COIL-ON-PLUG DIAGNOSIS

by:

Mac VandenBrink

A study of primary scope pattern analysis

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INTRODUCTION

COIL ON PLUG is a concept where each spark plug is ignited by its own individual ignition system, consisting of a driver or ECM and ignition coil.

The objective is to reduce energy losses by bringing the coil output as close as possible to the spark plug.

Other reasons may include to control spark timing on a per cylinder basis, or to use coil current as feedback to the computer.

The design may vary from:

- “COIL NEAR PLUG” with a very short plug wire.
- “COIL ON PLUG” with control module located away from engine heat.
- “COIL AND MODULE” in one assembly.
- “DI VERSION” with one coil tower directly connected to the spark plug, while the other tower uses a short plug wire.

As can be noticed from the chart of applications, the concept is not new.
However, when more manufacturers choose this method of ignition, it is essential to look objectively at a different approach of testing.

Using the primary pattern as a feedback from the secondary circuit is a new challenge, applying old techniques to a new concept.

Have fun with exploring the wonderful world of electronics to pinpoint electrical, mechanical and fuel related problems.

Mac Vanden Brink

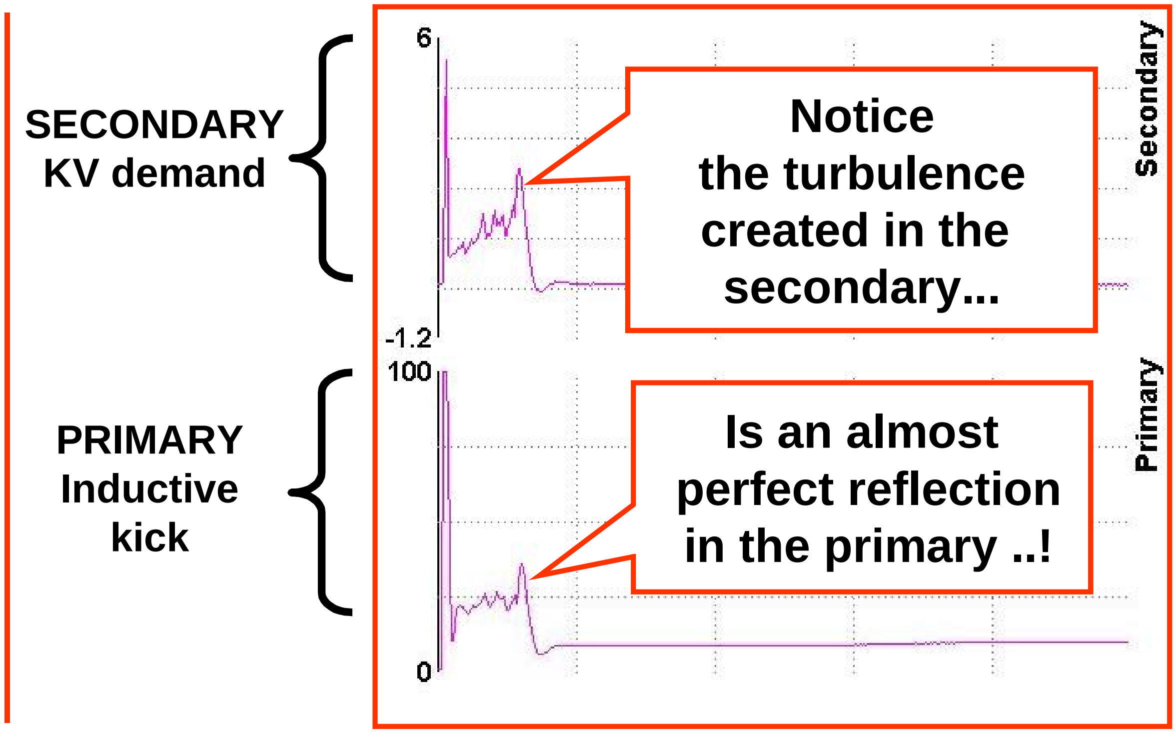
COIL ON PLUG vehicle applications up to1999 and still counting

