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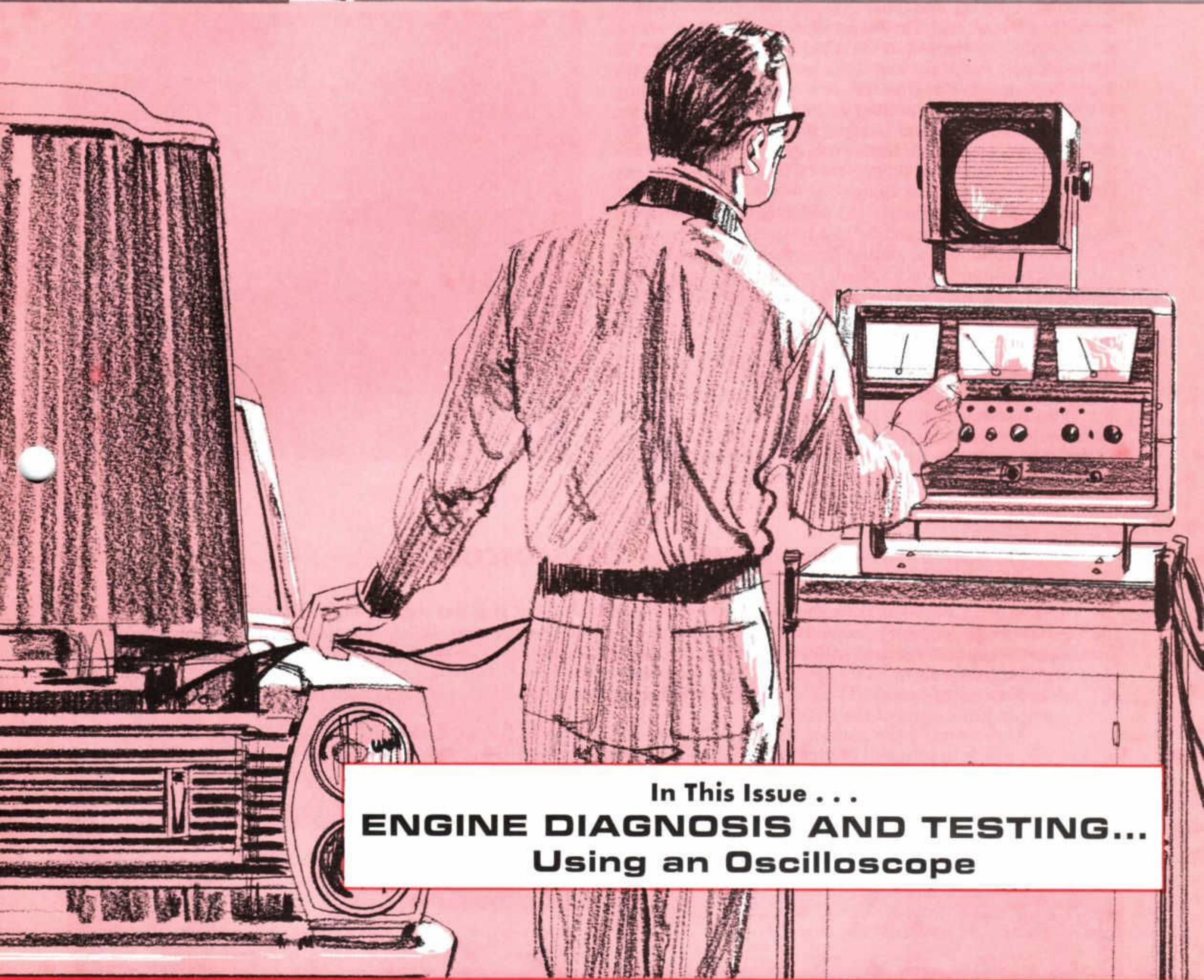


In This Issue . . .

ENGINE DIAGNOSIS AND TESTING... Using an Oscilloscope

From Your Ford Dealer

Be sure to file this and future bulletins for ready reference. If you have any suggestions for additional information that you would like to see included in this publication please write to: Ford Division of Ford Motor Company, Parts and Service Promotion and Training Dept., P. O. Box 598, Dearborn, Michigan 48121.

ENGINE DIAGNOSIS AND TESTING.

This is the third in a series of articles to help service technicians quickly diagnose and test engine problems by following a systematic procedure. The first two articles covered quick and simple tests of the Battery, Charging, Cranking, Ignition and Fuel systems for problems which cause hard starting. They are especially useful during service calls or when more detailed testing equipment is not available, to get the car "back on the road." However, if a comprehensive engine test is required, such as when performing a tune-up—pulling spark plug wires to test for a spark, hooking up and using a number of different instruments, meters, bench testers and gauges; not only takes a lot of time, but they simply aren't the modern efficient way to diagnose and test engines.

Today's highly sophisticated, and finely tuned engines require accurate and sensitive test instruments. They also require a careful and scientific diagnosis procedure.

Today's customers, to whom all the wonders of space-age technology are fast becoming common everyday occurrences, expect factual, modern, electronic diagnostic equipment to give them a picture they can understand of what services are needed. That this is so, one need only observe the high degree of customer acceptance and the increasing number of diagnostic service centers opening to the public. To take advantage of the enthusiastic customer acceptance and the impact this important change in the concept of automotive service has created, service technicians should become familiar with the USE of modern diagnostic equipment such as the OSCILLOSCOPE.

WHY AN OSCILLOSCOPE

The oscilloscope works something like a television set . . . but it is less complicated. Like a television set, the scope projects a beam of electron rays across a fluorescent screen. When the scope is hooked up to a car's ignition system, voltage variations in the ignition system make the beam move up or down. The fluorescent screen holds the beam for a moment, showing the voltage variation as a wavy line. This wave pattern gives you AND THE CUSTOMER a picture of the car's ignition system in action . . . and the entire firing cycle of the engine.

Any defect in the ignition system will cause a deviation in the regular voltage variations in the system . . . which in turn will produce a deviation in the scope wave pattern. These wave pattern deviations on the oscilloscope screen give an easy-to-read visual evidence of problems in any of the following:

Spark Plugs—worn electrode, excessive gap fouling, excessive deposits, open resistor, cracked insulation.

Spark Plug Wires—internal break, insulation leakage, excessive resistance, poor contact, cross fire.

Ignition Coil—reversed polarity, insufficient reserve, inadequate voltage output at cranking speed, short circuit, open circuit, high resistance in tower, insulation leakage.

Coil High Tension Wire—internal break, insulation leakage, high resistance, defective suppressor.

Condenser—leakage, high series resistance.

Primary Circuit—high resistance, insulation leakage, defective ballast resistor.

Distributor Cap and Rotor—cracked or worn, break or carbon tracks, insulation leakage, high resistance in towers, poor contact between rotor and center button, excessive rotor gap.

Distributor Breaker Points—dirty or burned points, point misalignment, point bounce, point arcing, improper point setting, irregular cam lobes, bent shaft, worn shaft or bushings.

. . Using An Oscilloscope

The oscilloscope also gives you an advantage over cumbersome, outdated testing techniques, by allowing you to follow a "sequence testing" procedure with only ONE set of test connections by which you can completely diagnose and test an engine in 10 minutes or less. Usually in that time, you'll have located the malfunctioning component. In the few cases where you haven't, you'll at least know which system it's in so that you won't have to spend time testing systems that are functioning properly. Furthermore, the oscilloscope tests components like plugs, coils and condensers under actual operating conditions and will indicate defects that *don't* show up on bench testing.

In short, the oscilloscope finds the trouble for you much easier and faster than *any* other method . . . whether you're an ignition expert or not. Your service and trouble shooting batting average are not only bound to improve, but your customers will have the feeling that their car has been checked and evaluated in a scientific, highly accurate, and objective manner.

If you already have an oscilloscope, dust off the operating manual and become familiar with ALL test procedures. If you don't have a scope, or have misplaced the operating manual, take a look at the typical oscilloscope described in this article.

COMPONENTS

Oscilloscopes combine several test instruments into one tester (Figure 1). This may make them seem complicated. However, a couple of minutes spent examining the oscilloscope will reveal it isn't as complicated as it looks. The

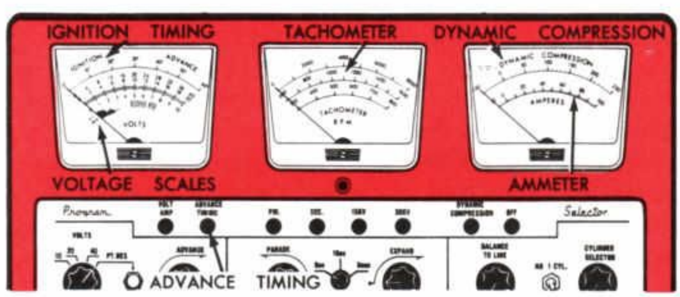


Figure 1—Oscilloscope Meters

Rotunda oscilloscope shown in this book is typical of most engine analyzers, and consists of:

1. Voltmeter and Ammeter to check:
    - Battery voltage
    - Charging circuit (alternator output and regulator setting)
    - Cranking circuit
    - Breaker point resistance (coil to ground)
2. Tachometer to adjust engine speed for various tests.
3. Ignition Timing scale to check timing and advance without guessing at marks on the pulley.
4. Dynamic Compression scale to check if each cylinder is contributing its full share of the total engine work.
5. Scope (Figure 2) to give a graphic view of what's going on in the complete ignition system.

