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Enhanced Ignition System Testing

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Enhanced Ignition System Testing

WARRANTY

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Secondary Ignition Diagnostics (DI Systems)

OHIO AUTOMOTIVE TECHNOLOGY

Section Contents:

This section will cover secondary ignition diagnostics on DI systems. DI is the new term for distributor type ignition systems that use a distributor cap and rotor.

Technical Training Seminars Should Include:

- Theory
- Specific manufacturer strategies
- Specific testing strategies
- Pattern failures
- Ideas on profit & productivity

Instructor Comments:

It all goes together. If we miss one of these critical points, it becomes like a chain with a weak or broken link.

Choosing Test Equipment

Instructor Comments:

When testing a circuit, it is important to understand what type of circuit it is before choosing a piece of test equipment. For example:

1. To test a high current primary control, you would use a 12-volt test light (open circuited) or a DSO (with device connected).

2. To test a low current PCM command (to control an ignition module), you would use a LED test light, logic probe, DVOM, or DSO.

3. To test a CKP/CMP sensor, you would use a LED test light, logic probe, DVOM, or DSO.

Forces That Attack The Ignition System

- Carbon tracking
- Fixed high secondary resistance
- Plug gap erosion
- Additional air gaps
- Center electrode doming
- Faulty triggering component
- RFI
- Inductive crossfire
- Secondary insulation breakdown

Instructor Comments:

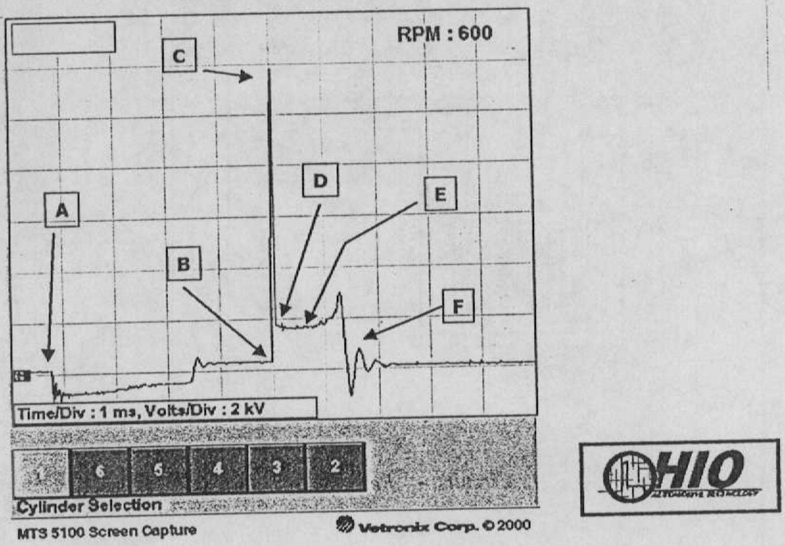
These are just some of the problems that attack the secondary circuit, typically beginning at 40K miles. You are looking at a minimum of nine reasons why ignition scope checks are important.

The 5 Types of Misfires

	Indicated on
• Electrical	***Firing line***
• Lean Density	***Spark line***
• Rich Density	***Spark line***
• Density	***Spark line***
• Primary Missed-Trigger	***Firing line or Dwell Section***

Notes:

Anatomy of a Secondary Waveform



Notes:

A. ______________________________

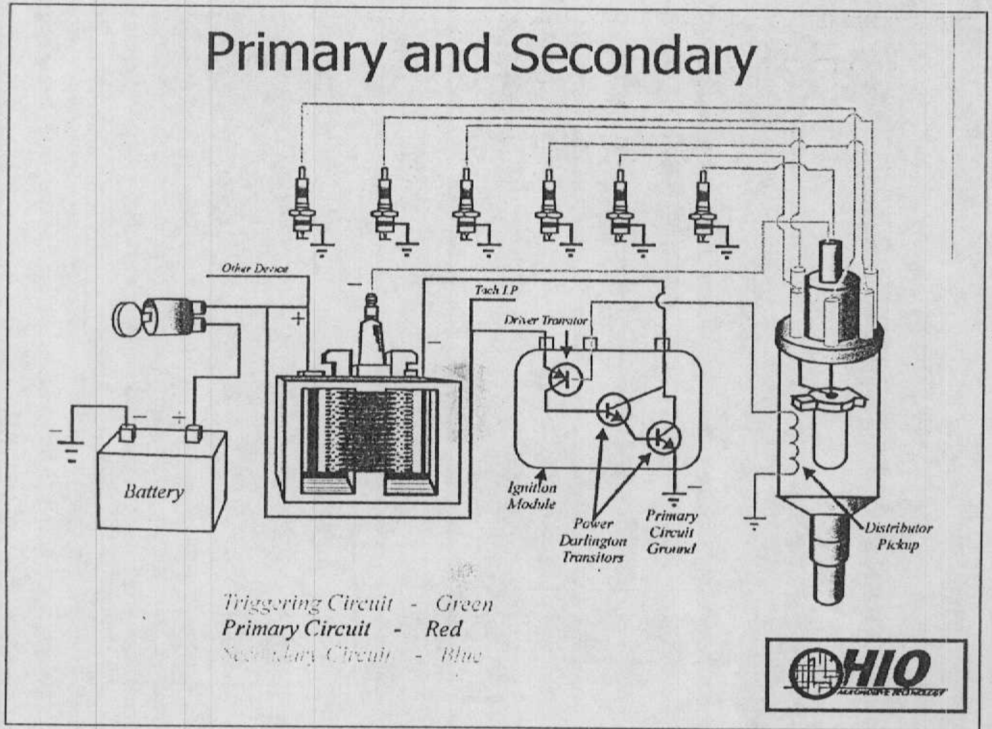
B. ______________________________

C. ______________________________

D. ______________________________

E. ______________________________

F. ______________________________



Instructor Comments:

The ignition system is actually two circuits and must be separated while scope testing. In some cases, before making any diagnostic decision.

The primary (low energy) side begins at the battery and includes the ignition switch, the primary side of the coil, the ignition driver (module), and the triggering device.

The secondary (high energy) side consists of the coil secondary windings, the coil wire, the cap/rotor, secondary leads, and the spark plugs.

Most modern day systems are known as "divorced systems"; whereas, there is no link between the primary and secondary circuit (usually just an air core inside the coil).

When is it necessary to scope check the ignition system?

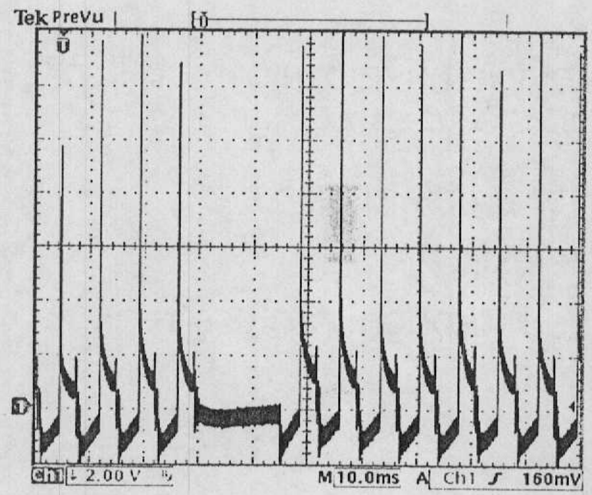
- Does the vehicle have over 40K miles?
- A maintenance tune-up is performed.
- A driveability problem exists.
- A hard code exists.
- Desire to be thorough, professional, and profitable.

Instructor Comments:

Many technicians don't take the time to do a secondary scope check, maybe because they don't realize the wealth of information available to them by viewing primary or secondary. In many cases, this is a 5 minute test. This course explains the diagnostic value of ignition system scope checks and the various test screens available.

Many vehicles have faulty components or diagnostic trouble codes that have no connection to the ignition system. However, good secondary scope checks will uncover pre-existing conditions which will create symptoms sooner or later.

Secondary Parade (Extended)



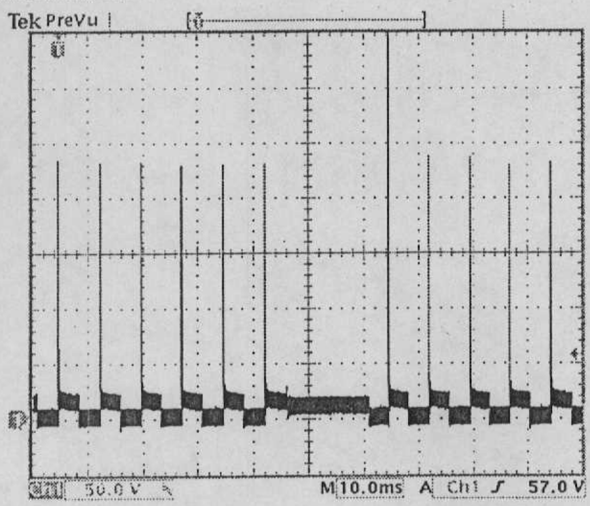
Instructor Comments:

Using a standard DSO on secondary will help us to easily confirm a misfire. This parade example, captured at high RPM, indicates a loss of firing events. Notice the #1 trigger icon in the upper left hand corner of the screen. The firing order on this vehicle is 1 – 6 – 5 – 4 – 3 – 2. Counting left to right, you will see that we lost the firing events of cylinders 3 and 2. As you continue counting, the firing order begins all over again indicating no misfires.

Because more than 1 cylinder is affected and the problem is not repeated, we suspect a primary triggering fault. When we increase the scope's time base, we increase the amount of firing events which, in turn, increases our chances of seeing these intermittent loss of events.

A word here about parade patterns. Misfires that are caused by electrical problems will show up well on a parade pattern. Density misfires, however, will not show up well on parade patterns because the attention/focus needs to be on the spark line. The increased time base needed to view a parade pattern will cause the spark line to become too compressed to monitor.

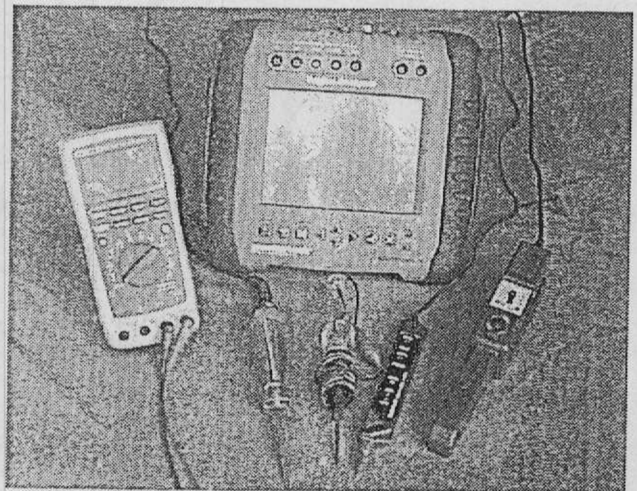
Primary Pattern (Extended)



Instructor Comments:

If you recall the previous example of a secondary misfire parade extended pattern, where a loss of 2 secondary firing events occurred, we could not make a diagnostic decision as to the cause of the problem. In this example, using an extended parade pattern, we shifted our scope to the primary side of the ignition system. The #1 trigger icon is in the upper left hand corner of the screen. Counting left to right, with a firing order of 1-6-5-4-3-2, you will notice that the #1 and #6 cylinders miss triggered. Because of this random cylinder misfire, we would suspect a faulty triggering component. Remember, the parade pattern screen is a good test screen to pinpoint electrical misfires, but a bad choice for pinpointing density misfires.

Ignition System Test Equipment



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Course Objectives:

✓ Choose diagnostic equipment carefully

✓ Explain the four types of misfires

✓ Why some problems show up at idle

✓ Why some problems only show up with dynamic loaded conditions

✓ Specific differences between some ignition systems

✓ Is the problem on the primary or secondary side of the system?

✓ Is the problem in the triggering system?

The Law of Diagnostics

- Says that you must understand the system before diagnostics begin.
- The art of diagnostics is to make the problem come to you.

Instructor Comments:

This author, instructor, as well as technician has spent over 30 years diagnosing and fixing engine performance problems. Experience has shown that a simple 10-minute secondary or primary scope check can yield a multitude of information.

The Rule of Diagnostics

- Teaching automotive technicians scan data and on-board computer strategies alone, will lead to a knowledge and developmental deficit among technicians.

Instructor Comments:

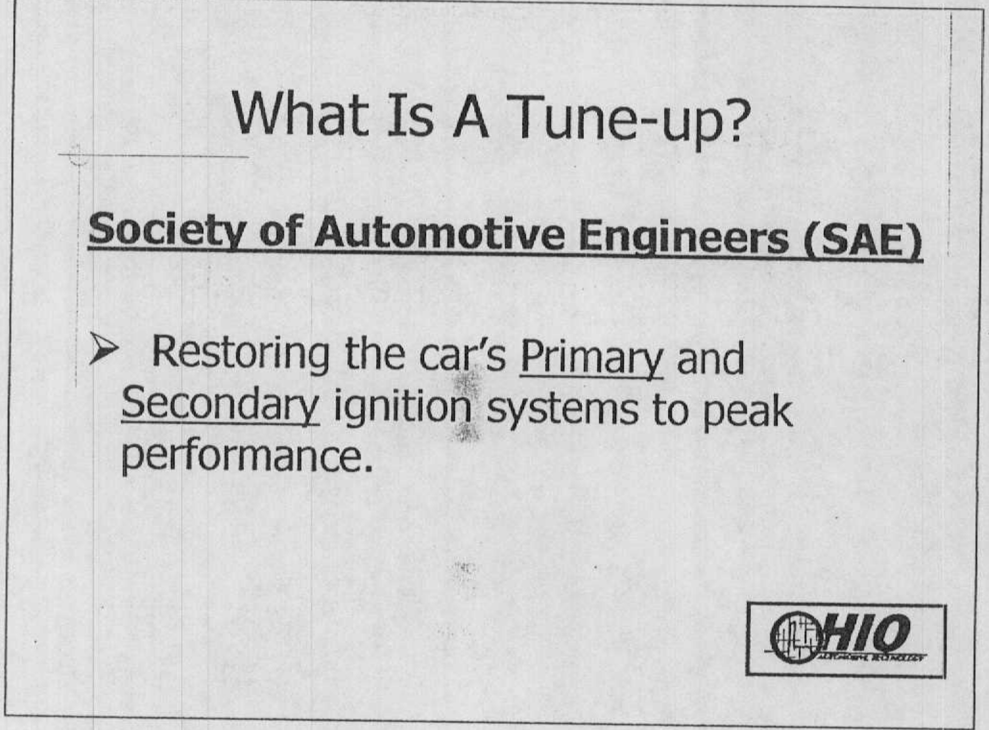
Scan data and PCM strategies only address 20% of today's poor driveability causes. 80% of all driveability problems are not caused by a PCM or sensor failure. 40% are caused by poor A/F ratios, 25% are caused by faulty ignition components, and 15% are caused by mechanical problems giving us a total of 80%. All of these problematic areas can be seen on the primary or secondary side of the ignition system.

Scan Data Diagnostics

- Chasing Scan Data alone is like settling for the map instead of exploring the territory.

Instructor Comments:

Too many times we, as technicians, would like to take the easy path to diagnostics and view the scan data alone. As good as scan tools are, especially on OBDII compliant systems, their information may not be able to pinpoint the specific cause of the problem. Scan tools can point you in the right direction, but actually pinpointing a misfire cause, for example, would require a focused test using a DSO.



Instructor Comments:

This definition is adapted to conventional ignition systems where breaker point wear factor and ignition timing variations were a concern. This definition has gone through some major changes on today's modern systems. Read on…

What Is A Tune-up?

Service Technicians Society (STS)

- Restoring the car's Secondary Ignition system, the Air Induction system and the Fuel Injection system to peak performance.

In what order?

