

MLR: Batteries, Starting and Charging



TABLE OF CONTENTS

Unit 1 Automotive Batteries	4
Chapter 1: Batteries Overview	4
Battery Function	4
Battery Construction	5
Maintenance-Free Batteries	7
Electrolyte and Specific Gravity	8
Battery Safety	9
Temperature, Efficiency, and Ratings	11
Chapter 2: Power Loss	12
How Batteries Lose Power	12
Corrosion	17
Battery Testing and Service	17
Hydrometer Testing	18
Chapter 3: Charging and Replacement	22
Load Testing	22
Battery Chargers	24
Battery Temperature	25
Battery Charging	26
Battery Replacement	29
Unit 2 Starting Systems	29
Chapter 1: Starting System Overview	29
Starting System	29
Motor Drive Mechanism	30
Gear Reduction	31
Starter Solenoids	31
Reduction Starters	32
Starting Circuit	33
Current Draw and Torque	33

Chapter 2: Starting System Diagnosis and Service	34
Diagnosis	34
Testing	35
Wires and Cables	38
Abnormal Noises	38
Replacement and Repair	40
Unit 3 Charging Systems.....	41
Chapter 1: Charging System Overview	41
System Components.....	41
Generators Functions	42
Generator Components.....	44
Rotor and Brushes	44
Stator	45
Diodes and Diode Bridges	45
Voltage Regulators.....	46
Chapter 2: Charging System Diagnosis and Service.....	49
Visual and Mechanical Inspection	49
Electrical Testing	51
Scan Tools and Scopes	51
Waveforms	52
Tests.....	54
Generator Repair	55

UNIT 1 AUTOMOTIVE BATTERIES

The following topics are addressed in this unit:

BATTERIES OVERVIEW

- Battery Function
- Battery Construction
- Maintenance Free Batteries
- Electrolyte and Specific Gravity
- Battery Safety
- Temperature, Efficiency, and Ratings

CHARGING AND REPLACEMENT

- Load Testing
- Battery Chargers
- Battery Temperature
- Battery Charging
- Replacing a Battery

POWER LOSS

- How Batteries Lose Power
- Corrosion
- Battery Testing and Service
- Hydrometer Testing

CHAPTER 1: BATTERIES OVERVIEW

BATTERY FUNCTION

An automotive battery is an electrochemical device that converts electrical energy into chemical energy and stores it until needed. When needed, the battery converts the stored chemical energy back into electrical energy.

The battery serves four purposes in an automobile:

- It supplies electricity to the accessories when the engine is not running
- It supplies high current to the starter, and system voltage to the ignition system during cranking
- It provides current to the electrical systems when the demand exceeds the output of the generator
- It acts as a voltage stabilizer in the electrical system

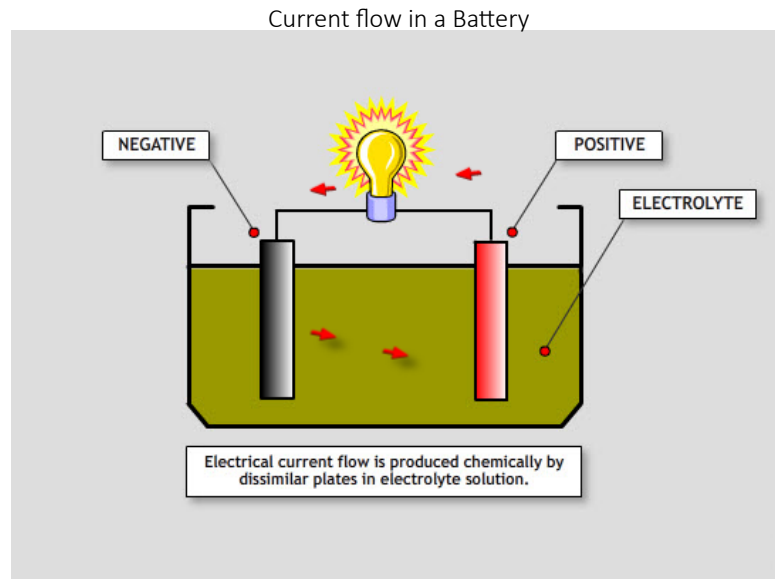
Automobiles generally use what is classified as a wet cell, lead-acid battery. Batteries produce current through a chemical reaction between the active materials of the plates and sulfuric acid in the electrolyte.

Automotive batteries never 'sit still'. They are always either charging or discharging. When a battery is supplying current to accessories or to the starter, it is said to be discharging. When the engine is running at sufficient speed, the generator carries the electrical load and charges the battery, and both are said to be charging.

A battery is discharging when:

- The engine is not running (parasitic loads or self-discharging)
- The engine is running at a low rpm under conditions of high electrical demand
- There is a fault in the charging system

A battery that is nearly or completely discharged is commonly said to be “dead,” “flat,” or “run down.” A battery in this condition will need to be recharged to full capacity in order to provide proper service. However, even though a generator will charge a battery, it is not designed to be a “battery charger.” Requiring a generator to recharge a completely dead battery may cause overheating and damage to the generator.



Complete Discharge:

Completely discharging an automotive battery in good condition does not necessarily ruin it, but it may shorten the life of the battery.

Unlike “**deep cycle**” batteries used in some RV and marine applications, an automotive battery is designed to remain at or near a full state of charge, and not to be completely discharged.

BATTERY CONSTRUCTION

A battery is made up of six individual cells, electrically connected in series to produce 12 Volts. Each battery cell contains an element made up of positive and negative plates, separators, and connecting straps.

Each plate consists of a stiff mesh grid of a lead alloy, coated with porous lead on the negative plates, and lead peroxide or lead dioxide on the positive plates. A strap of lead connects the negative plates to form a group, and another strap connects the positive plate group. On each end of the battery, the straps are extended to form battery terminals or posts. All of the plates are then submerged in an electrolyte solution.

Battery cells are housed in a durable, vented, plastic case, and have terminals on the top (“top post”) or side (side terminal). Many aftermarket batteries are equipped with both types of terminal arrangements.

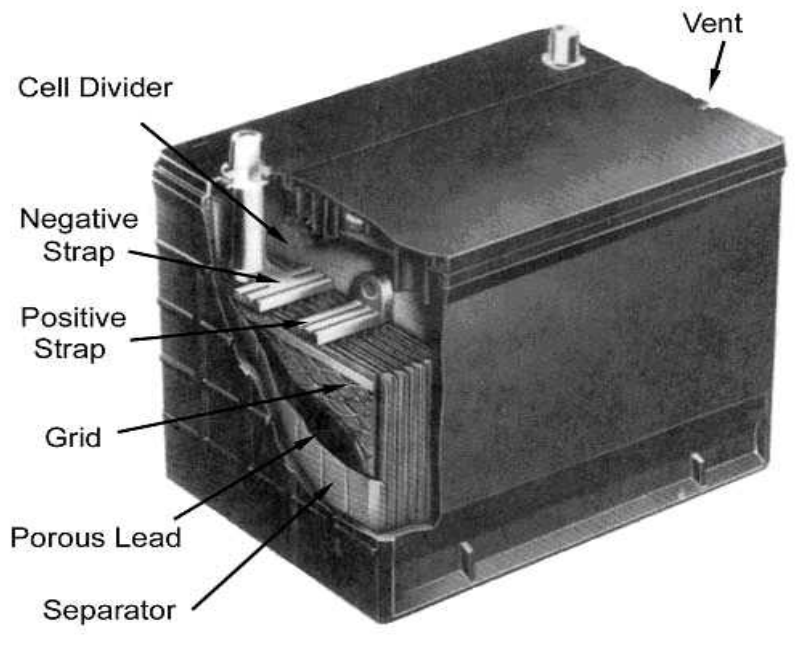
Negative battery cables are usually grounded to the engine block. On some applications, a small pigtail wire also connects the negative terminal to the vehicle body. The pigtail connects the body ground to the engine ground, and it must be connected for the starting and charging system to work properly.

Acid fumes and water vapor are formed and released during the chemical reactions of charging. This **gassing** causes the loss of electrolyte. Conventional batteries have removable vent caps, permitting the electrolyte levels to be checked and topped off, as well as to allow chemical testing. “Maintenance free” batteries are designed to minimize gassing and therefore not as accessible.

Between the positive and negative plates are separators, which are constructed to keep the plates from touching each other and shorting. The separators are porous, to allow electrolyte to circulate freely and permit the chemical process to take place.

Each battery cell is a separate unit that produces 2.1 volts. A “12 volt” automotive battery contains six cells connected in series for a total of 12.6 volts.

Cutaway of an Automotive Battery



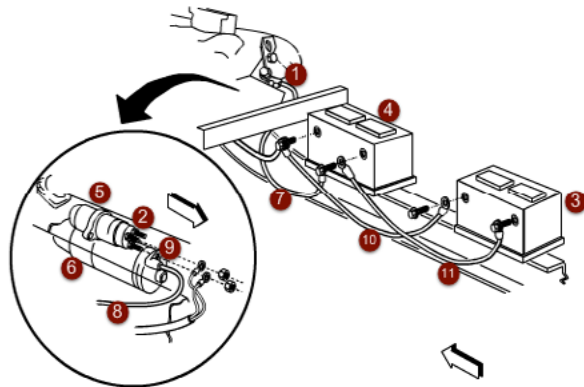
Terminal Covers

When installing batteries equipped for both top and side terminal arrangements, leave the plastic covers in place on the unused terminals to prevent corrosion or accidental shorting.

DUAL BATTERIES IN PARALLEL

1. Chassis Ground
2. Starter Solenoid Interconnect (OEM)
3. Secondary Battery (Diesel)
4. Battery
5. Starter Solenoid
6. Starter Motor
7. Negative Battery Cable
8. Positive Battery Cable
9. Connector
10. Secondary Positive Battery Cable (Diesel)
11. Secondary Negative Battery Cable (Diesel)

Parallel Battery Charging



Many diesel applications use two 12 volt batteries, connected in parallel (positive to positive and negative to negative), to provide the high current required to crank a diesel engine. Batteries connected in this fashion still supply 12 volts, but have twice the current capacity of a single battery.

MAINTENANCE-FREE BATTERIES

Many batteries are marketed as “Maintenance-Free,” meaning water should not need to be added during the life of the battery. The plates in these batteries tend to be slightly shorter to allow them to be submerged deeper in electrolyte.

Some Maintenance-Free batteries do not have removable covers or caps. Others do, to allow for the addition of water in case of overcharging or severe conditions, and to permit hydrometer testing. These batteries should not require additional water, but if the electrolyte can be checked, it should be checked approximately every six months.

Removable Caps

On some batteries, it may not be readily apparent that the cell covers are removable, so check carefully.

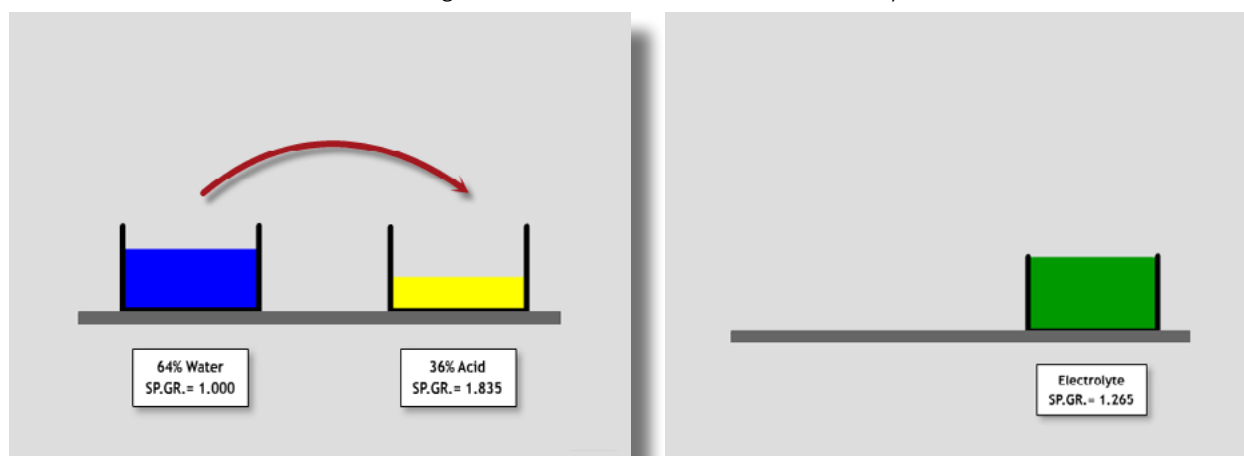
Top Post Battery With Vent Caps Removed



ELECTROLYTE AND SPECIFIC GRAVITY

Specific gravity is a measure of the density or weight of a fluid, when compared to water. Water has a specific gravity of 1.000, and pure sulfuric acid has a specific gravity of 1.835, meaning it is 1.835 times heavier than water. The electrolyte in batteries contains 64% water and 36% acid, which gives it a specific gravity of 1.265 to 1.270, when fully charged (this is often expressed as "twelve seventy," etc.). If the electrolyte is accessible, its specific gravity can be checked with a **hydrometer**. As a battery discharges, its electrolyte will contain less acid and more water, and a hydrometer will indicate the difference. For now, keep in mind that acid is heavier than water, and a discharged battery has more water in its electrolyte.

Adding Water and Sulfuric Acid to make Electrolyte



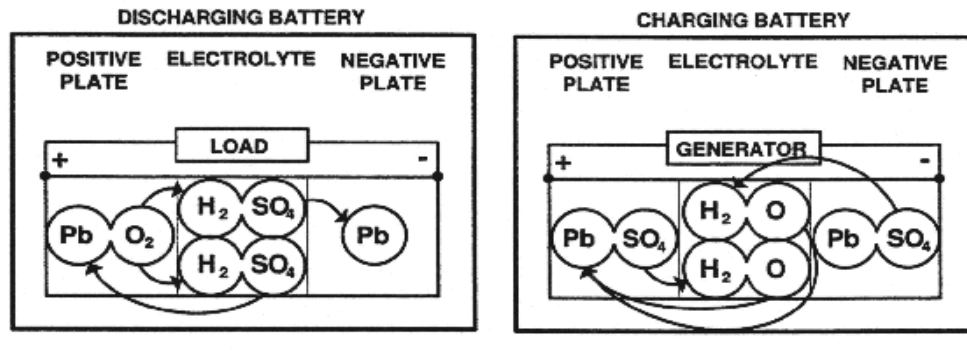
CHEMICAL REACTIONS WHILE DISCHARGING AND CHARGING

In a fully-charged battery, the active materials in the positive and negative plates are distinctly different in chemical composition, and the electrolyte has a high acid content. Positive plates contain a compound of lead and oxygen (PbO_2), while negative plates contain lead (Pb). The electrolyte is composed of water (H_2O) and sulfuric acid (H_2SO_4).

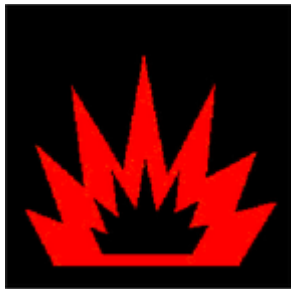
As a battery begins to discharge, the composition of the plates becomes more similar, and the water content of the electrolyte increases. Lead sulfate (PbSO_4) is formed on both the positive and negative plates, trapping the oxygen and sulfur, and leaving water molecules behind (left side of illustration). The voltage potential of a battery is dependent on the dissimilarity of the active materials in the positive and negative plates. As the lead sulfate content in the plates increases, the voltage and available current decreases.

This process is reversed when charging the battery. Current applied to the battery causes the lead sulfate residing on the plates to release its oxygen into the electrolyte. This release increases the acid content of the electrolyte, and returns the plates to their original compositions (right side of illustration).

Charging and Discharging Processes



BATTERY SAFETY



There are important safety concerns to keep in mind when working on or around automotive batteries. **Batteries can explode, and have enough power to arc weld.** Always respect the power of a battery, even a “dead” battery. **The sulfuric acid in electrolyte is extremely corrosive, and can cause severe chemical burns to the skin and eyes.** It will also damage painted surfaces and many other materials, including clothing. Always wear approved **safety glasses** when working around batteries and the use of **rubber gloves** is recommended when working with electrolyte.

Batteries can explode!

The sulfuric acid in electrolyte is extremely corrosive. Always wear approved safety glasses. The use of rubber gloves is recommended when working with electrolyte.

You should know the locations of all fire extinguishers and the First Aid Kit. First Aid Kits should contain a bottle of sterile, acid-neutralizing eyewash. Larger facilities often have an emergency shower and eyewash station located in the battery storage and service area.

Batteries release explosive hydrogen and oxygen gasses. A battery can explode, rupture its case, and spray acid in all directions. As such, you should always avoid creating sparks around a battery.

The following guidelines will help to reduce the chance of arcing or sparks:

- The ground terminal of a battery should always be disconnected **first** and reconnected **last**.
- Connect battery chargers to a battery **before** plugging in the charger.
- When jump-starting a vehicle, always follow the proper procedure. **Do not** connect the jumper cable to the negative battery terminal of the vehicle you are jump-starting! The correct procedure to follow when jump-starting will be presented later in this section.
- Do not attempt to charge, jump-start, or load test a battery with a broken or loose post, a cracked case, or one in which the electrolyte is frozen.

Proper Removal of a Ground Cable



Never hammer on a battery terminal or cable end, or attempt to remove a cable by prying.

Accidentally shorting the positive battery terminal, or any system voltage source, to ground with a tool or metal object can cause severe burns. Metal jewelry can be heated to its melting point in seconds. In addition, even a brief short of this nature can damage the PCM and other electronic components.

Never hammer on a battery terminal or cable end, or attempt to remove a cable by prying. To avoid damage to the battery or terminals, and possible personal injury, use a clamp spreading tool if the clamp doesn't seat at the bottom of the post. Also, a proper cable clamp puller should be used to remove stubborn clamps. Avoid contact with the white, flaky, or powdery corrosion that builds up around battery terminals and trays. This substance is sulfate and/or sulfide; it is corrosive and can cause chemical burns.

CAUTION: Always follow all general safety guidelines for servicing motor vehicles with regard to adequate ventilation, working around hot or moving parts, proper use of the parking brake, gear selector, wheel blocks, and disabling fuel or ignition systems. Refer to the equipment User's Manual and/or vehicle Service Manual for the applicable procedures.

Cold temperatures reduce a battery's available power.

TEMPERATURE, EFFICIENCY, AND RATINGS

BATTERY TEMPERATURE AND EFFICIENCY

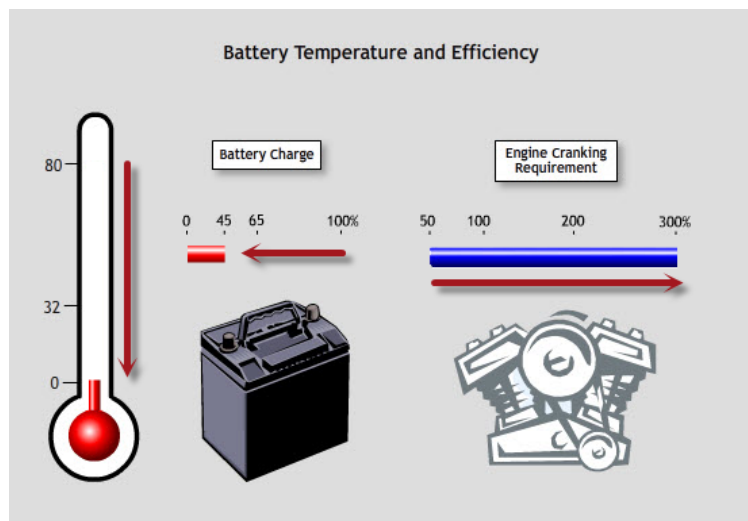
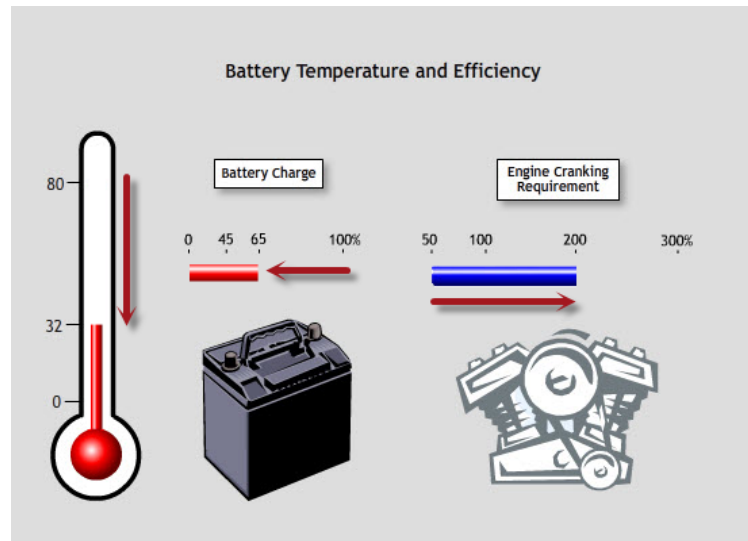
As temperatures fall, chemical reactions in a battery are slowed, and available power is reduced. At the same time, the current required by the starter to crank the engine increases, due to the thickening of the motor oil. Some examples of Temperature vs. Available Power

- At 80° F, 100 percent of a battery's starting power is available
- At 32° F, 65 percent of a battery's power is available, but current draw may be increased to 200 percent of normal
- At 0° F, 45 percent of a battery's power is available, but the starting power required may be 300 percent of normal
- At -20° F, only about 20 percent of a battery's power is available, while the starting power required can be more than 300 percent of normal

At this point, it should be obvious how important it is to have clean, tight connections and a fully charged battery in cold weather. Keep in mind that cold temperatures have the same effect on charging rates, that is, it takes longer to recharge a battery in cold temperatures.

Excessive heat also has an adverse effect on batteries as they will self-discharge faster in a hot environment. In addition, higher-compression engines require more current to start when they are hot.

Cold temperatures reduce a battery's available power.



BATTERY RATINGS

Cold Cranking Amps (CCA)

The Cold Cranking Amps rating indicates how much current (in amps) a battery can provide for 30 seconds at 0° F, while maintaining a minimum terminal voltage of at least 7.2 volts. This is the most important rating of a battery and it is used both in application specifications and in battery testing. The Cold Cranking rating is usually provided on a label or stamped into the battery case. Ratings from 350 CCA to 1000 CCA are common. The higher the number, the more powerful the battery, and the longer it will take to recharge.

The CCA rating is the most important rating of a battery.

Ampere-Hour Rating (AH)

This rating has been largely replaced by the other ratings, but is still sometimes used to calculate recharging times. The Ampere-Hour rating is a measurement of how much current a battery can produce for 20 hours at 80° F without the voltage dropping below 10.5 volts.

CHAPTER 2: POWER LOSS

HOW BATTERIES LOSE POWER

Several factors contribute to the discharging or weakening of a battery. These factors may include:

- Normal aging
- Overcharging or undercharging
- Parasitic loads and phantom drains
- Self-discharging
- