CHAPTER 15

STARTING AND CHARGING SYSTEM OPERATION AND DIAGNOSIS

OBJECTIVES

After studying Chapter 15, the reader will be able to:

1. Prepare for Engine Repair (A1) ASE certification test content area "E" (Fuel, Electrical, Ignition, and Exhaust Systems Inspections and Service).
2. List the precautions necessary whenever working with batteries.
3. Describe how to test a battery.
4. Explain how to safely charge a battery.
5. Describe how the cranking circuit works.
6. Describe how to perform cranking system testing procedures.
7. Discuss the various AC generator test procedures.

KEY TERMS

Alternator (p. 241)
Ampere Hour (p. 234)
Ampere-Hour Rating (p. 236)
Cold-Cranking Amperes (CCA) (p. 234)
Cranking Amperes (CA) (p. 234)
Load Test (p. 235)
Open-Circuit Battery Voltage Test (p. 235)
Reserve Capacity (p. 234)
Sealed Lead Acid (SLA) (p. 233)
Specific Gravity (p. 232)

For any engine to start, it must be rotated. It is the purpose and function of the cranking circuit to create the necessary power and transfer it from the battery to the starter motor that rotates the engine.

Everything electrical in a vehicle is supplied with current from the battery. The battery is one of the most important parts of a vehicle.

All vehicles operate electrical components by taking current from the battery. It is the purpose and function of the charging system to keep the battery fully charged. The SAE standardized name for an alternator is the generator.

All electrical generators use the principle of electromagnetic induction to generate electrical power from mechanical power. Electromagnetic induction involves the generation of an electrical current in a conductor when the conductor is moved through a magnetic field.

FIGURE 15-1 Photo of a cutaway battery showing the connection of the cells to each other through the partition.

PURPOSE OF A BATTERY

The primary purpose of an automotive battery is to provide a source of electrical power for starting and for electrical demands that exceed generator output. The battery also acts as a stabilizer to the voltage for the entire electrical system. The battery is a voltage stabilizer because it acts as a reservoir where large amounts of current (amperes) can be removed quickly during starting and replaced gradually by the alternator during charging. The battery *must* be in good (serviceable) condition before the charging system and the cranking system can be tested.

HOW A BATTERY WORKS

A fully charged lead–acid battery has a positive plate of lead dioxide (peroxide) and a negative plate of lead surrounded by a sulfuric acid solution (electrolyte). The difference in potential (voltage) between lead peroxide and lead in acid is approximately 2.1 volts in each cell. See Figure 15-1.

During Discharging

The positive-plate lead dioxide (PbO_2) combines with the SO_4 from the electrolyte and releases its O_2 into the electrolyte, forming H_2O. The negative plate also combines with the SO_4 from the electrolyte and becomes lead sulfate ($PbSO_4$). See Figure 15-2.

The Fully Discharged State

When the battery is fully discharged, both the positive and the negative plates are $PbSO_4$ (lead sulfate) and the electrolyte has become water (H_2O). It is usually impossible for a

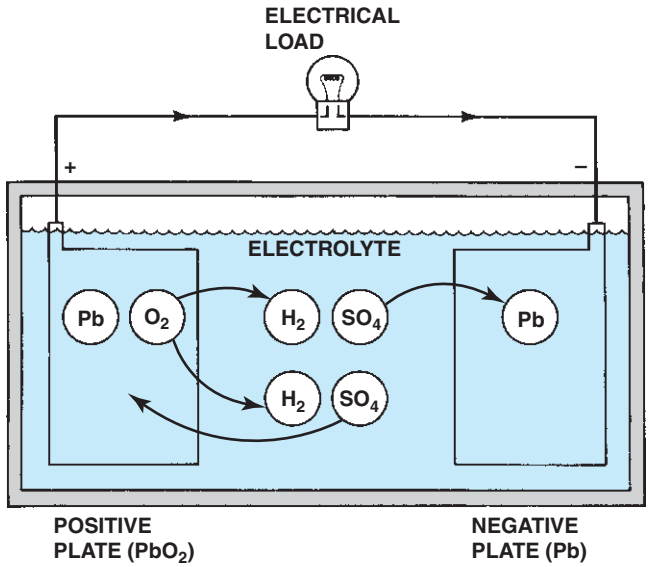


FIGURE 15-2 Chemical reaction for a lead–acid battery that is fully *charged* being discharged by the attached electrical load.

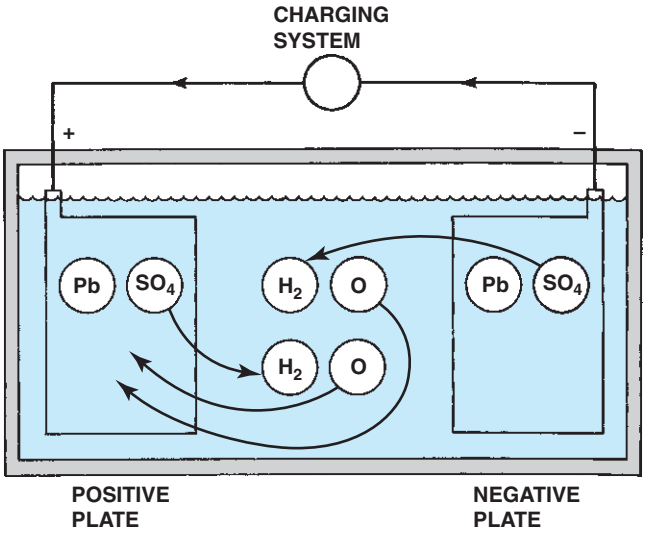


FIGURE 15-3 Chemical reaction for a lead–acid battery that is fully *discharged* being charged by the attached generator.

battery to become 100% discharged; however, as the battery is being discharged, the plates and electrolyte approach the completely dead situation.

CAUTION: There is danger of freezing when a battery is discharged, because the electrolyte is mostly water.

During Charging

During charging, the sulfate (acid) leaves both the positive and the negative plates and returns to the electrolyte, where it becomes normal-strength sulfuric acid solution. The positive plate returns to lead dioxide (PbO_2) and the negative plate is again pure lead (Pb). See Figure 15-3.

SPECIFIC GRAVITY

The amount of sulfate in the electrolyte is determined by the electrolyte's **specific gravity.** Specific gravity is the ratio of the weight of a given volume of a liquid to the weight of an equal volume of water. In other words, the more dense the material (liquid), the higher is its specific gravity. Pure water is the basis for this measurement and has a specific gravity of 1.000 at 80°F. Pure sulfuric acid has a specific gravity of 1.835. The *correct* concentration of water and sulfuric acid (called *electrolyte*—64% water, 36% acid) is 1.260 to 1.280 at 80°F.

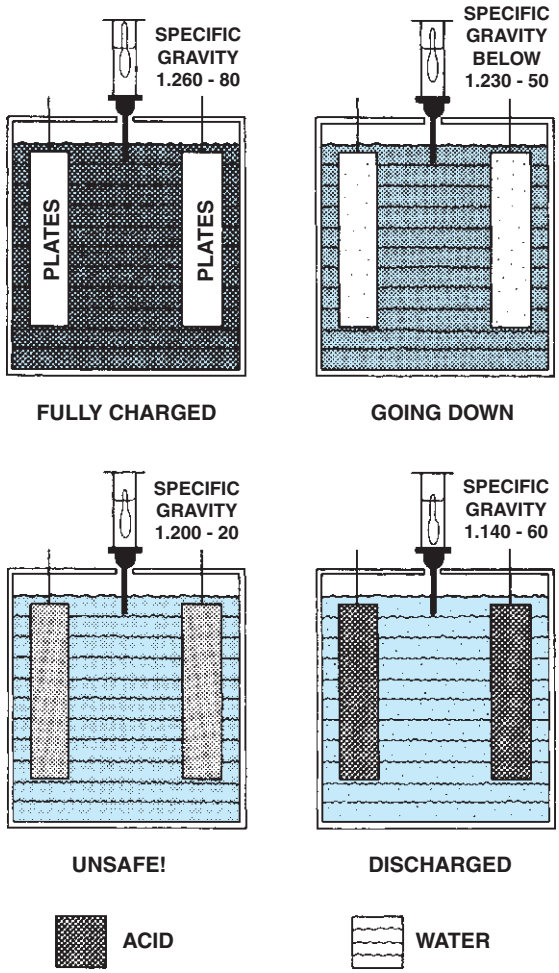


FIGURE 15-4 As the battery becomes discharged, the specific gravity of the battery acid decreases.