Instructor Comments:

- Air induction cleaning
- Fuel injection cleaning
- R/R needed secondary components and scope check secondary

As a charter member of STS, we have decided to augment the original SAE definition of a tune-up. This is in an attempt to be more congruent to the needs of today's modern engines.

100K Tune-Up?

- Replacing worn spark plugs can decrease firing kVs by as much as 30 % and increase spark duration by as much as 30 %.

Instructor Comments:

You can ignore these values if you agree with the 100K mile tune-up interval, knowing that modern high energy ignition systems will still deliver sufficient energy and durations (even with eroded or worn plugs).

While both points are true and valid, as plug gap erosion and center electrode molecular erosion occurs, the secondary firing kV demand increases. This increase causes both carbon tracking and coil pack failures.

Otherwise, who's going to replace the spark plug threads on that aluminum cylinder head at 100K miles?

100K Tune-Up?

- Normal spark plug gap erosion occurs at a rate of approximately .00016 inches for every 1000 miles.
- Another concern is known as Center Electrode Doming.

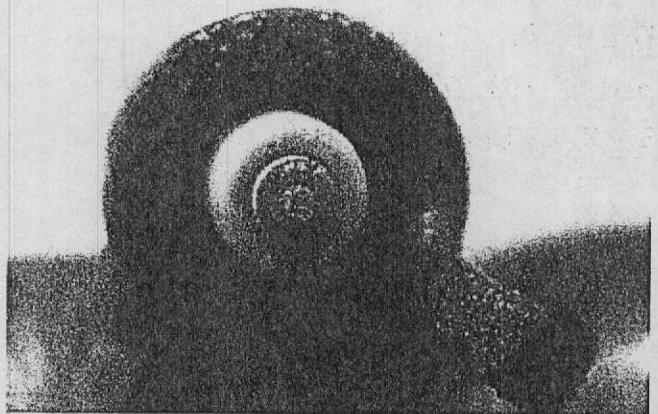
Instructor Comments:

The normal plug gap erosion specification only applies to conventional (non-platinum tipped plugs). On today's platinum tipped plugs, gap erosion has been minimized. There are two other considerations here that must also be factored in:

1. Rich A/F ratios, compression problems, or secondary misfires can and will foul any plug, regardless of the metal make-up of the electrodes.

2. Most platinum tipped electrodes minimize plug gap erosion due to the increased solidity of the platinum. However, the remaining part of the center electrode is surrounded by porcelain which cannot dissipate the heat (causing molecular erosion around the outer diameter).

Center Electrode Doming



Instructor Comments:

The 100K tune-up. Is it wise?

Notice the molecular erosion and the black ring around the center electrode. This plug only had 65K miles on it, how much worse would it be with 100K miles?

Refer to the next pages for the "before and after" scope checks…

Types of Misfires

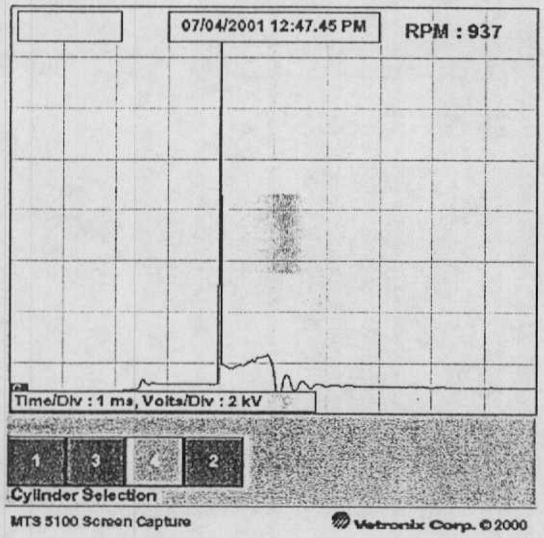
- Electrical - Caused by faulty secondary components such as:
  1. Weak Coil / Coil Pack ↓
  2. Open or Shorted Secondary Leads ↑↓
  3. Poor Terminal Connections ↑↓
  4. Carbon Tracking ↓
  5. Eroded Plug Gap ↑
  6. Center Electrode Doming ↑

Stress Point:

Electrical misfires are best detected while viewing the firing line under idle, loaded, or cranking kV tests.

The UP and DOWN arrows indicate the direction of our kV values in relation to these common types of problems. For example, an open secondary lead will drive kV values up. Be careful here, this only applies to DI systems. On EI systems, half of the cylinders are fired negatively while the other half are fired positively. In these cases, if the kV probe is before the open, the kV values will be high. If the probe is after the open, the kV values will be low. This principle becomes insignificant if the technicians always focus on spark duration periods (for minimum duration times and uniformity). Any open, regardless of the where it is in the secondary circuit, decreases spark duration periods.

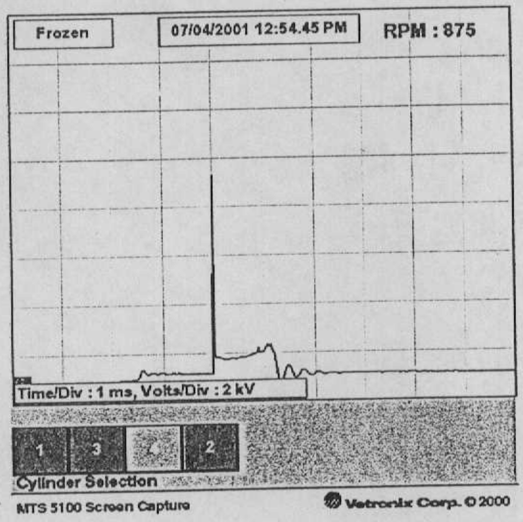
Secondary (Old Plugs)



Instructor Comments:

Here is an example of what takes place when an owner follows the manufacturer's recommended spark plug replacement interval of 100K miles. This secondary pattern was taken from a GM Type II DIS system with 65K on the original plugs. Do you notice the 14 kV firing demand? In addition, take note of the .7 to .8 ms spark duration. Remember, the leading cause of secondary ignition failures and carbon tracking is high secondary firing kVs.

Secondary (New Plugs)

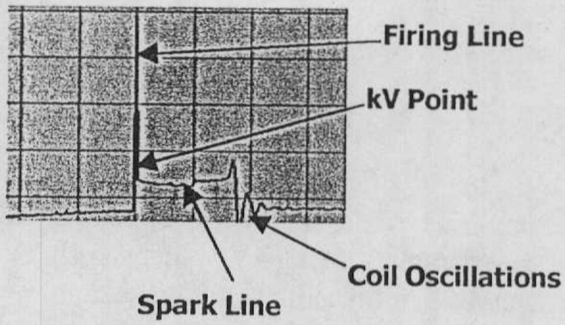


Instructor Comments:

If you recall, in the previous example of a GM Type II DIS system with 65K miles on the plugs, the secondary firing kV value was 14 kV. The spark duration period measured .8 milliseconds. In this example, with new plugs on the same engine, note the reduction of secondary kV values to 10 kV and the increase in spark duration to 1.1 milliseconds.

The Three Critical Points of a Secondary Waveform

- The firing kV line
- The spark kV point
- The spark line
  - Length
  - Angle
  - Presence of Turbulence



Instructor Comments:

- The firing line represents the total kV demand needed to overcome all air gaps in the secondary circuit.
- The spark kV point represents the point at which current flow is established across the spark plug.
- The spark line represents the amount of time that spark was sustained. This will be referred to as spark duration.
- Coil oscillations represent the residual electrical energy left over after the spark. Different coils have different characteristics.

The Fixed Resistance Components of Secondary

- Cap and rotor
- Carbon button
- Terminal Connections
- Plug wires / Coil wire
- Plugs
- Secondary coil windings

Instructor Comments:

These components, on either DI or EI systems, make up what we call the fixed resistances of the secondary circuit. Many electrical ignition misfires are caused by a defect in any one of these components. A quick scope check of secondary or primary will confirm this.

Always keep in mind that it may be necessary to create a high secondary kV demand by performing a WOT snap, a power brake, or a cranking kV test to pinpoint weak secondary insulation problems.

Secondary Resistance

- Fixed high secondary resistance values can be detected by noting the Spark kV Point.
- Typically, the spark kV point should not exceed 3 kV.

Instructor Comments:

The spark kV point is known as the point where the spark line intersects the firing line. The spark line, when established, represents the actual current flow across the plug gap. The spark kV point represents the voltage drop across the plug gap.

As a rule of thumb, the spark kV point should not exceed 3 kV. If the spark kV point is high, this tells us that a high fixed secondary resistance problem exists in the circuit. Ideally, good spark kV points are below 2 kV.

The Variable Resistances of Secondary

- Air / Fuel ratio
- Compression
- Heat

Instructor Comments:

These three factors make up what we call the variable resistances of the secondary circuit. In order to have good spark propagation, it is necessary to have good A/F ratios and good compression. Any problems in these two areas can be easily seen on a secondary waveform or even a primary waveform (for COP systems).

Law of Lab Scope Diagnostics

- Using the 3 M's

Milliseconds Matter Most

Instructor Comments:

It is extremely important that technicians measure spark duration values on secondary and primary COP systems (during "at idle/no load" conditions). In addition, as you will see, any type of density misfire will be shown on a primary or secondary waveform's spark line (under dynamic/loaded conditions).

Spark Line Measurements

- A secondary ignition waveform spark line (burn time) should never drop below 1 ms during idle/no load conditions.
- This will verify electrical integrity and A/F ratio characteristics.

Instructor Comments:

This minimum 1 ms specification is an absolute minimum value. As we explore different EI and DI systems, you will see that actually a minimum of 1.3 ms specification is more realistic (for most systems).

The stress point here is that while cylinder pressures are low, during no load/idle conditions, and we can catch a spark line duration under 1.3 ms, this is a good clue that there is an electrical or A/F ratio problem (in most cases). This critical point is very important to measure.

Secondary Ignition Carbon Tracking

- The leading cause of secondary ignition carbon tracking is High Secondary Firing kVs.

OHIO

Instructor Comments:

As spark plug gap erosion occurs and the effect of center electrode doming occurs, the secondary kV demand increases. Typically, the rule of thumb is that for every 10K miles, secondary firing kVs increase approximately 500 volts. When secondary kV demand is high, the insulation of the secondary circuit is stressed. Excessive kVs can lead to secondary insulation breakdown and carbon tracking misfires.

Secondary Misfires

- The leading cause of secondary misfires is <u>Lean</u> <u>Density</u> <u>Conditions</u>.

<u>Instructor Comments:</u>

40% of all engine performance problems are directly related to bad A/F ratios. You will see various examples in this manual proving that the spark line characteristics will help pinpoint problems in this area.

Types of Misfires

- Lean Density – Caused by insufficient hydro-carbons in the A/F mixture, resulting in poor spark propagation. This is caused by:
  1. Restricted Injectors ←
  2. Vacuum Leaks ←
  3. Contaminated MAF Sensing Element ←
  4. Low Fuel Pressure/Volume ←
  5. Carbon Buildup ←

Stress Point:

These problems are best detected by noting spark line duration and spark line characteristics under idle and loaded conditions.

The LEFT arrows indicate that the spark duration values will decrease (with all of the above common problems).

Types of Misfires

- Rich Density – Caused by excessive hydro-carbons in the A/F mixture or insufficient air. This is caused by:
  1. Leaking Injectors →
  2. High Fuel Pressure →
  3. Excessive EVAP Purge →
  4. Restricted Air Filter →
  5. Ruptured Fuel Pressure Regulator →
  6. Electrically Shorted Injectors →

Stress Point:

These problems are best detected by viewing the spark line duration at idle. Excessive EVAP purge normally will not occur at idle. Rich conditions will extend the spark duration and flatten out the spark line.

The RIGHT arrows indicate, that with any rich condition, the spark duration period will increase.

Types of Misfires

- Density Misfire – Caused by poor cylinder breathing ability. Such as:

1. Excessive EGR Flow ←
2. Low Cylinder Compression →
3. Retarded Valve Timing ←
4. Insufficient Valve Lash ←

Stress Point:

These problems are best detected by viewing the spark line duration and characteristics at idle/off idle, loaded conditions. Density misfires look much like lean density misfires in which the spark line shortens, bends abruptly upward, and exhibits an excessive amount of turbulence. Flowing propane will not improve these conditions.

The LEFT arrows indicate that the spark duration will decrease, while the RIGHT arrows represent a spark duration increase.

Types of Misfires

- Erratic Primary Performance – Caused by faulty primary components. Such as:

1. Erratic Trigger Signal
2. Low Coil Supply Voltage
3. Shorted Tach. or Accessory (at Coil -)
4. Excessive RFI on DREF or EST
5. Poor Module Performance
6. Faulty Primary Coil Windings

Stress Point:

These problems are best detected while viewing a primary voltage or amperage waveform. In cases of faulty triggering devices or excessive RFI, it will be necessary to view the trigger signal or EST signal independently.

RFI problems are best detected by shifting the scope to A/C coupling. 400 mv or more of A/C electrical ringing is undesirable. There are four possible sources of RFI:

1. Alternator
2. Secondary Ignition
3. Blower Motor (feeding into PCM)
4. Fuel Pump (feeding into PCM from the fuel pump monitor)

Misfire Detection Tips

- A good firing event begins first with the ______ ______ and ends with the ______ ______.
- Electrical misfires caused by high or low fixed resistance problems show up best on the ______ ______ as a ______ or ______ kV value.
- Lean density misfires are best detected on the spark line during _____ _____ _____ conditions.

Instructor Comments:

- Firing kV values are noted first
- Spark line characteristics and durations are noted second.
- High resistance in a plug wire will not raise the secondary kV demand.
- It is usually necessary on simultaneously injected systems to load the engine as you monitor the spark line, especially on V6, V8, and V10 engines.

Misfire Detection Tips (cont.)

- Density misfires caused by A/F ratio problems show up best on the _____ _____.
- Erratic dwell problems or erratic primary performance problems will usually cause a secondary misfire that randomly shifts from _____ to _____. This is best detected on the ____ ____.

Instructor Comments:

- Lean density misfires make up 40-50% of all misfires.
- Erratic dwell or primary miss-trigger problems cause 10-15% of all misfires.

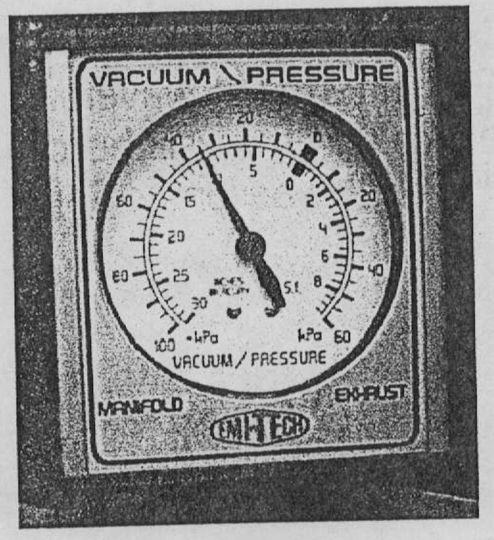
Misfire Detection Tips (cont.)

- Flowing propane to isolate a _____ _____ misfire, will not confirm a density misfire caused by excessive EGR or a valve train problem.
- High mileage vehicles that experience "lifter pump up" or insufficient valve lash, will exhibit misfire symptoms. This will show up best on the ______ ______.

Instructor Comments:

- 10-15% of all misfires are from these two areas.
- Flowing propane will not change these symptoms.
- Lifter pump-up or insufficient valve lash can be confirmed with a vacuum gauge or vacuum waveform.

Vacuum Gauge



Instructor Comments:

Some density misfires are caused by valve train problems such as insufficient valve lash from lifter pump up or sticking valves. These types of misfires look identical to a lean density misfire. You will see cases where this misfire randomly shifts from cylinder to cylinder. Flowing propane will make no difference. In these cases, it is best to detect this problem with a vacuum gauge. Abrupt needle pulsations towards the pressure side will confirm this problem.

Law of Waveform Interpretation

- Nothing in terms of waveform diagnostics and analysis becomes <u>Dynamic</u> until it becomes <u>Specific</u>.

<u>Instructor Comments:</u>

It is important to understand that while viewing secondary (for example) to detect a lean density misfire, it would be necessary (in most cases) to load the engine and view secondary spark line characteristics.

Many density misfires only occur under engine loaded conditions.

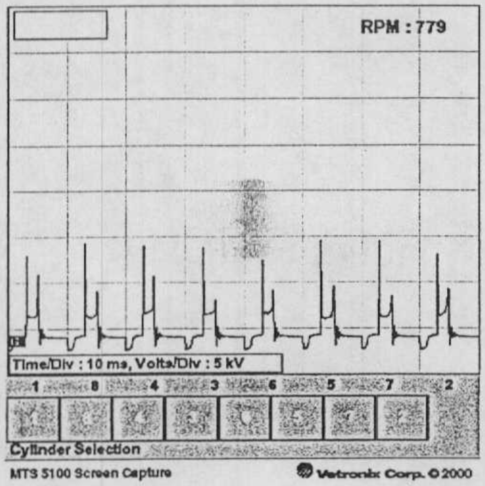
Critical Secondary Tests

- Idle kVs
- Cruise kVs
- WOT Snap
- Individual Cylinders Spark Line
- Cranking kV

Instructor Comments:

Here is a list of engine conditions under which technician's should scope the ignition system. It is not necessary to do all five tests. When technicians understand the dynamics of each test, a diagnostic decision can be easily made as to which test(s) may be needed. Typically, most ignition system problems will require 1 or 2 of these tests to verify/confirm a problem.

Secondary Idle kVs (Parade)



The two critical considerations when viewing a secondary parade pattern are:

- The actual kV values of the firing line. Typically at idle (no load), the plug gap is the most determining factor on the kV values. The following chart would be a good source:

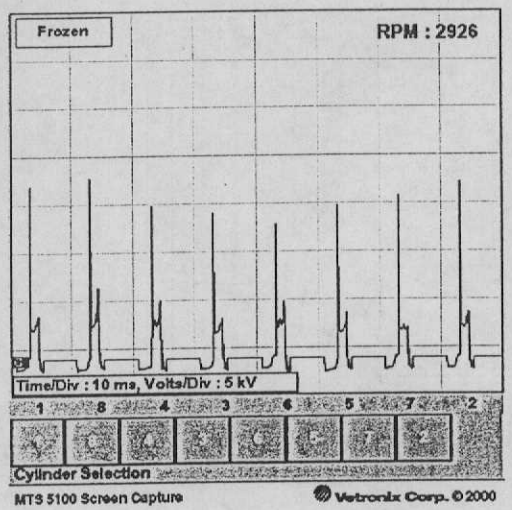
.035Plug Gap	**= 6-8 kV**
.045 Plug Gap	**= 8-10 kV**
.060 Plug Gap	**= 10-12 kV**
.080 Plug Gap	**= 12-14 kV**

  The amplitude of the firing line should always be measured to determine if other air gaps exist in the secondary circuit. These additional gaps can be caused by a broken coil wire, excessive rotor air gap, and/or any other open condition.

- In addition, you should see a 20% uniformity while comparing cylinder to cylinder. Low compression, fouled plugs, rich mixtures, and/or poor secondary insulation will drive the fixed resistance values of the secondary circuit too low resulting in lower than normal kV values. Keep in mind that these firing lines will float up and down due to compression and changing A/F ratios.

  Technicians should also make note of the time intervals between the firing events. Notice the <u>good</u> uniformity of this pattern. A misfire would slow down crank speed resulting in a larger "distance" gap between cylinders (between the misfire cylinder and the next cylinder in the firing sequence).

Secondary kVs (Parade/Off Idle)

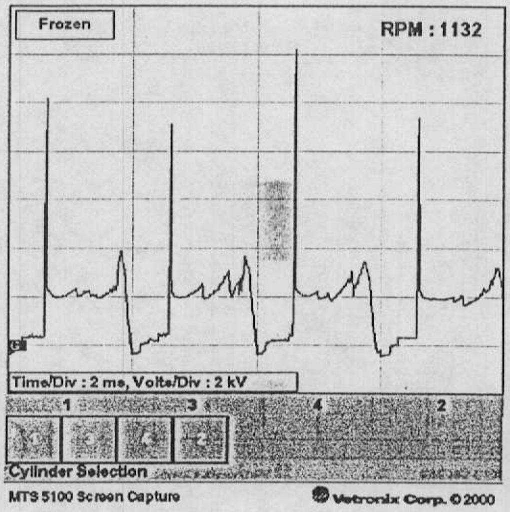


Instructor Comments:

It is sometimes necessary, on some systems or for some symptoms, to view a secondary parade pattern at an off idle condition. In the previous parade example, captured at idle, the scope indicated a secondary kV value of 8-10 kV. Keep in mind that at idle with throttle plates (mostly) closed, the cylinders' pressures are roughly ½ of what they would be during a WOT snap or cranking compression condition. When cylinder pressures are low, the secondary kV demand will proportionately be less.

In this off-idle example, note that the kV demand actually increased to 15 kV in direct relation to an increase in cylinder pressure (as the engine breathed in more air). Will this always be the case? No. It actually depends on the system. In this example, our PCM spark advance strategy will not advance timing off idle while there is no VSS signal present. However, most systems will. An increase in spark advance timing causes a firing event before peak cylinder pressures are reached, causing a decrease in kV demand (unlike this example). When no spark advance occurs, as in stuck centrifugal weights or loss of EST, then kV values will increase. A good test would be to disable spark advance and increase RPM. This will increase the secondary firing kVs, making it easier to detect a poor secondary insulation problem, such as carbon tracking.

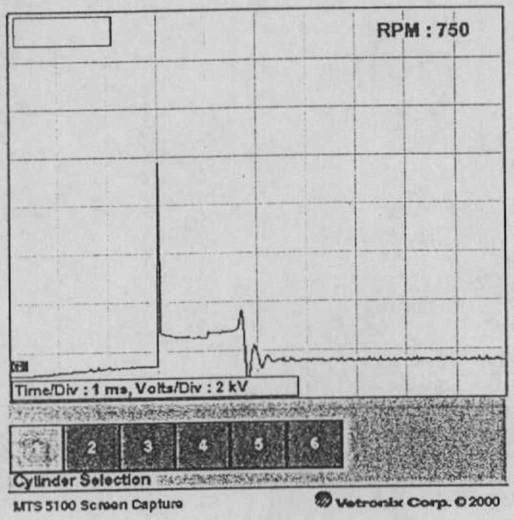
Secondary Parade (Expanded)



Instructor Comments:

Typically, the secondary parade pattern is used to focus on the firing lines for kV values and uniformity. However, in this expanded example, at 2 ms per division we get a good look at spark line characteristics as well. Notice the uniform 1.8 ms spark duration consistency with good spark line angles.

Spark Line (At Idle)

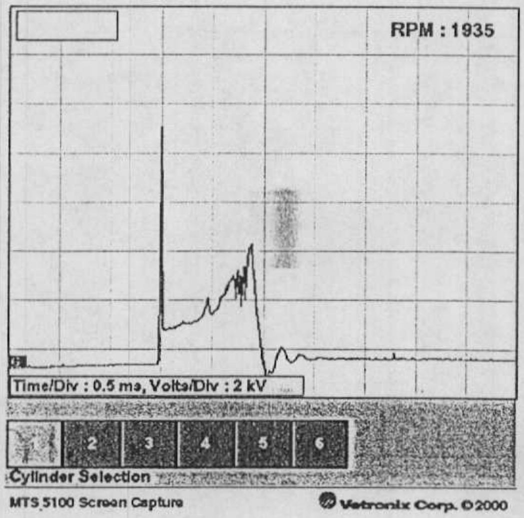


Instructor Comments:

Normally when rough, choppy idle conditions exist, it is best to individually view cylinder events. In this good example, taken at idle/no load conditions, notice the good spark line angle and duration of 1.5 milliseconds. Since we are at idle with the throttle plates closed, cylinder pressures are low which creates a smoother spark line with very little turbulence. It is at this test that we always look for a minimum spark line duration of 1.3 ms on most distributor equipped systems.

Notice the good 1.5 ms spark duration in this example. Remember that any increase in the secondary kV demand from faulty secondary components will raise the secondary kV values resulting in a shorter than normal spark line duration. These are all critical considerations that require technicians to take the time in measuring spark durations when misfire conditions are suspect.

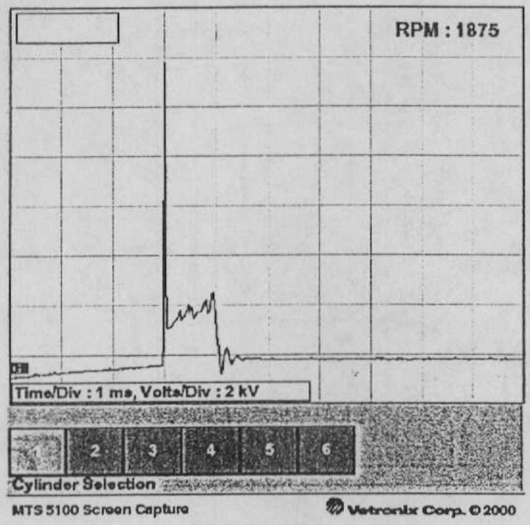
Expanded Spark Line Diagnostics



Instructor Comments:

Should a technician want a closer look at the important spark line characteristics, he/she can easily shift the scope to a .5 ms time base and a 1 kV per division. This voltage and time base is ideally suited to view the spark line during idle and off-idle load conditions. This helps to detect lean cylinder conditions or low compression problems. Keep in mind that it is perfectly normal for the spark line to bend upward at around the midway point. Lean problem cylinders will create an earlier rise and a more abrupt angle in the spark line and will also increase turbulence. Low compression problems will increase the spark duration and decrease the amount of turbulence on the spark line.

Secondary Single Cylinder (Off Idle/Loaded)

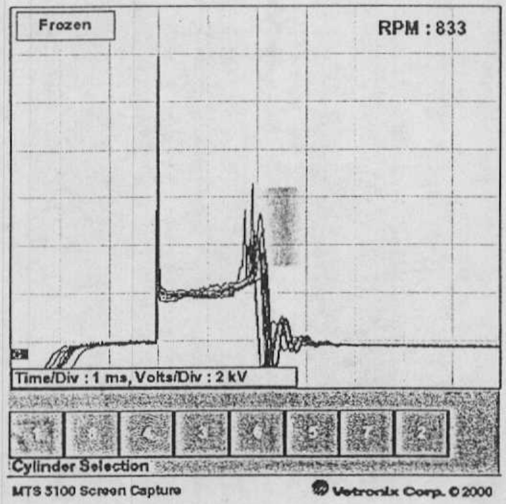


Instructor Comments:

When one or more cylinders are suspect, it is important to view a single cylinder's spark line characteristics while in off-idle/loaded conditions. For whatever reason, the spark line portion of a secondary waveform has been much overlooked throughout the years. This portion of the secondary waveform is the portion that yields the most diagnostic information to the technician. In fact, we refer to the spark line as our "window into the combustion chamber".

In this good off-idle/loaded condition example, note the increase in spark line turbulence which is directly related to the increase in cylinder pressure as we opened the throttle plate. In addition, A/F ratio problems can be easily detected here. When this occurs, the ionization demand increases which causes an upward angle in the spark line, an increase in spark line turbulence, and a shortened spark line duration period.

Superimposed Secondary

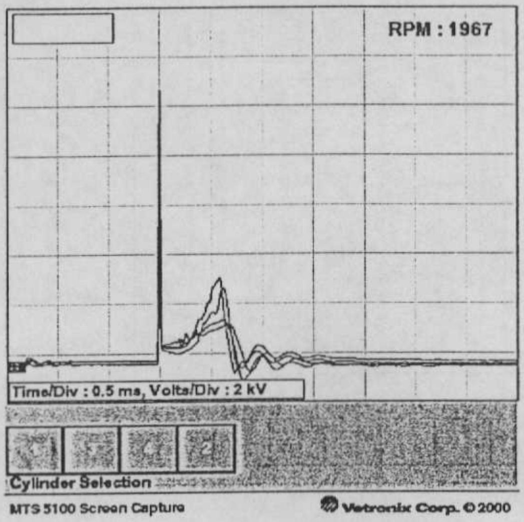


Instructor Comments:

The secondary super imposed pattern is an ideal test to check for good uniform spark kV points and spark line characteristics (under loaded conditions) between cylinders. Since all of the secondary firing events are stacked on top of each other, irregular spark kV points or short/long spark lines can be easily detected. It is important to always perform this test not only for idle conditions, but also for off idle/loaded conditions. This will help to pinpoint and decipher lean cylinders from restricted injectors or false air leaks.

Notice our good 1.5 ms spark duration and our good spark line angles. A 1 ms time base is an ideal setting for viewing this portion of secondary. If a technician wants to get a closer look at the spark line characteristics, he/she would simply shift the scope volts per division to 1 kV.

Superimposed Secondary (Loaded)



Instructor Comments:

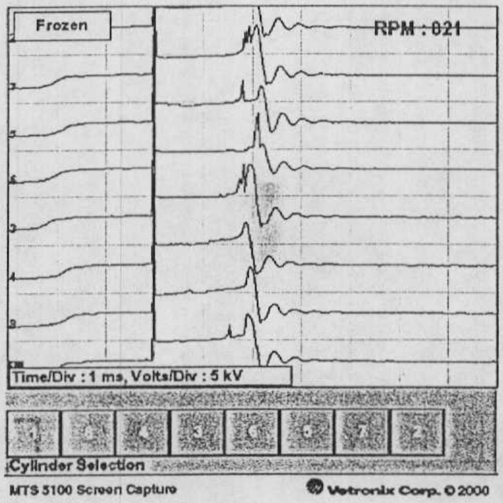
A superimposed secondary pattern at .5 ms per division is an excellent test to detect a weak cylinder for a lean A/F ratio problem or a cylinder with low compression.

Remember, to achieve **specific** results, it is important to load the secondary circuit under **dynamic** conditions. In this off-idle/power brake condition, notice the uniformity of the spark lines.

Why did the normal spark lines shorten and bend upward at about the midway point? As we open the throttle, the cylinder pressures increase and spark timing is retarded which forces a firing event under increased cylinder pressures.

Always keep in mind that the spark line is our window into the combustion chamber. Any undesirable firing event will be seen in the spark line.

Secondary Raster

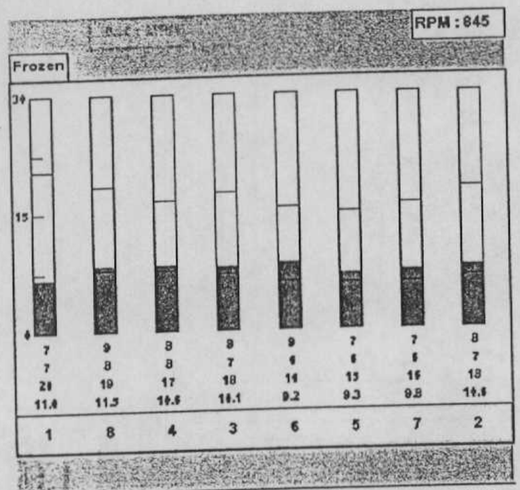


Instructor Comments:

Sometimes called a “stacked pattern”, unlike the parade pattern, a raster pattern gives a good view of the spark line characteristics and uniformity between cylinders. It will always be important to measure spark line duration when using this pattern. Any fixed high resistance problem in the secondary circuit, such as open secondary leads, poor terminal connections, an excessively wide rotor air gap, or a burnout carbon button will shorten the spark line duration.

A good rule of thumb is that at idle, during no load conditions, the spark line duration never drop below 1.3 ms on most DI systems. Notice in this example, our spark duration measures 1.6-1.8 milliseconds. This type of pattern is an excellent way to also test for lean conditions during an off idle/power break test. Remember, lean cylinders increase the ionization demand, thus bending the spark line abruptly upward which indicates that more voltage is needed to sustain the current flow across the plug gap. In addition, lean cylinders will also create excessive turbulence on the spark line.

Secondary kV Bar Graph



MTS 5100 Screen Capture

Vetronix Corp. © 2000

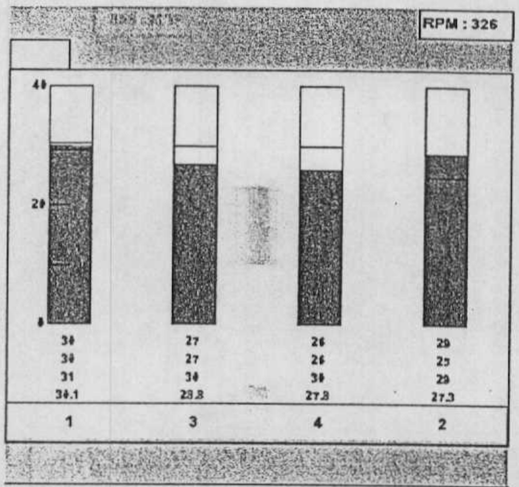
The secondary kV bar graph is an excellent screen to do the WOT snap test. The kV bar graph displays the minimum, maximum, and average secondary kV values during this test.

Whenever the throttle is snapped wide open, the resulting larger intake of air into the combustion chamber drastically increases cylinder pressures causing a major increase in kV demand. In addition, under these conditions, spark timing is retarded, resulting in a firing event very close to TDC. The resulting increase in kVs are directly related to the volumetric efficiencies of the engine. Valve train and compression problems will not give you good max kV readings. In cases of restricted exhaust, especially on speed density EFI systems, a good max kV demand will not be reached.

As the throttle is slammed shut, the air is cut off from the combustion chamber causing a hydrocarbon spike across the plug gap which was created from the initial snap enrichment. What basically is indicated here, looking at the minimum kV values, is that the spark plug air gap has been bridged leaving the rotor air gap as the only air gap left in the system. Most DI systems need a minimum of 3-5 kV to bridge the rotor air gap. There are some DI systems that will require slightly more. On EI systems, the minimum kV values detected during this test represent the amount of voltage needed to fire the waste firing event.

The maximum 20 kV demand in this example gives us a good determination of the engine's volumetric efficiency and cylinder compression.

Secondary Cranking kV Test



MTS 5100 Screen Capture

Vetronix Corp. © 2000

Instructor Comments:

This test is much more valuable than most technicians realize. Why? Look at the secondary kV demand indicated by this bar graph. Each secondary circuit is requiring 30,000 volts to fire the plug! This test is performed by doing a "WOT (Wide Open Throttle) Cranking kV" test in which the clear flood mode was entered by the PCM. This quick test is actually three tests in one:

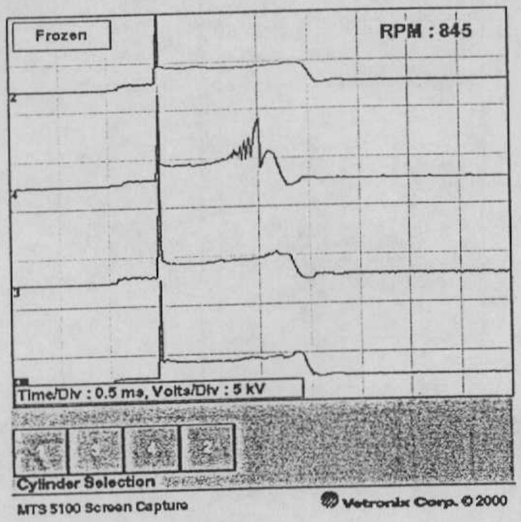
1. **A Dynamic Compression Test**
2. **A Secondary Insulation Stress Test**
3. **A Coil or Coil Pack Stress Test**

The excessive kV demand is achieved because there are little or no conductive fuel molecules inside the combustion chamber, which drives up the kV demand.

Since the throttle is wide open the volumetric efficiency of the engine is high. This allows for peak cylinder pressures to be reached requiring a peak kV demand which stresses the secondary circuit.

Spark timing is retarded requiring a firing event under peak cylinders pressures.

Secondary Raster (Idle/No Load)

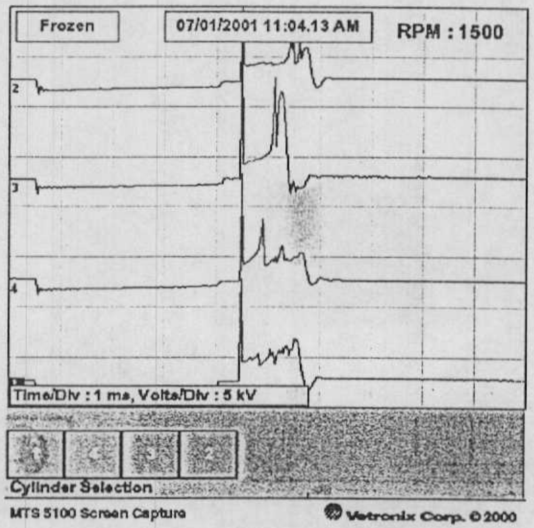


Instructor Comments:

A secondary raster pattern is one of the best screens to check for any density condition inside the combustion chamber. In this lean density condition, note the cylinder number 4 spark line characteristics as compared to other cylinders. The number 4 spark line is shorter than normal, contains excessive turbulence, and is plotted with a sharp upward angle. Since this condition is isolated to the number 4 cylinder, we would suspect a lean density condition. Flowing propane to the engine could easily confirm our diagnostics by increasing the spark line duration and smoothing out the turbulence. It is important to understand that not all lean density conditions will show up this way under "idle only" conditions. In some cases, technicians must monitor these spark line characteristics during power brake conditions.

If this problem randomly shifts from one cylinder to another with no response from propane, a technician would suspect a valve train problem. Valve train problems can include a wiped exhaust cam lobe and/or a sticking intake valve. In addition, also keep in mind that flowing propane will not help this condition or density misfire condition that is caused by excessive EGR flow.

Secondary Raster (Lean/Loaded)

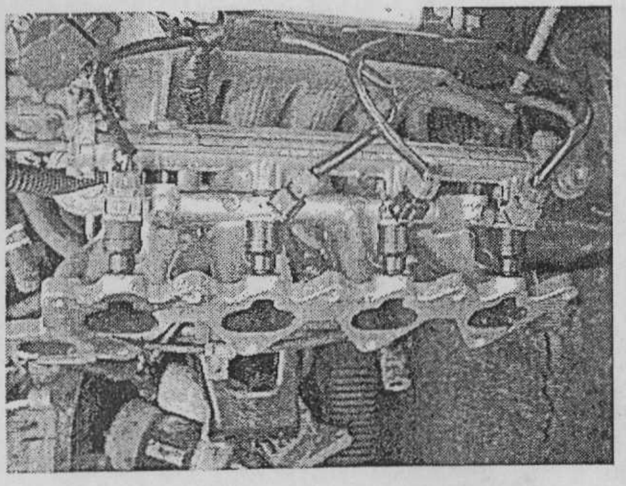


Instructor Comments:

Any density misfire can easily be detected by using the raster pattern at idle or loaded conditions. A density misfire can occur from lean injectors, vacuum leaks, valve train problems, and/or excessive EGR.

If the #3 spark line smoothes out and increases by flowing propane, then we would have confirmed a lean density misfire. However, flowing propane will usually <u>NOT</u> help a density misfire caused by excessive EGR or a valve train problem. Also, in cases of sticking valves, a valve train problem, or excessive EGR, the misfire may randomly shift from one cylinder to another.

Single Plenom / Single Plane Intake Manifold

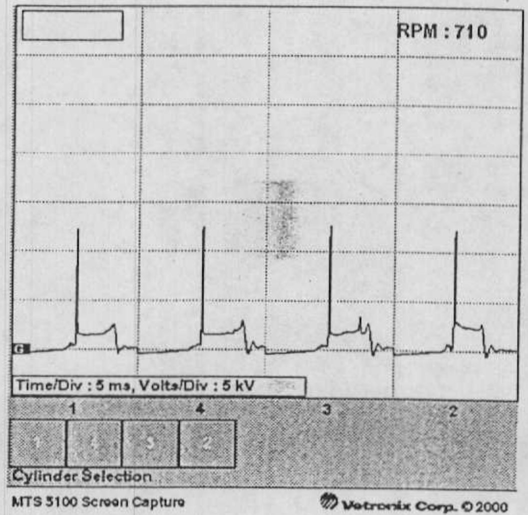


Instructor Comments:

Detecting lean density misfires is easier with a single plane intake manifold, used on PFI systems. In most cases, it is not necessary to load the engine to view spark line characteristics. However, in these types of systems, a lean cylinder cannot siphon fuel from an adjacent intake manifold runner.

On TBI, carbureted, and simultaneous injected systems, it is usually necessary to power brake the engine in order to lower manifold vacuum while noting spark line characteristics.

Expanded Secondary Parade



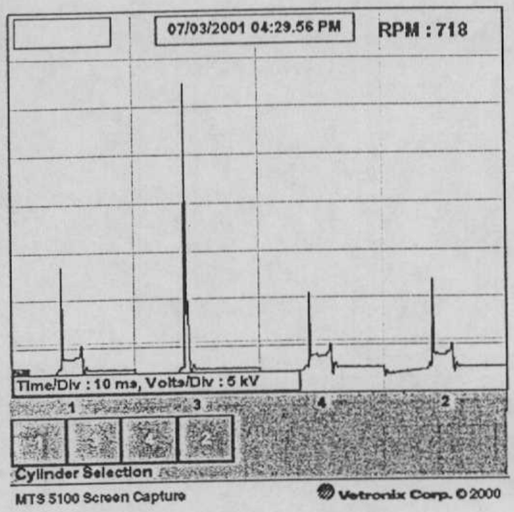
Instructor Comments:

Look closely at this expanded secondary pattern. Remember the three critical points of the secondary waveform: the firing kV line amplitude, the spark kV point value, and the spark line characteristics. Are our kV values, for a .050 gap plug, good and uniform? At 10 to 13 kV, the answer is yes.

The second consideration would be the spark kV point values. Do any of them exceed 2.5 kV? Notice the high spark kV point of cylinder #2. This is an indication of a high fixed secondary resistance problem for the #2 circuit. This could be caused by a poor secondary lead terminal correction or an excessive ohmic value of the plug lead. Does this problem affect firing kVs? No. Does it raise the spark kV point? Yes. Will it have an effect on the spark duration?

Compare the #2 spark duration time to that of #1, #3, and #4 cylinders. You will notice that the spark duration times of the #2 cylinder are dangerously close to falling below our 1.3 ms minimum rule. This condition was caused by a bad secondary lead with resistances over 30K ohms.

Secondary (High kV)

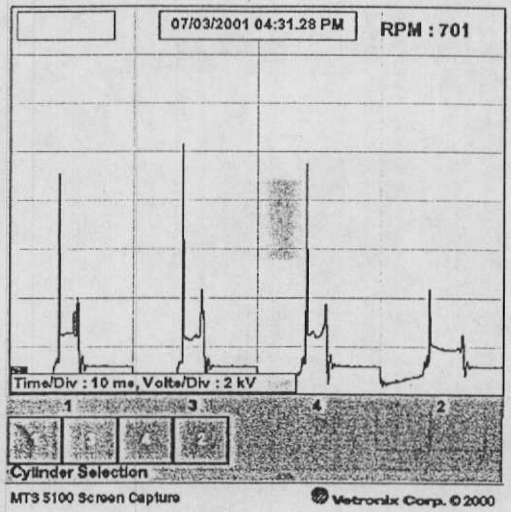


Instructor Comments:

There is another obvious problem indicated here by this secondary parade pattern. The #3 cylinder is firing in excess of 25 kV. Notice, due to this high kV demand, the spark line is non-existent.

If you were thinking that there must be an open somewhere in the #3 circuit, you would be correct (at least, for this DI system). If this problem existed on an EI system, with an open plug wire on the #3 cylinder (negatively fired), what would the #2 cylinder (positively fired) companion cylinder look like?

Secondary (Low kV)



Instructor Comments:

There is an apparent problem here with the low kV value of the #2 cylinder firing line. Below is a list of possibilities that could cause this. These problems could be inside or outside the combustion chamber.

Inside the Combustion Chamber:

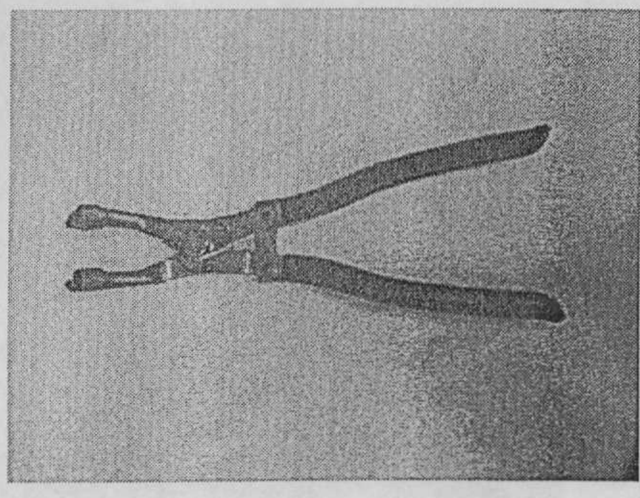
- No compression 2. Fouled plug
3. Rich condition 4. Grounded center electrode

Outside the Combustion Chamber

- Cracked spark plug porcelain (causing arc to ground) 2. Poor spark plug wire insulation
- Carbon tracking inside cap 4. Crack inside distributor cap

Stress Point: If this problem occurs at idle and off idle conditions, then the problem, most likely, is inside the combustion chamber. If the problem only occurs during off idle conditions (engine loaded), then the problem is, most likely, outside the combustion chamber.

Insulated Pliers

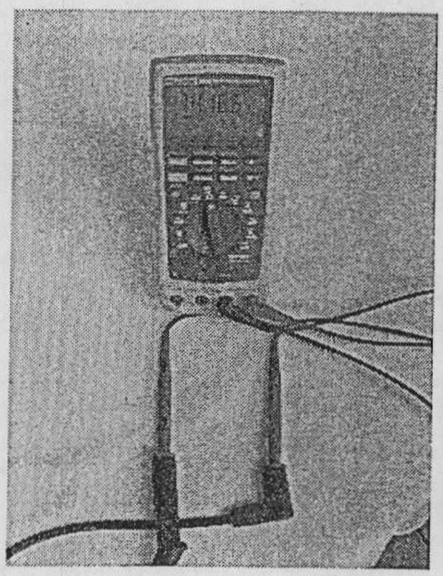


Instructor Comments:

One should never create an excessive open in the secondary circuit because of danger involved with the extremely high kV output of today's modern systems. However, to determine if a low firing kV value is caused by a problem inside/outside the combustion chamber, there are times that technicians may need to create a small air gap at the spark plug.

For example, let's say a short and low firing line is indicated on just one firing event. If we create a small gap between the wire and plug, and the firing line kVs increase, the problem is inside the combustion chamber. If the firing kVs do not change, then a firing event is happening outside of the combustion chamber, such as a grounded plug lead or cracks/carbon tracking inside the gap. If two low firing kVs are indicated on a DIS coil pack, it would be a good clue that the coil pack is bad.