MAKE	MODEL	YEAR	ENGINE
ACCURA	Legend	1991-1995	3.2L/C32A1
	NSX	1991-1998	3.0L/C30A1
	NSX	1997-1998	3.2L/C32B1
	RL	1996-1998	3.5L/C35A1
	SLX	1996-1997	3.2L/6VD1
	TL	1996-1998	3.2L/C32A6
ALFA ROMEO	164	1993-1995	3.0L/----
AUDI	A4	1997-1998	1.8L/AEB
	A4 Quattro	1997-1998	1.8L/AEB
	A8	1997-1998	3.7L/AEW
	A8 Quattro	1997-1998	4.2L/ABC
	S4	1992-1994	2.2L/AAN
	S6	1995-1996	2.2L/AAN
BMW	325i	1992-1995	2.5L/M50
	325ic	1994-1995	2.5L/M50
	325is	1991-1995	2.5L/M50
	328i	1996-1998	2.8L/M52
	328ic	1996-1998	2.8L/M52
	328is	1996-1998	2.8L/M52
	525i	1991-1995	2.5L/M50
	525it	1992-1995	2.5L/M50
	528l	1997-1998	2.8L/M52
	530l	1994-1995	3.0L/M60
	530it	1994-1995	3.0L/M60
	540i	1994-1995	4.0L/M60
	540l	1997-1998	4.4L/M62
	740l	1993-1995	4.0L/M60
	740il	1993-1995	4.0L/M60
	740il	1996-1998	4.4L/M60
	840ci	1994-1995	4.0L/M60
	840ci	1996-1997	4.4L/M62
	M3	1995-1996	3.0L/S50
	M3	1995-1996	3.2L/S53
	Z3	1997-1998	2.8L/M5
CADILLAC	Catera	1999	3.OL/----
CHEVROLET	Camaro	1998-1999	5.7L/----
	Corvette	1998-1999	5.7L/----
CHRYSLER	Concorde	1998-1999	3.2L/----

MAKE	MODEL	YEAR	ENGINE
FORD	Taurus (SHO)	1996-1998	3.4L/----
	Crown Vic/ Gran Matq	1998-1999	4.6L/----
	E150 Van	1997-1998	5.4L/----
	E250 Van	1997-1999	5.4L/----
	E350 Van	1997-1998	6.8L/----
	E350 Van	1997-1998	5.4L/----
	Expedition	1997-1998	5.4L/----
	F150	1997-1998	5.4L/----
	F250	1997-1998	5.4L/----
	Mustang	1997-2000	4.6L/----
HONDA	Passport	1996-1998	3.2L/6VD1
	Odyssey	1999	
HYUNDAI	Accent	1997	1.5LG4EK*
INFINITI	I30	1996-1998	3.0L/VQ30DE
	J30	1993-1997	3.0L/VE30DE
	Q45	1990-1996	4.5L/VH45DE
ISUZU	Rodeo	1998	3.2L/6VD1
	Trooper	1996-1997	3.2L/6VD1
	Trooper	1998	3.2L/6VE1
JAGUAR	Vandanplas	1995-1998	4.0L/----
	XJ6	1995-1997	4.0L/----
	XJ8	1995-1998	4.0L/----
	XJR	1995-1998	4.0L/----
	XJS	1995-1996	4.0L/----
	XK8	1997-1998	4.0L/----
JEEP	Wagoneer	1998-1999	4.0L/----
	Cherokee	1998-1999	4.0L/----
	Wagoneer	1998-1999	4.7L/----
	Cherokee	1998-1999	4.7L/----
KIA	Sophia	1998	1.8L/BP*
	Sportage	1996-1998	2.0L/FE*
LEXUS	ES300	1994-1998	3.0L/1MZFE
	GS300	1998	3.0L/2JZGE
	GS400	1998	4.0L/1UZFE
LINCOLN	Navigator	1998-1999	5.4L/----
MAZDA	Millenia	1995-1998	2.3L/----

MAKE	MODEL	YEAR	ENGINE
MITSUBISHI	Montero	1994-1995	3.5L/with slave
	Montero	1996	3.5L/*
NISSAN	300ZX	1990-1996	3.0L/VG30DT**
	300ZX	1990-1996	3.0L/VG30DE+
	Maxima	1992-1994	3.0L/VE30DE
	Maxima	1995-1998	3.0L/VQ30DE
	Pulsar	1997	1.6L/CA16D
	Pulsar	1998	1.8L/CA18D
OLDSMOBILE	Intrigue	1999	3.5L/----
PORSCHE	Boxster	1997	2.5L/M96.20
SAAB	900	1990-1999	2.3L/B 234Lturbo
	900	1990-1999	2.3L/B2341+
	900	1990-1999	2.3L/B234R^
	900	1990	2.0LB202T
SUBARU	SVX	1992-1997	3.3L/EG33D
SUZUKI	Sidekick Sport	1996-1999	1.8L/----
TOYOTA	4-Runner	1996-1998	3.4L/5VZFE
	Avalon	1995-1998	3.0L/1MZFE
	Camry	1994-1999	3.0L/1MZFE
	Passeo	1996-1998	1.5L/5EFE
	Sienna	1998	3.0L/1MZFE
	Supra	1994-1998	3.0L/2JZTE**
	T100	1995-1998	3.4L/5VZFE
	Tacoma	1995-1998	3.4L/5VZFE
	Tercel	1995-1998	1.5L/5EFE
VOLKSWAGEN	Passat	1998	1.8L/AEB
VOLVO	960	1992-1997	2.9LB6304F
	S90	1998	2.9LB6304F
	V90	1998	2.9LB6304F