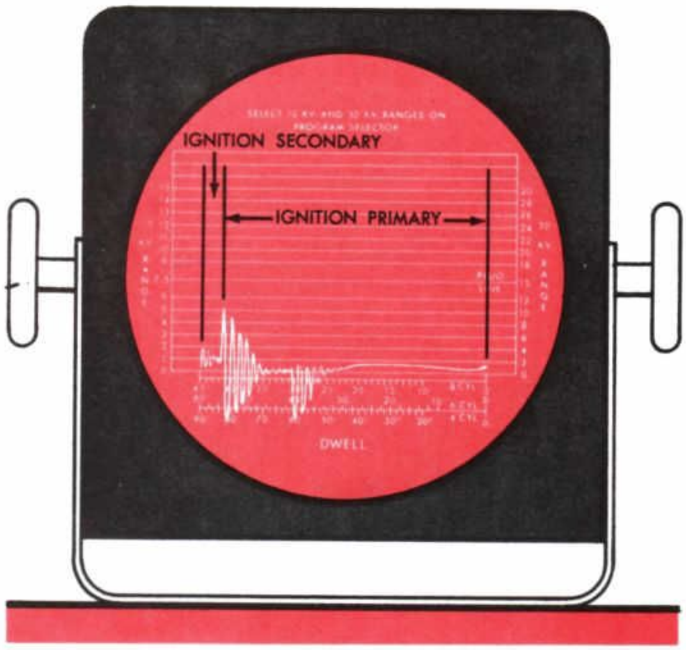


Figure 2—Scope Pattern

TEST CONNECTIONS

Before you make any connections, be sure the OFF button on the console is pushed in. Then plug the power cord into a 115-volt AC outlet. Connect the master cable (Figure 3) to the front of the panel. Usually the instructions for the test lead harness connections are printed on the panel around the master cable connector.

Remove the battery cables FIRST to prevent damage to the alternator diodes. Leave the ground cable off until all the connections are made to the positive battery post and you're sure none of them are grounded.

Install the post adapter switch on the positive battery post. Then connect the positive battery cable to the adapter positive terminal. The knife switch connects or disconnects the shunt from the circuit. With the switch open, the main load goes through the shunt and you can read current. To take the ammeter out of the circuit, close the knife switch to bypass the shunt. You can read battery voltage with the knife switch open or closed.

Clip the voltage pickup (yellow lead) to the positive terminal on the battery post adapter switch.

Reconnect the ground cable and clip the black ground lead to it. Be sure all other connections are secure and nothing is grounded.

Clip the primary scope pickup (green lead) to the distributor terminal of the coil (conventional system) or to the red-white wire terminal at the tach block (transistor ignition system). It is the pickup for the primary scope pattern and is also used as the voltage pickup for the point resistance test.

Remove the No. 1 spark plug wire from the distributor cap and insert the blue pickup in its place. Then plug the spark plug wire into the blue pickup. The No. 1 spark plug wire is used for timing, spark advance, to operate the tachometer, and to trigger the paraded scope pattern. Thus, when all the cylinder patterns are paraded across the screen, they'll be firing in order, starting with No. 1.

Clip the secondary scope pickup (red lead) around the coil high-tension wire. Be sure the wire is completely seated in the pickup and that the pickup is not grounded anywhere.

Connect the test lead cable to the master cable and tighten the lock ring. Be sure all leads clear the fan blade.

Set the controls to the positions shown in Figure 3. Set the ground polarity switch to agree with the system you're testing: minus (−) for negative ground; plus (+) for positive ground. Be sure the VOLTS switch corresponds to the vehicle battery voltage. Use 10 V for 6-volt systems, 20 V for 12-volt systems, and 40 V for 24 or 32-volt systems.

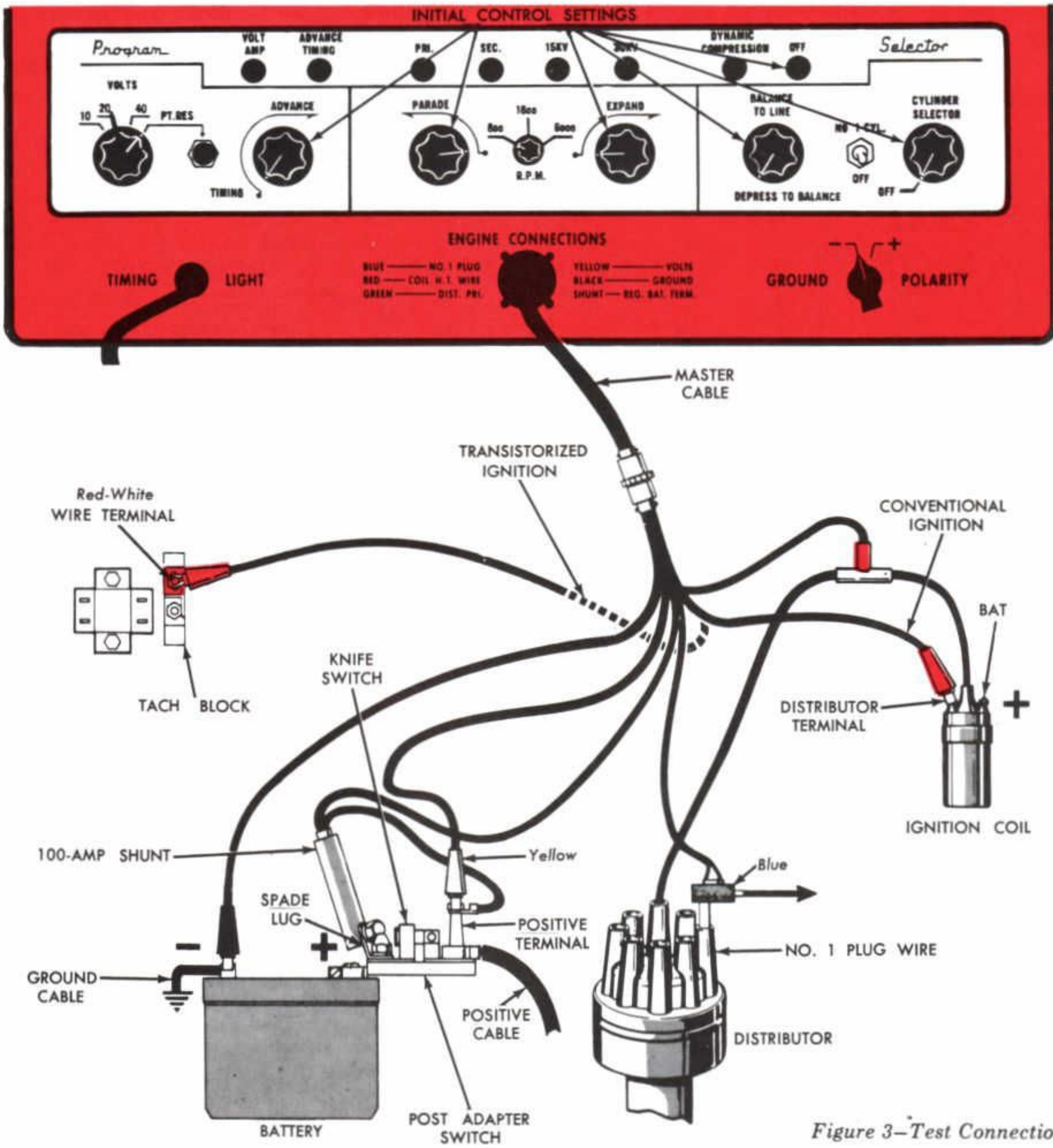


Figure 3—Test Connections

METERED TESTS

As explained in February Shop Tips, the coil steps up the 12 volts from the battery to sometimes over 20,000 volts at the spark plug. Therefore, every volt lost in the primary circuit due to excessive resistance or a weak battery, means a loss of 1,000 to 2,000 volts in the ignition secondary circuit. So always check the low-voltage circuit first, beginning with the battery voltage.

BATTERY VOLTAGE

1. Select the correct voltage scale for the battery being tested (Figure 4). For 6-volt systems, use the 10 volt scale; for 12 volt systems, use the 20 volt scale.
2. Push the VOLT-AMP button to turn the analyzer on.
3. Check to be sure the knife switch is closed.
4. Read the battery voltage on the voltmeter. The needle should be in the green IGN area.

If the battery voltage is low, no further tests can be made until it is corrected. Either charge the battery or install a known good one. If the battery circuit is O.K., proceed to the Cranking Circuit Test.

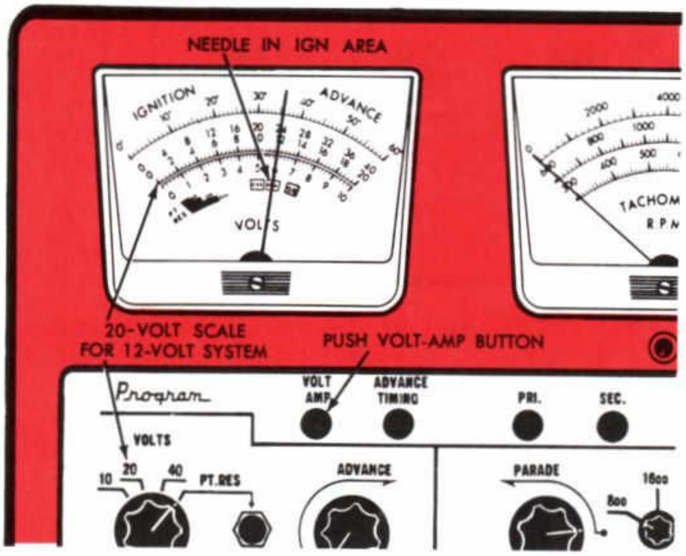


Figure 4—Battery Voltage Test

CRANKING CIRCUIT

The cranking circuit test indicates how much of the available voltage is being reduced by the cranking system. If high resistance causes the voltage to drop too much, it's possible there won't be enough voltage to fire the plugs.

