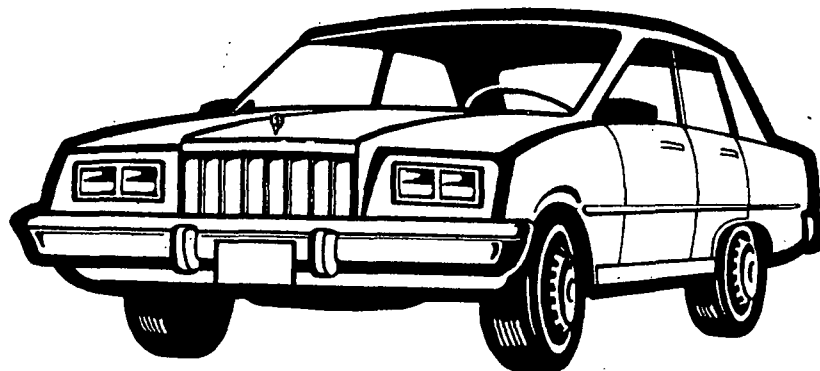




UNDERSTANDING AUTOMOTIVE SYSTEMS



4. ELECTRICAL & IGNITION

SCF-NAPA-2203

UNDERSTANDING AUTOMOTIVE SYSTEMS

4. ELECTRICAL & IGNITION

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FOREWARD

This program was conceived and produced by NAPA manufacturers as a part of their efforts to maintain the high standard of product knowledge and helpfulness to the customer that has characterized NAPA for years. The following NAPA manufacturers have made substantial contributions to the production of this manual: Echlin, NAPA Batteries, Rayloc, NAPA Lamps, NAPA/Champion Spark Plugs, NAPA Exhaust, Belden, and NAPA Filters.

When you complete this course you should know about each of the important systems on a car, basically how it works and how it is kept in good repair. This part of the study course deals with the electrical, fuel

and emission systems, their components and what is needed to maintain them. When you've worked your way through this manual, you'll be able to recognize the parts of each of these systems, and you will have important information about things you should consider in their repair and maintenance.

As you read through the manual you'll notice that the material is presented in two different kinds of type. The material in this type is of a more general nature and is important to anyone who wants to know about the system. The material in lighter type (*like this*) is more technical and usually deals with topics such as problems and solutions and installation procedures.

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OBJECTIVES:

When you have completed this chapter, you should be able to:

- Explain the functions of the electrical and ignition system, the fuel system, and the emissions system.
- Explain how the three systems work together and are dependent upon each other.
- Define common electrical terms such as conductor, semiconductor, insulator, volt, ohm, and three major types of circuits.

The gasoline internal combustion engine is extremely complicated. There are hundreds of interrelated parts and dozens of systems in the engine that work together to power an automobile efficiently and smoothly.

The key to the operation of the engine is the precise fit and timing of these parts, because if any of them does not perform its task at precisely the right moment, engine efficiency or power will suffer. At the heart of the process of timing in the engine is the electrical and ignition system.

The engine's fuel system mixes air with gasoline in the exact proportions needed for complete combustion. Through a precisely timed system of valves, this fuel-air mixture is delivered to the cylinder at the appropriate time during the four-stroke cycle of the engine.

The electrical and ignition system then delivers a perfectly timed spark to ignite the fuel-air mixture in the cylinder. The exact timing of this spark obviously has an effect on the power the engine produces. If it comes too early or late, combustion will be incomplete or less mechanical advantage will be derived from the explosion of fuel in the cylinder.

These are not the only effects, however. Changing the timing of the spark can increase or decrease certain types of undesirable emissions from the engine. It can reduce or increase the power the engine generates during acceleration, and it can also affect the miles per gallon the automobile gets.

There are many other functions that rely on the electrical and ignition system as well. In fact, a wide variety of engine operations depend on a properly functioning electrical and ignition system. A close examination of this system will

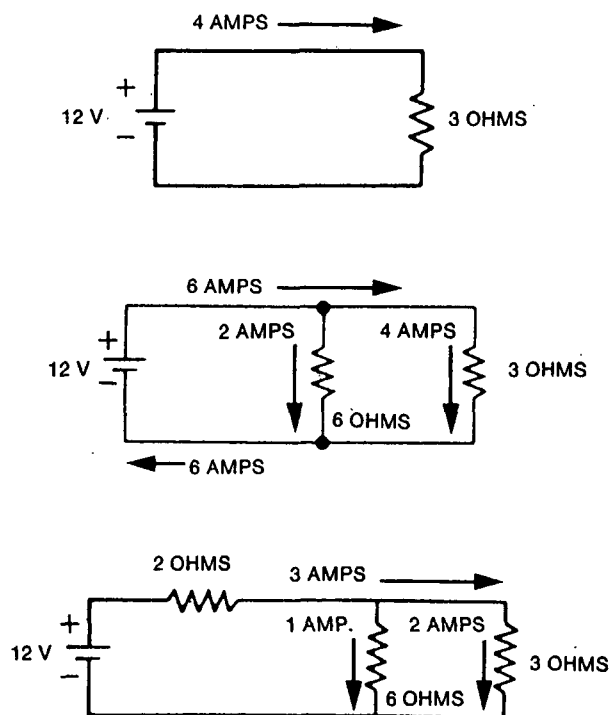
naturally require us to look at the other systems that are closely interconnected with it; so in this section of Understanding Automotive Systems we'll also take a look at the fuel system and the emissions system.

Before we go into the electrical and ignition system, however, let's take a look at some basic electrical principles.

BASIC ELECTRICAL PRINCIPLES

As you probably already know, the materials in electrical systems are usually either conductors or insulators. A conductor is simply a material that permits a flow of electrical current, while an insulator is a material that inhibits the flow of electrical current.

In modern electrical and ignition systems, you'll also run into materials that are semi-conductors. Often used in transistors and integrated circuits, semi-conductors permit the flow of electrical current only under certain conditions, which makes them useful in certain types of control systems.

Electrical Circuits

(Figure 1) Series, Parallel, and Series-Parallel Electrical Circuits.

An electrical circuit is a complete path from the energy source, through wires and electrical loads, and back to the source. A complete circuit is necessary for current to flow.

There are two theories of electric current flow. The conventional flow theory says that current flows from positive to negative, while the electron current flow theory says that current flows from negative to positive. While either theory can be used to describe current flow, automotive industry test equipment is based on the positive-to-negative conventional flow theory.

Electric current flows in three basic types of circuits: series, parallel, and series-parallel. In a series circuit, there is only one current path with several loads on it. In parallel circuits, there are as many current paths as there are loads. As you might expect, the series-parallel circuit is a combination of both series and parallel circuits.

Ampere: A measure of electrical current.

Volt: A measure of the force or "pressure" behind an electrical current.

Ohm: A measure of electrical resistance to current flow.

(Figure 2) Electrical Terms.

A simple law—Ohm's Law—defines the relationship between volts, current, and resistance and is very useful in troubleshooting problems in the electrical system. Ohm's law says that when one volt forces one ampere of current through a circuit, one ohm of resistance is present. Mathematically, it looks like Figure 3.

$$\text{Voltage (E)} = \text{Current (I)} \times \text{Resistance (R)}$$

$$\text{Current (I)} = \text{Voltage (E)} / \text{Resistance (R)}$$

$$\text{Resistance (R)} = \text{Voltage (E)} / \text{Current (I)}$$

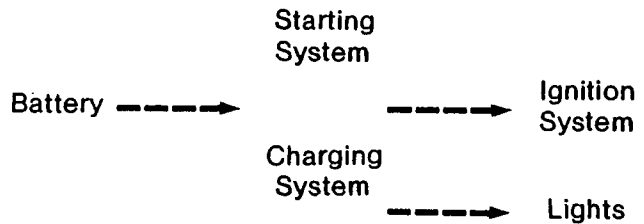
(Figure 3) Ohm's Law.

But how do we get an electrical current in the first place? One way is to turn a coil of wire into a magnetic field (as in an alternator or generator). The strength of the voltage depends on the strength of the magnetic field, the speed of the

motion, and a number of other factors.

Another way to create a current is by means of a chemical process in a battery. The battery and the charging system are components common to both the ignition and electrical systems, and in the next chapter we'll take a closer look at them.

ELECTRICAL AND IGNITION SYSTEM



(Figure 4) Electrical and Ignition System Flow-chart.

The electrical and ignition system could easily have been considered as two closely related but separate systems. Although there are separate chapters in this manual to examine them in detail, we still consider them to be one system since they share a number of common components such as the battery and alternator (or generator), and because they also encompass all the electrical functions of the car.

The purpose of the electrical and ignition system is to start the engine, ignite the fuel in the cylinders, charge the battery, and provide power to operate accessories such as lights, radios, and power windows and door locks.

In recent years, many new items have become a part of the electrical and ignition system—even computers. These advances have helped make engines more fuel-efficient and clean-burning, and the automobile itself safer and more comfortable. We'll go into the various parts of the electrical and ignition system in the next two chapters.

FUEL SYSTEM

Basically, the purpose of the fuel system is to mix gasoline with air and deliver the fuel-air mixture to the cylinders. This is not quite so simple as it might sound, however, and along the way a number of things must be taken into consideration.



(Figure 5) Fuel System Flow-Chart.

Cleanliness is critical to the efficient operation of the fuel system. There are filters in the gasoline line to prevent dirt and other contaminants from passing from the gas tank to the engine. There's also another filter to remove particles from the air before the air is mixed with the gasoline.

Mixing exactly the right amount of air with the fuel is also essential. The fuel system might best be called the "fuel-air" system, because the gasoline must be mixed with air before it can burn in the cylinders of the engine. This occurs in the carburetor, which is one of the most intricate pieces of equipment in the entire automobile.

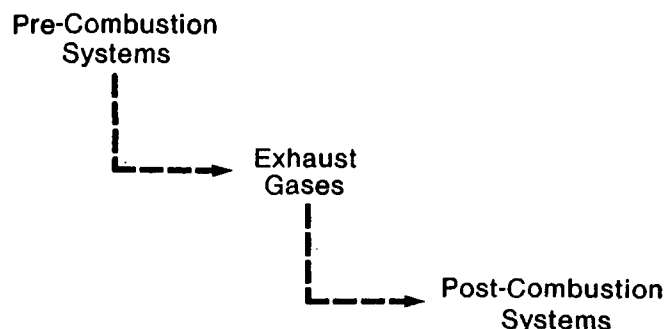
The carburetor has already been covered in considerable detail in the Engine module of Understanding Automotive Systems. In Chapter 4 of this manual, we'll review the carburetor briefly and explain the operation of the rest of the fuel system.

EMISSION CONTROL SYSTEMS

Back when there were few cars on the road, the gases emitted by automobile engines were not nearly the factor in air pollution that they are today. Unburned hydrocarbons (that is, gasoline vapor), carbon monoxide, and oxides of

nitrogen all cause various problems when they're emitted into the atmosphere.

Modern engines, however, have been designed with a number of systems to reduce the emission of these harmful gases, and some of these systems are closely tied into the electrical and ignition system. Again, these have been covered in detail in the Engine module, but will be reviewed later in this section as well.



(Figure 6) Emission Control System Flow-Chart.

SUMMARY

In this chapter, we reviewed the interrelatedness and function of the ignition and electrical system, the fuel system, and the emissions system. A brief overview outlining the purpose of the three systems was presented, and engine timing was discussed as one of the key reasons for relating these three systems together.

We also took a look at some basic electrical principles that will be helpful in understanding the operation of the electrical and ignition system.

Notes

OBJECTIVES:

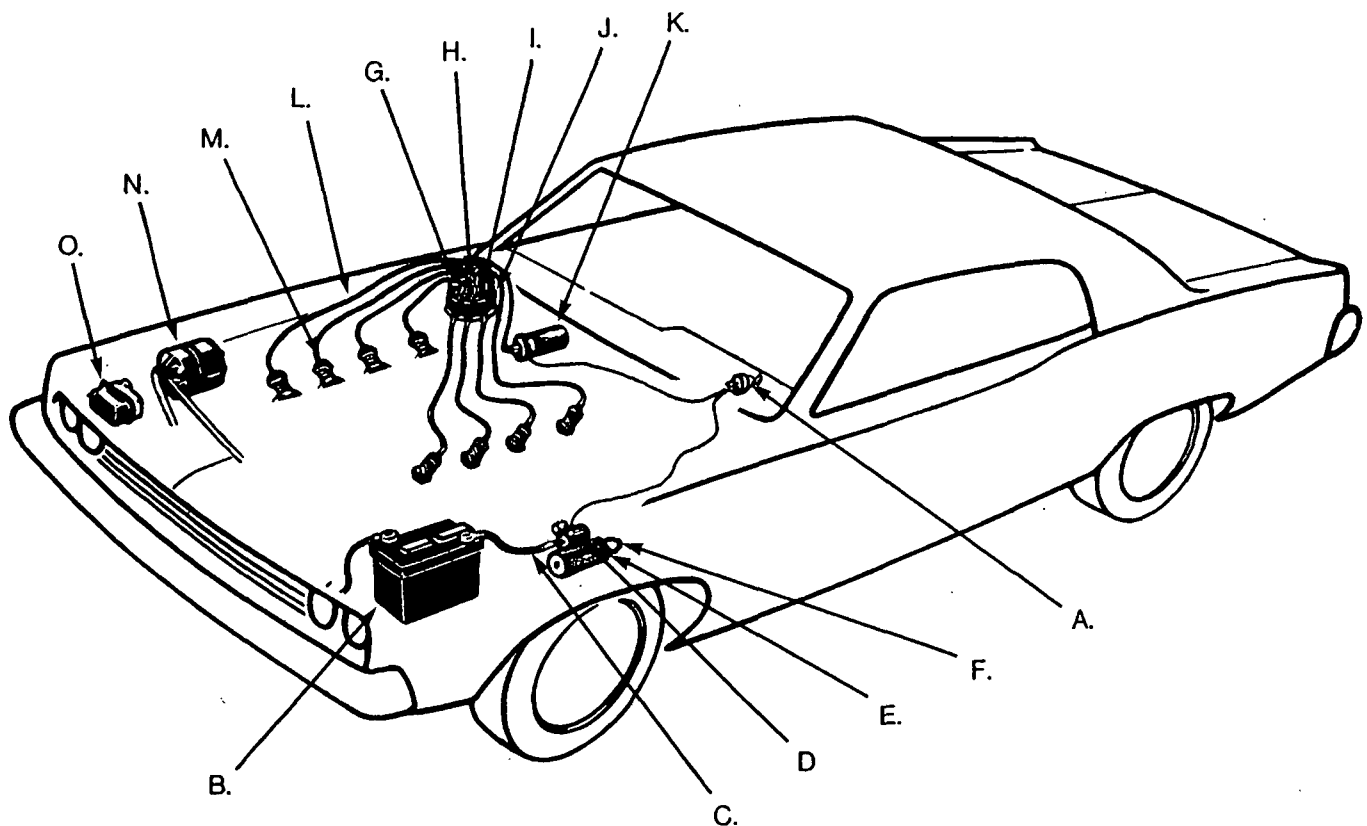
When you have completed this chapter, you should be able to:

- Label each of the major parts of the electrical system on a diagram and explain its function within the system.
- Explain the basic chemical reactions that take place inside a battery and how each part of the battery contributes to them.
- Identify the lights and accessories found on most late-model cars.

The specific components of the electrical and ignition system have changed dramatically over

the years. Even so, the major functions of those components have remained much the same.

- The battery, with the associated cables and charging system, is needed to store electrical energy.
- A starter motor is used to get the engine turning.
- An ignition system delivers a precisely timed spark to the cylinder to burn the air-fuel mixture.
- Lights and other electrical accessories add to the safety and comfort of the automobile.



- | | |
|----------------------------|----------------------|
| A. IGNITION SWITCH | H. CONDENSER |
| B. BATTERY | I. ROTOR |
| C. BATTERY CABLE | J. DISTRIBUTOR CAP |
| D. STARTER SOLENOID SWITCH | K. IGNITION COIL |
| E. STARTER | L. SPARK PLUG WIRES |
| F. STARTER DRIVE | M. SPARK PLUGS |
| G. CONTACT SET | N. ALTERNATOR |
| | O. VOLTAGE REGULATOR |

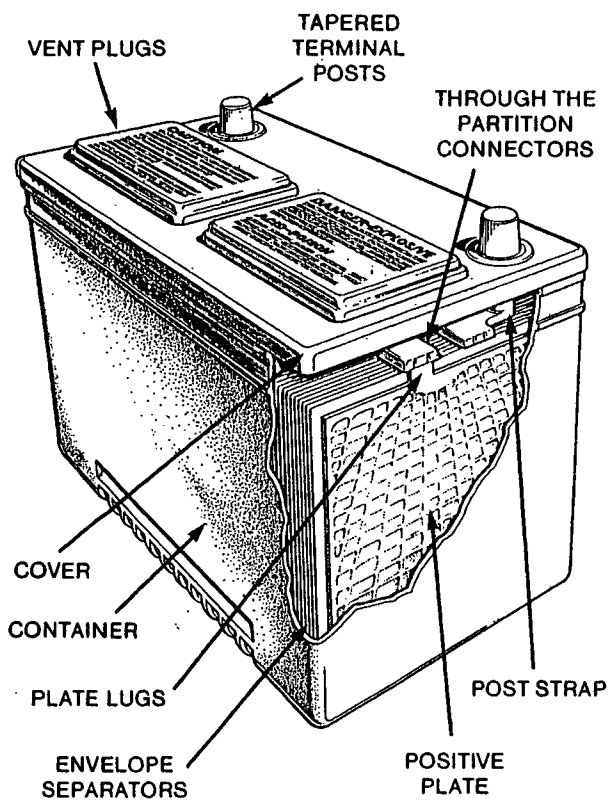
(Figure 7) The Automotive Electrical and Ignition System.

THE BATTERY

The typical automotive lead-acid storage battery stores electrical energy in chemical form and releases it when required by the automobile. It supplies the energy to drive the starter motor, and powers the ignition system when the car is starting. If the charging system fails, the battery may be called on to provide all the electricity needed by the car.

Unlike most of the smaller batteries that power flashlights and toys, an automotive battery is rechargeable. The energy that's "taken out" of the battery can be "put back in" by the car's charging system.

How A Battery Works



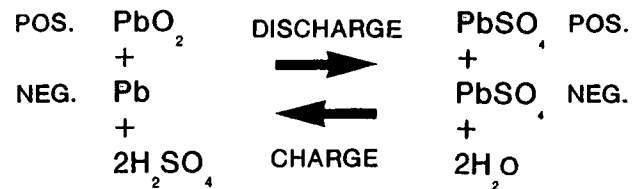
(Figure 8) Interior of a Battery.

The backbone of a storage battery is the grid, a framework that supports the electrically active material in the battery, which is arranged in plates. The grid supports both positive and negative active material, and provides a conductor path from the plate terminals where the cables are connected.

The primary ingredient of the active material is lead, although positive plates and negative plates are made with a slightly different formulation. Positive and negative plates are alternated, with separators placed between them for insulation, to form a cell. A connection is made between all the positive plates and between all the negative plates in each cell of the battery.

Each cell can produce a maximum of 2.1 volts. These cells are welded together in series to create a battery of the desired voltage. A 6-volt battery, for example, has three cells, and a 12-volt battery has six cells.

Once all the battery cells are welded together and placed in the battery case, the electrolyte, or acid, is added. Then the battery is given its initial charge, which establishes its electrical performance. During this process, the positive and negative plates undergo a chemical reaction that changes the active material into lead dioxide and lead respectively, storing up the electrical energy in a chemical form.



(Figure 9) Chemical reactions within a lead-acid storage battery.

When the battery is in use and discharging, the positive and negative active material tend to become more similar, reacting with the sulfate in the acid to form lead sulfate. Then as the alternator recharges the battery in the car, it again stores up electrical energy converting the active material back to lead dioxide and lead.

Types of Batteries

Batteries fall into three general categories: wet, dry-charged, and moist-n-charged.

Wet batteries are delivered complete from the factory, full of electrolyte and already charged. The biggest advantage of the wet battery is that it can be installed without having to add electrolyte. The disadvantage, however, is that it has

a shorter shelf life than dry-charged batteries and it must be monitored carefully to make sure it doesn't lose its charge.

Dry batteries are manufactured with charged plates but are not filled with electrolyte. Although they cannot be pretested at the factory, they have a long shelf life. At the time of installation, acid is added and the battery has to be charged.

Moist-n-charged batteries combine features of both systems. During manufacture, acid is added and the battery is charged and tested. Then the acid is drained and the battery sealed, leaving the plates moist and charged until it is sold. Shelf life is excellent. Acid has to be added at the time of installation, but usually the battery will not require a boost charge before it's used.

Battery Terminals

The most common battery terminal type has been the standard S.A.E. post. General Motors introduced side-terminal batteries several years ago, claiming they would corrode less since they are shielded and away from the top of the battery where gases accumulate. Special care must be taken on side terminal batteries not to overtighten the lugs, as they are more prone to breakage than S.A.E. posts. Use a torque wrench designed for side terminals.