FIRING TIME - A mirror image



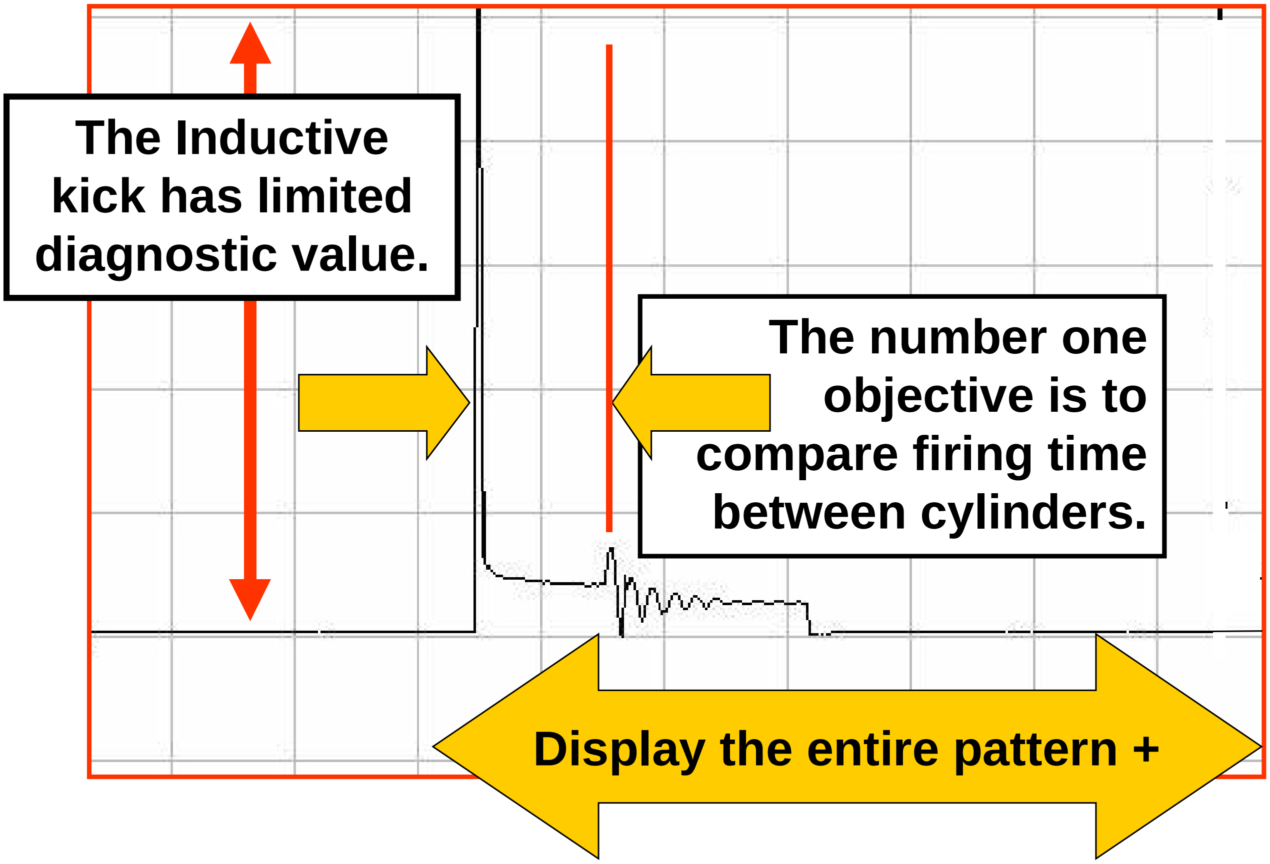
The objective of the ignition system is:

1. **To create a spark hot enough to ignite the fuel mixture.**
2. **To time the ignition for maximum efficiency.**
3. **To maintain the spark for as long as there is fuel in the combustion chamber.**

In primary analysis, the absence of the KV spike places all the diagnostic emphasis on the firing time. This in itself is not all that bad with a system that has no plug wires, and no multiple gaps. ("Waste gap" or "Rotor-air-gap").

If there is a spark, any problem will reflect in a reduced firing time. It is the interpretation of the firing time duration, slopes, turbulence and jaggies at various speed and load, assisted with a cylinder kill option, that leads to pinpointing the malfunction.

