Chapter 8

Automotive Electrical Circuits and Wiring

Topics

1.0.0 Charging Circuit

2.0.0 Starting Circuit

3.0.0 Safety Switches

4.0.0 Ignition System

5.0.0 Lighting Circuit

6.0.0 Instruments, Gauges, and Accessories

7.0.0 Automotive Wiring

To hear audio, click on the box.

Overview

The electrical systems on equipment used by the Navy are designed to perform a variety of functions. The automotive electrical system contains five electrical circuits: charging, starting, ignition, lighting, and accessory.

Electrical power and control signals must be delivered to electrical devices reliably and safely. This goal is accomplished through careful circuit design, prudent component selection, and practical equipment location. By carefully studying this chapter, you will understand how these circuits work and the adjustments and repairs required to maintain the electrical systems in peak condition.

Objectives

When you have completed this chapter, you will be able to do the following:

1. Identify charging-circuit components, their functions, and maintenance procedures.
2. Identify starting-circuit components, their functions, and maintenance procedures.
3. Identify ignition-circuit components, their functions, and maintenance procedures.
4. Identify lighting-circuit components, their functions, and maintenance procedures.
5. Identify instruments, gauges, and accessories, their functions, and maintenance procedures.
6. Identify the basic types of automotive wiring, types of terminals, and wiring diagrams.

Prerequisites

This course map shows all of the chapters in Construction Mechanic Basic. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

Automotive Chassis and Body	↑	C
Brakes		M
Construction Equipment Power Trains		
Drive Lines, Differentials, Drive Axles, and Power Train Accessories		
Automotive Clutches, Transmissions, and Transaxles		
Hydraulic and Pneumatic Systems		
Automotive Electrical Circuits and Wiring		B A
Basic Automotive Electricity		S
Cooling and Lubrication Systems		I
Diesel Fuel Systems		C
Gasoline Fuel Systems		
Construction of an Internal Combustion Engine		
Principles of an Internal Combustion Engine		
Technical Administration		

Features of this Manual

This manual has several features which make it easy to use online.

- Figure and table numbers in the text are italicized. The figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with italicized instructions telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is

incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

1.0.0 CHARGING CIRCUIT

The basic charging system consists of a battery, alternator, voltage regulator, ignition switch, and indicator light or indicator gauge or both. They must all work together to provide a source of electricity for the vehicle to operate. The charging system performs several functions:

- It recharges the battery after engine cranking or after the use of electrical accessories with the engine turned off.
- It supplies all the electricity for the vehicle when the engine is running.
- It must change output to meet different electrical loads.
- It provides a voltage output that is slightly higher than battery voltage.

1.1.0 Storage Battery

The storage battery is the heart of the charging circuit (*Figure 8-1*). It is an electrochemical device for producing and storing electricity. A vehicle battery has several important functions:

- It must operate the starting motor, ignition system, electronic fuel injection system, and other electrical devices for the engine during engine cranking and starting.
- It must supply all of the electrical power for the vehicle when the engine is not running.
- It must help the charging system provide electricity when current demands are above the output limit of the charging system.
- It must act as a capacitor (voltage stabilizer) that smoothes current flow through the electrical system.
- It must store energy (electricity) for extended periods.

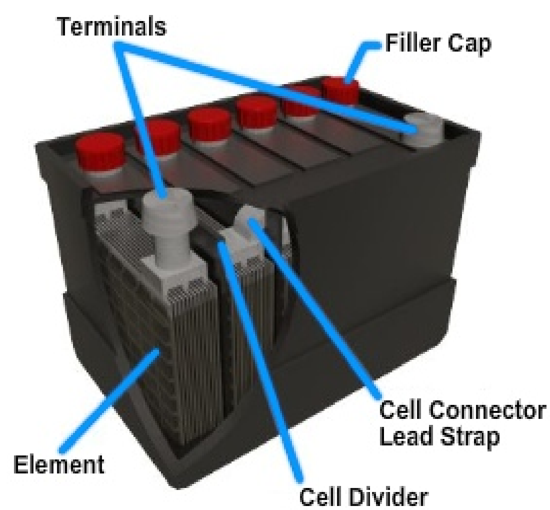


Figure 8-1 — Battery.

The type of battery used in automotive, construction, and weight-handling equipment is a lead-acid cell-type battery. This type of battery produces direct current (DC) electricity that flows in only one direction. When the battery is ***discharging***, it changes chemical energy into electrical energy, thereby, releasing stored energy. During charging (current flowing into the battery from the charging system), electrical energy is converted into chemical energy. The battery can then store energy until the vehicle requires it.

1.1.1 Battery Construction

The lead-acid cell-type storage battery is built to withstand severe vibration, cold weather, engine heat, corrosive chemicals, high current discharge, and prolonged periods without use. To test and service batteries properly, you must understand battery construction. The construction of a basic lead-acid cell-type battery is as follows:

- Battery element
- Battery case, cover, and caps
- Battery terminals
- ***Electrolyte***

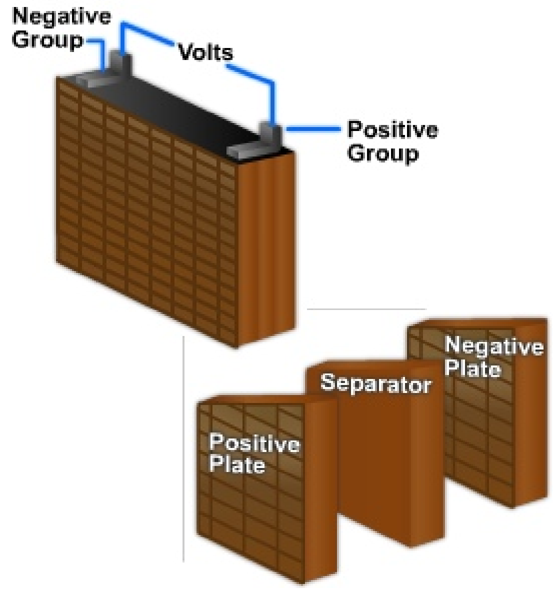


Figure 8-2 — Battery element.

The battery element is made up of negative plates, positive plates, separators, and straps (*Figure 8-2*). The element fits into a cell compartment in the battery case. Most automotive batteries have six elements.

Each cell compartment contains two kinds of chemically active lead plates, known as positive and negative plates. The battery plates are made of a stiff mesh framework coated with porous lead. These plates are insulated from each other by suitable separators and are submerged in a sulfuric acid solution (electrolyte).

Charged negative plates contain spongy (porous) lead (Pb), which is gray in color. Charged positive plates contain lead peroxide (PbO2), which has a chocolate brown color. These substances are known as the active materials of the plates. Calcium or antimony is normally added to the lead to increase battery performance and to decrease ***gassing***. Since the lead on the plates is porous like a sponge, the battery acid easily penetrates into the material. This aids the chemical reaction and the production of electricity.

Lead battery straps or connectors run along the upper portion of the case to connect the plates. The battery terminals (post or side terminals) are constructed as part of one end of each strap.

To prevent the plates from touching each other and causing a short circuit, sheets of insulating material (micro-porous rubber, fibrous glass, or plastic impregnated material), called separators, are inserted between the plates. These separators are thin and porous so the electrolyte will flow easily between the plates. The side of the separator that is placed against the positive plate is grooved so the gas that forms during charging will rise to the surface more readily. These grooves also provide room for any material that flakes from the plates to drop to the sediment space below.

The battery case is made of hard rubber or a high-quality plastic. The case must withstand extreme vibration, temperature change, and the corrosive action of the electrolyte. The dividers in the case form individual containers for each element. A container with its element is one cell.

Stiff ridges or ribs are molded in the bottom of the case to form a support for the plates and a sediment recess for the flakes of active material that drop off the plates during the life of the battery. The sediment is thus kept clear of the plates so it will not cause a short circuit across them.

The battery cover is made of the same material as the container and is bonded to and seals the container. The cover provides openings for the two battery posts and a cap for each cell.

Battery caps either screw or snap into the openings in the battery cover. The battery caps (vent plugs) allow gas to escape and prevent the electrolyte from splashing outside the battery. They also serve as ***spark arresters***. The battery is filled through the vent plug openings. Maintenance-free batteries have a large cover that is not removed during normal service.

WARNING

Hydrogen gas can collect at the top of a battery. If this gas is exposed to a flame or spark, it can explode.

Battery terminals provide a means of connecting the battery plates to the electrical system of the vehicle. Either two round post or two side terminals can be used.

Battery terminals are round metal posts extending through the top of the battery cover. They serve as connections for battery cable ends. The positive post will be larger than the negative post. It may be marked with red paint and a positive (+) symbol. The negative post is smaller, may be marked with black or green paint, and has a negative (-) symbol on or near it.

Side terminals are electrical connections located on the side of the battery. They have internal threads that accept a special bolt on the battery cable end. Side terminal polarity is identified by positive and negative symbols marked on the case.

The electrolyte solution in a fully charged battery is a solution of concentrated sulfuric acid in water. This solution is about 60 percent water and about 40 percent sulfuric acid.

The electrolyte in the lead-acid storage battery has a specific gravity of 1.28, which means that it is 1.28 times as heavy as water. The amount of sulfuric acid in the electrolyte changes with the amount of electrical charge; the specific gravity of the electrolyte also changes with the amount of electrical charge. A fully charged battery will have a specific gravity of 1.28 at 80°F. The figure will go higher with a temperature decrease, and lower with a temperature increase.

As a storage battery discharges, the sulfuric acid is depleted and the electrolyte is gradually converted into water. This action provides a guide in determining the state of discharge of the lead-acid cell. The electrolyte that is placed in a lead-acid battery has a specific gravity of 1.280.

The specific gravity of an electrolyte is actually the measure of its density. The electrolyte becomes less dense as its temperature rises, and a low temperature means a high specific gravity. The hydrometer that you use is marked to read specific gravity at 80°F only. Under normal conditions, the temperature of your electrolyte will not vary much from this mark. However, large changes in temperature require a correction in your reading.

For every 10-degree change in temperature ABOVE 80°F, you must add 0.004 to your specific gravity reading. For every 10-degree change in temperature below 80°F, you must subtract 0.004 from your specific gravity reading. Suppose you have just taken the gravity reading of a cell. The hydrometer reads 1.280. A thermometer in the cell indicates an electrolyte temperature of 60°F. That is a normal difference of 20 degrees from the normal of 80°F. To get the true gravity reading, you must subtract 0.008 from 1.280. Thus the specific gravity of the cell is actually 1.272. A hydrometer conversion chart is usually found on the hydrometer. From it, you can obtain the specific gravity correction for temperature changes above or below 80°F.

1.1.2 Battery Capacity

The capacity of a battery is measured in ampere hours. The ampere-hour capacity is equal to the product of the current in amperes and the time in hours during which the battery is supplying current. The ampere-hour capacity varies inversely with the discharge current. The size of a cell is determined generally by its ampere-hour capacity. The capacity of a cell depends upon many factors, the most important of which are as follows:

- Area of the plates in contact with the electrolyte
- Quantity and specific gravity of the electrolyte
- Type of separators
- General condition of the battery (degree of sulfating, plates buckled, separators warped, sediment in bottom of cells, etc.)
- Final limiting voltage

1.1.3 Battery Ratings

Battery ratings were developed by the Society of Automotive Engineers (SAE) and the Battery Council International (BCI). They are set according to national test standards for battery performance. They let the mechanic compare the cranking power of one battery to another. The two methods of rating lead-acid storage batteries are the cold-cranking rating and the reserve capacity rating.

The cold cranking rating determines how much current in amperes the battery can deliver for thirty seconds at 0°F while maintaining terminal voltage of 7.2 volts or 1.2 volts per cell. This rating indicates the ability of the battery to crank a specific engine (based on starter current draw) at a specified temperature.

For example, one manufacturer recommends a battery with 305 cold-cranking amps for a small four-cylinder engine but a 450 cold-cranking amp battery for a larger V-8 engine. A more powerful battery is needed to handle the heavier starter current draw of the larger engine.

The reserve capacity rating is the time needed to lower battery terminal voltage below 10.2 V (1.7 V per cell) at a discharge rate of 25 amps. This is with the battery fully charged and at 80°F. Reserve capacity will appear on the battery as a time interval in minutes.

For example, if a battery is rated at 90 minutes and the charging system fails, the operator has approximately 90 minutes (1 1/2 hours) of driving time under minimum electrical load before the battery goes completely dead.

1.1.4 Battery Charging

Under normal conditions, a hydrometer reading below 1.265 specific gravity at 80°F is a warning signal that the battery needs charging or is defective.

When testing shows that a battery requires charging, a battery charger is required to re-energize it. The battery charger will restore the charge on the plates by forcing current back into the battery. The battery charger uses AC (Alternating Currnet) current from a wall outlet, usually 120 volts, and steps it down to a voltage slightly above that of a battery, usually 14-15 volts. There are basically two types of chargers, the slow charger and the fast (quick) charger.

The slow charger is also known as the trickle charger. It feeds a small amount current back into the battery over a long period of time. When using a trickle charger, it takes about 12 hours at 10 amps to fully charge a dead battery. However, the chemical action inside the battery is improved. During a slow charge, the active materials are put back onto the battery plates stronger than they are during a fast charge. It is always better for the battery to use a trickle charge when time allows.

The fast charger, or quick charger and sometimes called the boost charger, forces a high amount of current flow back into the battery. A fast charger is commonly used in shops to start an engine or get the vehicle out of the shop quickly because there is no time to wait for a slow charge. Fast charging is beneficial if you just need to start the engine; if time allows, use the slow charge.

When using a fast charger, do not exceed a charge rate in excess of 35 amps. Also, ensure the battery temperature does not exceed 125^{o}F. Exceeding either one could cause damage to the battery.

If there is a possibility that the battery is frozen, do not charge the battery. Charging a frozen circuit can rupture the battery case and cause an explosion. Always allow the battery time to thaw before charging it.

It is easy to connect the battery to the charger, turn the charging current on, and, after a normal charging period, turn the charging current off and remove the battery. Certain precautions, however, are necessary both before and during the charging period. These practices are as follows:

- Clean and inspect the battery thoroughly before placing it on charge. Use a solution of baking soda and water for cleaning, and inspect it for cracks or breaks in the container.

⚠ CAUTION ⚠

Do not permit the baking soda and water solution to enter the cells. To do so would neutralize the acid within the electrolyte.

- Connect the battery to the charger. Be sure the battery terminals are connected properly; connect the positive post to the positive (+) terminal and the negative post to the negative (-) terminal. The positive terminals of both battery and charger are marked; those unmarked are negative. The positive post of the battery is, in most cases, slightly larger than the negative post. Ensure all connections are tight.

  See that the vent holes are clear and open. Do NOT remove battery caps during charging. This prevents acid from spraying onto the top of the battery and keeps dirt out of the cells.

  Check the electrolyte level before charging begins and during charging. Add distilled water if the level of electrolyte is below the top of the plate.

⚠ WARNING ⚠

Keep the charging room well ventilated. Do NOT smoke near batteries being charged. Batteries on charge release hydrogen gas. A small spark may cause an explosion.

Take frequent hydrometer readings of each cell and record them. You can expect the specific gravity to rise during the charge. If it does not rise, remove the battery and dispose of it as per local hazardous material disposal instruction.

Keep close watch for excessive gassing, especially at the very beginning of the charge, when using the constant voltage method. Reduce the charging current if excessive gassing occurs. Some gassing is normal and aids in remixing the electrolyte.

Do not remove a battery until it has been completely charged.

1.1.5 Placing New Batteries in Service

New batteries may come to you full of electrolyte and fully charged. In this case, all that is necessary is to install the batteries properly in the piece of equipment. Most batteries shipped to ***NCF*** units are received charged and dry.

Charged and dry batteries will retain their state of full charge indefinitely so long as moisture is not allowed to enter the cells. Therefore, batteries should be stored in a dry place. Moisture and air entering the cells will allow the negative plates to oxidize. The oxidation causes the battery to lose its charge.

To activate a dry battery, remove the restrictors from the vents and remove the vent caps. Then fill all the cells to the proper level with electrolyte. The best results are obtained when the temperature of the battery and electrolyte is within the range of 60°F to 80°F.

Some gassing will occur while you are filling the battery due to the release of carbon dioxide that is a product of the drying process of the hydrogen sulfide produced by the presence of free sulfur. Therefore, the filling operations should be in a well-ventilated area. These gases and odors are normal and are no cause for alarm.

Approximately 5 minutes after adding electrolyte, check the battery for voltage and electrolyte strength. More than 6 volts or more than 12 volts, depending upon the rated voltage of the battery, indicates the battery is ready for service. From 5 to 6 volts or from 10 to 12 volts indicates oxidized negative plates, and the battery should be charged before use. Less than 5 or less than 10 volts, depending upon the rated voltage, indicates a bad battery, which should not be placed in service.

If, before the battery is placed in service, the specific gravity, when corrected to 80°F, is more than .030 points lower than it was at the time of initial filling or if one or more cells gas violently after adding the electrolyte, the battery should be fully charged before use. If the electrolyte reading fails to rise during charging, discard the battery.

Most shops receive ready-mixed electrolyte. Some units may still get concentrated sulfuric acid that must be mixed with distilled water to get the proper specific gravity for electrolyte.

Mixing electrolyte is a dangerous job. You have probably seen holes appear in a uniform for no apparent reason. Later you remembered replacing a storage battery and having carelessly brushed against the battery.

WARNING

When mixing electrolyte, you are handling pure sulfuric acid, which can burn clothing quickly and severely bum your hands and face. Always wear rubber gloves, an apron, goggles, and a face shield for protection against splashes or accidental spilling.

When you are mixing electrolyte, NEVER pour water into the acid. Always pour acid into water. If water is added to concentrated sulfuric acid, the mixture may explode or splatter and cause severe burns. Pour the acid into the water slowly, stirring gently but thoroughly all the time. Large quantities of acid may require hours of safe dilution.

Let the mixed electrolyte cool down to room temperature before adding it to the battery cells. Hot electrolyte will eat up the cell plates rapidly. To be on the safe side, do not add the electrolyte if its temperature is above 90°F. After filling the battery cells, let the electrolyte cool again because more heat is generated by its contact with the battery plates. Next, take hydrometer readings. The specific gravity of the electrolyte will correspond quite closely to the values on the mixing chart if the parts of water and acid are mixed correctly.

1.1.6 Battery Maintenance

If a battery is not properly maintained, its service life will be drastically reduced. Battery maintenance should be done during every vehicle serviceing. Complete battery maintenance includes the following:

- Visually checking the battery. Battery maintenance should always begin with a thorough visual inspection. Look for signs of ***corrosion*** on or around the battery, signs of leakage, a cracked case or top, missing caps, and loose or missing hold-down clamps.
- Checking the electrolyte level in cells on batteries with caps, and adding water if the electrolyte level is low. On vent cap batteries, you can check the electrolyte level by removing the caps. Some batteries have a fill ring which indicates the electrolyte level. The electrolyte should be even with the fill ring. If there is no fill ring, the electrolyte should be high enough to cover the tops of the plates. Some batteries have an electrolyte-level indicator (Delco Eye). This gives a color code visual indication of the electrolyte level, with black indicating that the level is okay and white meaning a low level.

  If the electrolyte level in the battery is low, fill the cells to the correct level with distilled water (purified water). Distilled water should be used because it does not contain the impurities found in tap water. Tap water contains many chemicals that reduce battery life. The chemicals contaminate the electrolyte and collect in the bottom of the battery case. If enough contaminates collect in the bottom of the case, the cell plates short out, ruining the battery.

  If water must be added at frequent intervals, the charging system may be overcharging the battery. A faulty charging system can force excessive current into the battery. Battery gassing can then remove water from the battery.

  Maintenance-free batteries do NOT need periodic electrolyte service under normal conditions. They are designed to operate for long periods without loss of electrolyte.
- Cleaning off corrosion around the battery and battery terminals. If the top of the battery is dirty, using a stiff bristle brush, wash it down with a mixture of baking soda and water. This action will neutralize and remove the acid-dirt mixture. Be careful not to allow cleaning solution to enter the battery.

⚠ CAUTION ⚠

Do NOT use a scraper or knife to clean battery terminals. This action removes too much metal and can ruin the terminal connection.

To clean the terminals, remove the cables and inspect the terminal posts to see if they are deformed or broken. Clean the terminal posts and the inside surfaces of the cable clamps with a cleaning tool before replacing them on the terminal posts.

When reinstalling the cables, tighten the terminals just enough to secure the connection, over-tightening will strip the cable bolt threads. Coat the terminals with petroleum or white grease. This will keep acid fumes off the connections and keep them from corroding again.

- Checking the condition of the battery by testing there state of charge. When measuring battery charge, you check the condition of the electrolyte and the battery plates. As a battery becomes discharged, its electrolyte has a larger percentage of water. Thus the electrolyte of a discharged battery will have a lower specific gravity number than a fully charged battery. This rise and drop in specific gravity can be used to check the charge in a battery. There are several ways to check the state of charge of a battery.

  Non maintenance-free batteries can have the state of charge checked with a hydrometer. The hydrometer tests specific gravity of the electrolyte. It is fast and simple to use.

  A fully charged battery should have a hydrometer reading of at least 1.265 or higher. If below 1.265, the battery needs to be recharged, or it may be defective.

  A defective battery can be discovered by using a hydrometer to check each cell. If the specific gravity in any cell varies excessively from other cells (25 to 50 points), the battery is bad. Cells with low readings may be shorted. When all of the cells have equal specific gravity, even if they are low, the battery can usually be recharged. On maintenance-free batteries a charge indicator eye shows the battery charge. The charge indicator changes color with levels of battery charge. For example, the indicator may be green with the battery fully charged. It may turn black when discharged or yellow when the battery needs to be replaced. If there is no charge indicator eye or when in doubt of its reliability, you can use a voltmeter and ammeter or a load tester to determine battery condition quickly.

1.1.7 Battery Test

As a mechanic you will be expected to test batteries for proper operation and condition. These tests are as follows:

- A battery leakage test will determine if current is discharging across the top of the battery. A dirty battery can discharge when not in use. This condition shortens battery life and causes starting problems. To perform a battery leakage test, set a voltmeter on a low setting. Touch the probes on the battery, as shown in *Figure 8-3*. If any current is registered on the voltmeter, the top of the battery needs to be cleaned.
- The battery terminal test quickly checks for poor electrical connection between the terminals and the battery cables. A voltmeter is used to measure voltage drop across terminals and cables.

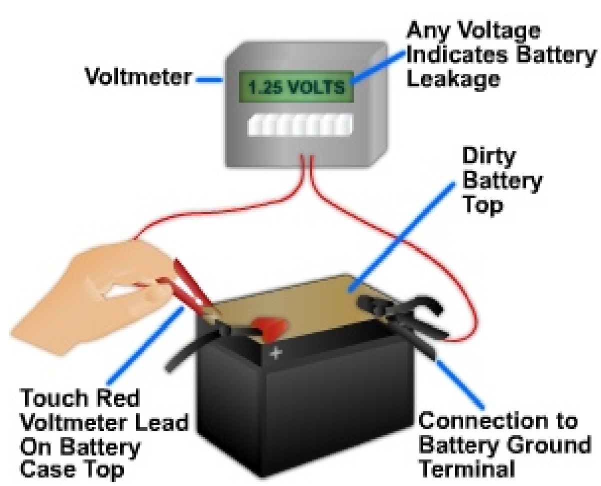


Figure 8-3 — Battery leak test.

To perform a battery terminal test, connect the negative voltmeter lead to the battery cable end (*Figure 8-4*). Touch the positive lead to the battery terminal. With the ignition or injection system disabled so that the engine will not start, crank the engine while watching the voltmeter reading.

If the voltmeter reading is .5 volts or above, there is high resistance at the battery cable connection. This indicates that the battery connections need to be cleaned. A good, clean battery will have less than a .5 volt drop.

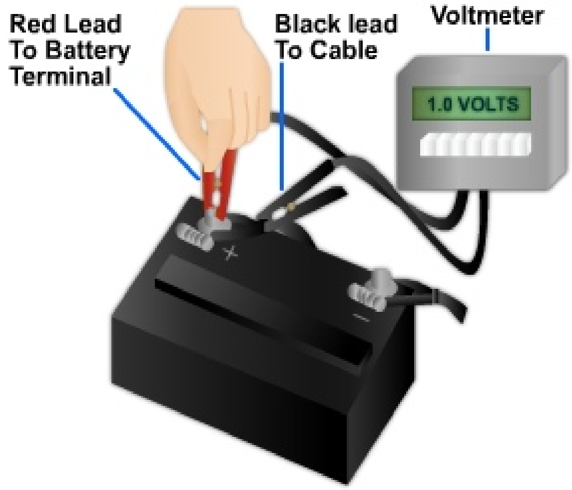


Figure 8-4 — Battery terminal leak test.

- The battery voltage test is done by measuring total battery voltage with an accurate voltmeter or a special battery tester (*Figure 8-5*). This test determines the general state of charge and battery condition quickly.

  The battery voltage test is used on maintenance-free batteries because these batteries do not have caps that can be removed for testing with a hydrometer. To perform this test, connect the voltmeter or battery tester across the battery terminals. Turn on the vehicle headlights or heater blower to provide a light load. Now read the meter or tester. A well-charged battery should have over 12 volts. If the meter reads approximately 11.5 volts, the battery is not charged adequately, or it may be defective.

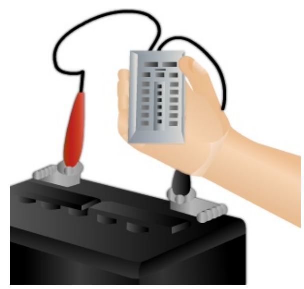


Figure 8-5 — Battery voltage test.

- The cell voltage test will let you know if the battery is discharged or defective. Like a hydrometer cell test, if the voltage reading on one or more cells is .2 volts or more lower than the other cells, the battery must be replaced.

  To perform a cell voltage test, use a low voltage reading voltmeter with special cadmium (acid-resistant metal) tips (*Figure 8-6*). Insert the tips into each cell, starting at one end of the battery and working your way to the other. Test each cell carefully. If the cells are low but equal, recharging usually will restore the battery. If cell voltage readings vary more than .2 volts, the battery is BAD.

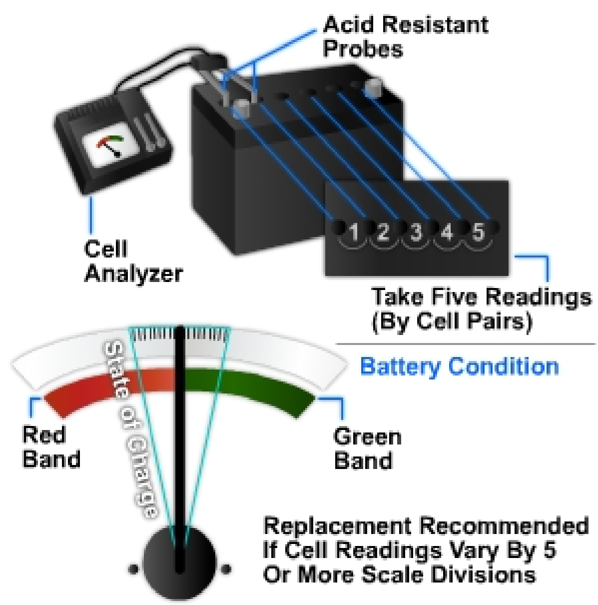


Figure 8-6 — Cell voltage test.

A battery drain test checks for abnormal current draw with the ignition off. If a battery goes dead without being used, you need to check for a current drain.

To perform a battery drain test, set up an ammeter, as shown in *Figure 8-7*. Pull the fuse if the vehicle has a dash clock. Close all doors and the trunk (if applicable). Then read the ammeter. If everything is off, there should be a zero reading. Any reading indicates a problem. To help pinpoint the problem, pull fuses one at a time until there is a zero reading on the ammeter. This action isolates the circuit that has the problem.

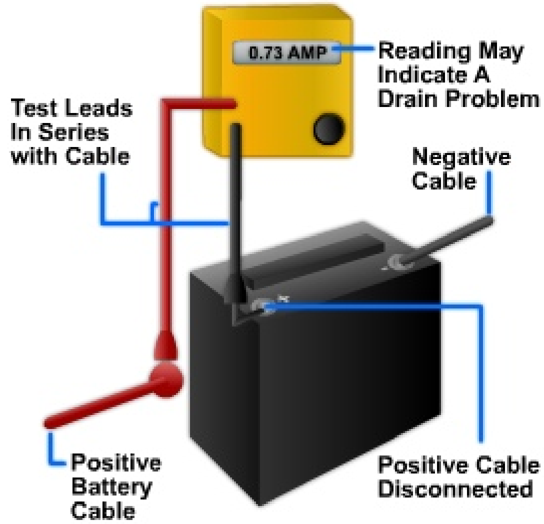


Figure 8-7 — Battery drain test.

- A battery load test, also termed a battery capacity test, is the best method to check battery condition. The battery load test measures the current output and performance of the battery under full current load. It is one of the most common and informative battery tests used today.

  Before load testing a battery, you must calculate how much current draw should be applied to the battery. If the ampere-hour rating of the battery is given, load the battery to three times its amp-hour rating. For example, if the battery is rated at 60 amp hours, test the battery at 180 amps (60 x 3 = 180). The majority of the batteries are now rated in SAE cold cranking amps, instead of amp-hours. To determine the load test for these batteries, divide the cold-crank rating by two. For example, a battery with 400 cold cranking amps rating should be loaded to 200 amps (400 ÷ 2 = 200). Connect the battery load tester, as shown in *Figure 8-8*. Turn the control knob until the ammeter reads the correct load for your battery.

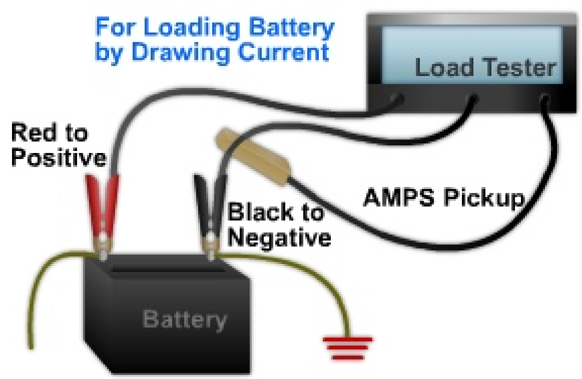


Figure 8-8 — Battery load test.

  After checking the battery charge and finding the amp load value, you are ready to test battery output. Make sure that the tester is connected properly. Turn the load control knob until the ammeter reads the correct load for your battery. Hold the load for 15 seconds. Next, read the voltmeter while the load is applied. Then turn the load control completely off so the battery will not be discharged. If the voltmeter reads 9.5 volts or more at room temperature, the battery is good. If the battery reads below 9.5 volts at room temperature, battery performance is poor. This condition indicates that the battery is not producing enough current to run the starting motor properly.

Familiarize yourself with proper operating procedures for the type of tester you have available. Improper operation of electrical test equipment may result in serious damage to the test equipment or the unit being tested.

- The quick charge test, also known as 3-minute charge test, determines if the battery is sulfated. If the results of the battery load test are poor, fast charge the battery. Charge the battery for 3 minutes at 30 to 40 amps. Test the voltage while charging. If the voltage goes ABOVE 15.5 volts, the battery plates are sulfated and the battery needs to be replaced.

1.2.0 Alternators

The alternator has replaced the DC (Direct Current) generator because of its improved efficiency (*Figure 8-9*. It is smaller, lighter, and more dependable than the DC generator. The alternator also produces more output during idle, which makes it ideal for late model vehicles.

The alternator has a spinning magnetic field. The output windings (stator) are stationary. As the magnetic field rotates, it induces current in the output stator windings.

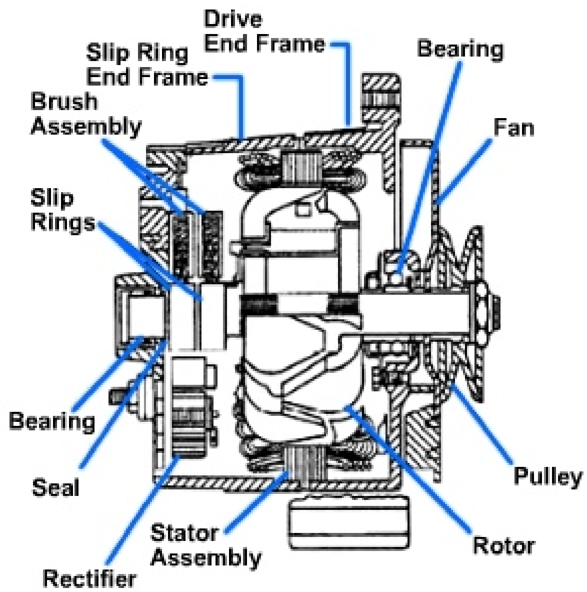


Figure 8-9 — Alternator.

1.2.1 Alternator Construction

Knowledge of the construction of an alternator is required before you can understand the proper operation, testing procedures, and repair procedures applicable to an alternator.

The primary components of an alternator are as follows:

- The rotor assembly (rotor shaft, slip rings, claw poles, and field windings) consists of field windings (wire wound into a coil placed over an iron core) mounted on the rotor shaft (*Figure 8-10*). Two claw-shaped pole pieces surround the field windings to increase the magnetic field.

  The fingers on one of the claw-shaped pole pieces produce south (S) poles and the other produces north (N) poles. As the rotor rotates inside the alternator, alternating N-S-N-S polarity and AC current are produced. An external source of electricity (DC) is required to excite the magnetic field of the alternator.

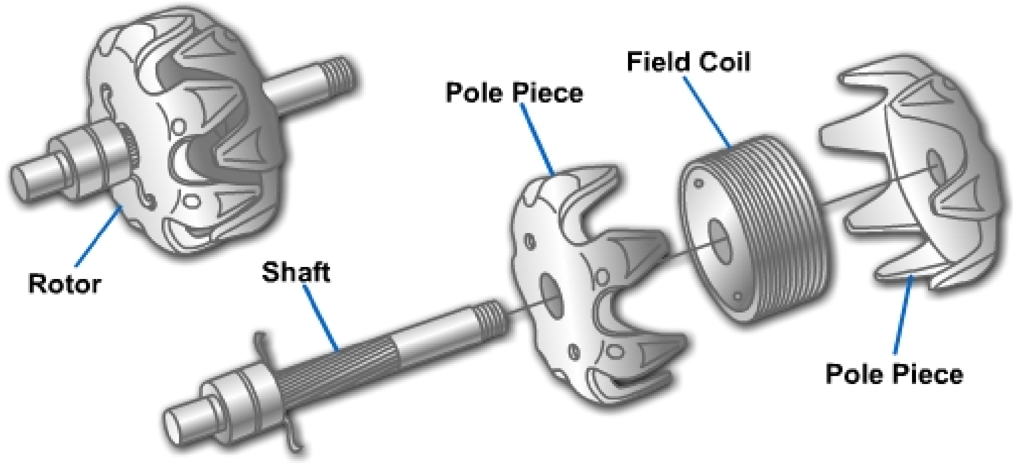


Figure 8-10 — Rotor assembly.

Slip rings are mounted on the rotor shaft to provide current to the rotor windings. Each end of the field coil connects to the slip rings.

- Stator assembly (three stator windings or coils, output wires, and stator core).

The stator assembly produces the electrical output of the alternator (*Figure 8-11*). The stator, which is part of the alternator frame when assembled, consists of three groups of windings or coils which produce three separate AC currents. This is known as three-phase output. One end of the windings is connected to the stator assembly and the other is connected to a rectifier assembly. The windings are wrapped around a soft laminated iron core that concentrates and strengthen the magnetic field around the stator windings. There are two types of stators—Y-type stator and delta-type stator.

The Y-type stator has the wire ends from the stator windings connected to a neutral junction (*Figure 8-12, View A*). The circuit looks like the letter Y. The Y-type stator provides good current output at low engine speeds.

The delta-type stator (*Figure 8-12, View B*) has the stator wires connected end-to-end. With no neutral junction, two circuit paths are formed between the diodes. A delta-type stator is used in high output alternators.

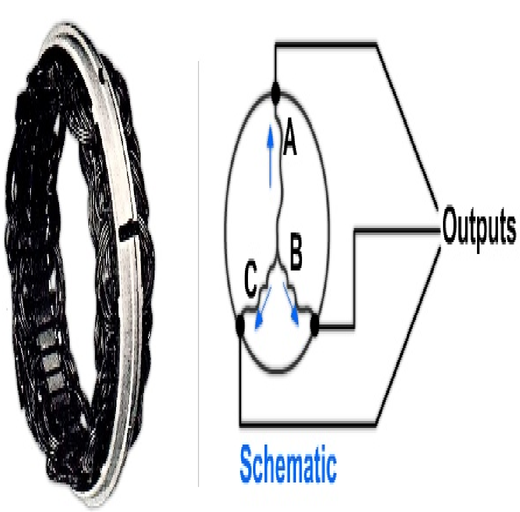


Figure 8-11 — Stator assembly.

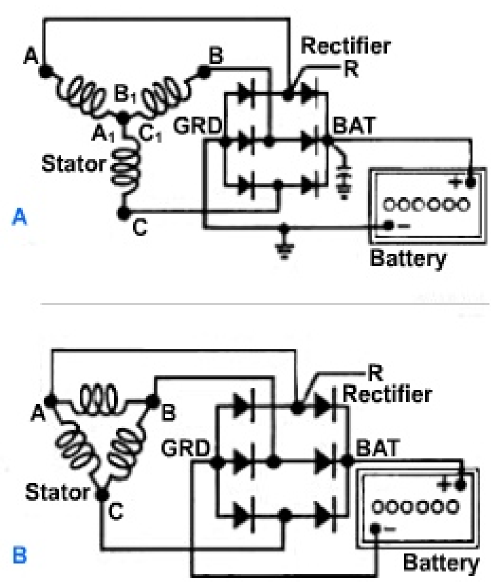


Figure 8-12 — Stator assembly types.

- The rectifier assembly, also known as a diode assembly, contains the heat sink, diodes, diode plate, and electrical terminals. It consists of six diodes used to convert stator AC output into DC current. The current flowing from the stator winding is allowed to pass through an insulated diode. As the current reverses direction, it flows to ground through a grounded diode. The insulated and grounded diodes prevent the reversal of current from the rest of the charging system. By this switching action and the number of pulses created by motion between the windings of the stator and rotor, a fairly even flow of current is supplied to the battery terminal of the alternator.

  The rectifier diodes are mounted in a ***heat sink*** or diode bridge. Three positive diodes are press fit in an insulated frame. Three negative diodes are mounted into an uninsulated or grounded frame.

  When an alternator is producing current, the insulated diodes pass only out-flowing current to the battery. The diodes provide a block, preventing reverse current flow from the alternator.

1.2.2 Alternator Operation

The operation of an alternator is somewhat different than the DC generator. An alternator has a rotating magnet (rotor) which causes the magnetic lines of force to rotate with it. These lines of force are cut by the stationary (stator) windings in the alternator frame as the rotor turns with the magnet rotating the N and S poles to keep changing positions. When S is up and N is down, current flows in one direction, but when N is up and S is down, current flows in the opposite direction. This is called alternating current as it changes direction twice for each complete revolution. If the rotor speed were increased to 60 revolutions per second, it would produce 60-cycle AC.

Since the engine speed varies in a vehicle, the frequency also varies with the change of speed. Likewise, increasing the number of pairs of magnetic north and south poles will increase the frequency by the number pair of poles. A four-pole generator can generate twice the frequency per revolution of a two-pole rotor.

1.2.3 Alternator Output Control

A voltage regulator controls alternator output by changing the amount of current flow through the rotor windings. Any change in rotor winding current changes the strength of the magnetic field acting on the stator windings. In this way, the voltage regulator can maintain a preset charging voltage. The three basic types of voltage regulators are as follows:

- Contact point voltage regulator, mounted away from the alternator in the engine compartment.

  The contact point voltage regulator uses a coil, set of points, and resistors that limit system voltage. The electronic or solid-state regulators have replaced this older type. For operation, refer to the "Regulation of Generator Output" section of this chapter.

- Electronic voltage regulator, mounted away from the alternator in the engine compartment.

  The electronic voltage regulators use an electronic circuit to control rotor field strength and alternator output. It is a sealed unit and is not repairable. The electronic circuit must be sealed to prevent damage from moisture, excessive heat, and vibration. A rubberlike gel surrounds the circuit for protection.

An integral voltage regulator is mounted inside or on the rear of the alternator. This is the most common type used on modern vehicles. It is small, efficient, dependable, and composed of integrated circuits.

- The integral voltage regulator is mounted on the back of or inside the alternator. It performs the same operation as a contact point or electronic regulator, except that it uses transistors, diodes, resistors, and capacitors to regulate voltage in the system. To increase alternator output, the voltage regulator allows more current into the rotor windings, thereby strengthening the magnetic field around the rotor. More current is then induced into the stator windings and out of the alternator.

  To reduce alternator output, the voltage regulator increases the resistance between the battery and the rotor windings. The magnetic field decreases, and less current is induced into the stator windings.

  Alternator speed and load determines whether the regulator increases or decreases charging output. If the load is high or rotor speed is low (engine at idle), the regulator senses a drop in system voltage. The regulator then increases the rotor's magnetic field current until a preset output voltage is obtained. If the load drops or rotor speed increases, the opposite occurs.

1.2.4 Alternator Maintenance

Alternator testing and service call for special precautions since the alternator output terminal is connected to the battery at all times. Use care to avoid reversing polarity when performing battery service of any kind. A surge of current in the opposite direction could burn the alternator diodes.

Do not purposely or accidentally "short" or "ground" the system when disconnecting wires or connecting test leads to terminals of the alternator or regulator. For example, grounding of the field terminal at either alternator or regulator will damage the regulator. Grounding of the alternator output terminal will damage the alternator and possibly other portions of the charging system.

Never operate an alternator on an open circuit. With no battery or electrical load in the circuit, alternators are capable of building high voltage (50 to over 110 volts) which may damage diodes and endanger anyone who touches the alternator output terminal.

Alternator maintenance is minimized by the use of prelubricated bearings and longer-lasting brushes. If a problem exists in the charging circuit, check for a complete field circuit by placing a large screwdriver on the alternator rear-bearing surface. If the field circuit is complete, there will be a strong magnetic pull on the blade of the screwdriver, which indicates that the field is energized. If there is no field current, the alternator will not charge because it is excited by battery voltage.

Should you suspect troubles within the charging system after checking the wiring connections and battery, connect a voltmeter across the battery terminals. If the voltage reading, with the engine speed increased, is within the manufacturer's recommended specification, the charging system is functioning properly. Should the alternator tests fail, the alternator should be removed for repairs or replacement. Do NOT forget, you must ALWAYS disconnect the cables from the battery first.

1.2.5 Alternator Testing

To determine what component or components have caused the problem, you will be required to disassemble and test the alternator.

To test the rotor for grounds, shorts, and opens, perform the following:

- To check for grounds, connect a test lamp or ohmmeter from one of the slip rings to the rotor shaft (*Figure 8-13*). A low ohmmeter reading or the lighting of the test lamp indicates that the rotor winding is grounded.
- To check the rotor for shorts and opens, connect the ohmmeter to both slip rings (*Figure 8-14*). An ohmmeter reading below the manufacturer's specified resistance value indicates a short. A reading above the specified resistance value indicates an open. If a test lamp does not light when connected to both slip rings, the winding is open.

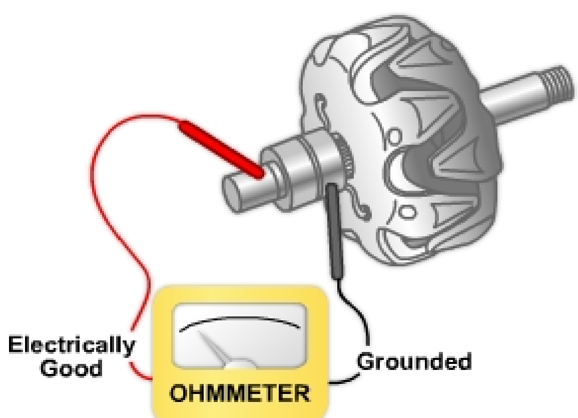


Figure 8-13 — Testing for grounds.

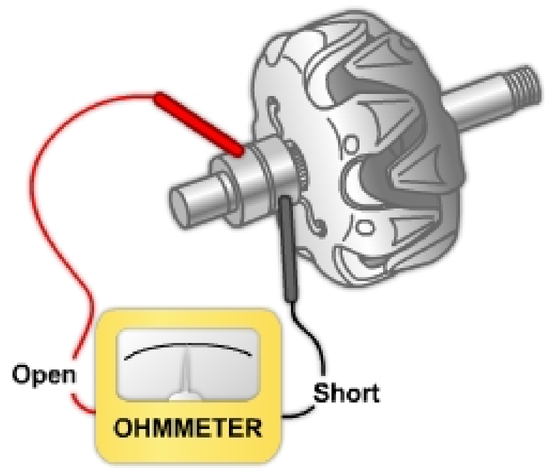


Figure 8-14 — Testing for shorts.

The stator winding can be tested for opens and grounds after it has been disconnected from the alternator end frame and voltage regulator.

If the ohmmeter reading is low when connected between each pair of stator leads, the stator winding is electrically good (*Figure 8-15*).

A high ohmmeter reading or failure of the test lamp to light when connected from any one of the leads to the stator frame indicates the windings are not grounded (*Figure 8-16*). It is not practical to test the stator for shorts due to the very low resistance of the winding.

To test for correct diode operation, disconnect the stator windings and perform the test with an ohmmeter as follows:

- Connect one ohmmeter test lead to the diode lead and the other to the diode case. Note the reading. Then reverse the ohmmeter's leads to the diode and again note the reading. If both readings are very low or very high, the diode is defective. A good diode will give one low and one high reading.

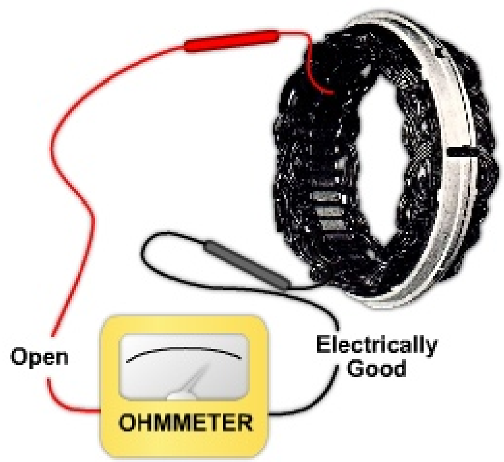


Figure 8-15 — Testing stator for opens.

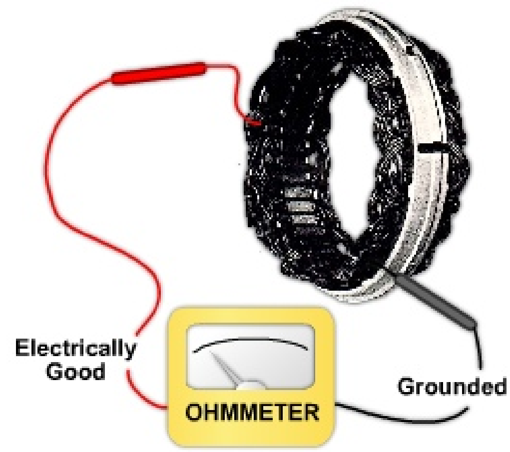


Figure 8-16 — Testing stator for grounds.

After completing the required test and making any necessary repairs or replacement of parts, reassemble the alternator and install it on the vehicle. After installation, start the engine and check that the charging system is functioning properly. Never attempt to polarize an alternator. Attempts to do so serve no purpose and may damage the diodes, wiring, and other charging circuit components.

1.3.0 Charging System Test

Charging system tests should be performed when problems point to low alternator voltage and current. These tests will quickly determine the operating condition of the charging system. Common charging system tests are as follows:

- Charging system output test-measures current and voltage output of the charging system.
- Regulator voltage test—measures charging system voltage under low output, low load conditions.
- Regulator bypass test—connects full battery voltage to the alternator field, leaving the regulator out of the circuit.
- Circuit resistance tests—measures resistance in insulated and grounded circuits of the charging system.

Charging system tests are performed in two ways—by using a load tester or by using a volt-ohm millimeter (VOM/multimeter). The load tester provides the accurate method for testing a charging system by measuring both system current and voltage.

1.3.1 Charging System Output Test

The charging system output test measures system voltage and current under maximum load. To check output with a load tester, connect tester leads as described by the manufacturer, as you may have either an inductive (clip-on) amp pickup type or a non-inductive type tester. Testing procedures for an inductive type tester are as follows:

With the load tester controls set as prescribed by the manufacturer, turn the ignition switch to the run position. Note the ammeter reading.

Start the engine and adjust the idle speed to test specifications or IAW manufacturer's specifications.

Adjust the load control on the tester until the ammeter reads specified current output. Do not let voltage drop below specifications (about 12 volts). Note the ammeter reading.

Rotate the control knob to the off position. Evaluate the readings.

To calculate charging system output, add the two ammeter readings. This will give you total charging system output in amps. Compare this figure to the specifications within the manufacturer's manual.

Current output specifications will depend on the size (rating) of the alternator. A vehicle with few electrical accessories may have an alternator rated at 35 amps, whereas a larger vehicle with more electrical requirements could have an alternator rated from 40 to 80 amps. Always check the manufacturer's service manual for exact values.

If the charging system output current tested low, perform a regulator voltage test and a regulator bypass test to determine whether the alternator, regulator, or circuit wiring is at fault.

1.3.2 Regulator Voltage Test

A regulator voltage test checks the calibration of the voltage regulator and detects a low or high setting. Most voltage regulators are designed to operate between 13.5 to 14.5 volts. This range is stated for normal temperatures with the battery fully charged.

Set the load tester selector to the correct position using the manufacturer's manual. With the load control off, run the engine at 2,000 rpm or specified test speed. Note the voltmeter reading and compare it to the manufacturer's specifications.

If the voltmeter reading is steady and within manufacturer's specifications, then the regulator setting is okay. However, if the volt reading is steady but too high or too low, then the regulator needs adjustment or replacement. If the reading were not steady, this would indicate a bad wiring connection, an alternator problem, or a defective regulator, and further testing is required.

1.3.3 Regulator Bypass Test

A regulator bypass test is an easy and quick way of determining if the alternator, regulator, or circuit is faulty. Procedures for the regulator bypass test are similar to the charging system output test, except that the regulator is taken out of the circuit. Direct battery voltage (unregulated voltage) is used to excite the rotor field. This should allow the alternator to produce maximum voltage output.

Depending upon the system, there are several ways to bypass the voltage regulator. The most common ways are as follows:

CAUTION

Follow the manufacturer's directions to avoid damaging the circuit. You must NOT short or connect voltage to the wrong wires, or the diodes or voltage regulator may be ruined.

- Selecting a test tab to ground on the rear of the alternator (if equipped).
- Placing a jumper wire across the battery and field terminals of the alternator.

- With a remote regulator, unplugging the wire from the regulator and placing a jumper wire across the battery and field terminals in the wires to the alternator.

When the regulator bypass test is being performed, charging voltage and current will increase to normal levels. This indicates a bad regulator. If the charging voltage and current remain the same, then you have a bad alternator.

1.3.4 Circuit Resistance Test

A circuit resistance test is used to locate faulty wiring, loose connections, partially burnt wire, corroded terminals, or other similar types of problems.

There are two common circuit resistance tests: insulated resistance test and ground circuit resistance test.

To perform an insulated resistance test, connect the load tester as described by the manufacturer. A typical connection setup is shown in *Figure 8-17, View A*. Notice how the voltmeter is connected across the alternator output terminal and positive battery terminal.

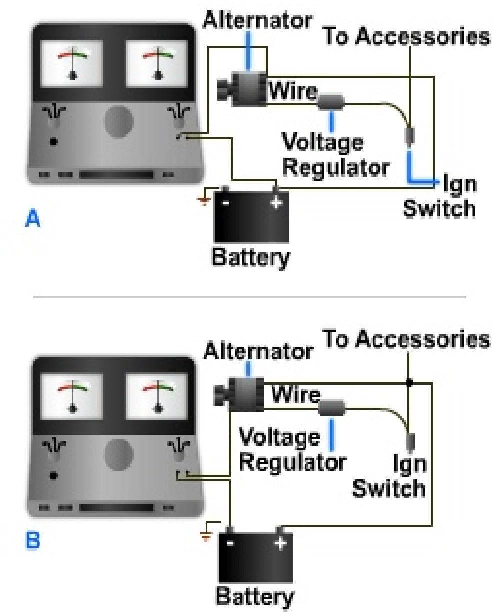


Figure 8-17 — Circuit resistance test.

With the vehicle running at a fast idle, rotate the load control knob to obtain a 20-amp current flow at 15 volts or less. All accessories and lights are to be turned off. Read the voltmeter. The voltmeter should NOT read over 0.7-volt drop (0.1 volt per electrical connection) for the circuit to be considered in good condition. However, if the voltage drop is over 0.7 volt, circuit resistance is high and a poor electrical connection exists.

To perform a ground circuit test, place the voltmeter leads across the negative battery terminal and alternator housing (*Figure 8-17, View B*).

The voltmeter should NOT read over 0.1 volt per electrical connection. If the reading is higher, this indicates such problems as loose or faulty connections, burnt plug sockets, or other similar malfunctions.

Test your Knowledge (Select the Correct Response)

1. What substance is contained in a positive plate of a fully charged battery?

    A. Calcium antimony
    B. Lead peroxide
    C. Micro-porous rubber
    D. Sulfur dioxide

2. What type of gas collects at the top of a battery?

    A. Antimony
    B. Sulfuric
    C. Sulfur
    D. Hydrogen

3. What assembly in the alternator contains the heat sink, the diodes, the diode plate, and the electrical terminals?

   A. Rectifier
   B. Rotor
   C. Stator
   D. Grounding

4. What type of alternator stator is used in high output alternators?

   A. Delta-type
   B. Omega-type
   C. Y-type
   D. K-type

2.0.0 STARTING CIRCUIT

The internal combustion engine is not capable of self-starting. Automotive engines (both spark-ignition and diesel) are cranked by a small but powerful electric motor. This motor is called a cranking motor, starting motor, or starter.

The battery sends current to the starter when the operator turns the ignition switch to start. This causes a pinion gear in the starter to mesh with the teeth of the ring gear, thereby rotating the engine crankshaft for starting.

The typical starting circuit consists of the battery, the starter motor and drive mechanism, the ignition switch, the starter relay or solenoid, a neutral safety switch (automatic transmissions), and the wiring to connect these components.

2.1.0 Starter Motor

The starting motor converts electrical energy from the battery into mechanical or rotating energy to crank the engine (*Figure 8-18*). The main difference between an electric starting motor and an electric generator is that in a generator, rotation of the armature in a magnetic field produces voltage. In a motor, current is sent through the armature and the field; the attraction and repulsion between the magnetic poles of the field and armature coil alternately push and pull the armature around. This rotation (mechanical energy), when properly connected to the flywheel of an engine, causes the engine crankshaft to turn.

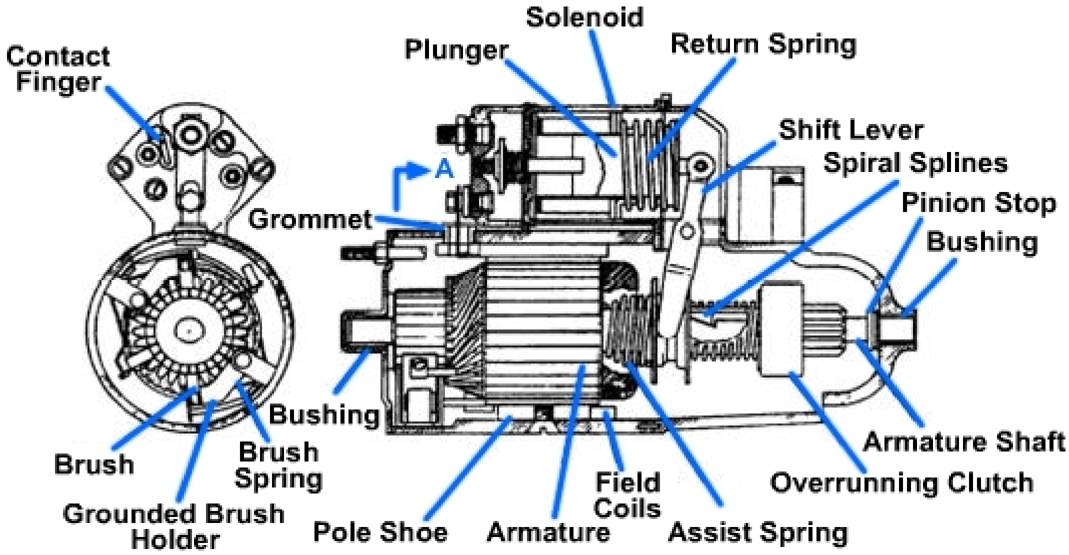


Figure 8-18 — Starter.

2.1.1 Starting Motor Construction

The construction of all starting motors is very similar. There are, however, slight design variations. The main parts of a starting motor are as follows:

- The armature assembly consists of an armature shaft, armature core, commutator, and armature windings.

  The armature shaft supports the armature assembly as it spins inside the starter housing. The armature core is made of iron and holds the armature windings in place. The iron increases the magnetic field strength of the windings.

  The commutator serves as a sliding electrical connection between the motor windings and the brushes and is mounted on one end of the armature shaft. The commutator has many segments that are insulated from each other. As the windings rotate away from the pole shoe (piece), the commutator segments change the electrical connection between the brushes and the windings. This action reverses the magnetic field around the windings. The constant changing electrical connection at the windings keeps the motor spinning.

- The commutator end frame houses the brushes, the brush springs, and the armature shaft bushing.

  The brushes ride on top of the commutator. They slide on the commutator to carry battery current to the spinning windings. The springs force the brushes to maintain contact with the commutator as it spins, thereby no power interruptions occurs. The armature shaft bushing supports the commutator end of the armature shaft.

- The pinion drive assembly includes the pinion gear, the pinion drive mechanism, and solenoid. There are two ways that a starting motor can engage the pinion assembly: first with a movable pole shoe that engages the pinion gear, and second with a solenoid and shift fork that engages the pinion gear.

The pinion gear is a small gear on the armature shaft that engages the ring gear on the flywheel. Most starter pinion gears are made as part of a pinion drive mechanism. The pinion drive mechanism slides over one end of the starter armature shaft. The pinion drive mechanism found on starting motors that you will encounter is of three designs: the bendix drive, the overrunning clutch, and the dyer drive.

- The field frame is the center housing that holds the field coils and pole shoes. It is a stationary set of windings that creates a strong magnetic field around the motor armature. When current flows through the winding, the magnetic field between the pole shoes becomes very large. Acting against the magnetic field created by the armature, this action spins the motor with extra power. Field windings vary according to the application of the starter motor. The most popular configurations are as follows (*Figure 8-19*):

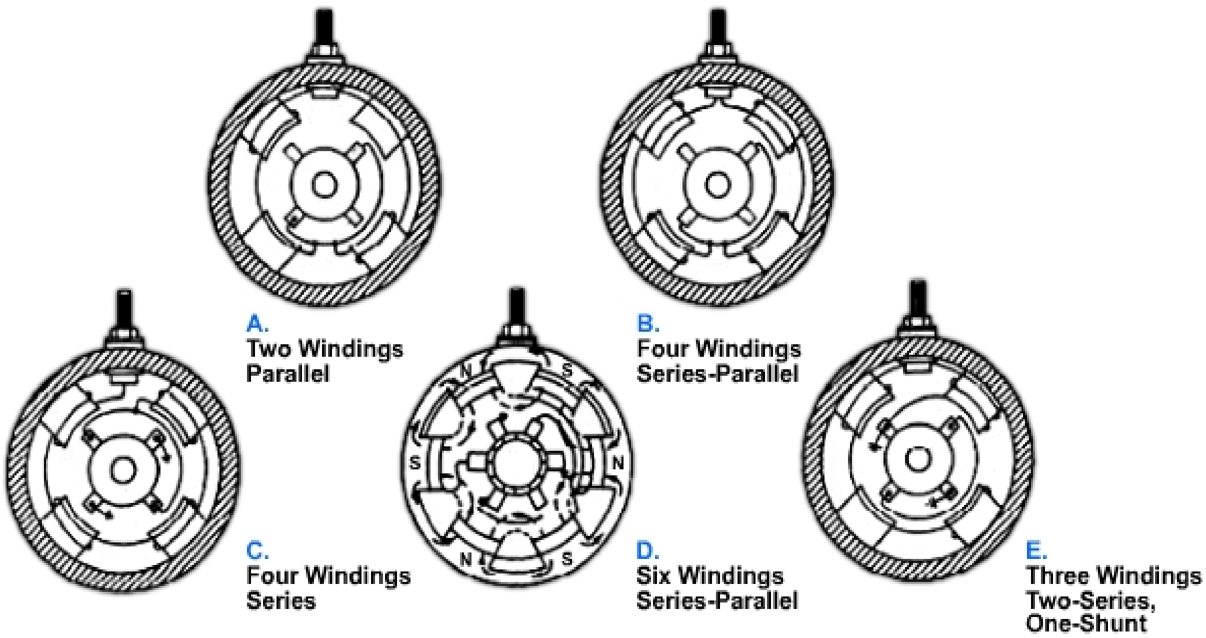


Figure 8-19 — Field winding configurations.

The two windings, parallel (the wiring of the two field coils in parallel) increases their strength because they receive full voltage. Note that two additional pole shoes are used. Though they have no windings, their presence will further strengthen the magnetic field.

The four windings, series-parallel (the wiring of four field coils in a series-parallel combination) creates a stronger magnetic field than the two field coil configuration.

The four windings, series (the wiring of four field coils in series) provides a large amount of low-speed torque, which is desirable for automotive starting motors. However, series wound motors can build up excessive speed if allowed to run free, to the point where they will destroy themselves.

The six windings, series-parallel (three pairs of series-wound field coils) provides the magnetic field for a heavy-duty starter motor. This configuration uses six brushes.

The three windings, two series, one shunt (the use of one field coil that is shunted to ground with a series-wound motor) controls motor speed. Because the shunt coil is not affected by speed, it will draw a steady heavy current, effectively limiting speed.

- The drive end frame is designed to protect the drive pinion from damage and to support the armature shaft. The drive end frame of the starter contains a bushing to prevent wear between the armature shaft and drive end frame.

There are two types of starting motors that you will encounter on equipment: the direct drive starter and the double reduction starter. All starters require the use of gear reduction to provide the mechanical advantage required to turn the engine flywheel and crankshaft.

Direct drive starters make use of a pinion gear on the armature shaft of the starting motor. This gear meshes with teeth on the ring gear. There are between 10 to 16 teeth on the ring gear for every one tooth on the pinion gear. Therefore, the starting motor revolves 10 to 16 times for every revolution of the ring gear. In operation, the starting motor armature revolves at a rate of 2,000 to 3,000 revolutions per minute, thus turning the engine crankshaft at speeds up to 200 rpm.

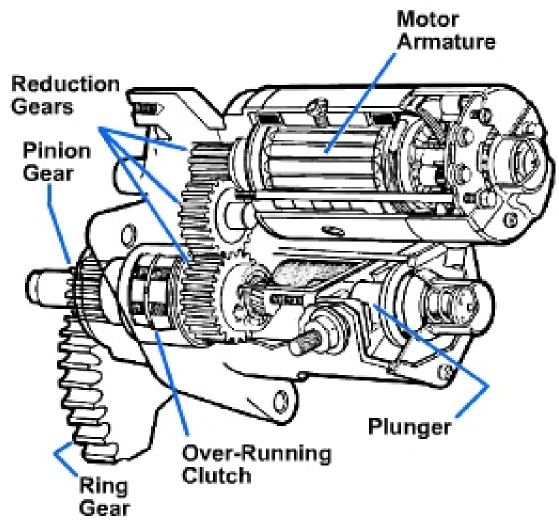


Figure 8-20 — Gear reduction starter.

The double reduction starter makes use of gear reduction within the starter and the reduction between the drive pinion and the ring gear. The gear reduction drive head is used on heavy-duty equipment.

Figure 8-20 shows a typical gear reduction starter. The gear on the armature shaft does not mesh directly with the teeth on the ring gear, but with an intermediate gear which drives the driving pinion. This action provides additional breakaway, or starting torque, and greater cranking power. The armature of a starting motor with a gear reduction drive head may rotate as many as 40 revolutions for every revolution of the engine flywheel.

2.1.2 Operation

A starter motor's operation is dependent upon the type of drive it contains. Below are the three drive systems, along with an explanation of the operation of each.

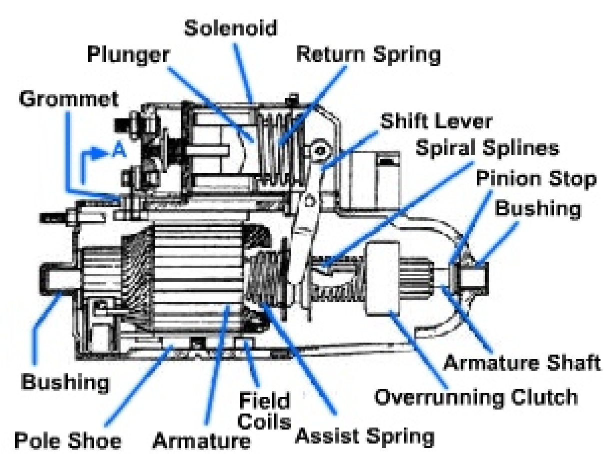


Figure 8-21 — Bendix drive starter.

The Bendix drive relies on the principle of inertia to cause the pinion gear to mesh with the ring gear (*Figure 8-21*). When the starting motor is not operating, the pinion gear is out of mesh and entirely away from the ring gear. When the ignition switch is engaged, the total battery voltage is applied to the starting motor, and the armature immediately starts to rotate at high speed.

The pinion, being weighted on one side and having internal screw threads, does not rotate immediately with the shaft but because of inertia, runs forward on the revolving threaded sleeve until it engages with the ring gear. If the teeth of the pinion and ring gear do not engage, the drive spring allows the pinion to revolve and forces the pinion to mesh with the ring gear. When the pinion gear is engaged fully with the ring gear, the pinion is then driven by the starter through the compressed drive spring and cranks the engine. The drive spring acts as a cushion while the engine is being cranked against compression. It also breaks the severity of the shock on the teeth when the gears engage and when the engine kicks back due to ignition. When the engine starts and runs on its own power, the ring gear drives the pinion at a higher speed than does the starter. This action causes the pinion to turn in the opposite direction on the threaded sleeve and automatically disengages from the ring gear. This prevents the engine from driving the starter.

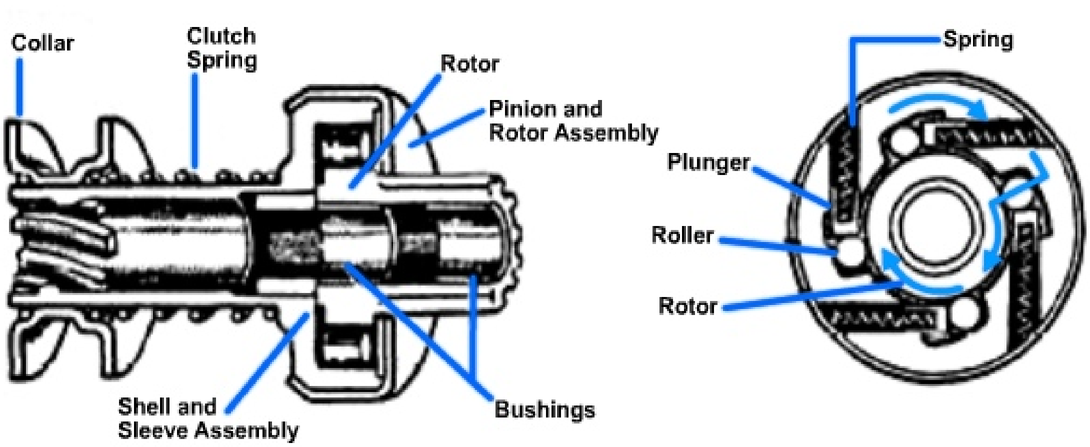


Figure 8-22 — Overrunning clutch starter.

The overrunning clutch provides positive meshing and demeshing of the starter motor pinion gear and the ring gear (*Figure 8-22*). The starting motor armature shaft drives the shell and sleeve assembly of the clutch. The rotor assembly is connected to the pinion gear, which meshes with the engine ring gear. Spring-loaded steel rollers are located in tapered notches between the shell and the rotor. The springs and plungers hold the rollers in position in the tapered notches. When the armature shaft turns, the rollers are jammed between the notched surfaces, forcing the inner and outer members of the assembly to rotate as a unit and crank the engine.

After the engine is started, the ring gear rotates faster than the pinion gear, thus tending to work the rollers back against the plungers, and thereby causing an overrunning action. This action prevents excessive speed of the starting motor. When the starting motor is released, the collar and spring assembly pulls the pinion out of mesh with the ring gear.

The Dyer drive provides complete and positive meshing of the drive pinion and ring gear before the starting motor is energized (*Figure 8-23*). It combines principles of both the Bendix and overrunning clutch drives and is commonly used on heavy-duty engines.

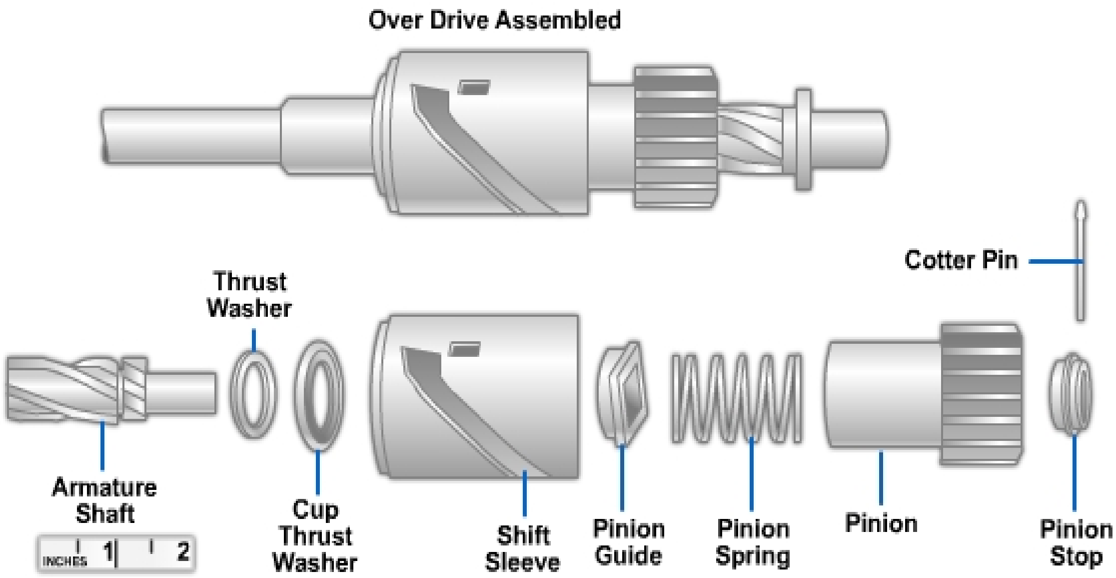


Figure 8-23 — Dyer drive starter.

A starter solenoid is used to make the electrical connection between the battery and the starting motor. The starter solenoid is an electromagnetic switch; it is similar to other relays but is capable of handling higher current levels. A starter solenoid, depending on the design of the starting motor, has the following functions:

- Closes battery-to-starter circuit.
- Pushes the starter pinion gear into mesh with the ring gear.
- Acts as an electro-magnetic switch to engage the starter.

The starter solenoid may be located away from or on the starting motor. When mounted away from the starter, the solenoid only makes and breaks electrical connection. When mounted on the starter, it also slides the pinion gear into the flywheel.

In operation, the solenoid is actuated when the ignition switch is turned or when the starter button is depressed. The action causes current to flow through the solenoid (causing a magnetic attraction of the plunger) to ground. The movement of the plunger causes the shift lever to engage the pinion with the ring gear. After the pinion is engaged, further travel of the plunger causes the contacts inside the solenoid to close and directly connects the battery to the starter.

If cranking continues after the control circuit is broken, it is most likely to be caused by either shorted solenoid windings or by binding of the plunger in the solenoid. Low voltage from the battery is often the cause of the starter making a clicking sound. When this occurs, check all starting circuit connections for cleanliness and tightness.

Test your Knowledge (Select the Correct Response)

5. What type of starter uses gear reduction within the starter and gear reduction between the drive pinion and the ring gear?

   A. Single reduction
   B. Double reduction
   C. Speed
   D. High current

6. What term refers to the center housing of a starter that holds the field coils and pole shoes?

   A. Field frame
   B. Pinion drive assembly
   C. Commutator
   D. Commutator end frame

3.0.0 SAFETY SWITCHES

3.1.0 Neutral Safety Switch

Vehicles equipped with automatic transmissions require the use of a neutral safety switch. The neutral safety switch prevents the engine from being started unless the shift selector of the transmission is in neutral or park. It disables the starting circuit when the transmission is in gear.

The neutral safety switch is wired into the circuit going to the starter solenoid. When the transmission is in forward or reverse gear, the switch is in the open position (disconnected). This action prevents current from activating the solenoid and starter when the ignition switch is turned to the start position. When the transmission is in neutral or park, the switch is closed (connected), allowing current to flow to the starter when the ignition is turned.

A misadjusted or bad neutral safety switch can keep the engine from cranking. If the vehicle does not start, you should check the action of the neutral safety switch by moving the shift lever into various positions while trying to start the vehicle. If the starter begins to work, the switch needs to be readjusted.