Specialty batteries may be equipped with a low profile "L" terminal. This design saves room in tight-fit situations and provides a more sturdy fit for rough applications like snowmobiles and garden tractors.

The most versatile post is a combination S.A.E. post and the stud terminal. This terminal was designed for easy servicing of batteries that are often removed for recharging, such as marine batteries. The combination design can be used with several types of cables.

Deep Cycle Batteries

An automotive battery is asked only to give a short burst of energy before the alternator takes over, recharging the battery and providing current to the engine. Deep cycle batteries, however, are especially designed to go through many deep discharges, sometimes drained to practically nothing before being recharged. Such batteries are commonly used to power golf

carts, motor home electrical systems, trolling motors, and for other marine uses.

Deep cycle batteries use thicker grids and alloys that tolerate the deep cycling better than plates used in "regular" batteries. An automotive battery, for example, might go through 50 to 75 deep discharges and charges before it stops accepting a charge. Only the first 15 to 20 of these cycles would recharge back to a full 100%. On the other hand, a deep cycle battery actually increases in capacity during its first 15 to 20 recharges.

Battery Ratings

After years of non-standard, vague descriptions that made some batteries appear to be better than others, three standard guidelines were developed to identify all automotive-type batteries.

These guidelines categorize batteries by size, cranking power, and reserve capacity.

B.C.I. uses group sizes to identify batteries with certain physical dimensions, terminal types and locations, and voltage. For example, all Group 71 batteries should be of the same size and voltage, no matter who manufactures them.

Cranking power is the most important rating to compare between batteries, since the most important function of the battery is to start the engine. Technically speaking, the Cold Cranking Power of a battery is a measure of the maximum amount of current in amperes that a new, fully charged battery can deliver at zero degrees Fahrenheit while maintaining a minimum cell voltage of 1.2 for the critical first thirty seconds of engine cranking.

The cranking power needed to start an engine will vary, depending on the size of the engine, the compression ratio, the cranking speed necessary, and so on. A used car may be harder to start than a new one, thus requiring a battery with more cranking amps than original equipment specifications.

The third battery rating is for reserve capacity, or the number of minutes that the battery should be able to supply all the electrical needs of the vehicle if the charging system fails. Technically, it's the number of minutes a new battery can sustain a 25 amp discharge at 80 degrees down to a minimum cell voltage of 1.75.

Adequate reserve capacity is especially necessary for cars with on-board computers and clocks. These electronic devices constantly drain power even when the car is not being used, and if the car is parked for a few weeks, it might not start if the battery only has minimal reserve capacity.

Deep cycle batteries use a rating similar to reserve capacity—that is, a rating based on the number of minutes the battery will power radios, lights, and so on with a draw of 25 amps before recharging is necessary.

Battery Maintenance

While batteries use lead as the primary ingredient in the grids, small quantities of other materials are added to give the grids greater strength. For many years, antimony was used as such an alloy, but during the chemical reactions of charge and discharge, gassing and water loss occurred at a rapid rate. Today, low antimony batteries are frequently identified as maintenance-free, since decreasing the amount of antimony drastically reduces the water loss.

Another approach to decrease water loss has been to substitute a different alloy for antimony—like calcium. Different alloys have meant new manufacturing processes, but they do gas very little and will require a minimum of water under normal operating circumstances. Neither low-antimony nor non-antimony is the ultimate answer; however, another alternative is to combine low-antimony plates with calcium plates. These are called hybrid or dual-alloy batteries and combine many of the attributes of both systems.

Many batteries appear to be sealed or have sealed vent caps, but nearly all, except Delco batteries, at least have some sort of access port to check electrolyte levels. All batteries have some type of venting system to release gases, so no battery is totally sealed.

There is an obvious advantage to having removable vent caps. No matter what type of battery you have, a faulty voltage regulator can overcharge the battery and cause water loss. A sealed battery cannot be saved, but water can be added to a "maintenance possible" battery to save it from premature failure.

When water is added to a battery, make sure

that the plates are covered and that the battery is not overfilled.

Battery Installation

The first step is preparing the battery. Most batteries are filled, charged, and ready to go when they're delivered to you. But to make sure, clean the terminals with a wire brush or post cleaner and test the battery according to your standard test procedures.

If the vent caps are removable, check the specific gravity with a hydrometer. There shouldn't be more than a 50 point difference between cells, and all cells should read at least 1.235. If the test reads low, boost charge the battery and test it again to make sure.

If the battery is sealed, use a digital voltmeter to read the open circuit voltage and make sure it's 12.4 volts or higher. Remember that when you use a voltmeter to estimate the state of charge, you have to make sure the battery hasn't been charged or discharged for the last 24 hours.

A moist-n-charge type battery will need to be filled with electrolyte before you check the specific gravity and boost charge it if required. Since the electrolyte is acid, common-sense precautions are in order.

Wear splashproof goggles, rubber gloves and protective clothing. Hydrogen gas is produced by charging; so remember to keep all flames, sparks, and cigarettes away from the battery. Spilled acid can be neutralized with baking soda mixed with water. If you come into contact with the acid, immediately wash it off under running water and contact a doctor.

After the battery's been prepared for installation, take out the old battery. Mark the positive cable with a piece of tape or a twist tie to keep track of it. Remove the negative ground cable first (it's usually connected to the engine block), then remove the positive cable and lift out the old battery.

Clean the tray with baking soda and water and dry it thoroughly.

Check and clean the battery holddown, cables and clamps, replacing them if necessary.

Put the new battery on the tray, and reattach the cables, positive cable first. Don't overtighten

the clamps, or pound the clamp onto the post.

Keep in mind that the connections on side terminal batteries are a bit more fragile than top terminal batteries; so exercise even more caution when tightening the cable connectors. Use a torque wrench designed for side terminals.

Finally, coat the cable connectors with petroleum jelly to help retard corrosion.

Battery Testing

How do you tell if a new battery is needed? In order to troubleshoot a problem, you'll need to run some tests. The tools are much the same as they've been in the past: a hydrometer, a load tester, a voltmeter, and your own common sense.

Before you begin, you'll need some information. What are the symptoms of the problem? Does the engine turn over but just not start? Does it turn over fast, or is it just a slow grind? Or is there no cranking at all when the key is turned on? For instance, if the car turns over with a slow grind, it could mean a defective battery, undercharging, or heavily corroded cable connections.

Start with a visual check. Look for corrosion on the posts and cable connectors that may be reducing the current flow. Check for broken cables, cracks, and missing parts. Check to see that the alternator belt is tight. Then proceed with testing the battery.

A computerized electrical system tester will enable you to test the entire electrical system by connecting the unit to the battery and one spark plug wire. Or if you don't have a computerized tester, check to see if the battery has sealed vents. If so, you can check the state of charge with a digital voltmeter. If the battery is below a 75% charge, slow charge the battery and then load test it.

Charged Level Specific Gravity Voltage

100%	1.265	12.7
75%	1.225	12.4
50%	1.190	12.2
25%	1.155	12.0
Discharged	1.120	11.9

(Figure 10) Typical Open Circuit Voltages and Specific Gravity Values

Never charge a frozen battery—it might rupture the container.

Not all batteries that look like they're sealed are really sealed. Some actually have access ports, though they may be hidden under labels. You can cut or remove the labels for the electrolyte check and hydrometer testing, but be careful you don't remove the warnings.

Remove the vent caps and check the fluid level. If any cell shows exposed plates, add water up to the bottom of the vent wells and slow charge for one hour. Any water suitable for drinking will do, but distilled water is best.

Insert the hydrometer into each cell, draw electrolyte into it and read the specific gravity at eye level. Then measure the battery temperature in a middle cell. For each ten degrees over 80 degrees Fahrenheit, add four points (.004) to the specific gravity reading. For example, if you have a reading of 1.235 at 90 degrees, add four points for a total of 1.239. Subtract four points from the reading for each ten degrees under 80 degrees.

If the cell readings average less than 1.235, recharge the battery and test again. If your readings after charge are still below 1.235, the battery should be replaced.

If some of the readings were above and some were below 1.235, and if the difference between the highest and the lowest adjusted readings is 50 or more points, the battery has failed and must be replaced.

For example: readings have been recorded from all the cells in a battery. The temperature in a middle cell is 60 degrees, so we subtract 8 points from each cell reading.

1.263	1.238	1.252	1.212	1.249	1.256
-.008	-.008	-.008	-.008	-.008	-.008
1.255	1.230	1.244	1.204	1.241	1.248

Subtract the lowest reading from the highest:

$$\begin{array}{r}
 1.255 \\
 -1.204 \\
 \hline
 .051
 \end{array}$$

Because the result is more than 50 points, this particular battery must be replaced.

If the battery passes this test, the next step is to determine if it can hold a charge. This is determined by a load test. If the battery is in a vehicle, disconnect the cables and hook the load tester to it, making sure that the tester is in the "off" position. Connect positive to positive, negative to negative.

Then set the tester for one-half the battery's cold crank rating. If the battery is rated at 350 amps, then load test it for 175 amps. (If the battery has no CCA listed on it, load test it at one-half the original equipment recommended cold crank rating.)

Load the battery for 15 seconds and check the tester's voltage dial for a reading at 15 seconds while under load. A reading of 9.6 volts or more at 80 degrees indicates the battery is good. A lower reading indicates that the battery should be replaced.

Many testers are color-coded for "good" and "bad." If your first reading shows up bad, you may want to recharge the battery and test again. If the reading is good, you have a good battery and the problem is elsewhere in the electrical system.

There's one more test you can perform before you send your customer to a certified mechanic for a complete electrical system check. This is a voltage regulator check. Voltage regulator output on most cars is set between 13.5 and 15 volts. Some late model General Motors cars with high output alternators have regulators set at over 15 volts.

Inventory Management

In one important way, batteries are different from other replacement parts: batteries are perishable.

The key to good inventory management is FIFO: first in, first out. Use shelves that allow flow-thru, which means that you stock them from the back and sell from the front.

Batteries should never be stacked one on top of the other unless they're cartoned or there are protective layers of cardboard between the batteries. You should also keep your stock organized by group size and power levels, both for wet and dry batteries.

All batteries will self-discharge in storage. How much they will discharge depends on the

type of battery and the storage temperature. If it's summer, or you're in a hot climate, store your batteries in as cool a place as possible. In the winter or in a colder climate, however, you've got to protect a discharged battery from freezing, which can cause serious damage to the case and cover.

Wet batteries in inventory should be checked when they've been in stock more than four or five months—or two to three months in warmer climates. Check the voltage with a digital voltmeter. If the battery voltage is below 12.4 volts, charge the battery at a rate of 5 to 10 amps until the specific gravity comes back up to 1.265. Then mark the date of recharge with chalk or a grease pencil.

Naturally, when you sell a battery, you still have to make sure that the voltage is 12.4 or higher. If it isn't, boost charge it.

Moist-n-charged batteries still have a small amount of acid left in them and if the battery is not up to 12.6 volts after being filled, it should be boost charged. Store moist-n-charged batteries with plugs in the vents to keep out the outside air. Both moisture and warmth in the outside air will speed up the self-discharge process.

Finally, don't forget the batteries on display. Boost charge them periodically as well.

CHARGING SYSTEMS

Without a system for recharging the battery, it would soon become useless. The two most commonly used recharging devices are generators and alternators.

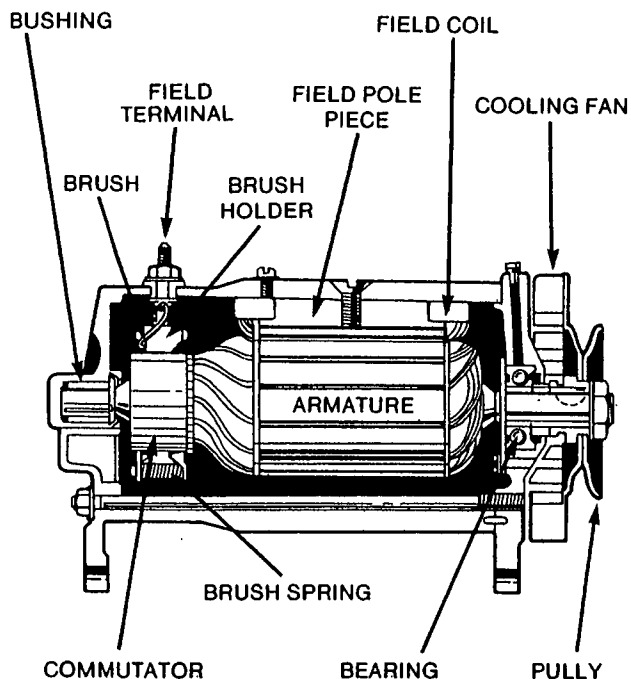
The electrical output of a generator is direct current (D.C.), and this current is used directly to charge the battery and operate the electrical accessories on the vehicle when the engine is running at the proper revolutions per minute. The type of generator used in cars is called "shunt-wound," which refers to a type of electrical winding in the generator that forms an alternate route for current.

Troubleshooting Generators

Two basic types of circuits are found in generators. An "A" type circuit is designed with the field current externally grounded to the voltage

regulator contact points. A "B" type circuit is designed with an internally grounded field current. In order for either circuit to work as designed, they must be polarized correctly.

If a generator won't "motor" (that is, run like a motor when current is passed through it), it won't generate voltage. But even if it motors, there's no guarantee that it will produce the proper voltage output, because it's possible for a generator to motor with a bad field coil.



(Figure 11) Automobile Generator.

To check the field coil of the generator, motor the generator without the field terminal jumper wire. Observe the motoring speed of the generator. Then connect the field terminal jumper wire. If the field coils are good and likely to produce the proper voltage, the speed of the generator will be slower.

If a unit generates voltage with the field terminal jumper wire installed, retest the unit without the field terminal jumper wire connected. The output should drop. If it doesn't, there may be a grounded field coil on the "A" circuit, or a touching insulated brush or brush lead to the field coil.

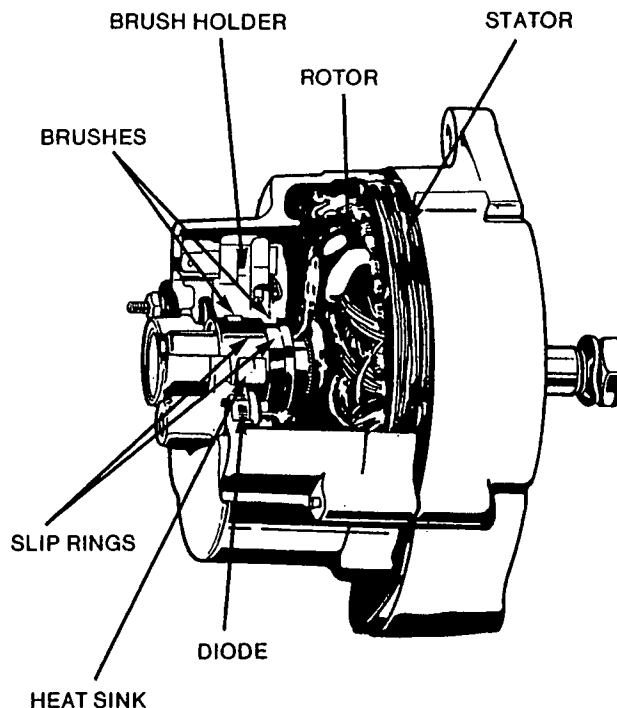
A generator must be driven in the direction it motors or it will be damaged. Most generators motor clockwise (looking from the pulley end).

Some units motor counter-clockwise (Corvair, and some industrial and marine units).

Ground polarity, either positive or negative, does not affect motoring direction but does affect the output of the generator.

Alternators

All late-model automobiles now have alternators instead of generators because of increasing demands made on the charging system. The alternator is the source of electrical power when the engine is running, and the principle advantage of the alternator over the generator is that it produces a usable output at engine idle speeds, and full output at relatively low operating speeds. This is because the alternator produces alternating current (A.C.), which is then converted to direct current by diode rectifiers.



(Figure 12) Alternator.

An alternator has a self-limiting feature which controls current flow in the charging circuit. It does not, however, control voltage output. The function of the voltage regulator is to limit the output voltage to a preset value by controlling the strength of the alternator field current. Without the regulator, the voltage generated at high engine speeds would overcharge the battery.

Troubleshooting Alternators

When troubleshooting the alternator, the battery must be at least three-quarters charged and the insulated and ground circuits of the charging system should be tested to make sure there's no excessive resistance in the system. Such resistance will interfere with even a properly functioning alternator and will produce misleading readings on the test instruments.

LIGHTING SYSTEMS

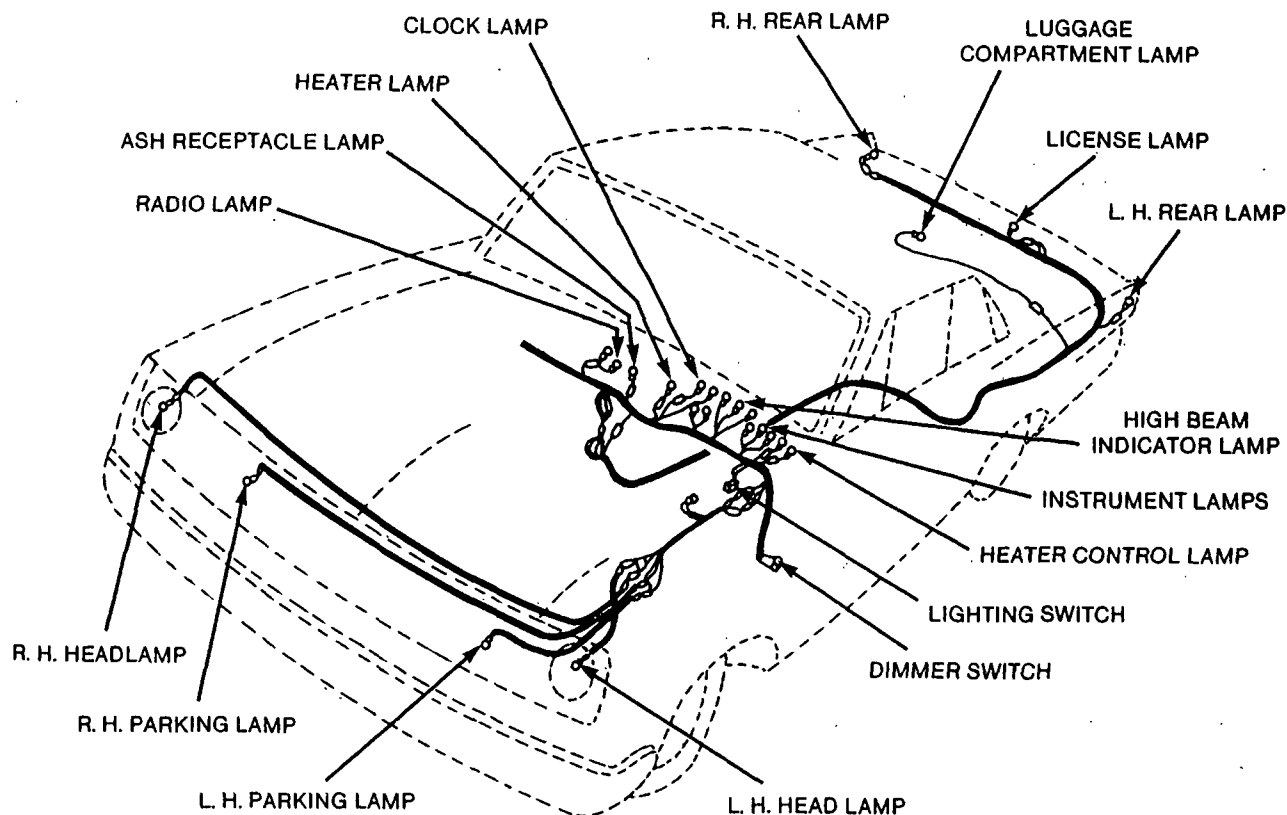
Automotive lighting systems have become increasingly more sophisticated. Headlights and tail lights have grown into multiple lamp systems, turn signal indicators have changed from optional accessories into standard equipment and evolved further into emergency and hazard warning systems. Indicator lights on the dashboard commonly warn of failure or improper operation of the charging system, seat belts, brake system, parking brakes, door latches, and other items on the vehicle.

Light systems normally use one wire to the light, making use of the car body or frame to provide the ground back to the battery. Since many of the manufacturers have gone to plastic sockets and mounting plates to reduce weight, many lights must now use two wires to provide the ground connection. Some double filament lamps use two "hot" wires and a third ground wire.

Headlamps that used to be replaced as a complete unit now use replaceable bulbs on some vehicles. Other changes have taken place in the instrument cluster lamps, which may now be mounted on circuit boards and in a different configuration than simply individual bulbs and wires.

Troubleshooting Lights

By far the most common problem encountered in lighting systems is a burned out bulb. A bulb has no predictable life span and may fail without warning.



(Figure 13) Lighting System.

Switches develop resistance as they age, causing lamps to lose their brilliance. Wear in the switch may cause an intermittent connection, which will result in flickering.

A fuse will usually burn out due to an overload, normally from a short circuit. Tail lights and stop lights may use the same fuse as some of the interior lights; so the driver will not be driving without rear lights without knowing something is wrong.

Wiring may develop loose or dirty connections which result in the same types of problems that bad switches cause. Insulation may be worn off by rubbing and cause a short circuit. Occasionally the socket may lose connection with the body of the vehicle, breaking contact with the ground.

Late model cars have many accessories on board, which are all connected to the wiring circuits. Any problem in an electrically powered unit will have to be checked for power, correct wiring, proper fuse size, and ground path back to the battery.

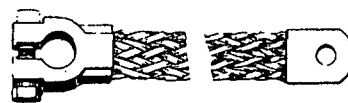
Circuits can be checked for conductivity with a test light, for resistance with an Ohmmeter, and for voltage drop with a voltmeter. When you test primary wire leads or battery cables, do not remove them from the vehicle before testing; just touch one probe of the voltmeter or volt/ohmmeter to each of the electrical components to which the cable or lead is attached. (When checking a negative battery cable, for example, one probe should touch the negative battery post and the other probe should touch the stud or bolt head used to secure the battery cable. When the engine is cranked and carrying its greatest electrical load, such as during starting, the reading should not exceed 0.1 volt.)

Wire should be clearly stripped approximately $\frac{1}{16}$ " longer than the length of the terminal's conductor clamp. Care should be taken not to nick or cut any of the strands during stripping. When attaching the wire to the terminal, insert it until it "bottoms" in the clamp or approximately $\frac{1}{16}$ " protrudes beyond the clamp. Make sure that no insulation is put into the clamp.

STARTING SYSTEM

The automobile starting system includes both the battery cables and the starter motor.

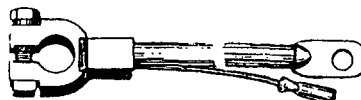
Battery Cables



6 & 12 VOLT BRAIDED
TINNED COPPER
BATTERY CABLE STRAPS



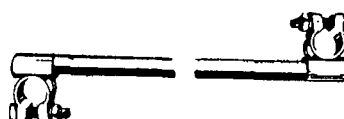
5TH WHEEL GROUND
STRAP



12 VOLT UNIVERSAL
NUT AND BOLT
TERMINAL WITH
6" TRAILING LEAD



6 & 12 VOLT INSULATED
SWITCH TO STARTER
CABLES



BATTERY JUMPER
CABLES



6 & 12 VOLT BONDING
STRAP

(Figure 14) Battery cables.

The battery cables link the battery to the electrical systems of the vehicle. Because of the relatively low voltage (pressure) and high amperage (flow) needed to supply these electrical systems, the battery cable is a large, stranded and jacketed cable. Although some manufacturers use aluminum or copper-clad aluminum, most use all copper, which is an all-around superior conductor for battery cables.

In most cables, the copper is stranded and insulated for easy handling and for protection of the electrical system. Some vehicles, however, use a braided ground strap, generally tin-coated copper for corrosion resistance. Because of the harsh environment battery cables exist in, the insulation is designed to withstand abrasion caused by vibration and to be resistant to attack by air and battery vapors.

Battery cable connections take many different forms, the most common of which is a lead casting. This casting sometimes includes a trailing lead used for grounding.

Some Chrysler applications use separate wires for connecting to the charging and starting systems. General Motors products which use side terminal batteries require a side post connection which is encased in vinyl for additional corrosion protection.

The stackable cable system, found in heavy-duty applications, also uses an insulated conductor and allows two cables to be connected to one battery terminal. It is used most often in farm equipment, heavy-duty trucks and heavy equipment.

A switch-to-starter cable is used to connect to the starter solenoid switch when it's mounted away from the starter.

The battery jumper cable is used when connecting batteries in series on heavy-duty applications.

Servicing Battery Cables

Battery cable failure is usually the resistance to the flow of electricity. A drop of just one volt means a loss of up to 15% of the voltage available during cranking.

Replacement battery cables should be at least as large (in terms of cable size) as the original equipment. The cable size is determined by the size of the conductor, not by the outside diameter of the insulation. An exception to this rule occurs when you are replacing aluminum or copper-clad aluminum with copper conductor; in this instance, the copper equivalent will be two gage sizes smaller.

The most common source of resistance is in the cable connections. It is very important that battery cable connections be kept clean. This includes new cables, since they can gather dirt and oxidation while they are on the store shelves.

This oxidation occurs when air combines with moisture to form an insulating film. Corrosion on the cable connection results from acid vapors vented from the battery, grease, oil and dirt. Since all of these can increase resistance to the flow of electricity, care should be taken to prevent them. Connections should be as air tight as possible, and protectants, either spray sealants, heat shrink tubing or specially formulated protective compounds, may be used on the terminations.

Several types of battery cable repair ends are available for temporary repair of battery cables, ranging from a basic emergency end to quick connect ends that allow the connection to be made away from the top of the battery.

Starter Motor Assembly

The electric starter motor was invented by Charles F. Kettering in 1910. It appeared in 1912 on all Cadillacs and from that day forward, the acceptance of the gasoline engine was assured. Up until that time, many people were afraid to crank the engine by hand, or simply unable to.

The starter motor cranks the engine at approximately 200 revolutions per minute. When the engine starts running on its own, the crankshaft and flywheel ring gear are almost immediately turning at a much higher speed, and could damage the starter motor. To prevent this, the starter motor has an "overrun clutch" or starter drive which transmits torque in only one direction and turns freely in the other. As soon as the engine starts to run on its own, the overrun clutch releases the wedge rollers in the starter drive housing. This allows the pinion gear to exceed the revolutions per minute of the armature assembly, and prevents damage to the starter motor.

When the driver releases the ignition key switch from the "start" or "crank" position, electrical power is cut from the motor and a spring-loaded solenoid disengages the starter drive pinion gear from the engine flywheel ring gear.

All starters use this type of solenoid except the Ford Motorcraft "positive engagement starter." This type of starter uses a movable field pole shoe to engage the starter drive pinion gear with the flywheel ring gear.

While a starter motor is small, it can deliver tremendous torque and has a tremendous appetite for current when it attempts to turn such a heavy load as a cold engine. When the starter drive pinion gear first engages the engine flywheel ring gear, the starter motor armature shaft is essentially stalled by the static load of the engine. The initial surge of current through the starter motor may be as much as several hundred amps, and this brief surge places a

heavy demand on the battery, battery connections, and cables.

To limit the burden placed on these parts, the ignition system must get the engine working on its own as quickly as possible, especially in cold weather. A battery's cold cranking capacity at zero degrees Fahrenheit usually drops to about 40% of its capacity at 80 degrees.

Starter Components

The starter motor is made up of several mechanical and electrical parts, including the armature assembly, field coil and pole shoe assembly, commutator and drive end housings, brushes, starter drive, and solenoid.

The armature is the rotating part of the motor and is formed by winding many lengths of large gauge insulated wire on a laminated iron core assembly.

The field coil pole shoe assembly is the strong electromagnet that produces the motor field.

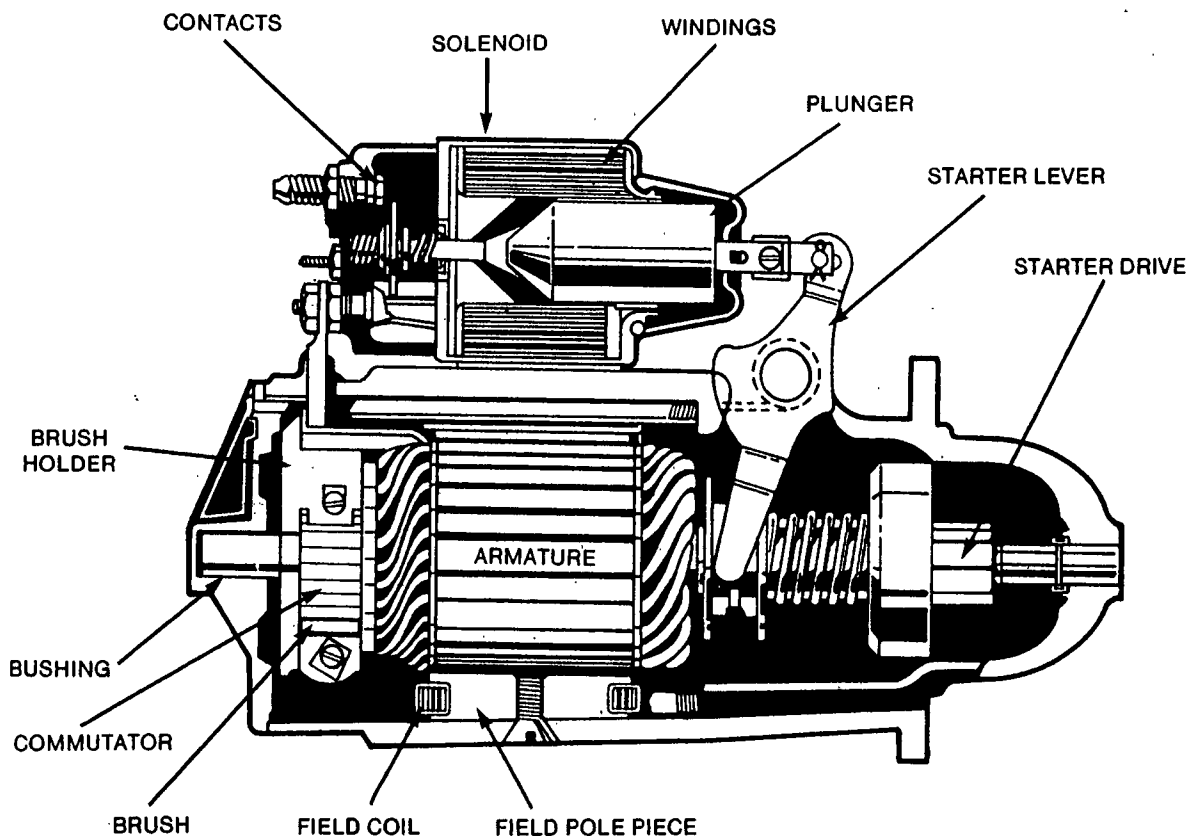
The field pole is constructed by winding heavy insulated ribbons of copper wire around a soft iron core known as the pole shoe.

Usually, two brushes are responsible for carrying heavy current from the field coil assemblies to the commutator, and from the commutator to the ground.

The solenoid is energized when the ignition switch is turned to start the car. As mentioned before, it engages the starter drive pinion gear with the flywheel ring gear so that the starter motor is connected to the engine.

SUMMARY

In this chapter, we looked at the major parts of the automobile electrical system: the battery, the battery charging system, the lights, and the starting system. These systems play an important role in the operation of the engine and the comfort and safety of the driver. They also provide the foundation for engine ignition, which will be covered in the next chapter.



(Figure 15) Starter motor components.

OBJECTIVES

When you have completed this chapter, you should be able to:

- Explain the difference between the primary ignition system and the secondary ignition system.
- Label each of the major parts of the ignition system on a diagram and explain its function within the system.
- List the three major types of ignition systems and the differences between them.

In one minute, the ignition system produces several thousand 7,000 to 20,000 volt sparks, and distributes them at precisely the right instant to exactly the right combustion chamber to ignite the air/fuel mixture that powers the engine. This is no small accomplishment. The spark must be strong enough to jump the gap of the spark plug and cause the mixture to burn as

completely as possible. It must also be timed at exactly the right moment of the engine cycle.

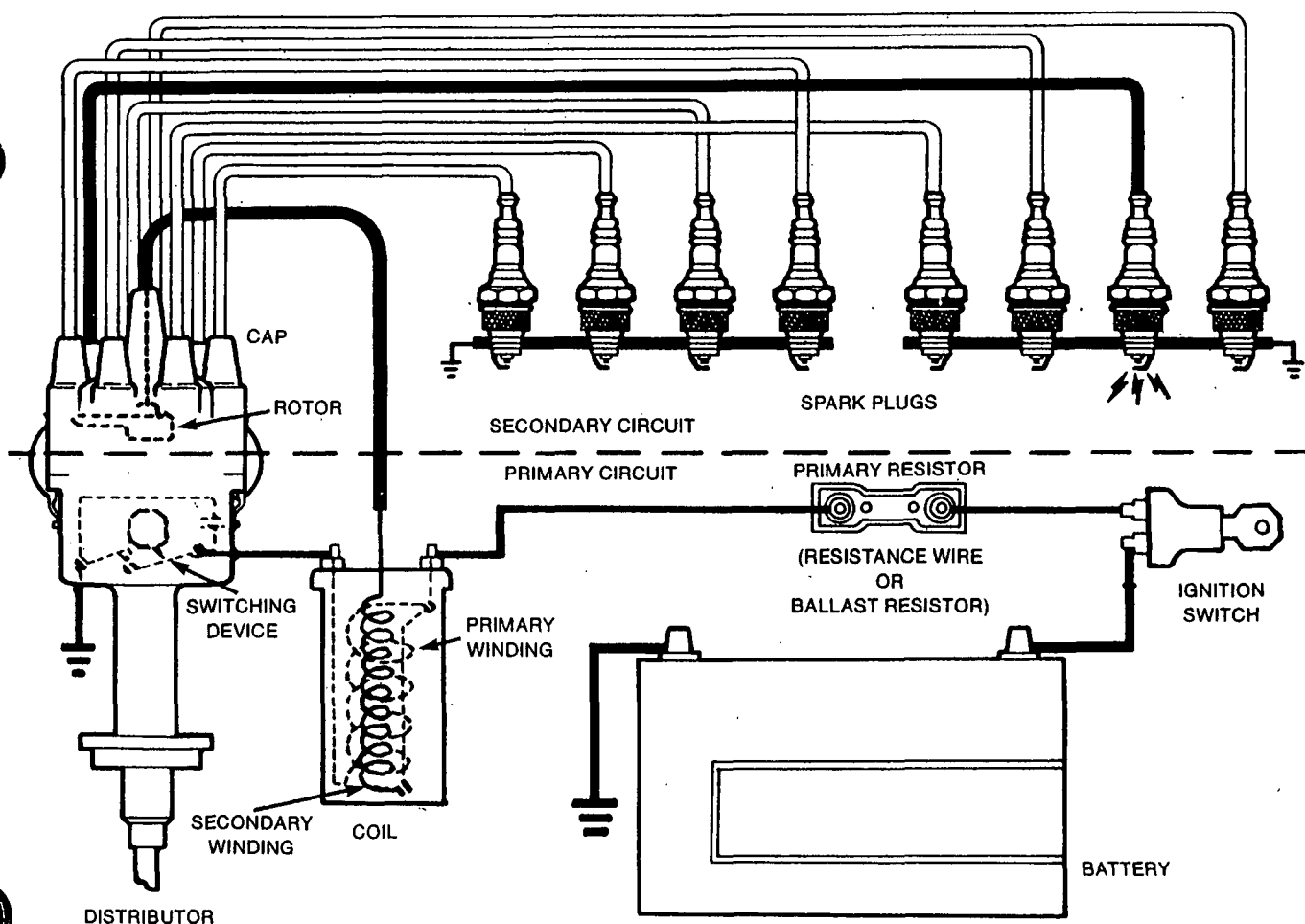
The ignition system is made up of two circuits, the primary circuit and the secondary circuit.

Primary Circuit

The primary circuit includes the battery, ignition switch, ballast resistors, primary windings of the coil, some type of triggering device (usually found inside the distributor housing), and all the wires that connect these parts.

Secondary Circuit

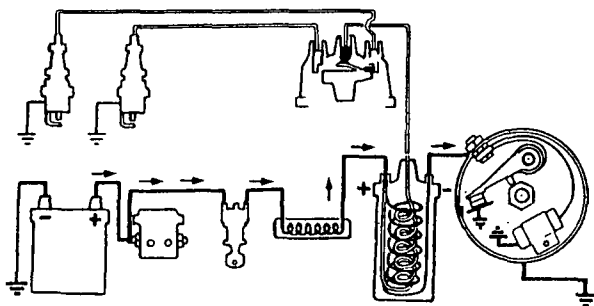
The secondary circuit consists of the finer interior windings of the ignition coil, the center electrode of the coil, the distributor cap and rotor, spark plugs, and spark plug wires.



(Figure 16) Ignition system primary and secondary circuit.

BASIC OPERATION OF THE IGNITION SYSTEM

Here's how it works. When the triggering device inside the distributor is closed, current flows through the primary circuit: the ignition switch (when on), through a voltage-reducing resistor, through the primary or outside windings of the coil, and on to the trigger and to the ground. As the current flows through the coil's heavy primary windings, a magnetic field is created.

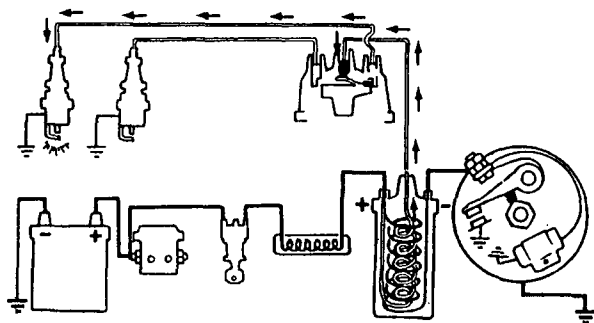


CONTACTS CLOSED

(Figure 17) Primary circuit current flow.

When the primary circuit is opened by the trigger, current flow in the circuit is stopped and the magnetic field around the outer windings of the coil collapses. As the magnetic lines of force collapse across the many fine inner coil windings of the secondary circuit, a high "induced voltage" is produced. This high secondary voltage then leaves the tower of the coil, is carried to the distributor cap center terminal, and is sent to the proper spark plug by the rotor.

Once at the spark plug, the high voltage jumps across the air gap on the spark plug, producing a spark. This spark ignites the air/fuel



CONTACTS OPEN

(Figure 18) Secondary circuit current flow.

mixture. On an 8-cylinder car, this cycle is repeated approximately 40 times per second at idle, and over 200 times per second at highway speeds.

The proper time to fire the spark plug changes as engine speed and load conditions change. Therefore, there must be some way of changing the timing of the distributor.

In conventional distributors, there are two methods used. A centrifugal or mechanical advance uses spring-mounted weights that move outward against the spring tension as distributor rotation speed increases. A vacuum advance uses a vacuum pull to rotate the trigger device. Both of these methods advance the firing time by moving the breaker plate (or mounting plate) of the trigger, thereby causing a quicker firing of the secondary system.

There are several types of ignition systems, all working to produce the effects just described. While components and names may change, the basic theory remains the same. The types of ignition systems found on today's automobiles are:

- Conventional
- Electronic
- Computer-controlled

The basic difference between the three systems is in the triggering device and the way the current is distributed to the spark plugs.

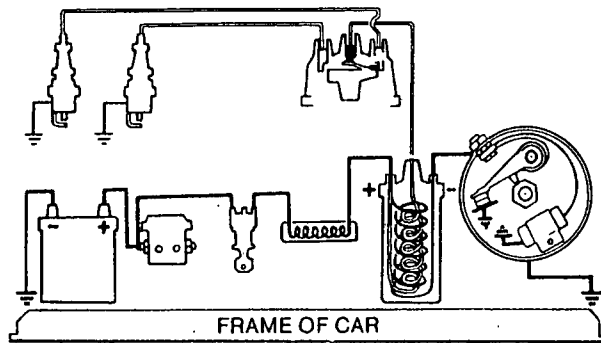
CONVENTIONAL IGNITION SYSTEM

The conventional ignition system uses a standard contact set and condenser type of trigger. Standard contacts are often called "breaker points."

In this system, a contact set is mounted in the distributor, and an arm rides against a cam on the distributor shaft. The cam has one lobe for each cylinder of the engine. As a cam lobe rotates and pushes the arm, the contact points are forced apart, thus breaking the primary current flow. This collapses the magnetic field in the coil, inducing the necessary secondary voltage to provide the spark at the plug gap.

As the points open, a self-induced voltage from the coil primary windings could cause an arc across the points, damaging them. To prevent this, a small capacitor, or condenser, is wired in to absorb and dissipate this primary voltage. Because the condenser allows a quick,

complete break in the primary circuit, the coil's magnetic field is collapsed 20 times faster than if no condenser were used. This allows for greater induced secondary voltage, and a quicker recovery time for the coil.



(Figure 19) Conventional Ignition System.

Average duration of a tune-up with this type of system is 10-12,000 miles, or about one year. In this period, the rubbing block on the contact arm wears down and doesn't open the points as quickly or as wide as necessary. Ignition timing slows, and the points remain closed longer, causing them to burn. Spark plug electrodes are burned so much that the gap is widened, and the coil may not be able to produce the required secondary voltage to jump the gap under all conditions.

CONVENTIONAL IGNITION SYSTEM COMPONENTS

The following components are used in the conventional type of ignition system.

Ignition Switch

The ignition switch controls the current flow to the ignition system as well as to the starting and accessory circuits. It is manufactured to specifications for each application. In the start position, the accessory circuits are off to prevent damage from electrical surges during starting.

As the switch ages, it may experience problems from excessive resistance, worn or dirty contacts, or bad connections. These conditions may prevent enough current from reaching components for proper operation.

