General Information

The conventional breaker point system met the requirements placed on the ignition system for many years. It provided sufficient voltage to the spark plug to cause a spark across the air gap of sufficient intensity to ignite the air/fuel mixture in the combustion chamber. It timed the spark to arrive at the correct cylinder at the proper moment in the compression stroke of that cylinder. It also could vary the time the spark arrived at the cylinder in relation to engine speed and load to achieve maximum power and economy from the engine.

These are still the requirements of an ignition system but the voltage and energy needed to complement modern engine operation increased beyond the capabilities of the conventional system under some operating conditions due to leaner gas mixtures, plug erosion and 50,000 mile operations. Adverse operating conditions can vary from cold or wet weather starting to highway cruising with an ignition system or spark plugs that are in need of maintenance.

Higher secondary voltage could be obtained by simply increasing the current in the primary circuit.

By reducing the resistance in the primary circuit, the current would be increased giving a higher secondary voltage. Unfortunately the breaker points were already operating at the maximum current they could handle.

In most breaker point systems, the primary circuit operates on 3.5 to 4.0 amperes depending on temperature. This current value in itself is a trade-off between contact point life and system output. Maximum point life is realized at approximately one ampere. As current is increased from one ampere, point life decreases steadily until just over a current of 4 amperes is reached. As the current is increased above this value, point life begins to decrease at an increased rate, giving a very limited point life. This means that more maintenance would be needed to keep the system operating at its best and emission regulations dictated 50,000 mile operation without reduced spark energy.

What was needed was a system that did not use breaker points to control primary current flow. The replacement for the breaker points must be able to carry a current greater than 4 amperes and require little or no maintenance. Electronics was the answer.

High Energy Ignition

The High Energy Ignition System (HEI) (Figure 0-1) has undergone many improvements since its introduction in 1974. The system (HEI) is an electronic system that requires no scheduled maintenance, provides up to 35,000 volts to fire the spark plugs and increases spark plug life, especially when unleaded fuel is used. The HEI system has 40% more voltage output and 85% higher energy level than the conventional breaker point system to fire lean fuel mixtures even under the most adverse conditions.