Ohm Check on Secondary Lead



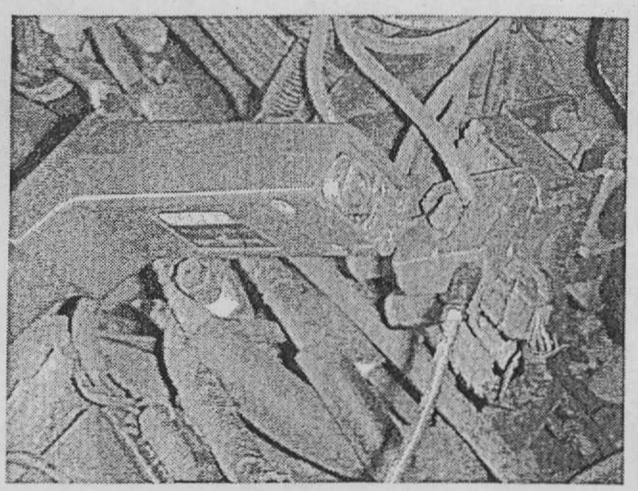
Instructor Comments:

A conventional way to test a secondary suppression lead is to do a simple ohmmeter test, as in this example.

While this is a good test, keep in mind that it is a static test. Typically, a maximum 8K ohms per foot should be allowed. Most good leads will ohm out at 3K to 5K ohms per foot. GM specifications state that a single lead should not exceed 30K ohms.

A much better dynamic test would be to scope the secondary circuit. Excessive resistance values will elevate the spark kV point, thus shortening the spark duration.

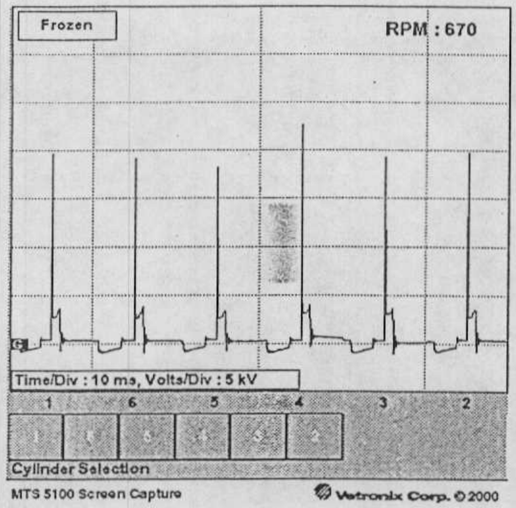
Timing Light



Instructor Comments:

The use of a timing light, with the inductive pickup clamp around a suspected lead, can be a quick test to verify a firing event. However, this test has severe limitations. Primarily speaking, to trigger the light, the inductive pick-up only requires a 400 mv potential from the magnetic field. Unless you have supernatural abilities, you will not be able to measure the important spark duration value. Scope it out…

GM 4.3 Secondary (High kVs)



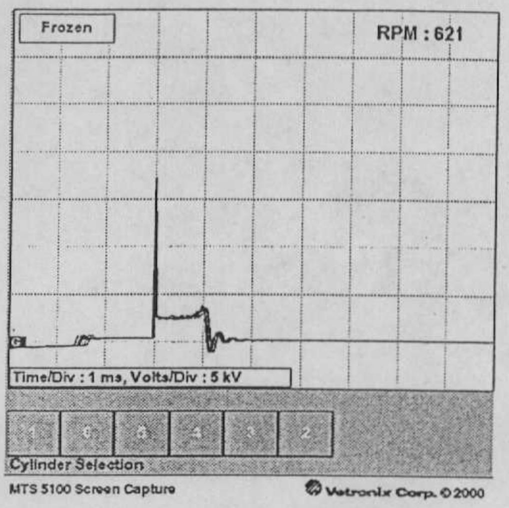
Instructor Comments:

What's wrong with this picture?

Since we are looking at a parade pattern, we need to check for good amplitude on the secondary firing events. Notice, at 5 kV per division, these are extremely high (too high) for a .045 plug gap. Since all of them are uniformly high, it must be one common problem as in coil wire, coil tower, or excessive rotor air gap. Always remember, if secondary kV values are too high, then the spark duration will be too low.

Let's take a look at the next example…

GM HEI Secondary (Short Spark Line)



Instructor Comments:

A super-imposed secondary waveform confirms our previous statement. You are looking at a 18 - 20kV excessively high firing line with an insufficient spark duration of less than 1 millisecond.

GM 4.3 Cap

Instructor Comments:

The side feed distributor caps used on the GM Vortec engines are known to open circuit inside the coil tower of the distributor cap. The result will be elevated secondary kV demands and shortened spark duration periods. A simple ohmmeter test, as indicated here, will confirm this problem.

OBD II False Misfire Codes?

- GM
- Chrysler
- Ford

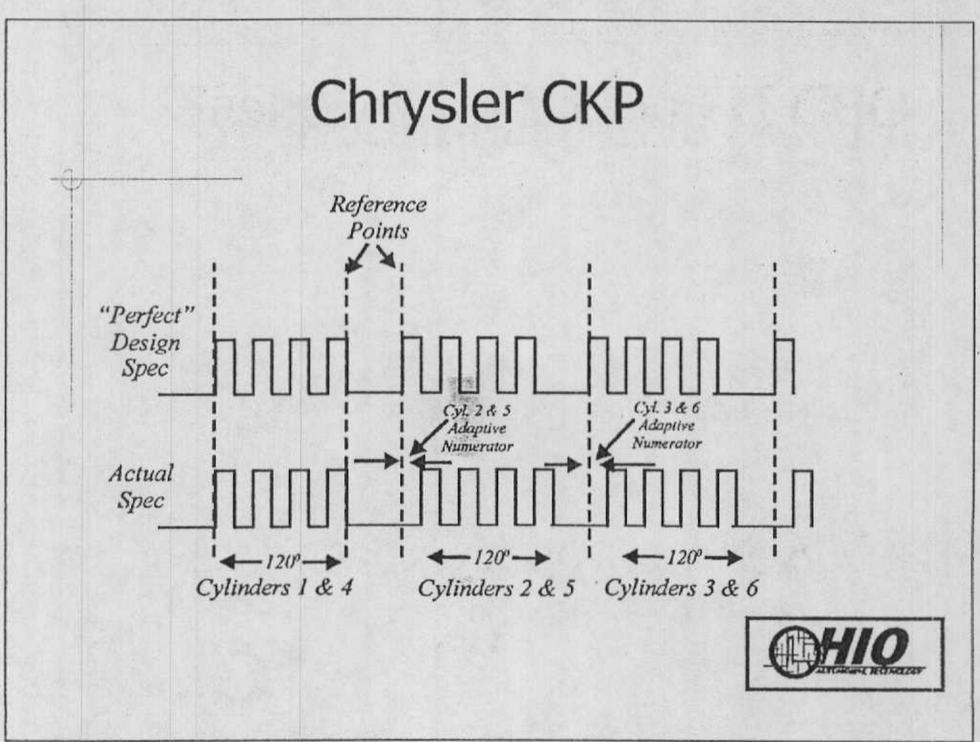
<u>Instructor Comments:</u>

GM, Ford, and Chrysler OBD II systems, before model year 1998, were notorious for false misfire codes. It is still advisable to scope the secondary circuit for both good kV values and spark duration periods. If a technician feels that it is a false misfire code (no symptoms), below is list of procedures to teach the PCM new crank angle values.

<u>Chrysler</u> – Disconnect battery for 15 minutes (PCM reset). Drive vehicle to 55 MPH and de-accelerate back to idle (three times). The misfire monitor will be disabled until the PCM learns new numerator values.

<u>Ford</u> – Disconnect battery for 15 minutes (PCM reset). Drive vehicle to 60 MPH and de-accelerate back to 40 MPH without braking (3-5 times). Monitor the misfire PID on the scan tool to make certain is says NO.

<u>GM</u> – Before 1997, it is not possible to dump the PCM's learned crank values by disconnecting the battery. A PCM reflash must be done on these systems (earlier than 1997). Beginning model year 1997, the case relearn procedure can be done on some engines. In model year 1998, the manufacturer's obtained misfire relief to minimize the possibilities of false misfire codes.



Instructor Comments:

The distance between the groups of crankshaft position signals is known as "learned numerator values". The PCM learns these values on a decel condition when the injector enleanment strategies are used. Since there are no power strokes, the crankshaft speed is uniform. The actual numerator values can vary as much as 2-4%.

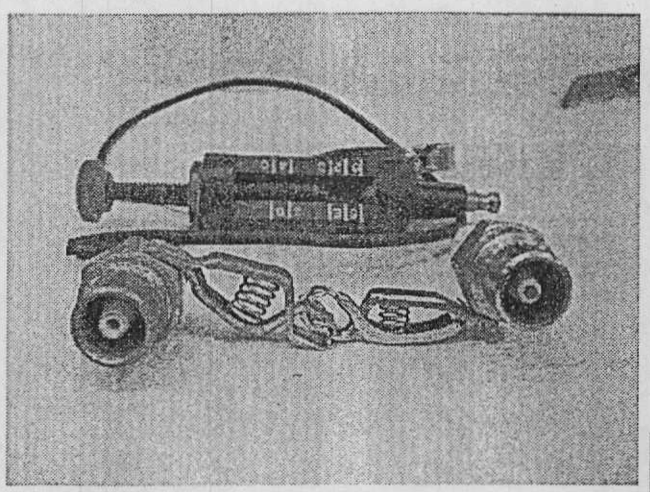
Secondary Ignition Diagnostics
(EI Systems)

OHIO

Section Contents:

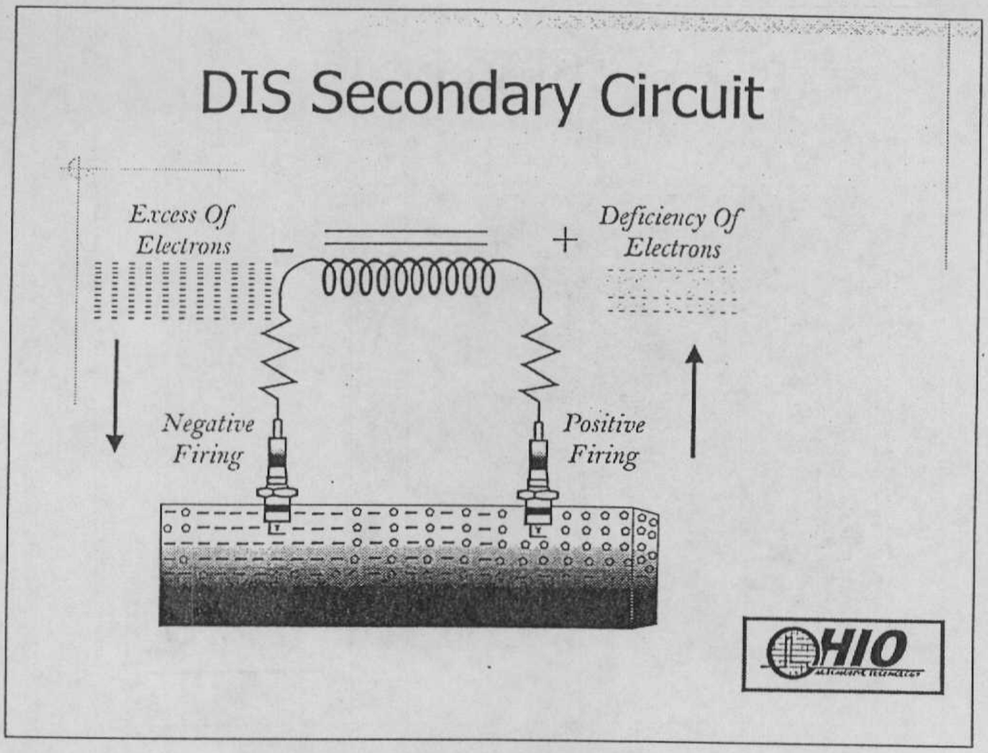
This section will cover secondary ignition diagnostics on EI systems. EI is the new dedicated term for distributor-less type ignition systems. These systems conduct a true waste and firing event.

Spark Testers



Instructor Comments:

Be careful when choosing spark testers when stressing DIS coil packs or distributor ignition systems. This picture shows three different spark testers. Some DIS coil packs, as in GM, can fire two of the high energy spark testers clamped together, requiring a 50 kV demand. The high energy style is shown in the lower left hand corner. To double stress a Chrysler or Ford EDIS multi-spark system, it is best to use two low energy spark testers clamped together. The lower energy version is shown in the lower right hand corner. When using an adjustable spark tester (top of picture), don't exceed the kV demand indicated on various systems found in this manual.

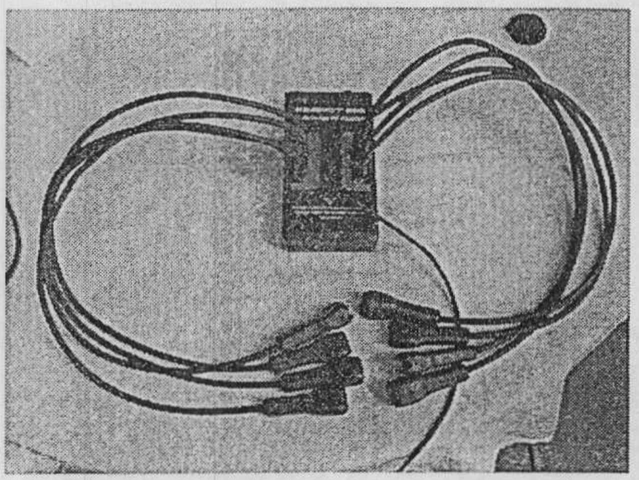


Instructor Comments:

The DIS secondary circuit is actually a simple series circuit. The fixed polarity of the secondary windings determine that current flow will be from negative to positive.

Always keep in mind that one plug will fire as a negative firing event, while the other will fire positively. An open in one plug wire will affect the spark duration of both firing events. In addition, the cylinder head and the spark plug thread contact area are part of the circuit. Any problem on one half of the circuit will affect the other half.

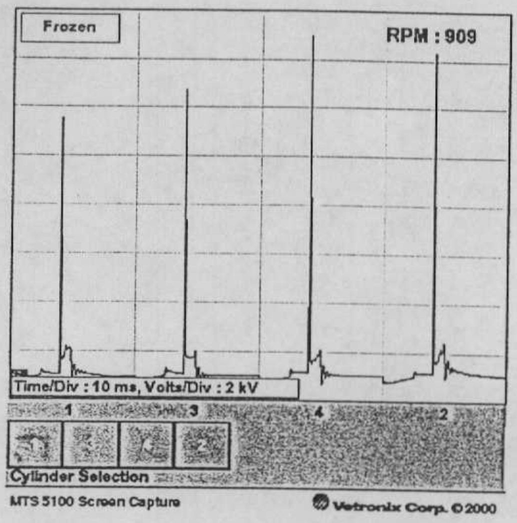
Ferret DIS Adaptor



Instructor Comments:

The Ferret DIS adaptor is an inexpensive tool to allow technicians to view a secondary parade pattern using a standard DSO. Since you are restricted to a parade pattern, technicians will not have the raster pattern available to monitor spark line characteristics (as in the raster pattern). Whenever a misfire is created by an electrical problem, the parade pattern should give us sufficient firing lines to monitor electrical misfires.

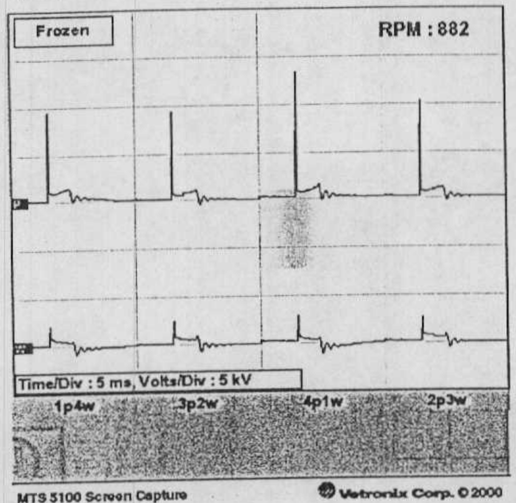
DIS Parade



Instructor Comments:

Notice the kV values of the #1 and #3 cylinders are lower than #2 and #4. This is a normal occurrence created by the location of the kV probes in relation to the plug air gap. Negative firing events will always read slightly higher than the positive firing events. However, spark duration periods should always be uniform and on this system, a minimum of 1 millisecond.