To readjust a neutral safety switch, loosen the fasteners that hold the switch. With the switch loosened, place the shift lever into park (P). Then, while holding the ignition switch in the start position, slide the neutral switch on its mount until the engine cranks. Without moving the switch, tighten the fasteners. The engine should now start with the shift lever in park or neutral. Check for proper operation after the adjustment.

If after adjusting the switch to normal, operation is not resumed, you may need to test the switch. All that is required to test the switch is a 12-volt test light. To test the switch, touch the test light to the switch output wire connection while moving the shift lever. The light should glow as the shift lever is slid into park or neutral. The light should not work in any other position. If the light is not working properly, check the mechanism that operates the switch. If the problem is in the switch, replace it.

3.2.0 Starter Safety Switch

Some late model vehicles have the brake light switch wired into the same control circuit as the neutral safety switch. In order to operate the starter, you must press and hold the brake pedal. This is in addition to ensuring that the vehicle is in neutral or park and in the case of a manual transmission; the clutch pedal is pressed down as well.

3.3.0 Clutch Safety Switch

Vehicles equipped with manual transmissions require the use of a clutch safety switch to prevent engine cranking. The switch is closed only when the operator presses the clutch pedal down. This prevents the vehicle from moving while the engine is cranking.

3.4.0 Starting Circuit Maintenance

The condition of the starting motor should be carefully checked at each PM service. This permits you to take appropriate action, where needed, so equipment failures caused by a faulty starter can be reduced, if not eliminated.

A visual inspection for clean, tight electrical connections and secure mounting at the flywheel housing is the extent of the maintenance check. Then operate the starter and observe the speed of rotation and the steadiness of operation.

CAUTION

Do NOT crank the engine for more than 30 seconds or starter damage can result. If the starter is cranked too long, it will overheat. Allow the starter to cool for a few minutes if more cranking time is needed.

If the starter is not operating properly, remove the starter, disassemble it, and check the commutator and brushes. If the commutator is dirty, you may clean it with a piece of No. 00 sandpaper. However, if the commutator is rough, pitted, or out-of-round or if the insulation between the commutator bars is high, it must be reconditioned using an armature lathe.

Brushes should be at least half of their original size. If not, replace them. The brushes should have free movement in the brush holders and make good, clean contact with the commutator.

Once you have checked the starter and repaired it as needed, you should reassemble it, making sure that the starter brushes are seated. Align the housings and install the bolts securely. Install the starter in the opening in the flywheel housing and tighten the attaching bolts to the specified torque. Connect the cable and wire lead firmly to clean terminals.

3.5.0 Starting Motor Circuit Tests

There are many ways of testing a starting motor circuit to determine its operating condition. The most common tests are as follows:

- The starter current draw test is used to measure the amount of amperage used by the starting circuit.
- The starter circuit voltage drop tests (insulated circuit resistance test and starter ground test) are used to quickly locate parts with higher than normal resistance.

3.5.1 Starter Current Draw Test

The starter current draw test measures the amount of amperage used by the starting circuit. It quickly tells you about the condition of the starting motor and other circuit components. If the current draw is lower or higher than the manufacturer's specifications, there is a problem in the circuit.

To perform a starter current draw test, you may use either a voltmeter or inductive ammeter or a battery load tester. These meters are connected to the battery to measure battery voltage and current flow out of the battery. For setup procedures, use the manufacturer's manual for the type of meter you intend to use.

To keep a gasoline engine from starting during testing, disconnect the coil supply wire or ground the coil wire. With a diesel engine, disable the fuel injection system or unhook the fuel shutoff solenoid. Check the manufacturer's service manual for details.

With the engine ready for testing, crank the engine and note the voltage and current readings. Check the manufacturer's service manual. If they are not within specifications, there is something wrong with the starting circuit.

3.5.2 Starting Circuit Voltage Drop Tests

A voltage drop test will quickly locate a component with higher than normal resistance. This test provides an easy way of checking circuit condition. You do NOT have to disconnect any wires or components to check for voltage drops. The two types of voltage drop tests are the insulated circuit resistance test and the starter ground circuit test.

The insulated circuit resistance test checks all components between the positive terminal of the battery and the starting motor for excess resistance.

Using a voltmeter, connect the leads to the positive terminal of the battery and the starting motor output terminal.

With the ignition or injection system disabled, crank the engine. Note the voltmeter reading. It should not be over 0.5 volts. If voltage drop is greater, something within the circuit has excessive resistance. There may be a burned or pitted solenoid contact, loose electrical connections, or other malfunctions. Each component must then be tested individually.

The starter ground circuit test checks the circuit between the starting motor and the negative terminal of the battery.

Using a voltmeter, connect the leads to the negative terminal of the battery and to the end frame of the starting motor. Crank the engine and note the voltmeter reading. If it is higher than 0.5 volts, check the voltage drop across the negative battery cable. The engine may not be properly grounded. Clean, tighten, or replace the battery cable if needed. A battery cable problem can produce symptoms similar to a dead battery, bad solenoid, or weak starting motor. If the cables do NOT allow enough current to flow, the starter will turn slowly or not at all.

Test your Knowledge (Select the Correct Response)

7. What safety switch prevents a vehicle equipped with a manual transmission from starting in an unsafe situation?

   A. Neutral
   B. Clutch
   C. Brake
   D. Automatic

8. What is the maximum amount of time, in seconds, a starter may be cranked before damage can occur?

   A. 60
   B. 45
   C. 30
   D. 20

4.0.0 IGNITION SYSTEM

4.1.0 Operation

The ignition circuit supplies high voltage surges (some as high as 100,000 volts in electronic ignition circuits) to the spark plugs in the engine cylinders. These surges produce electric sparks across the spark plug gaps. The heat from the spark ignites the compressed air-fuel mixture in the combustion chambers. When the engine is idling, the spark appears at the spark plug gap just as the piston nears top dead center (TDC) on the compression stroke. When the engine is operating at higher speeds, the spark is advanced. It is moved ahead and occurs earlier in the compression stroke. This design gives the compressed mixture more time to burn and deliver its energy to the pistons.

The functions of an ignition circuit are as follows:

- Provide a method of turning the ignition circuit on and off.
- Provide capability of operating on various supply voltages (battery or alternator voltage).
- Produce a high voltage arc at the spark plug electrodes to start combustion.
- Distribute high voltage pulses to each spark plug in the correct sequence.
- Time the spark so that it occurs as the piston nears TDC on the compression stroke.
- Vary spark timing with engine speed, load, and other conditions.

The ignition circuit is actually made of two separate circuits which work together to cause the electric spark at the spark plugs: the primary and secondary.

4.2.0 Primary Circuit

The primary circuit of the ignition circuit includes all of the components and wiring operating on low voltage (battery or alternator voltage). Wiring in the primary circuit uses conventional wire, similar to the wire used in other electrical circuits on the vehicle.

4.3.0 Secondary Circuits

The secondary circuit of the ignition circuit is the high voltage section. It consists of the wire and components between the coil output and the spark plug ground. Wiring in the secondary circuit must have a thicker insulation than that of the primary circuit to prevent leaking (arcing) of the high voltage.

4.4.0 Ignition System Components

Various ignition circuit components are designed to achieve the functions of the ignition circuit. Basic ignition circuit components are as follows:

- The battery provides power for the circuit.
- The ignition switch allows the operator to turn the circuit and engine on and off.
- The ignition coil changes battery voltage to high ignition voltage (30,000 volts and greater).
- The ignition distributor distributes ignition voltage to the spark plug. Contains either mechanical contact points or an electronic switching circuit.

- The spark plug is a device that provides an air gap in the combustion chamber for an electric arc.

4.4.1 Ignition Switch

The ignition switch enables the operator to turn the ignition on for starting and running the engine and to turn it off to stop the engine (*Figure 8-24*). Most automotive ignition switches incorporate four positions: off, accessory, ignition on, and start:

The off position shuts off the electrical system. Systems such as the headlights are usually not wired through the ignition switch and will continue to operate.

The accessory position turns on power to the entire vehicle's electrical system with the exception of the ignition circuit.

The ignition-on position turns on the entire electrical system including the ignition circuit.

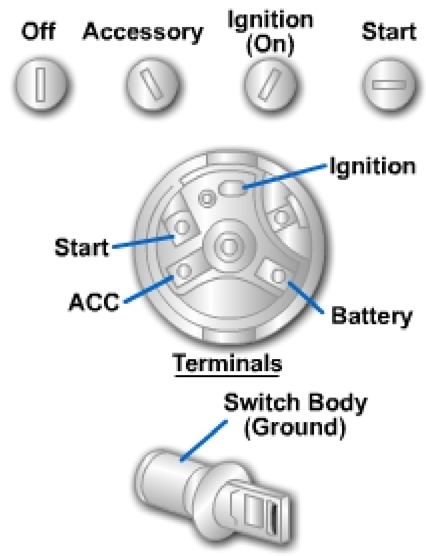


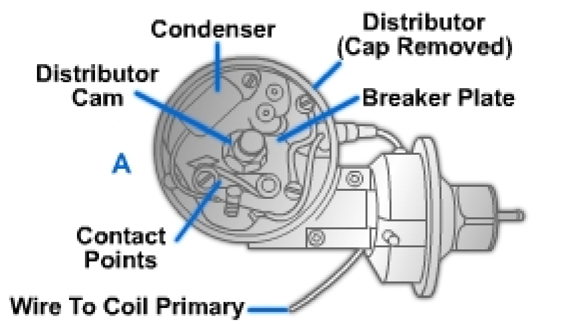
Figure 8-24 — Ignition switch.

The start position energizes the starter solenoid circuit to crank the engine. The start position is spring-loaded to return to the ignition-on position when the key is released automatically.

4.4.2 Ignition Distributor

An ignition distributor can be a contact point (*Figure 8-25, View A*), or pickup coil type (*Figure 8-25, View B*). A contact point distributor is commonly found in older vehicles, whereas the pickup coil type distributor is used on many modern vehicles. The ignition distributor has several functions:

- It actuates the on/off cycles of current flow through the primary windings of the coil.
- It distributes the high voltage surges of the coil to the spark plugs.
- It causes the spark to occur at each spark plug earlier in the compression stroke as speed increases.



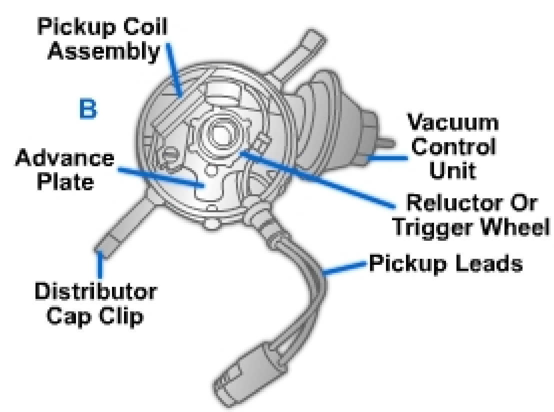


Figure 8-25 — Ignition distributors.

- It changes spark timing with the changes in engine load. As more load is placed on the engine, the spark timing must occur later in the compression stroke to prevent spark knock.
- In some cases, the bottom of the distributor shaft powers the engine oil pump.
- In some electronic distributors, the distributors house the ignition coil and the electronic switching unit.

The distributor cap is an insulating plastic component that covers the top of the distributor housing. Its center terminal transfers voltage from the coil wire to the rotor. The distributor cap also has outer terminals that send electric arcs to the spark plugs. Metal terminals are molded into the plastic cap to provide electrical connections.

The distributor rotor transfers voltage from the coil wire to the spark plug wires. The rotor is mounted on top of the distributor shaft. It is an electrical switch that feeds voltage to each spark plug wire in turn.

A metal terminal on the rotor touches the distributor cap center terminal. The outer end of the rotor almost touches the outer cap terminals. Voltage is high enough that it can jump the air space between the rotor and cap. Approximately 4,000 volts are required for the spark to jump this rotor-to-cap gap.

4.4.3 Solid State Ignition (Replaces Ignition Coil)

An electronic ignition, also called solid state ignition, uses an electronic control circuit and distributor pickup coil to operate the ignition coil.

An electronic ignition is more dependable than a system of contact points because there are no mechanical breakers to burn out or wear down. This avoids trouble with ignition timing.

An electronic ignition is capable of producing a significantly higher secondary voltage over a points system. This allows for a wider spark plug gap and higher voltage to burn lean air-fuel mixtures. Leaner mixtures are now used to reduce emissions and improve fuel economy.

4.4.4 Distributorless Ignition

A distributorless ignition uses multiple ignition coils, a coil control unit, engine sensors, and a computer to operate the spark plugs (*Figure 8-26*).

The electronic coil module consists of more than one coil and a coil control unit that operates the coils. The module's control unit performs about the same function as the Ignition Control Module (ICM) in an electronic ignition. It will analyze data from different engine sensors and the system computer.

The coils are wired so they fire two spark plugs at the same time. One plug will fire on the power stroke and the other will fire on the exhaust stroke (there is no effect on engine operation). This system reduces the number

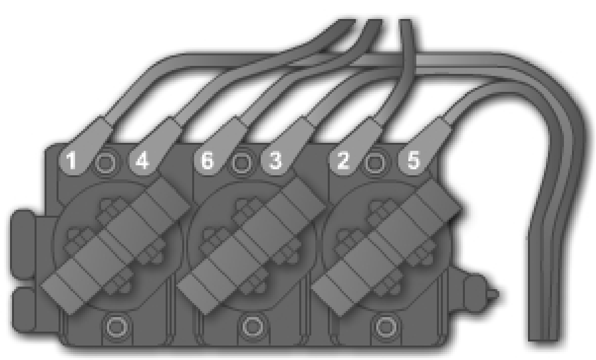


Figure 8-26 — Distributorless ignition.

of ignition coils required to operate the engine. For instance, a four cylinder would have only two coils, a six cylinder would have only three coils and so on.

A camshaft position sensor is installed in place of the ignition distributor. It sends an electrical pulse to the coil control unit providing data on camshaft and valve position.

4.4.5 Coil over Plug or IDI

A coil over plug ignition system has coils mounted on top of each spark plug (*Figure 8-27*). This type of system operates very similar to the distributorless ignition except for the lack of spark plug wires and the increase of coils. Sensor inputs allow the electronic control module to alter ignition timing with changes in operating conditions.

Figure 8-27 — Coil over plug ignition.

4.5.0 Spark Plug

The spark plug consists of a porcelain insulator in which there is an insulated electrode supported by a metal shell with a grounded electrode. Spark plugs have the simple purpose of supplying a fixed gap in the cylinder across which the high voltage surges from the coil must jump after passing through the distributor.

The spark plugs use ignition coil high voltage to ignite the fuel mixture. Somewhere between 4,000 and 10,000 volts are required to make current jump the gap at the plug electrodes. This is much lower than the output potential of the coil.

Spark plug gap is the distance between the center and side electrodes. Normal gap specifications range between .030 to .060 inch. Smaller spark plug gaps are used on older vehicles equipped with contact point ignition systems.

Spark plugs are either resistor or non-resistor types (*Figure 8-28*). A resistor spark plug has internal resistance (approximately 10,000 ohms) designed to reduce the static in radios. Most new vehicles require resistor type plugs. Non-resistor spark plugs have a solid metal rod forming the center electrode. This type of spark plug is NOT commonly used except for racing and off-road vehicles.

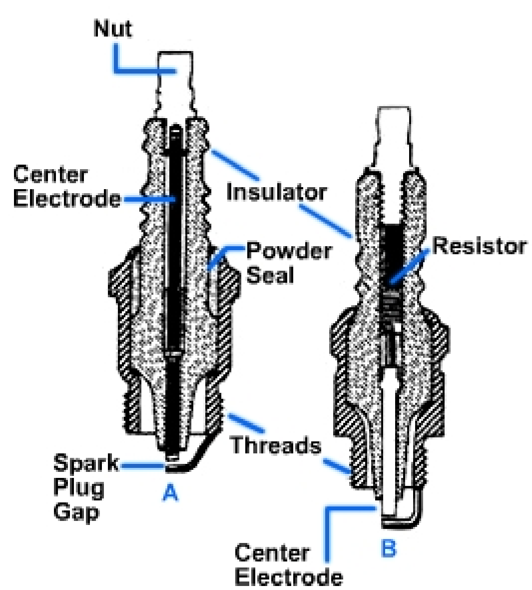


Figure 8-28 — Spark plugs.

4.5.1 Spark Plug Heat Range and Reach

The heat range of the spark plug determines how hot the plug will get. The length and diameter of the insulator tip and the ability of the spark plug to transfer heat into the cooling system determine spark plug heat range.

A hot spark plug has a long insulator tip that prevents heat transfer into the water jackets. It will also bum off any oil deposits. This provides a self-cleaning action.

A cold spark plug has a shorter insulator tip and operates at a cooler temperature. The cooler tip helps prevent overheating and preignition. A cold spark plug is used in engines operated at high speeds.

Vehicle manufacturers recommend a specific spark plug heat range for their engines. The heat range is coded and given as a number on the spark plug insulator. The larger the number on the plug, the hotter the spark plug tip will operate. For example, a 54 plug would be hotter than a 44 or 34 plug.

The only time you should change from spark plug heat-range specifications is when abnormal engine or operating conditions are encountered. For instance, if the plug runs too cool, sooty carbon will deposit on the insulator around the center electrode. This deposit could soon build up enough to short out the plug. Then high voltage surges would leak across the carbon instead of producing a spark across the spark plug gap. Using a hotter plug will bum this carbon deposit away or prevent it from forming.

Spark plug reach is the distance between the end of the spark plug threads and the seat or sealing surface of the plug. Plug reach determines how far the plug reaches through the cylinder head. If spark plug reach is too long, the spark plug will protrude too far into the combustion chamber, and the piston at TDC may strike the electrode. However, if the reach is too short, the plug electrode may not extend far enough into the cylinder head, and combustion efficiency will be reduced. A spark plug must reach into the combustion chamber far enough so that the spark gap will be properly positioned in the combustion chamber without interfering with the turbulence of the air-fuel mixture or reducing combustion action.

4.6.0 Spark Plug Wires

The spark plug wires carry the high voltage electric current from the distributor cap side terminals to the spark plugs. In vehicles with distributorless ignition, the spark plug wires carry coil voltage directly to the spark plugs. The two types of spark plug wires are solid wire and resistance wire.

Solid wire spark plug wires are used on older vehicles. The wire conductor is simply a strand of metal wire. Solid wires can cause radio interference and are no longer used.

Resistance spark plug wires consist of carbon-impregnated strands of rayon braid. They are used on modern vehicle because they contain internal resistance that prevents radio interference. Also known as radio interference wires, they have approximately 10,000 ohms per foot. This prevents high voltage-induced popping or cracking of the radio speakers.

On the outer ends of the spark plug wires, boots protect the metal connectors from corrosion, oil, and moisture that would permit high voltage to leak across the terminal to the shell of the spark plug.

4.7.0 Electronic Ignition System

The basic difference between the contact point and the electronic ignition system is in the primary circuit. The primary circuit in a contact point ignition system is open and closed by contact points. In the electronic system, the primary circuit is open and closed by the electronic control unit (ECU).

The secondary circuits are practically the same for the two systems. The difference is that the distributor, ignition coil, and wiring are altered to handle the high voltage produced by the electronic ignition system. One advantage of this higher voltage (up to 60,000 volts) is that spark plugs with wider gaps can be used. This results in a longer spark, which can ignite leaner air-fuel mixtures. As a result, engines can run on leaner mixtures for better fuel economy and lower emissions.

4.7.1 Electronic Ignition System Components

The components of an electronic ignition system regardless of the manufacturer all perform the same functions. Each manufacturer has its own preferred terminology and location of the components. The basic components of an electronic ignition system are as follows:

- The trigger wheel, also known as a reluctor, pole piece, or armature, is connected to the upper end of the distributor shaft. The trigger wheel replaces the distributor cam. Like the distributor cam lobes, the teeth on the trigger wheel equal the number of engine cylinders.
- The pickup coil, also known as a sensor assembly, sensor coil, or magnetic pickup assembly, produces tiny voltage surges for the ignition systems electronic control unit. The pickup coil is a small set of windings forming a coil.
- The ignition system electronic control unit amplifier or control module is an "electronic switch" that turns the ignition coil primary current ON and OFF. The ECU performs the same function as the contact points. The ignition ECU is a network of transistors, capacitors, resistors, and other electronic components sealed in a metal or plastic housing. The ECU can be located in the engine compartment, on the side of the distributor, inside the distributor, or under the vehicle dash. ECU dwell time (number of degrees the circuit conducts current to the ignition coil) is designed into the electronic circuit of the ECU and is NOT adjustable.

4.7.2 Electronic Ignition System Operation

With the engine running, the trigger wheel rotates inside the distributor. As a tooth of the trigger wheel passes the pickup coil, the magnetic field strengthens around the pickup coil. This action changes the output voltage or current flow through the coil. As a result, an electrical surge is sent to the electronic control unit as the trigger wheel teeth pass the pickup coil.

The electronic control unit increases the electrical surges into on/off cycles for the ignition coil. When the ECU is on, current passes through the primary windings of the ignition coil and develops a magnetic field. Then, when the trigger wheel and pickup coil turn off the ECU, the magnetic field inside the ignition coil collapses and fires a sparkplug.

4.8.0 Ignition Timing Devices

Ignition timing refers to how early or late the spark plugs fire in relation to the position of the engine pistons. Ignition timing must vary with engine speed, load, and temperature.

Timing advance happens when the spark plugs fire sooner than the compression strokes of the engine. The timing is set several degrees before top dead center (TDC). More time advance is required at higher speeds to give combustion enough time to develop pressure on the power stroke.

Timing retard happens when the spark plugs fire later on the compression strokes. This is the opposite of timing advance. Spark retard is required at lower speeds and under high load conditions. Timing retard prevents the fuel from burning too much on the compression stroke, which would cause spark knock or ping.

The basic methods to control ignition system timing are as follows:

- Centrifugal advance (controlled by engine speed)
- Vacuum advance (controlled by intake manifold vacuum and engine load)
- Computerized advance (controlled by various sensors—speed, temperature, intake, vacuum, throttle position, etc.)

4.8.1 Centrifugal Advance / Mechanical

Centrifugal advance makes the ignition coil and spark plugs fire sooner as engine speed increases, using spring-loaded weights, centrifugal force, and lever action to rotate the distributor cam or trigger wheel. Spark timing is advanced by rotating the distributor cam or trigger wheel against distributor shaft rotation. This action helps correct ignition timing for maximum engine power. Basically the centrifugal advance consists of two advance weights, two springs, and an advance lever.

During periods of low engine speed, the springs hold the advance weights inward towards the distributor cam or trigger wheel. At this time there is not enough centrifugal force to push the weights outward. Timing stays at its normal initial setting.

As speed increases, centrifugal force on the weights moves them outwards against spring tension. This movement causes the distributor cam or trigger wheel to move ahead. With this design, the higher the engine speed, the faster the distributor shaft turns, the farther out the advance weights move, and the farther ahead the cam or trigger wheel is moved forward or advanced. At a preset engine speed, the lever strikes a stop and centrifugal advance reaches maximum.

The action of the centrifugal advance causes the contact points to open sooner, or the trigger wheel and pickup coil turn off the ECU sooner. This causes the ignition coil to fire with the engine pistons not as far up in the cylinders.

4.8.2 Vacuum Advance/Electrical

The vacuum advance provides additional spark advance when engine load is low at part throttle position. It is a method of matching ignition timing with engine load. The vacuum advance increases fuel economy because it helps maintain idle fuel spark advance at all times. A vacuum advance consists of a vacuum diaphragm, link, movable distributor plate, and a vacuum supply hose.

At idle, the vacuum port from the carburetor or throttle body to the distributor advance is covered, thereby no vacuum is applied to the vacuum diaphragm, and spark timing is not advanced. At part throttle, the throttle valve uncovers the vacuum port and the port is exposed to engine vacuum.

The vacuum pulls the diaphragm outward against spring force. The diaphragm is linked to a movable distributor plate, which is rotated against distributor shaft rotation and spark timing is advanced. The vacuum advance does not produce any advance at full throttle. When the throttle valve is wide open, vacuum is almost zero. Thus vacuum is not applied to the distributor diaphragm and the vacuum advance does not operate.

4.8.3 Computerized Advance

The computerized advance, also known as an electronic spark advance system, uses various engine sensors and a computer to control ignition timing. The engine sensors check various operating conditions and sends electrical data to the computer. The computer can change ignition timing for maximum engine efficiency.

Ignition system engine sensors include the following:

- Engine speed sensor (reports engine speed to the computer)
- Crankshaft position sensor (reports piston position)
- Throttle position switch (notes the position of the throttle)
- Inlet air temperature sensor (checks the temperature of the air entering the engine)
- Engine coolant temperature sensor (measures the operating temperature of the engine)
- Detonation sensor (allows the computer to retard timing when the engine knocks or pings)
- Intake vacuum sensor (measures engine vacuum, an indicator of load)

The computer receives different current or voltage levels (input signals) from these sensors. It is programmed to adjust ignition timing based on engine conditions. The computer may be mounted on the air cleaner, under the dash, on a fender panel, or under a seat.

The following is an example of the operation of a computerized advance. A vehicle is traveling down the road at 50 mph; the speed sensor detects moderate engine speed. The throttle position sensor detects part throttle, and the air inlet and coolant temperature sensors report normal operating temperatures. The intake vacuum sensor sends high vacuum signals to the computer.

The computer receives all the data and calculates that the engine requires maximum spark advance. The timing would occur several degrees before TDC on the compression stroke. This action assures that high fuel economy is attained on the road.

If the operator begins to pass another vehicle, intake vacuum sensor detects a vacuum drop to near zero and a signal is sent to the computer. The throttle position sensor detects a wide open throttle and other sensor outputs say the same. The computer receives and calculates the data, then, if required, retards ignition timing to prevent spark knock or ping.

4.9.0 Ignition System Maintenance

Ignition troubles can result from a myriad of problems, from faulty components to loose or damaged wiring. Unless the vehicle stops on the job, the operator will report trouble indications, and the equipment is turned in to the shop for repairs.

Unless the trouble is known, a systematic procedure should be followed to locate the cause. Remember, electric current will follow the path of least resistance. Trace ignition wiring while checking for grounds, shorts, and open circuits. Bare wires, loose connections, and corrosion are found through visual inspection.

After checking the system, you must evaluate the symptoms and narrow down the possible causes. Use your knowledge of system operation, a service manual troubleshooting chart, basic testing methods, and common sense to locate the trouble. Many shops have specialized equipment that provides the mechanic a quick and easy means of diagnosing ignition system malfunctions.

4.9.1 Spark Plugs and Spark Plug Wires

Bad spark plugs cause a wide range of problems such as misfiring, lack of power, poor fuel economy, and hard starting. After prolonged use, the spark plug tip can become coated with ash, oil, and other residue. The spark plug electrodes can also burn and widen the gap. This makes it more difficult for the ignition system to produce an electric arc between the electrodes.

To read spark plugs closely, inspect and analyze the condition of each spark plug tip and insulator. This will give you information on the condition of the engine, the fuel system, and the ignition system. The conditions commonly encountered with spark plugs are as follows:

- Normal operation condition appears as brown to grayish-tan deposit with slight electrode wear (*Figure 8-29, View A*). This indicates the correct spark plug heat range and mixed periods of high- and low-speed operation. Spark plugs having this appearance may be cleaned, regapped, and reinstalled.
- Carbon-fouled condition appears as dry, fluffy black carbon (*Figure 8-29, View B*). This results from slow operating speeds, wrong heat range (too cold), weak ignition (weak coil, worn ignition cables, etc.), faulty automatic choke, sticking manifold control valve, or rich air-fuel mixture. Spark plugs having this appearance may be cleaned, regapped, and reinstalled.

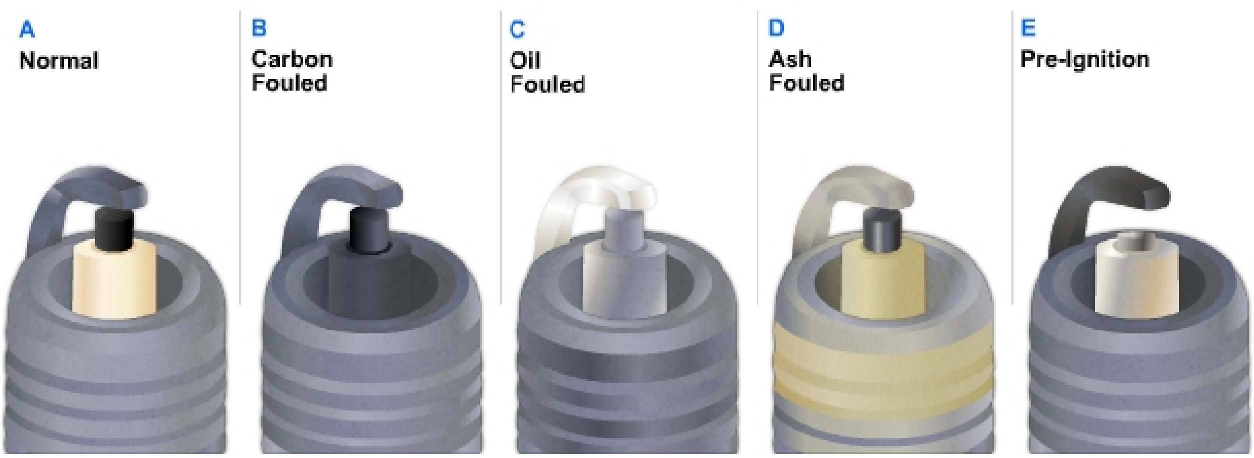


Figure 8-29 — Spark plug conditions.

- Oil-fouled condition appears as wet, oily deposits with very little electrode wear (*Figure 8-29, View C*). This results from worn rings, scored cylinder, or leaking valve seals. Spark plugs having this appearance may be degreased, cleaned, regapped, and reinstalled.
- Ash-fouled condition appears as red, brown, yellow, or white colored deposits which accumulate on the insulator (*Figure 8-29, View D*). This results from poor fuel quality or oil entering the cylinder. Most ash deposits have no adverse effect on the operation of the spark plug as long as they remain in a powdery state. However, under certain conditions these deposits melt and form a shiny glaze on the insulator which, when hot, acts as a good electrical conductor, allowing current to follow the deposit instead of jumping the gap, thus shorting out the

spark plug. Spark plugs having a powdery condition may be cleaned, regapped, and replaced. Those having a glazed deposit must be replaced.

- Preigniton damage appears as burned or blistered insulator tips and badly worn electrodes (*Figure 8-29, View E*). This results from over-advanced timing, low octane fuel, wrong spark plug heat range (too high), or a lean air-fuel mixture. Spark plugs having this condition must be replaced with ones having the recommended heat range.

When a spark plug is removed for cleaning or inspection, it should be regapped to the engine manufacturer's specifications. New spark plugs must also be regapped before installation, as they may have been dropped or mishandled and may not be within specifications.

Use a wire type feeler gauge to measure spark plug gap. Slide the feeler gauge between the electrodes. If needed, bend the side electrode until the feeler gauge fits snugly. The gauge should drag slightly as it is pulled in and out of the gap. Spark plug gaps vary from 0.030 inch on contact point ignitions to over 0.060 inch on electronic ignition systems.

When you are reinstalling spark plugs, tighten them to the manufacturer's recommendation. Some manufacturers give spark plug torque, while others recommend bottoming the plugs on the seat and then turning an additional one-quarter to one-half turn. Refer to the manufacturer's service manual for exact procedures.

A faulty spark wire can either have a burned or broken conductor, or it could have deteriorated insulation. Most spark plugs wires have a resistance conductor that can be easily separated. If the conductor is broken, voltage and current cannot reach the spark plug. If the insulation is faulty, sparks may leak through to ground or to another wire instead of reaching the spark plugs. To test the wires for proper operation, you can perform the following:

- A spark plug wire resistance test will check the spark plug conductor or coil wire conductor. To perform a wire resistance test, connect an ohmmeter across each end of the wire. The meter will read internal wire resistance in ohms. Typically resistance should NOT be over 5,000 ohms per inch or 100,000 ohms total. Since specifications vary, compare your readings to the manufacturer's specifications.
- A spark plug wire insulation test checks for sparks arcing through the insulation to ground. To perform an insulation test with the hood up, block out as much light as possible, start the engine, and move a grounded screwdriver next to the insulation. If a spark jumps through the insulation to the screwdriver, the wire is bad. Spark plug leakage is a condition in which electric arcs pass through the wire insulation.

Installing new spark plug wire is a simply task, especially when you replace one wire at a time. Wire replacement is more complicated if all of the wires have been removed. Then you must use engine firing order and cylinder numbers to route each wire correctly. You can use service manuals to trace the wires from each distributor cap tower to the correct spark plug.

4.9.2 Distributor Service

The distributor is critical to the proper operation of the ignition system. The distributor senses engine speed, alters ignition timing, and distributes high voltage to the spark plugs. If any part of the distributor is faulty, engine performance suffers.

When problems point to possible distributor cap or rotor troubles, remove and inspect them. The distributor cap should be carefully checked to see that sparks have not been arcing from point to point. Both interior and exterior must be clean. The firing points should not be eroded, and the interior of the towers must be clean.

The rotor tip, from which the high-tension spark jumps to each distributor cap terminal, should not be worn. It also should be checked for excessive burning, carbon trace, looseness, or other damage. Any wear or irregularity will result in excessive resistance to the high-tension spark. Make sure that the rotor fits snugly on the distributor shaft.

A common problem arises when a ***carbon trace*** forms on the inside of the distributor cap or outer edge of the rotor. The carbon trace will short coil voltage to ground or to a wrong terminal lug in the distributor cap. A carbon trace will cause the spark plugs to either fire poorly or not at all.

Using a droplight, check the inside of the distributor cap for cracks and carbon trace. Carbon trace is black, which makes it hard to see on a black colored distributor cap. If you find carbon trace or a crack, replace the distributor cap or rotor.

In a contact point distributor, there are two areas of concern: the contact points and the condenser.

Bad contact points cause a variety of engine performance problems. These problems include high speed missing, no-start problems, and many other ignition troubles. Visually inspect the surfaces of the contact points to determine their condition. Points with burned and pitted contacts or with a worn rubbing block must be replaced. However, if the points look good, point resistance should be measured. Turn the engine over until the points are closed and then use an ohmmeter to connect the meter to the primary point lead and to ground. If resistance reading is too high, the points are burned and must be replaced.

A faulty condenser may leak (allow some DC current to flow to ground), be shorted (direct electrical connection to ground), or be opened (broken lead wire to the condenser foils). If the condenser is leaking or open, it will cause point arcing and burning. If the condenser is shorted, primary current will flow to ground and the engine will not start. To test a condenser using an ohmmeter, connect the meter to the condenser and to ground. The meter should register slightly and then return to infinity (maximum resistance). Any continuous reading other than infinity indicates that the condenser is leaking and must be replaced.

Installing contact points is a relatively simple procedure but must be done with precision and care in order to achieve good engine performance and economy. Make sure the points are clean and free of any foreign material.

Proper alignment of the contact points is extremely important (*Figure 8-30*). If the faces of the contact points do not touch each other fully, heat generated by the primary current cannot be dissipated and rapid burning takes place. The contacts are aligned by bending the stationary contact

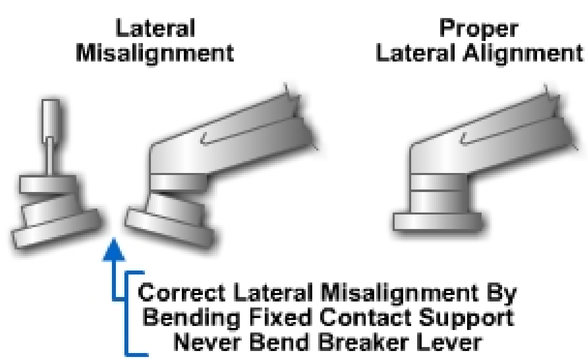


Figure 8-30 — Contact point alignment.

bracket only. Never bend the movable contact arm. Ensure the contact arm-rubbing block rests flush against the distributor cam. Place a small amount of an approved lubricant on the distributor cam to reduce friction between the cam and rubbing block. Once you have installed the points, you can adjust them using either a feeler gauge or dwell meter.

To use a feeler gauge to set the contact points, turn the engine over until the points are fully open. The rubbing block should be on top of a distributor cam lobe. With the points open, slide the specified thickness feeler gauge between them. Adjust the points so that there is a slight drag on the blade of the feeler gauge. Depending upon point design, use a screwdriver or Allen wrench to open and close the points. Tighten the hold-down screws and recheck the point gap. Typically point gap settings average around .015 inch for eight-cylinder engines and .025 inch for six- and four-cylinder engines. For the gap set of the engine you are working on, consult the manufacturer’s service manual.

CAUTION

Ensure the feeler gauge is clean before inserting it between the points. Oil and grease will reduce the service life of the points.

To use a dwell meter for adjusting contact points, connect the red lead of the dwell meter to the distributor side of the ignition coil (wire going to the contact points). Connect the black lead to ground.

If the distributor cap has an adjustment window, the points should be set with the engine running. With the meter controls set properly, adjust the points through the window of the distributor cap using an Allen wrench or a special screwdriver. Turn the point adjustment screw until the dwell meter reads within manufacturer’s specification. However, if the distributor cap does not have an adjustment window, remove the distributor cap and ground the ignition coil wire. Then crank the engine; this action will simulate engine operation and allow point adjustment with the dwell meter.

Dwell specifications vary with the number of cylinders. An eight-cylinder engine requires 30 degrees of dwell. An engine with few cylinders requires more dwell time. Always consult the manufacturer’s service manual for exact dwell values.

Dwell should remain constant as engine speed increases or decreases. However, if the distributor is worn, you can have a change in the dwell meter reading. This is known as dwell variation. If dwell varies more than 3 degrees, the distributor should either be replaced or rebuilt. Also, a change in the point gap or dwell will change ignition timing. For this reason, the points should always be adjusted before ignition timing.

Most electronic ignition distributors use a pickup coil to sense trigger wheel rotation and speed. The pickup coil sends small electrical impulses to the ECU. If the distributor fails to produce these electrical impulses properly, the ignition system can quit functioning.

A faulty pickup coil will produce a wide range of engine troubles, such as stalling, loss of power, or failure to start at all. If the small windings in the pickup coil break, they will cause problems only under certain conditions. It is important to know how to test a pickup coil for proper operation.

The pickup coil ohmmeter test compares actual pickup resistance with the manufacturer’s specifications. If the resistance is too high or low, the pickup coil is faulty. To perform this test, connect the ohmmeter across the output leads of the pickup coil. Wiggle the wire to the pickup coil and observe the meter reading. This will assist in locating any breaks in the wires to the pickup. Also, using a screwdriver, lightly tap the coil. This action will uncover any break in the coil windings.

Pickup coil resistance varies between 250 and 1,500 ohms, and you should refer to the service manual for exact specifications. Any change in the readings during the pickup coil resistance test indicates the coil should be replaced. Refer to the manufacturer's service manual for instructions for the removal and replacement of the pickup coil.

Once you have replaced the pickup coil, you need to set the pickup coil air gap. The air gap is the space between the pickup coil and the trigger wheel tooth. To obtain an accurate reading, use a nonmagnetic feeler gauge (plastic or brass).

With one tooth of the trigger wheel pointing at the pickup coil, slide the correct thickness non-magnetic feeler gauge between the trigger wheel and the pickup coil. Move the pickup coil in or out until the correct air gap is set. Tighten the pickup coil screws and double check the air gap setting.

4.9.3 Ignition Timing

The ignition system must be timed so the sparks jump across the spark plug gaps at exactly the right time. Adjusting the distributor on the engine so that the spark occurs at this correct time is called setting the ignition timing. The ignition timing is normally set at idle or a speed specified by the engine manufacturer. Before measuring engine timing, disconnect and plug the vacuum advance hose going to the distributor. This action prevents the vacuum advance from functioning and upsetting the readings. Make the adjustment by loosening the distributor hold-down screw and turning the distributor in its mounting.

Turning the distributor housing against the distributor shaft rotation advances the timing. Turning the distributor housing with shaft rotation retards the timing (*Figure 8-31*).

When the ignition timing is too advanced, the engine may suffer from spark knock or ping. When ignition timing is too retarded, the engine will have poor fuel economy and power and will be very sluggish during acceleration. If extremely retarded, combustion flames blowing out of the open exhaust valve can overheat the engine and crack the exhaust manifolds.

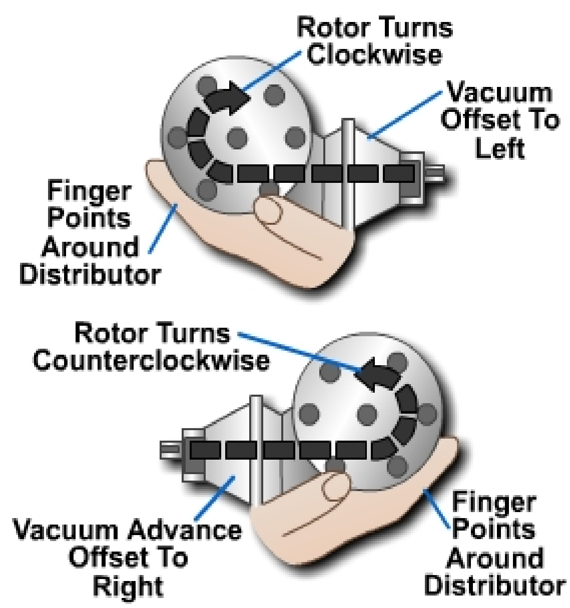


Figure 8-31 — Determining direction of rotor rotation.

A timing light is used to measure ignition timing. It normally has three leads—two small leads that connect to the battery, and one larger lead that connects to the number one spark plug wire. Depending on the type of timing light, the large lead may clip around the plug wire (inductive type), or it may need to be connected directly to the metal terminal of the plug wire (conventional type).

Draw a chalk line over the correct timing mark. This will make it easier to see. The timing marks may be either on the front cover in harmonic balance of the engine, or they may be on the engine flywheel.

With the engine running, aim the flashing timing light at the timing mark and reference pointer. The flashing timing light will make the mark appear to stand still. If the timing mark and the pointer do not line up, turn the distributor in its mounting until the timing mark and pointer are aligned. Tighten the distributor hold-down screw.

⚠ **CAUTION** ⚠

Keep your hands and the timing light leads from the engine fan and belts. The spinning fan and belts can damage the light or cause serious personal injury.

After the initial ignition timing, you should check to see if the automatic advance mechanism is working. This can be done by keeping the timing light flashes aimed at the timing mark and gradually increasing speed. If the advance mechanism is operating, the timing mark should move away from the pointer. If the timing mark fails to move as the speed increases or it hesitates and then suddenly jumps, the advance mechanism is faulty and should either be repaired or replaced.

Replace the distributor vacuum line and see if timing still conforms to the manufacturer's specifications. If the timing is NOT advanced when the vacuum line is connected and the throttle is opened slightly, the vacuum advance unit or tubing is defective.

Most computer-controlled ignition systems have no provision for timing adjustment. A few, however, have a tiny screw or lever on the computer for small ignition timing changes.

A computer-controlled ignition system has what is known as base timing. Base timing is the ignition timing without computer-controlled advance. Base timing is checked by disconnecting a wire connector in the computer wiring harness. This wire connector may be found on or near the engine or sometimes next to the distributor. When in the base timing mode, a conventional timing light can be used to measure ignition timing. If ignition timing is not correct, you can rotate the distributor, in some cases, or move the mounting for the engine speed or crank position sensor. If base timing cannot be adjusted, the electronic control unit or other components will have to be replaced. Always refer to the manufacturer's service manual when timing a computer-controlled ignition system.

Test your Knowledge (Select the Correct Response)

9. Of the two circuits within the ignition circuit, which one uses conventional wiring?

   A. Primary
   B. Secondary
   C. Charging
   D. Reacting

10. What are the two types of sparkplugs?

   A. Resistor and non-resistor
   B. Electric and mechanical
   C. Cold and hot
   D. Short and long

5.0.0 LIGHTING CIRCUIT

The lighting circuit includes the battery, vehicle frame, all the lights, and various switches that control their use. The lighting circuit is known as a single-wire system since it uses the vehicle frame for the return.

The complete lighting circuit of a vehicle can be broken down into individual circuits, each having one or more lights and switches. In each separate circuit, the lights are connected in parallel, and the controlling switch is in series between the group of lights and the battery.

The marker lights, for example, are connected in parallel and are controlled by a single switch. In some installations, one switch controls the connections to the battery, while a selector switch determines which of two circuits is energized. The headlights, with their high and low beams, are an example of this type of circuit.

In some instances, such as the courtesy lights, several switches may be connected in parallel so that any switch may be used to turn on the light.

When a wiring diagram is being studied, all light circuits can be traced from the battery through the ammeter to the switch (or switches) to the individual light.

5.1.0 Headlights

The headlights are sealed beam lamps that illuminate the road during nighttime operation (*Figure 8-32*). Headlights consist of a lens, one or two elements, and an integral reflector. When current flows through the element, the element gets white hot and glows. The reflector and lens direct the light forward. Many modern passenger vehicles use a halogen or HID headlights.

Figure 8-32 — Sealed beam headlight assembly.

5.1.1 Headlight Switch

The headlight switch is an on/off switch and rheostat (variable resistor) in the dash panel or on the steering column. The headlight switch controls current flow to the lamps of the headlight system. The rheostat is for adjusting the brightness of the instrument panel lights.

5.2.0 Lamps

Small gas-filled incandescent lamps with tungsten filaments are used on automotive and construction equipment (*Figure 8-33*). The filaments supply the light when sufficient current is flowing through them. They are designed to operate on a low voltage current of 12 or 24 volts, depending upon the voltage of the electrical system used.

Figure 8-33 — Different types of lamps.

Lamps are rated as to size by the candlepower (luminous intensity) they produce. They range from small 1/2-candlepower bulbs to large 50-candlepower bulbs. The greater the candlepower of the lamp, the more current it requires when lighted. Lamps are identified by a number on the base.

When you replace a lamp in a vehicle, be sure the new lamp is of the proper rating. The lamps within the vehicle will be of the single- or double-contact types with nibs to fit bayonet sockets (*Figure 8-34*).

5.2.1 Halogen

Most vehicles made today use a halogen headlamp bulb insert (*Figure 8-35, View A*). These are small heat-resistant quartz bulbs filled with halogen gas to protect the filament from damage. They are inserted to a headlight lens assembly. This assembly will protect the light bulb and disperse the light given from the halogen bulb.

CAUTION

Never touch the glass surface of a halogen or HID light. The oil in your skin and the high operating temperature can shorten the life of the bulb or cause the glass to shatter.

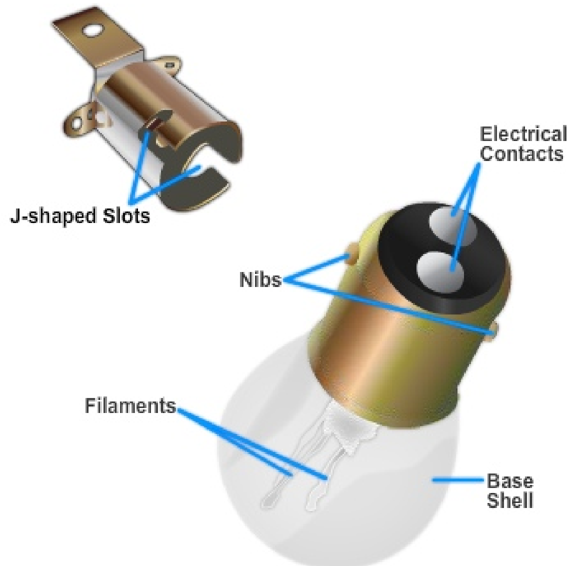


Figure 8-34 — Double-contact bulb and bayonet socket.

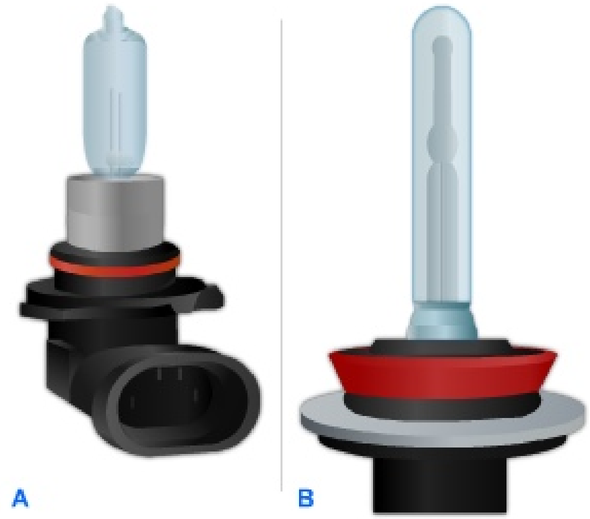


Figure 8-35 — Halogen and HID headlights.

The white halogen bulb increases visibility and increases output by about 25% while drawing the same amount of current. A typical low beam bulb is 45 watts and a high beam bulb is 65 watts.

5.2.2 High Intensity Discharge (HID)

A high intensity discharge lamp does not use a filament (*Figure 8-35, View B)*. Instead, a high voltage electric arc flows between two electrodes in the bulb. This arc excites xenon vapor contained in the bulb, producing a bright blue-white light.

An external ballast is used to convert battery voltage into high-voltage AC to create and maintain the arc. When it is first turned on, an igniter works with the ballast to provide several thousand volts to establish the arc. The ballast then provides as many as 450 volts to maintain the arc. As the bulb warms up, the voltage needed to maintain the lamp can be as low as 50 volts.

HID lights produce more light than a standard halogen bulb while consuming less power, and they last longer.

WARNING

HID bulbs require a large amount of voltage for startup: beware of a shock hazard. Also, HID bulbs are under pressure when hot and may lead to an explosion hazard.

5.2.3 Light Emitting Diode (LED)

A light emitting diode is a semiconductor that will emit light when electrically energized. The LED converts electricity directly into light; this makes it much more efficient than a normal filament bulb.

The LED is an N-P junction with special doped semiconductors. When energized, photons (electrons) are emitted from the semiconductor substance. We then see these photons as light.

5.3.0 Dimmer Switch Blackout Lights (Military Application)

Military vehicles used in tactical situations are equipped with a headlight switch that is integrated with the blackout lighting switch (*Figure 8-36*).

The blackout select is operated by a 2-way rocker switch. This switch allows an operator to select between normal or blackout mode. To select normal mode, press the smaller bottom switch up and hold, while pressing the main switch down. To select blackout mode, instead of pressing the main switch down, press it up.

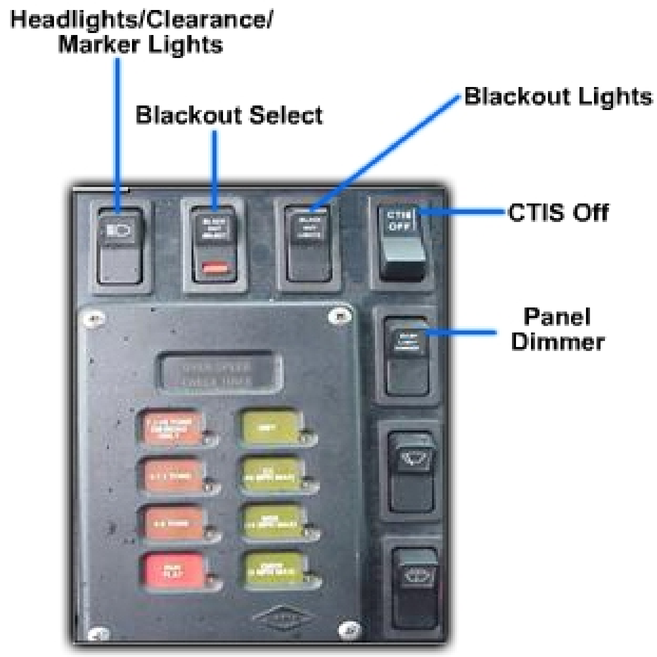


Figure 8-36 — Blackout light/ headlight switch.

NOTE

In blackout mode, the backup alarm will not operate.

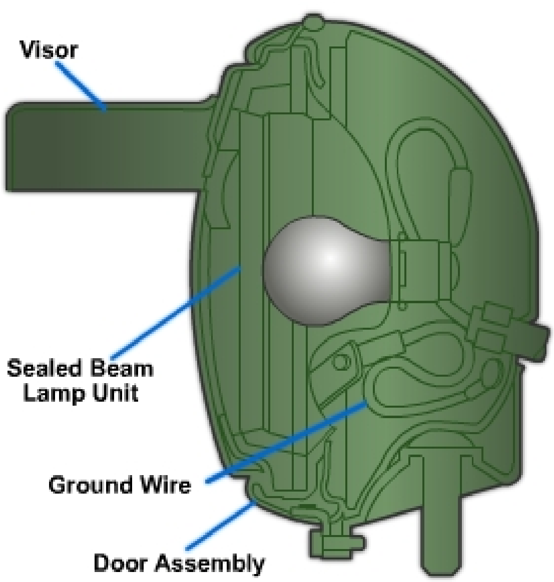


Figure 8-37 — Blackout driving light.

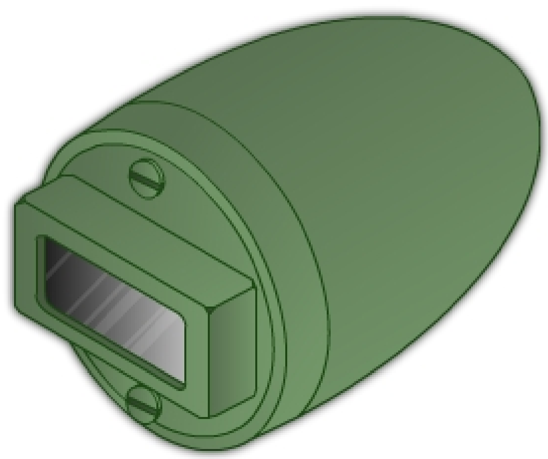


Figure 8-38 — Blackout marker light.

The purposes of blackout lighting are as follows:

- To provide the vehicle operator with sufficient light to operate the vehicle in total darkness.
- To provide minimum lighting to show vehicle position to a leading or trailing vehicle when illumination must be restricted to a level not visible to a distant enemy.

The three types of blackout lighting are as follows:

- The blackout driving light is designed to provide a white light of 25 to 50 candlepower at a distance of 10 feet directly in front of the light (*Figure 8-37*). The light is shielded so that the top of the low beam is directed not less than 2 degrees below the horizon. The beam distribution on a level road at 100 feet from the light is 30 feet wide.
- The blackout stop/taillight and marker light are designed to be visible at a horizontal distance of 800 feet and not visible beyond 1,200 feet (*Figure 8-38*). The lights also must be invisible from the air above 400 feet with the vehicle on upgrades and downgrades of 20 percent. The horizontal beam cutoff for the lights is 60 degrees right and left of the beams center line at 100 feet.

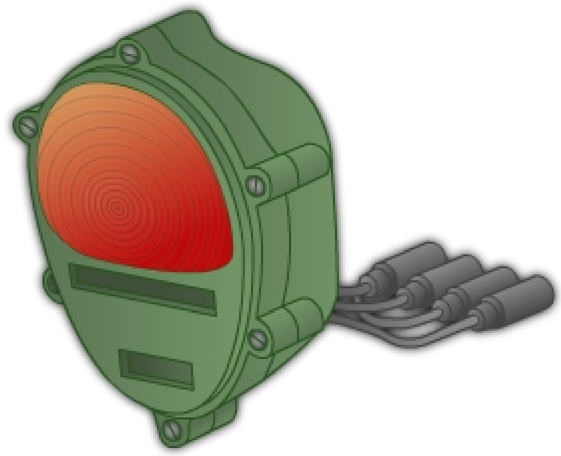


Figure 8-39 — Blackout composite light.

- The composite light is currently the standard light unit that is used on the rear of tactical military vehicles. The composite light combines service, stop, tail, and turn signals with blackout stop and tail lighting (*Figure 8-39*).

Blackout lighting control switches are designed to prevent the service lighting from being turned on accidentally.

5.4.0 Turn-Signal Systems

Vehicles that operate on any public road must be equipped with turn signals. These signals indicate a left or right turn by providing a flashing light signal at the rear and front of the vehicle.

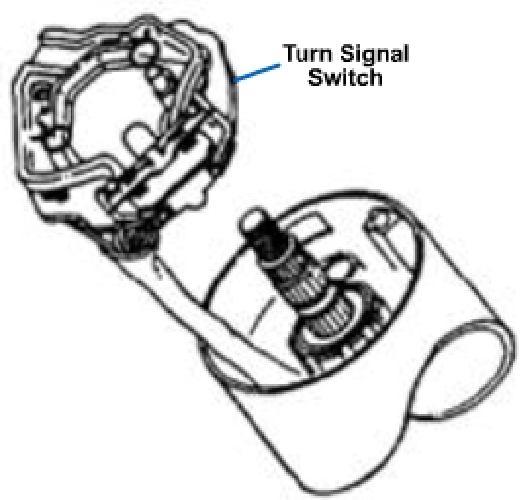


Figure 8-40 — Turn signal switch.

The turn-signal switch is located on the steering column (*Figure 8-40*). It is designed to shut off automatically after the turn is completed by the action of the canceling cam.

A wiring diagram for a typical turn-signal system is shown in *Figure 8-41*. A common design for a turn signal system is to use the same rear light for both the stop and turn signals. This somewhat complicates the design of the switch in that the stoplight circuit must pass through the turn-signal switch. When the turn signal switch is turned off, it must pass stoplight current to the rear lights. As a left or right turn signal is selected, the stoplight circuit is open and the turn signal circuit is closed to the respective rear light.

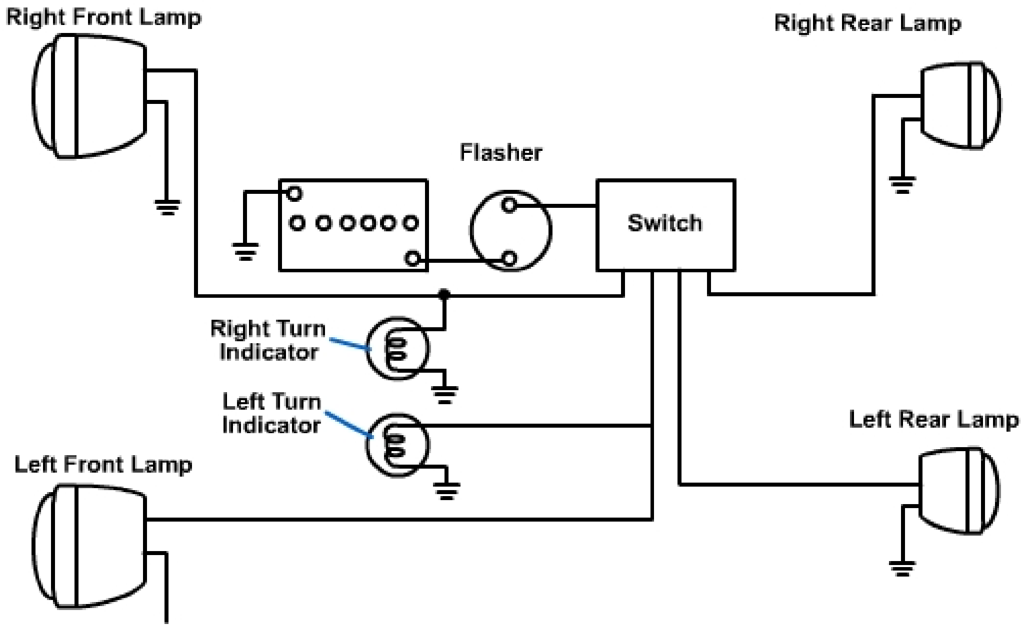


Figure 8-41 — Turn signal wiring diagram.

The turn signal flasher unit creates the flashing of the turn signal lights (*Figure 8-42*). It consists basically of a bimetallic (two dissimilar metals bonded together) strip wrapped in a wire coil. The bimetallic strip serves as one of the contact points.

When the turn signals are actuated, current flows into the flasher—first through the heating coil to the bimetallic strip, then through the contact points, then out of the flasher, where the circuit is completed through the turn-signal light. This sequence of events will repeat a few times a second, causing a steady flashing of the turn signals.

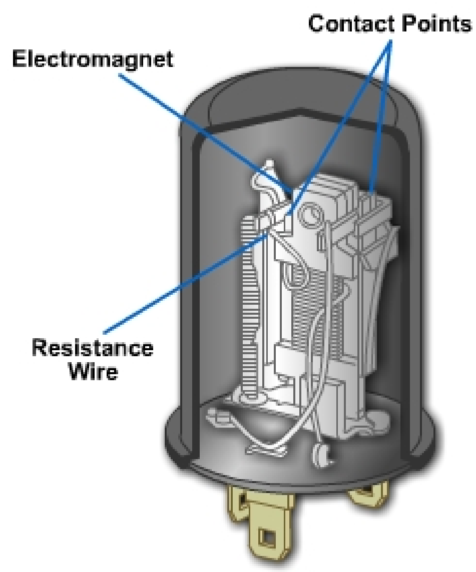


Figure 8-42 — Flasher unit.

5.5.0 Backup Light System

The backup light system provides visibility to the rear of the vehicle at night and a warning to the pedestrians, whenever the vehicle is shifted into reverse. The backup light system has a fuse, gearshift or transmission-mounted switch, two backup lights, and wiring to connect these components.

The backup light switch closes the light circuit when the transmission is shifted into reverse. The most common backup light switch configurations are as follows:

- The backup light switch mounted on the transmission and operated by the shift lever.
- The backup light switch mounted on the steering column and operated by the gearshift linkage.
- The transmission- or gearshift-mounted backup light switch on many automatic transmission equipped vehicles is combined with the neutral safety switch.

5.6.0 Stop-Light System

All vehicles that are used on public highways must be equipped with a stoplight system. The stoplight system consists of a fuse, brake light switch, two rear warning lights, and related wiring (*Figure 8-43*).

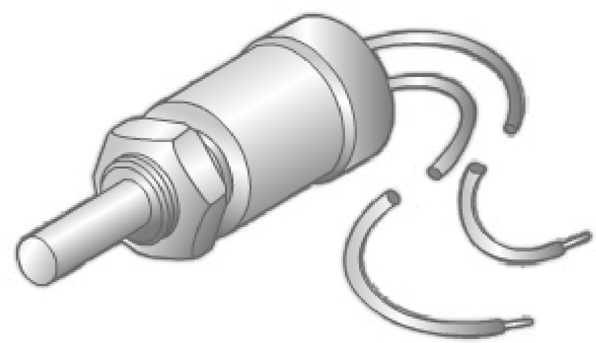


Figure 8-43 — Brake light switch.

The brake light switch on most automotive equipment is mounted on the brake pedal. When the brake pedal is pressed, it closes the switch and turns on the rear brake lights. On construction and tactical equipment, you may find a pressure light switch. This type of switch uses either air or hydraulic pressure, depending on the equipment. It is mounted on the master cylinder of the hydraulic brake system or is attached to the brake valve on an air brake system. As the brakes are depressed, either air or hydraulic pressure builds on a diaphragm inside the switch. The diaphragm closes, allowing electrical current to turn on the rear brake lights.

5.7.0 Emergency Light System

The emergency light system, also termed hazard warning system, is designed to signal oncoming traffic that a vehicle has stopped, stalled, or pulled over to the side of the road. The system consists of a switch, flasher unit, four turn-signal lights, and related wiring. The switch is normally a push-pull switch mounted on the steering column.

When the switch is closed, current flows through the emergency flasher. Like a turn signal flasher, the emergency flasher opens and closes the circuit to the lights. This causes all four turn signals to flash.

5.8.0 Circuit Breakers and Fuses (Application or Uses)

Fuses are safety devices placed in electrical circuits to protect wires and electrical units from a heavy flow of current. Each circuit, or at least each individual electrical system, is provided with a fuse that has an ampere rating for the maximum current required to operate the units. The fuse element is made from metal with a low-melting point and forms the weakest point of the electrical circuit. In case of a short circuit or other trouble, the fuse will be burned out first and open the circuit just as a switch would do. Examination of a burnt-out fuse usually gives an indication of the problem. A discolored sight glass indicates the circuit has a short either in the wiring or in one of its components. If the glass is clear, the problem is an overloaded circuit. Be sure when replacing a fuse that it has a rating equal to the one burned out. Ensure that the trouble of the failure has been found and repaired.

A circuit breaker performs the same function as a fuse. It disconnects the power source from the circuit when current becomes too high. The circuit breaker will remain open until the trouble is corrected. Once the trouble is corrected, a circuit breaker will automatically reset itself when current returns to normal levels. The fuses and circuit breakers can usually be found behind the instrument panel on a fuse block (*Figure 8-44*).

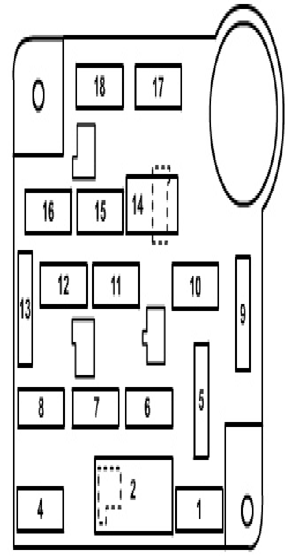


Figure 8-44 — Fuse block.

5.8.1 Mini Fuses

A mini fuse is a blade type fuse with two prongs that fit into sockets in the fuse block (*Figure 8-45, View A*). Mini fuses are color coded in accordance to the ampere rating between 1 and 40 amps. They are the smaller type of blade fuse with a dimension of 10.9x3.6x16.3mm.

5.8.2 Conventional Fuses

A conventional fuse is a blade type fuse and is a larger version of the mini fuse (*Figure 8-45, View B)*. Conventonal fuses also are color coded in accordance to the ampere rating between 1 and 40 amps. They are the regular type of blade fuse with a dimension of 19.1x5.1x18.5mm.

5.8.3 Maxi Fuses

A maxi fuse is a also blade type fuse with two prongs that fit into sockets; however, they are quite a bit larger and are usually found under the hood (*Figure 8-45, View C)*. The maxi fuse is available in current ratings from 20 to 80 amps. They are color coded in accordance to the ampere rating and their dimensions are 29.2x8.5x34.3mm.

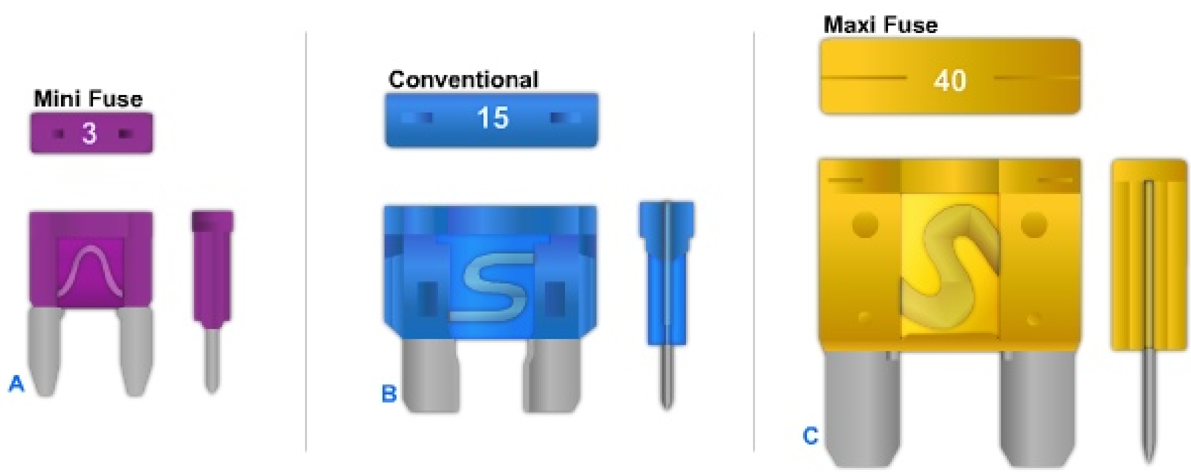


Figure 8-45— Fuses.

5.8.4 Circuit Breakers

A circuit breaker performs the same function as a fuse. The difference is that the circuit breaker is still usable after it trips. It will sense a high current condition, disconnect the circuit temporarily, and then if the current draw returns to normal, it will reset itself.

A circuit breaker contains a bi-metal strip that remains cool and straight under normal load. Under high current load, the metal strip heats up, bends or warps, and opens the breaker.

Type 1 circuit breakers are cycling circuit breakers (*Figure 8-46*). This means that after the breaker cools down, the metal strip straightens out again and closes the circuit. These are sometimes seen in headlight, fog light, and windshield wiper circuits.

Type 2 circuit breakers are noncycling breakers. This means that after the breaker heats up, the current flows through an armature on the breaker. The armature heats up and bends away from the contact points. Now the electricity can flow only through a resister, also mounted on the breaker. When a noncycling breaker trips, current can pass only through the resistor, resulting in greatly reduced current and voltage to the circuit.

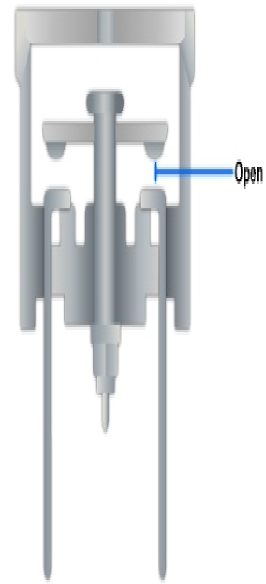


Figure 8-46 — Cycling circuit breaker.

To reset this circuit breaker, you must open the circuit and allow it to cool off. The cooling effect will allow the metal to straighten and make contact with the points again. Noncycling circuit breakers are used extensively in truck electrical circuits.

Test your Knowledge (Select the Correct Response)

11. By what percentage is light output increased when using halogen headlights?

    A. 45
    B. 35
    C. 25
    D. 15

12. What component of the headlight switch allows for adjusting the brightness of the instrument panel lights?

    A. Brightness compensator
    B. Illuminator
    C. Dimmer dial
    D. Rheostat

13. On most automotive vehicles, the brake light switch is mounted at what location?

A. At the brake light
B. In the brake line
C. In the steering column
D. At the brake pedal

6.0.0 INSTRUMENTS, GAUGES, and ACCESSORIES

The instrument panel is placed so that the instruments and gauges can easily be read by the operator. They inform the operator of the vehicle speed, engine temperature, oil pressure, rate of charge or discharge of the battery, amount of fuel in the fuel tank, and distance traveled.

6.1.0 Battery Gauge

The battery condition gauge is one of the most important gauges on the vehicle. If the gauge is interpreted properly, it can be used to troubleshoot or prevent breakdowns. The following are the three basic configurations of battery condition gauges—ammeter, voltmeter, and indicator lamp.

The ammeter is used to indicate the amount of current flowing to and from the battery. It does NOT give an indication of total charging output because of other units in the electrical system. If the ammeter shows a 10-ampere discharge, it indicates that a 100 ampere-hour battery would be discharged in 10 hours, as long as the discharge rate remained the same. Current flowing from the battery to the starting motor is never sent through the ammeter, because the great quantities of amperes used (200 to 600 amperes) cannot be measured due to its limited capacity. In a typical ammeter, all the current flowing to and from the battery, except for starting, actually is sent through a coil to produce a magnetic field that deflects the ammeter needle in proportion to the amount of current (*Figure 8-47*). The coil is matched to the maximum current output of the charging unit, and this varies with different applications.

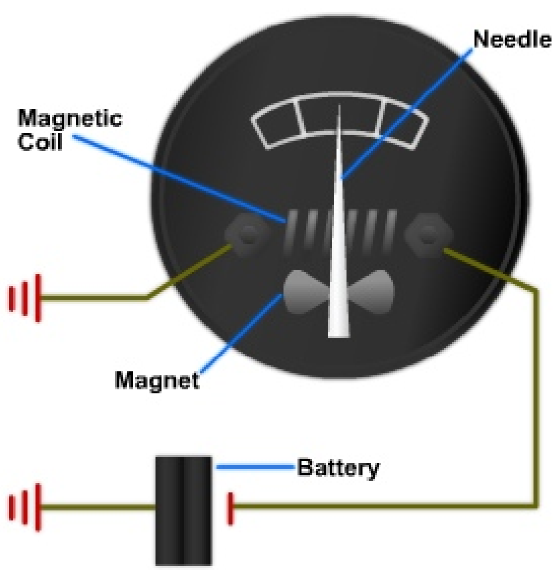


Figure 8-47 — Ammeter schematic.

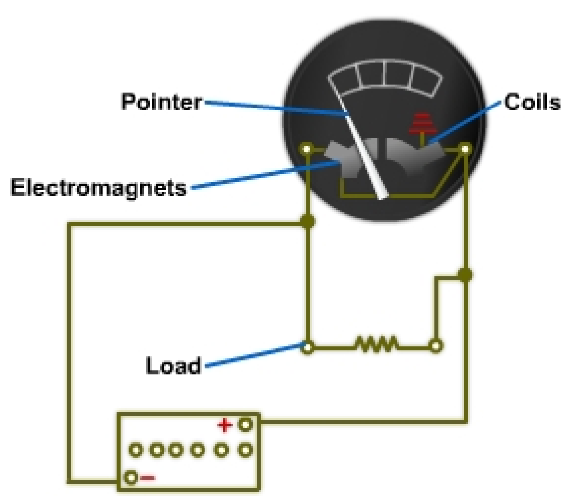


Figure 8-48 — Voltmeter schematic.

The voltmeter provides a more accurate indication of the condition of the electrical system and is easier to interpret by the operator (*Figure 8-48*). During vehicle operation, the voltage indicated on the voltmeter is considered to be normal in a range of 13.2 to 14.5 volts for a 12-volt electrical system. As long as the system voltage remains in this range, the operator can assume that no problem exists. This contrasts with an ammeter, which gives the operator no indication of problems, such as an improperly calibrated voltage regulator, which could allow the battery to be drained by regulating system voltage to a level below normal.