Scope observation! 1



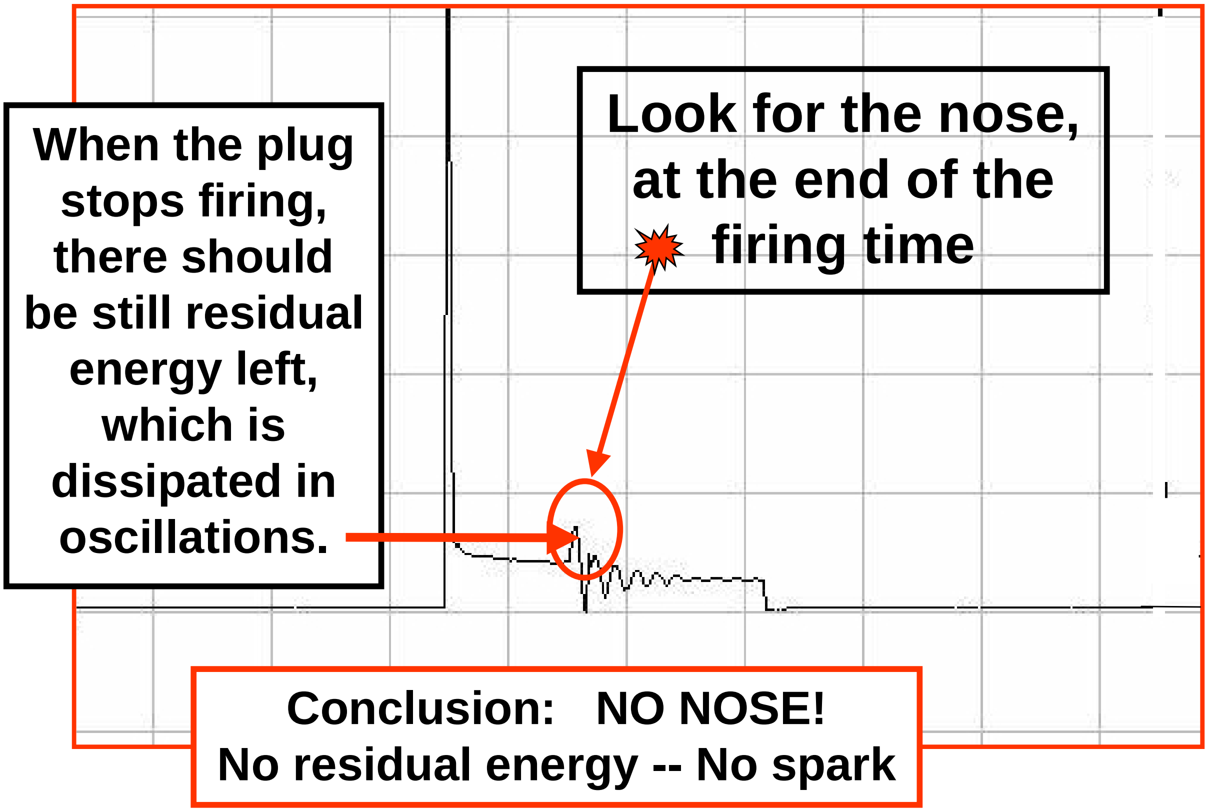
The purpose of the ignition system is not only to ignite the spark in the combustion chamber at the right time, but also to maintain the firing for as long as there is fuel in the combustion chamber.

Therefore, observing the firing time is the first objective!

Most ignition or mechanical malfunctions will show up as a shorter than normal firing time, in comparison to a good performing cylinder. The objective is to isolate the cylinder or cylinders and later determine the cause.

The inductive kick has limited diagnostic value and does not tell us anything about the combustion efficiency. It is helpful to verify a low coil output.