Measuring Waste Spark kVs



Instructor Comments:

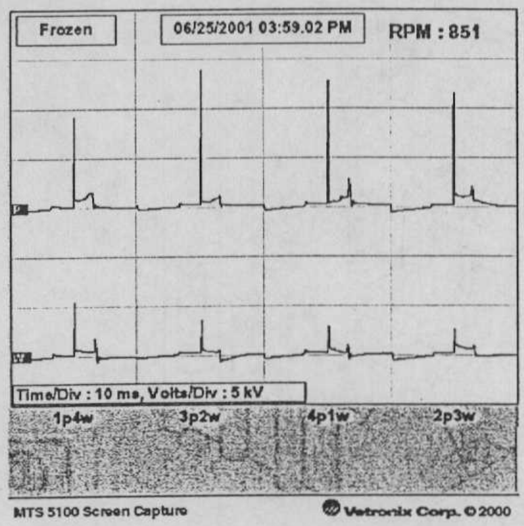
In cases where there is an open plug resistor, a poor terminal connection, or excessive plug gap erosion, a technician can easily view the kV demand needed to fire the waste events. Typically, this value should not exceed 4 kV on a .045 inch plug gap. Why? Remember, we are firing the plugs under "no compression" conditions with the exhaust valve open. Any excessive or additional air gap in the secondary circuit will elevate the kV value. Keep in mind that it is still necessary to view the spark line duration as well.

In this example, note the uniform 2 - 3 kV demand. Two factors that must always be considered, should an open condition exist in a plug wire:

- If the kV probe is after the open in a positively fired waste event, then the kV value will be lower than normal and a shorter than normal spark duration will occur.
- If the kV probe is before the open in a positively fired waste event, then the kV value will be higher than normal and a shorter than normal spark duration will occur.

Keep in mind that the exact opposite will exist in a negatively fired waste event.

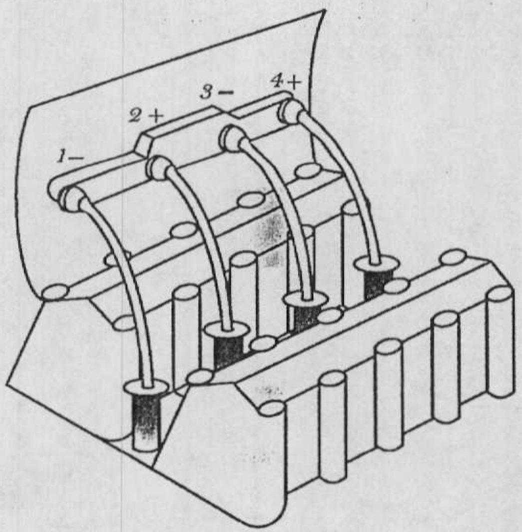
High Waste Firing kV



Instructor Comments:

Notice the bottom trace of a paraded waste firing event. Remember, since we are firing a .045 gap plug under no cylinder pressures, we want to see a 2 to 3 kV demand. Look closely at the #4 waste event, which measures over 5 kV. This was caused by an open lead in the #4 negative waste firing event. If this open existed in a positive waste event, then the kV value would have been below 3 kV (also indicating an open). Remember, this is determined by whether the scope lead is upstream or downstream of the open.

Testing IDI

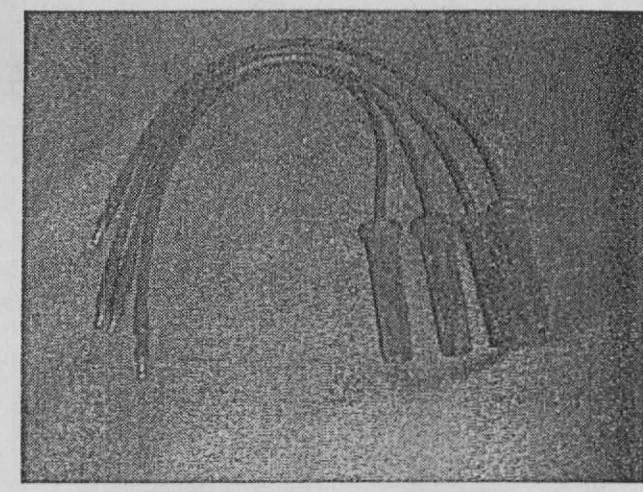


Instructor Comments:

GM's integrated direct ignition systems are found on the 2.3L, 2.4L, and the new 3.5L V6 engines. Since there are no secondary leads, it is necessary to remove the ornament cover and install some secondary leads. This will allow us to scope test the secondary.

Caution: since the module is bolted to the underside of the ornament cover, a jumper wire between the cover and ground needs to be used. There is no access to view a primary voltage function. You can, however, monitor primary current events at the module feed wire (using a low amp probe).

Integrated Direct Ignition Secondary Test Lead Set

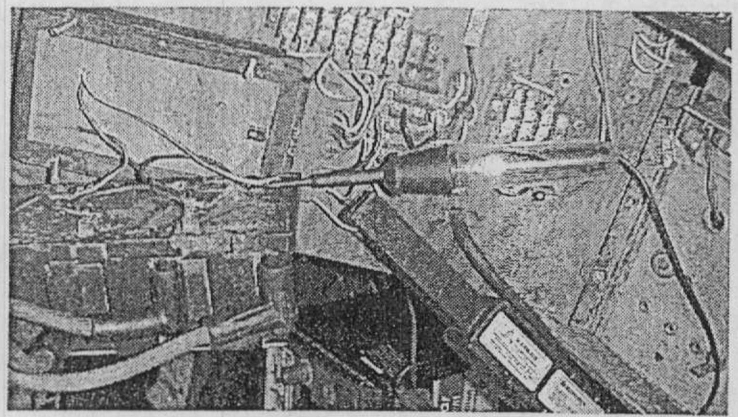


OHIO

Instructor Comments:

To properly scope out the secondary circuit, it is necessary to use a secondary lead set on GM's 2.3L, 2.4L, and 3.5L engines.

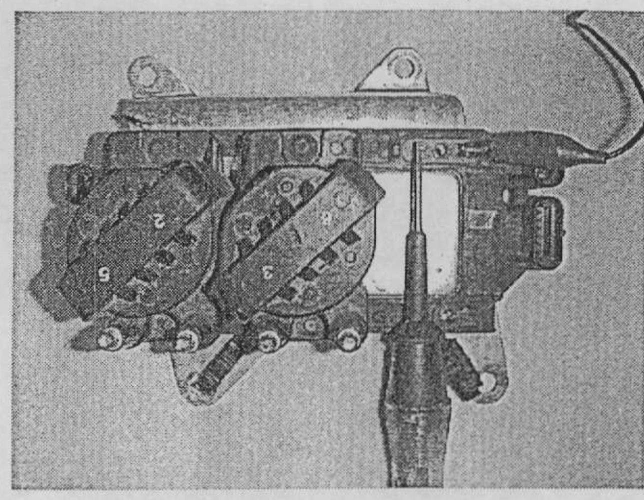
Testing Module on Type I



Instructor Comments:

When a single coil pack is not firing, it is a good idea to check the module driver using a low impedance test light. The test light alligator clip is attached to BATT +. The "ice pick" end of the test light is probing coil negative. This wire will have a black tracer. A low impedance test light will sufficiently load the module driver. A solid light indicates a shorted driver. No light means an open driver.

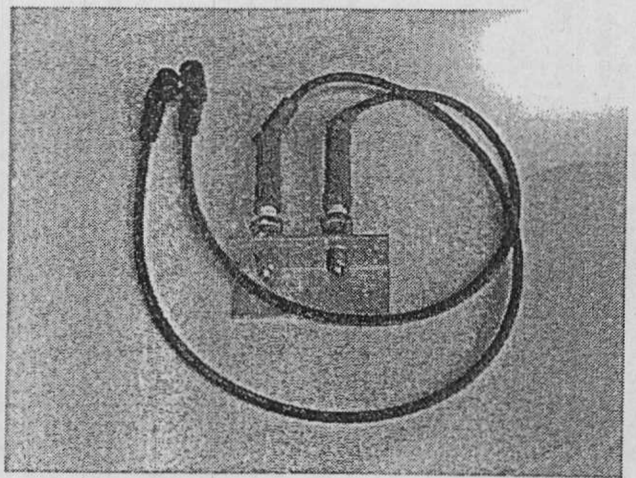
Testing Module on Type II



Instructor Comments:

Using a low impedance test light on a type II coil pack module, will give you the same results. In this example, we have placed a test light across the primary coil plus and coil negative terminals. A blinking test light confirms that a primary driver is switching.

DIS Spark Tester

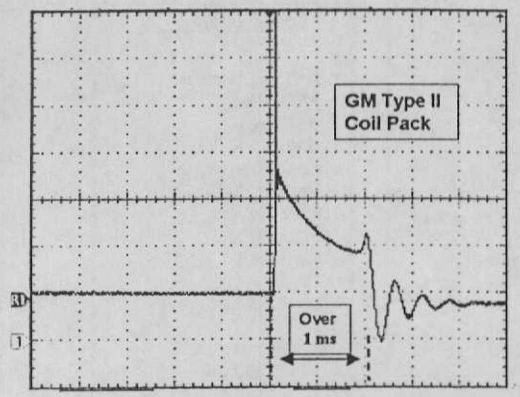


Instructor Comments:

This is our example of a calibrated "home made" spark tester, using two 3-foot suppression leads and two .045 gap spark plugs attached to a 2-inch piece of aluminum channel. One might ask, why would a technician use this tester?

We can unload the secondary circuit and view the spark line characteristics with no influence from the engine's compression and A/F ratio. With the unloading of the secondary circuit, we want to see a nice smooth transfer of energy on the secondary spark line. Refer to the following examples of using this tester.

Secondary Ignition Testing
(GM Type II, EI Systems – "Good")



Scope Settings

Volts Per Division
⇒*500 Volts*
Time Base
⇒*.5 ms*
Scope Trace Mode
⇒*Normal*
Trigger Source
⇒*Channel 1*
Trigger Slope
⇒*Positive*
Trigger Level
⇒*500 Volts*
Engine Speed/Load
⇒ *Idle/No Load*

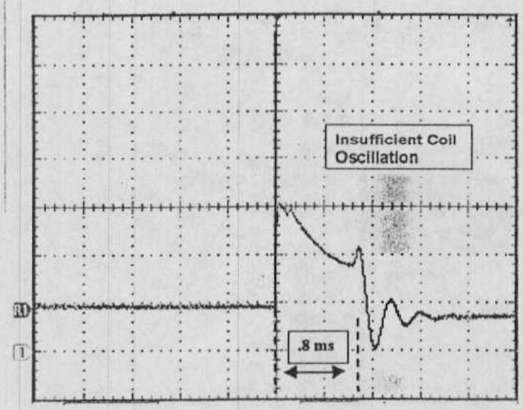
Instructor Comments:

This secondary waveform was obtained from a GM Type II coil pack, under "no load" conditions, using our "homemade" spark tester. Look closely at this good pattern and notice:

- We have a nice smooth transfer of energy (indicated by the spark line).
- We have the good 1 millisecond burn time.
- We also have 2 ½ good, uniform coil oscillations. The coil pack also measured out with a good 5.6 kΩ value. GM Type II coil packs should ohm out between 5 kΩ and 7 kΩ.

Secondary Ignition Testing

(GM Type II, EI Systems – "Bad")



Scope Settings

Volts Per Division
⇒*500 Volts*
Time Base
⇒*.5 ms*
Scope Trace Mode
⇒*Normal*
Trigger Source
⇒*Channel 1*
Trigger Slope
⇒*Positive*
Trigger Level
⇒*2 kV*
Engine Speed/Load
⇒ *Idle/No Load*

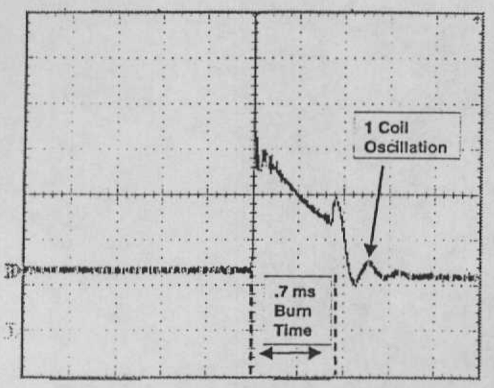
Instructor Comments:

Let's look at this "bad" example of a GM Type II coil pack using our "homemade" spark tester. Let's see if the DSO can dynamically point out a bad coil pack.

We have set our scope on 500V at .5 ms, just to focus on the spark line and the coil oscillations. This pattern was obtained from a system with "no loaded" conditions, firing a .045 plug to ground, outside the pressures of the combustion chamber. Note the following:

1. A small erratic transfer of energy at the beginning of the spark line.
2. A shorter spark burn time of .8 milliseconds.
3. A reduction of coil oscillations to barely 1.5 times.

Secondary Ignition Testing
(GM Type II, EI Systems – "Ugly")



Scope Settings

Volts Per Division
⇒*500 Volts*
Time Base
⇒*.4 ms*
Scope Trace Mode
⇒*Normal*
Trigger Source
⇒*Channel 1*
Trigger Slope
⇒*Positive*
Trigger Level
⇒*1.5 kV*
Engine Speed/Load
⇒ *Idle/No Load*

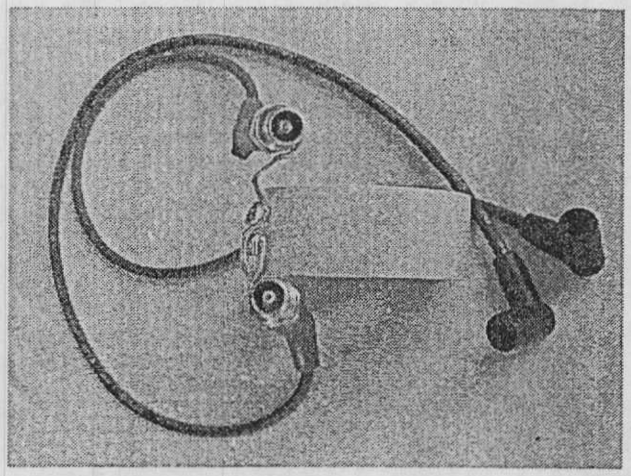
Instructor Comments:

Ohmmeters can usually identify a bad coil pack, as in this example where the coil actually measured 4 mega ohms! But what can the DSO do dynamically? Look at this secondary pattern and note the following:

1. The disturbance in the transfer of energy at the beginning of the spark line.
2. The shortened .7 millisecond burn time.
3. The coil oscillations are now down to barely 1 oscillation.

This pattern was obtained from a system with "no loaded" conditions, firing our "homemade" spark tester under atmospheric air pressures.

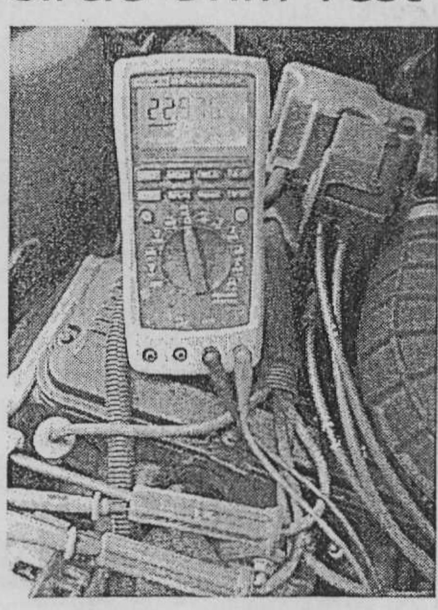
Chrysler Spark Tester



Instructor Comments:

These are two low energy (15 kV each) spark testers clamped together. This is a good stress test for Chrysler DIS systems. These coil packs are not the high energy style as in the GM versions. These units will only peak out at 30 kV. On the Ford EDIS multi-spark systems, it is also advisable to use the low energy spark testers.

