dwell Time to Fire method with 100% firing consistency at 0 deg timing error. This same coil was tested on the ECCT by applying an abrupt 12V pulse of electricity to the coil similar to a magneto voltage pulse at normal engine speed except the amplitude of the voltage pulse remains constant for the duration of the pulse. The relationship between voltage pulse and coil current is shown in the oscilloscope measurement illustrated in figure 9. We can see the coil fires the 1st and only spark when coil current (blue trace) reaches a respectable 6A that takes 1.95ms to occur after timer contact. The abrupt rise time of the timer contact on 12V battery is more representative of coil operation with magneto operating at normal engine speed. Thus under more normal engine operating conditions, this ECCT adjusted coil does not exhibit the double spark behavior when tested on the ECCT or tested on the HCCT when cranked at 250 RPM or greater. The ECCT adjusted coil only double sparks on the HCCT when cranked at abnormally slow engine speeds (60-150RPM) giving the false impression the coil points are misadjusted. This is a key point.

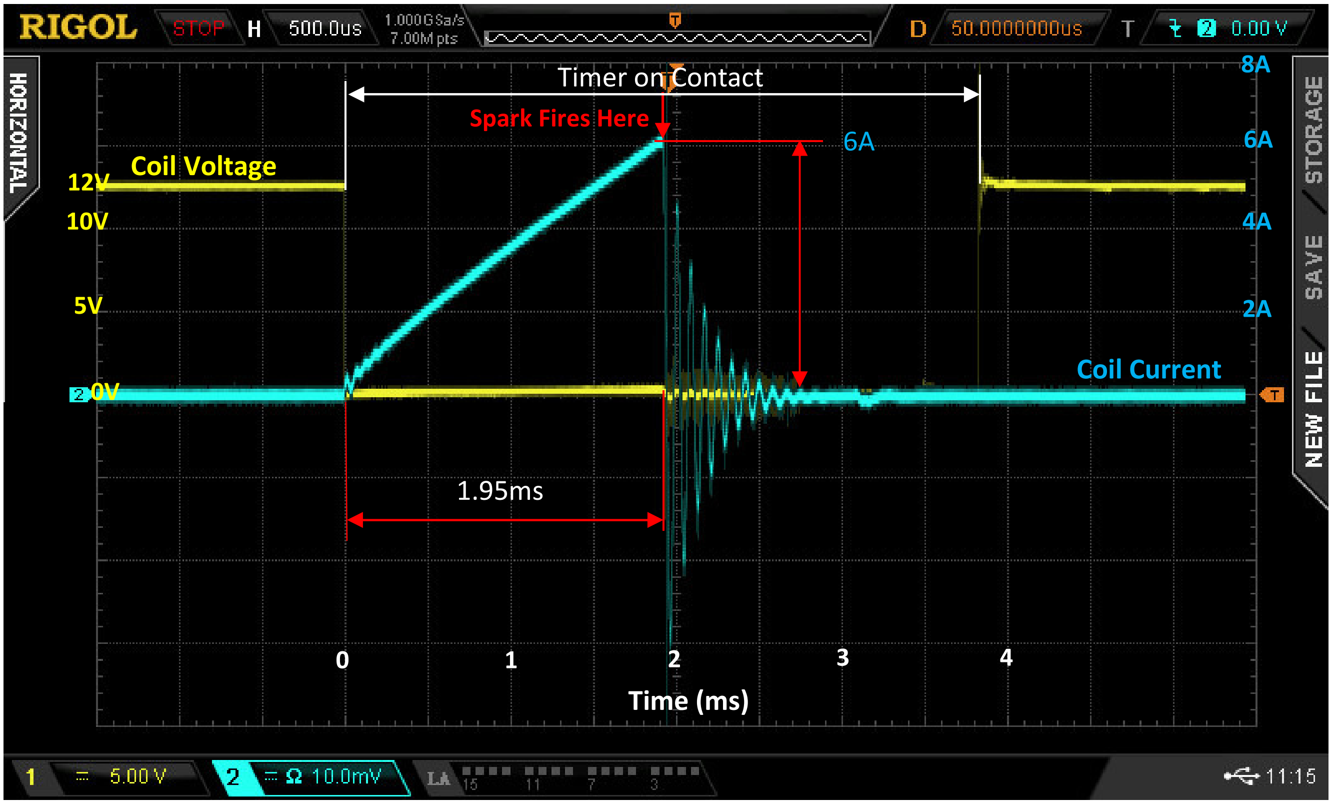


Figure 9. ECCT Coil Voltage and Current of Same ECCT Adjusted Coil

This same coil tested on the ECCT; Note the coil firing time and current agrees with the oscilloscope data displayed in figure 9. Multi-Spark firing consistency test shows 100% of the sparks fire at 0 degrees (TDC).