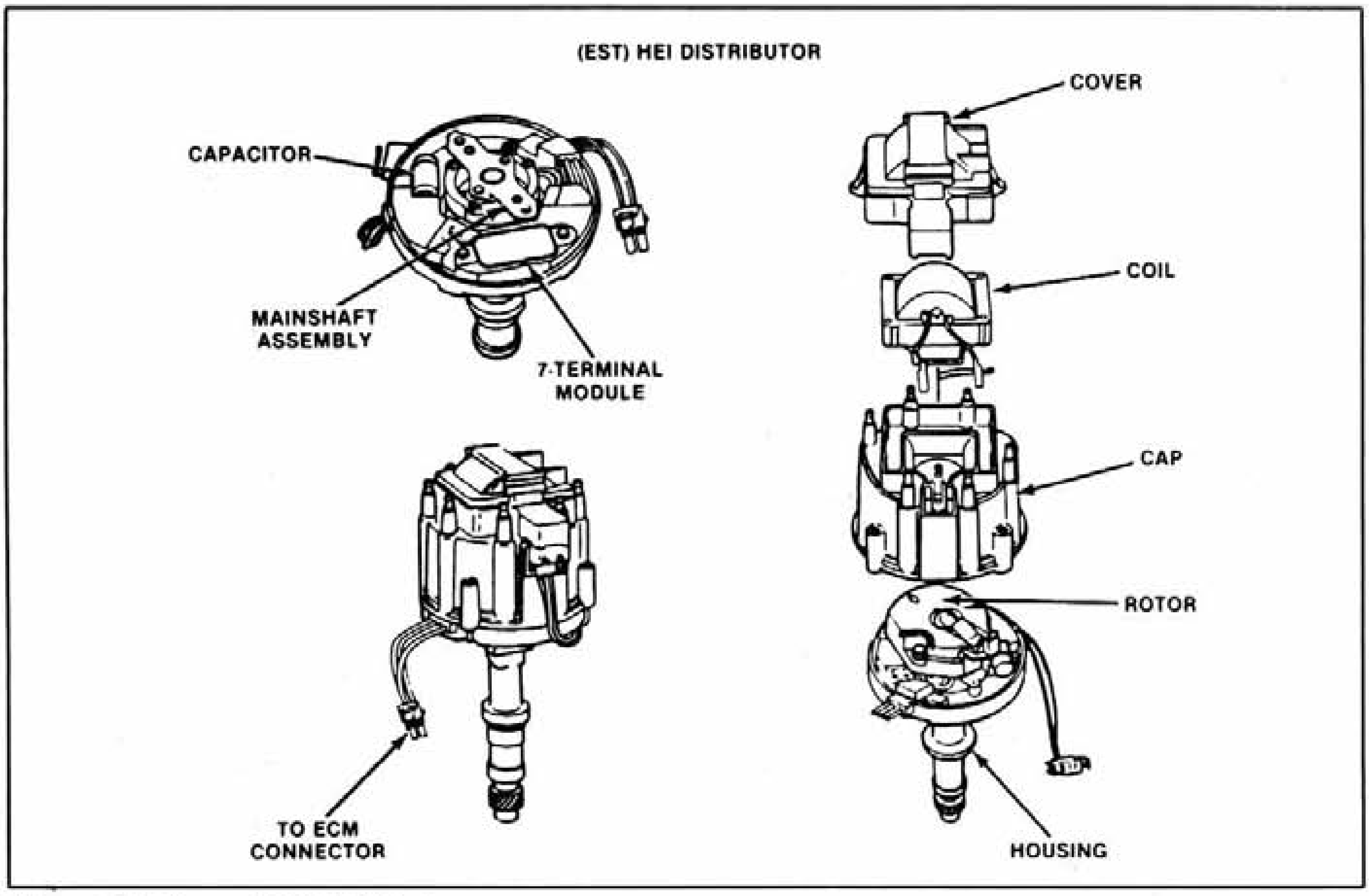


Figure 0-1. Integral HEI Distributor

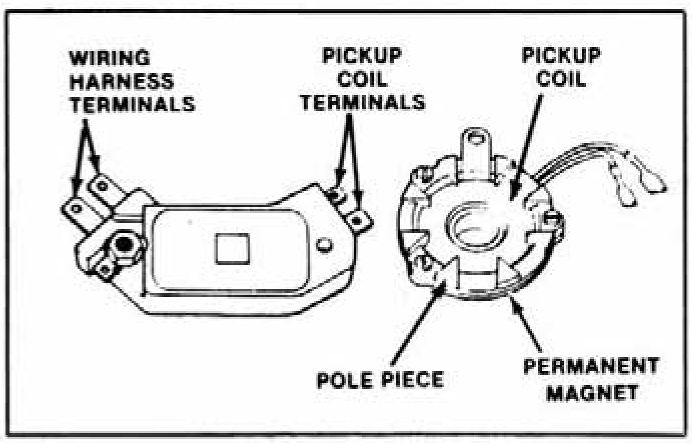


Figure 0-2. Module and Pulse Generator

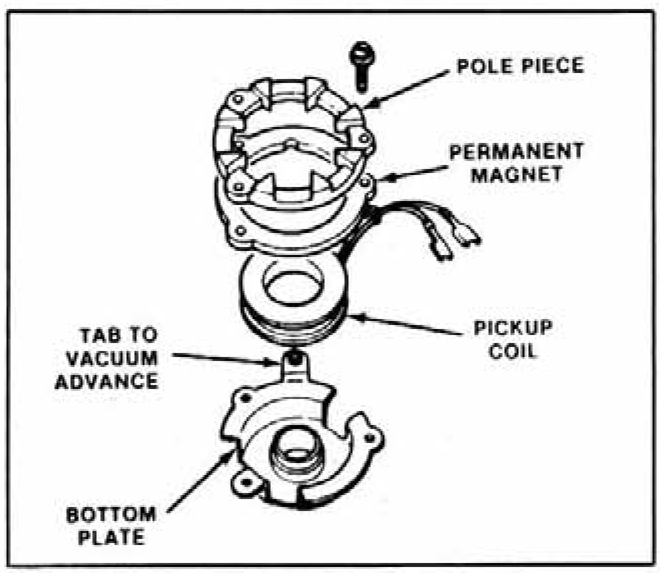


Figure 0-3. Pulse Generator Construction

Module

The HEI system uses an electronic module and a magnetic pulse generator to control primary circuit current (Figure 0-2). The electronic module has several integrated circuits that contain resistors, transistors, diodes and capacitors. These circuits and components are small enough to allow the module to be mounted inside the distributor.

The ability of the module to turn the primary current on and off is due to the transistor. A transistor is an electrical device that is used to control current flow like a mechanical switch except that it is turned on and off by electrical current and has no moving parts.

Pulse Generator

Since a transistor is turned on and off by electrical current a properly timed electrical pulse will control the primary current in the ignition system. The magnetic pulse generator, or magnetic pick-up assembly, consists of a permanent magnet and a pick-up coil. Both are sandwiched between a pole piece with internal teeth and a bottom plate and held together by three screws (Figure 0-3). The bottom plate then fits over a bushing which is installed in the distributor housing.

Magnetic Flux Path

A timer core on the main shaft of the distributor has external teeth which align with an equal number or pole piece teeth.

The magnetic pick-up assembly, by the varying magnetic field around the pick-up coil, produces an electric current in the pick-up coil by electromagnet induction. As the timer core rotates past the pole piece, the air gap between timer core and pole piece teeth varies. Since air is not a good path for magnetic flux to travel through, the magnetic field is relatively weak when the teeth are not aligned. As the timer core rotates, the teeth move closer together, the air gap decreases and the magnetic field increases until the timer core teeth and pole piece teeth are aligned (Figure 0-4).

At this point, the magnetic field is at its strongest. As the teeth move apart, the air gap increases and the magnetic field decreases until the teeth begin to move back together.

Applying the principle of electromagnetic induction which states that a voltage will be induced in a conductor whenever a magnetic field is moved so that its lines of force (flux) cut across a conductor. During the strengthening and weakening of the magnetic field, the lines of force cut across the pick-up coil inducing a voltage in the coil.

The principle of electromagnetic induction also states that the polarity of the induced voltage depends on which side of the conductor is striking the magnetic lines first. This means that the voltage induced by a strengthening or expanding magnetic field will be of the opposite polarity of a voltage induced by a weakening or collapsing magnetic field.

This signal is used to turn on and off the transistors in the module that controls the current in the primary circuit. With one exception, which will be covered later, the pole piece has the same number of teeth as the engine has cylinders. This gives the correct number of "firing" pulses per distributor shaft rotation.

We have eliminated the contact points and breaker cam by using a pulse generator to time the turning on and off of the primary circuit. In place of the breaker cam and points, transistors are used to turn the current on and off. The wear of the rubbing block and contact points has been eliminated as has the current limitations of the contact points.

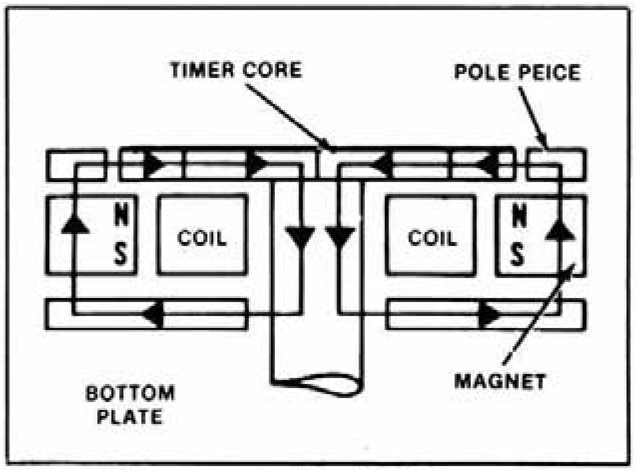


Figure 0·4. Magnetic Flux Path

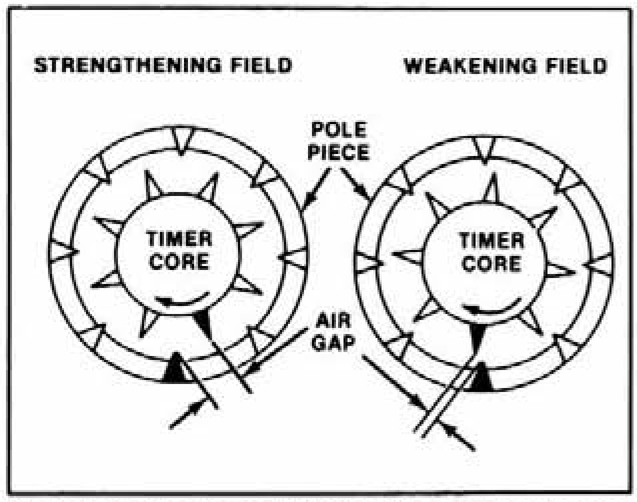


Figure 0·5. Magnetic Field Strength Variation

Current Limiting Circuit

In the past, the transistor was made to operate at a value less than its maximum to protect it from transient voltage and current extremes found in the automobile. These extremes are of short duration but of great magnitude and can be endured by electromechanical devices like switches, motors and contacts without permanent damage. But for electronic devices, even a few milliseconds (thousandths of a second) exposure to voltage and current above its maximum capability may cause failure. By designing the system with enough resistance so that these extremes are within the capabilities of the electronic devices used, these failures were avoided. This is why no available voltage gain was achieved.

To eliminate this problem, a current limiting circuit was added to the HEI module to limit primary current to 5.5 amperes rather than using resistance. This feature allows the electronic device to operate at their maximum value. Since the HEI circuit current is not limited by circuit resistance, the resistance wire was eliminated from the system.

Dwell Control Circuit

For the ignition coil to put out maximum secondary voltage, the maximum primary current must be reached before the primary circuit is broken. In the breaker point system the length of time the primary current is "ON," is controlled by the speed of the breaker cam. This period is called "dwell angle" and is given in the number of degrees of distributor shaft rotation. Most V-8 engines have a dwell angle of 30 degrees before the points open and fire the cylinder. This dwell angle remains the same regardless of engine speed but as engine speed increases, the time the points are closed decreases. This causes available voltage and coil energy to decrease as engine speed increases due to the reduced saturation time of the ignition coil.

When the contact points close, the current does not instantaneously reach a value of 4 amperes but it takes several milliseconds for this value to be reached (Figure 0·6). At 1000 engine RPMs, the distributor shaft rotates once every .12 seconds. Of this time, the points are closed for .010 seconds or 10 ms for every cylinder of an eight cylinder engine. This is sufficient time for the primary current to build up to its maximum current of just over 4 amperes.