Scope observation! 2

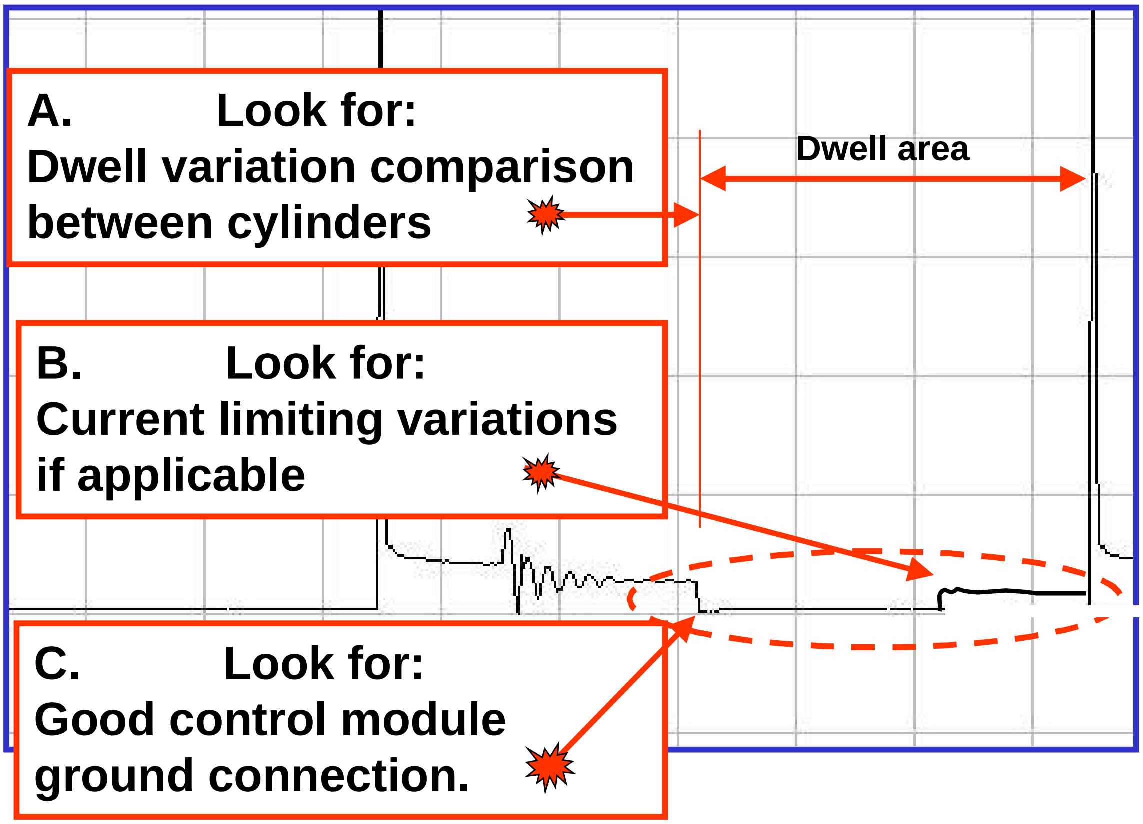


Take a quick look at the upward nose of the first oscillation, which indicates the end of plug firing.
When there is not enough energy left to maintain firing, this "residual energy" dissipates into oscillations.
An absence of this nose indicates that the energy is drained off to ground without firing.

CONCLUSION: FOULED PLUG or SHORTED PLUG.
In rare cases it may be a shorted coil to ground,
(but only if it is a dead short and no arc-over).

NOTE:
The old school of thought, counting the number of oscillations has been a source to evaluate the coil integrity. However, with no rotor-air-gap and a lower primary resistance, it is no longer reliable for diagnosis.

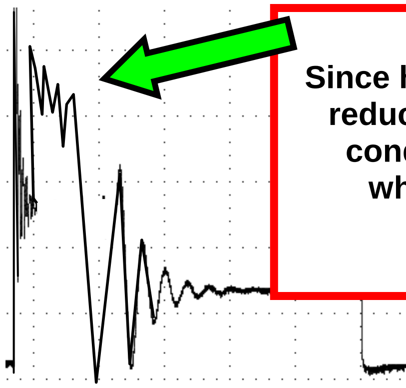
Scope observation! 3



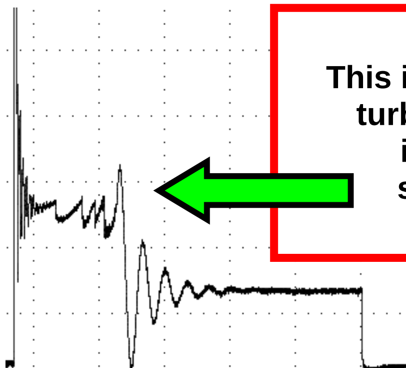
The dwell section is a significant evaluation of module comparison. Since each cylinder has its own coil and driver, make a mental note of any variation that does not occur on the other coils.
DWELL TIME changes with RPM.
If the complaint is "rough running at idle", look for the coil with a shorter dwell, to identify the cylinder. Verify with a cylinder kill.

TRANSISTORS do increase in resistance when getting hot. Ideally, the initial ground is almost perfect with a slight increase in voltage drop when the dwell increases.
Excessive heat can be caused by poor heat dissipation (heatsink) or shorted coil windings.
The best spec is comparison with the other coils.