1. Close the knife switch.
2. Remove the brown wire from the "I" terminal and the red-blue wire from the "S" terminal of the starter relay.
3. Connect a remote starter button between the "S" terminal and the battery terminal (Figure 5).

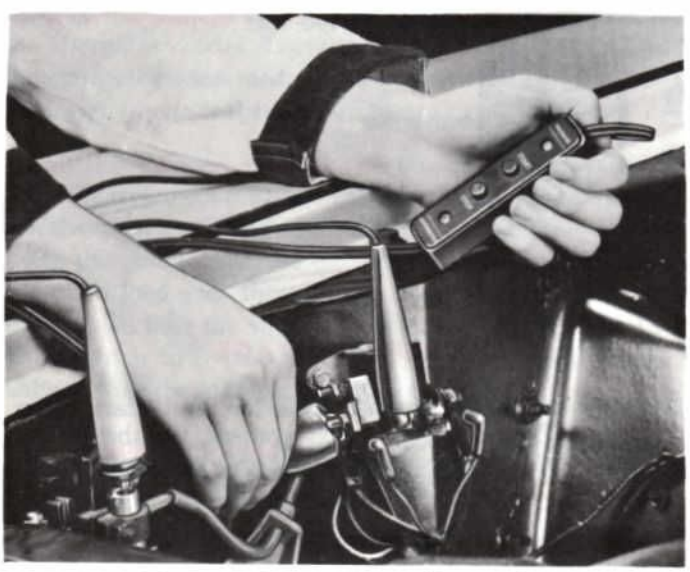


Figure 5—Remote Starter Connection

4. Crank the engine for 15 seconds and watch the voltmeter. The needle should stay in the yellow CRK area (Figure 6) and not indicate less than 9.6 volts.
5. If the voltage is low, check to see if the needle bounces back to the IGN area when you stop cranking.

The needle should never fall below the yellow area while you are cranking. If it does, you have too much resistance in the cables, the starter relay, the starter or battery. If the needle bounces back to the IGN area when you stop cranking, the battery is O.K. and the trouble is farther on in the cranking circuit.

If the engine cranks and the voltage *doesn't* drop below the CRK area, the cranking system is O.K.

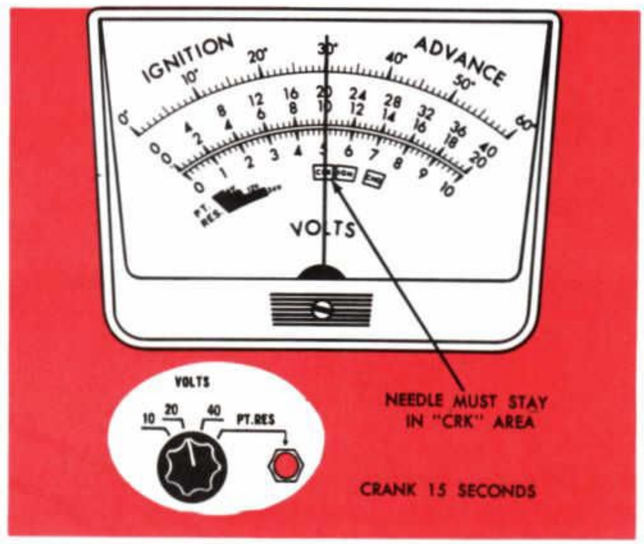


Figure 6—Cranking Circuit Test

POINT RESISTANCE

The point resistance or coil to ground test tells whether or not there's too much resistance between the coil, distributor terminal and ground. It must be performed before the engine is started, and with the breaker points closed.

1. Turn the VOLTS switch to PT. RES. position (Figure 7). In this position, the green pickup on the coil distributor terminal is now the voltmeter positive lead. With the ignition switch on, we read battery voltage on the 40-volt scale if the points are open.
2. Turn on the ignition switch.
3. Bump the starter until the voltmeter reads zero. Now the points are closed.
4. Push the PT. RES. button and read the voltage drop from coil to ground. With the PT. RES. button pushed in, the 10-volt scale becomes a one-volt scale. The black areas on the meter are the voltage drop limits, 0.1 volt drop in a 12-volt system or 0.05 volt drop in a 6-volt system.

   In this part of the circuit, current flow is from the coil, through the coil-distributor lead to the point terminal in the distributor, and through the points to ground. If the needle is in the black, this part of the primary ignition circuit is O.K.
5. If the voltage drop is out of the black, bump the starter

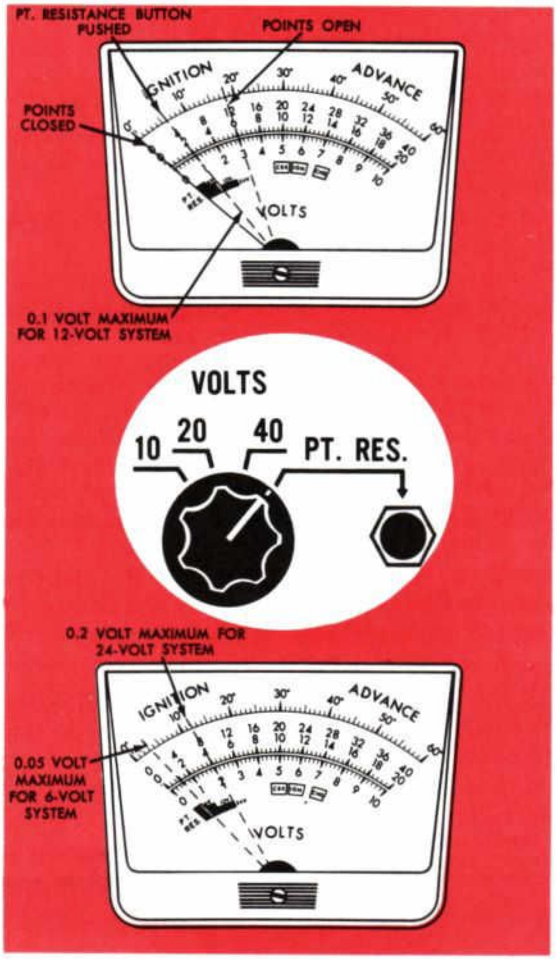


Figure 7—Point Resistance Test

again to be sure the points are fully closed.

6. If the voltage is still out of the black, move the green pickup to the point terminal and repeat the test.

   Now you know whether the resistance is in the distributor lead or between the points and ground. If the resistance is still too high, either the points need servicing or you don't have a good ground.

7. Return the voltmeter to the appropriate scale for the battery voltage.

ALTERNATOR OUTPUT

The battery should be slightly discharged after completing the cranking circuit test, so it will take a charge from the alternator when the engine is started. The ammeter will indicate how much current the battery is receiving. This will be about five amps less than the rated output of the alternator. Be sure and get the reading quickly before the alternator restores the battery to full charge.

1. Select the 8000 rpm tachometer scale.
2. Open the knife switch.
3. Crank the engine and immediately adjust it to about 2000 rpm while watching the ammeter (Figure 8). The reading should be within five amps of the alternator's rated output. If the alternator output is low, the charging system should be checked out. However, the rest of the ignition system can be checked providing the battery is O.K.

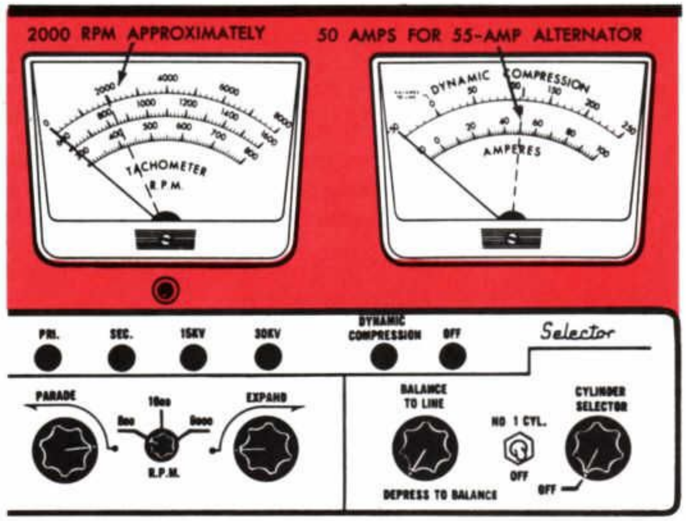


Figure 8—Alternator Output Test

REGULATOR SETTING

If you're working on a cold engine, save the voltage regulator setting test until you finish the scope analysis. That will give it time to warm up and be sure the battery is fully charged. If the engine is good and warm and the battery fully charged, make the regulator test now.

1. Push the VOLT-AMP button and open the knife switch.
2. Check that the ammeter reads 10 amps or less (Figure 9). This indicates the charge is being regulated.
3. The voltmeter reading is the regulator setting. Check it against specifications.