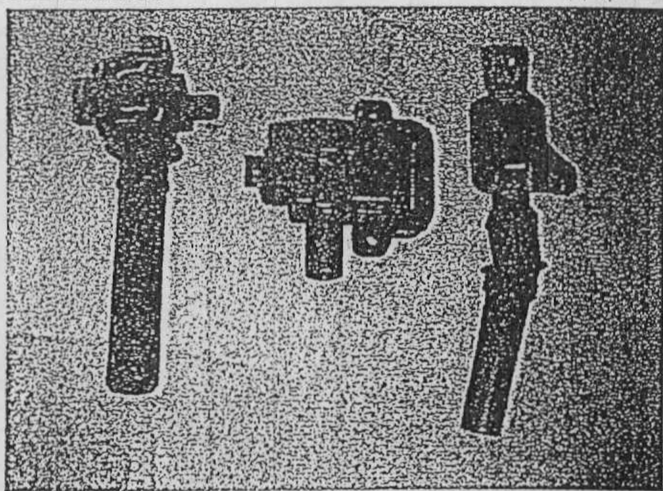
Circle Ohm Test



__Instructor Comments:__

A quick test of a DIS circuit, if initial access to the coil pack is not available, would be to do a circle ohm test. Though this is never conclusive, it will however, locate an open circuit. In this example, we are testing a secondary circuit, which includes the plug leads and the secondary windings of coil pack #3 and #2. If the ohmic value of the secondary windings are 7K ohms and each plug wire is 8K ohms (2 leads), then our meter is very close to the 23K ohm specification. Any high ohmic specification would lead us to check each individual secondary lead and the coil pack.

COP Units



Instructor Comments:

These are three domestic versions of COP units. The Chrysler and Ford units will have easy access to a primary voltage trace by back probing the connector. This is due to the fact that the coil drivers are located inside the PCM.

The GM versions of the Coil-Near-Plug units have the primary driver (or module) built into the unit. This means that access to a primary voltage trace is not possible. This is not a problem should you decide to scope check the GM unit by selecting the secondary function of the scope and using the secondary kV probe on the short secondary lead. A primary function can easily be determined by using an amp probe.

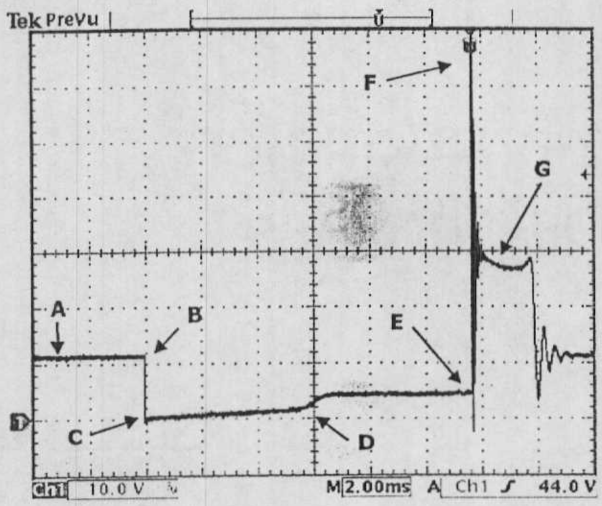
Primary Ignition Diagnostics

OHIO AUTOMOTIVE TECHNOLOGY

Section Contents:

This section will cover primary ignition diagnostics on both EI and DI systems.

Anatomy of a Waveform



Instructor Comments:

- ________________________________
- ________________________________
- ________________________________
- ________________________________
- ________________________________
- ________________________________
- ________________________________

Electrical Theory

- Electrical energy is neither created or destroyed, it is simply stored or transferred.

Notes:

Law of Ignition System Energy

- The amount of electrical energy produced by the primary and used by the secondary is the same with every <u>Firing Event</u>.
- The only variable is the amount of time, measured in milliseconds, it took to use the energy. This is known as the <u>Spark Duration</u>.

<u>Instructor Comments:</u>

- This manual will prove to you, the technician, that whatever disturbs a good secondary firing event can be seen in primary. You will see dual trace examples of good and bad primary/secondary patterns indicating mirror effect.

- The spark duration period becomes the critical point and this manual stresses the importance of noting this period (whether it is on the primary or secondary side of the ignition system.

Law of Mutual Induction

- In terms of ignition scope patterns, any electrical problem in the secondary circuit will be mirrored in the Primary Pattern.
- In addition, poor performance of the primary system, whether mechanical or electrical, will affect Secondary.
- This is known as the theory of Mutual Induction.

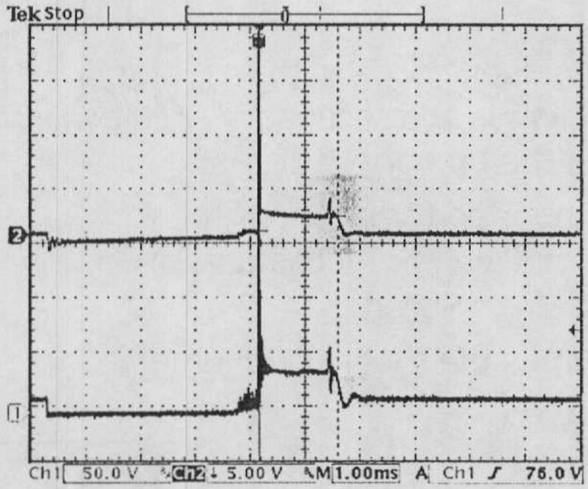
Instructor Comments:

➢ Whenever access to the secondary circuit is not possible, as in COP systems, technicians can make good sound diagnostic decisions by viewing the primary side of the ignition system. Any secondary problem that is electrical, A/F ratio related, or mechanical (as in compression), will be mirrored in the primary pattern.

➢ Some secondary misfires are the cause of poor primary ignition performance. There are occasions where technicians must access the primary side of the ignition system before making any diagnostic decision.

➢ The theory of mutual induction, between the primary and secondary side of the ignition system, makes this possible.

Primary vs. Secondary (Good)



Instructor Comments:

On "coil on plug" systems or where access to secondary is not easily available, technicians can easily make sound diagnostic decisions by viewing primary. The theory of mutual induction and the principle of the secondary loading effect tells us that any secondary misfire, regardless of the cause, can be seen in primary.

In this good example of a dual trace primary and secondary firing event, focus on the spark line characteristics and duration. Notice that they are identical, both indicating a 1.4 ms spark duration.

Primary Ignition Waveform

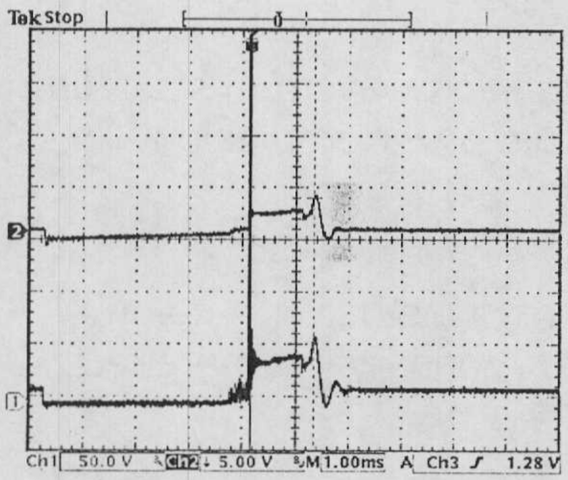
- A primary ignition waveform spark line duration should never drop below 1 ms at idle.
- This will verify whether or not you have a good secondary loading effect.

Instructor Comments:

- Most modern day ignition systems will maintain a minimum of 1.3 ms spark duration at idle, on both the primary and secondary side of the ignition system. This manual points out this important specification, captured during idle/no load conditions (obtained from popular systems).

- The secondary loading effect on primary consists of all the secondary components, the A/F ratio, and compression. Most problems in these areas are easily seen in the primary (if access to the secondary is not possible, as in COP systems). The key here is to measure for good spark duration.

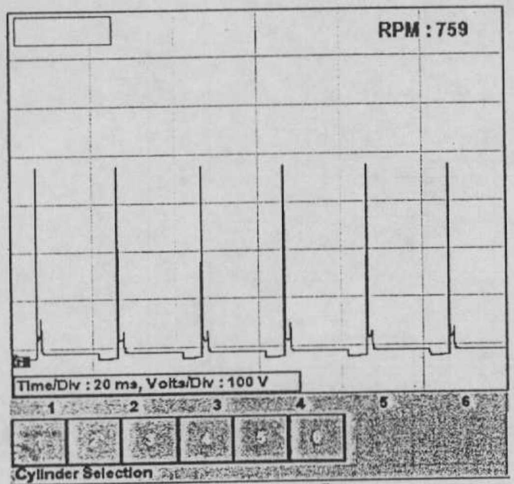
Primary vs. Secondary (Lean)



Instructor Comments:

To further prove our point, let's look at a lean density misfire while viewing both primary and secondary. The first critical point here is that the spark duration measures below 1.2 milliseconds. On most DI systems, the minimum spark duration is 1.3 milliseconds. With no conductive fuel molecules inside the combustion chamber, this spark duration drops below 1.3 milliseconds. This minimum specification is very reliable and can be used on most DI systems during hot idle/no load conditions.

Primary Parade



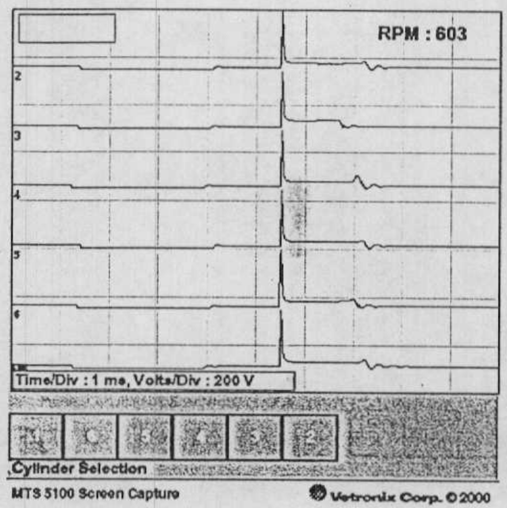
MTS 5100 Screen Capture

Vetronix Corp. © 2000

Instructor Comments:

The primary parade pattern is an excellent screen to verify that the secondary loading effect (on individual firing events) is uniform. On this good example, note the uniformity of the 375 volt primary inductive kicks.

Primary Raster

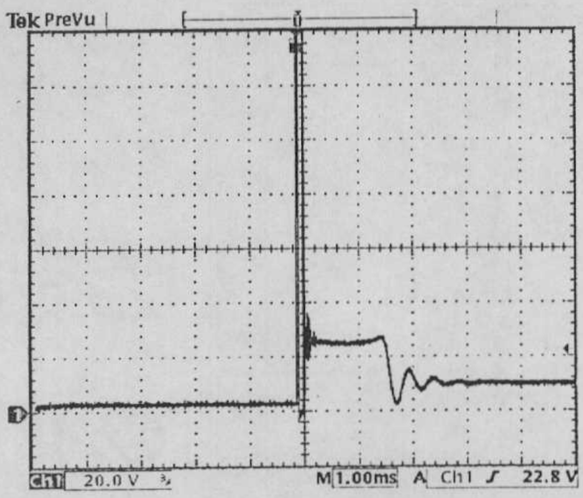


Instructor Comments:

The primary raster pattern can be used for two important tests. The first test, at 2 ms per division, we can easily measure spark line duration and uniformity between cylinders.

In addition, another critical test is to check for excessive dwell variation caused by poor primary components or mechanical wear in the distributor or the drive mechanism. This test would require a technician to disable (if possible) any PCM timing control. Since the firing lines will all be in alignment due to the number 1 trigger input, technicians must focus on the uniformity of the primary turn-on between cylinders. You will always see some variation between cylinders due to the fact as RPM increases, the internal circuitry of most modules will increase dwell (or turn on primary sooner). In reversal, as RPM decreases, the point of primary turn on will occur later. Keep in mind that this is typically a 7-13° variance. Normally, any excessive dwell problem will be easily detected by noting major variances between cylinders (in reference to the point of primary turn on).

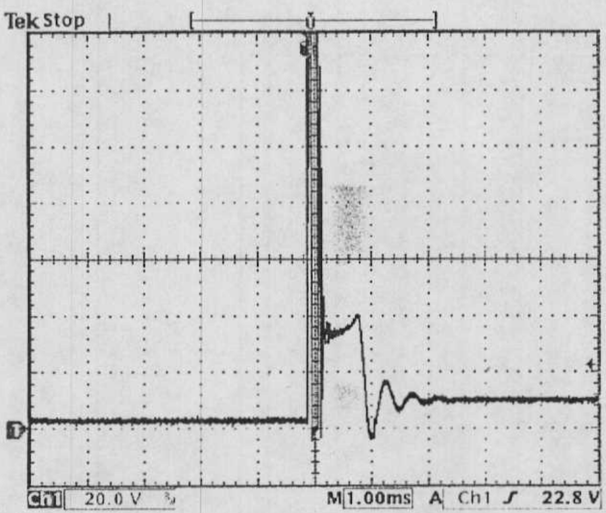
Good Primary Spark Duration



Instructor Comments:

Whenever access to the secondary circuit with a secondary kV probe is not possible, such as coil on plug systems, technicians can easily verify a good firing event or detect a faulty firing event by viewing primary. It is important here to understand the theory of mutual induction. Simply stated, any secondary problem will be mirrored in the primary waveform. All of the secondary circuit components make up the secondary loading effect which determines how quickly the energy from primary is released into the secondary circuit. In this example of good controlled release, note the good 1.4 ms spark duration. Notice, that when we shift the scope to 20 volts per division, we get a better view of this transfer of energy.

Poor Primary Spark Duration

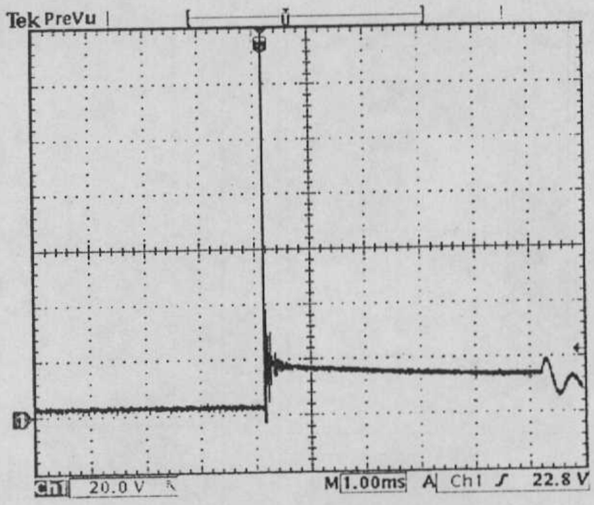


Instructor Comments:

With poor performance from the secondary loading effect components, you will see insufficient spark duration values in the primary firing event.

Notice in this example, the short spark duration of .8 ms indicating a secondary loading effect problem. This could be caused by an open circuit, an eroded plug gap, or an open plug resistor. Always keep in mind that it is very easy to diagnose secondary problems by viewing the primary side of the circuit. The theory of mutual induction makes this possible.

Long Primary Spark Duration

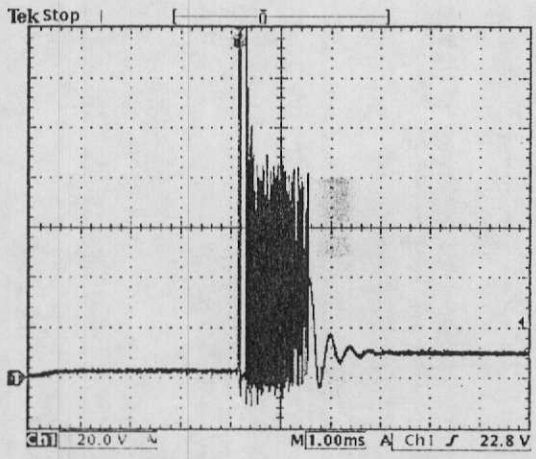


Instructor Comments:

In this example, captured at 1 ms per division, note the 5 ms spark duration time. What could cause this? One of two possibilities. The first, and most common, would be a fouled plug. The second possibility would be an arc to ground in the secondary circuit.

The latter possibility may not occur until off idle/loaded conditions are present, whereas the secondary kV demand increases stressing the secondary insulation.

Primary Spark Line Disturbance

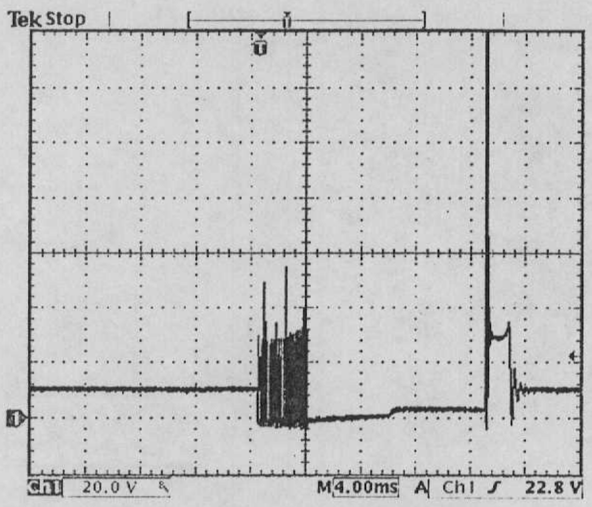


Instructor Comments:

How well the transfer of electrical energy from the primary side of the system into the secondary is indicated by the spark line characteristics.

In this bad example, notice the massive amount of electrical ringing indicated by the spark line. This is just one example of internal coil carbon tracking usually caused by excessively high secondary firing kVs.

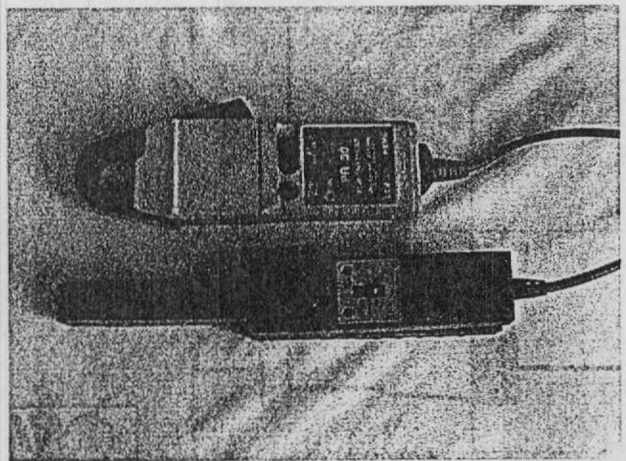
Primary Turn-On Problem



Instructor Comments:

A technician would have to be real analytical here before making a diagnostic decision on what to do. During hot loaded conditions, this engine exhibited misfire symptoms. By viewing the point of primary turn-on and looking at the voltage disturbances, one might suspect a weak module driver or an erratic trigger signal. However, a closer look is needed here. At the point of primary turn-on, notice the 30 volts of electrical ringing. You will also note that the point of primary turn-on is clean with good ground integrity. Finally, note that the coil saturation period took over 8 ms to reach peak current. Internal coil carbon tracking is the problem here.

Low Current Amps Probe



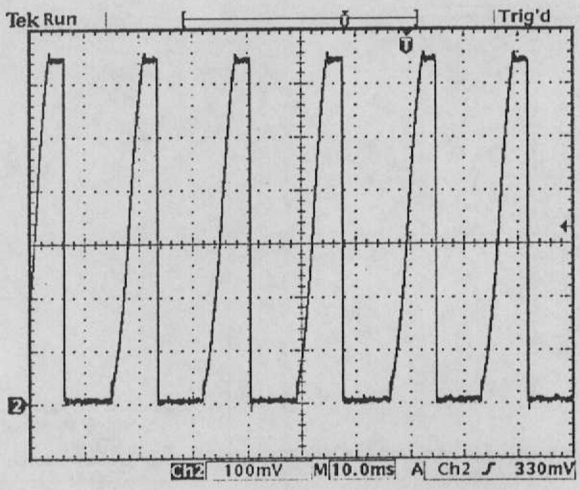
Instructor Comments:

A low current amps probe is an excellent tool to help technicians analyze primary and secondary ignition problems. We will illustrate this in the next few pages.

There are many different makes and models to choose from. Be careful when choosing a "low cost" unit. Typically, the better the shielding, the less electrical noise and interference will be seen.

The low current amps probe allows us to dynamically check components and circuits in a very quick and efficient manner.

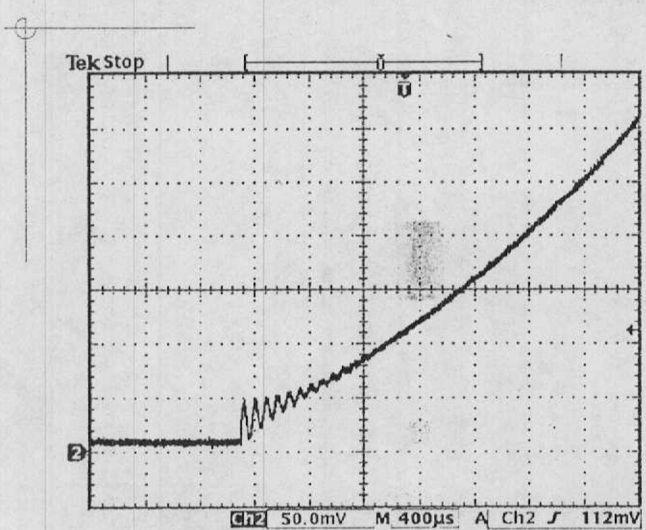
Uniform Coil Current



Instructor Comments:

With an amp probe clamped around the B+ feed wire to the coil pack or module, notice the uniform spacing and amplitude. This tells us that the coil primary and triggering components are good.

Primary Current Oscillations

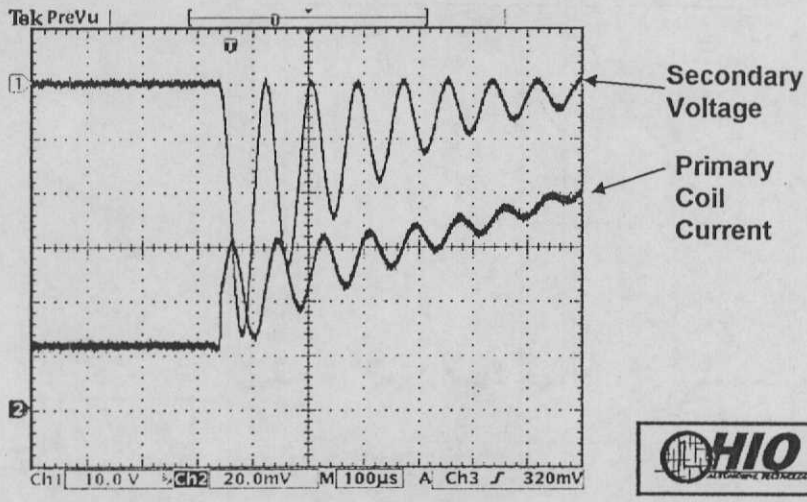


Instructor Comments:

In this amperage waveform of coil primary current flow, we have focused on the point of primary turn-on. We have shifted the scope to .5 amp (100 mv = 1 amp) and a time base of 400 microseconds. You may wonder what these good oscillations mean and how are they caused?

As the primary magnetic field is established, the adjacent secondary windings, if good, will also establish a magnetic field of opposite polarity. These good oscillations are created by the magnetic resonance from opposing magnetic fields and are a good initial indication of coil integrity.

Coil Current vs. Secondary Voltage

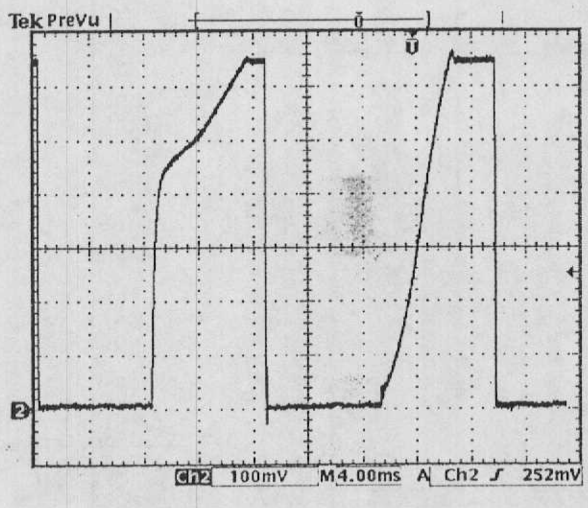


Instructor Comments:

This dual trace example of primary coil current (Ch 2) and secondary voltage (Ch 1) will help technicians pinpoint open or shorted primary or secondary windings. Let's focus first on channel 2 using a low inductive amp probe (set at .2 amps per division) clamped around the B+ terminal. Take note of the current oscillations. As opposing magnetic fields are established, on both the primary and secondary circuits, the magnetic resonance from the magnetic fields produce a counter voltage effect which creates the good oscillations.

Next, let's focus on channel 1. Channel 1 voltage probe is set at 10 volts per division with the probe laying on a secondary lead. Do you see the relationship? Notice that the voltage shifts (oscillations) on secondary always lag behind the current oscillations on channel 2. You will not see these oscillations if an open or short exists on either side of the ignition system.

Coil Current (Shorted Secondary)

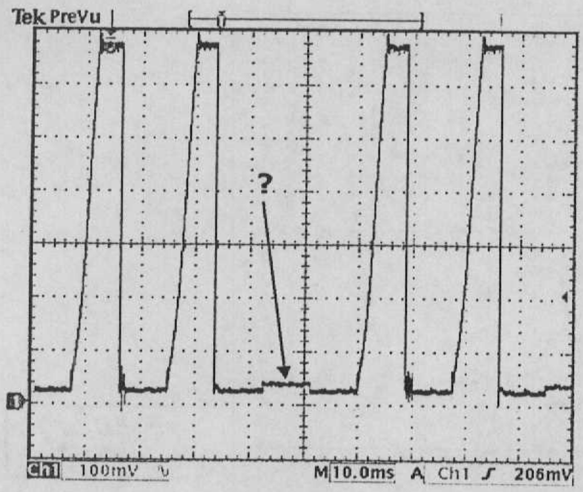


Instructor Comments:

Due to the principle of mutual induction and magnetism, some secondary problems can be seen on primary current waveforms. Notice the steep initial current ramp and the delayed current clamping on the first current waveform. This condition is caused by shorted secondary windings or a shorted secondary circuit.

You will also note the lack of initial current oscillations. This also tells us that the opposing secondary magnetic field was never established.

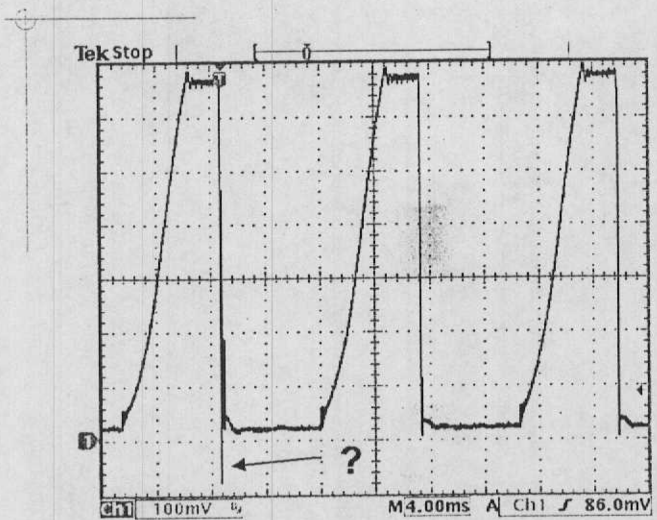
Coil Current (Missing Event)



Instructor Comments:

A quick look at these primary current events tells us that 1 primary event did not occur. A closer look tells us that a minor event did occur. The small current transition tells us that the primary driver did in fact, turn on. What we are seeing here is the base to emitter current flow; whereas the primary driver turned on, but since an open existed in the coil primary winding, a normal peak current transition did not occur.

Open Secondary

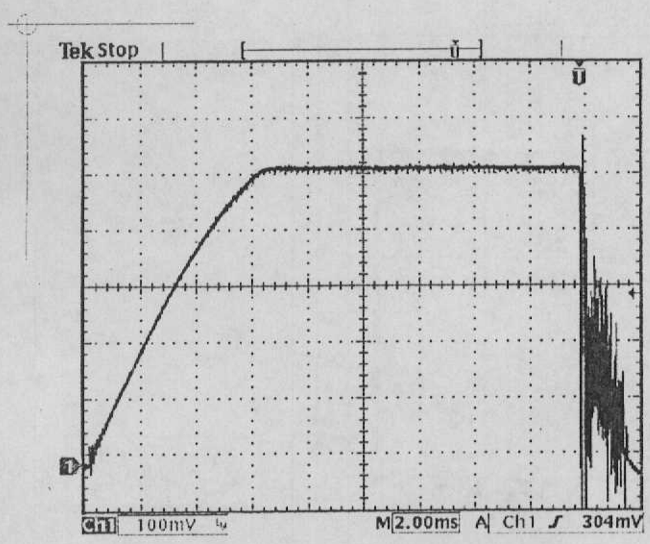


Instructor Comments:

Additional information can be seen on a primary current waveform from secondary circuit problems. Note the downward spike at the point of primary turn off. This condition is the result of an open in the secondary circuit (plug wire).

Be careful here when making a diagnostic decision. You can view primary on the secondary circuit by using an amps probe. The downward spike must be distinct and consistent. Always remember that the amp probe, if clamped close to the coil pack, is in a very electrical noisy environment; therefore, some inconsistent spikes are normal.

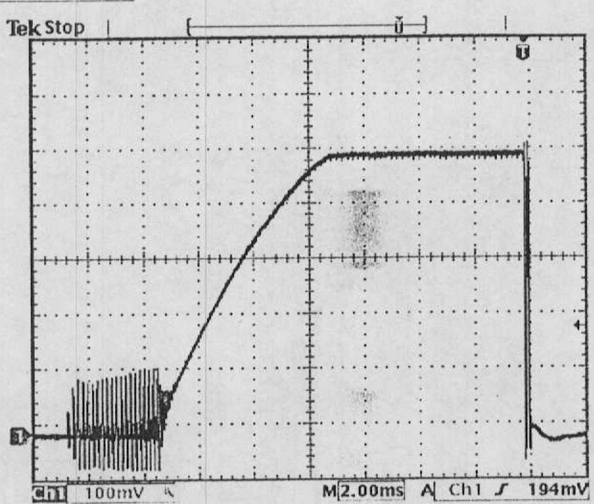
Coil Current (Carbon Tracking)



Instructor Comments:

Notice the massive amount of electrical disturbance after the point of primary turn-on on this primary coil current example. This is a common problem that is created by internal coil carbon tracking. This condition is usually created when an air pocket was left in during the potting process (while making the coil). Typically, it takes a long time for this to become a problem (as indicated here). As plug gap erosion occurs, the secondary kV demand increases which sooner or later ionizes this air pocket. This condition can create a secondary misfire. Ohmmeters will not detect this problem.

Coil Current Problem



Instructor Comments:

Notice the electrical disturbance seen here just before the actual point of primary turn-on. One could easily make a misdiagnosis by blaming a poor primary driver or erratic triggering device. The actual problem, however, was created by voltage feedback (from secondary) into the primary circuit. This is typically caused by internal coil carbon tracking.