The higher the battery's specific gravity, the more fully it is charged. See Figure 15-4.

Charge Indicators

Some batteries are equipped with a built-in state-of-charge indicator. This indicator is simply a small ball-type hydrometer that is installed in one cell. This hydrometer uses a plastic ball that floats if the electrolyte is dense enough (when the battery is about 65% charged). When the ball floats, it appears in the hydrometer's sight glass, changing its color. See Figures 15-5 and 15-6. Because the hydrometer is only testing one cell (out of six on a 12-volt battery), and because the hydrometer ball can easily stick in one position, it should not be trusted to give accurate information about a battery's state of charge.

Specific Gravity versus State of Charge and Battery Voltage

Values for specific gravity, state of charge, and battery voltage at 80°F (27°C) are given in the following table.

Specific Gravity	*State of Charge*	*Battery Voltage (V)*
1.265	Fully charged	12.6 or higher
1.225	75% charged	12.4
1.190	50% charged	12.2
1.155	25% charged	12.0
Lower than 1.120	Discharged	11.9 or lower

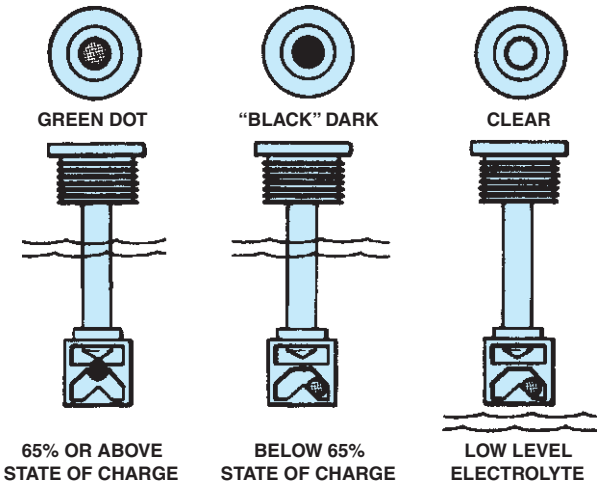


FIGURE 15-5 Typical battery charge indicator. If the specific gravity is low (battery discharged), the ball drops away from the reflective prism. When the battery is charged enough, the ball floats and reflects the color of the ball (usually green) back up through the sight glass and the sight glass is dark.

FIGURE 15-6 Cutaway of the battery showing the charge indicator. If the electrolyte level drops below the bottom of the prism, the sight glass shows clear (light). Most battery manufacturers warn that if the electrolyte level is low on a sealed battery, the battery must be replaced. Attempting to charge a battery that has a low electrolyte level can cause a buildup of gases and possibly an explosion.

Battery Hold-Downs

All batteries must be attached securely to the vehicle to prevent battery damage. Normal vehicle vibrations can cause the active materials inside the battery to shed. Battery hold-down clamps or brackets help reduce vibration, which can greatly reduce the capacity and life of any battery.

ABSORBED GLASS MAT (AGM) BATTERY

Absorbed glass mat (AGM) batteries are sealed batteries where the electrolyte is absorbed into spongelike glass mats between the plates. The expected life is longer than the regular (called *flooded-type*), and AGM batteries can be installed in any position, even upside down. An AGM battery with a broken seal will quickly lose capacity if the plates are exposed to outside air. AGM batteries (also referred to as **sealed lead acid [SLA]** batteries) convert the released hydrogen and oxygen back into water instead of escaping as gasses. AGM batteries are able to better withstand vibration and last longer than conventional batteries that contain liquid electrolyte. See Figure 15-7.

BATTERY RATINGS

Batteries are rated according to the amount of current they can produce under specific conditions.

FIGURE 15-7 An example of an AGM battery. An AGM battery requires a special charger that allow the battery to be charged at a high current (ampere) rate but not over 15 volts. Conventional chargers often exceed 16 volts.

Cold-Cranking Amperes

Every automotive battery must be able to supply electrical power to crank the engine in cold weather and still provide voltage high enough to operate the ignition system for starting. The cold-cranking power of a battery is the number of amperes that can be supplied by a battery at 0°F (−18°C) for 30 seconds while the battery still maintains a voltage of 1.2 volts per cell or higher. This means that the battery voltage would be 7.2 volts for a 12-volt battery and 3.6 volts for a 6-volt battery. The cold-cranking performance rating is called **cold-cranking amperes (CCA).** Try to purchase a battery with the highest CCA for the money. See vehicle manufacturers' specifications for recommended battery capacity.

Cranking Amperes

Cranking amperes (CA) are not the same as CCA, but are often advertised and labeled on batteries. The designation CA refers to the number of amperes that can be supplied by the battery at 32°F (0°C). This rating results in a higher number than the more stringent rating of CCA. See Figure 15-8.

Marine Amperes

Similar to cranking amperes, this rating also tests the battery at 32°F (0°C).

Reserve Capacity

The **reserve capacity** rating for batteries is *the number of minutes* for which the battery can produce 25 amperes and still have a battery voltage of 1.75 volts per cell (10.5 volts for a 12-volt battery). This rating is actually a measurement of the time for which a vehicle can be driven in the event of a charging system failure.

FIGURE 15-8 This battery has a cranking amperes (CA) rating of 1000, which means that this battery is capable of supplying 1000 amperes to crank an engine for 30 seconds at a temperature of 32°F (0°C) at a minimum of 1.2 volts per cell (7.2 volts for a 12-volt battery).

Ampere Hour

Ampere hour is an older battery rating system that measures how many amperes of current the battery can produce over a period of time. For example, a battery that has a 50-amp-hour (A-H) rating can deliver 50 amperes for one hour or 1 ampere for 50 hours or any combination that equals 50 amp-hours.

BATTERY SERVICE

Safety Considerations

Batteries contain acid and release explosive gases (hydrogen and oxygen) during normal charging and discharging cycles. To help prevent physical injury or damage to the vehicle, always adhere to the following safety procedures:

1. When working on any electrical component of a vehicle, disconnect the negative battery cable from the battery. When the negative cable is disconnected, all electrical circuits in the vehicle will be open, which will prevent accidental electrical contact between an electrical component and ground. Any electrical spark has the potential to cause explosion and personal injury.
2. Wear eye protection when working around any battery.
3. Wear protective clothing to avoid skin contact with battery acid.
4. Always adhere to all safety precautions as stated in the service procedures for the equipment used in battery service and testing.
5. Never smoke or use an open flame around any battery.

Battery Maintenance

Battery maintenance includes making certain that the battery case is clean and adding clean water, if necessary. Distilled water is recommended by all battery manufacturers, but if distilled water is not available, clean ordinary drinking water, low in mineral content, can be used. Because water is the only thing in a battery that is consumed, acid should never be added to a battery. Some of the water in the electrolyte escapes during the normal operation of charging and discharging, but the acid content of the electrolyte remains in the battery. Do not overfill a battery, because normal bubbling (gassing) of the electrolyte will cause the electrolyte to escape and start corrosion on the battery terminals, hold-down brackets, and battery tray. Fill batteries to the indicator that is approximately 1 1/2 inches (3.8 centimeters) from the top of the filler tube.

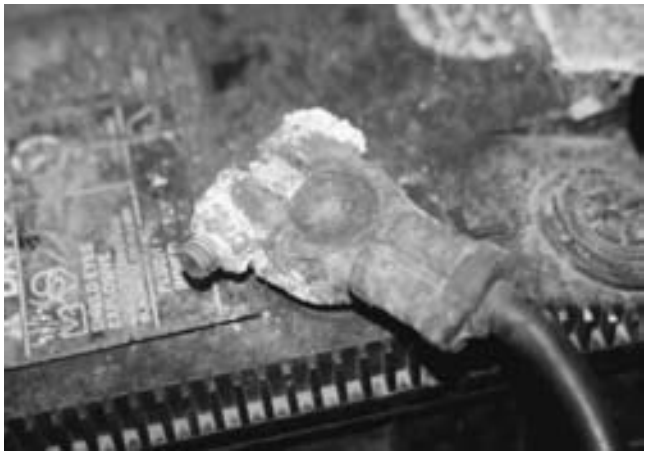


FIGURE 15-9 A corroded battery terminal.