SCOPE PATTERN OBSERVATIONS

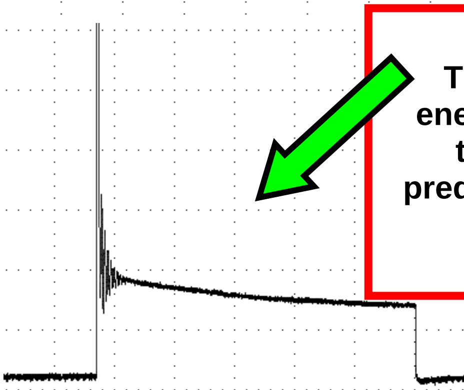


LEAN MISFIRE:
Since hydrocarbon is a conductor, lack of HC will reduce conductivity and raises resistance. This condition will not likely occur at a steady RPM, when the computer compensates for the lean injector. It will show in a snap-test, when the computer is not in control.



GOOD SPARK:
This is a normal scope pattern. The jaggies and turbulence indicate that the spark indeed fires inside the combustion chamber, where it is subject to fuel and compression variations. Verify jaggies with quick acceleration.

CROSS-FIRING:
A consistent nice clean firing time indicates that the spark occurs outside of the combustion chamber, not affected by pressures and fuel variables.



FOULED PLUG.
The voltage does not even start to rise and the energy is drained off, leaving no residual energy to dissipate into oscillations. If this condition predominantly appears on deceleration or at idle, but shows oscillations again at high RPM, suspect a leaky injector.

What is the

SNAP-TEST ?

A quick acceleration to create a low vacuum and low speed simultaneously!

Purpose:

- **To simulate a road test conditions of a quick acceleration.**
- **To creates the highest possible ignition stress.**

SNAPTEST OBJECTIVE

Force the highest possible demand under any driving condition.

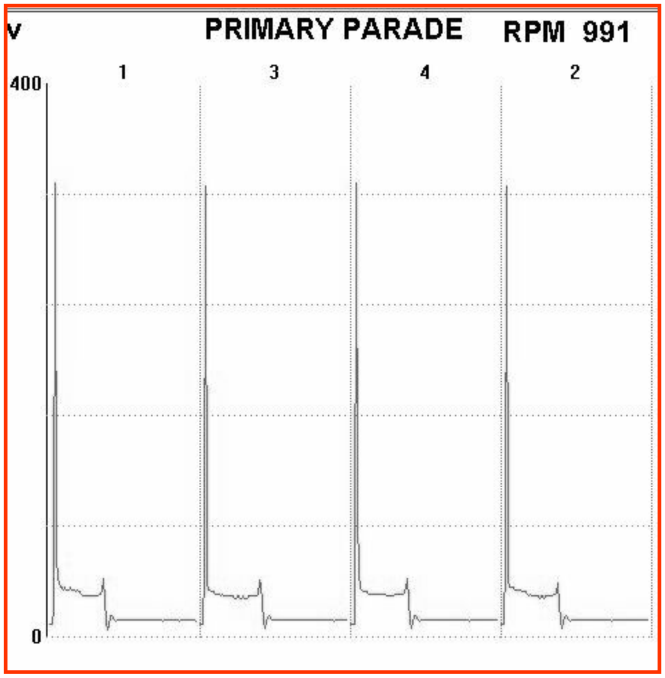
HOW it works → On ACCELERATION, at W.O.T., before RPM increase, timing is still near TDC. This, plus high volumetric efficiency & a lean mixture, creates an extremely high ignition demand.

WHY?: To reveal any possible cross-fire, secondary leakage or fuel starvation..

PRIMARY ANALYSIS before SNAP-TEST

COMPLAINT: Hesitation on acceleration

If you had to pick a cylinder…. Which one would you select for further analysis?



For the “Die-hard Scope Wizard", looking at a scope pattern without KV, feels like diagnosing blind folded. However, that is only a matter of practice and applying the lessons learned from secondary analysis.

Not only is the secondary scope hookup in "coil-on-plug application in most cases time consuming, but the inconsistency of a capacitive pickup in the proximity of a coil winding on each coil, can be deceiving. In addition, if there is no spark jumping a gap, there is no secondary pattern to diagnose the cause.

As an exercise in primary analysis, this is a typical 4 cylinder engine to illustrate the effect of a snap-test.

Knowing the complaint, which cylinder would you select for further analysis? Here are the preliminary test results:

- Speed is just under 1000 RPM. - No miss at this time.
- Cylinder balance test is equal for all cylinders.
- O2 appears more rich than lean, but a good response.