The indicator lamp has gained popularity as an electrical system condition gauge over the years. Although it does not provide as detailed analysis of the electrical system condition as a gauge, it is considered more useful to the average vehicle operator. This is because it is highly visible when a malfunction occurs, whereas a gauge usually is ignored because the average vehicle operator does not know how to interpret its readings. The indicator lamp can be used in two different ways to indicate an electrical malfunction:

- Low voltage warning lamp is set up to warn the operator whenever the electrical system voltage has dropped below the normal operational range (*Figure 8-49*).

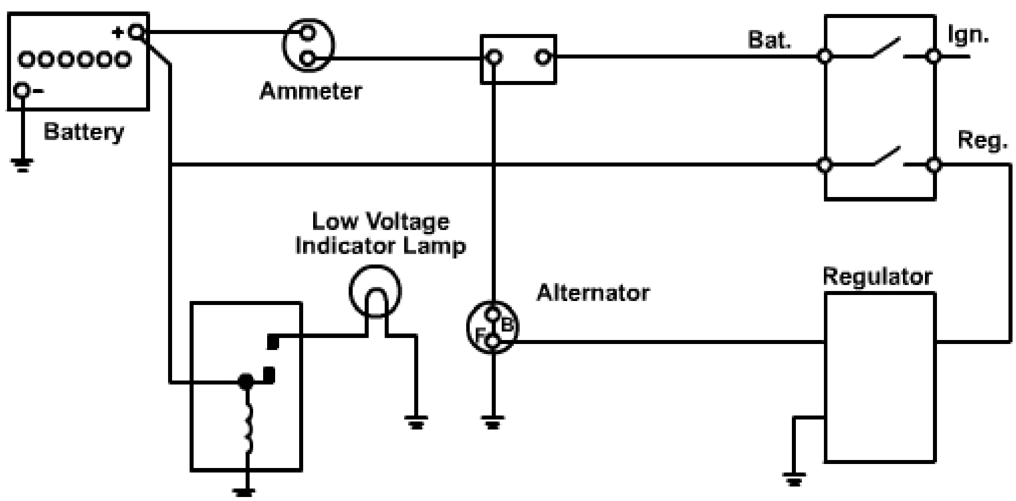


Figure 8-49 — Low voltage warning lamp schematic.

- No-charge indicator is set up to indicate whenever the alternator is not producing current (*Figure 8-50*).

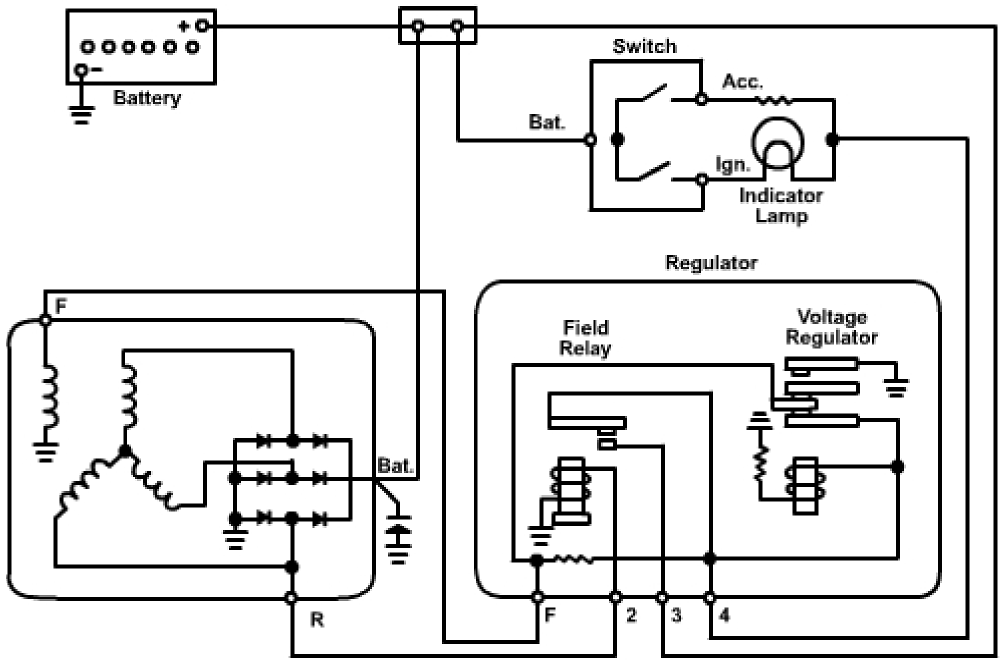


Figure 8-50 — No-charge indicator schematic.

6.2.0 Fuel Gauge

Most fuel gauges are operated electrically and are composed of two units—the gauge, mounted on the instrument panel; and the sending unit, mounted in the fuel tank. The ignition switch is included in the fuel gauge circuit, so the gauge operates only when the ignition switch is in the ON position. The basic fuel gauge circuit uses a variable resistor to operate either a bimetal or magnetic type indicator assembly (*Figure 8-51*).

Located in the trunk, the sending unit consists of a float and arm that operate a variable resistor. When the fuel tank is empty, the float is down so the variable resistance will be high. This allows only a little amount of current to flow through the fuel gauge. The bimetal arm stays cool and the needle shows that the tank is low.

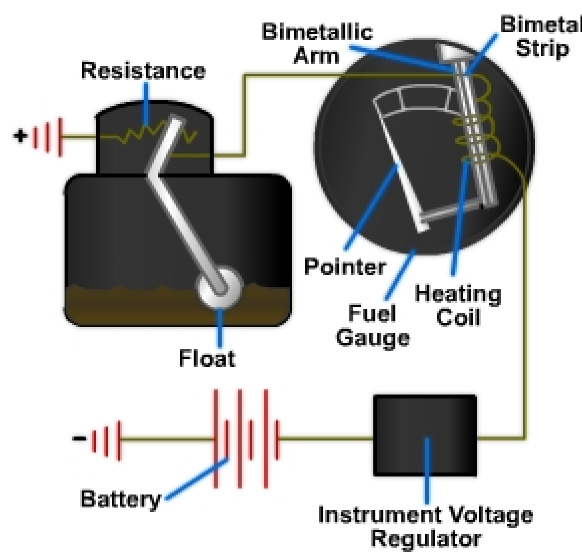


Figure 8-51 — Fuel gauge schematic.

When the tank is filled, the float rises to the top of the tank. This slides the wiper to the low resistance position on the variable resistor. More current then flows through the fuel gauge circuit. The bimetal arm heats up and warps to move the needle to the full side of the gauge.

6.3.0 Oil Pressure Gauge

A pressure gauge is used widely in automotive and construction applications to keep track of such things as oil pressure, fuel line pressure, air brake system pressure, and the pressure in the hydraulic systems. Depending on the equipment, a mechanical gauge, an electrical gauge, or an indicator lamp may be used.

The mechanical gauge uses a thin tube to carry an actual pressure sample directly to the gauge (*Figure 8-52*). The gauge basically consists of a hollow, flexible C-shaped tube called a bourbon tube. As air or fluid pressure is applied to the bourbon tube, it tends to straighten out. As it straightens, the attached pointer moves, giving a reading.

The electric gauge may be of the thermostatic or magnetic type as previous discussed (*Figure 8-53*). The sending unit that is used with each gauge type varies as follows:

Figure 8-52 — Mechanical oil pressure gauge.

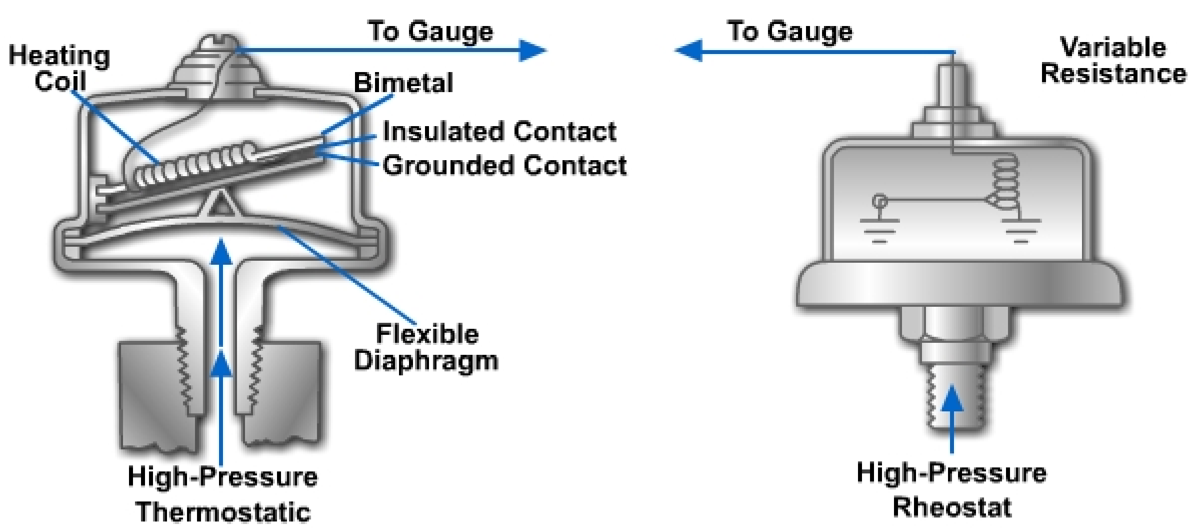


Figure 8-53 — Electric oil pressure gauge.

- The sending unit used with the thermostatic pressure gauge uses a flexible diaphragm that moves a grounded contact. The contact that mates with the grounded contact is attached to a bimetallic strip. The flexing of the diaphragm, which is done with pressure changes, varies the point tension. The different positions of the diaphragm produce gauge readings.
- The sending unit used with the magnetic-type gauge also translates pressure into the flexing of a diaphragm. In the case of the magnetic gauge sending unit, however, the diaphragm operates a rheostat.

The indicator lamp (warning light) is used in place of a gauge on many vehicles. The warning light, although not an accurate indicator, is valuable because of its high visibility in the event of a low-pressure condition. The warning light receives battery power through the ignition switch. The circuit to ground is completed through a sending unit. The sending unit consists of a pressure-sensitive diaphragm that operates a set of contact points that are calibrated to turn on the warning light whenever pressure drops below a set pressure.

6.4.0 Engine Temperature Gauge

The temperature gauge is a very important indicator in construction and automotive equipment. The most common uses are to indicate engine coolant, transmission fluid, differential oil, and hydraulic system temperatures. Depending on the type of equipment, the gauge may be mechanical, electric, or a warning light.

The electric gauge may be the thermostatic or magnetic type, as described previously. The sending unit that is used varies, depending upon application (*Figure 8-54*).

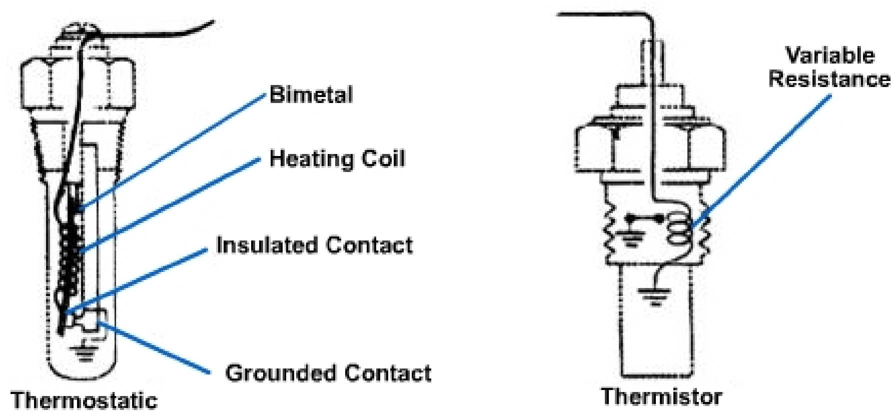


Figure 8-54 — Temperature sending unit.

The sending unit used with the thermostatic gauge consists of two bimetallic strips, each having a contact point. One bimetallic strip is heated electrically. The other strip bends to increase the tension of the contact points. The different positions of the bimetallic strip create the gauge readings.

The sending unit used with the magnetic gauge contains an electronic device called a thermistor whose resistance decreases proportionally with an increase in temperature.

The magnetic gauge contains a bourbon tube and operates by the same principles as the mechanical pressure gauge.

The indicator lamp (warning light) operates by the same principle as the indicator light previously discussed.

6.5.0 Transmission Temperature Gauge

A transmission temperature gauge operates on the same principles as the engine temperature gauge. The sending unit, a gauge and connection wire, may be mounted in the transmission oil pan, the cooling line between the radiator and the transmission, or in the valve body of the transmission. The importance of a transmission temperature gauge is that if the automatic transmission fluid gets too hot, it can actually start to boil. When this occurs, catastrophic transmission failure is eminent.

6.6.0 Speedometer and Tachometer

6.6.1 Mechanical Speedometers and Tachometers

Both the mechanical speedometer and the tachometer consist of a permanent magnet rotated by a flexible shaft. Surrounding the rotating magnet is a metal cup attached to the indicating needle. The revolving magnetic field exerts a pull on the cup that forces it to rotate. The rotation of the cup is countered by a calibrated hairspring. The influence of the hairspring and the rotating magnetic field on the cup produces accurate readings by the attached needle. The flexible shaft consists of a flexible outer casing made of either steel or plastic and an inner drive core made of wire-wound spring steel. Both ends of the core are molded square so they can fit into the driving member at one end and the driven member at the other end, and can transmit torque.

Gears on the transmission output shaft turn the flexible shaft that drives the speedometer. This shaft is referred to as the speedometer cable. A gear on the ignition distributor shaft turns the flexible shaft that drives the tachometer. This shaft is referred to as the tachometer cable.

The odometer of the mechanical speedometer is driven by a series of gears that originate at a spiral gear on the input shaft. The odometer consists of a series of drums with digits printed on the outer circumference that range from zero to nine. The drums are geared to each other so that each time the one farthest to the right makes one revolution, it will cause the one to its immediate left to advance one digit. The second to the right then will advance the drum to its immediate left one digit for every revolution it makes. This sequence continues to the left through the entire series of drums. The odometer usually contains six digits to record 99,999.9 miles or kilometers. However, models with trip odometers do not record tenths, therefore contain only five digits. When the odometer reaches its highest value, it will automatically reset to zero. Newer vehicles incorporate a small dye pad in the odometer to color the drum of its highest digit to indicate the total mileage is in excess of the capability of the odometer.

6.6.2 Electric Speedometers and Tachometers

The electric speedometer and tachometer use a mechanically driven permanent magnet generator to supply power to a small electric motor (*Figure 8-55*). The electric motor then is used to rotate the input shaft of the speedometer or tachometer. The voltage from the generator will increase proportionally with speed, and speed will likewise increase proportionally with voltage enabling the gauges to indicate speed.

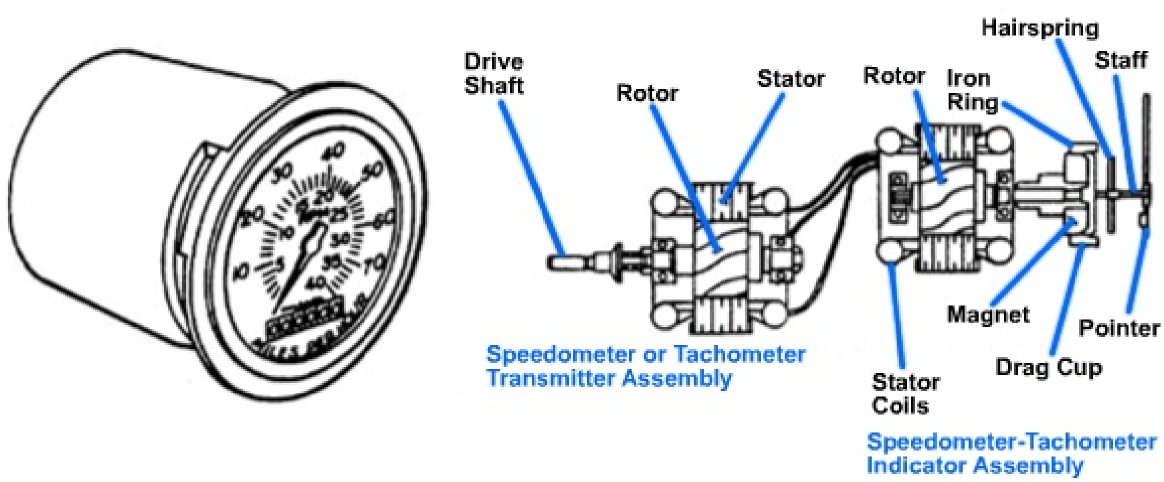


Figure 8-55 — Electric speedometer and tachometer operation.

The signal generator for the speedometer is usually driven by the transmission output shaft through gears. The signal generator for the tachometer usually is driven by the distributor through a power takeoff on gasoline engines. When the tachometer is used with a diesel engine, a special power takeoff provision is made, usually on the camshaft drive.

6.6.3 Electronic Speedometers and Tachometers

Electronic speedometers and tachometers are self-contained units that use an electric signal from the engine or transmission. They differ from the electric unit in that they use a generated signal as the driving force. The gauge is transistorized and will supply information through either a magnetic analog (dial) or light-emitting diode (LED) digital gauge display. The gauge unit derives its input signal in the following ways:

An electronic tachometer obtains a pulse signal from the ignition distributor as it switches the coil on and off. The pulse speed at this point will change proportionally with engine speed. This is the most popular signal source for a tachometer that is used on a gasoline engine.

A tachometer that is used with a diesel engine uses the alternating current generated by the stator terminal of the alternator as a signal. The frequency of the AC current will change proportionally with engine speed.

An electronic speedometer derives its signal from a magnetic pickup coil that has its field interrupted by a rotating pole piece. The pickup coil is located strategically in the transmission case to interact with the reluctor teeth on the input shaft.

6.7.0 Horn

The horn currently used on automotive vehicles is the electric vibrating type. The electric vibrating horn system typically consists of a fuse, horn button switch, relay, horn assembly, and related wiring. When the operator presses the horn button, it closes the horn switch and activates the horn relay. This completes the circuit, and current is allowed through the relay circuit and to the horn.

Most horns have a diaphragm that vibrates by means of an electromagnetic. When the horn is energized, the electromagnet pulls on the horn diaphragm. This movement opens a set of contact points inside the horn. This action allows the diaphragm to flex back towards its normal position. This cycle is repeated rapidly. The vibrations of the diaphragm within the air column produce the note of the horn.

Tone and volume adjustments are made by loosening the adjusting locknut and turning the adjusting nut. This very sensitive adjustment controls the current consumed by the horn. Increasing the current increases the volume. However, too much current will make the horn sputter and may lock the diaphragm.

When an electric horn will not produce sound, check the fuse, the connections, and test for voltage at the horn terminal. If the horn sounds continuously, a faulty horn switch is the most probable cause. A faulty horn relay is another cause of horn problems. The contacts inside the relay may be burned or stuck together.

6.8.0 Windshield Wipers

The windshield wiper system is one of the most important safety factors on any piece of equipment. A typical electric windshield wiper system consists of a switch, motor assembly, wiper linkage and arms, and wiper blades. The descriptions of the components are as follows:

The windshield wiper switch is a multi-position switch, which may contain a rheostat. Each switch position provides for different wiping speeds. The rheostat, if provided, operates the delay mode for a slow wiping action. This permits the operator to select a delayed wipe from every 3 to 20 seconds. A relay is frequently used to complete the circuit between the battery voltage and the wiper motor.

The wiper motor assembly operates on one, two, or three speeds (*Figure 8-56*). The motor has a worm gear on the armature shaft that drives one or two gears, and in turn operates the linkage to the wiper arms. The motor is a small shunt-wound DC motor. Resistors are placed in the control circuit from the switch to reduce the current and provide different operating speeds.

The wiper linkage and arms transfer motion from the wiper motor transmission to the wiper blades. The rubber wiper blades fit on the wiper arms.

The wiper blade is a flexible rubber squeegee-type device. It may be steel or plastic backed and is designed to maintain total contact with the windshield throughout the stroke. Wiper blades should be inspected periodically. If they are hardened, cut, or split, they should be replaced.

When electrical problems occur in the windshield wiper system, use the service manual and its wiring diagram of the circuit. First check the fuses, electrical connections, and all grounds. Then proceed with checking the components.

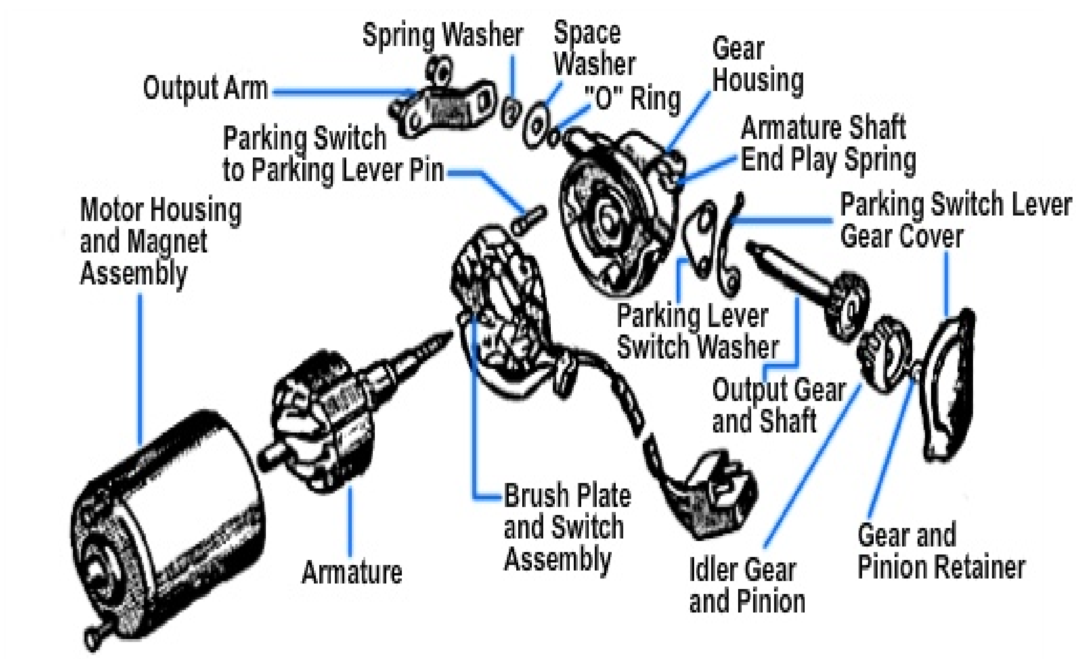


Figure 8-56 — Wiper motor assembly.

Test your Knowledge (Select the Correct Response)

14. Which type of battery condition gauge provides the most accurate indication of the condition of the electrical system?

    A. Ammeter
    B. Voltmeter
    C. Ohmmeter
    D. Inductive ammeter

15. The signal generator for an electric tachometer used on a gasoline engine is driven by what component?

A. Transmission
B. Distributor
C. Coil
D. ECM

16. What type of oil pressure gauge has a bourbon tube?

A. Mechanical
B. Electrical
C. Magnetic
D. Electronic

7.0.0 AUTOMOTIVE WIRING

Electrical power and control signals must be delivered to electrical devices reliably and safely so that the electrical system functions are not impaired or converted to hazards. To fulfill power distribution, military vehicles use one- and two-wire circuits, wiring harnesses, and terminal connections.

Among your many duties will be the job of maintaining and repairing automotive electrical systems. All vehicles are not wired in exactly the same manner; however, once you understand the circuit of one vehicle, you should be able to trace an electrical circuit of any vehicle using wiring diagrams and color codes.

7.1.0 One-Wire Circuit

Tracing wiring circuits, particularly those connecting lights or warning and signal devices, is no simple task. Branch circuits making up the individual systems have one wire to conduct electricity from the battery to the unit requiring it, and ground connections at the battery and the unit to complete the circuit. These are called one-wire circuits or branches of a ground return system. In automotive electrical systems with branch circuits that lead to all parts of the equipment, the ground return system saves installation time and eliminates the need for an additional wiring to complete the circuit. The all-metal construction of the automotive equipment makes it possible to use this system.

7.2.0 Two-Wire Circuits

The two-wire circuit requires two wires to complete the electrical circuit—one wire from the source of electrical energy to the unit it will operate, and another wire to complete the circuit from the unit back to the source of the electrical power.

Two-wire circuits provide positive connection for light and electrical brakes on some trailers. The coupling between the trailer and the equipment, although made of metal and a conductor of electricity, has to be jointed to move freely. The rather loose joint or coupling does not provide the positive and continuous connection required to use a ground return system between two vehicles. The two-wire circuit is commonly used on equipment subject to frequent or heavy vibrations. Tracked equipment, off-road vehicles (tactical), and many types of construction equipment are wired in this manner.

7.3.0 Shielded Wiring

Shielded wire has a center conductor that is surrounded by an outer metal shield. Insulation is used to separate the shield and the conductor. This construction keeps magnetic pulses from being inducted into the center conductor causing unwanted voltage pulses.

This type of wire is mostly used for the automotive antenna. The lead must be protected from the magnetic fields from the engine's ignition system to prevent static from being heard over the radio.

There is also twisted shield wire. This type of wire uses multiple insulated conductors wrapped around each other. This design still provides the protection from the magnetic fields and is used to connect the computer to various sensors, particularly those near the ignition system. Twisted shield wire helps keep high voltage pulses from interfering with the tiny voltage signals going between the computer and other sensors in the vehicle.

7.4.0 Unshielded Wiring

Unshielded wire is the most common type of wire found in automotive manufacturing. There is no shield on the wire except for the insulation wrapped around the wire to prevent accidental grounding. There is no special shield to protect the wire from electromagnetic force.

7.5.0 Wiring Assemblies

Wiring assemblies consist of wires and cables of definitely prescribed length, assembled together to form a subassembly that interconnect specific electrical components and/or equipment. The two basic types of wiring assemblies are as follows:

The cable assembly consists of a stranded conductor with insulation or a combination of insulated conductors enclosed in a covering or jacket from end to end. Terminating connections seal around the outer jacket so that the inner conductors are isolated completely from the environment. Cable assemblies may have two or more ends.

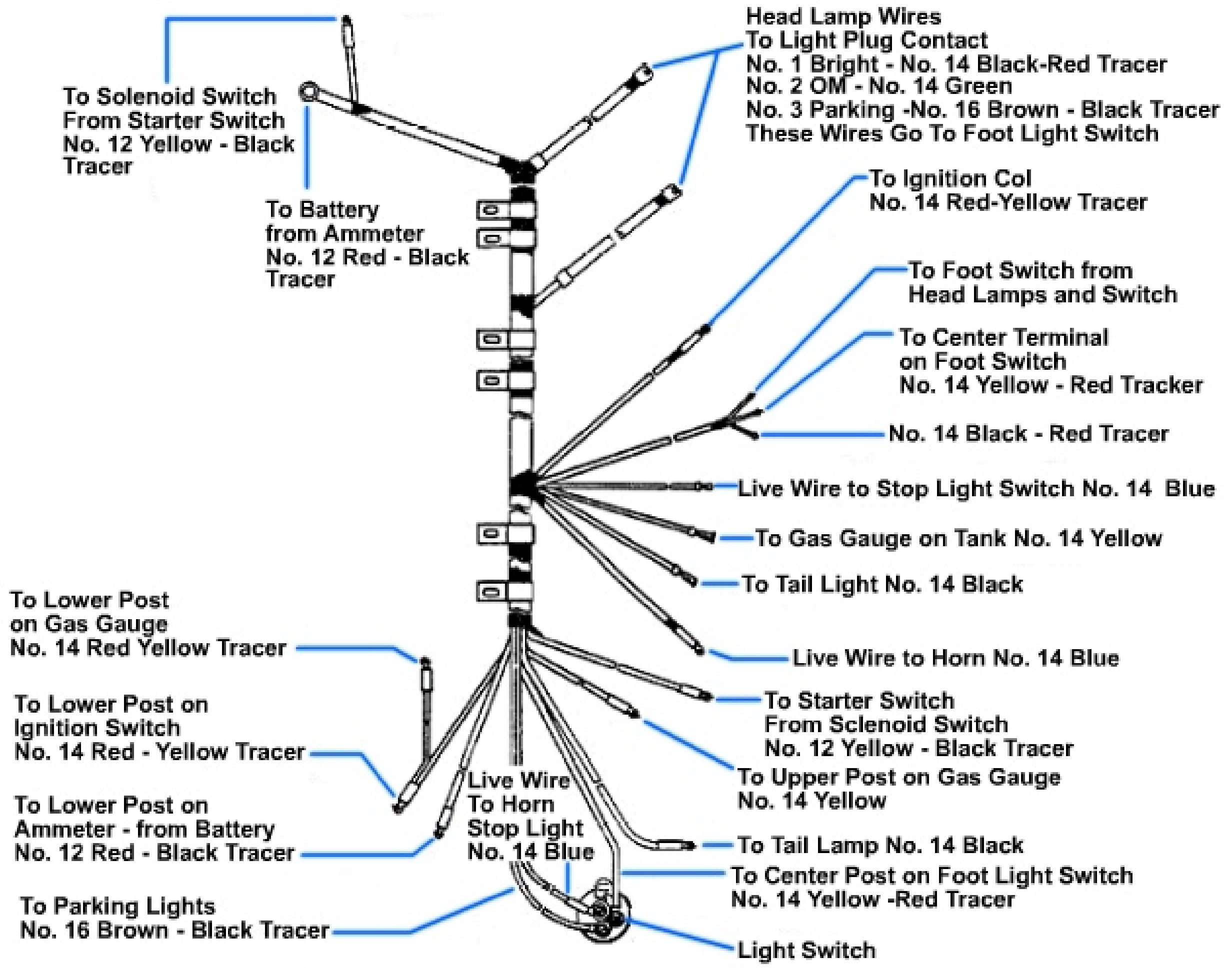


Figure 8-57— Wiring harness.

Wiring harness assemblies serve two purposes (*Figure 8-57*). They prevent chafing and loosening of terminals and connections caused by vibration and road shock while keeping the wires in a neat condition away from moving parts of the vehicle. Wiring harnesses contain two or more individual conductors laid parallel or twisted together and wrapped with binding material, such as tape, lacing cord, and wire ties. The binding materials do not isolate the conductors from the environment completely, and conductor terminations may or may not be sealed. Wiring harnesses also may have two or more ends.

7.6.0 Wiring Identification

Wires in the electrical system should be identified by a number, color, or code to facilitate tracing circuits during assembly, troubleshooting, or rewiring operations. This identification should appear on wiring schematics and diagrams and whenever practical on the individual wire. The assigned identification for a continuous electrical connection should be retained on a

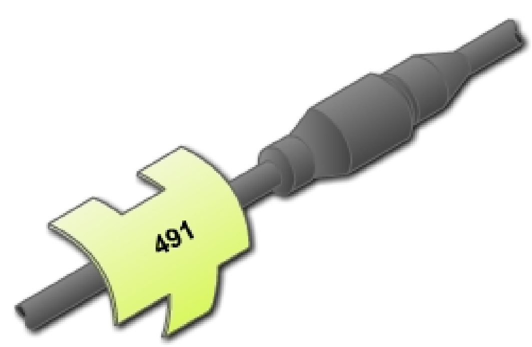


Figure 8-58 — Metal tag wire identification.

schematic diagram until the circuit characteristic is altered by a switching point or active component.

Wiring color codes are used by manufacturers to assist the mechanics in identifying the wires used in many circuits and making repairs in a minimum of time. No color code is common to all manufacturers. For this reason, the manufacturer's service manual is a must for speedy troubleshooting and repairs.

Wiring found on tactical equipment (M-series) has no color. All the wires used on these vehicles are black. Small metal tags stamped with numbers or codes are used to identify the wiring illustrated by diagrams in the technical manuals (*Figure 8-58*). These tags are securely fastened near the end of individual wires.

7.7.0 Wiring Diagrams

Wiring diagrams are drawings that show the relationship of the electrical components and wires in a circuit (*Figure 8-59*). They seldom show the routing of the wires within the electrical system of the vehicle.

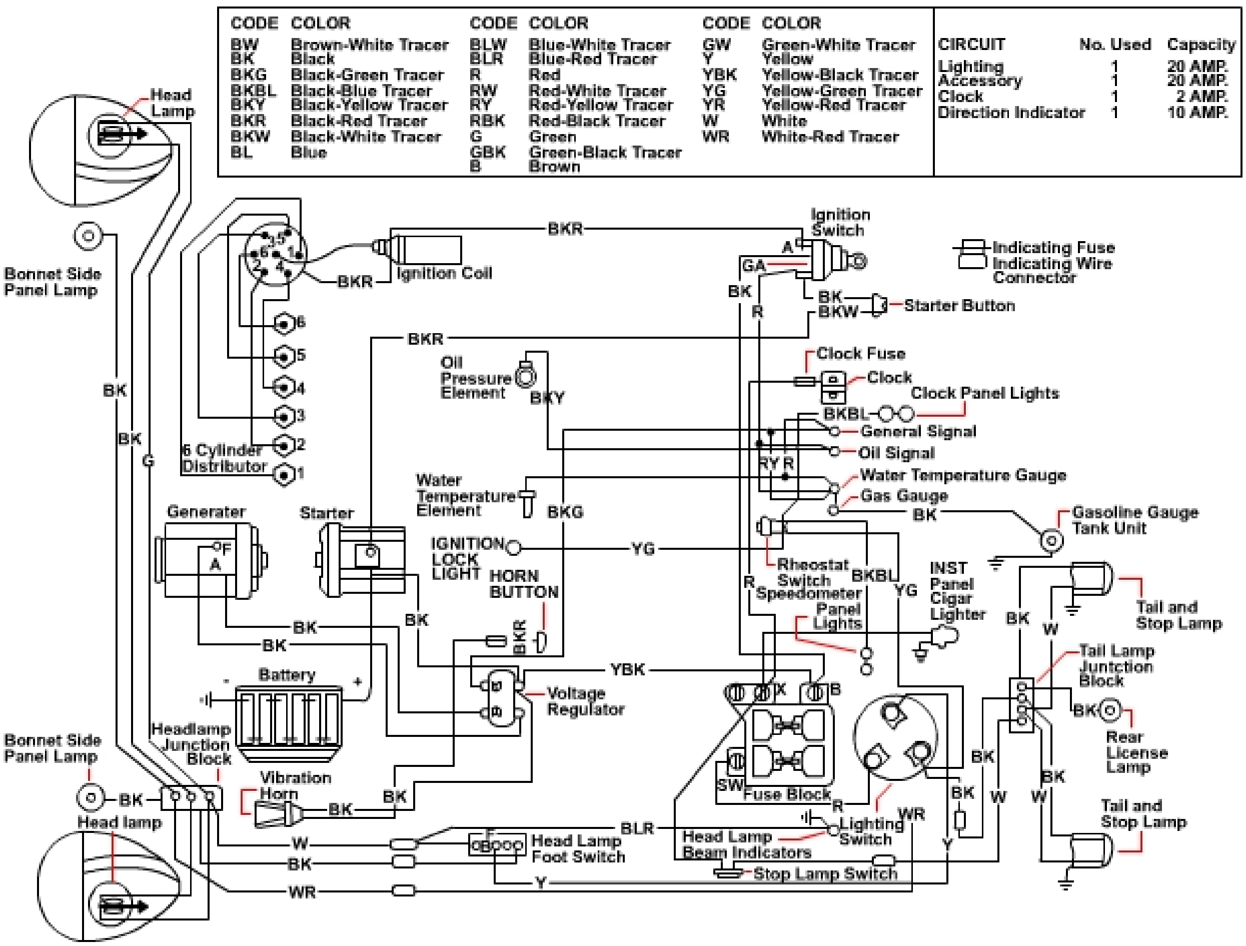


Figure 8-59 — Wiring diagram.

Often you will find electrical symbols used in wiring diagrams to simulate individual components. *Figure 8-60* shows some of the symbols you may encounter when tracing individual circuits in a wiring diagram.

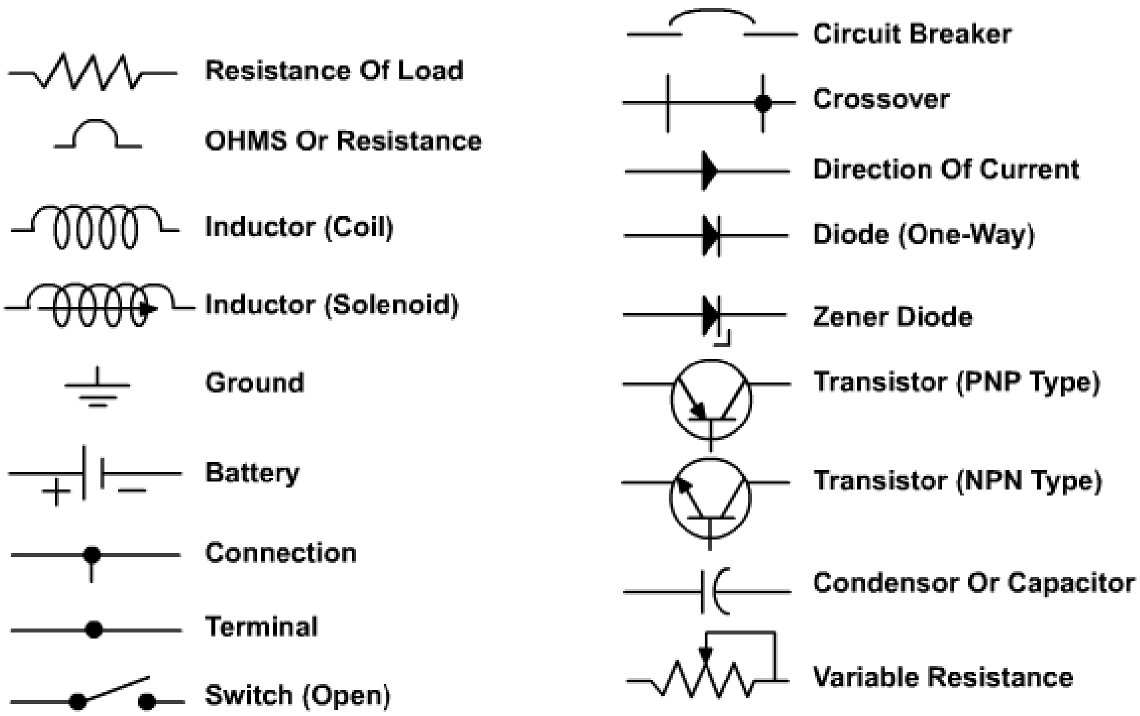


Figure 8-60 — Wiring diagram symbols.

7.8.0 Wire Terminal Ends

Wire terminals are divided into two major classes—the solder type and the solder-less type, which is also known as the pressure or crimp type. The solder type has a cup in which the wire is held by solder permanently. The solder-less type is connected to the wire by special tools that deform the barrel of the terminal and exert pressure on the wire to form a strong mechanical bond and electrical connection. Solder-less type terminals are gradually replacing solder type terminals in military equipment.

7.9.0 Wire Support and Protection

Wire in the electrical system should be supported by clamps or fastened by wire ties at various points about the vehicle. When installing new wiring, be sure to keep it away from any heat-producing component that would scorch or bum the insulation.

Wire passing through holes in the metal members of the frame or body should be protected by rubber grommets. If rubber grommets are not available, use a piece of rubber hose the size of the hole to protect the wiring from chafing or cutting on sharp edges.

Test your Knowledge (Select the Correct Response)

17. What type of wire circuit is commonly used on equipment that is subject to heavy vibrations?

    A. One-wire
    B. Shielded wire
    C. Two-wire
    D. Unshielded wire

18. How many different types of wiring assemblies are there?

    A. 4
    B. 3
    C. 2
    D. 1

Summary

In this chapter we discussed the different automotive electrical systems, their functions, and associated troubleshooting methods. Because there are so many different components and designs, always check with the manufacturer's specifications when working on an unfamiliar circuit. Almost everything you work on will have an electrical circuit of some sort, and you need to be familiar with how the components operate. To be a good construction mechanic you will need to study these systems and stay up to date with current systems to keep them operating in peak condition.

Review Questions (Select the Correct Response)

1. In a lead-acid battery, current is produced by what type of reaction?

   A. Photochemical
   B. Chemical
   C. Electrochemical
   D. Electronic

2. A 12-volt lead-acid automotive battery consists of how many elements connected in series?

   A. Six
   B. Four
   C. Three
   D. Two

3. Why are the cell elements of a storage battery elevated inside the case?

   A. To allow the electrolyte to circulate under the elements.
   B. To prevent the elements from shorting against the case.
   C. To reduce the amount of lead required for connecting the elements and terminal posts.
   D. To prevent shorting of the elements when material from the plates settles to the bottom of the case.

4. When the temperature is 80°F, a fully charged lead-acid battery will produce what specific gravity reading?

   A. 1.28
   B. 1.82
   C. 2.18
   D. 2.81

5. When taking a hydrometer reading of a battery whose temperature is 100°F, you must make what modification to the reading to determine the actual specific gravity of the electrolyte?

   A. Add 0.006
   B. Add 0.008
   C. Add 0.003
   D. Add 0.004

6. What are the two methods for rating lead-acid storage batteries?

   A. Reserve capacity and discharge
   B. Reserve capacity and ampere-hour
   C. Cold-cranking and reserve capacity
   D. Cold-cranking and discharge

7. When charging batteries, you should take which action?

   A. Add electrolyte to any cell in which the fluid level is below the top of the plates before charging.
   B. Remove the vent plugs to prevent an accumulation of gases.
   C. Take frequent hydrometer readings to determine if the battery is functioning properly during charging.
   D. Remove each battery for a 10-minute break when half charged.

8. What procedure is considered the only safe way to mix electrolyte for a lead-acid battery?

   A. Pour water into acid slowly and stir gently.
   B. Pour water into acid slowly and stir vigorously.
   C. Pour acid into water slowly and stir gently.
   D. Pour acid into water slowly and stir vigorously.

9. When cleaning the top of a lead-acid battery, which combination should you use?

   A. Soft bristle brush and a mixture of water and baking soda
   B. Soft bristle brush and a mixture of water and muratic acid
   C. Stiff bristle brush and a mixture of water and baking soda
   D. Stiff bristle brush and a mixture of water and muratic acid

10. What test allows you to determine the general condition of a maintenance free battery?

   A. Cell voltage
   B. Battery leakage
   C. Battery drain
   D. Battery voltage

11. When load testing a battery with a cold-cranking rating of 350 amps, you should load the battery to what total number of amps?

   A. 150
   B. 175
   C. 200
   D. 225

12. The current generated by an alternator is converted to direct current by means of what component?

   A. Armature coil
   B. Condenser
   C. Rectifier
   D. Station field coil

13. What component of an alternator is mounted on the rotor shaft and provides current to the rotor windings?

    A. Slip rings
    B. Claw poles
    C. Stator core
    D. Coils

14. In what manner are stator windings connected in an alternator?

    A. One end is connected to the positive diodes and the other end to the negative diodes.
    B. One end is connected to the stator assembly and the other end to the rectifier assembly.
    C. One end is connected to the negative diodes and the other end to the field windings.
    D. One end is connected to the electrical terminals and the other end to the rotor shaft.

15. What type of stator will provide good current output at low engine speeds?

    A. Delta-type
    B. Omega-type
    C. K-type
    D. Y-type

16. A total of how many diodes are grounded in an alternator?

    A. Four
    B. Three
    C. Two
    D. One

17. Grounding the field terminal of the alternator will result in damage to the _______.

    A. regulator
    B. diodes
    C. rotor windings
    D. alternator

18. By what means can the proper operation of a charging system containing an alternator be checked?

    A. Ammeter
    B. Voltmeter
    C. Screwdriver
    D. Jumper wire

19. To determine if an alternator rotor is internally shorted, you can test the rotor windings with what device?

    A. Armature growler
    B. Galvanometer
    C. Test lamp
    D. Ohmmeter

20. When performing a regulator bypass test, which method should you use to bypass the voltage regulator?

    A. Place a jumper wire from the field terminals of the alternator to the engine block.
    B. Place a jumper wire from the test tab to the field terminals of the alternator.
    C. Place a jumper wire across the battery and field terminals of the alternator.
    D. Unplug the wire from the regulator.

21. What mechanism relies on the principle of inertial force to make the drive pinion mesh with the flywheel?

    A. Bendix drive
    B. Overruning clutch
    C. Dyer drive
    D. Reduction drive

22. In a starting circuit containing a solenoid, when is battery current supplied to the starter motor?

    A. When the remote control switch is closed.
    B. At the time the ignition switch is turned to the start position.
    C. After the starter pinion is engaged with the flywheel.
    D. When the plunger closes the contacts in the solenoid.

23. Field windings vary according to application. What is the most popular configuration used to provide a large amount of low-speed torque?

    A. Six windings, series-parallel
    B. Two windings, parallel
    C. Three windings, series-parallel
    D. Four windings, series

24. Which starting circuit component is common to all vehicles and equipment having automatic transmissions?

    A. Starter solenoid
    B. Relay
    C. Neutral safety switch
    D. Double reduction starter

25. When it is necessary to adjust a neutral safety switch, which test equipment is required?

A. Voltmeter
B. Ohmmeter
C. Inductive ammeter
D. Test light

26. The battery-ignition circuit consists of a total of how many circuits?

A. Four
B. Three
C. Two
D. One

27. In an ignition circuit, high voltage is directed to the spark plugs in the correct firing order by what component?

A. Ballast resistor
B. Ignition coil
C. Distributor rotor
D. Spark plug wires

28. When troubleshooting an ignition circuit, you should change the manufacturer's specified heat range of the spark plugs when what condition exists?

A. Increased resistance is required by the circuit.
B. Abnormal operating conditions are encountered.
C. Ignition timing is changed from the manufacturer’s setting.
D. High voltage surges in the primary circuit are reduced.

29. What component opens and closes the primary circuit of an electronic ignition system?

A. Electronic module control (EMC)
B. Electronic primary control (EPC)
C. Electronic circuit control (ECC)
D. Electronic control unit (ECU)

30. In a computerized timing advance mechanism, what sensor reports piston position to the computer?

A. Crankshaft
B. Camshaft
C. Throttle
D. Height

31. A grayish tan deposit on the insulator of a spark plug indicates what condition?

    A. Normal operation
    B. Carbon-fouled
    C. Ash-fouled
    D. Preignition damage

32. How often should spark plugs be regapped?

    A. Each time the vehicle is serviced
    B. At 6,000 mile intervals
    C. Any time they are removed for inspection
    D. During a "B" PM only

33. You have performed a spark plug wire resistance test. The test should not show the resistance to be over 5,000 ohms per inch, or what total number of ohms?

    A. 25,000
    B. 50,000
    C. 100,000
    D. 125,000

34. On a distributor cap, which condition will short coil voltage to ground?

    A. Faulty distributor lead
    B. Broken coil wire
    C. Carbon trace
    D. Broken rotor

35. After installing contact points, you notice that the faces do not make full contact. What corrective action should you take?

    A. File the faces straight across the edge that is riding high.
    B. Bend the movable breaker arm.
    C. Bend the stationary contact bracket.
    D. Remove the points and realign the faces.

36. **(True or False)** To advance timing, you should turn the distributor housing in the same direction as the shaft rotation.

    A. True
    B. False

37. Navy automotive and construction equipment lighting systems operate on what voltages?

    A. 6 or 12 volts
    B. 12 or 18 volts
    C. 12 or 24 volts
    D. 18 or 24 volts

38. You are operating a vehicle with a 12-volt electrical system. The voltmeter in the vehicle should indicate a reading that falls within what voltage range?

A. 11.5 to 12.2
B. 13.2 to 14.5
C. 15.5 to 16.2
D. 17.5 to 18.3

Trade Terms Introduced in this Chapter

Discharging	The current flowing out of the battery.
Gassing	Acid fumes that are formed during chemical reaction.
Electrolyte	Any substance containing free ions that make the substance electrically conductive.
Spark arresters	A device intended to prevent combustible materials, usually sparks, from escaping into areas where they might start fires.
NCF	Naval Construction Force.
Corrosion	The wearing away of metals due to a chemical reaction.
Heat sink	A metal mount for removing excess heat from electronic parts.
Carbon trace	A small line of carbon-like substance that conducts electricity.

Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

Diesel Technology Seventh Edition, Andrew Norman and John "Drew" Corinchock, The Goodheart-Wilcox Company, Inc., 2007. (ISBN-13: 978-1-59070-770-8)

Medium/Heavy Duty Truck Engines, Fuel & Computerized Management Systems 2nd Edition, Sean Bennett, The Thomson/Delmar Learning Company, INC., 2004. (ISBN-13:978-1-4018-1499-1)

Heavy Duty Truck Systems 4th Edition, Sean Bennet, Delmar Cengage Learning, 2006. (ISBN-13:978-1-4018-7064-5)

Modern Automotive Technology 7th Edition, James Duffy, The Goodheart-Wilcox Company, Inc., 2009. (ISBN: 978-1-59070-956-6)

Auto Electricity and Electronics, James Duffy, The Goodheart-Wilcox Company, Inc., 2004. (ISBN: 1-59070-271-9)

Automatic Transmissions and Transaxles, James Duffy, The Goodheart-Wilcox Company, Inc., 2005. (ISBN: 1-59070-426-6)

Construction Mechanic Basic, Volume 2, NAVEDTRA 14273, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1999

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