FIGURE 15-10 This battery cable was found to be corroded underneath. The corrosion had eaten through the insulation yet was not noticeable until it was carefully inspected. This cable should be replaced.

FIGURE 15-11 Carefully inspect all battery terminals for corrosion. This vehicle uses two positive battery cables connected at the battery using a long bolt. This is a common source of corrosion that can cause a starting (cranking) problem.

Battery cable connections should be checked and cleaned to prevent voltage drop at the connections. One common reason for an engine not starting is loose or corroded battery cable connections. See Figures 15-9 through 15-11.

Battery Voltage Testing

Testing the battery voltage with a voltmeter is a simple method for determining the state of charge of any battery. The voltage of a battery does not necessarily indicate whether the battery can perform satisfactorily, but it does indicate to the technician more about the battery's condition than a simple visual inspection. A battery that "looks good" may not be good. This test is commonly called an **open-circuit battery voltage test,** because it is conducted with an open circuit—with no current flowing and no load applied to the battery.

1. If the battery has just been charged or the vehicle has recently been driven, it is necessary to remove the surface charge from the battery before testing. A surface charge is a charge of higher-than-normal voltage that is only on the surface of the battery plates. The surface charge is quickly removed when the battery is loaded and therefore does not accurately represent the true state of charge of the battery.
2. To remove the surface charge, turn the headlights on high beam (brights) for 1 minute, then turn the headlights off and wait 2 minutes.
3. With the engine and all electrical accessories off, and the doors shut (to turn off the interior lights), connect a voltmeter to the battery posts. Connect the red positive lead to the positive post and the black negative lead to the negative post.

NOTE: If the meter reads negative, the battery has been reverse charged (has reversed polarity) and should be replaced, or the meter has been connected incorrectly.

4. Read the voltmeter and compare the results with the following state-of-charge chart. The voltages shown are for a battery at or near room temperature (70° to 80°F) or (21° to 27°C). See Figure 15-12.

Battery Voltage (V)	*State of Charge*
12.6 or higher	100% charged
12.4	75% charged
12.2	50% charged
12.0	25% charged
11.9 or lower	Discharged

Battery Load Testing

One of the most accurate tests to determine the condition of any battery is the **load test.** Most automotive starting and charging

(a)

(b)

FIGURE 15-12 (a) Voltmeter showing the battery voltage after the headlights were on (engine off) for 1 minute. (b) Headlights were turned off and the battery voltage quickly recovered to indicate 12.6 volts.

testers use a carbon pile to create an electrical load on the battery. The amount of the load is determined by the original capacity of the battery being tested. The capacity is measured in cold-cranking amperes, which is the number of amperes that a battery can supply at 0°F (−18°C) for 30 seconds. *The proper electrical load to be used to test a battery is one-half the CCA rating or three times the ampere-hour rating, with a minimum 250-ampere load.* After the battery has been tested to be at least 75% charged by observing the built-in hydrometer or by performing an open-circuit voltage test, a load test can be performed. Apply the load for a full 15 seconds and observe the voltmeter at the end of the 15-second period while the battery is still under load. A good battery should indicate above 9.6 V. Many battery manufacturers recommend performing the load test twice, using the first load period to remove the surface charge on the battery and the second test to provide a truer indication of the condition of the battery. Wait 30 seconds between tests to allow time for the battery to recover. See Figure 15-13.

If the battery fails the load test, recharge the battery and retest. If a second failure occurs, replace the battery.

NOTE: Some battery testers measure the capacitance of the battery to determine the state of charge and battery condition. Always follow the test equipment manufacturer's recommended test procedure.

Electronic Battery Testers

Electronic (non-load testing) testers use the conductance of the battery to determine capacity and condition. Conductance is a measurement of the battery's ability to produce

FIGURE 15-13 A Bear Automotive starting and charging tester. This tester automatically loads the battery for 15 seconds to remove the surface charge, then waits 30 seconds to allow the battery to recover, then again loads the battery. The display indicates the status of the battery.

current. To measure conductance, the tester creates a small signal that is sent through the battery and then measures a portion of the AC current response. Conductance is a measure of the plate surface available in the battery, which determines how much power the battery can supply. As a battery ages, the plate surface can sulfate or shed active material, which adversely affects its ability to perform. In addition, conductance can be used to detect cell defects, shorts, and open circuits, which will reduce the ability of the battery to deliver current. To operate the tester, use the keys and follow the directions on the display. The tester will test the battery and display the results. See Figure 15-14.

NOTE: Good connections to the battery are critical for the proper operation of the electronic battery tester.

FIGURE 15-14 A typical electronic battery tester which, depending on the model, can also be used to test the starting and the charging systems.

Battery Charging

If the state of charge of a battery is low, it must be recharged. It is best to slow-charge any battery to prevent possible overheating damage to the battery. See Figure 15-15 for the recommended charging rate. *Remember, it may take 8 hours or more to charge a fully discharged battery.* The initial charge rate should be about 35 amperes for 30 minutes to help start the charging process. Fast-charging a battery increases the temperature of the battery and can cause warping of the plates inside the battery. Fast-charging also increases the amount of gassing (release of hydrogen and oxygen), which can create a health and fire hazard. The battery temperature should not exceed 125°F (hot to the touch). *Most batteries should be charged at a rate equal to 1% of the battery's CCA rating.*

Fast charge: 15 amperes maximum
Slow charge: 5 amperes maximum

Charging Time

The time needed to charge a battery depends on the state-of-charge and the battery reserve capacity. See the following chart.

State of Charge	*75%*		*50%*		*25%*		*0%*	
Charge Rate (Amps)	*5*	*10*	*5*	*10*	*5*	*10*	*5*	*10*
50 RC	75	35	150	75	225	130	300	150
60 RC	90	45	180	90	270	135	360	180
70 RC	105	50	210	105	315	155	420	210
80 RC	120	60	240	120	360	180	480	240
90 RC	135	65	270	135	405	200	540	270
100 RC	150	75	300	150	450	225	600	300
110 RC	165	80	330	165	495	240	660	330
120 RC	180	90	360	180	540	270	720	360
Battery Reserve (RC) Capacity Rating in Minutes	Charge Time in Minutes							

FIGURE 15-15 This battery charger is charging the battery at a 10-ampere rate. A slow rate such as this is easier on the battery than a fast charge that may overheat the battery and cause warpage of the plates inside the battery.

TECH TIP

IT COULD HAPPEN TO YOU!

The owner of a Toyota replaced the battery. After replacing the battery, the owner noted that the "airbag" amber warning lamp was lit and the radio was locked out. The owner had purchased the vehicle used from a dealer and did not know the four-digit security code needed to unlock the radio. Determined to fix it, the owner tried three four-digit numbers, hoping that one of them would work. However, after three tries, the radio became permanently disabled.

Frustrated, the owner went to a dealer. It cost over $300 to fix the problem. A special tool was required to reset the airbag lamp. The radio had to be removed and sent out of state to an authorized radio service center and then reinstalled into the vehicle.

Therefore, before disconnecting the battery, please check with the owner to be certain that the owner has the security code for a security-type radio. A "memory saver" may be needed to keep the radio powered when the battery is being disconnected. See Figure 15-16.

JUMP STARTING

To jump start another vehicle with a dead battery, connect good-quality copper jumper cables as indicated in Figure 15-17. The last connection made should always be on the engine block or an engine bracket as far from the battery as possible.