The switch may be mounted in the dash panel or in the steering column, where it also serves as an anti-theft device by manually locking the steering wheel in one position.

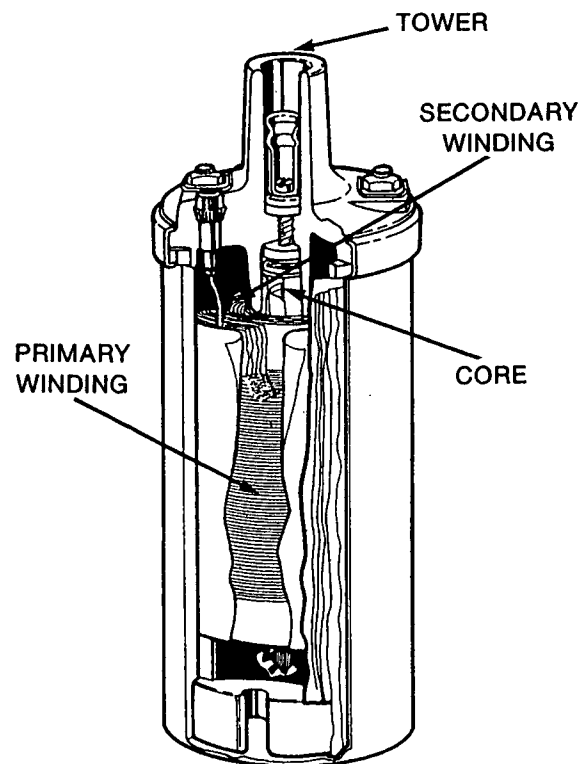
When trouble-shooting switches, check both the electrical and mechanical functions. Some switches are two-part, using a lock cylinder which may be replaced independently of the switch body.

Ballast Resistor

Ballast resistors limit the amount of electrical current allowed to pass through a particular circuit and are usually heat-sensitive, or thermal. They are used to protect components from too much voltage or from surges in the electrical system. In ignition systems, the resistor will protect the coil and triggering devices.

Resistors are sometimes in the form of a resistor wire in the wiring harness, or may even be built into the ignition coil. It is extremely important to use the correct value resistor for a circuit.

Ignition Coil



(Figure 20) Ignition Coil.

An ignition coil is a transformer which uses induction to produce high secondary voltage from a low primary voltage. It consists of two separate windings: the outer, heavy primary winding, and a much finer inner secondary winding. The secondary winding is wrapped around a metal core, and is connected to the center terminal, or tower.

Selecting the correct coil is very important. A coil has 3/1000 of a second to produce up to 20,000 volts in a conventional ignition system, and needs to be matched to the particular system it operates in. Number of windings, type of insulating materials, positive connections, and height of tower should be considered when replacing the coil.

There is no predictable failure rate for coils. Even resistance and continuity checks may be good on a weak coil. Strength of the secondary voltage is the only full test of a coil's capability. A diagnostic scope or an ignition spark tester should be used.

The Distributor

The distributor serves both the primary and secondary systems. It must do two main things: operate the trigger for the primary circuit, and route the induced secondary voltage to the proper spark plug. In addition, it must mechanically time the ignition spark.

A gear on the lower part of the distributor shaft is driven by the camshaft of the engine. A cam with one lobe for each engine cylinder is on the upper part of the shaft to open and close the breaker points. The distributor rotor is mounted on the top of the cam assembly to distribute the spark to the spark plugs, and a cap fits over the top as a cover.

In a distributor with a mechanical advance, a system of weights and springs advances the rotation of the cam ahead of the rotation of the shaft.

With a vacuum advance, the breaker points and condenser are mounted on a movable plate which is adjusted by engine vacuum.

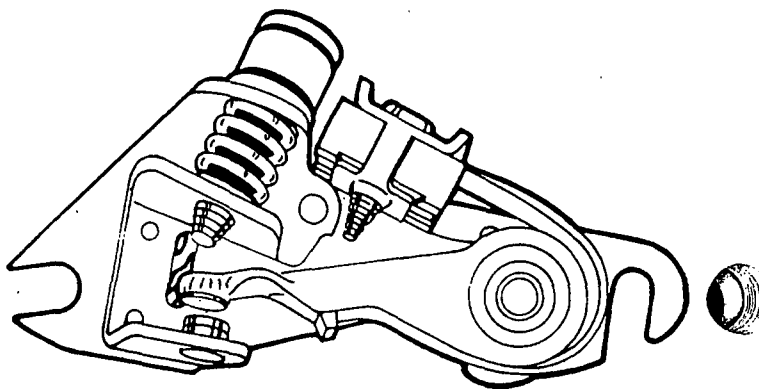
Mechanical wear is unpredictable and the major cause of distributor problems. It is very important to keep the distributor assembly clean and free of abrasives. Over a period of time, the mechanical advance device may also

become dirty, or the springs may weaken. Any of these conditions may change the timing curve and affect engine performance.

For instance, if abrasives such as aluminum oxide (a common by-product of caps with aluminum terminals) are present, the cam becomes scored and worn, no longer properly operating the rubbing block. As the point operation changes, the timing or the intensity of the spark may vary.

The breaker plate may also tip or warp, causing misalignment of the breaker points. Any deficiencies in the distributor will greatly affect overall performance of the engine.

Contact Set or Breaker Points



(Figure 21) Contact Set or Breaker Points.

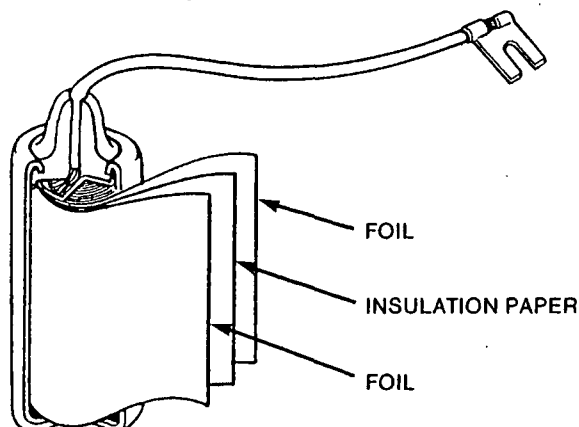
The contact set uses the mechanical action of the distributor to control the primary current flow to ground. When closed, the circuit is completed and primary current flows, creating the magnetic field in the coil. When opened, primary current stops, and secondary voltage is induced.

Effective life of a contact set is about 10-12,000 miles. After that, engine performance and economy begin to suffer. Things to look for in a quality contact set are: type of contact material, finish, type of rubbing block, a positive lead wire binding post, and a heavy duty bushing for the mounting post.

Condenser

Sometimes called an "electrical shock absorber," the job of the condenser is to absorb and dissipate the voltage surge as the points open. This action prevents a spark from jumping

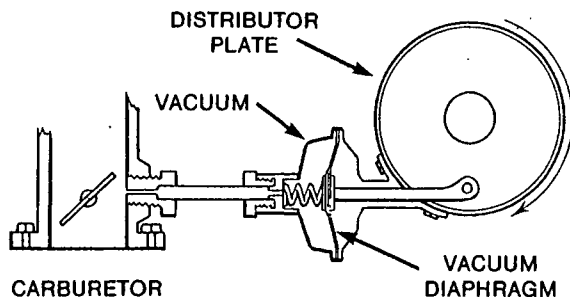
across the contacts, which would burn them. Since its purpose is to protect the contact set, any internal resistance will cause premature failure of new points.



(Figure 22) Condenser.

A new condenser should be installed with new points. Look for a seal against moisture contamination, flexible lead wire, and type of terminal used when replacing the condenser.

Vacuum Control



(Figure 23) Vacuum Control.

The vacuum control device is attached to the distributor housing and mechanically linked to the breaker plate. It moves the plate to advance ignition timing as engine operational conditions provide a vacuum signal. This allows for smoother, more efficient engine operation.

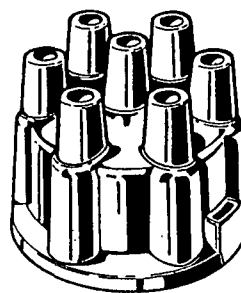
Distributor Cap

The distributor cap serves a dual purpose: to provide the terminals for the spark to be delivered to individual spark plugs, and to protect internal parts from dirt, moisture, and other contaminants.

Any accumulation of contaminants inside the cap may provide paths for the secondary voltage to short circuit, thus causing engine misfire. When this occurs, a path called a "carbon track" is left and will repeatedly cause problems. This tracking cannot be cleaned away and isn't visible in early stages.

Because of this, the finish is very important. A high lustre finish will repel dirt and moisture, helping to prevent carbon tracking. The inserts used are also important, since aluminum allows the formation of aluminum oxide, an abrasive which may damage other parts.

If no carbon tracking or other physical problems occur, the distributor cap is usually effective for about 30,000 miles.



(Figure 24) Distributor Cap.

Distributor Rotor

The rotor turns with the distributor shaft, routing the high secondary voltage spark from the center terminal of the cap to the correct outer terminal. There is a small gap between the end of the rotor blade and the cap insert. As the spark jumps this gap, it will eventually burn away the blade and inserts. This gap is very important, and is precisely machined. It cannot be adjusted, and too wide a gap will weaken the spark to the plug.



(Figure 25) Distributor Rotor.

Caps and rotors should be replaced as a set. Check new rotors for stainless steel spring, brass blades, and be sure to use correct applications.

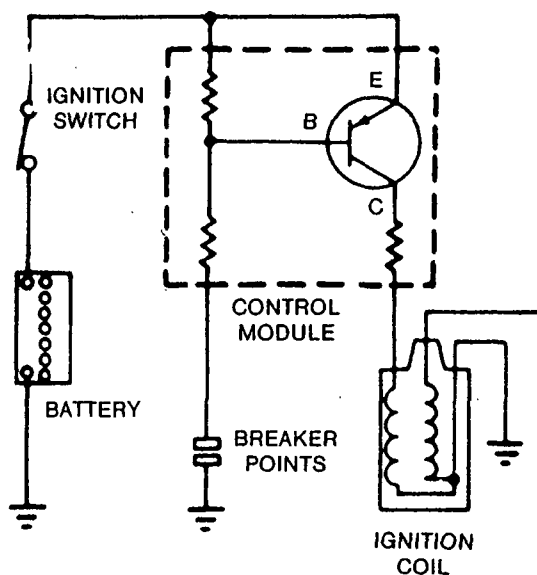
ELECTRONIC IGNITION SYSTEMS

As the number of automobiles and the quantity of dangerous pollutants emitted by them has increased, air quality standards have been established to help protect our environment and health. In order to meet these increasingly strong standards, the automobile manufacturers were pushed into developing more efficient ignition systems.

Although solid-state ignition systems had been around for some time, they had not been used extensively. They were adopted by manufacturers and improved to help meet clean air standards in the early 1970's, when they came into widespread use on domestic vehicles.

Solid-state, or electronic ignition systems are designed to provide higher secondary voltage, reliable performance for longer periods of time, better operation under a wider range of conditions, and longer component life for decreased maintenance. The development of the transistor (an electronic semi-conductor switch with no moving parts) made it possible to replace the weakest link in conventional systems, the breaker points.

Breaker Point Transistor Systems



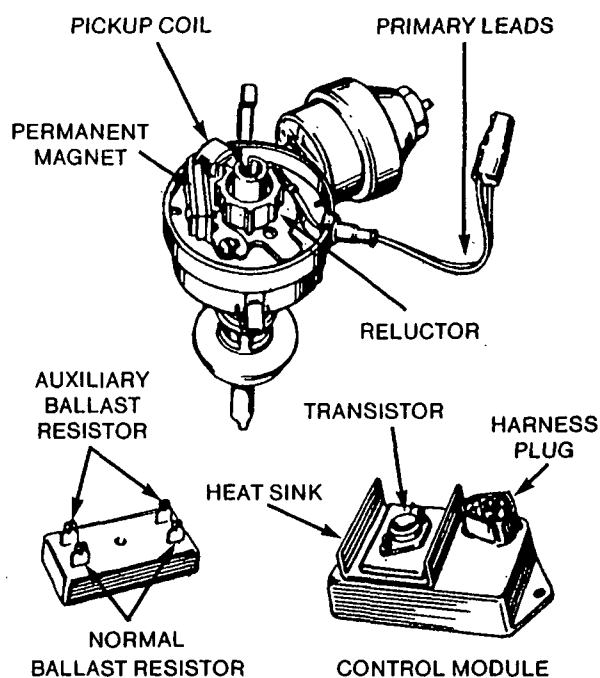
(Figure 26) Breaker Point Transistor System.

The first transistorized ignition systems still used breaker points as a signal for the transistor

to control primary current flow. The points no longer conduct primary current, just a small signal current, and point life and performance are greatly improved. However, there is still mechanical wear, and high speed efficiency is not aided.

In this system, when the breaker points close, the transistor is switched on, allowing primary current flow through the coil to develop the magnetic field. As the points open, the transistor switches off, interrupting primary current and thus inducing secondary voltage.

Breakerless Transistor Systems



(Figure 27) Breakerless Transistor System.

The transistorized ignition system was improved with the introduction of a magnetic pulse control unit, which replaced the breaker points. Output of the transistorized ignition system is increased, even at high engine speeds. The increased available secondary voltage reduces engine misfiring, which in turn reduces plug fouling, increases plug life, improves fuel economy, and reduces exhaust gas emissions.

In the breakerless transistor system, the breaker points and condenser used in a conventional system are replaced by a magnetic or optical triggering device.

ELECTRONIC IGNITION COMPONENTS

The following components are unique to the electronic ignition system:

Control Module

The solid-state control module is a self-contained sealed unit that houses the necessary circuits to switch the ignition primary current flow off and on. It is usually mounted on the fender well or firewall of the engine compartment, although some vehicles mount it inside the distributor housing. There are no user serviceable parts inside, and failure of any component means replacement of the entire module.

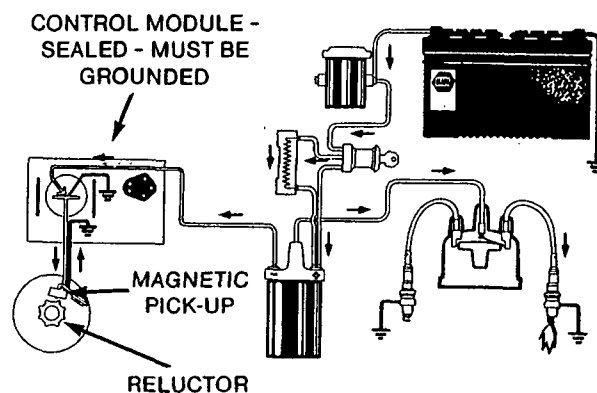
The transistors which actually control primary current flow are in the control module. The base circuit of the transistor, through which a small current flow is passed to the triggering device when it completes the ground circuit, lets primary current flow through the outer coil primary windings, building the magnetic field. When this small control current flow is interrupted, the transistor turns off, which fires the coil by stopping the primary current flow.

Other circuits for control of dwell, retardation of timing during starting, and similar functions may also be inside the control module.

Triggering Devices

The triggering device, usually found in the distributor, is responsible for completing and interrupting the transistor base circuit. It may

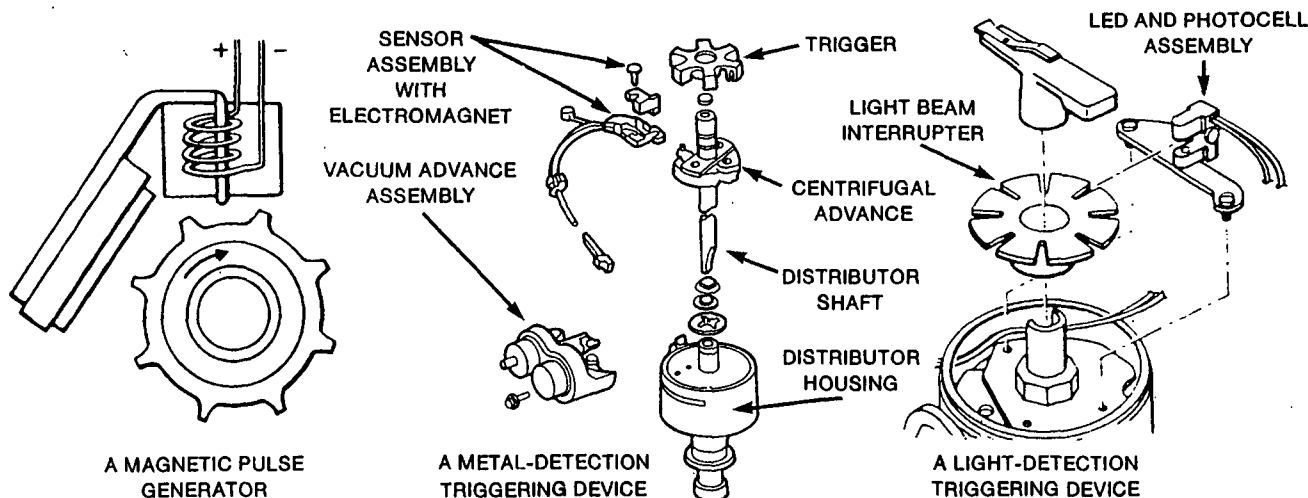
be one of several different types, but all will produce a pulsating voltage that signals the transistor to turn on and off.



(Figure 28) Ignition Control Module.

The most common of the three types of trigger is the magnetic pulse generator or pickup. Inside the distributor, a non-magnetic trigger wheel with metal teeth called a "reluctor" turns near a pole piece with a permanent magnetic field. As a metal tooth approaches the magnet, the magnetic field increases, and as the tooth passes the pole piece, the strength of the magnetic field starts to decrease.

The rapid increase and decrease of the magnetic field in the pole piece induces a low voltage signal in the pickup coil. The electrical signal triggers the transistor, which collapses the primary circuit, again generating a high voltage in the secondary circuit.



(Figure 29) Triggering Devices.

Another type of trigger is the metal detection type. It uses an electromagnet instead of a permanent one. Metal teeth on the trigger wheel affect the magnetic field as they pass over it, and this change is sensed by the control module and triggers the transistor.

Some add-on units use the optical, or light-detection type of trigger. In this system, a light-emitting diode (LED) and a light sensitive photo transistor are used to produce voltage signals. A slotted rotating disc interrupts the light beam, which then signals the module. Periodic cleaning and realignment is necessary for proper operation.

Although other components like caps and rotors may have changed in appearance, their function remains the same.

COMPUTERIZED ENGINE CONTROL SYSTEMS

In the late 1970's, vehicle manufacturers were being pushed to develop cars with lower emissions, higher mileage, and better performance. Although electronic ignition was a vast improvement over older systems, it was not able to meet all of these objectives by itself, since it controlled only ignition of the air/fuel mixture.

The most important development in meeting these goals has been the use of computerized engine controls. These systems are capable of constantly adjusting fuel, ignition, and emission controls as the vehicle is being driven. The result is lower emissions, higher mileage, and better performance. Another result, however, is the increasingly complex wiring, control units, and sensors the system requires.

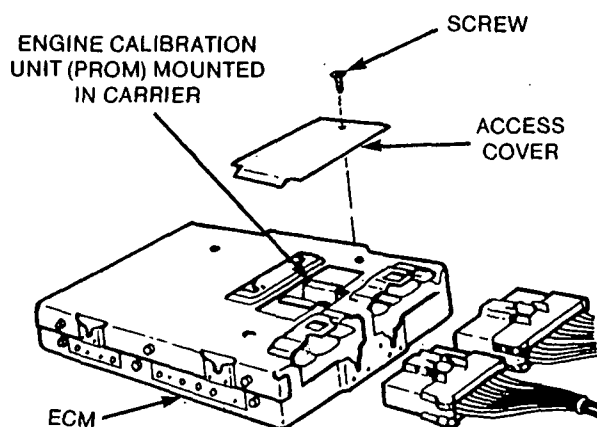
Computer-controlled systems are now capable of processing thousands of inputs per second, making instantaneous adjustments through the various control devices used, and monitoring the results. Most of these types of systems are now controlling timing and ignition as well as the air/fuel mixture.

COMPUTERIZED ENGINE CONTROL SYSTEM COMPONENTS

Control Units

The heart of any computer system is the control unit, which is a microprocessor. These units

are usually sealed inside a metal box, and are tied into the wiring harness by one or more multi-pin connectors. Most manufacturers put the computers inside the passenger compartment of the vehicle for protection from moisture, dirt, vibration, and temperature extremes.



(Figure 30) Control Unit.

The computer's job is to match vehicle operation with driving conditions and re-adjust engine performance as any of these conditions may change. A programming unit, or calibration device, is used for each vehicle and takes into account important factors such as size, weight, engine, transmission, and special equipment. With this unit, engineers can program the computer with the best adjustments for economy, driveability, and low emissions.

Sensors

Information is fed to the computer by a number of sensors, which provide whatever data is needed by the system. The control unit is constantly checking the sensor data and comparing it to the calibrations built into it.

Most of the sensors are similar to an oil pressure switch or fuel gauge sending unit, either being on/off or giving a variable resistance reading. The most common sensors monitor exhaust oxygen, vehicle speed, coolant temperature, and throttle position or engine vacuum.