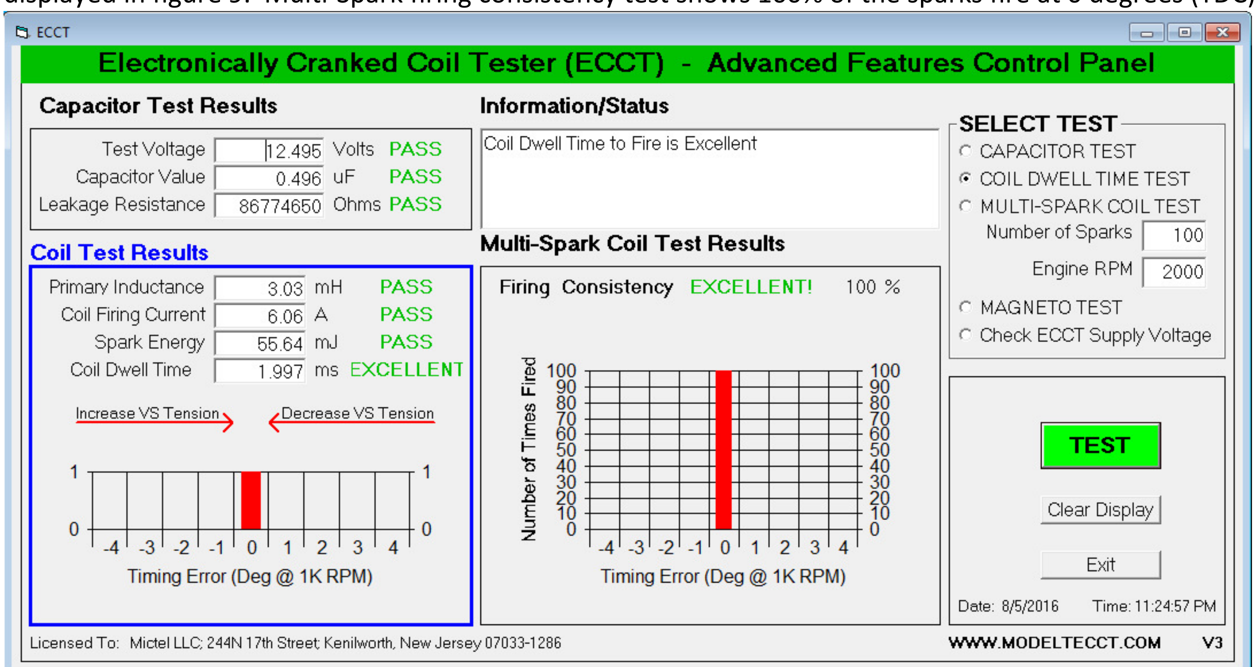


Figure 10. ECCT Advanced Features Software Display Showing Single Spark Detection

The standalone ECCT front panel display also indicates a single spark firing at the correct time, 0 degrees timing error as shown in Figure 11.

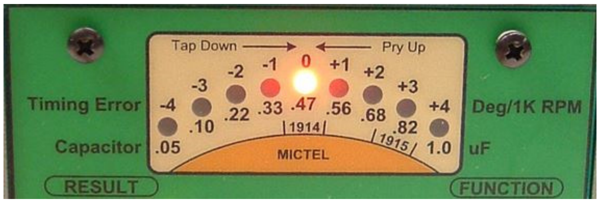


Figure 11. ECCT Display Showing a Single Spark Firing at the Correct Time

The Accepted Single Spark

Lastly, we examine coil points adjusted to fire spark as the HCCT voltage pulse is well past its peak value, at Point 3 of Figure 1, to produce the "Accepted Single Spark". Such a coil was tested on the HCCT and results illustrated in Figure 12. The coil current (blue) reaches its peak value of 3.8A as the 1st and only spark fires well past (2.5ms past) the peak magneto voltage of 10V. The points remain open for about 1ms before closing and allow coil current to begin flowing again but by this time the HCCT magneto voltage pulse is now too weak to force enough current through the coil to make it spark a 2nd time. **Note that firing the 1st spark so late after the magneto voltage peak can actually mask other adjustment anomalies from being readily detected on the HCCT because the magneto voltage pulse is too weak to fire a 2nd spark even if the points were misadjusted.** The average HCCT coil current reading for this coil was 1.5A and relatively steady regardless of cranking speed (90~150RPM). Sparks appeared bright blue and regular accompanied by consistent snapping sound as the crank was turned and no double sparks were visible. This coil is an example of the "Accepted Single Spark" coil behavior typical of coils adjusted on a HCCT by a skilled professional with years of experience.