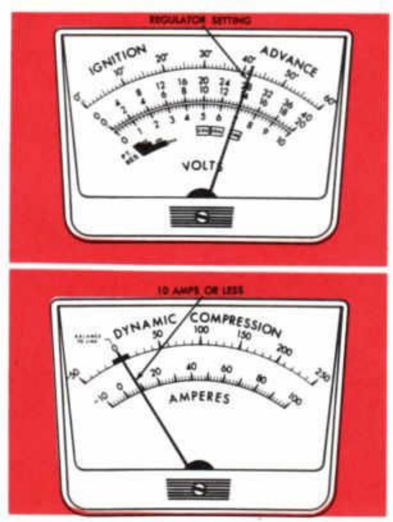


Figure 9—Regulator Setting Test

TIMING

To check timing, adjust the advance knob on the console, or on the timing light (Figure 10), so that the light flashes when the mark on the pulley is lined up with top-dead-center (TDC). Read the timing on the IGNITION ADVANCE meter scale. (On scope analyzers with the advance knob on the timing light, the knob on the console is a two-position control. In the TIMING position, you have a straight timing light. In the ADVANCE position, you can adjust the flash at knob on the light.)

Initial timing is specified in degrees before top-dead-center (BTDC), depending on the engine and transmission type. This causes the spark to occur before the piston gets to the top of the compression stroke to allow sufficient time for complete combustion of the air/fuel mixture for the most efficient power stroke. Always refer to the correct specifications before adjusting timing.

To test initial timing:

1. Push the ADVANCE TIMING button in.
2. Select the 800 rpm scale on the tachometer.

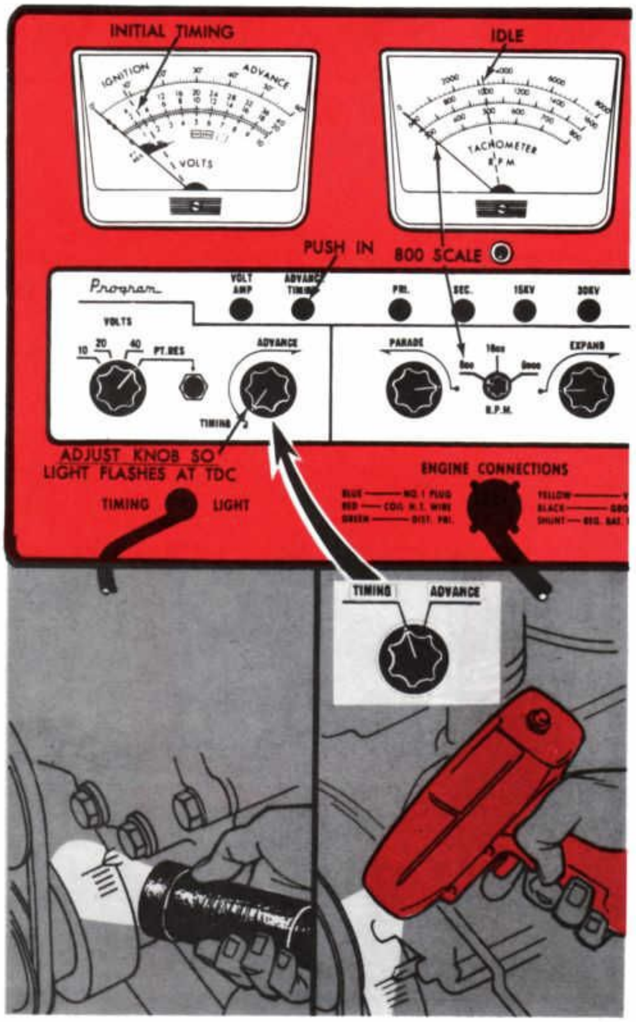


Figure 10—Initial Timing Test

3. Adjust the engine rpm to idle specifications.
4. Disconnect the vacuum advance line at the distributor if equipped with vacuum advance mechanism.
5. Point the timing light at the indicator and adjust the ADVANCE knob on the console or light so that the timing mark is at TDC.
6. Read the initial timing on the IGNITION ADVANCE scale and check it against specifications.

   To adjust the initial timing, turn the knob so the meter indicates the specified initial timing, and then turn the distributor until the timing mark is at TDC.

Ignition Advance is necessary when the engine operates faster, or combustion is slowed down under part-throttle operating conditions. As engine speed and load increase, the timing is advanced by centrifugal and/or vacuum advance mechanisms to give more degrees of crankshaft rotation to complete combustion. To check total ignition advance at higher engine speed:

1. Connect the vacuum advance line to the distributor if equipped with vacuum advance.
2. Select the 8000 rpm scale on the tachometer.
3. Increase engine speed to the specified rpm.
4. Point the timing light at the indicator and adjust the ADVANCE knob on the console or light so that the timing mark is at TDC.
5. Read the total advance on the IGNITION ADVANCE (Figure 11).

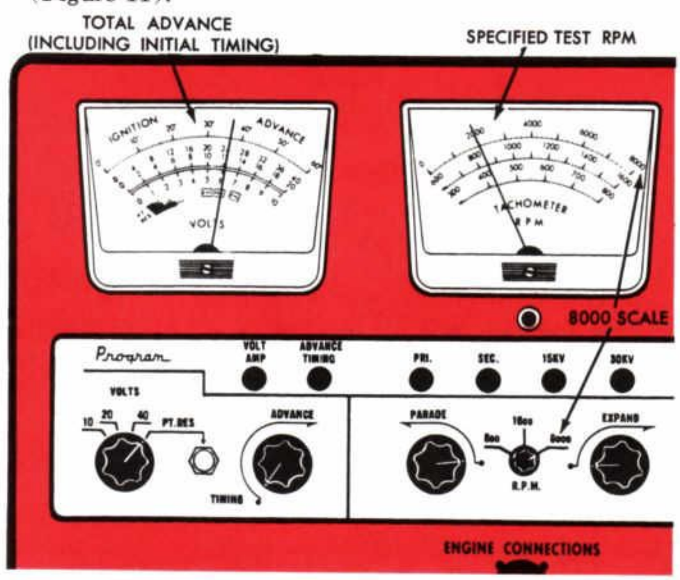


Figure 11—Total Advance Test

SCOPE IGNITION ANALYSIS

The next four buttons on the console (Figure 12) are used to analyze the ignition system on the scope. Much like a television set, the scope projects a picture on the screen of the complete ignition system under actual operating conditions. The *primary* circuit, with all the cylinders superimposed, can be viewed by pushing the PRI button. Then

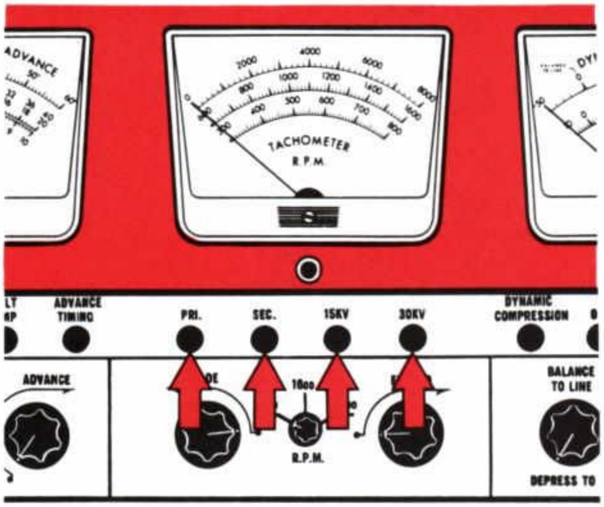


Figure 12–Scope Pattern Buttons

by pushing the SEC button, you can see all the cylinders superimposed as viewed from the secondary or high voltage circuit.

To diagnose trouble in individual cylinders, all the cylinders can be "paraded" on the 15-KV and 30-KV scales. High tension voltage is read on the 15,000-volt scale at the left of the grid on 15-KV, and the 30,000-volt scale at the right of the grid on 30-KV (Figure 13). These scales

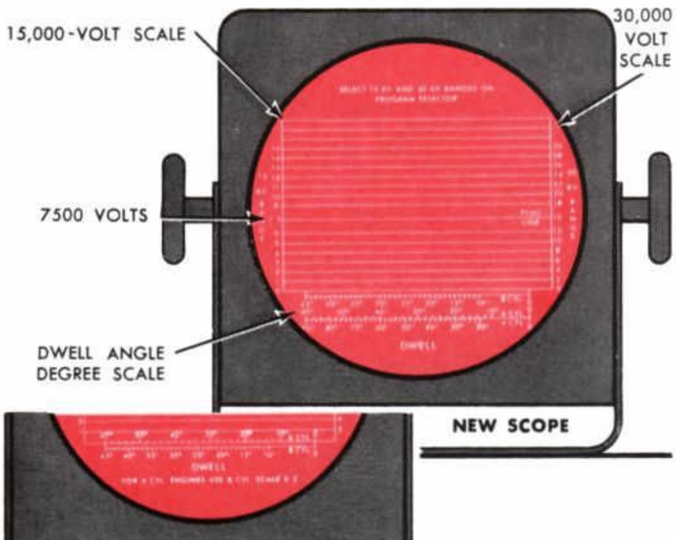


Figure 13–Scope Calibrations

indicate firing voltage in thousands of volts or kilovolts. The PLUG LINE in the middle of the scope is 7500 volts on the 15-KV scale. This is the normal firing voltage for a spark plug.

The scale at the bottom of the scope is divided into 60 degrees for 6-cylinder engines, 45 degrees for 8-cylinder engines, and 90 degrees for 4-cylinder engines. Earlier scopes may not have the 4-cylinder scale, in which case the 8-cylinder scale can be used by multiplying by 2.