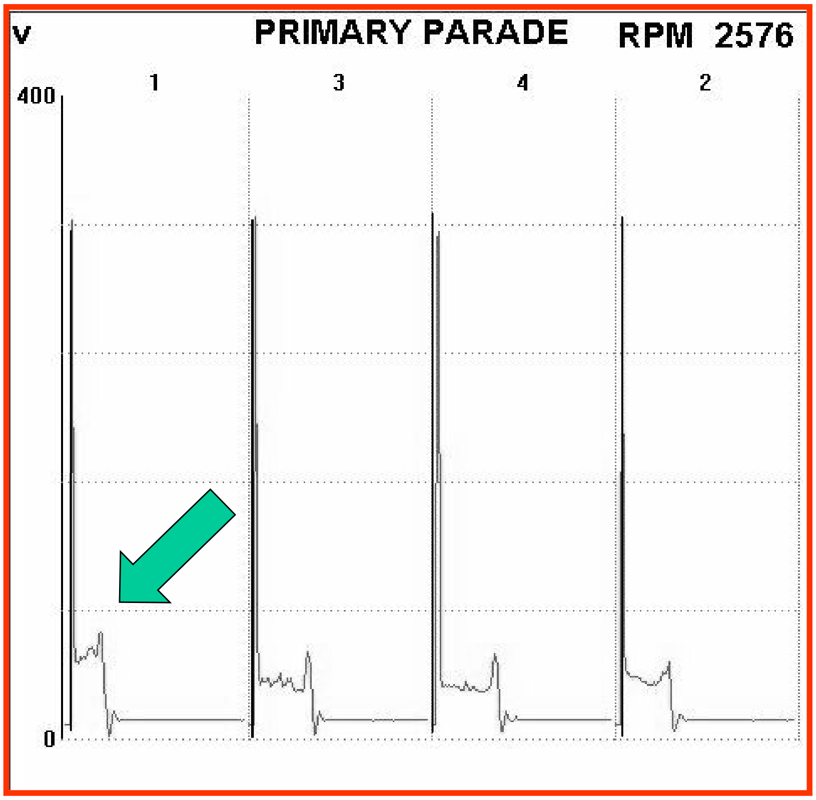
TEST RESULTS of SNAP-TEST

OBSERVE:

1.Locate Cylinder

2. Identify problem

3. Verify



It is now obvious that cylinder # 1 has a poorer conductivity to maintain a spark, compared to the other cylinders.
Since the spark plug gap is fixed and higher compression can be ruled out, the only logical conclusion is lack of hydrocarbon.

CONCLUSION - RESTRICTED INJECTOR:

WHY? The computer has no chance to compensate for a lean injector during the snap test.
TO VERIFY; Increase speed to 2500 RPM and observe:

- If firing time returns to normal, this confirms ECM compensates with more injector on-time. **LEAN INJECTOR CONFIRMED.**
- Kill cylinder at 2500 RPM. If RPM loss is equal to all cylinders, this proves **NO MECHANICAL PROBLEM.**
- O2 sensor indicates unequal HC distribution, **RE-CONFIRMS FUEL.**

Recommendation: Fuel system service

The Logic of COP-III

To make the Scope work for you on "Coil per Plug" ignition.

Preliminary Logic without Scope

Applying Logic to the Scope

Isolate: Is problem related to a cylinder?
Identify: Which cylinder or cylinders?
The only safe way to kill a spark is by inhibiting coil output without shorting the current limiting.

Justify:
Scope hookup.
Verify:
1. Power input.
2. Presence of a trigger pulse.

Identify:
Which is trigger connection.

Verify:
1. Coil inductive kick--to indicate that the coil is energized.
2. The spark is killed when the button is pushed.

Observe: Intensity is lower with a weak coil.

Above description applies to the model COP-II and the COP-III, serving as a preliminary check and a quick way to justify a scope hookup.

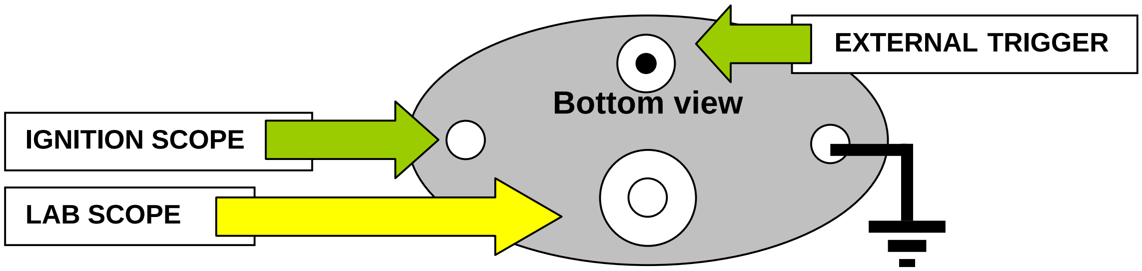
Additional uses for CYLINDER KILL applications:
1. Use in conjunction with exhaust gas analyzer, to determine hydro-carbon per cylinder.
2. Observe O2 sensor response - upper limit and lower limit range.
3. Observe idle compensation response using a tachometer.
4. Verify valve malfunction with power balance at various speeds.
5. Observe fuel trim compensation on the scan tool.

If no primary connection is accessible:
Connect to the pulse signal. The kill button safely prevents any trigger signal to activate the module.

If engine dies when killing a cylinder:
Some vehicles feature a fuel shut-off when the ignition stops firing. This usually occurs only when button is **held** in the kill position.
Solution: Kill momentarily, just long enough to indicate function.

SCOPE APPLICATIONS

In order to perform any meaningful combustion analysis in the primary, it is essential to amplify the firing time amplitude. To make this possible the objective is to provide a means to stabilize the scope pattern with an external trigger, independent of signal variations on the display pattern.



USING AN IGNITION SCOPE:

- **EXTERNAL TRIGGER:**
Most ignition scopes demand a sync probe placed on the secondary #1 plug wire when primary display is selected. This makes the ignition scope useless for COIL PER PLUG primary hookup. The COP-III provides a trigger output to connect to the scope sync input. This eliminates the warning and solves the problem of an unstable pattern even on a snap test.

- **ISOLATED OUTPUT**
There is no attenuation required. However, with the latest high current ignition types, some low impedance scopes may load the ignition enough to distort the primary pattern or even kill the ignition. Isolating DC from the output solves this problem. This feature protects both the scope and the ignition of excessive current drain.

- **BASIC IGNITION ANALYSIS:**
Select the 400 or 500 volt scale and connect the scope primary to the female banana output after removing the alligator clip from the cable that comes with the scope.

- **ADVANCED FIRING TIME ANALYSIS:**
Select a 100-volt scale or lower to optimize firing time voltage analysis.
A time base of 2 Ms is adequate for most applications.

USING A LAB SCOPE:

- **BASIC PATTERN:**
The lab scope output of the COP-III is attenuated 10x to reduce the 400+ primary inductive kick to protect the equipment. If the objective is to check this induction and measure firing time, a single channel is adequate.

- **EXPANDED FIRING TIME ANALYSIS:**
If the objective is to perform combustion analysis, a snap-test or amplifying firing time may cause multiple triggering and loss of pattern stability.

- **THE SOLUTION:**
If the lab scope is equipped with an external trigger option, use the trigger output provided by COP-III. (See above) When the scope does not have an external trigger option, a second channel may be used for triggering. One channel is for sync and the other channel for amplified pattern analysis.

- **HOOK UP:**
Connect the BNC connector to channel number 2. Feed the trigger signal into channel 1. Channel 2 can be set at any desired amplitude, since the trigger is external and not affected by snap-test, acceleration, or high residual energy.

CYLINDER PERFORMANCE TESTING

NON-LOADING CYLINDER KILL METHOD:
This new concept, utilized by the COP-II & COP-III, uses a very unique method. The circuit allows the primary current to build up normally, but absorbs the energy of the collapsing magnetic field, effectively preventing the plug from firing. Because the primary current is not affected, no computer code is generated in most cases.

OTHER METHODS

TRADITIONAL METHOD:
Inhibiting the cylinder from firing by means of shorting the module is no longer safe on most late ignition systems with low primary impedance. In addition, this system is prone to set a code.

NON-INTRUSIVE METHOD:
Most scan tools display the non-intrusive method of tracking time delay between cylinders. This is very effective at low speed and on totally dead cylinders. It becomes less effective at higher RPM or when the difference per cylinder is less. In addition, it does nothing for HC per cylinder.

HELPFUL HINTS

INTEGRATED CIURCUIT:
With no neon light lit, and a dim green light, the ignition systems likely has an integrated module built in the coil assembly, and the COP III is connected to the trigger pulse. While the primary winding is inaccessible for scope analysis, Power Performance testing is still very effective by inhibiting the trigger from activating the coil.

ENGINE DIES WHEN ONE CYLINDER KILLED:
Some vehicles feature a "Fuel-Shut-off" upon prolonged misfire detection.
SOLUTION: Reduce kill time, just long enough to observe a RPM drop.

SPEED SELECTION:
For power performance, choose a speed just beyond idle RPM, since the idle compensating feature may nullify any drop in RPM.
Killing a cylinder at idle is an effective way to verify idle compensation.

DISABLE EGR VALVE:
When killing a spark in one cylinder, HC enters the exhaust, which is immediately inhaled via the EGR system into the already lean neighboring cylinders. This increase in RPM of several cylinders may partially nullify the drop in RPM of the cylinder under test. Disabling the EGR system, may produce more accurate test results. EXCEPTION: When misfire already exists.


DC
Trigger
AC
Inductance
COP-III


DC
Trigger
AC
Inductance
COP-III


DC
Trigger
AC
Inductance
COP-III


DC
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