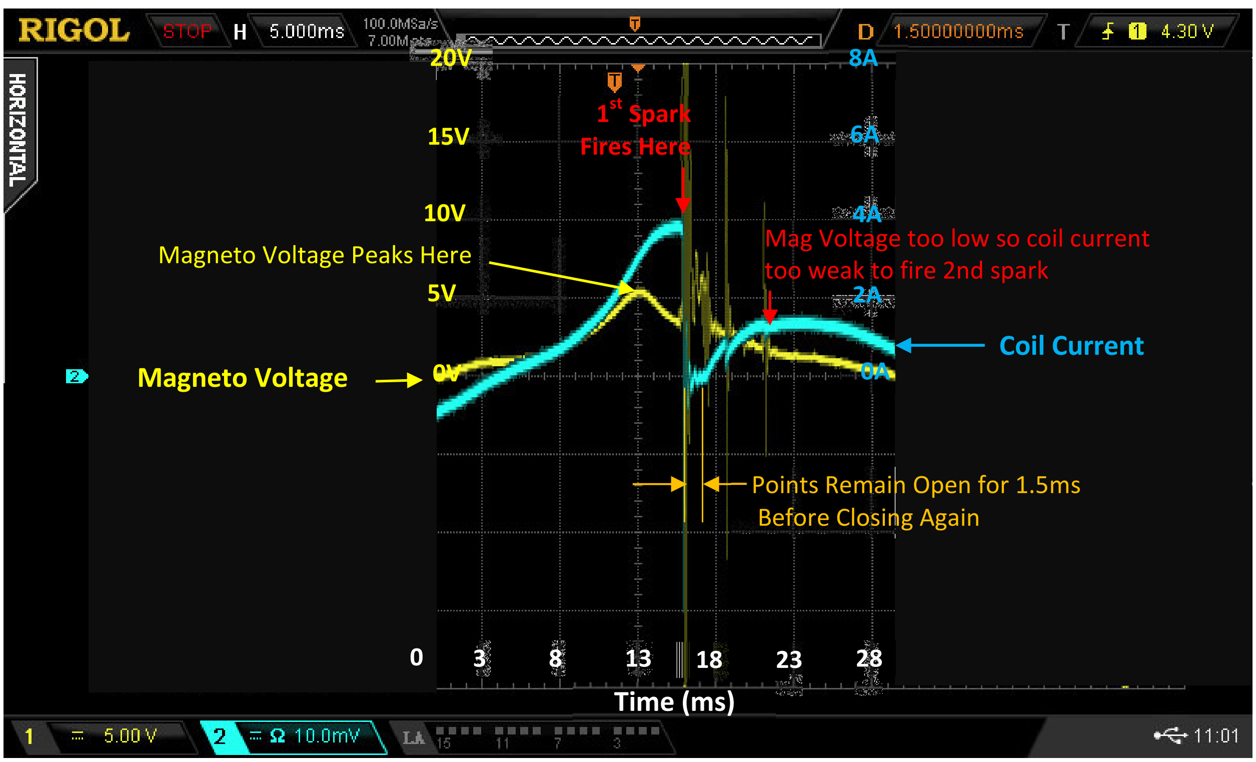


Figure 12. Example of coil points adjusted for the "Accepted Single Spark", 130 RPM

Again, we investigate what happens when this coil is tested on the HCCT cranked at significantly faster speed; 235RPM to apply a higher voltage pulse to the coil. This can be seen in the oscilloscope measurement illustrated in figure 13. The coil current (blue) reaches its peak value of 5.4A as spark fires well past (2ms past) the peak magneto voltage of 9.5V. Also note that the coil points are now thrust open wider due to being accelerated greater by the higher coil current and takes longer to close, about 2.5ms to close. Coil current begins flowing again but by this time the HCCT magneto voltage pulse is now too weak to force enough current through the coil to make it spark a 2nd time.