When engine speed is increased to 2000 RPM, the time the points are closed for each plug firing is reduced to 5 ms. A duration of 5 ms allows the primary current to build to 3.8 amperes. At an engine speed of 3000 RPM, the duration time drops to 3.3 ms and the current to 3.2 amperes.

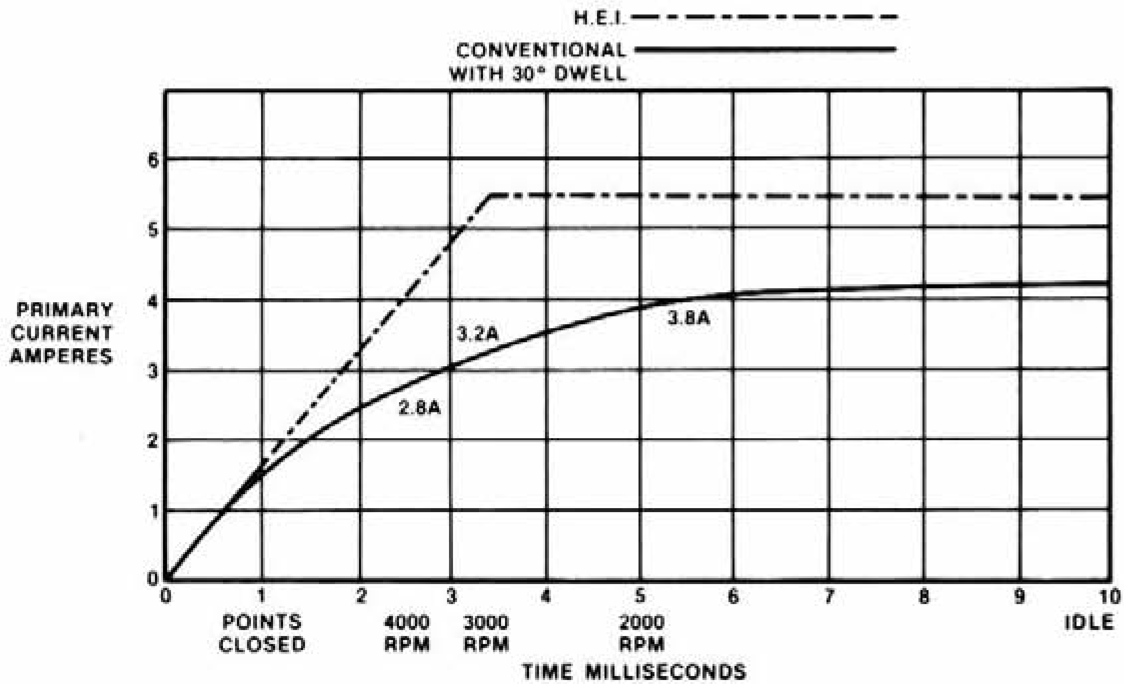


Figure 0-6. Current vs. Time

Two features were incorporated in the HEI system to give it a higher energy level at higher engine speeds.

First, by decreasing the resistance in the primary circuit, the time needed for the current to reach its maximum is greatly reduced. It takes 10 ms for the current to reach maximum in a coil that has a resistance of 2.6 ohms. In the HEI system, the primary winding has a resistance of .5 ohms. This allows full current to be reached in about 3.4 ms.

Because it takes less time to reach full current, coil saturation can be obtained at much higher engine speeds. Also, since the current is much higher in the HEI system, heat generation must be controlled so the module can live. This is done by the dwell control circuit in the module. What this circuit does is electronically sense the primary current to see if maximum current was reached in the last dwell period. If maximum current was reached and no current limiting took place, the dwell period will remain the same. If current limiting did take place, the dwell period will be shortened by turning on the primary circuit later. Since the turning off of the circuit is always at the same time, the dwell period is shorter. If maximum primary current is not reached, the primary circuit is turned on sooner giving a greater dwell period allowing maximum current to be reached.

By using this circuit, the HEI system is able to put out 35,000 volts to speeds above 3000 engine RPM while the conventional ignition system's maximum voltage is reached about 1000 engine RPM and then begins to fall off. Also, by using dwell control to reduce the time that the current limiting is taking place, the operating temperature of the system is reduced, further increasing the reliability and life of the HEI system.

Ignition Coil

So far we have only talked about the magnetic pick-up assembly and the module's role in greater available voltage and energy, but the design and construction of the ignition coil also affects the system's output.

The design requirements for the HEI coil was that it would have a low primary resistance for reasons we have already covered and have a size and shape that may be mounted in the distributor cap.

The primary resistance was decreased by reducing the length of wire used in the primary windings. Resistance of a wire is determined by its length and diameter. As length increases, resistance increases and as diameter increases, resistance decreases. So by reducing the length of the wire used in the primary winding, low resistance is possible with a reasonable wire diameter.

In the oil-filled ignition coil used with conventional ignition systems, the primary winding is wrapped around the secondary winding and the secondary winding is wrapped around the iron core (Figure 0-7). The HEI coil has the secondary winding wrapped around the primary winding and the primary winding is wrapped around the iron core. The HEI coil is not oil filled, the windings are covered in an epoxy compound for protection against moisture and arc-over within the coil.

The inductance values of the primary and secondary winding are also different in the HEI coil. Inductance of a coil is the ability of the coil to induce a counter-voltage while carrying an increasing or decreasing current (self-induction). This counter-voltage works against the changing current trying to keep the current wire from changing and is a limiting factor on the maximum output of a coil. The increased secondary inductance provides a higher voltage and a longer spark duration than the conventional system.

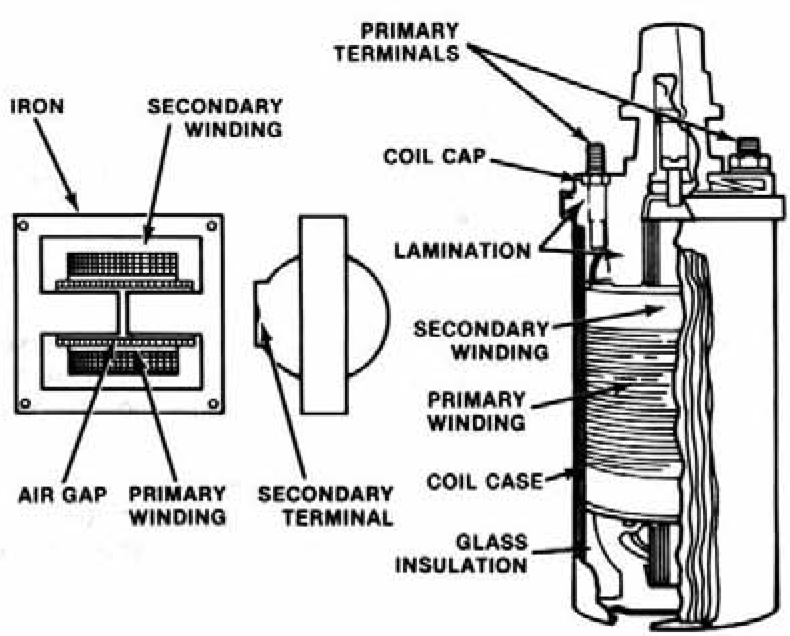


Figure 0-7. Conventional and HEI Ignition Coil Construction

The HEI system was developed as an integrated package that combines the distributor, magnetic pick-up, ignition coil and electronic module into one package. By doing this, these components are well-protected from physical and environmental abuses and the number of electrical connections are reduced.

There are some models that use a remotely mounted coil. This coil is constructed the same as the integral coil with the exception of a mounting bracket and a terminal for the connection of a high tension lead. These models are used on most in-line engines where additional clearance was needed.

The size of the distributor was increased due to the wide spacing that must exist between the distributor cap inserts to prevent high-voltage arc-over (Figure 0-8). A wider spacing was also needed between the cap inserts and the distributor housing to prevent arc-over and leakage to ground.

The higher voltage output of the HEI system required new insulation materials. To prevent ignition failure due to carbon tracking, a special material is used for the distributor cap and rotor. It is a thermoplastic, injection-molded, glass-reinforced polyester. This material provided the dielectric and insulation properties needed and also prevented carbon tracking.

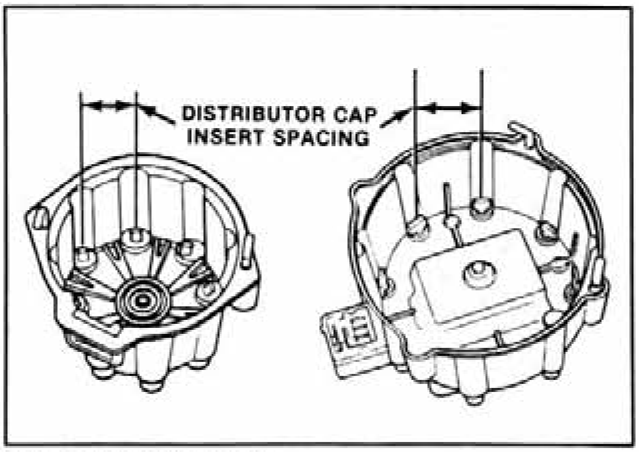


Figure 0-8. Cap Size

The high voltage terminals used in the distributor cap are similar in appearance to spark plug terminals. These connections provide easier attachment and better sealing of the connection. Latches are used to ensure proper connections of the plug wires to the cap and prevent any loosening or movement which might reduce the moisture protection of the connection.

The spark plug wires are a carbon-impregnated cord conductor encased in an 8 millimeter diameter silicone rubber jacket. Silicone wiring will withstand very high temperature and is an excellent insulator for the higher voltages.

Silicone is soft, pliable, and therefore, more susceptible to scuffing and cutting. It is extremely important that the spark plug cables be handled with care. They should be routed so as not to cross each other, or to be in contact with, other parts of the engine to prevent rubbing.

Centrifugal and Vacuum Advance

Early HEI distributors used a centrifugal advance and vacuum advance system. These systems operate in much the same way they did on the conventional distributor, compensating for engine speed and load. This is done so that maximum pressure is exerted on the top of the piston as soon as the rod passes top dead center.

The weights in the centrifugal advance move against spring tension as engine speed increases. This motion of the weights turns the timer core assembly so that the timer core is rotated in the direction of shaft rotation (Figure 0-9). The teeth on the timer core will now align with the pole piece teeth sooner, signaling the module to "fire" sooner.

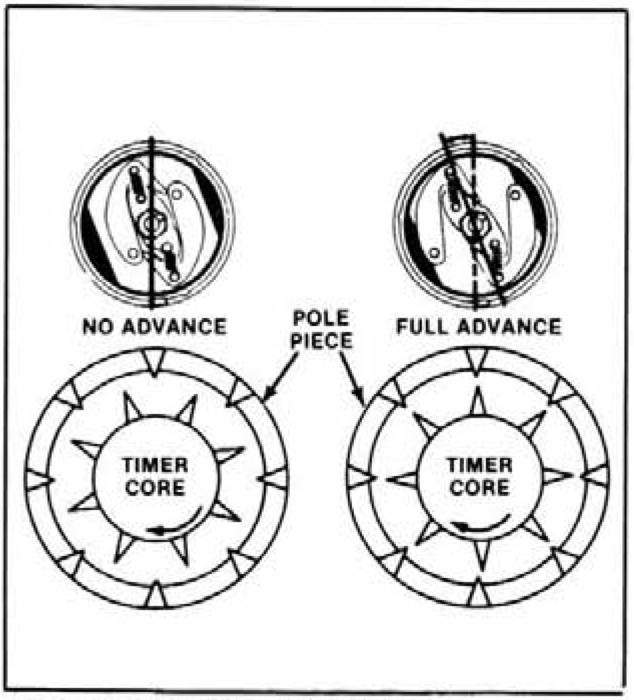


Figure 0-9. Centrifugal Advance

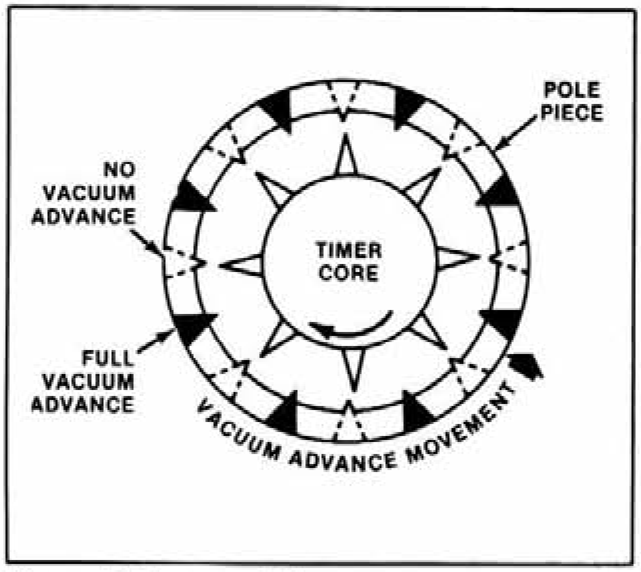


Figure 10. Vacuum Advance

The vacuum advance uses engine vacuum to move a spring loaded diaphragm which is connected by a connecting rod to the bottom plate of the magnetic pick-up assembly. The magnetic pick-up assembly is mounted over the main bearing on the distributor housing so it is able to rotate. When a vacuum signal is applied to the diaphragm it moves against spring pressure pulling the connecting rod with it. This movement causes the magnetic pick-up assembly (pole piece) to rotate in the cpposite direction of the distributor shaft (timer core) rotation (Figure 0-10). This causes the pole piece teeth to align sooner with the timer core teeth signaling the module to "fire" sooner.

HEI Models

There are two basic HEI distributors used. One has an integral ignition coil mounted in the distributor cap. This model is used on all V-8 and V-6 engines. The V-6 distributor differs from the V-8 not only in the number of secondary wire terminals but that they are unevenly spaced and have extended contacts on the inside of the cap. These features are necessary to meet the requirements of the V-6's unique firing sequence. Unlike the L-6 engine which fires every 60 degrees of distributor rotation, the V-6 fires alternately at 45 degrees and 75 degrees. A unique timer core and pole piece is also necessary in this distributor (Figure 0-11). The V-6 has three evenly spaced teeth on the timer core and six alternately spaced at 45 degrees and 75 degrees on the pole piece. On the other engines, the pole piece and timer core have the same number of teeth and are evenly spaced.

The second type HEI distributor uses a remotely mounted ignition coil (outside of the distributor) which is similar in appearance to the coil used with the integral unit (Figure 0-12). Since the ignition coil is not mounted inside the distributor, these units are slightly shorter than the V-6 and V-8 models and use a few more wires to connect the ignition coil to the distributor.

The number of teeth on the pole piece and timer core reflects the number of cylinders in the engine that it is to be used on (four teeth for four cylinders and six teeth for six cylinders).