More specialized sensors provide input to the computer on such things as engine "ping," atmospheric and/or manifold absolute pressure, outside air temperature, and even incoming air temperature and density.

Control Devices

The commands from the computer are carried out by a control device, which may be a solenoid, a motor, or other type of control. For example, solenoids may be used to control vacuum to some components, or for fuel flow, or even air bleeds. Electric motors may control such things as idle speed or air flow.

Typical controls found on computer-controlled systems are idle speed control motors, feedback control stepper motors, throttle kicker actuators, EGR control solenoids, air control solenoids, mixture control solenoids, and electronic fuel injection units.

In some cases, computers may have direct control over certain functions such as timing. For example, if an engine knock sensor hears "pinging," the computer may automatically retard ignition timing until the noise stops.

Automotive Computer Service

Since most computers used in the automotive industry have no user serviceable parts, the repair technician's job is to find the part that is not functioning properly and replace it. There are some cautions that must be observed first.

Be sure to eliminate non-computer related components as causes of trouble first. Where possible, make all regular diagnostic checks as though there were no computer on the vehicle. Some manufacturers have built self-diagnostic features into these systems. The computer doesn't have control over such things as the compression, valve train, and other such areas (at least not yet!).

In testing and repairing these systems, be sure to follow recommended procedures from an appropriate service manual.

Component Testing

It is usually not possible to test a computer while it is in the car; so the usual service approach is to test for other causes of trouble first. If all else checks out, the computer is the last possible cause. To reach this conclusion, individual components must be tested.

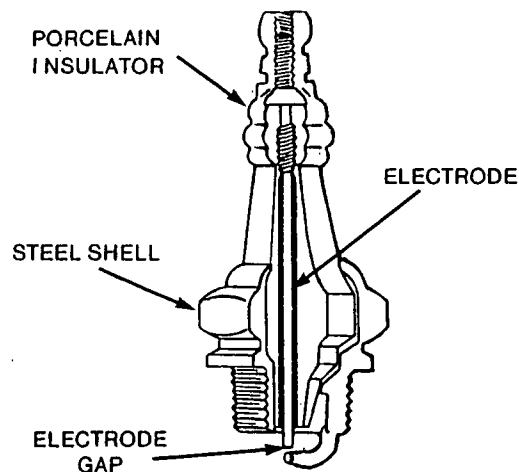
Use the proper testing equipment to check sensors to see if they are operating correctly, or if the proper resistance values are present. Solenoids may be checked by applying the correct

levels of voltage to see if they operate. Continuity and resistance values in the components should be checked for improper grounding or shorted circuits.

If components check out, the circuitry should also be checked for resistance and continuity, as well as grounding. Use of wiring diagrams will help to trace circuits and connectors.

After all sensors, control devices, and wiring have been checked, the computer may be suspected. In many cases, the computer has circuits to look for and identify problems within itself. Be sure to use proper tools, test equipment, and above all, a good service manual with appropriate procedures.

THE SPARK PLUG



(Figure 31) Spark Plug.

The modern spark plug is a carefully engineered product combining highly specialized technology in ceramics and metallurgy, as well as precision manufacturing techniques. Its basic job is to provide a means of delivering high voltage spark into the combustion chamber to ignite the fuel and air mixture.

The plug must properly fit the cylinder head, having the proper diameter and reach of threads as indicated by SAE and ISO specifications. It must also provide a gas-tight seal to prevent harmful leakage of combustion gases.

The spark plug is assaulted by a tremendous range of temperatures and pressures, and has to be capable of transferring combustion heat from

its firing end into the cooling system to avoid becoming a source of pre-ignition. It must also operate at a high enough temperature at low speeds to prevent the formation of conductive deposits.

Spark Plug Troubleshooting

All spark plugs will eventually wear as a result of normal operation, and will therefore require periodic replacement. This wear results from the burning effect of the high heat of combustion, the chemical attack of combustion deposits, and the electrical erosion of the spark discharge. As a general rule of thumb, spark plug replacement should be on a once-a-year basis to assure fast cold weather starting, safe passing power, good fuel economy, and low exhaust emissions.

A spark plug's life can be affected by a number of factors. When a plug has a shorter life than expected, the following questions need to be answered:

- 1. Was the plug properly selected? If the plug is too hot, it will have a short electrode life. If too cold, excessive deposits will form on the insulator and short-circuit the spark. Check the VIN number and be sure the correct plug is being used.*
- 2. Was it gapped before installation to fit the vehicle's requirements? If the gap is too wide, it will stress the ignition system; if it's set too close it may prevent the ignitable mixture from entering. Check the specifications and adjust accordingly.*
- 3. Was it properly installed? If the spark plug is installed onto dirty threads or too loosely, its life can be shortened. It will be unable to pass the combustion heat into the cooling system.*
- 4. Is the ignition system up to specifications? If the ignition system is weak, it cannot provide the required high voltage, and, therefore, the spark plug cannot deliver the spark into the cylinder.*
- 5. Is the correct fuel mixture reaching the combustion chamber? Is the mixture too rich or too lean? If too much fuel (a rich mixture) reaches the cylinder, it will*

drown the plug, resulting in carbon fouling and short-circuiting of the spark. If too little fuel (a lean mixture) reaches the cylinder, it will not allow the spark to ignite the mixture, or the fire will go out without completely burning the mixture.

When properly selected and correctly gapped for the engine, a spark plug will have a long life and provide excellent performance. For proper plug selection, always refer to the recommendation chart. Different vehicles with similar engines can require different spark plugs depending on the type of fuel system, transmission or load requirements.

SPARK PLUG WIRES

Spark plug wire, sometimes referred to as ignition cable or ignition wire, is the connecting link between the coil, distributor, and the spark plugs. Spark plug wires carry the voltage required to fire the spark plugs.

Even though spark plug wires may appear to be quite simple, they are complex and perform a very important function. Failure of spark plug wire will often cause failure of other ignition system components, producing such effects as fouled spark plugs and oxide build-up in the distributor cap. This may make the vehicle difficult to start, run rough in wet weather, and have poor acceleration, decreased gas mileage, and increased exhaust emissions.

These wires must also contain extremely high voltage and, in most applications, suppress radio frequency interference (RFI). When the high voltage crosses the gap at the plug, it generates radio frequencies. A metallic core spark plug wire will act as an antenna and radiate the RFI. Since 1960, All American made cars and most trucks have used non-metallic distributed resistance wire that effectively suppresses RFI.

Distributed Resistance Wire

There are several varieties of distributed resistance wire manufactured today including those using a fiberglass/graphite core wrapped with fiberglass and others that use linen, nylon or some other material instead of fiberglass.

The outer insulation, called the jacket, is designed to withstand the harsh conditions

encountered under the hood. These conditions include extreme temperatures, ozone, water or condensation, oil and grease, steam cleaning, strong detergents, solvents, acid and antifreeze.

Spark plug wire jackets are produced in two popular thicknesses which result in overall cable diameters of 7 and 8mm. For many years 7mm was the industry standard. In 1974 General Motors introduced HEI using 8mm spark plug wire and Ford followed in 1977. This change was made to contain the higher voltages and withstand the higher underhood temperatures.

The insulation and jacket are generally separated by a fiberglass braid which facilitates the manufacturing process and can help improve terminal pull.

Spark Plug Wire Service and Maintenance

During tune-ups, spark plug wire maintenance should include a visual inspection for cracks and other jacket deterioration caused by chemicals or abrasion. This generally occurs where the wire runs close to the exhaust manifolds or other sources of heat. Water and dirt, or the combination, contain conductive materials which can provide a path for voltage to reach ground without crossing the plug gap. For this reason it is important that spark plug wires be kept clean and free of dust which may trap moisture.

A visual inspection of the boots and terminals may uncover cracks in the boots, or loose, worn or corroded terminals. These connections are critical and should be replaced or repaired as necessary. The spark plug or distributor terminal will be one of the two common types. One type just slides over or into the mating part and is not securely retained. The other type incorporates a lock or mechanical retention in the terminal design.

The conductor can be tested with the use of an oscilloscope analyzer or an ohmmeter. The oscilloscope analyzer determines if the voltage needed to fire the spark plug is too high. It will show up as an inconsistent voltage spike line on the scope screen. The problem may be caused by corrosion, improperly seated terminals, or deteriorated or improperly gapped plugs.

Total wire resistance is measured by an ohmmeter. When testing resistance you are looking for a significant increase from when the wire was new. Since most wire is manufactured with less than 9000 ohms per foot (SAE Specification) resistance, a good guideline for determining faulty wire is 1000 ohms per inch. Any wire with resistance in excess of 1000 ohms per inch should be replaced.

When removing or replacing spark plug wires, follow these steps to avoid problems related to handling, routing, or fit.

- When removing a spark plug wire from the plug, twist the boot to loosen the connection. Hold the boot over the terminal and pull straight. This will help avoid damage to the boot or terminal.
- When replacing spark plug wires, do them one at a time, beginning with the longest. Replace that lead with the longest lead in the new set. This procedure will help you avoid ending up with a lead too long or too short.
- By replacing spark plug wires one at a time they can be routed just as they were originally. Proper routing of spark plug wires will avoid contact with exhaust manifolds and other engine parts which can shorten the service life. Proper routing also prevents cross-firing (ignition voltage jumping from the distributor rotor to the wrong spark plug) caused by wires being run in parallel too close together, which can result in internal engine damage.
- When installing spark plug wires on the plug, or at the distributor cap and coil, be sure the terminal is properly seated. With plugs manufactured with snap lock terminals, you will hear a snap when these terminals are properly seated. Any excess air trapped inside the boots or nipples should be allowed to escape. If the excess air is not removed, it will expand when heated and can force the terminal off. If a terminal is improperly seated, the voltage will jump that gap as it does the spark plug, generating heat that will cause the rapid deterioration of the terminal.

IGNITION PRIMARY WIRING

The secondary ignition circuit can generate a high voltage spark of 7,000 to 20,000 volts. Although the voltage in the ignition primary circuit is only 6 or 12 volts, the wiring is no less essential to the successful operation of the ignition system.

As we turn on the ignition key, primary ignition wiring carries low voltage current from the battery through the primary windings of the coil, through the breaker points (which are closed) to an electrical ground inside the distributor.

Wiring for the primary ignition circuit is generally of light gages. There are several connections within the circuit, which must be kept tight and free of corrosion because this can increase resistance. Primary wire is subject to vibration and may be cracked or damaged by

abrasion. The wire insulation and conductor should be kept clean and periodically inspected for damage.

SUMMARY

The automotive ignition system performs some astonishing feats in igniting the fuel/air mixture in the cylinders at precisely the right moment.

In this chapter, we looked at the functions of both the primary and secondary ignition systems, and how they are connected to each other. We also examined the three major types of ignition systems in use today: the conventional system, the electronic system, and the computer controlled system.

Finally, we looked at spark plugs and the wiring for both the secondary and primary ignition systems.

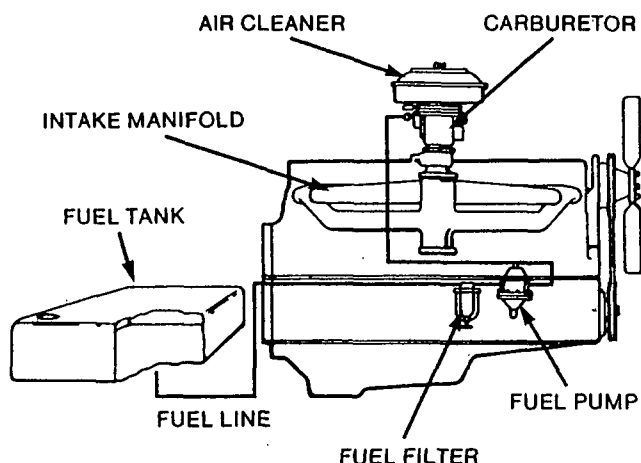
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OBJECTIVES:

When you have completed this chapter, you should be able to:

- Name the parts of the fuel system and explain the function of each within the system.
- Define common fuel system terms such as vacuum, low pressure area, atmospheric pressure and venturi principle.
- Explain the difference between a fuel system using a carburetor and one using fuel injection.
- Describe the types of filters found in the fuel system.
- List the various types of fuel system hoses.



(Figure 32) The Fuel and Air System.

The typical fuel system is fairly simple in design—at least until it reaches the components that mix the fuel with air. The fuel is stored in the fuel tank. Fuel filters, which may be located in the fuel tank or lines, in the fuel pump, or on the carburetor, remove contaminants such as rust, dirt and other foreign particles as the fuel is pumped through the system.

When the filtered fuel moves into the carburetor, it is “atomized” and mixed with air, which has also been carefully filtered. In some engines, a fuel injection system takes the place of the carburetor. It is the carburetor or fuel injection system which creates the precise blend of air and fuel needed by the engine at any given time.

The engine draws this fuel/air mixture into the combustion chamber as the piston moves downward in the cylinder. This occurs during

the intake stroke of the four-stroke engine cycle. A stroke is the movement of the piston from the top of the cylinder to the bottom, or from the bottom to the top. In the four-stroke automobile engine, there are four strokes of the piston in each cycle of the engine.

1. Intake Stroke: The fuel and air mixture fills the cylinder in the correct proportions.

2. Compression Stroke: The mixture in the cylinder is compressed by the piston.

3. Power Stroke: The mixture is ignited and burned, and the expanding gas drives the piston downward.

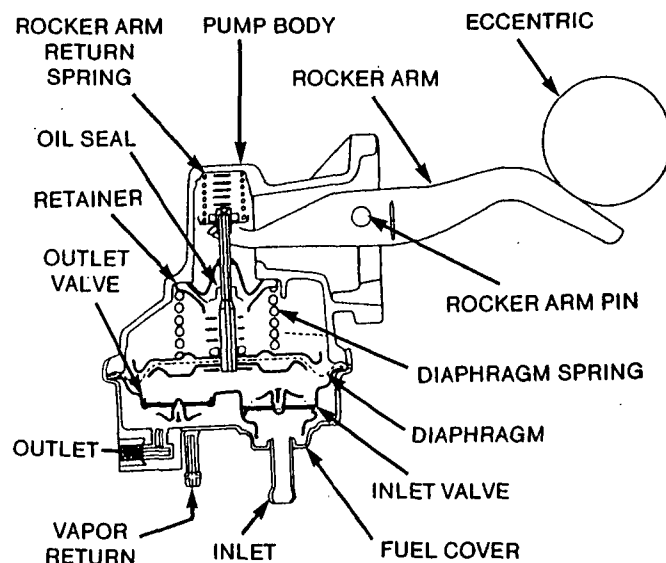
4. Exhaust Stroke: The burned exhaust gases are released through the exhaust valve as the piston comes up again.

For more details on the four-stroke cycle, see the Engine module of Understanding Automotive Systems.

THE FUEL PUMP

The fuel pump is an important component of the fuel system because it must supply enough fuel for a wide variety of situations, from idling to acceleration to constant speeds.

The most common type of fuel pump is the mechanical diaphragm-type pump. This type of pump is almost universally used, although some vehicles have electric fuel pumps. The diaphragm-type pump consists of a diaphragm, an inlet valve, an outlet valve, and a rocker arm.

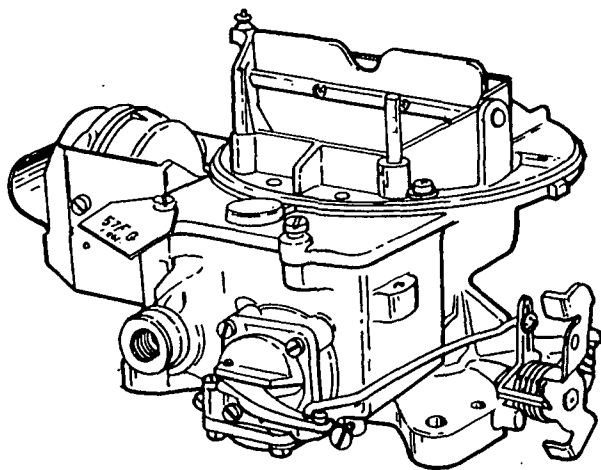


(Figure 33) Fuel Pump.

Here's how the pump works. The rocker arm rides against an eccentric lobe on the camshaft and makes a stroke with each revolution of the camshaft. The faster the camshaft rotates, the more fuel is pumped. The maximum working pressure of the fuel pump is established by the force of the diaphragm spring, which limits the amount of fuel according to engine requirements.

The fuel pump must deliver just enough fuel at the proper pressure to the fuel bowl of the carburetor, or the carburetor will not function properly. To ensure that an engine is in good working order and will continue to perform properly, fuel pump capacity and pressure should be checked frequently.

THE CARBURETOR



(Figure 34) Carburetor.

It is technically incorrect to say that cars run on gasoline. It is actually a precise mixture of gasoline and air that gets us from here to there in any vehicle.

The carburetor can be considered the "chemist" of the vehicle, since it mixes the fuel with air and releases it to the engine according to the needs of the engine in various situations.

The air/fuel mixture is created when the carburetor subdivides or "atomizes" the fuel and mixes these fine particles of fuel with air. A small amount of air is added to the liquid fuel as

it moves through the carburetor passages. This air/fuel mixture is sprayed through nozzles or jets into a stream of fast-moving air, which enters through the intake manifold, which breaks it up into particles. The heat of the intake manifold converts this air/fuel mixture into vapor, which then enters the engine's combustion chamber.

It's very important that the ratio of air to fuel be kept within flammable limits, but the mixture must also vary according to the vehicle's speed and load. The carburetor must constantly perform this "juggling act" with the air and fuel components of the mixture.

To see how this happens, we must first understand some basic scientific principles.

The Theory of Pressure Difference

The carburetor operates on a principle known as "pressure differential." If we understand certain terms such as vacuum, low pressure area, atmospheric pressure and venturi principle, we can better understand the theory of pressure difference.

- **Vacuum**—A true vacuum would be an enclosed area where there is absolutely no air. Although an absolute vacuum is NOT created in a carburetor, we refer to an area which has less pressure than is found in our atmosphere as a "vacuum" or "low pressure area."
- **Atmospheric Pressure**—Air actually has weight, with a cubic foot of air weighing 1¼ ounces. The force of the weight of the air that surrounds us is called "atmospheric pressure," and it's exerted equally in all directions. At sea level, this pressure equals about 14.7 pounds per square inch.
- **Venturi Principle**—A venturi is a partial blockage or restriction in the throat or bore of the carburetor. This restriction causes an increase in air velocity and a lowering of pressure of the air that is passing through it. The greater the air velocity, the lower the air pressure at the venturi.

The lower pressure, or vacuum, in the carburetor bore, combined with the atmospheric pressure on the outside, is the basic force that causes carburetors to function.

Atmospheric pressure outside the bore forces fuel through the passages in the carburetor into the area of lower pressure, where the fuel is

mixed with the fast-moving stream of air before it enters the engine. The velocity of the air in the bore (and thus the amount of fuel being forced through the carburetor into the airstream at any given time) is regulated by the throttle valve.

This is a more complicated process than it may sound, however. For instance, when the engine is idling, the air velocity through the venturi is not great enough to draw fuel into the air stream. And with sudden changes in engine operation such as rapid acceleration, the venturi effect is temporarily lost. So other systems are designed into the carburetor to cope with these situations.

A more detailed presentation of carburetor function is available in the Engine module of Understanding Automotive Systems.