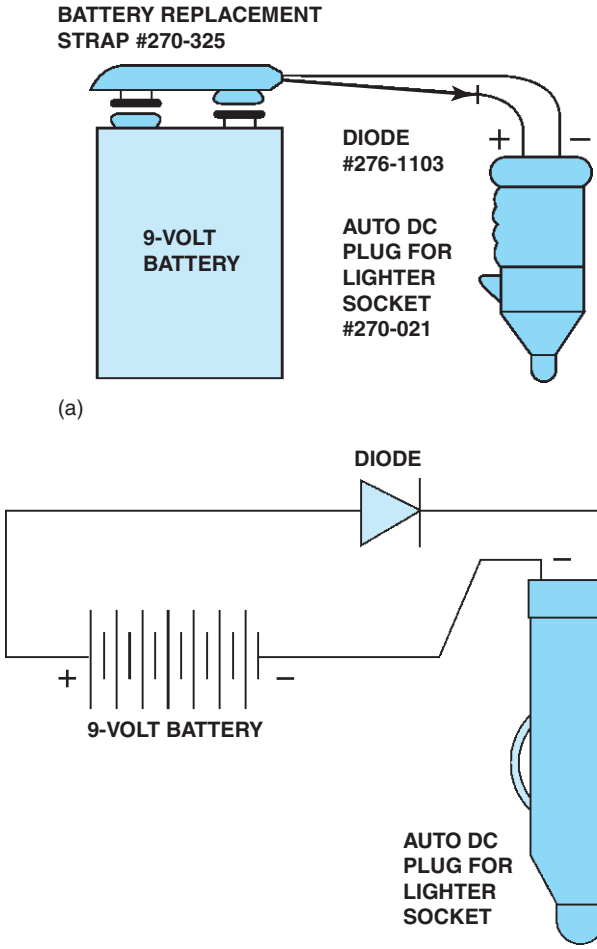


FIGURE 15-16 (a) Memory saver. The part numbers represent components from Radio Shack™. (b) A schematic drawing of the same memory saver.

It is normal for a spark to be created when the jumper cables finally complete the jumping circuit, and this spark could cause an explosion of the gases around the battery. Many newer vehicles have special ground connections built away from the battery just for the purpose of jump starting. Check the owner's manual or service manual for the exact location.

CRANKING CIRCUIT

The cranking circuit includes those mechanical and electrical components required to crank the engine for starting. In the early 1900s, the cranking force was the driver's arm. Modern cranking circuits include the following:

1. **Starter motor.** The starter is normally a 0.5 to 2.6-horsepower (0.4 to 2.0-kilowatt) electric motor. See Figure 15-18 on page 240.
2. **Battery.** The battery must be of the correct capacity and be at least 75% charged to provide the necessary current and voltage for correct operation of the starter.

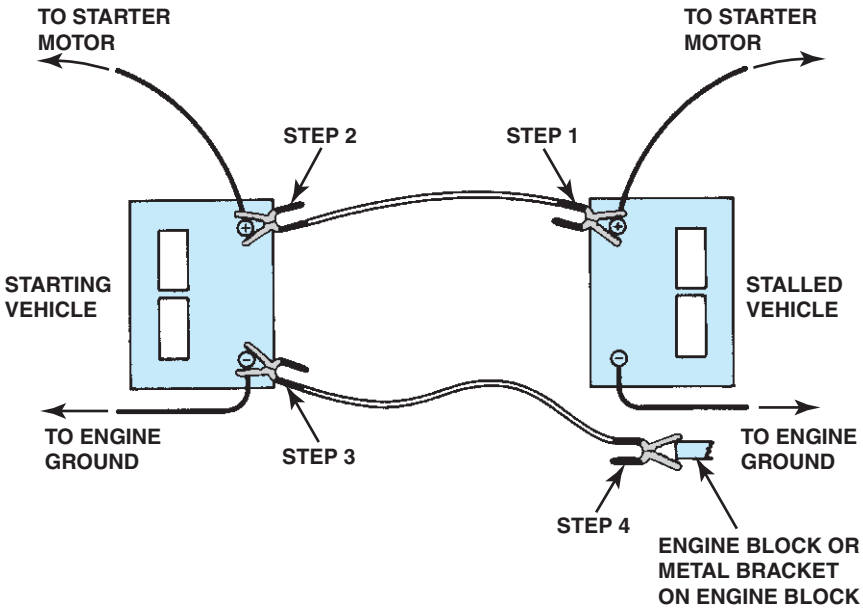


FIGURE 15-17 Jumper cable usage guide. Notice that the last electrical connection is made to the engine block or an engine bracket away from the battery to help prevent a spark that could occur, causing harm to the disabled vehicle or to the person performing the jump starting.

3. **Starter solenoid or relay.** The high current required by the starter must be able to be turned on and off. A large switch would be required if the current were controlled by the driver directly. Instead, a small current switch (ignition switch) operates a solenoid or relay that controls the high starter current.
4. **Starter drive.** The starter drive uses a small gear that contacts the engine flywheel gear and transmits starter motor power to rotate the engine.
5. **Ignition switch.** The ignition switch and safety control switches control the starter motor operation.
6. **Neutral safety (clutch switch).** This switch prevents the operation of the starter unless the gear selector is in park or neutral or the clutch pedal is depressed. See Figure 15-19.

FREQUENTLY ASKED QUESTION

SHOULD BATTERIES BE KEPT OFF CONCRETE FLOORS?

All batteries should be stored in a cool, dry place when not in use. Many technicians have been warned not to store or place a battery on concrete. According to battery experts, it is the temperature difference between the top and the bottom of the battery that causes a difference in the voltage potential between the top (warmer section) and the bottom (colder section). This difference in temperature causes self-discharge to occur. In fact, submarines cycle seawater around their batteries to keep all sections of the battery at the same temperature to help prevent self-discharge.

Therefore, always store or place batteries off the floor and in a location where the entire battery can be kept at the same temperature, avoiding extreme heat and freezing temperatures.

Concrete cannot drain the battery directly, because the battery case is a very good electrical insulator.

TECH TIP

WATCH THE DOME LIGHT

When diagnosing any starter-related problem, open the door of the vehicle and observe the brightness of the dome or interior light(s).

- The brightness of any electrical lamp is proportional to the voltage.
- Normal operation of the starter results in a slight dimming of the dome light.
- If the light remains bright, the problem is usually an open circuit in the control circuit.
- If the light goes out or almost goes out, the problem is usually a shorted or grounded armature of field coils inside the starter or a defective battery.

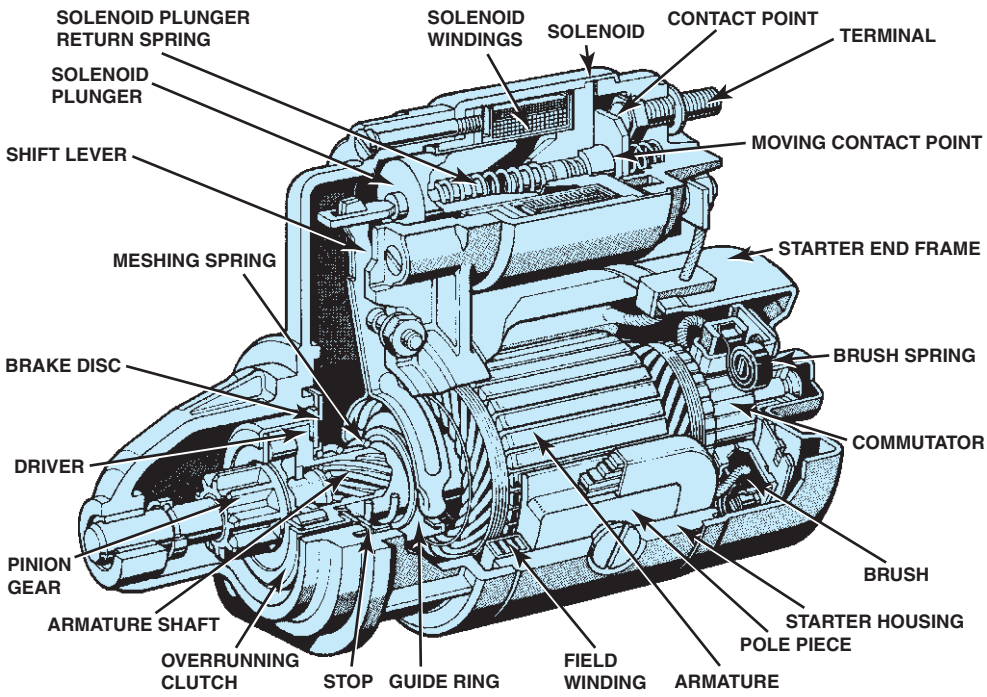


FIGURE 15-18 A cutaway view of a typical starter motor.

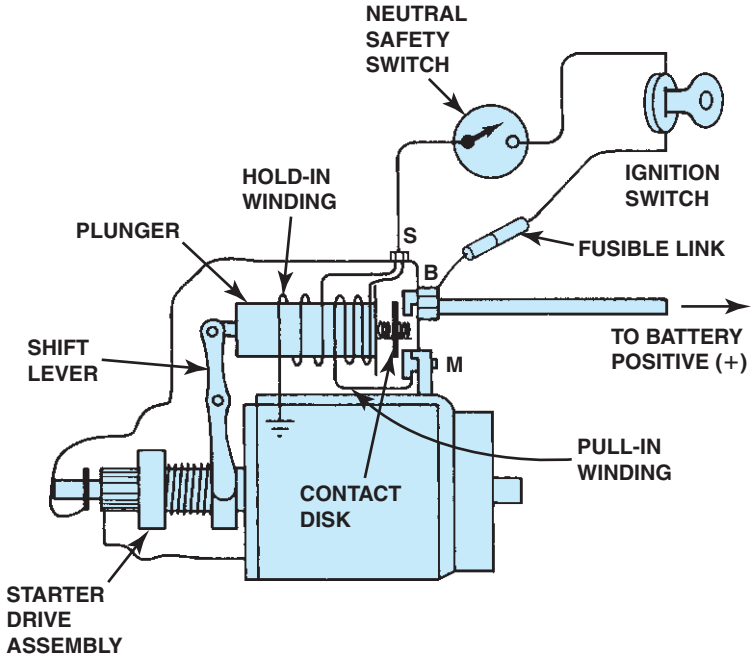


FIGURE 15-19 Wiring diagram of a typical starter solenoid. Notice that both the pull-in winding and the hold-in winding are energized when the ignition switch is first turned to the "start" position. As soon as the solenoid contact disk makes electrical contact with both the B and M terminals, the battery current is conducted to the starter motor.

STARTING SYSTEM TROUBLESHOOTING

The proper operation of the starting system depends on a good battery, good cables and connections, and a good starter motor. Because a starting problem can be caused by a defective component anywhere in the starting circuit, it is important to check for the proper operation of each part of the circuit to diagnose and repair the problem quickly.

TECH TIP

DON'T HIT THAT STARTER!

In the past, it was common to see service technicians hitting a starter in their effort to diagnose a no-crank condition. Often the shock of the blow to the starter aligned or moved the brushes, armature, and bushings. Many times, the starter functioned after being hit—even if only for a short time.

However, most of today's starters use permanent-magnet (PM) fields, and the magnets can be easily broken if hit. A magnet that is broken becomes two weaker magnets. Some early PM starters used magnets that were glued or bonded to the field housing. If struck with a heavy tool, the magnets could be broken with parts of the magnet falling onto the armature and into the bearing pockets, making the starter impossible to repair or rebuild.

NOTE: Starter remanufacturers state that the single most common cause of starter motor failure is low battery voltage.

STARTER AMPERAGE TESTING

Before performing a starter amperage test, be certain that the battery is sufficiently charged (75% or more) and capable of supplying adequate starting current.

TECH TIP

TOO HOT!

If a cable or connection is hot to the touch, there is electrical resistance in the cable or connection. The resistance changes electrical energy into heat energy. Therefore, if a voltmeter is not available, touch the battery cables and connections while cranking the engine. If any cable or connection is hot to the touch, it should be cleaned or replaced.

A starter amperage test should be performed when the starter fails to operate normally (is slow in cranking) or as part of a routine electrical system inspection. Some service manuals specify normal starter amperage for starter motors being tested on the vehicle; however, most service manuals only give the specifications for bench-testing a starter without a load applied. If exact specifications are not available, the following can be used as general specifications for testing a starter on the vehicle:

4-cylinder engines = 150–185 amperes
6-cylinder engines = 160–200 amperes
8-cylinder engines = 185–250 amperes

Excessive current draw may indicate one or more of the following:

1. Binding of starter armature as a result of worn bushings
2. Oil too thick (viscosity too high) for weather conditions
3. Shorted or grounded starter windings or cables
4. Tight or seized engine

Also see the starter trouble diagnostic chart in Figure 15-20.

BENCH TESTING

Every starter should be tested before it is installed in a vehicle. The usual method includes clamping the starter in a vise to prevent rotation during operation and connecting heavy-gauge jumper wires (minimum 4 gauge) to a battery known to be good, and the starter. The starter motor should rotate as fast as specifications indicate and not draw more than the free-spinning amperage permitted.

AC GENERATORS

How an AC Generator Works

A rotor inside an AC generator (also called an **alternator**) is turned by the engine through an accessory drive belt. The magnetic field of the rotor generates a current in the windings of the stator by electromagnetic induction. See Figures 15-21 and 15-22 on page 243.

Most AC generators are designed to supply between 13.5 and 15.0 volts at 2000 engine RPM. Be sure to check the vehicle manufacturer's specifications. For example, most General Motors vehicles specify a charging voltage of 14.7 volts ± 0.5 (or between 14.2 and 15.2 volts).

Charging-system voltage tests should be performed on a vehicle with a battery at least 75% charged. If the battery is discharged (or defective), the charging voltage may be below specifications. To measure charging-system voltage, follow these steps:

1. Connect the voltmeter to the positive and negative terminals of the battery.

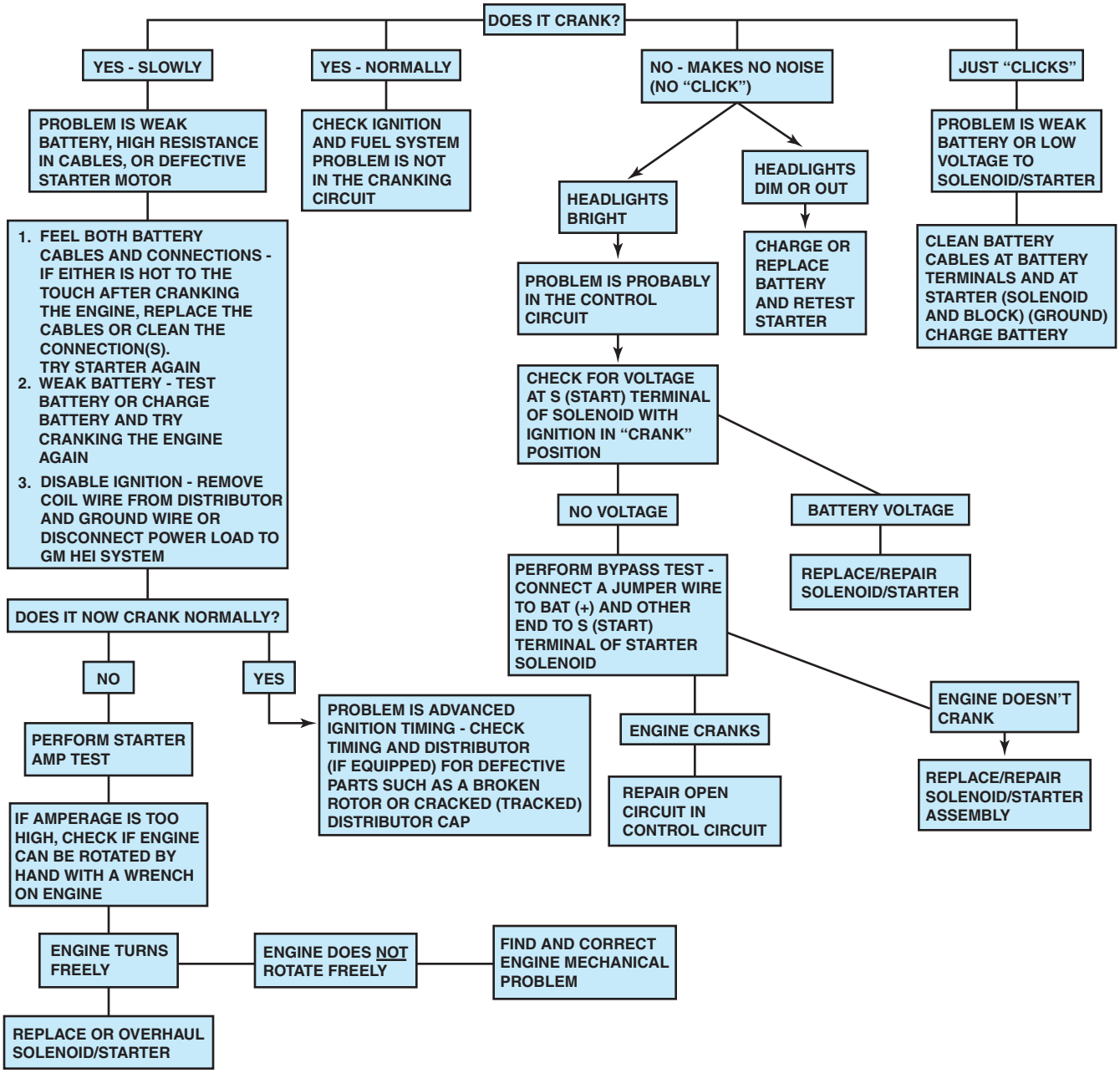


FIGURE 15-20 Starter trouble diagnostic chart.

2. Set the meter to read DC volts.
3. Start the engine and raise to a fast idle (about 2000 RPM).
4. Read the voltmeter and compare it with specifications. See Figure 15-23. If lower than specifications, charge the battery and test for excessive charging-circuit voltage drop before replacing the alternator.

NOTE: If the voltmeter reading rises then becomes lower as the engine speed is increased, the generator drive (accessory drive) belt is loose or slipping.

AC Voltage Check

A good AC generator should *not* produce any AC voltage. It is the purpose of the diodes in the AC generator to rectify all AC voltage into DC voltage. The procedure to check for AC voltage includes the following steps:

Step 1 Set the digital meter to read AC volts.
Step 2 Start the engine and operate it at 2000 RPM (fast idle).
Step 3 Connect the voltmeter leads to the positive and negative battery terminals.

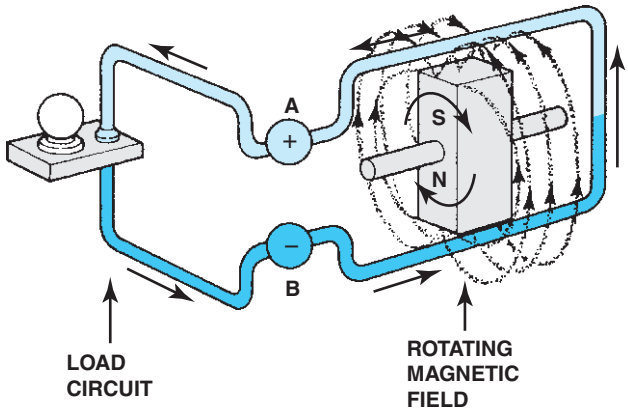


FIGURE 15-21 Magnetic lines of force cutting across a conductor induce a voltage and current in the conductor.

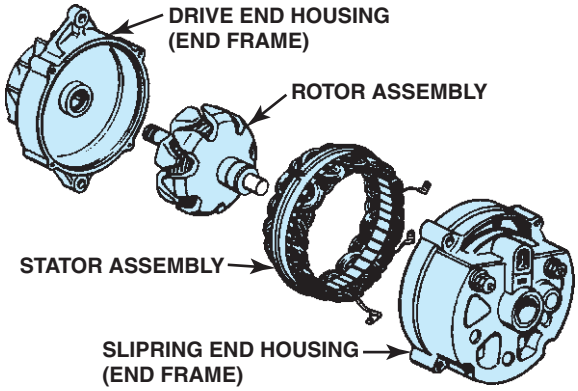


FIGURE 15-22 The aluminum housing of the generator (alternator) houses the stationary stator and the rotating rotor.

Step 4 Turn on the headlights to provide an electrical load on the AC generator.

NOTE: A higher, more accurate reading can be obtained by touching the meter lead to the output terminal of the AC generator.

The results should be interpreted as follows: If the diodes are good, the voltmeter should read *less* than 0.4 volt AC. If the reading is over 0.5 volt AC, the rectifier diodes are defective.

NOTE: This test will *not* test for a defective diode trio.

AC Generator Output Testing

A charging circuit may be able to produce correct charging-circuit voltage but not adequate amperage output. If in doubt about charging-system output, first check the condition of the AC generator drive belt. With the engine off, attempt to rotate the fan of the AC generator by hand. Replace or tighten the drive belt if the AC generator fan can be rotated by hand. See Figures 15-25 and 15-26 for typical test equipment hookup.

The testing procedure for AC generator output is as follows:

1. Connect the starting and charging test leads according to the manufacturer's instructions. Place the ammeter probe from the tester around the output cable from the back of the generator (alternator).
2. Start the engine and operate it at 2000 RPM (fast idle). Turn the load increase control slowly to obtain the highest reading on the ammeter scale. Note the ampere reading.

FIGURE 15-23 The digital multimeter should be set to read DC volts; the red lead is connected to the battery positive (+) terminal and the black meter lead is connected to the negative (−) battery terminal.

TECH TIP

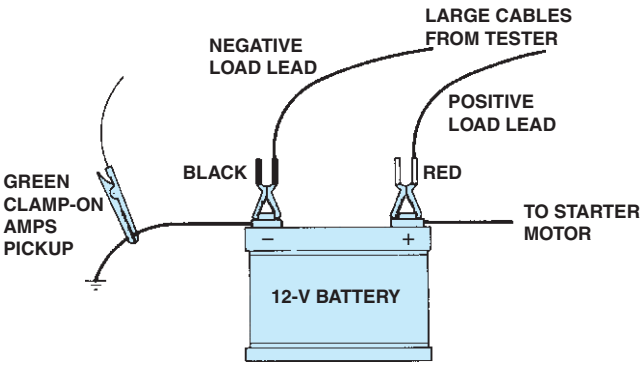
THE LIGHTER PLUG TRICK

Battery voltage measurements can be read through the lighter socket. See Figure 15-24. Simply construct a test tool using a lighter plug at one end of a length of two-conductor wire and the other end connected to a double banana plug. The double banana plug will fit most meters in the common (COM) terminal and the volt terminal of the meter.

(a)

(b)

FIGURE 15-24 (a) A simple and easy-to-use tester can be made from a lighter plug and double banana plug that fits the COM and V terminals of most digital meters. (b) By plugging the lighter plug into the lighter, the charging-circuit voltage can be easily measured.



TEST LEAD CONNECTIONS FOR TESTING THE STARTING SYSTEM, CHARGING SYSTEM, VOLTAGE REGULATOR, AND DIODE STATOR.

FIGURE 15-25 Typical hookup of a starting and charging tester.

FIGURE 15-26 When connecting an inductive ammeter probe, be certain that the pickup is over *all* wires. The probe will work equally well over either all positive or all negative cables, because all current leaving a battery must return.

TECH TIP

USE A TEST LIGHT TO CHECK FOR A DEFECTIVE FUSIBLE LINK

Most AC generators (alternators) use a fusible link between the output terminal located on the slip-ring-end frame and the positive (+) terminal of the battery. If this fusible link is defective (blown), then the charging system will not operate. Many AC generators have been replaced repeatedly because of a blown fusible link that was not discovered until later. A quick and easy test to check if the fusible link is okay is to touch a test light to the output terminal. With the other end of the test light attached to a good ground, the fusible link is okay if the light lights. This test confirms that the circuit between the AC generator and the battery has continuity.

The AC generator output should be within 10% of its rated output.

NOTE: When applying a load to the battery with a carbon pile tester during an AC generator output test, do not permit the battery voltage to drop below 12 volts. Most AC generators will produce their maximum output (in amperes) above 13 volts.

ACCESSORY DRIVE BELT REPLACEMENT Step-by-Step

STEP 1

A special tool used to remove and replace most serpentine accessory drive belts. This tool comes with various sockets that fit a variety of vehicles.

STEP 2

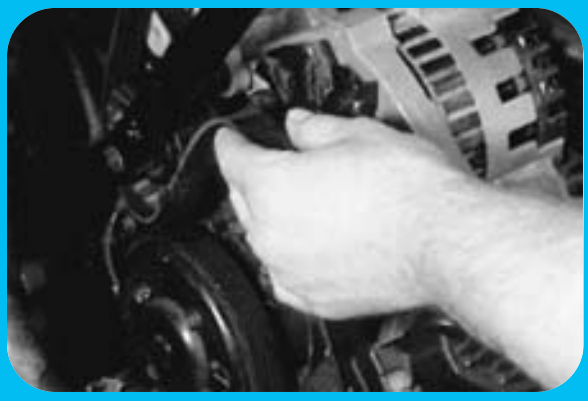
The tool attaches to the tensioner. The long handle provides leverage needed to remove the tension from the belt.

STEP 3

By rotating the tensioner, the tension on the belt is removed.

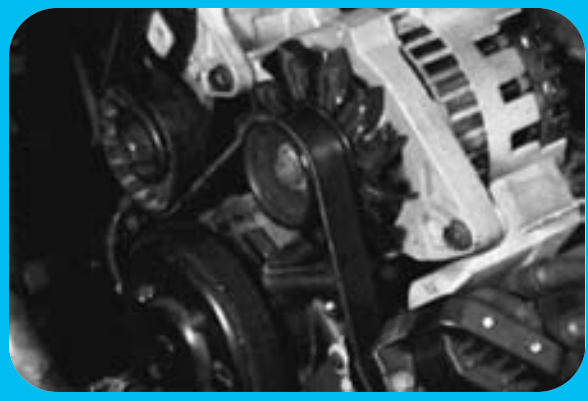
STEP 4

The belt can be easily removed after the tension has been removed.



STEP 5

Installing a new serpentine accessory drive belt requires that force be maintained on the tool while the belt is routed onto all of the accessory pulleys. Most vehicles have a placard under the hood showing the correct routing of the accessory drive belt.



STEP 6

After the belt is positioned over the pulleys, the tension can be removed from the tensioner and the tool removed. Start the engine and verify proper accessory drive belt installation.

STARTING AND CHARGING VOLTMETER TEST Step-by-Step

STEP 1

Prepare a digital multimeter to read volts by placing the red meter lead into the "VΩ" (red) input terminal and the black meter lead into the input terminal labeled "COM" as shown.

STEP 2

Connect the red meter lead clip to the positive (+) terminal of the battery and connect the black meter lead clip to the negative (−) terminal of the battery.

STEP 3

Turn the meter on and select DC volts.

STEP 4

Turn the headlights on for about 1 minute to remove the surface charge from the battery.

STEP 5

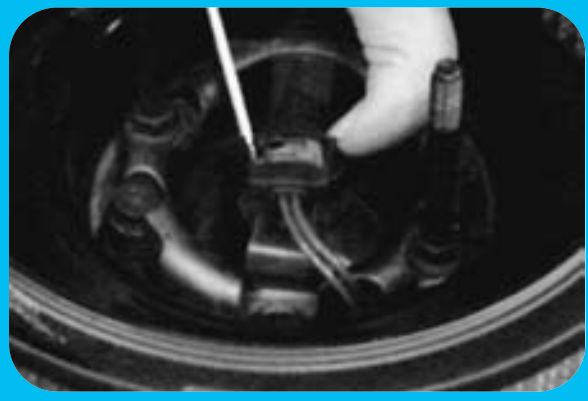
Watch the meter display with the headlights on. A good fully charged battery will indicate a slight drop in voltage such as shown here (12.44 volts). A weak or discharged battery will usually indicate a rapidly falling voltage reading when the headlights are first turned on.

STEP 6

Turn off the headlights after about I minute or when the voltage reading stops rising.

STARTING AND CHARGING VOLTMETER TEST continued

STEP 7 The voltage should increase after the lights are turned off. Record the voltage when the reading stops increasing. A reading of 12.6 or higher indicates a fully charged 12-volt battery.



STEP 8 To prevent the engine from starting during a cranking voltage part of the test, the fuel injector can be disconnected.

STEP 9 Crank the engine using the ignition switch.

STEP 10 Observe the voltmeter while cranking. A reading of about 9.6 volts indicates that the cranking circuit is okay.

STEP 11 Reconnect the fuel injector.

STEP 12 Start and operate the engine at 2000 RPM (fast idle).

(continued)

STARTING AND CHARGING VOLTMETER TEST continued

STEP 13 Observe the voltmeter. Acceptable charging system voltage should be between 13.5 and 15.0 volts.

STEP 14 Turn the engine off and disconnect the meter leads. This test is complete.

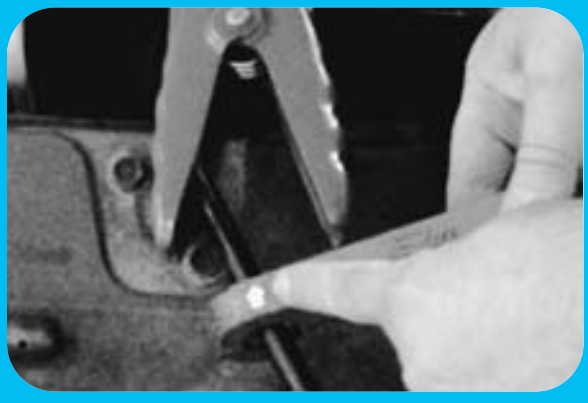
BATTERY LOAD TEST Step-by-Step

STEP 1

This type of tester uses a carbon pile to provide a connective path to load the battery, and therefore is often called a carbon-pile tester.

STEP 2

Start by connecting the large red clamp from the tester to the positive (+) terminal of the battery and the large black clamp to the negative (−) terminal of the battery.



STEP 3

Attach the inductive amp probe over the meter red tester lead wire. According to Sun Electric, the arrow on the probe should point toward the battery.

STEP 4

Zero the ammeter by turning the zero adjust knob until the needle on the meter indicates zero.

STEP 5

Determine the cold-cranking amperes (CCA) of the battery. This rating is usually on a sticker on the battery case.

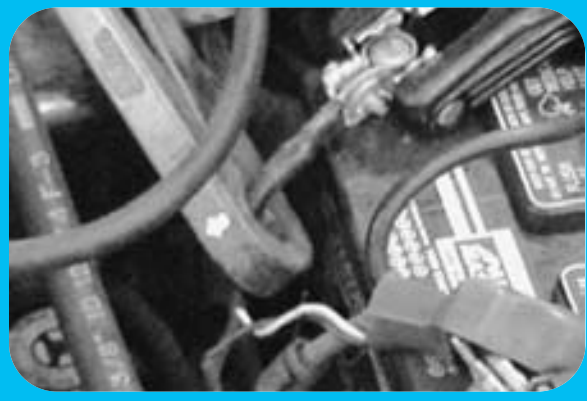
STEP 6

Turn the load knob until the ammeter reading is one-half of the CCA rating of the battery. Maintain applying this load for 15 seconds. With the load still applied, observe the voltmeter reading at the end of the 15-second test. The battery voltage should be above 9.6 volts.

STARTER AMPERAGE DRAW TEST Step-by-Step

STEP 1

A Sun Electric VAT-40 is being used to measure the amount of current, in amperes, required to crank the engine.



STEP 2

Clamp the inductive ampere probe around either all of the wires from the positive terminal or over all of the wires from the negative terminal as shown.

STEP 3

Select "starting" with the test selector knob.

STEP 4

Disable the ignition or the fuel system to prevent the engine from starting when the engine is being cranked.

STEP 5

Crank the engine and observe the ammeter reading.

STEP 6

The starter on this vehicle equipped with a V-6 engine requires 120 amperes as displayed on the VAT-40 display. Disregard the first initial higher amperage reading.

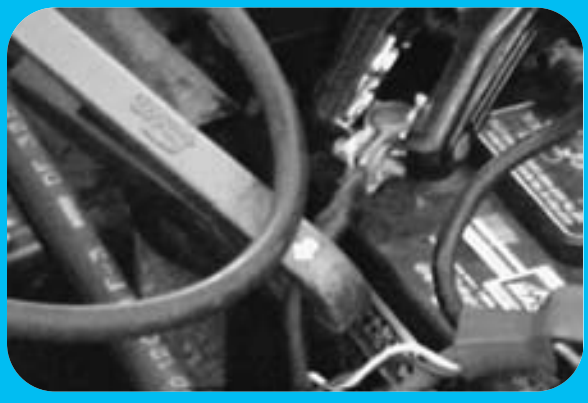
GENERATOR (ALTERNATOR) OUTPUT TEST Step-by-Step

STEP 1

A typical Sun Electric VAT-40 (volt/amp tester model 40) used to measure the output of an AC generator (alternator).

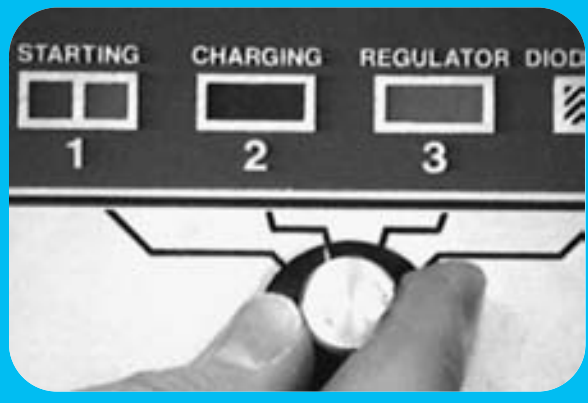
STEP 2

Connect the large black clamp from the VAT-40 to the negative (−) terminal of the battery and the large red clamp to the positive (+) terminal of the battery.



STEP 3

Attach the ammeter inductive probe to either the negative or positive vehicle battery cable, whichever is most accessible. Be sure to clamp over *all* of the wires connecting to the battery terminal.

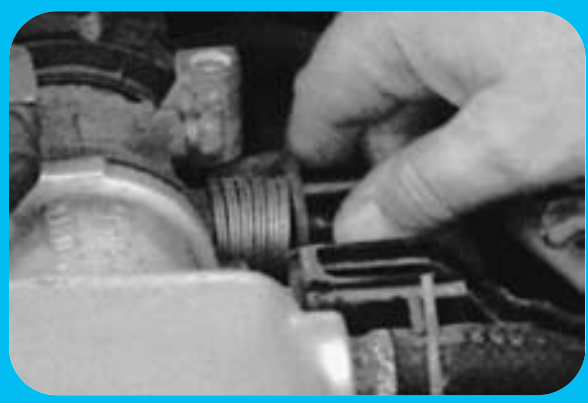


STEP 4

Select "charging" on the VAT-40 unit.

STEP 5

Start the engine. To measure the maximum output, the battery must be loaded and the engine speed increased.



STEP 6

To measure the maximum AC generator (alternator) output, increase engine speed to 2000 RPM.

(continued)

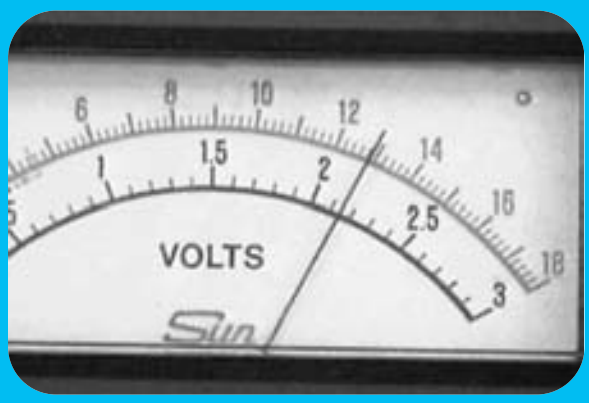
GENERATOR (ALTERNATOR) OUTPUT TEST continued

STEP 7

With the engine operating at 2000 RPM, turn the load knob until the highest ampere reading is displayed.

STEP 8

The output should be within 10% of its rated output. The specification for this vehicle was 90 amperes and output was measured at 92 amperes. This amperage should be added to the amount measured above to determine the actual maximum generator output.



STEP 9

When loading the battery during a generator output test, be sure to keep the voltage above 12 volts. Most charging systems produce the maximum output at about 13 volts, as shown here during the test.

SUMMARY

1. When a battery is being discharged, the acid (SO_4) is leaving the electrolyte and being deposited on the plates. When the battery is being charged, the acid (SO_4) is forced off the plates and back into the electrolyte.
2. Batteries are rated according to CCA, CA, ampere-hour, and reserve capacity.
3. All batteries should be securely attached to the vehicle with hold-down brackets to prevent vibration damage.

4. Batteries can be tested with a voltmeter to determine the state of charge. A battery load test loads the battery to one-half its CCA rating. A good battery should be able to maintain higher than 9.6 volts for the entire 15-second test period.
5. Proper operation of the starter motor depends on the battery being at least 75% charged and the battery cables being of the correct size (gauge) and having no more than a 0.2 voltage drop.
6. Voltage-drop testing includes cranking the engine, measuring the drop in voltage from the battery to the starter, and measuring the drop in voltage from the negative terminal of the battery to the engine block.
7. The cranking circuit should be tested for proper amperage draw.
8. Normal charging voltage (at 2000 engine RPM) is 13.5 to 15.0 volts.
9. The AC generator output is tested using a carbon pile tester connected to load the battery and measure the maximum amount of current being generated.
10. If more than 0.5 volt AC is measured at the output terminal of the battery, then the diode or stator is defective inside the AC generator.

REVIEW QUESTIONS

1. List the parts of the cranking circuit.
2. Explain why discharged batteries can freeze.
3. Identify three battery rating methods.
4. Describe the results of a voltmeter test of a battery and its state of charge.
5. List the steps for performing a battery load test.
6. Discuss how to measure the amperage output of an AC generator.
7. Explain how testing can be used to determine whether a diode or stator is defective.

CHAPTER QUIZ

1. When a battery becomes completely discharged, both positive and negative plates become _____ and the electrolyte becomes _____.
   - **a.** H_2SO_4; Pb
   - **b.** $PbSO_4$; H_2O
   - **c.** PbO_2; H_2SO_4
   - **d.** $PbSO_4$; H_2SO_4
2. A fully charged 12-volt battery should indicate _____.
   - **a.** 12.6 volts or higher
   - **b.** A specific gravity of 1.265 or higher
   - **c.** 12 volts
   - **d.** Both a and b
3. A battery measures 12.4 volts after removing the surface charge. This battery is charged at what percent?
   - **a.** 100%
   - **b.** 75%
   - **c.** 50%
   - **d.** 25%
4. Reserve capacity for batteries means _____.
   - **a.** The number of *hours* the battery can supply 25 amperes and remain higher than 10.5 volts
   - **b.** The number of *minutes* the battery can supply 25 amperes and remain higher than 10.5 volts
   - **c.** The number of *minutes* the battery can supply 20 amperes and remain higher than 9.6 volts
   - **d.** The number of *minutes* the battery can supply 10 amperes and remain higher than 9.6 volts
5. A battery high-rate discharge (load capacity) test is being performed on a 12-volt battery. Technician A says that a good battery should have a voltage reading of higher than 9.6 volts while under load at the end of the 15-second test. Technician B says that the battery should be discharged (loaded to two times its CCA rating). Which technician is correct?
   - **a.** Technician A only
   - **b.** Technician B only
   - **c.** Both Technicians A and B
   - **d.** Neither Technician A nor B

6. When charging a maintenance-free (lead-calcium) battery, _____.
   a. The initial charging rate should be about 35 amperes for 30 minutes
   b. The battery may not accept a charge for several hours, yet may still be a good (serviceable) battery
   c. The battery temperature should not exceed 125°F (hot to the touch)
   d. All of the above are correct

7. When jump starting, _____.
   a. The last connection should be the positive post of the dead battery
   b. The last connection should be the engine block of the dead vehicle
   c. The alternator must be disconnected on both vehicles
   d. Both a and c

8. Slow cranking by the starter can be caused by all *except* the following _____.
   a. A low or discharged battery
   b. Corroded or dirty battery cables
   c. Engine mechanical problems
   d. An open neutral safety switch

9. A starter motor draws more amperage than specifications. Technician A says that the battery may be discharged. Technician B says that the starter may be defective. Which technician is correct?
   a. Technician A only
   b. Technician B only
   c. Both Technicians A and B
   d. Neither Technician A nor B

10. An acceptable charging circuit voltage on a 12-volt system is _____.
   a. 13.5 to 15.0 volts
   b. 12.6 to 15.6 volts
   c. 12 to 14 volts
   d. 14.9 to 16.1 volts