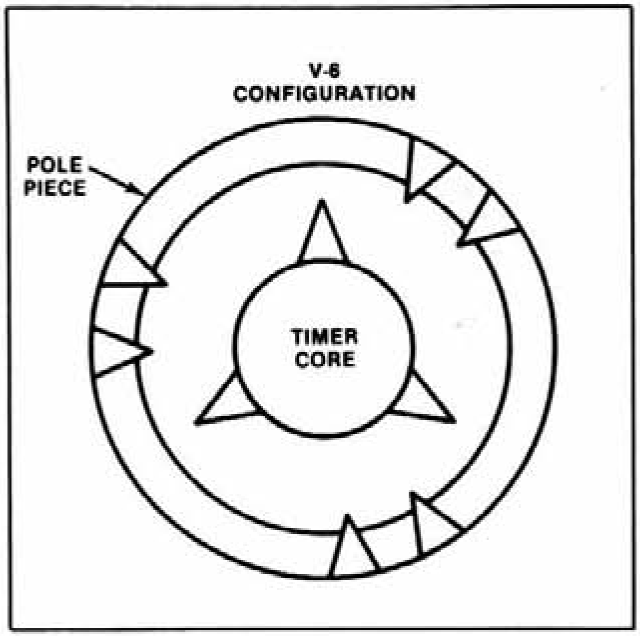


Figure O-11. V-6 Timer Core and Pole Piece

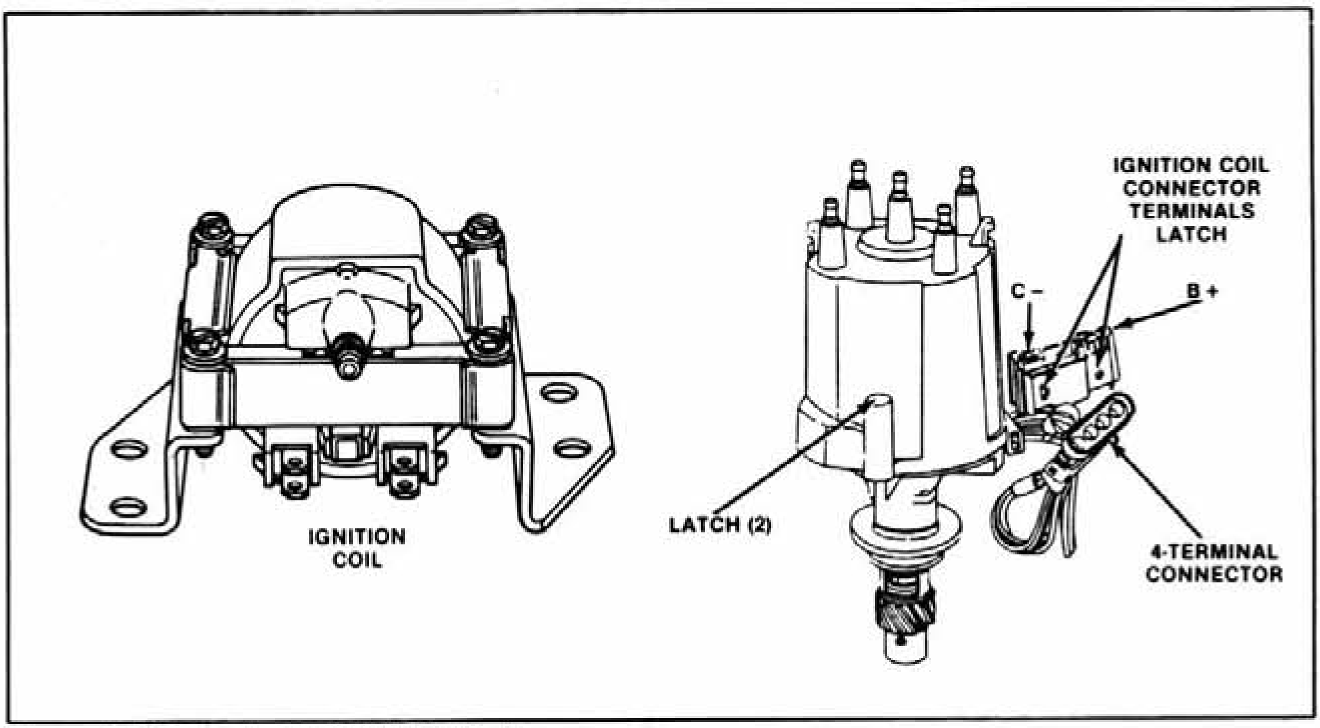


Figure O-12. Remote Coil HEI Distributor

Although there are minor differences between applications, all HEI systems operate the same.

Part Identification

As stated earlier, there are minor differences between applications to tailor the HEI system to each vehicle line. Besides the physical differences necessary to mount the distributor to the various engines, there are three different ignition coils and three different pick-up coils used.

Pick-Up Coils

Two of the coils have opposite magnetic polarity to be used with the ignition coil of the same magnetic polarity. Opposite magnetic polarity pick-up coils are needed because of the under hood relationship of the distributor location to the starter and battery cable. During starting, magnetic fields are created. The pick-up coil can be affected by these magnetic fields and give false "turn on" and fire signals to the module causing engine misfire. By using a pick-up coil of proper magnetic polarity, the external magnetic fields will not affect the pick-up coil in such a way as to give a false "turn on" or "fire" signal to the module.

The third pick-up coil has the same polarity as one of the other coils, but it has longer leads, which are necessary in its application. Pick-up coils can either be identified by the color of the plastic tie around the leads or by the color of the plastic connector at the end of the leads (Figure 0-13). The pick-up coil will use either the plastic tie or the connector, not both.

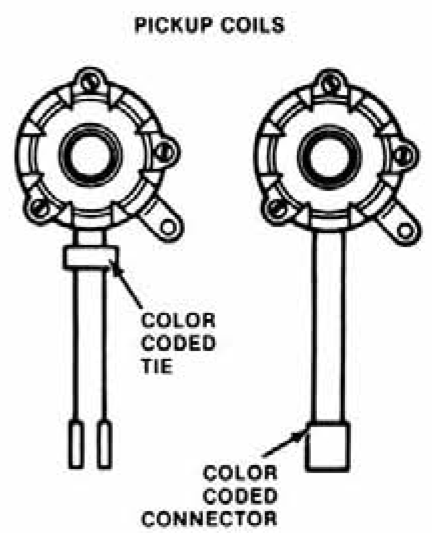


Figure 0-13. Pick Up Coil Identification

The pick-up coil is not serviced separately but as an assembly with the bottom plate, pole piece and permanent magnet. This assembly, called the "pole piece and plate" in the parts book, should not be disassembled because the pole piece is centered around the axis of the distributor shaft during production. This sets the clearance between the teeth of the pole piece and timer core.

There are seven different pole pieces and plate assemblies available. The correct part number of the pole piece and plate assembly for a particular vehicle should be determined from the appropriate parts book. The part number of a pole piece and plate assembly can be determined by visual inspection by the colored ties or connectors and the number of teeth on the timer core and pole piece. The following is a list of pole piece and plate assemblies by pick-up coil color code.

Blue Tie or Black Connector Body
- 1876210 (V-8)
- 1891209 (V-6)
- 1880020 (L-4)

Yellow Tie or Yellow Connector Body
- 1875981 (V-8)
- 1880040 (L-6)
- 1892175 (L-4)

Clear Tie or Clear Connector Body
- 1876495 (V-8)

Yellow Connector
- 1894237 V-6 (200 CID)

Black Connector
- 1893894 V-6 Even Fire (196 and 231 CID)

Coil Identification

One type of coil is used for remote coil applications (Figure 0-14). The remote coil can be easily identified by its mounting brackets and the high tension terminal.

There are two types of coils that are integral with the distributors. They can be identified by the different color "tach" leads and the part number stamped on the coil as shown in Figure 0-15.

The coil with the yellow "tach" lead (#1875894) is used on all Cadillac (except Seville), Chevrolet and Oldsmobile Toronado V-8 engines.

The coil with the white "tach" lead (#1876209) is used on all Buick, Oldsmobile (except Toronado), Pontiac and Cadillac Seville V-8 engines and all V-6 engines.

These two coils are very similar in appearance, perform identically, can be installed in any integral coil distributor, but are of opposite magnetic polarity. This was done to match the high tension coil to the magnetic pick-up coil. The misapplication of these coils can cause hard or no starting and/or backfiring while cranking.

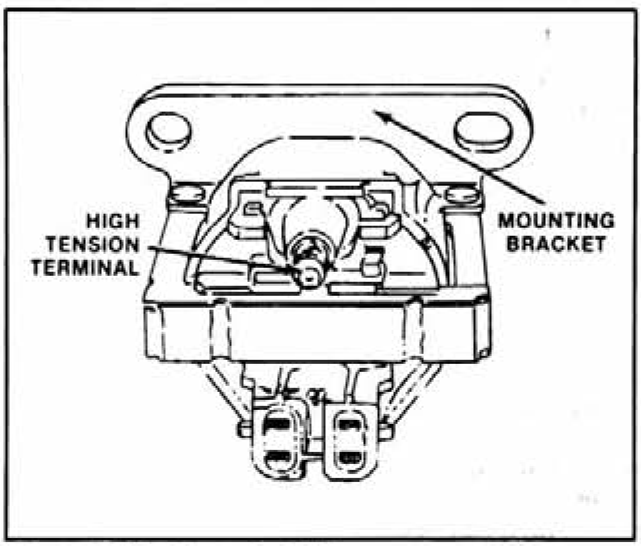


Figure 0-14. Remote Coil

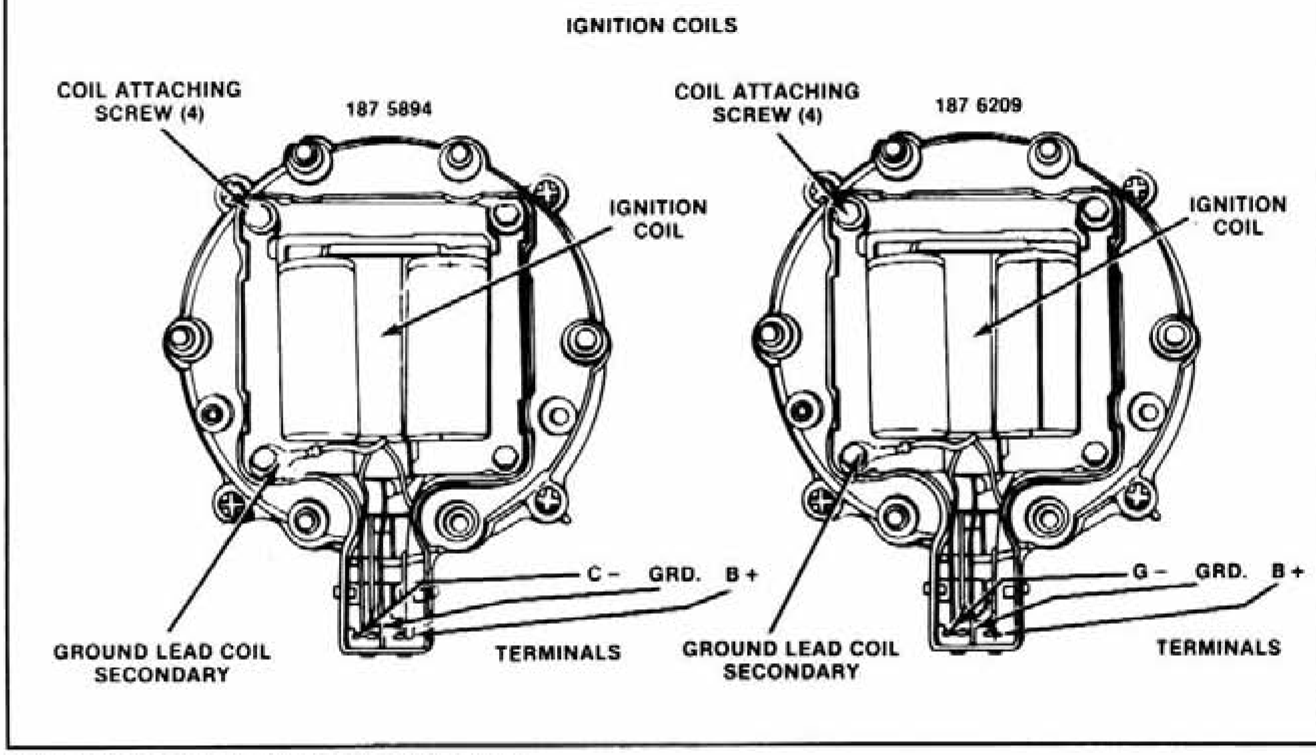


Figure 0-15. Ignition Coil Identification

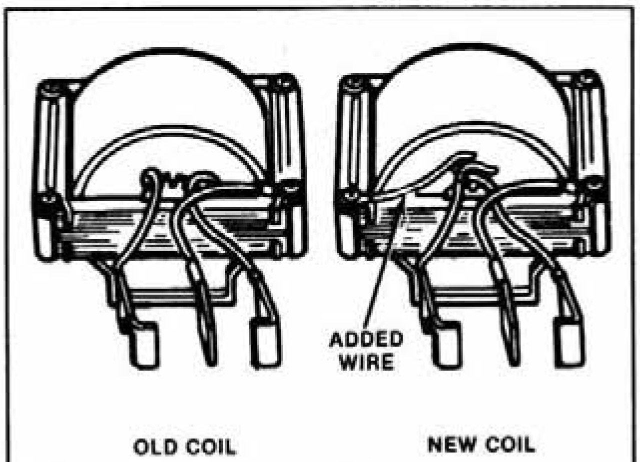


Figure 0-16. Ignition Coil Change

In addition to the three coils already mentioned, the internal coil had a design change during the 1975 model year. The original coil had the secondary winding connected to the primary winding internally to provide a ground to complete the secondary circuit. The second design coil uses an additional eternal wire to connect the secondary winding to the iron frame of the ignition coil (Figure 0-16). The frame was already grounded on the original coil to bleed off any charge that may accumulate on the frame and now is also the ground for the secondary. This new coil design results in complete isolation of the secondary circuit from the primary circuit.

First and second design coils are interchangeable as long as they are of the same polarity.

Electronic Spark Timing (EST)

An improved ignition coil and distribution system is used with the 2.8L engine (Figure 0-17). The 80 mm (3.15 in.) distributor and high efficiency ignition coil are smaller in size and lighter in weight. Reliability was increased while maintaining the high energy performance and functions of a larger component. The inherent reliability of the new distributor is enhanced through simplicity of design by providing multifunction components wherever possible and by using weatherproof connectors at the electrical interfaces.

The high energy ignition coil is more compact, lighter in weight, and is designed for remote mounting. The size and weight reduction was possible by using new lamination material that allowed a substantial reduction in the cross-sectional area without compromising performance.

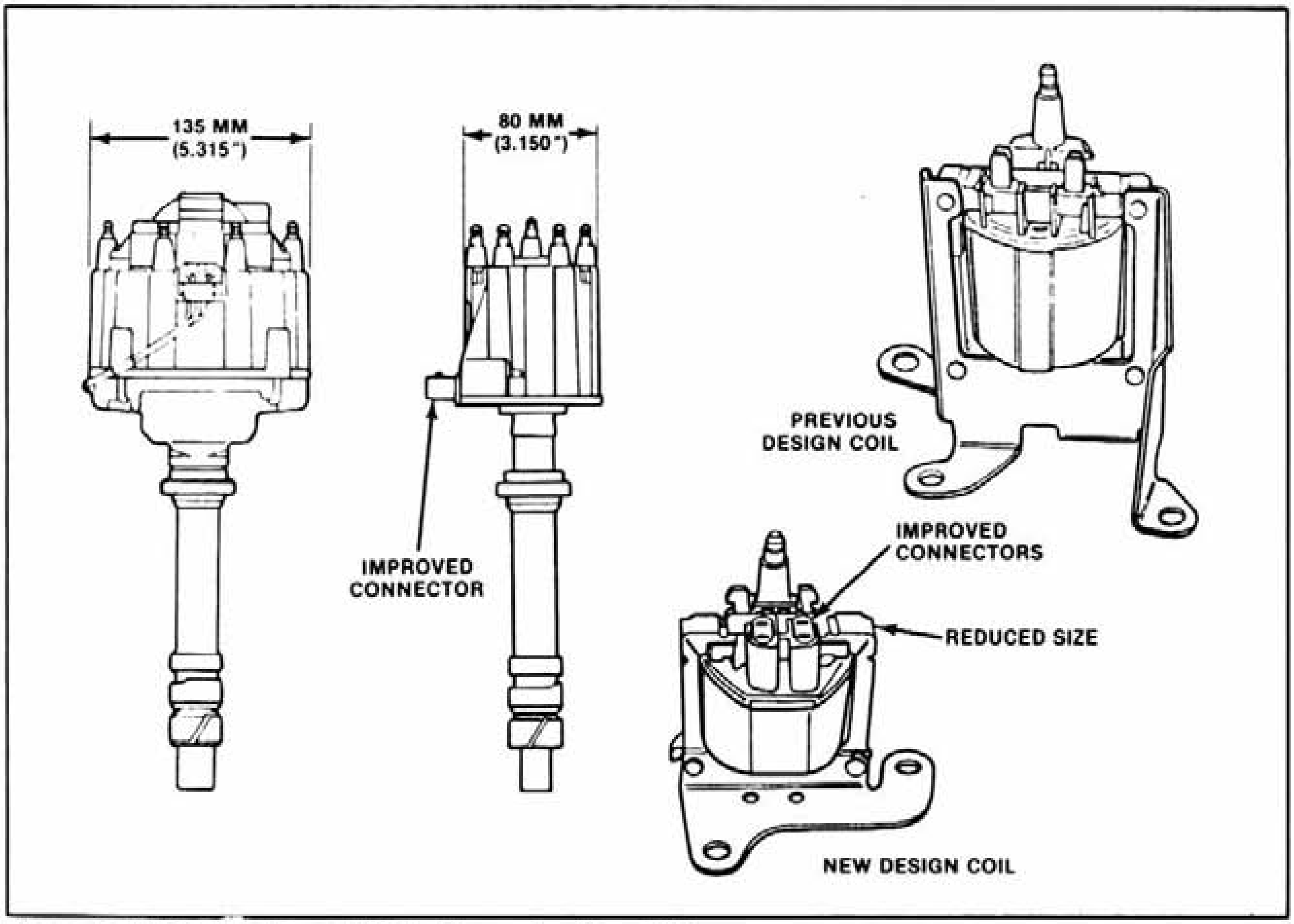


Figure 0-17. Distributor and High Energy Ignition Coil

Ignition Coils (Internal)

1875894 (Straight Wires)
- Cadillac (except Seville)
- Chevrolet and GMC
- Oldsmobile Toronado and GMC Motor Home

1876209 (Crossed Wires)
- Buick
- Oldsmobile (except Toronado)
- Pontiac
- Seville by Cadillac

Special D1-Electric Heat Transfer Compound for bottom of module and wires or:
— D1920 (Delco) 3 oz. tube
— Dow Corning Compound 5
— GM—1974984
— General Electric—G642
— Dow Corning—341

As the timer core turns inside the magnetic pick-up, its triangular points pass very close to the magnet's points. When this happens, a small voltage is generated and sent to the HEI module (Figure 0-18).

The voltage signal coming from the pick-up coil is alternating current. The little computer used is like any other microprocessor and will not work with alternating current.

Inside the module is a converter that changes the voltage to direct current and a square wave. The ECM is well-suited to function in the HEI system.

HEI eliminates the point set to keep better pace with engine speed. HEI will not wear or change timing, and it provides more voltage to the spark plugs.

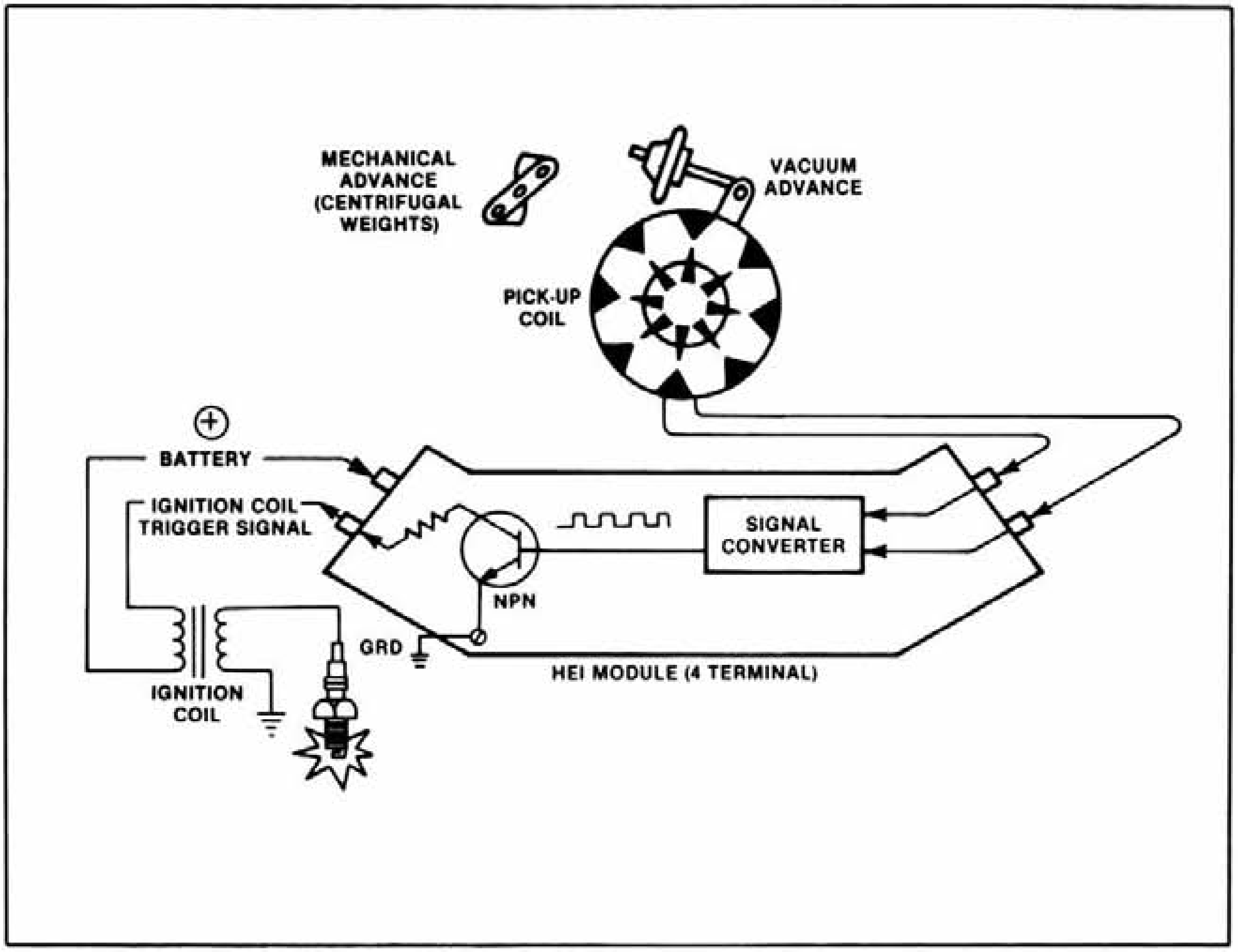


Figure 0-18. HEI Ignition System (4-Terminal)

The colored wire tie used in 1975 HEI pick-up, to identify their application, will be changed in 1976. A connector on the wire terminals will be the key to application as follows:

Black connector (Replaces blue tie)	Clear connector	Yellow connector
V8 Olds (except Toronado)	V8 Pontiac	V8 Chevrolet, Cadillac, Olds Toronado
V8 Buick		Inline 6 cylinders
V6 and 4 cylinder engines		

The purpose of these various pick-up windings is to hold in the suppression of radio interference generated by the HEI system.

The HEI distributor cap will no longer have a separate replaceable center carbon button. This button will now be pressed into the cap. This was changed due to spinning of the old style.

When the HEI distributor is removed from the engine for service such as pick-up replacement (the weak link in Delco system), a small drill mark will be found on the drive gear. When you reassemble the distributor, make sure the drill mark is aligned under the rotor tip or the distributor becomes 3^{o} out of phase. This applies to <u>all</u> Delco distributors.

Starting in late 1977 the small ground wire from the coil core has been replaced by a bent metal strap. This change required the use of a modified distributor cap, meaning the old wire will fit the new cap but the new metal strap cannot be used in an old cap.

As a running change during 1978 a new type of H.E.I. wiring harness is used. This new harness eliminated the condensor wire thus lowering the distributor generated R.F., (radio frequency) noise.

Also during late 1978 a new super dielectric white rotor was introduced as a replacement for the black rotor. In addition to increased arc over strength to prevent burn thru, the rotor tip is coated with a silicone varnish to reduce R.F. noise. This silicone varnish is used in place of silicone grease as is used by Ford.

General Motors is also in the process of introducing a new replacement distributor cap center carbon button. The new button is made of a higher strength, denser, carbon and the cap end is copper coated.

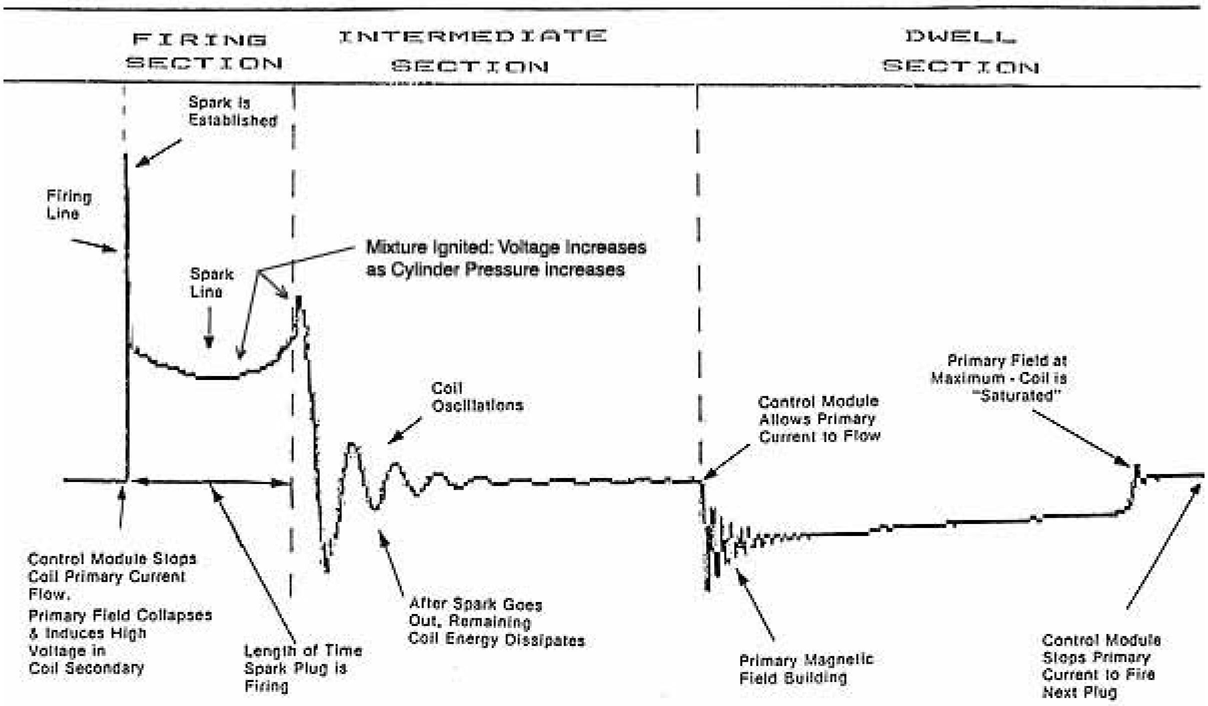
H.E.I. DIAGNOSTIC HINTS

When looking for an intermittent misfire on General Motors H.E.I., which is not caused by secondary ignition problems, be sure, in addition to ohm meter tests of the pick-up coil while actuating the vacuum advance, to check for:

Poor crimpling of the pick-up coil leads at terminals - in some cases the terminal is attached more to the wire insulation than to the conductor.

A loose fitting terminal on the module - if this is found, simply bend the sides inward to tighten it.

Ozone oxidation of the module terminals can also cause an intermittent misfire. This is caused as a result of the ozone created by the high voltage arc between cap segments and rotors. If the module terminals are dark in color, sand them clean and apply a coating of Vaseline to the terminals. This is a good idea in any case according to AC-Delco.


FIRING SECTION
INTERMEDIATE SECTION
DWELL SECTION
Spark is Established
Firing Line
Spark Line
Mixture Ignited: Voltage Increases as Cylinder Pressure Increases
Coil Oscillations
Control Module Allows Primary Current to Flow
Primary Field at Maximum - Coil is "Saturated"
Control Module Stops Coil Primary Current Flow.
Primary Field Collapses & Induces High Voltage in Coil Secondary
Length of Time Spark Plug is Firing
After Spark Goes Out, Remaining Coil Energy Dissipates
Primary Magnetic Field Building
Control Module Stops Primary Current to Fire Next Plug