FUEL INJECTION

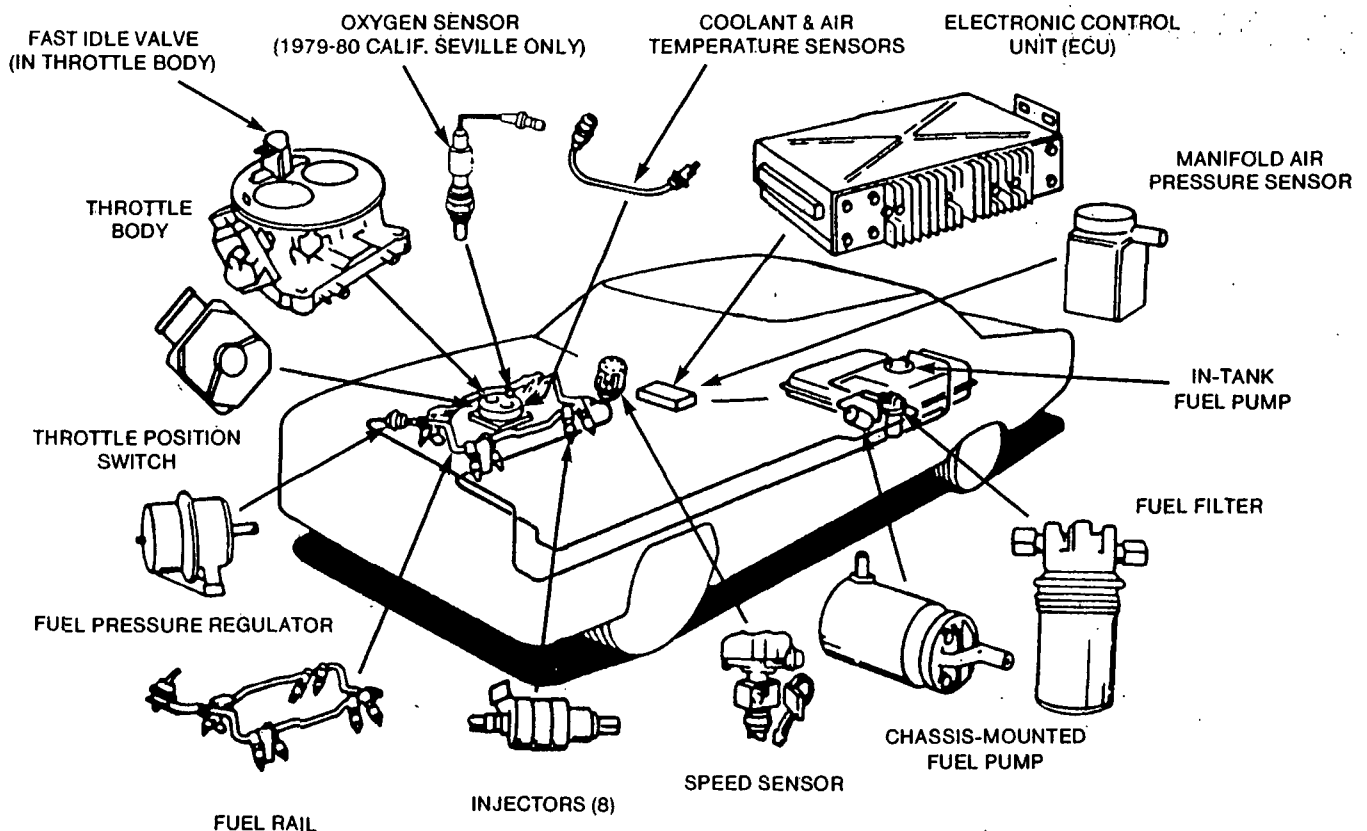
In fuel injection systems, fuel is forced under pressure through a small opening into the air.

Unlike a carburetor, the pressure forcing the fuel into the air is not atmospheric pressure but produced by a pump in the injection system itself.

Most injection systems deliver gasoline at an intake port in the cylinder head. In this case, only air passes through the intake manifold. Another type of gasoline fuel injection system delivers fuel at the throttle body. When this is done at one central point the system is called a throttle body injection (TBI) or central fuel injection (CFI) system.

Fuel injection provides more precise control of the air/fuel ratio, improved emission control, fuel efficiency, and driveability. Fuel injection systems, however, are more expensive, require clean fuel, and are usually considered difficult to service.

The most widely-used systems are electronic fuel injection (EFI). These systems provide a pulse of fuel, with the electronic system controlling how long the injector is held open (pulse width).



(Figure 35) Electronic Fuel Injection System.

Fuel is pressurized by an electric fuel pump. A fuel damper prevents pulsations in the line and maintains fuel pressure in the system. The fuel filter is important because extremely clean fuel is required for fuel injection. Fuel pressure is regulated according to manifold absolute pressure, with excess fuel returned to the tank through a return line.

An airflow sensor measures air flowing into the intake system. The signals from the airflow sensor are called the base pulse, providing the minimum fuel to be injected. The base pulse is modified by a solid state electronic control unit (ECU) to increase the time the injector stays open, adjusting the injectors to engine operating conditions. To do this, the ECU receives and interprets signals from other sensors monitoring coolant temperature, air temperature, throttle positions, engine speed and engine load.

Electronic injectors open the nozzle valve with a solenoid. The ECU controls pulse width at the injector by the length of time the solenoid receives a voltage signal.

Provisions are made for cold starting and warmup with a cold start injector valve, a thermostatic switch, and an auxiliary air device. The cold start injector delivers extra fuel while the engine is cranking. The auxiliary air device provides extra air during start and warmup to overcome cold engine friction.

The air/fuel mixture can be metered more closely with a feedback or closed loop fuel control system. A closed loop system continually monitors itself and adjusts the injection pulse rate so the air/fuel ratio is kept as close to ideal as possible. In an open loop operation, the ECU sends pre-programmed signals for warmup, idle, and full-load enrichment.

Fuel Injector Systems

Several popular fuel injector systems are briefly described below.

In the Bosch L-Jetronic system, all injectors open and close at the same time, delivering fuel into the intake manifold to be drawn into each cylinder when the individual intake valves open. The system is easily adapted to turbocharged systems.

Another Bosch electronic fuel injection system is the LN-Jetronic, a low pressure system

designed for lower-cost systems in small cars.

In the LH-Jetronic system, the airflow sensor is a hot wire instead of a moving flap. Airflow is calculated by the amount of current the wire requires to stay at a constant temperature when passing air cools it. Other systems use acoustic waves to measure airflow. In the older D-Jetronic system, manifold pressure is monitored instead of airflow to control the injection pulse width.

The K-Jetronic (CI) is a continuous fuel injection system. It's a port injection system, delivering fuel to the intake manifold. Fuel delivery rate is controlled by varying the amount of fuel coming out of each injector. K-Jetronic systems can be fitted with an oxygen (Lambda) sensor for feedback control of the amount of fuel delivered to the injector.

The KE-Jetronic fuel injection system combines the benefits of a basic mechanical system with simple electronic controls for enrichment, cutoff, and closed loop feedback.

The GM Throttle Body Injection (TBI) has central, intermittent injection, and has feedback sensors and an electronic control unit GM calls the ECM (Electronic Control Module).

The Ford Central Fuel Injection (CFI) system uses a microprocessor to control intermittent fuel injection as well as spark time, EGR, and evaporative canister purge. Fuel pressure in this system is developed by an electric pump in the tank.

The Chrysler Electronic Fuel Injection is a single point, continuous flow system. The system measures air flow and fuel flow, comparing these to a set of programmed ratios stored in the ECU. In closed loop, exhaust gas oxygen is monitored to keep the air/fuel ratio correct.

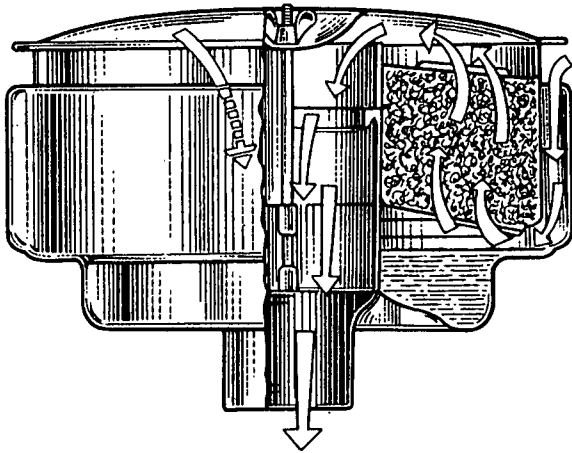
AIR FILTERS

Since the average internal combustion engine "breathes in" approximately 10,000 gallons of air for every one gallon of fuel it consumes, the air that comes into the system must be very clean to avoid damage to the engine.

An air filter permits air to flow freely into the system, while trapping airborne contaminants such as vegetable matter, insects, exhaust soot and dirt. The type of contaminants likely to be introduced into an engine depends on a number

of factors: geographical location, type of vehicle (trucks or other four-wheel drive or off-the-road vehicles may be subject to more soot and dirt than would most automobiles), and so on.

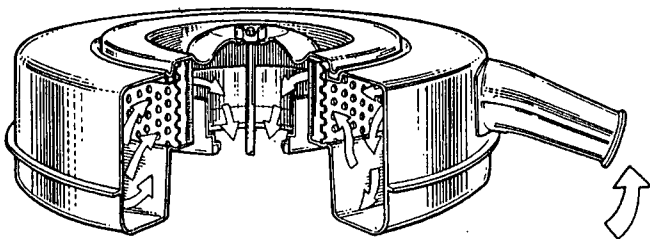
Oil Bath Air Filter



(Figure 36) Oil Bath Air Filter.

The oil bath air cleaner was once a widely-used system of cleaning the intake air of engines, removing airborne contaminants by physically entrapping particles on the surface of an oil pool. The problem is that an oil bath air filter works poorly at low speeds, with efficiency dropping to perhaps 70%. The dry type air filter was a great improvement in air filtering.

Light Duty Dry Type Air Filter



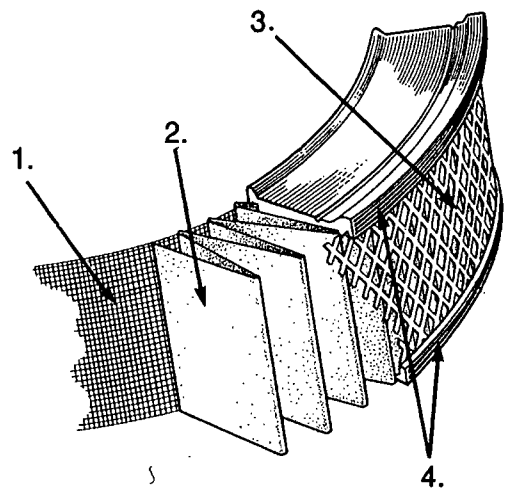
(Figure 37) Dry Type Air Filter.

The dry type air filter is one of the most significant innovations for prolonging engine life. This filter permits air to flow into the engine with little resistance, while it effectively traps and holds airborne contaminants. Unlike the oil

bath air cleaner, the dry type air filter protects the engine under all load and speed conditions. When these filters become plugged with contaminants, they are disposed of and replaced with a new element.

There are two basic types of dry type air filters—light duty and heavy duty. Light duty air filters are usually used on passenger car and pickup truck engines. These filters are usually small in size, because of space limitations under the hood. Still, these filters allow the free flow of air for even the largest gasoline engines, while still carrying a minimum efficiency rating of 98.0%.

1. Mesh screen—helps support the pleated paper and reduces fire hazards in the event of engine backfire.
2. Pleated paper—folded to obtain maximum amount of exposed surface area and treated with fire retardant.
3. Outer screen—protects paper media and supports filter assembly.
4. Molded plastisol top and bottom—a soft and pliable sealing surface that won't harden or deteriorate.



(Figure 38) Parts of a Light Duty Air Filter.

Servicing Light Duty Air Filters

Frequent servicing of these filters is essential to maintain peak performance of the vehicle, since a dirty filter can cause loss of power and erratic engine performance. Light duty air filters should be serviced by replacement only, never cleaned or re-used. They should be

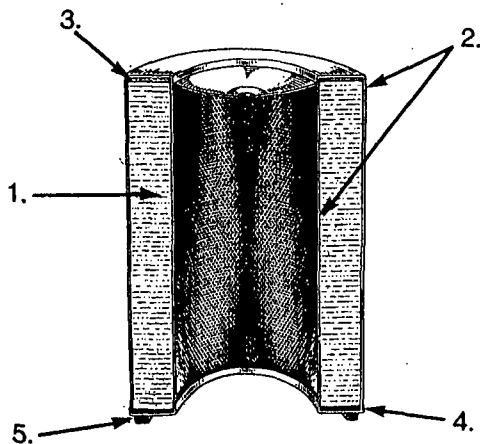
changed every 10,000 miles or at tune-up time. More frequent replacement may be necessary if the vehicle is subjected to lots of dust or off-the-road travel.

Heavy Duty Air Filters

Heavy duty air filters come in a variety of shapes and sizes. They all have a minimum efficiency rating of 99.9%. These filters are much larger than light duty types, so a tighter, more efficient paper can be used, while still letting enough air pass through with minimum restriction.

Servicing Heavy Duty Air Filters

1. Heavy duty pleated paper—provides minimum of 99.9% efficiency for maximum engine protection.
2. Plated perforated or expanded metal inner and outer bodies—protect paper and strengthen filter assembly.
3. Adhesive plastisol—permanently bonds paper to metal end caps.
4. Plated metal end caps—will not warp or rust.
5. Low compression—set silicone gasket is permanently bonded to the end cap. May be used over and over again, even after cleaning.



(Figure 39) Features of Heavy Duty Air Filters.

Because of the wide variety of heavy duty air filters available, we will only cover the basic procedures of servicing them here. Their replacement time or service schedule may be

based on a number of factors: miles traveled, hours of operation or restriction reading. The restriction reading, or pressure drop of these filters is almost always measured in inches of water.

A U-tube monometer is hooked into the clean or engine side of the filter, the engine is operated at maximum speed, and the restriction is noted. A round dial type gauge can also be used to determine the restriction reading. This gauge may be permanently mounted in the dashboard of the vehicle.

If these methods are not convenient, heavy duty air filters may be replaced on a routine time or mileage basis.

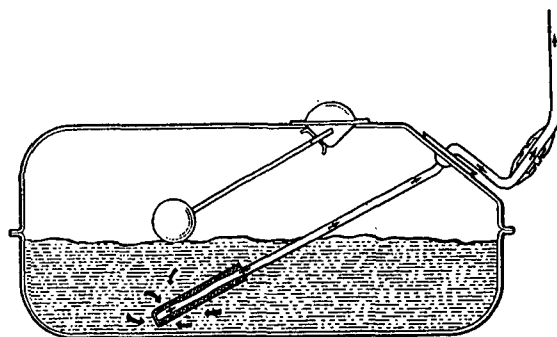
THE FUEL FILTER

A carburetor has many small passageways and intricate parts which can be damaged by dirt particles. A dirty carburetor can cause faulty performance and eventually complete engine shutdown, so the fuel must be as clean as possible to ensure smooth operation of the vehicle.

There are a number of ways in which contaminants may enter the fuel system of a vehicle:

1. Unfiltered fuel may be pumped into the vehicle tank.
2. Tank caps may be loose or sealing gaskets may be faulty.
3. Rust—a powerful abrasive—may flake off from the fuel tank and fuel lines.
4. Contaminants or dirt particles may be left in the tanks or lines during the manufacturing and assembly process.

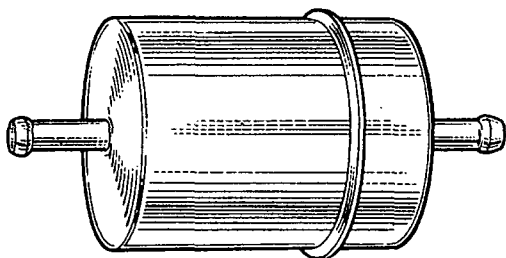
Types of Gasoline Filter Systems



(Figure 40) In-tank Fuel Filter.

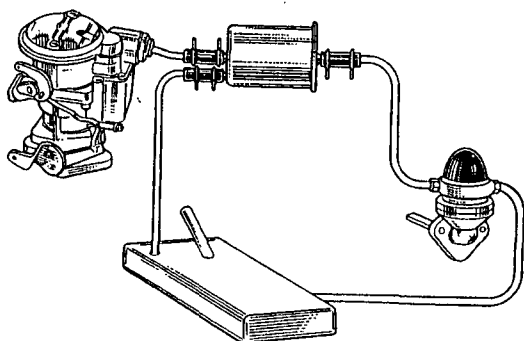
Some cars and light trucks have two gasoline filters. The first filter—found in the gasoline tank—is made of fine woven fabric. This filter prevents large pieces of dirt or other contaminants from damaging the fuel pump. The tank filter also prevents most water from going to the carburetor. Under normal conditions, the tank filter will not require servicing or replacement.

The second filter can be found in one of several locations in the engine compartment. This filter requires regular service. One type is called an in-line fuel filter.



(Figure 41) In-line Fuel Filter.

For vehicles which may have a vapor lock problem, a second outlet line is used on the filter. Gasoline used by the carburetor passes through the filter media and out the center fitting. A small amount of gasoline exits through the second outlet fitting and returns to the tank. The recirculation of gasoline through the vapor line cools the gas and prevents vapor lock.



(Figure 42) Fuel Filter to Prevent Vapor Lock.

Some fuel filters screw into the fuel inlet fitting of the carburetor and connect to the fuel line with a hose and clamps. Another style is the in-carburetor fuel filter. These are small pleated paper filters with a built-on gasket to

provide a positive seal, although some are sintered bronze and would be considered a strainer type filter. Some NAPA filters of this type contain a built-in check valve to limit fuel leakage if the vehicle overturns.

FUEL SYSTEM HOSES

Hoses first appear in the fuel system at the gas tank. Here a fuel filler neck hose connects the filler pipe with the tank. This short connection is made by a straight or curved hose that is roughly 1½ to 2½ inches in diameter, usually with an internal wire coil that resists collapsing.

The fuel filler neck hose cover must be able to resist gasoline. It must also be nonpermeable, so gas and gas vapors can't evaporate through the hose.

Many fuel tanks have vent hoses to allow air in the fuel tank to escape when the tank is being filled with fuel. Vent hoses are usually installed alongside the filler neck hose.

A third fuel system hose that connects to the fuel tank is the fuel line hose. This hose carries fuel from the fuel tank to the fuel pump, the fuel filter, and to the carburetor or fuel metering pump. These lines are usually made of metal, although some sections are constructed of rubber hose to allow for car vibrations.

Fuel line hoses, unlike filler neck or vent hoses, must work under pressure or vacuum. Because of this, they must be stronger. This is especially true for the hoses on fuel injection systems, where pressures reach 50 psi or more.

Fuel line hose tubes must also have special resistance properties. In fuel injection systems, unused gas is returned to the fuel tank, where it becomes "sour gas," which ages when hydroperoxide molecules form. Hydroperoxides can cause some fuel line hoses to crack and disintegrate.

Note: NAPA fuel line hose should only be used as a delivery hose to the fuel metering unit in fuel injection systems. It should NOT be used on the pressure side of injector systems. This application requires a special high pressure hose.

SUMMARY

The automobile's fuel system is both simple and complicated: simple in the systems that

transfer fuel to the engine, and complex in the carburetor or fuel injector system that mix that fuel with air in the correct amounts and proportions to meet all needs of the engine.

This chapter has reviewed the basic operation and parts of the fuel and air system. It covered

the basic parts of the fuel transport system, including the fuel tank, fuel lines, fuel pump, fuel filters. We also examined the principles and function of the carburetor and fuel injector system, and looked at the function of air filters and fuel system hoses.

Notes

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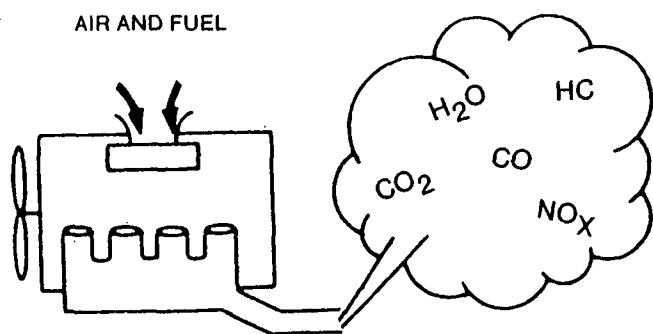
OBJECTIVES:

When you have completed this chapter, you should be able to:

- List the three major emissions that are the by-products of internal combustion.
- Describe the various emission control systems, both pre- and post-combustion types.
- Explain the principle of the catalytic converter, how the various types of converters work and what they control.
- List the two types of emission control filters.
- Describe where emission recycling system hoses are used.

In a society that has become increasingly dependent on the automobile, one of the inevitable side effects has been the emission of pollutants into the air that are the by-products of the internal combustion engine.

To understand these emissions and how they're created, we must first review the process that takes place inside the engine.



(Figure 43) Combustion.

For any organic combustion to occur, three basic elements are required: fuel, oxygen and heat. Under ideal conditions, combustion produces heat, carbon dioxide (CO_2), and water vapor (H_2O). But in almost every internal combustion reaction, other by-products are produced.

The three major pollutants caused by the operation of the internal combustion engine—carbon monoxide (CO), hydrocarbons (HC) and oxides of nitrogen (NO_x)—have been determined to be hazardous to human health. Legislation has been passed which limits the maximum

levels of these pollutants which can be emitted by the cars and light trucks sold in the United States.

- **Carbon Monoxide (CO)**—Carbon monoxide is a molecule made up of equal parts of carbon and oxygen. It is a colorless, odorless gas, and is one of the results of incomplete combustion. CO is extremely poisonous. By weight, carbon monoxide accounts for about 47% of air pollution.
- **Hydrocarbons (HC)**—Hydrocarbons are made up of carbon and hydrogen atoms in various combinations. They are the product of any engine that does not operate at 100% efficiency using a hydrocarbon fuel. Hydrocarbons are a major component in the formation of photochemical smog.
- **Oxides of Nitrogen (NO_x)**—Oxides of nitrogen consist of nitrogen combined with varying amounts of oxygen. NO_x is produced by heat and pressure during the combustion process. NO_x is also a main component of photochemical smog.

Photochemical smog results when HC and NO_x are combined in the presence of bright sunlight. Smog, originally thought to be a combination of smoke and fog, is actually the formation of ozone, nitrogen dioxide and nitrogen nitrate when HC, NO_x and bright sunlight are combined.

Exhaust systems also emit lead and carbon (soot). Lead is being eliminated from gasoline for three reasons: because it is such a hazardous pollutant, because engines are being designed which no longer need it as a lubricating agent, and because lead in an exhaust system can rapidly destroy the efficiency of a catalytic converter.