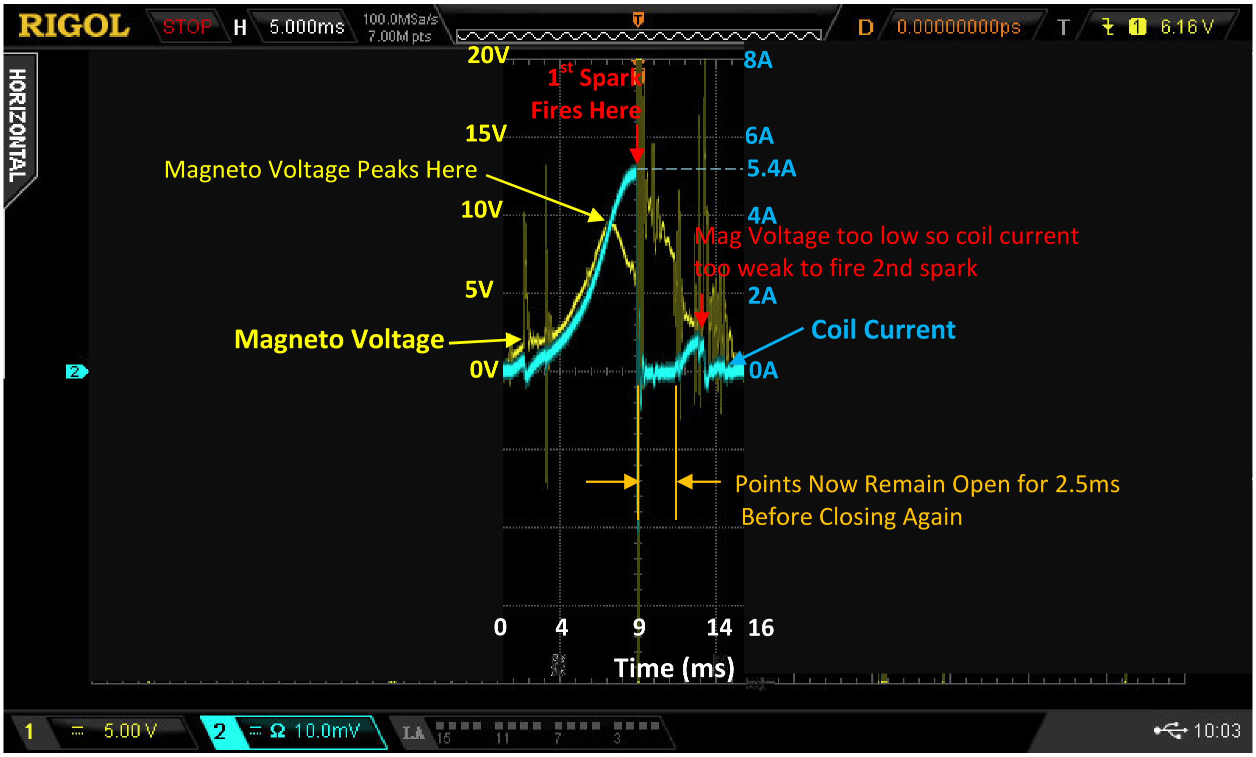


Figure 13. Example of coil points adjusted for the "Accepted Single Spark", 235 RPM

The same “Accepted Single Spark” coil was tested on the ECCT by applying an abrupt 12V pulse of electricity to the coil similar to a magneto voltage pulse at normal engine speed except the amplitude of the voltage pulse remains constant for the duration of the pulse. The relationship between coil voltage pulse and coil current is shown in the oscilloscope measurement illustrated in figure 14. We can see the 1st and only spark occurs when the coil current (blue trace) reaches a higher than necessary 7.5A but takes longer (2.4ms) after timer contact to reach and fires a more retarded spark.

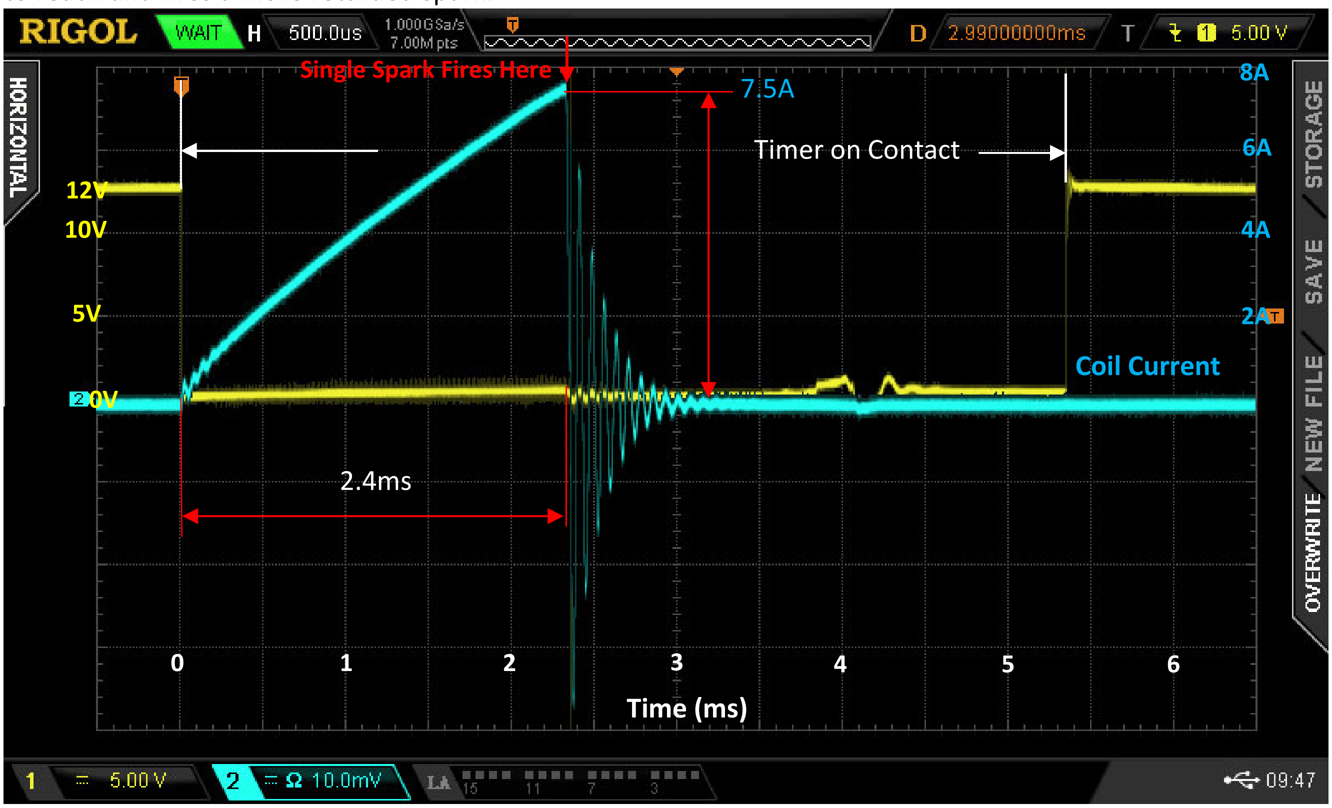


Figure 14. Dwell Time to Fire Measurement of ECCT Adjusted Coil Using the Dwell Time to Fire Method