PRIMARY SUPERIMPOSED PATTERN

1. Switch the tachometer to the 1600 scale and adjust the engine speed to 1000 rpm.
2. Push the PRI button in.
3. Adjust the PARADE control to align the left end of the pattern with the left end of the degree scale.
4. Adjust the EXPAND control to stretch the right end of the pattern to the zero mark on the degree scale.

A *normal primary pattern* for a negative-ground system (Figure 14) should appear on the screen. All the cylinders are superimposed, and the pattern should begin at the left of the scale (point "A") where the breaker points open and the plug fires.

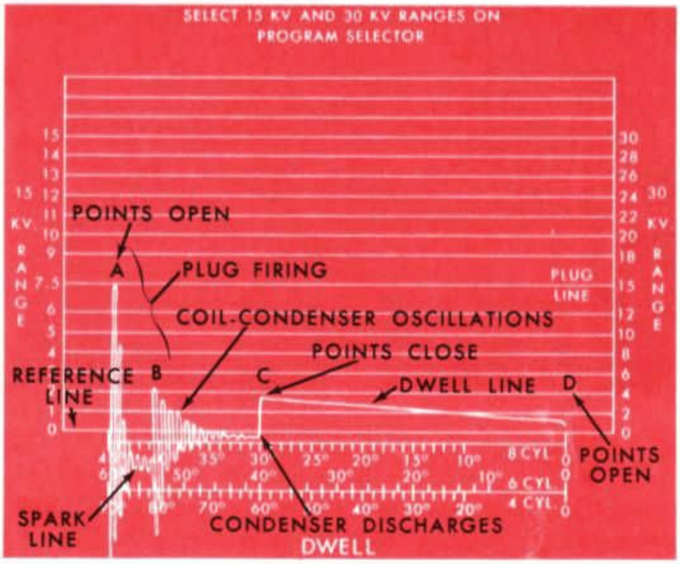


Figure 14–Normal Primary Superimposed Pattern

Spark Line

The plug firing oscillations diminish after the plug begins to fire because it takes more voltage to jump the plug gap than it does to sustain firing once it's started. In a normal pattern, the firing oscillations become a horizontal *spark line* up to point "B" where the plug stops firing. The spark line is below the grid reference line on the scope because it takes place in the secondary circuit and we are looking at it from the primary circuit, so the polarity is reversed.

Coil-Condenser Oscillations

The breaker points still are open at point "B" and the excess coil energy that wasn't used to fire the plug must be discharged by the condenser. Otherwise, the voltage could jump across the breaker point gap. The condenser discharges back through the primary circuit, through the coil primary, across the battery to the opposite plate of the condenser. Then, the current reverses from the opposite side, and comes back to charge the original side. This happens several times, and each time some energy is lost to resistance. Before the points close at "C", the condenser is almost fully discharged.

Dwell Line

The breaker points close at "C" and open again at "D" to fire the next plug. The pattern from "C" to "D" is the *dwell line*. The voltage increases at "C" as the circuit is closed; then, diminishes as the coil is saturated.

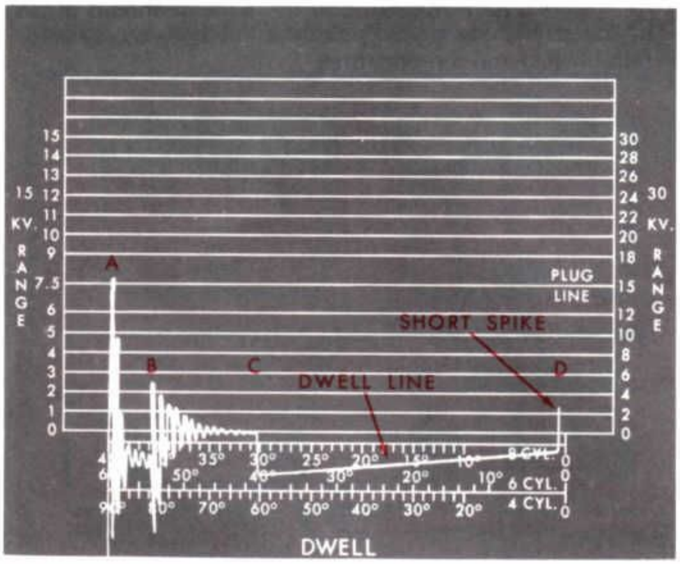


Figure 15—Transistorized Primary Pattern

Positive-Ground and Transistorized Ignition

If the system is positive-ground, or is transistorized, the *primary* circuit is reversed and the dwell line appears below the reference line (Figure 15). The transistorized system has a short spark plug firing spike (Figure 15). A positive-ground system has a high spike just like the negative-ground system. Regardless of the type of system, the primary superimposed pattern breaks down into three parts (Figure 14):

- "A" to "B"—Plug firing oscillations diminishing to a "spark line"
- "B" to "C"—Coil condenser oscillations diminishing to nearly zero
- "C" to "D"—Dwell line

Distortions of this basic pattern indicate defects in the ignition system. Some easily spotted defects follow.

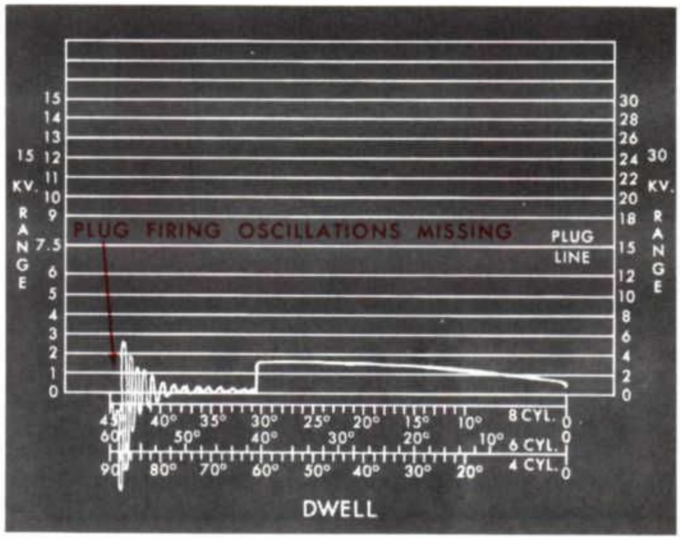


Figure 16—Primary Circuit Resistance

PRIMARY CIRCUIT RESISTANCE

Figure 16 shows the pattern distortions when there is too much resistance in the primary circuit. Notice that the spark plug firing oscillations are missing from the pattern. The primary circuit has already been tested from the coil to ground (Point Resistance Test). If it was O.K., this pattern distortion must be caused somewhere between the battery and the coil. Check for loose or corroded terminals, a defective resistance wire or ignition switch, or trouble in the wiring harness.

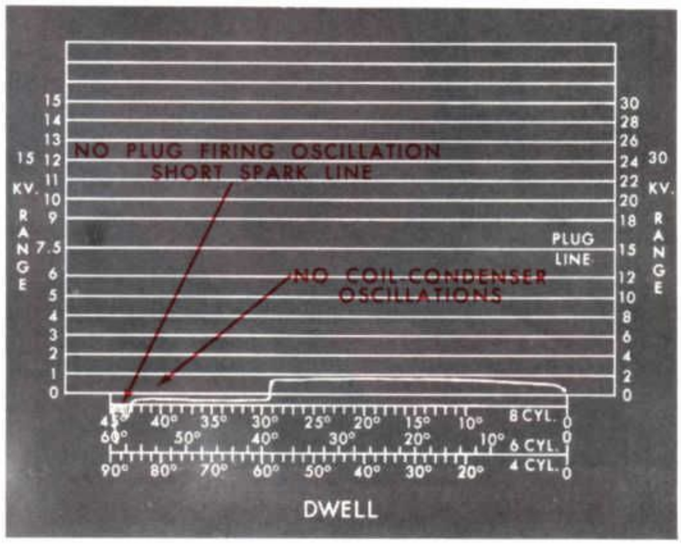


Figure 17—Partially Shorted Condenser

PARTIALLY SHORTED CONDENSER

When a condenser is partially shorted, or "leaky", it drains off all of the coil reserve energy directly to ground.

The condenser *doesn't* discharge back through the coil, so there are *no* coil-condenser oscillations (Figure 17). The plug firing oscillations also are missing from the primary pattern with this condition.

The engine may operate with a leaky condenser, but there's no coil reserve for conditions where more firing energy is needed. Hard starting, skipping and missing under load will result if this isn't corrected by replacing the condenser.

DWELL

During the dwell period, the points are closed and current is flowing in the primary circuit-from the battery, through the ignition switch and resistance wire to the primary windings of the coil, then through the closed breaker points to ground. The current flow in the primary windings of the coil builds up a magnetic field which collapses when the points open, creating high voltage in the secondary circuit to fire the spark plugs.

Checking Dwell

Checking dwell is nothing more than a highly accurate way of checking point gap, because the width of the gap determines the length of time the points are open and closed.

To check dwell on the primary superimposed pattern:

1. Return the tachometer to the 800 rpm scale.
2. Adjust the engine speed idle to take out any vacuum spark advance effect.
3. Check the length of the dwell line in degrees against specifications.

Dwell Too Short

If the points have too wide a gap, they'll close later and open sooner than they should; in other words the dwell is too short (Figure 18), the coil hasn't time to build up to maximum strength. Some coil output is lost and there may not be enough left to fire the spark plugs, especially at high speeds. Also, opening the points too soon advances the timing and can cause rough operation.