Carbon or soot is a by-product of incomplete combustion in a diesel engine. There are currently no federal standards for soot emissions. One reason is that a properly adjusted engine emits very little soot. Another is that no effective controls have been developed to contain or trap soot.

EMISSION CONTROL SYSTEMS

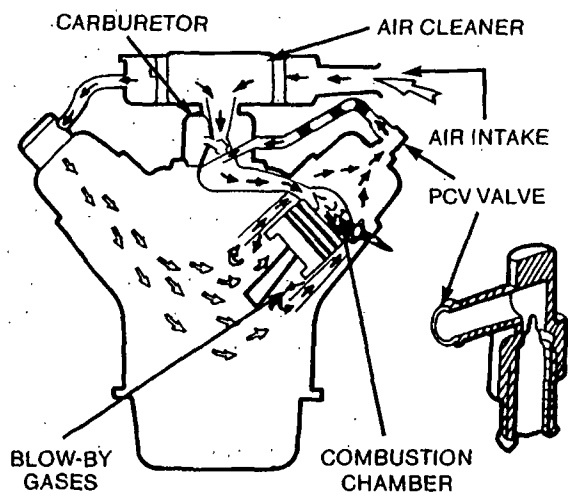
There are two basic types of emission control systems: those which prevent the formation of pollutants ("pre-combustion" systems—the

preferred method) and those which reduce or control pollutants after they have been formed ("post-combustion" systems). For a more detailed discussion of the following systems, see the Engine module.

Pre-Combustion Control Systems

Pre-combustion systems are by far the most efficient of the two types of control systems. It's better, easier and cheaper not to produce emissions in the first place than it is to control or destroy them after they've been formed. Most of the pollution control systems we use today prevent emissions from being created in the engine, either during or before the combustion cycle.

Crankcase Ventilation



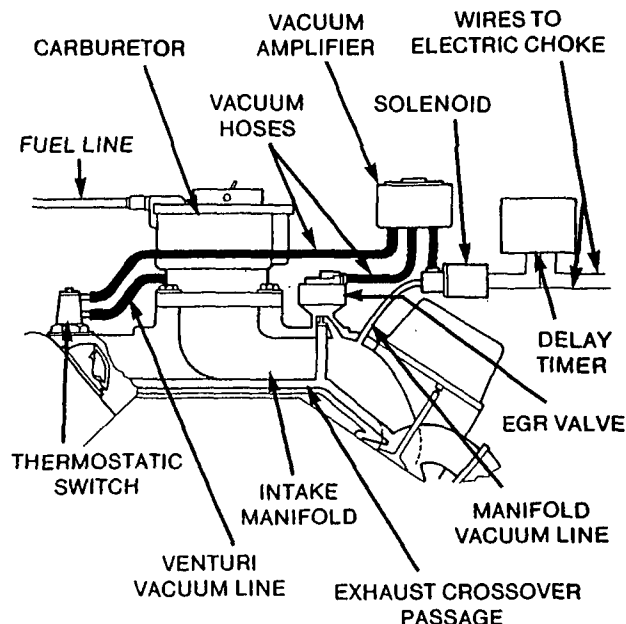
(Figure 44) Crankcase Ventilation.

The first crankcase ventilation systems were installed not to control emissions, but to remove harmful fuel vapors and combustion "blow-by" from inside the engine crankcase. Later, it was discovered that these harmful interior elements were damaging when they were released into the atmosphere. Modern crankcase ventilation systems prevent these vapors from reaching the atmosphere by recycling them through the engine. This reduces emissions, while still allowing for ventilation.

Exhaust Gas Recirculation

One of the best methods of controlling the formation of NO_x emissions is through exhaust

gas recirculation (EGR). Designed to reduce the temperature of combustion in the cylinders of the engine, EGR is also the only major emissions control that is used on modern diesel engines.



(Figure 45) Exhaust Gas Recirculation.

EGR reduces combustion temperatures by introducing small amounts of inert exhaust gas into the combustion cycle. The exhaust gas dilutes the incoming air/fuel mixture, which results in less fuel in the combustion chamber. With less fuel to burn, less heat (and power) is produced.

Since it was first introduced into cars in 1971, many advancements have been made in the area of EGR control. Methods have been developed to control when EGR flow should occur and how much it can be used. But other than refinements in control, the EGR systems in use today are basically the same as the first systems of the early 1970's.

Spark Controls

There have been two phases in spark control development. The first designs were simple, usually consisting of a vacuum control valve added to the existing ignition advance system. These devices were designed to either prevent or increase spark advance under certain conditions.

Newer spark controls are based at least partially, and in some cases totally, on the use of modern spark control computers. These computers have increased the precision of ignition timing, because combustion is extremely sensitive to the time at which the ignition spark occurs. Modern spark control methods have drastically reduced total emissions output.

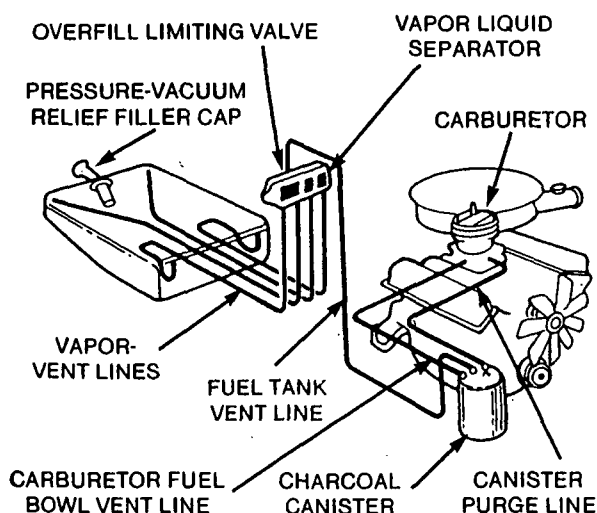
Engine Design Modifications

Engine modification is one of the most effective ways to control emissions. Because the modification of basic engine designs such as combustion chambers and piston heads requires no new working parts, car manufacturers tend to favor this method.

Computer Engine Controls

The use of the "mini-computer" has resulted in a complete restructuring of emissions control. Many of the controls are the same ones that had been previously used, but their efficiency at reducing emissions has been improved because they're computer-controlled. The computer, when attached to the appropriate sensors, is capable of monitoring and reacting to far more situations in the engine than any mechanical system of monitoring is able to do.

Evaporative Controls



(Figure 46) Evaporative Controls.

These emission control devices are designed to prevent hydrocarbons from evaporating into

the atmosphere from the fuel system.

Air must enter the fuel tank to replace fuel used by the engine, and before evaporative emission controls were developed and required, this air was provided through vent tubes. When the vehicle was stopped with the engine off, however the vents also allowed fuel vapors to flow into the atmosphere.

Evaporative emissions control systems trap fuel vapors from the fuel tank and from the carburetor in a carbon filter and then recycle them back into the engine.

Post-Combustion Control Systems

Post-combustion control systems clean up the exhaust gases after the fuel has been burned. After a brief overview of the air injection system, we'll take a more detailed look at the catalytic converter.

Air Injection

Air injection was one of the earliest methods developed to control emission levels of HC and CO. This design is still used today on most vehicles and is one of the more efficient means of reducing those pollutants. While it's listed here as a "post-combustion" system, air injection really has elements of both post- and pre-combustion systems.

The air injection system introduces extra air (oxygen) into the exhaust stream of the engine. In most cases, combustion in the cylinders is limited by the amount of oxygen available to sustain burning; so when extra air is introduced into the hot exhaust system, all the remaining fuel is oxidized, or burned.

Since air injection helps the process of combustion, it qualifies as a pre-combustion device. But the fact that the combustion process is continued in the exhaust system (and requires additional components) qualifies air injection as a post-combustion system.

However it may be classified, air injection is an effective system which economically reduces HC and CO emissions.

THE CATALYTIC CONVERTOR

Harmful emissions that contribute to air pollution come from three sources—the fuel tank

and carburetor (through evaporation), the crankcase (through unburned fuel vapors), and the engine exhaust—which is by far the most significant source of emissions.

The catalytic converter is a major part of most emission control systems. Catalytic converters in the exhaust system began to appear on new cars in 1975. In that year, a reduction in the allowable emission levels set by the EPA came into effect.

Until 1975, car makers had done an effective job of controlling emissions by the use of other systems—auxiliary air injection systems, exhaust gas recirculation systems, and positive crankcase ventilation. But controlling emissions with these systems meant lean mixtures and exotic ignition timing, which often severely penalized power and fuel economy.

When catalytic converters were introduced, much of the emission control job could be taken out of the engine and moved into the exhaust system. This change allowed manufacturers to retune the engine for better performance and improved fuel economy.

What A Catalytic Converter Does

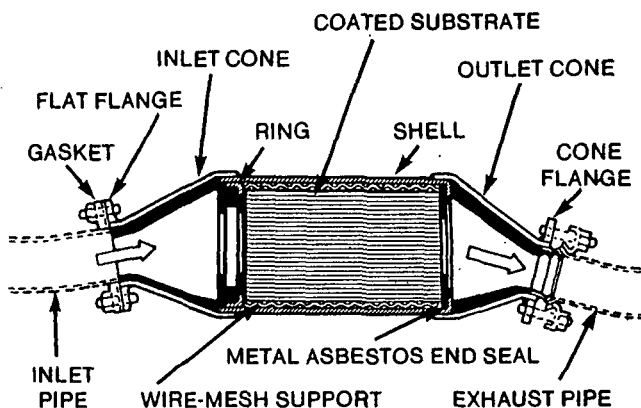
A catalyst is an element that causes a chemical reaction in other elements without actually becoming a part of the chemical change itself, and without being used up or consumed in the process. A automotive catalytic converter is a device that uses catalysts to cause a change in the elements of the waste exhaust gases as they pass through the exhaust system.

The catalyst or “change causing” elements used in catalytic converters are platinum, palladium and rhodium. These elements are used alone, or in combination, to change the undesirable hydrocarbons, carbon monoxide, and nitrogen oxides into harmless water vapor, carbon dioxide, nitrogen and oxygen.

These noble metal elements thinly coat a substrate supported inside the converter shell. The substrate is a ceramic material designed to withstand the high temperature of the exhaust gases and the additional heat that is caused by the chemical changes of the catalytic reaction. It's also designed so that a very large surface—several thousand square yards of area—is exposed to the exhaust gases.

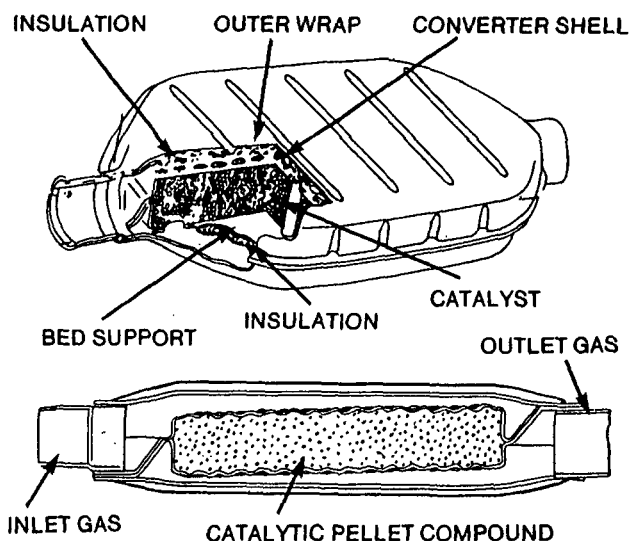
The hydrocarbons, carbon monoxide, and nitrogen oxide molecules enter the converter and contact and attach themselves to the noble metals which cover the substrate. When heat is applied, the catalytic process causes the molecules to rearrange themselves into less harmful elements.

The converter itself is located either under the floor of the automobile or in the exhaust manifold. There are two basic designs of catalytic converters—monolithic and pelletized.



(Figure 47) Monolithic Catalytic Converter.

A monolithic type catalytic converter has an interior that's a porous honeycomb one-piece substrate. The exhaust gases flow through thousands of tiny channels in the substrate where they contact the catalytic metal.



(Figure 48) Pelletized Catalytic Converter.

A pelletized type converter is a shell that contains a bed of small catalyst-coated ceramic beads. The exhaust gases are forced to flow around these beads in their path to the outlet of the exhaust system.

There are four basic types of converter functions—oxidation, reduction, dual bed three-way and single-bed three-way. Each one of these converter functions (or a combination of two or more) is designed to meet the requirements of the specific emission control system.

- **Oxidation**—The carbon monoxide (CO) and hydrocarbons (HC) that have not been totally consumed by combustion are channeled into an oxidation converter and then changed into harmless water (H₂O) and carbon dioxide (CO₂).
- **Reduction**—The converter reduces the nitrous oxides (NO_x) produced during combustion into nitrogen and carbon dioxide (CO₂).
- **Reduction and Oxidation (Dual Bed)**—A reduction catalyst requiring an oxygen deficient environment is followed by an oxidation catalyst requiring an oxygen rich environment.
- **Three-way**—Reduction and oxidation functions take place simultaneously. Used only on cars with electronic fuel injection, the mixture cycles from rich to lean and the converter operates alternately in a reduction mode when the mixture is rich and in an oxidation mode when the mixture is lean.

Converter Problems

A catalytic converter can be harmed or destroyed in many ways. Under normal conditions, a catalytic converter will last at least 50,000 miles, or even longer. But with the wrong fuel, excessive combustion heat, or an incorrect air-fuel mixture, a catalytic converter can be seriously damaged or destroyed.

Leaded Fuel

Catalytic converters must be used with unleaded fuel only. Lead and phosphorus will severely reduce the catalyst effect and performance. When leaded fuel is used, lead coats the catalyst in the converter and forms a barrier,

preventing the exhaust gases from contacting it. The result is a less active chemical reaction or, in the event of severe lead contamination, no chemical reaction at all.

Sometimes, returning to unleaded fuel will allow the converter to regain some of its functional efficiency. The efficiency regained depends on how much and how long leaded fuel has been used.

It is a violation of federal law to sell leaded fuel for use in vehicles equipped with converters. To help regulate this, converter-equipped cars and trucks have a restrictor in the fuel tank filler that will only allow the use of an unleaded gasoline pump nozzle. Unleaded gasoline pump nozzle spouts are smaller in diameter than are spouts of leaded gasoline nozzles.

Heat and Engine Conditions

Heat is a normal part of converter operation. The optimum temperature for high converter efficiency is 1500 degrees F. If the temperature in the catalyst area rises, however, the substrate of the converter may break up or melt.

Poor engine conditions usually cause this problem. Engines in need of a tune-up will deliver a too-rich exhaust gas to the converter, having either not enough air or too much fuel.

When this rich fuel mixture reaches the catalyst, the converter becomes a furnace. The catalyst converts the pollutants, heat is released in the process, and combustion takes place while raw fuel is present. The additional heat ruins the converter substrate.

A similar problem can be caused by spark plugs that misfire. When more than two spark plugs misfire simultaneously, raw fuel is pumped into the converter. If this misfiring condition occurs over an extended period, the raw fuel causes the internal temperature of the converter to rise quickly. This can lead to a meltdown, as we've already described.

Even an engine in good operating condition can have converter problems. These are normally caused by a severe service condition, such as a long idling period. More heat builds up when idling; so if more than ten minutes of idling is required it's usually better to turn the engine off and restart it later.

Here are some other precautions to help avoid converter damage:

1. Don't start the engine by pushing the vehicle. Use jumper cables or a booster system.
2. Don't crank the engine for more than 1 minute when it's flooded or when it's firing intermittently.
3. Fix obvious problems like dieseling, power surge, back-firing, choke sticking or any other problems immediately.
4. Don't disconnect spark plugs to test the ignition. If this is unavoidable, don't run the engine for more than 30 seconds when a plug isn't firing.

Unusual Converter Odors

Besides controlling hydrocarbon and carbon monoxide emissions, a converter may also produce small quantities of its own emissions. Most gasoline contains a small amount of sulfur and other compounds that are not completely removed during refining. The sulfur can react with water vapor that is produced in the converter to make hydrogen sulfide. This toxic substance causes a "rotten egg" odor, which is usually noticed while the engine is warming up or during deceleration.

This odor can also indicate that the engine is not operating properly, especially when it happens at normal operating temperatures. This is often caused by the engine being out of tune, or running too rich. Adjusting the idle screw will not necessarily eliminate the odor since it's probably not caused by an incorrect mixture adjustment, but by some other problem in the engine ignition or carburetion.

The amount of sulfur in gasoline blends can vary, so switching brands may eliminate the odor.

EMISSION CONTROL FILTERS

There are two emission control systems on an engine that require the use of a filter: the crankcase ventilation system and the fuel tank evaporative control system. Maintenance of the filters on these systems is essential for long engine life and control of harmful emissions into the atmosphere.

Service Procedures

Emission control filters should be checked at each oil change and replaced every 10,000 miles.

Crankcase Ventilation Filter Service Procedure

Road Draft Tube and Open PCV Type

1. Remove breather filter from engine. (If pleated paper media is used, replace with new filter.)
2. Soak filter in solvent or carburetor cleaner until all dirt and residue is removed.
3. Rinse thoroughly and allow to dry by draining, or use compressed air.
4. Squirt clean oil into small outer opening until media is damp.

Closed PCV Type

1. Loosen wing nut and remove cover of air filter housing.
2. Using pliers, remove the metal clip from the breather filter.
3. Remove rubber hose from breather filter and discard filter.
4. Install new breather filter, rubber hose and metal clip.
5. Squirt clean oil into filter media until damp.
6. Replace air filter housing cover and tighten wing nut securely.

Gasoline Evaporative Control System Filter Procedure

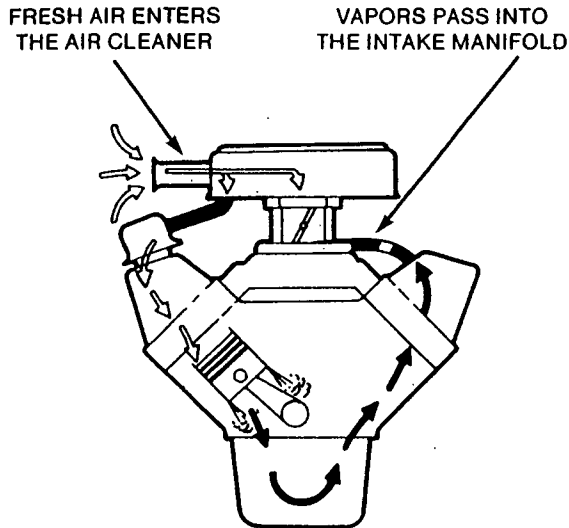
The filter for this system is found in the bottom of the carbon canister. The canister is located in the engine compartment, usually on the right side.

1. Loosen bolt which holds strap around canister.
2. Lift out canister, leaving hoses connected.
3. Remove dirty pad from bottom of canister.
4. Slip new pad into place and tuck in edges.
5. Replace canister and tighten strap.

EMISSION RECYCLING SYSTEMS HOSES

Various vacuum hoses and vapor hoses are used in the carburetor and air cleaner area. These hoses help to recycle crankcase vapors, fuel vapors and hot air.

Crankcase Vapor Recycling



(Figure 49) PCV Hose.

Positive crankcase ventilation hoses or PCV hoses recycle crankcase vapors which develop from combustion gases and contaminants that blow past the engine's piston rings and collect in the crankcase.

A PCV hose connected to the rocker cover draws these vapors up and sends them to the carburetor where they're mixed with fuel and sent back to the engine. A second PCV hose sends fresh air from the air cleaner back into the rocker cover to help purge the vapors and to fill the vacuum that occurs when they flow out.

Fuel Vapor Recycling

Evaporative emission control or EEC hoses recycle fuel vapors that would otherwise evaporate from the carburetor and fuel tank. These hoses carry vapors from the gas tank and carburetor to a canister containing activated charcoal which stores vapors when the engine is off. When the engine is operating, a purge line carries the vapors from the canister to the

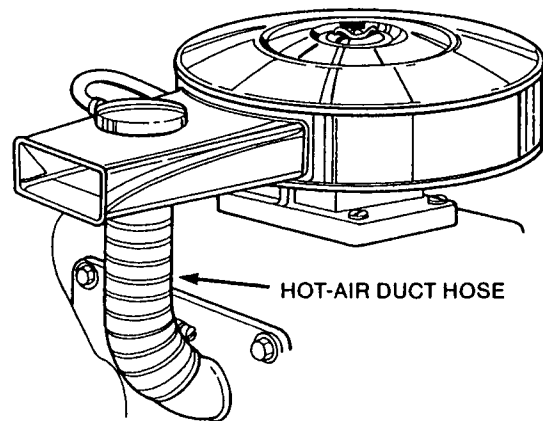
engine to be burned. EEC vapor hoses can also replace vent hoses in the gas tank.

Exhaust Gas Recycling

The exhaust gas recirculation or EGR system channels up to 20% of the exhaust gases back into the combustion chamber. This type of system reduces combustion temperatures and the production of nitrogen oxide pollutants.

An EGR valve on the intake manifold acts like a thermostat by letting exhaust gas flow into the intake manifold. EGR vacuum hoses supply suction to the EGR valve from the vacuum of the carburetor, intake manifold or from a special vacuum pump.

Hot Air Duct



(Figure 50) Hot Air Duct Hose.

Hot air from a shroud surrounding the engine manifold can be routed to the intake snorkel of the air cleaner via the hot-air duct hose. This hot air is used to assist in warm-up when the car engine is still fairly cold. A heat sensing switch regulates the amount of warm air that enters.

SUMMARY

Emission control systems have become an important component in car design and manufacture, and have reduced the amount of harmful emissions into the atmosphere. This chapter reviewed the process of internal combustion, and the emissions that are by-products of this process.

Finally, we reviewed emission control filters and their servicing, and examined the various types of emission recycling system hoses.

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GLOSSARY

A-Circuit—A generator or alternator field circuit that is grounded externally through the regulator contacts.

After Top Dead Center—The position of a piston after it has passed top dead center. Abbreviated: atdc. Usually expressed in degrees, such as 5 degrees atdc.

Air-Fuel Ratio—The ratio of air to gasoline by weight in the air-fuel mixture drawn into an engine.

Alternating Current—A flow of electricity through a conductor, first in one direction and then rapidly changing to the opposite direction.

Ambient Temperature—The temperature of the air surrounding a particular device or location.

Ammeter—A meter used to measure electrical current flow in amperes.

Ampere—The unit for measuring the rate of electrical current flow.

Ampere-Hour Rating—A battery rating based on the amperes of current that a battery can supply steadily for 20 hours, with no battery cell falling below 1.75 volts. Also called a 20-hour discharge rating.

Analog—Describes a computer that uses variations in voltage to make calculations, as opposed to the discrete numbers used by a digital computer.

Armature—The movable part in a relay. The revolving part in a generator or motor.

Available Voltage—The peak voltage that a coil can produce.

Bakelite—A synthetic plastic material that is a good insulator. Distributor caps are often made of bakelite.

Ballast (Primary) Resistor—A resistor in the primary circuit that stabilizes ignition system voltage and current flow.

Base—The center layer of semiconductor material in a transistor.

B-Circuit—A generator or alternator field circuit that is grounded internally.

Before Top Dead Center—The position of a piston as it nears top dead center. Abbreviated: btcd. Usually expressed in degrees, such as 5 degrees btcd.

Biassing—Applying voltage to a junction of semiconductor materials.

Bottom Dead Center—The exact bottom of a piston stroke. Abbreviated: bdc.

Breakdown Voltage—The voltage above which a zener diode will allow reverse current flow.

Breaker Points—The metal contact points that act as an electrical switch in a distributor. They open and close the ignition primary circuit.

Brushes—Bars of carbon, or other conductive material, that make an electrical connection with the rotating commutator or sliprings.

Buss Bar—A solid metal strip, or bar, used as a conductor in a fuse panel.

Capacitance—The ability of two conducting surfaces, separated by an insulator, to store an electric charge.

Carbon Monoxide—An odorless, colorless, tasteless poisonous gas. A major pollutant given off by an internal combustion engine.

Centrifugal (Mechanical) Advance—A method of advancing the ignition spark, using weights in the distributor that react to centrifugal force.

Centrifugal Force—The natural tendency of objects, when rotated, to move away from the center of rotation.

Circuit—A circle or unbroken path through which an electric current can flow.

Circuit Diagram—A combination of a schematic and a wiring diagram. It shows the wires, the connections, and what the loads do in an electrical circuit.

Circuit Number—The number, or number and letter, that carmakers use to identify an electrical circuit in a diagram.

Clutch Switch—A starting safety switch that is operated by the clutch pedal.

Cold-Cranking Rating—A battery rating based on the amperes of current that a battery can supply for 30 seconds at 0 degrees F, with no battery cell falling below 1.2 volts.

Collector—The outside layer of semiconductor material, in a transistor, that conducts current away from the base.

Color Coding—The use of colored insulation on wire to identify an electrical circuit.

Commutator—A segmented ring attached to one end of an armature in a generator or a motor, providing an electrical connection between the armature and brushes. In a generator, it rectifies the alternating current. In a motor, it provides a current path to the armature.

Compound Motor—A motor that has both series and shunt field windings. Often used as a starter motor.

Concentric—Having the same center, such as two circles drawn around a common centerpoint.

Condenser—A device that stores an electrical charge. Also called a capacitor.

Conductors—Materials that allow easy electron flow because of their many free electrons.

Continuity—Continuous, unbroken. Used to describe a working electrical circuit or component that is not open.

Conventional Theory—The current flow theory which says electricity flows from positive to negative. Also called the positive current flow theory.

Core—A magnetic path through a coil or transformer. In a generator, a core and the windings that surround it are called an armature.

Counterelectromotive Force—An induced voltage that opposes the source voltage and any change (increase or decrease) in the charging current. Abbreviated: CEMF.

Cross-Firing—Ignition voltage jumping from the distributor rotor to the wrong spark plug electrode inside the distributor cap. Also, ignition voltage jumping from one spark plug cable to another due to worn insulation.

Current Regulator—A relay that limits a generator's current output.

Cutout Relay—A relay that keeps the battery from discharging when the engine is off or idling. It acts as a circuit breaker to open the circuit between the battery and the generator.

Cycling—Battery electrochemical action. One complete

cycle is the operation from fully charged to discharged and back to fully charged.

D'Arsonval Movement—A small, current-carrying coil mounted within the field of a permanent horseshoe magnet. Interaction of the magnetic fields causes the coil to rotate. Used as a measuring device within electrical gauges and test meters.

Delta-Type—An alternator stator design in which the three windings of a 3-phase alternator are connected end-to-end. The beginning of one winding is attached to the end of another winding. Used in alternators that might give high amperage output.

Detented—Positions in a switch that allow the switch to stay in that position. In an ignition switch, the On, Off, Lock, and Accessory positions are detented.

Diaphragm—A thin, flexible wall separating two spaces, such as the diaphragm in a vacuum advance unit.

Dielectric—An electrically nonconducting material; synonymous with insulation.

Digital—Describing a computer that makes calculations with quantities represented electronically as digits.

Diode—An electronic device made of P-material and N-material bonded at a junction. A diode allows current flow in one direction and blocks it in the other.

Direct Current—A flow of electricity in one direction through a conductor.

Doping—The addition of a small amount of a second element to a semiconductor element.

Dwell Angle—Also called cam angle, or dwell. The measurement in degrees of how far the distributor cam rotates while the breaker points are closed.

Eddy Current—Small, induced current flow in a core. In a generator, armature design minimizes the heat caused by eddy currents.

Electrolyte—The chemical solution in a battery that conducts electricity and reacts with the plate materials.

Electrochemistry—In a battery, voltage caused by the chemical action of two dissimilar materials in the presence of a conductive chemical solution.

Electromagnet—A soft iron core wrapped in a coil of a current-carrying conductor.

Electromagnetic Induction—The creation of a voltage within a conductor when relative motion exists between the conductor and a magnetic field.

Electromagnetics—The relationship of magnetic energy to electrical energy.

Electron Theory—The current flow theory which says that electricity flows from negative to positive.

Electrostatic Field—The area around an electrically charged body resulting from the difference in voltage between two points or surfaces.

Emitter—The outside layer of semiconductor material, in a transistor, that conducts current to the base.

Equivalent Resistance—The total resistance of a parallel circuit. The single mathematical equivalent of all the parallel resistance.

Extended-Core Spark Plug—Also called power tip. The insulator core and the electrodes in this type of spark plug extend further into the combustion chamber than

they do on other types.

Farad—The unit of measurement of capacitance.

Field Relay—A magnetic switch used to open and close the alternator field circuit or, in a charging circuit with a warning lamp, to control the lamp circuit.

Firing Order—The order in which combustion occurs in the cylinders of an engine.

Firing Voltage (Required Voltage)—The voltage level that must be reached to ionize and create a spark in the air gap between the spark plug electrodes.

Flux Density—The number of flux lines in a magnetic field area. The more flux lines in a unit of area, the stronger the magnetic field at that point.

Forward Bias—The application of a voltage to produce current flow across the junction of a semiconductor.

Four-Stroke Cycle—One complete operating cycle of a piston in a 4-stroke engine. The four strokes of the cycle are: intake, compression, power, and exhaust.

Full-Wave Rectification—A process by which all of an a.c. voltage wave is rectified and allowed to flow as d.c.

Ground Cable—The battery cable that provides a ground connection from the vehicle chassis to the battery.

Half-Wave Rectification—A process by which only one-half of an a.c. voltage wave is rectified and allowed to flow as d.c.

Heat Range—The measure of a spark plug's ability to dissipate heat from its firing end.

Hold-In Winding—The coil of smaller-diameter wire in a solenoid that creates a magnet field to hold the solenoid plunger in position inside the coil.

Hydrocarbon—A chemical compound of hydrogen and carbon. A major pollutant given off by an internal combustion engine. Gasoline; itself, is a hydrocarbon compound.

Ignition Interval (Firing Interval)—The number of degrees of crankshaft rotation between ignition sparks.

Impurities—The doping elements added to pure silicon or germanium to form semiconductor materials.

Induced Voltage—The voltage which appears in a conductor when relative motion exists between it and magnetic flux lines.

Inductive Discharge Ignition—A method of igniting the air-fuel mixture in an engine cylinder. It is based on the induction of a high voltage in the secondary winding of the coil.

Inertia—The tendency of an object at rest to remain at rest, and of an object in motion to remain in motion.

Installation Diagram—A drawing that shows where the wires, loads, attachment hardware, and other parts of an electrical circuit are installed in a car.

Insulated (Hot) Cable—The battery cable that conducts battery current to the automotive electrical system.

Insulators—Materials that will not conduct electron flow because of their many bound electrons.

Ionize—To break up molecules into two or more oppositely charged ions. The air gap between the spark plug electrodes is ionized when the air-fuel mixture is changed from a non-conductor to a conductor.

Isolated-Field Circuit—A variation of the A-circuit. Field

current is drawn from the alternator output outside of the alternator and sent directly to an insulated brush. The other brush is grounded through the regulator.

Junction—The area where two types of semiconductor materials (P- and N-material) are joined.

Lap Winding—A method of wiring a motor armature. The two ends of a conductor are attached to two commutator bars that are next to each other.

Magnetic Field—The area surrounding a magnet that is influenced by the magnet's energy.

Magnetic Flux—The invisible, directional lines of force which make up a magnetic field.

Magnetic Saturation—The condition when a magnetic field reaches full strength and maximum flux density.

Magnetic Shunt (Magnetic Bypass)—A piece of metal on a voltage regulator coil that controls voltage output at varying temperatures by affecting the coil's magnetic field.

Magnetism—A form of energy caused by the alignment of atoms within certain materials. The ability of a metal to attract iron.

Manifold Vacuum—Low pressure in an engine's intake manifold, below the carburetor throttle plate.

Mica—A mineral that is often used as an insulator.

Minus Rule—Minus metal on the minus side of the distributor breaker points means a minus-capacity condenser.

Module—A self-contained, sealed unit that houses the solid-state circuits needed to control certain electrical or mechanical functions.

Mutual Induction—Creation of voltage in one conductor by the rise and collapse of the magnetic field surrounding another conductor.

Negative Polarity—Also called ground polarity. A correct polarity of the ignition coil connections. Coil voltage is delivered to the spark plugs so that the center electrode of the plug is negatively charged and the grounded electrode is positively charged.

Neutral Junction—The center connection of the three windings in a Y-type stator.

N-material—A semiconductor material that has excess free electrons because of the type of impurity added. It has a negative charge and will repel additional electrons.

No-Load Oscillation—The rapid, back-and-forth, peak-to-peak oscillation of voltage in the ignition secondary circuit when the circuit is open.

Ohm—The unit for measuring electrical resistance.

When one volt pushes one ampere through a circuit, the resistance present is one ohm.

Ohmmeter—A meter used to measure resistance to current flow.

Orifice—A small opening in a tube, pipe, or valve.

Oxides of Nitrogen—Chemical compounds of nitrogen given off by an internal combustion engine. They combine with hydrocarbons to produce smog.

Parallel Circuit—A circuit that has more than one path through which current can flow.

Peak Inverse Voltage—The highest reverse bias voltage that can be applied to a junction of a diode before its atomic structure breaks down and allows current to flow.

Permeability—A measure of the ease or difficulty with which materials can be penetrated by magnetic flux lines. Iron is more permeable than air.

Photoelectricity—Voltage caused by the energy of light as it strikes certain materials.

Piezoelectricity—Voltage caused by physical pressure applied to the faces of certain crystals.

P-material—A semiconductor material that has holes for additional electrons because of the type of impurity added. It has a positive charge and will attract additional electrons.

Polarity—Having poles, such as the north and south poles of a magnet. The poles of a battery or an electrical circuit are its positive and negative terminals.

Polarizing—A method of maintaining the electrical and magnetic polarity of the pole shoes and field in a generator.

Pole—The areas of a magnetized body where the lines of magnetic force are concentrated. One end of a magnet.

Pole Shoes (Pole Pieces)—Magnetic iron cores, or poles, that provide the magnetic field in a generator or motor and strengthen the electromagnetic field of the field windings.

Ported Vacuum—Vacuum immediately above the throttle plate in a carburetor.

Positive Polarity—Also called reverse polarity. An incorrect polarity of the ignition coil connections. Coil voltage is delivered to the spark plug so that the center electrode of the plug is positively charged and the grounded electrode is negatively charged.

Potential—Possible, but not yet in use. The voltage between two points.

Potentiometer—A variable resistor.

Primary Battery—A battery in which chemical processes destroy one of the metals necessary to create electrical energy. Primary batteries cannot be recharged.

Primary Winding—The coil winding made of a few turns of a heavy wire, which uses battery current to create a magnetic field.

Primary Wiring—The low-voltage wiring in an automobile electrical system.

Pull-In Winding—The coil of large-diameter wire in a solenoid that creates a magnetic field to pull the solenoid plunger into the coil.

Reach—The length of the spark plug from the seat to the bottom of the shell.

Reciprocating Engine—Also called a piston engine. An engine in which the pistons move up and down or back and forth, as a result of combustion in the top of the cylinder.

Rectify—To change alternating current to direct current.

Regulator—In most cases, a shortened name for current and voltage limiters. It uses a combination of relays to keep generator output voltage and current to specified limits. Used with alternators to limit voltage only.

Relative Motion—Movement of a conductor in relation to magnetic flux lines or movement of magnetic flux lines in relation to a conductor.

Relay—An electromagnetic switch. A relay uses a small

amount of current flow to control the flow of a larger amount of current through a separate circuit.

Reluctance—The tendency of some materials to resist penetration by magnetic flux lines.

Reserve Capacity Rating—A battery rating based on the number of minutes a battery at 80 degrees Fahrenheit can supply 25 amperes, with no battery cell falling below 1.75 volts.

Resistance—Opposition to electrical current flow.

Resistor-Type Spark Plug—A plug that has a resistor in the center electrode to reduce the inductive portion of the spark discharge.

Reverse Bias—The application of a voltage so that normally no current will flow across the junction of a semiconductor.

Rheostat—A variable resistor.

Schematic Diagram—A drawing of a circuit, or any part of a circuit, that shows how it works.

Secondary Battery—A battery in which chemical processes can be reversed. A secondary battery can be recharged so that it will continue to supply voltage.

Secondary Winding—The coil winding made of many turns of a fine wire, in which voltage is induced by the rise and collapse of the magnetic field of the primary winding.

Self-induced Voltage—Voltage created in a conductor by the magnetic lines of a current through that same conductor.

Semiconductors—Materials that have four electrons in their valence ring and are neither good conductors nor good insulators.

Series Circuit—A circuit that has only one path through which current can flow.

Series Contacts—The normally closed set of contacts in a double-contact regulator. When they open, field current must flow through a resistor.

Series-Gap Spark Plug—Also called booster. A spark plug in which the center electrode has an extra gap to increase ionization voltage.

Series Motor—A motor that has only one path for current flow through the field and armature windings. Commonly used for starter motors.

Series-Parallel Circuit—A circuit that has some parts in series with the voltage source and some parts in parallel with each other and with the voltage source.

Servo—A device operated by electrical or mechanical impulses that automatically operates another device.

Shorting Contacts—The normally open set of contacts in a double-contact regulator. When closed, they short-circuit the field to ground.

Shunt—Parallel. An electrical connection or branch circuit in parallel with another branch circuit or connection.

Shunt Motor—A motor that has its field windings wired in parallel with its armature. Not used as a starter motor, but often used to power vehicle accessories.

Shunt-Wound—A method of wiring a generator so that some armature current is routed (shunted) through a parallel circuit to the field windings.

Sine Wave Voltage—The constant charge, first to a positive peak and then to a negative peak, of an induced alter-

nating voltage in a conductor.

Single-Phase Current—The full wave current induced within one conductor by one revolution of an alternator rotor.

Single-Phase Voltage—The full wave voltage induced within one conductor by one revolution of an alternator rotor.

Sintered—Welded together without using heat to form a porous material, such as the metal disc used in some vacuum delay valves.

Solenoid-Actuated Starter—A starter that uses a solenoid both to control current flow in the starter circuit and to engage the starter motor with the engine flywheel.

Sour Gas—In fuel injection systems, unused gas is returned to the tank where hydroperoxide molecules form. Hydroperoxides can cause some lower quality fuel line hoses to crack and disintegrate.

Spark Voltage—The inductive portion of a spark that maintains the spark in the air gap between the electrodes of a spark plug. Usually about one-quarter of the firing voltage level.

Specific Gravity—The weight of a volume of liquid divided by the weight of the same volume of water at a given temperature and pressure. Water has a specific gravity of 1.000.

Starting Bypass—A parallel branch circuit that bypasses the primary ballast resistor during cranking.

Starting Safety Switch—A neutral start switch. It keeps the starting system from operating when a car's transmission is in gear.

Static Electricity—Voltage resulting from the transfer of electrons from the surface of one material to the surface of another material. The electrons are "static," meaning at rest.

Stroboscopic Effect—The effect caused by a rapidly flashing light as it makes moving objects appear stationary.

Stroke—One complete top-to-bottom or bottom-to-top movement of an engine piston.

Sulfation—The crystallization of lead sulfate on the plates of a constantly discharged battery.

System Diagram—A drawing that shows all of the different circuit diagrams in a complete electrical system.

Thermistor (Thermal Resistor)—A resistor especially built to reduce its resistance as the temperature increases.

Three-Phase Current—Three overlapping, evenly spaced, single-phase currents that make up the total a.c. output of an alternator.

Top Dead Center—The exact top of a piston stroke. Also a specification used when tuning an engine. Abbreviated: tdc.

Torque—Twisting or rotating force; usually expressed in foot-pounds, inch-pounds, or Newton-meters.

Transducer—A device that changes one form of energy into another. In an ignition system, it may sense a mechanical movement and change it to an electrical signal.

Vacuum—A pressure less than atmospheric pressure.

Vacuum Advance—The use of engine vacuum to advance or retard ignition spark timing by moving the distributor

breaker plate.

Valve Timing—A method of coordinating camshaft rotation and crankshaft rotation so that the valves open and close at the right times during each of the piston strokes.

Venturi—A restriction in an airflow, such as in a carburetor, that speeds the airflow and creates a vacuum.

Volt—The unit for measuring the amount of electrical force.

Voltage—The electromotive force that causes current flow. The potential difference in electrical force between two points when one is negatively charged and the other is positively charged.

Voltage Creep (Voltage Drift)—Extreme voltage at high speeds due to too much field current flow through a single-contact regulator.

Voltage Decay—The rapid oscillation and dissipation of secondary voltage after the spark in a spark plug air gap has stopped.

Voltage Drop—The measurement of the loss of voltage caused by the resistance of a conductor or a circuit device.

Voltage Regulator—A relay that limits a generator's voltage output.

Voltage Reserve—The amount of coil voltage available in excess of the voltage required to fire the spark plugs.

Voltmeter—A meter used to measure electromotive force in volts.

Watt—The unit of measurement for electric power. One way to measure the rate of doing work. Watts equals volts times amperes.

Watts Rating—A method of rating the available cranking power of a battery. The rating can be found by multiplying the current available from the battery by the battery voltage at 0 degrees Fahrenheit.

Wave Winding—A method of wiring a motor armature. The two ends of a conductor are attached to two commutator bars that are opposite each other.

Wire Gauge—Wire size numbers based on the cross section area of the conductor. Larger wires have lower gauge numbers.

Wiring Diagram—A drawing that shows only the wires and connections in an electrical circuit.

Wiring Harness—A bundle of wires enclosed in a plastic cover and routed to various areas of the vehicle. Most harnesses end in plug-in connectors. Harnesses are also called looms.

Y-Type—An alternator stator design in which one end of each of the three windings in a 3-phase alternator is connected at a neutral junction. This design is used in alternators that require high voltage at low alternator speed.

Zener Diode—A junction of semiconductor materials that has been heavily doped so that the junction will allow reverse current flow without damage at any voltage above a specific value.



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