The Same coil tested on the ECCT; Note the coil firing time and firing current agrees with the oscilloscope data.

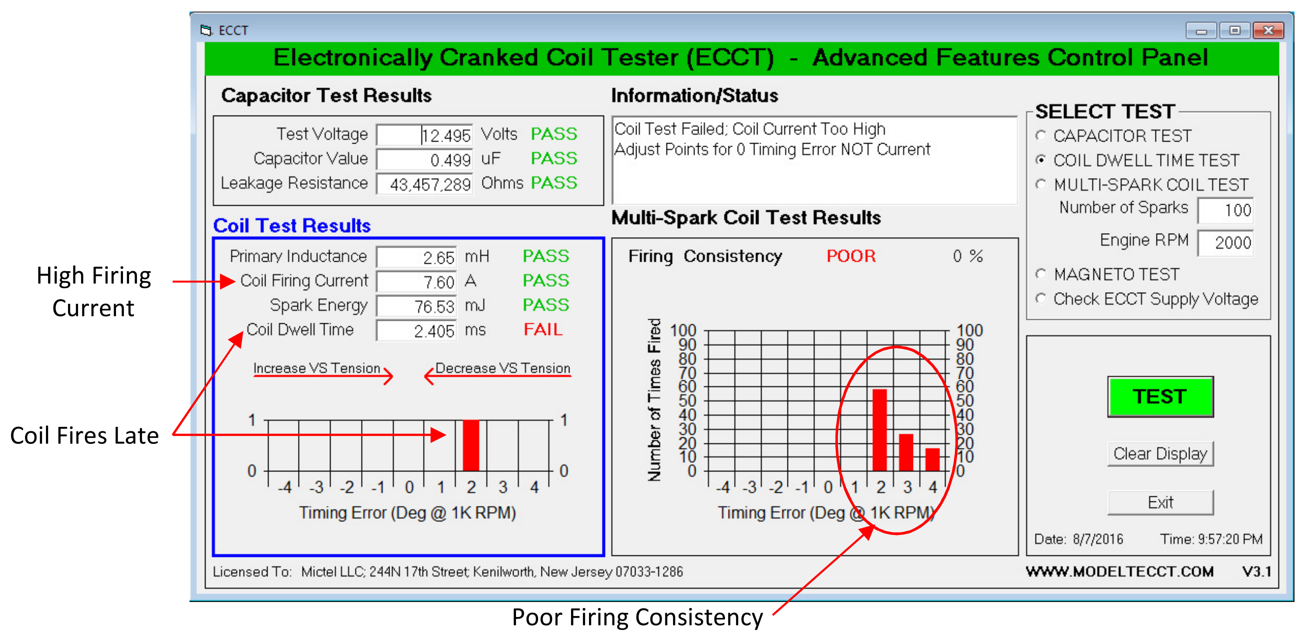


Figure 15. ECCT Advanced Features Software Showing Single Spark Detection Firing Later Than Nominal

Referring to figure 15, the ECCT coil test results show the coil fires later than normal (+2deg timing error) and the firing consistency is poor as indicated by the Multi-Spark coil test results. The coil fires at +2, +3 and +4 degrees later than what is considered nominal (0 degrees). The standalone ECCT front panel display also indicates a single spark firing later than normal, +2 degrees timing error as shown in Figure 16.

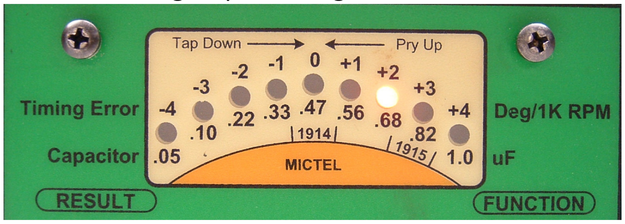


Figure 16. ECCT Display Showing Single Spark Detection Firing Later (+2 deg) Than Nominal

The ECCT front panel display of the ECCT Multi-Spark Firing Consistency test result of figure 17 shows poor firing consistency at +2, +3 and +4 degrees later than normal (0 degrees).

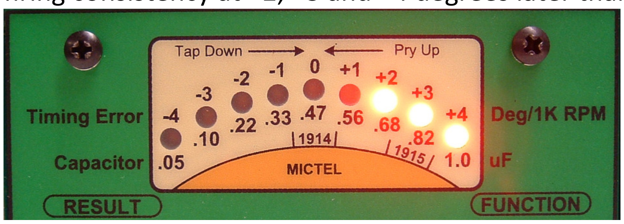


Figure 17. ECCT Display Showing Poor Multi-Spark Firing Consistency

[Test and Analysis Considerations]

Don't confuse HCCT coil firing rate with HCCT cranking speed. Cranking the HCCT at 120 RPM produces abnormally low magneto voltage pulse amplitude that rises and falls abnormally slowly compared with normal engine operation (500 – 2000 RPM). It is true that cranking the HCCT at 120RPM causes the coil to fire spark at the rate of 120 RPM x 16 magneto voltage pulses per HCCT revolution = 1920 spark firings per minute. That equates to 3840 engine Revolutions Per Minute since a coil fires spark once every 2 crank shaft rotations. However, that does not change the fact the physical speed of the HCCT crank is only turning at 120 RPM and that is what determines how fast the magneto voltage pulse rises, falls and the maximum voltage pulse amplitude produced. A comparison of the Magneto voltage pulse amplitude at 120 RPM, 1000 RPM and the ECCT test pulse is illustrated in figure 18. Note that the Magneto voltage pulses produced at normal engine speed of 1000RPM shown in green rises 8 times faster with amplitude 4 times higher than the single positive voltage pulse produced by the HCCT in yellow cranked at the abnormally slow engine speed of 120RPM. Also note that the ECCT voltage pulse shown in red more closely represents the positive Magneto voltage pulses operating at normal engine speeds.

The magneto voltage pulse rise time and amplitude are very important parameters because they partly determine how long a coil takes to fire spark, not the firing rate. Adjusting coils for equal firing time using a voltage pulse that more closely resembles magneto voltage pulses at normal engine speed is a distinct advantage for this reason. The voltage pulse can be positive like the ECCT Pulse or negative because the polarity does not change during the dwell time it takes the coil to fire spark.

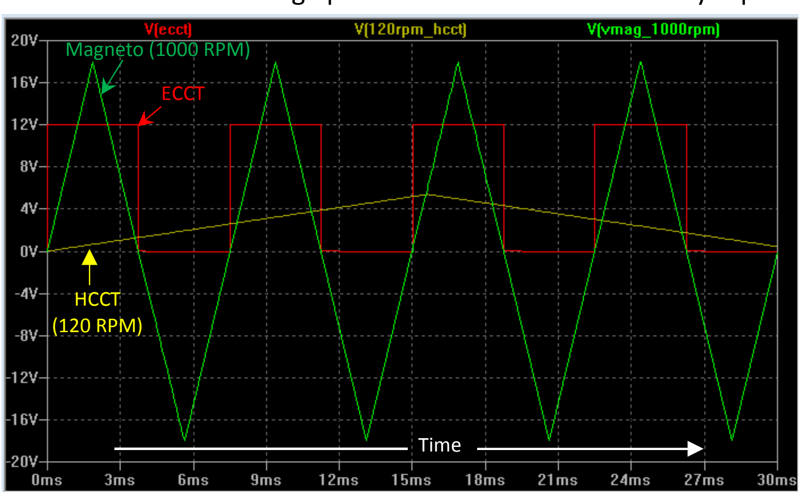


Figure 18. Magneto Voltage Pulse Comparison at 120RPM, 1000RPM and ECCT Voltage Pulse

Further Study

Still think the HCCT Double Spark Doctrine is absolute? Have a look at the following experiment of coil firing consistency operating from **an adjustable AC voltage** to simulate actual AC magneto voltage output range at fixed frequency of 60 Hz; equivalent to engine speed of 450 RPM. The voltage was varied from **5VAC to 20VAC** and half wave rectified so only the positive pulses were used to fire the coil. This simulated the presence of the Timer function which allows the coil to rest in between spark firings. Coil current was measured and recorded on a Digital Storage Oscilloscope with infinite persistence to capture the dwell time to fire of each spark firing. The results of a coil adjusted using the ECCT for exact firing time (2ms) and excellent (95%) firing consistency is shown in Figure 19. This is the "Advisable Double Sparking" coil case that produced double sparks when tested on the HCCT at typical hand cranking speed (60-150RPM). The last captured coil firing is shown in light blue. All past current firings are shown in memory in darker blue. You can see the coil spark timing variation is limited to less than 0.8ms (0.0008s). That equates to +/- 4.8 crank degrees of ignition timing variation operating at 2000 RPM with approximately 3.5A variation in coil firing current (spark energy). Note that some of this variation is expected as the dwell time to fire decreases as the magneto voltage rises from 5V to 20V with engine RPM and the coil fires spark sooner.

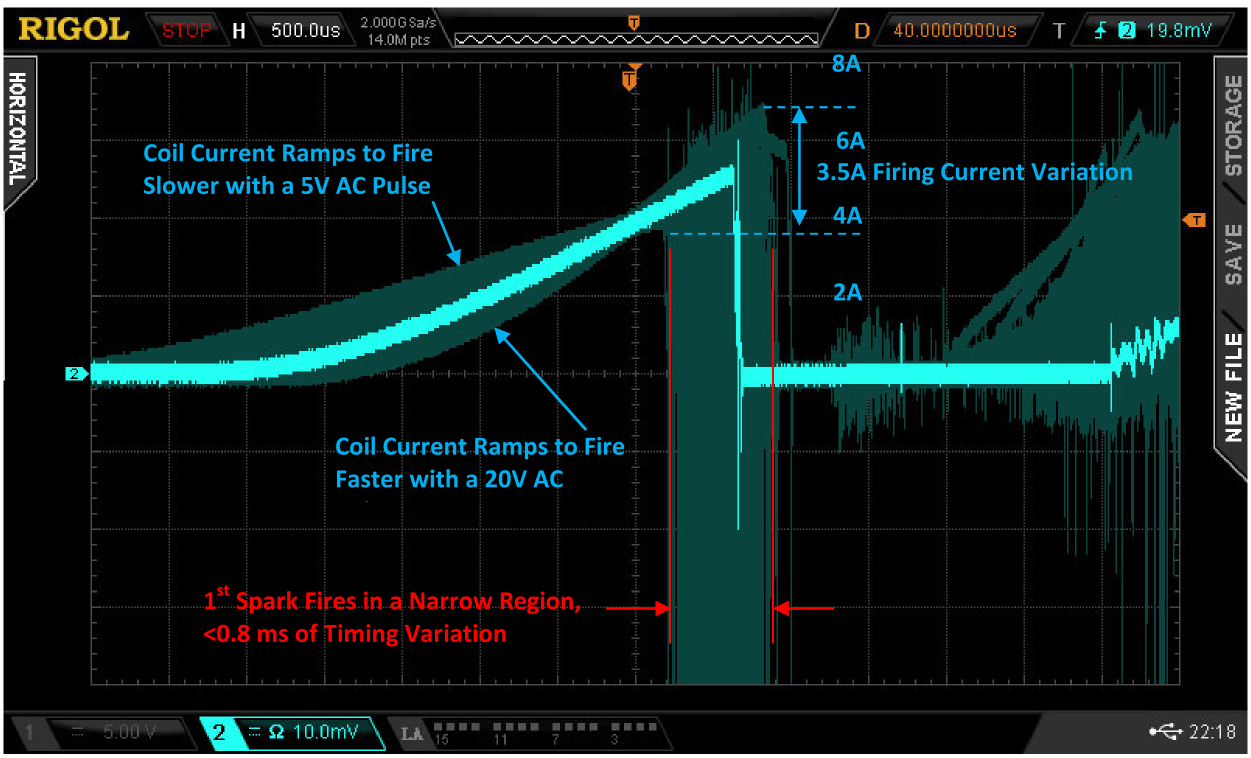


Figure 19. ECCT adjusted Coil Firing History on Digital Oscilloscope with Infinite Persistence

We now repeat this same AC test using the professionally adjusted HCCT coil with the "Accepted Single Spark" illustrated in figure 20. The last captured coil firing is shown in light blue. All past current firings are shown in memory in darker blue. Note that the coil spark timing variation is now more than twice as much 1.8ms (0.0018s) compared with the ECCT adjusted coil. That equates to +/- 10.8 crank degrees of ignition timing variation operating at 2000 RPM. Note the greater change in coil firing current (spark energy) over the firing range. Also note several retarded firings due to improper cushion spring tension that causes point arcing and delayed firing. This result was not apparent on the HCCT steady Ammeter current reading averaged over time on the HCCT.

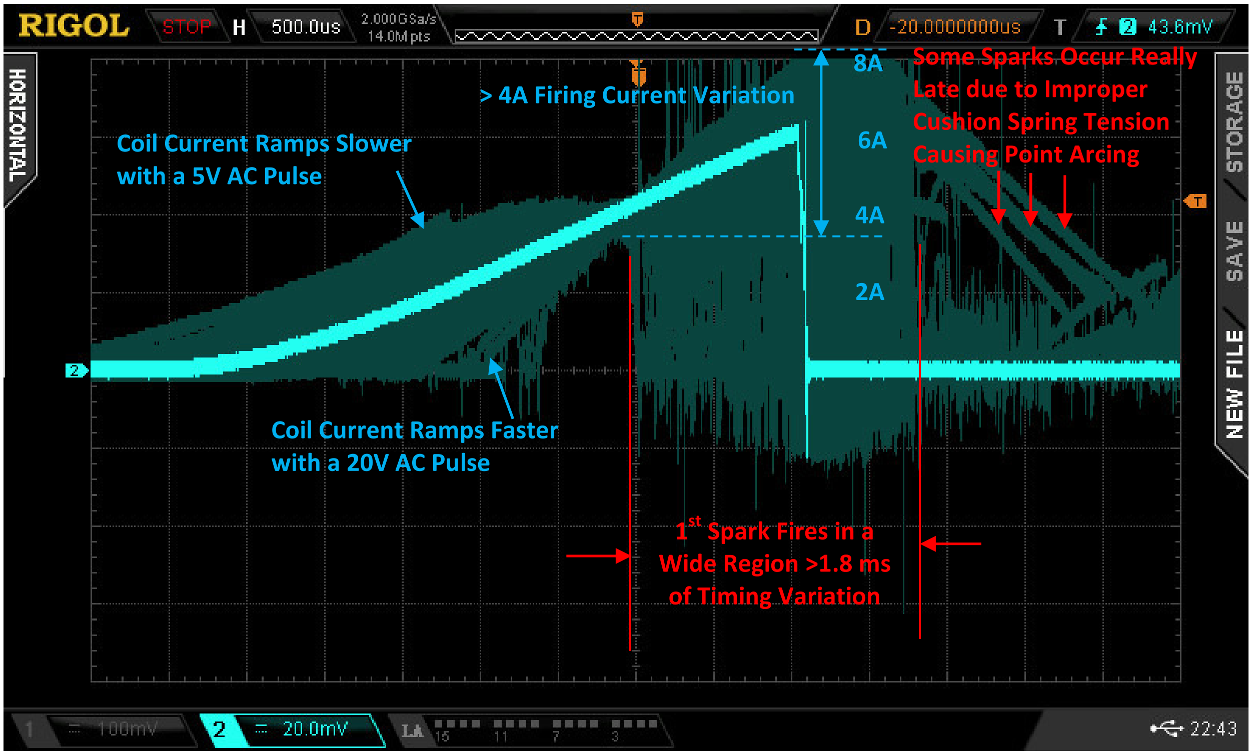
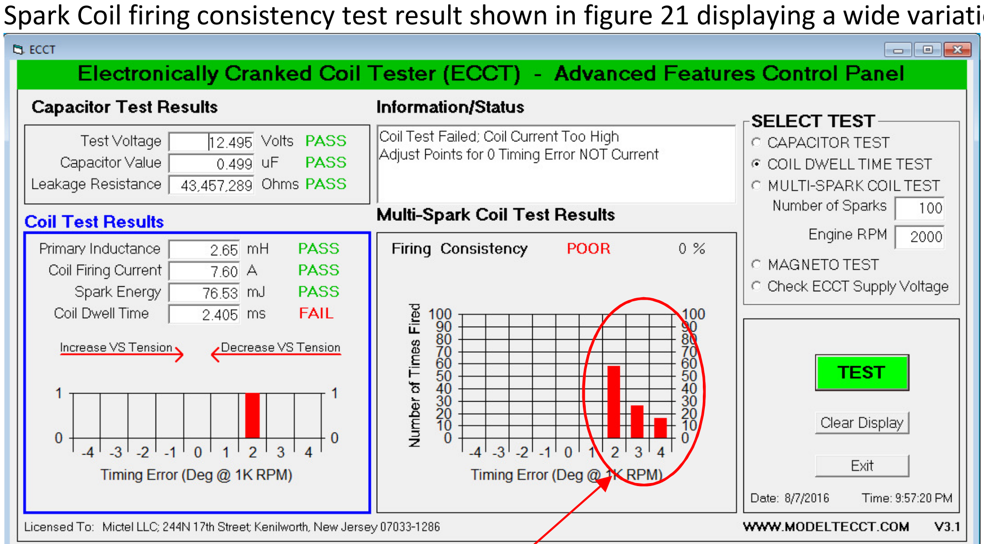


Figure 20. Professionally Adjusted HCCT Coil Firing History on Digital Oscilloscope with Infinite Persistence

The improper cushion spring tension on this coil is immediately apparent when tested using the ECCT Multi-Spark Coil firing consistency test result shown in figure 21 displaying a wide variation in spark firing time.



Poor Firing Consistency

Figure 21. ECCT Multi-Spark Firing Consistency Test of the Professionally Adjusted HCCT Coil

Conclusion

The HCCT is a time proven, trusted method of Model T coil point adjustment capable of achieving excellent engine performance. Proper HCCT coil adjustment is much more complicated than simply applying the double spark doctrine to achieve best results. Coils that produce double sparks on an HCCT **can indicate** improper coil adjustment **but not necessarily indicate** improper coil adjustment. The data presented confirmed ECCT adjusted coils can produce double sparks when tested on an HCCT but do not exhibit the same characteristics as a double sparking coil known to yield poor engine performance.

I think the Ford Engineers had it right based on the data presented herein. Coils that do produce double sparks on the HCCT **could** actually be advisable over coils adjusted to produce a single spark. Hence, the Double Spark Doctrine Paradox. This paradox only applies when the HCCT is cranked at abnormally slow engine speed (<200RPM) in which it is typically operated. There is no paradox when ECCT adjusted coils are tested on the HCCT at normal engine speeds (500-2500RPM) because they don't produce double sparks operating on magneto at normal engine speeds.