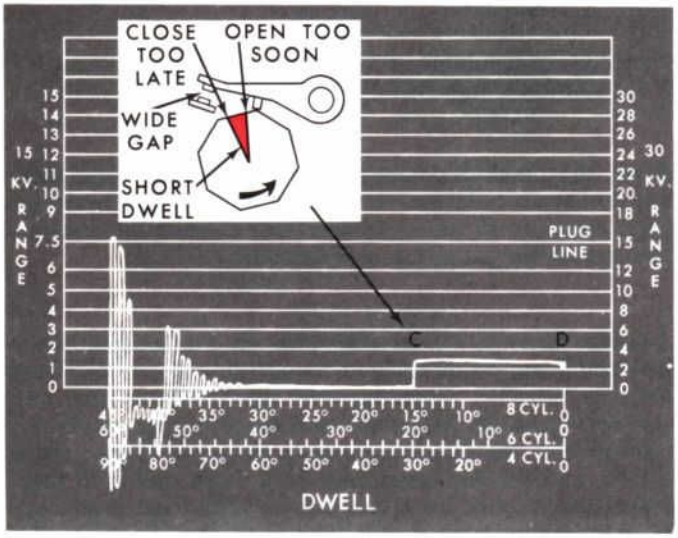


Figure 18—Dwell Too Short

Dwell Too Long

If the points are gapped too close, they close sooner and open later resulting in too much dwell (Figure 19). Too much dwell usually means the points close before the coil-condenser oscillations are discharged, and the breaker points get burned.

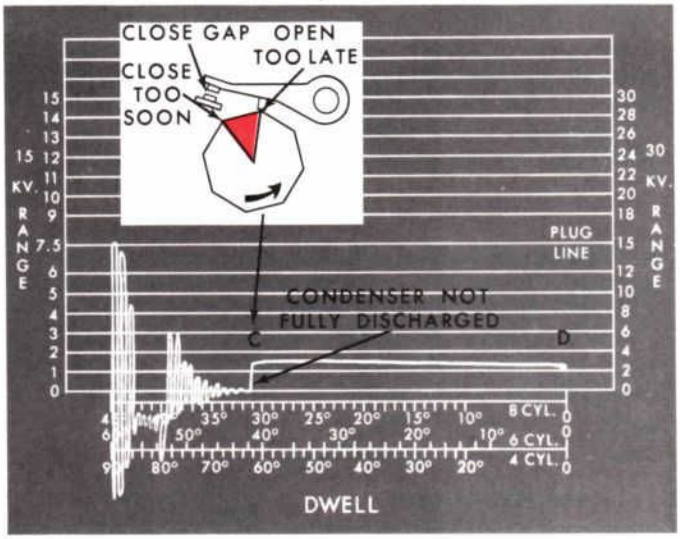


Figure 19—Dwell Too Long

ENGINE WON'T START

If you have an engine that won't start, you can still get a lot of good information from the primary pattern. Crank the engine with the ignition switch ON and check the pattern for irregularities. If the pattern is good, you can pretty much eliminate the primary circuit, and look for trouble in the secondary high tension wires, distributor cap or rotor. If the pattern is distorted, you've probably found the trouble. And if you can't get a pattern at all, the primary circuit must be open or grounded somewhere.

CONCLUSION—PRIMARY SUPERIMPOSED

If the primary superimposed pattern is good, it means that the following items are O.K. and *don't* need further checking:

- No excess resistance or loose connections in the primary circuit
- Condenser is not leaking
- Points are opening and closing at the right time
- Distributor shaft, bushing and cam are O.K.

SECONDARY SUPERIMPOSED PATTERN

1. Adjust the engine speed to 1000 rpm.
2. Push the SEC button in.
3. Adjust the parade and expand controls, if necessary, so that the pattern coincides with the degree scale (Figure 20).

The secondary superimposed pattern is very similar to the primary.

- "A" to "B"—Plug firing oscillations and spark line
- "B" to "C"—Coil-condenser oscillations
- "C" to "D"—Dwell line

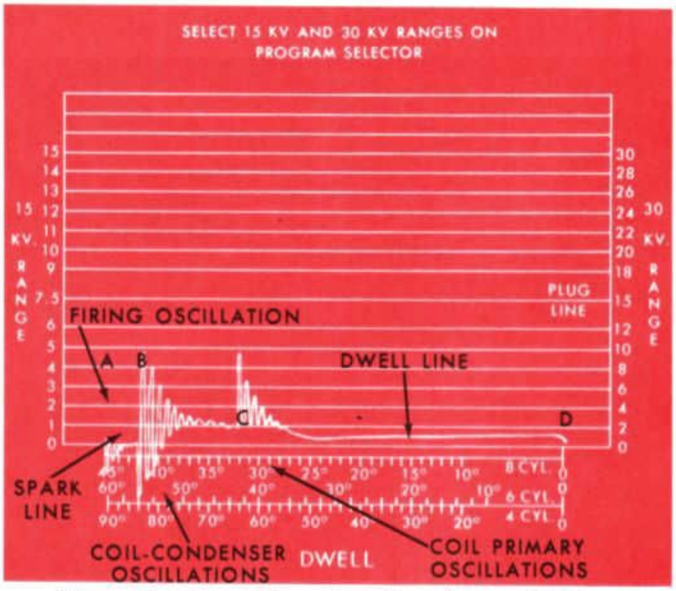


Figure 20—Normal Secondary Superimposed Pattern

COIL POLARITY

Reverse coil polarity causes the pattern shown in Figure 21. It is caused by the coil primary leads being reversed, or by a mismarked coil. It is important to correct this condition because it takes about one third more voltage to fire a spark plug when the coil polarity is reversed.

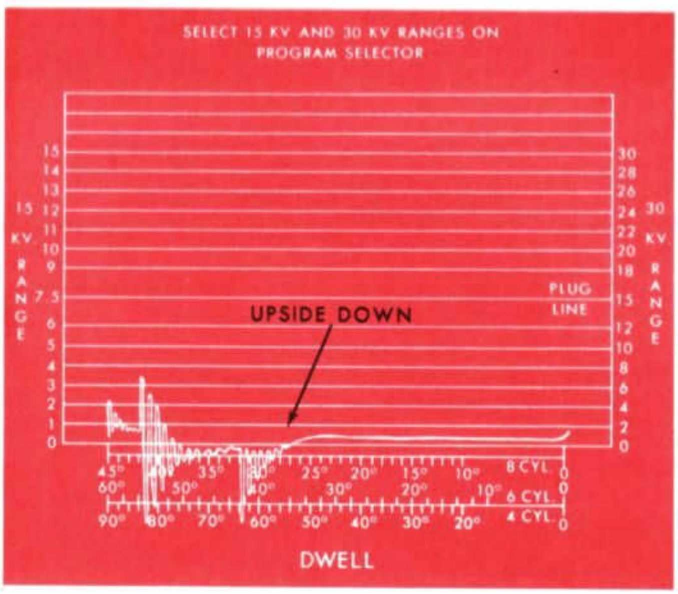


Figure 21—Reversed Coil Polarity

SHORTED COIL

Shorted coil primary windings cause the distorted pattern shown in Figure 22. The coil-condenser oscillations ("B" to "C") are missing and so are the primary oscillations at the beginning of the dwell line. Even though the engine may operate, there is no coil reserve, and firing becomes erratic at higher speeds because with shorted primary windings the amount of high voltage available is decreased.

If the coil secondary windings are shorted, the coil output would be low. The test for this condition is made later with the 30-KV button.

Figure 22—Shorted Coil

ARCING BREAKER POINTS

If the breaker points are burned or pitted, they arc when they open. The secondary pattern shows this very clearly as a blot at point "D" (Figure 23). Most of the conditions which cause arcing will show up on the analyzer:

- Excessive primary or secondary resistance
- Wrong coil
- Incorrect dwell
- Wrong condenser capacity
- Voltage regulator set too high
- Continual high speed operation

BOUNCING OR MISALIGNED BREAKER POINTS

When the breaker points are "bouncing" or misaligned, the primary oscillations at the beginning of the dwell line don't come up to the reference line. Correct by checking the breaker point tension or alignment.

HIGH SECONDARY RESISTANCE

Anytime there is excess resistance in the secondary circuit, the firing oscillations and spark line slope downward from "A" to "B". Note the level line in the normal pattern of Figure 20. Excessive resistance can be caused by the coil wire, the distributor cap or the rotor. If the normal pattern and the high resistance both show, that is, if there are multiple spark lines, the trouble is the distributor cap or an individual plug circuit. This is checked on the 15-KV button.

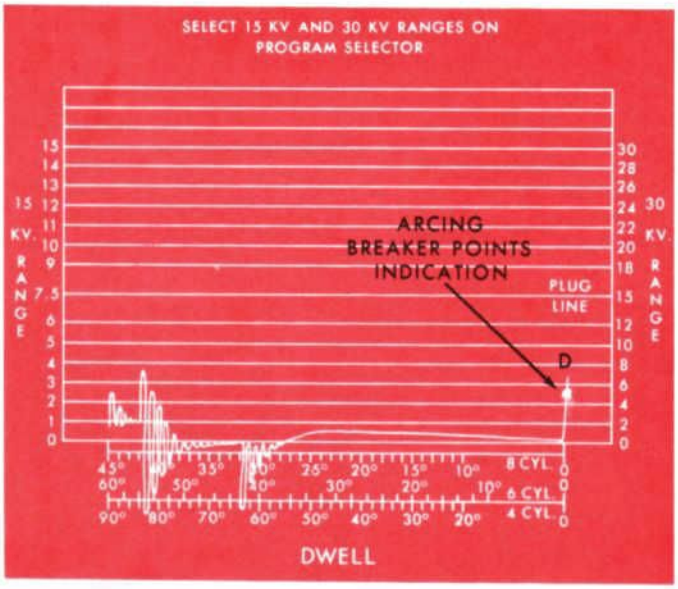


Figure 23—Arcing Points

CONCLUSIONS—SECONDARY SUPERIMPOSED

The ignition system has now been tested for most any defect that could cause trouble in the complete system. If the secondary superimposed pattern is normal:

- Coil polarity is correct
- Coil primary windings are O.K.
- Points are not arcing and condenser capacity is correct
- Points are properly aligned and point spring tension is correct
- No excess resistance in the secondary circuit

Now the paraded patterns are used to see if there is any trouble in the individual cylinders.

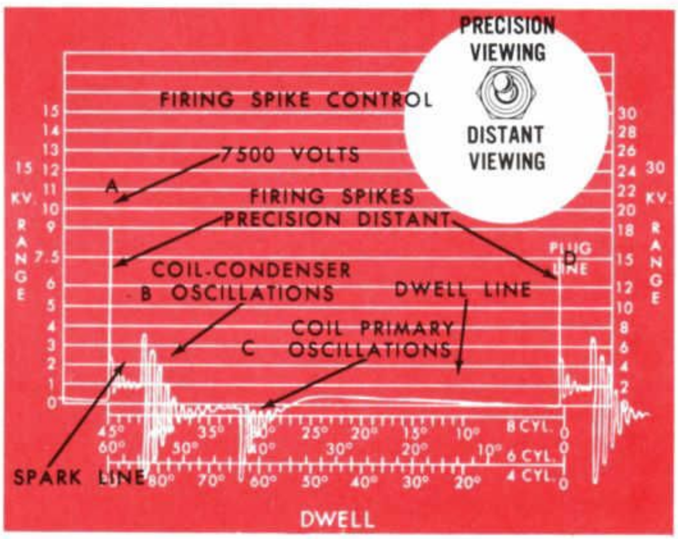


Figure 24—15-KV Parade Expanded To One Cylinder

PARADED PATTERN 15-KV SCALE

1. Maintain 1000 rpm engine speed.
2. Push the 15-KV button in.
3. Adjust the PARADE and EXPAND controls so that one cylinder pattern fills the grid screen (Figure 24). This is an *expanded* parade pattern.
4. Late model analyzers have a PRECISION VIEWING-DISTANT VIEWING toggle switch. On PRECISION, you get a normal thin voltage spike for close-up viewing; on DISTANT, the spike is fanned out at the top so you can see it from farther away. The height of the firing spike indicates the voltage required to fire the spark plug.

ALL PATTERNS PARADED

By adjusting the PARADE and EXPAND controls, all the cylinder patterns can be seen, side by side, starting with No. 1 (Figure 25). The other cylinders following the firing order. The firing spike for No. 1 appears at the far right. On the 15-KV button, check for defects in the plugs and plug circuits, and for even firing voltage requirements.

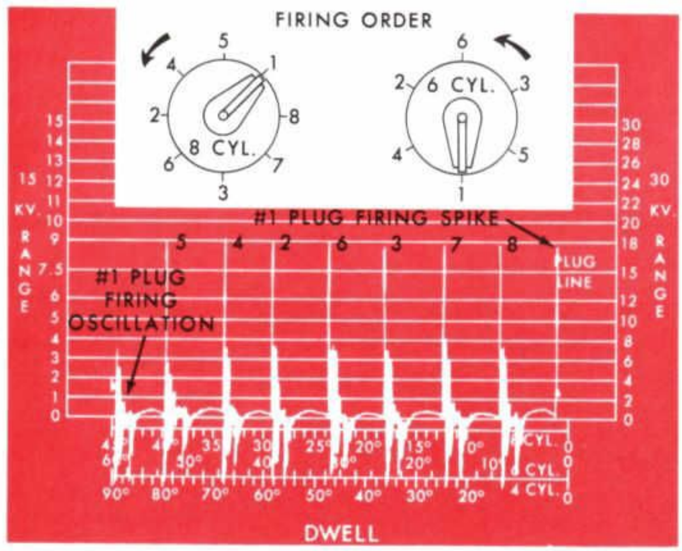


Figure 25—15-KV Parade Patterns for All Cylinders

WIDE PLUG GAP

The pattern distortion for a wide plug gap or too much resistance in the plug itself is shown in Figure 26. The firing spike is normal in height, but the spark line oscillations are sloped up from "A" to "B". This is because higher voltage is required to sustain firing with a wide gap plug.

HIGH RESISTANCE IN PLUG CIRCUIT

There are two indications of high resistance in the plug circuit:

- The firing spike is very high because more voltage is needed to overcome the high resistance
- The spark line is sloped downward

3. Observe whether or not the firing spikes are all the same height.

Uneven firing voltage can be caused by manifold or carburetor gasket leaks, or by unequal adjustment of multiple-barrel carburetors. This is because it takes more voltage to fire a lean mixture than a rich mixture.

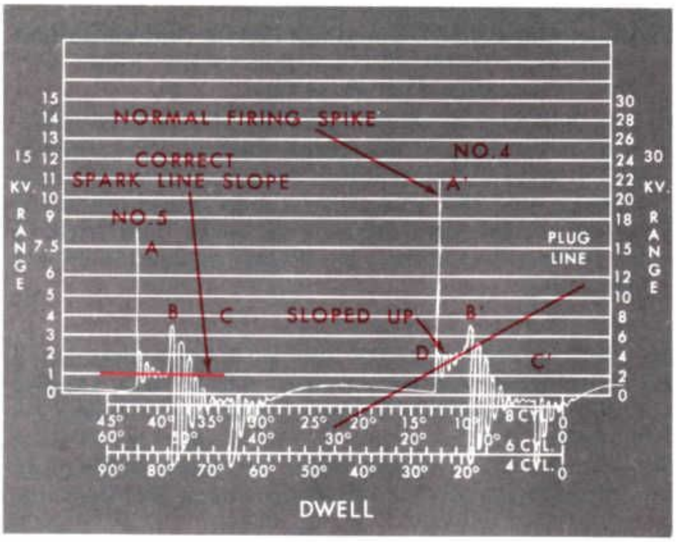


Figure 26—Wide Plug Gap

PARADED PATTERN 30-KV SCALE

1. Turn the rpm selector to the 1600 scale.
2. Press the 30-KV button.

The pattern appears the same as the 15-KV pattern, except it is reduced by 50 percent vertically (Figure 27).

The firing spikes are only half as high. However, the firing voltage is still about 7500 volts because each line on the 30-KV scale represents 2-KV (2000 volts).

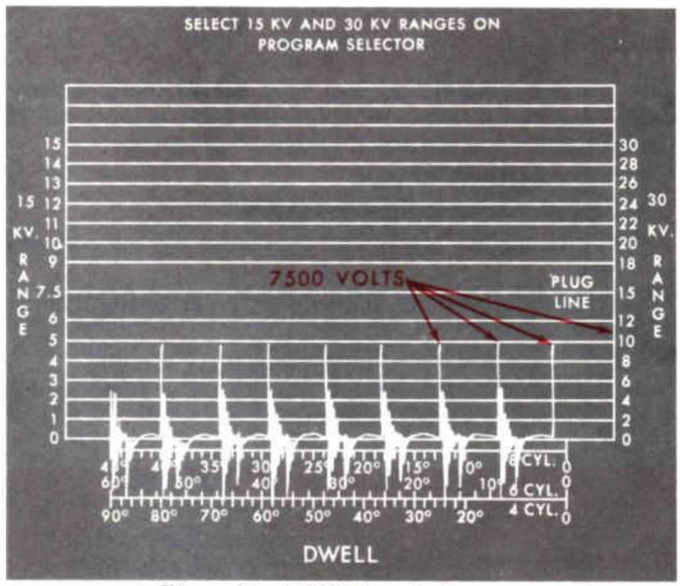


Figure 27—30-KV Parade Pattern

To find the resistance:

1. Pull the wire from the plug and ground it. If that gets rid of the high spike, the plug is at fault.

If the pattern doesn't change with the plug wire grounded:

2. Pull the wire from the distributor and ground the terminal in the distributor cap.

Now if you lose the firing spike, you know the wire needs replacing. If the spike is still there, check the distributor cap terminal for corrosion.

LOW FIRING VOLTAGE

If the firing voltage is too low (short spike) and the spark line is longer than normal, it means the plug may be shorted, fouled or gapped too close. Another possibility is a cracked distributor cap with one terminal grounded. To check this, switch to the 30-KV scale for a second and remove the plug wire. The firing spike should rise to coil output (Figure 29). If it doesn't rise, the distributor cap is grounding out the cylinder.

UNEVEN FIRING VOLTAGE

1. Adjust the engine speed to idle.
2. Adjust the PARADE and EXPAND controls so that all patterns are on the screen together.

PLUG FIRING UNDER ACCELERATION

On cars equipped with an automatic transmission, the plugs can be tested for firing voltage under acceleration or load as follows:

1. Block the car wheels and apply the parking brake fully.
2. Operate the engine at 1500 rpm in drive position for no longer than 15 seconds (foot brake applied).
3. Check whether any voltage spike goes above the Plug Line (Figure 28). The plug line is now 15,000 volts, the

maximum allowed. If any plug takes more than 15,000 volts to fire, it has excessive internal resistance. Replace the plug. Cleaning it won't help.

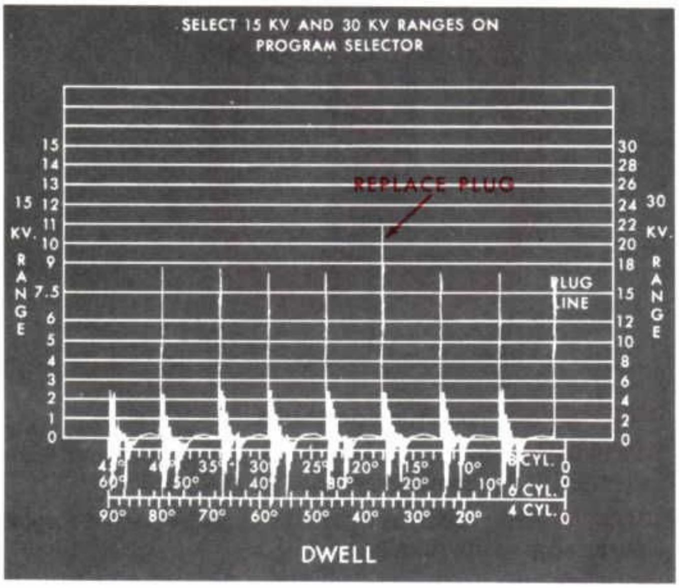


Figure 28—Plug Firing Under Acceleration

COIL OUTPUT

1. Adjust the engine speed to 1000 rpm.
2. Remove one high-tension wire at the plug (except No. 1).
3. Read the *total coil output* on the 30-KV scale (Figure 29).

The firing spike for the plug removed rises to the highest voltage available for firing, because disconnecting the plug is like putting an infinite resistance in the circuit. The coil output should be at least a minimum of 20 KV, or engine may skip and miss under load.

ROTOR AIR GAP TEST

1. Ground the plug wire removed for the coil output test.
2. Read the voltage required to jump the rotor air gap on the 30-KV scale.

   It should be no more than 3000 volts.

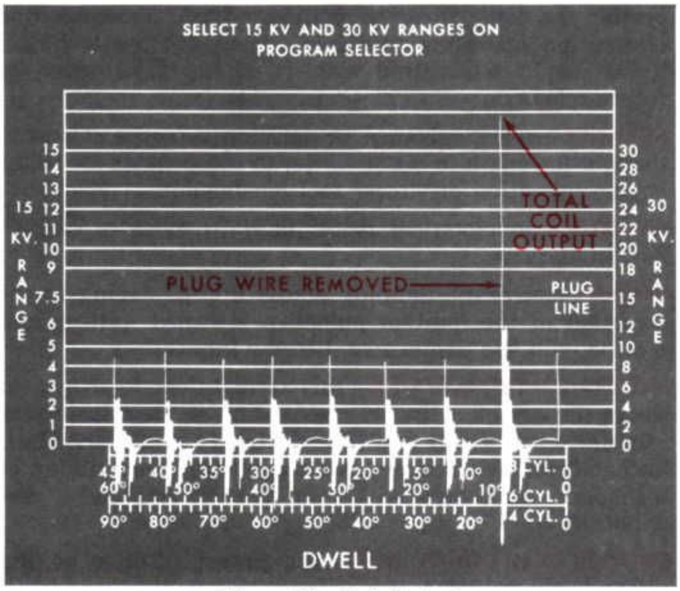


Figure 29—Coil Output

CROSS-FIRING

If there is any cross-firing or arcing in the distributor cap, the bottom of the oscillation is lost intermittently (Figure 30). This means the rotor is defective or the distributor cap needs cleaning or replacing.

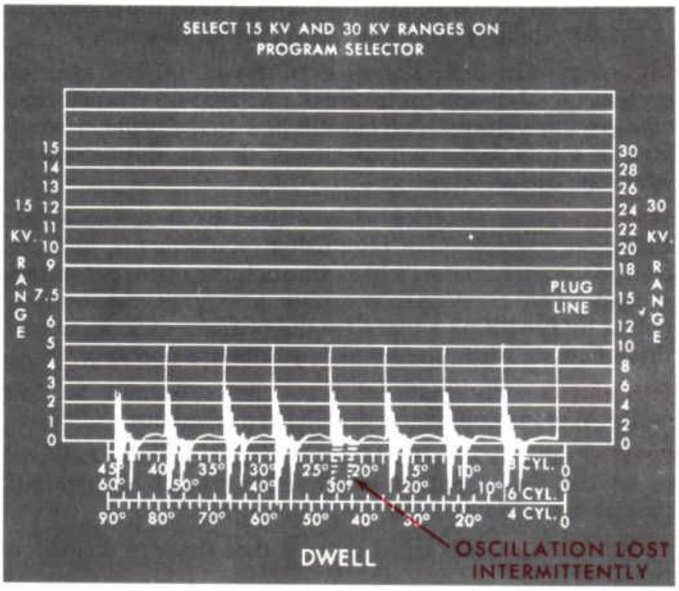


Figure 30—Cross Firing

CONCLUSION—PARADED PATTERNS

The engine electrical system has now been completely analyzed. You are in a position to recommend any necessary electrical services.

DEFINITIONS

Understanding the operation of the Oscilloscope and interpreting the tests correctly requires a basic understanding of ignition operating principles. Here are the technical terms you'll be involved with, in alphabetical order for future reference.

ADVANCE—spark advance or ignition advance. Causing the ignition spark to occur earlier to compensate for faster engine operation or slower fuel combustion.

AMMETER—an electrical meter used to measure current flow in amperes.

ARCING—electricity jumping across a gap. Arcing is not desirable in the ignition points as it causes pitting and erosion, and the points soon become inoperable.

BATTERY IGNITION SYSTEM—this term refers to a system where the engine cylinders are fired by an electrical spark jumping a spark plug gap. The electricity is furnished by a lead-acid storage battery, and the potency and timing of the spark are controlled by an ignition coil and a distributor.

BOTTOM DEAD-CENTER (BDC)—the lowest position of the piston in the cylinder.

BREAKER POINTS—contact points in the distributor which open and close the ignition primary circuit.

CHARGING CIRCUIT—the alternator (or generator) and associated circuit used to keep the battery charged, and furnish power to operate the ignition system, lights and accessories while the vehicle is in operation.

CIRCUIT—the complete path of an electrical current, including the generating device. When the path is continuous, the circuit is *closed* and current flows. When the continuity is broken, the circuit is *open* and current flow stops.

COIL—a spiral winding of wire. In the automobile ignition system, a step-up transformer. A step-up transformer changes low-voltage, high current flow in the *primary* windings to a high voltage, low-current flow in the *secondary* windings by induction.

CONDENSER—an electrical device used to store the excess coil energy above spark plug firing requirements, and discharge the excess energy back through the primary ignition system. The condenser prevents arcing at the breaker points by providing a place for the primary current to continue flowing while the breaker points are opening.

CONDUCTOR—any material that allows current to flow easily. A poor conductor is called an insulator.

CURRENT—the movement of electricity. Generally believed to be the movement of electrons or negatively charged particles, within the electrical conductor.

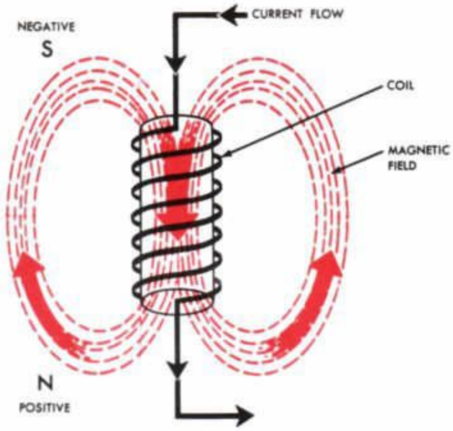
DIRECT CURRENT—electrical current that flows in one direction only.

DWELL—the period during which the ignition breaker points are closed.

FIRING SPIKE—the high-voltage line that appears on the scope at the point where the plug begins to fire.

INDUCTION—the transfer of electricity by magnetism rather than a direct connection. When electrical current flows through a wire or coil, it builds up a magnetic field. If another conductor moves through this field or if the field moves through another conductor, a voltage is *induced* in the other conductor.

In the ignition coil, *direct current* in the primary builds up a field. When the breaker points open, the field collapses, *inducing* high-voltage in the secondary.



KILOVOLT (KV)—one thousand volts.

OSCILLATION—backward and forward surges of a charge of electricity. A complete cycle of an electric wave.

PARADED—the condition where the cylinder patterns appear on the scope individually.

POLARITY—the quality or condition in a body which has opposite properties or directions; having poles.

PRIMARY—pertaining to the current inducing side of a transformer. The low-voltage circuit in the ignition system.

RESISTANCE—the opposition offered by a substance or body to the flow of electric current.

SATURATION—when current flowing through a coil or wire has built up to a maximum magnetic field, the coil has reached a point of saturation.

SCOPE—an oscilloscope. A device that projects electrical oscillations on a *cathode ray tube* or *picture tube*.

SECONDARY—pertaining to the side of a transformer in which high-voltage current is induced.

SHUNT—a parallel circuit used to bypass current to limit or regulate the current in the main circuit.

SUPERIMPOSED—the condition where all cylinder patterns are shown at once, one superimposed atop the other.

TOP DEAD-CENTER (TDC)—the highest position of the piston in the cylinder.

VOLT—the unit of electromotive force that will cause current of one ampere to flow in a conductor with a resistance of one ohm.

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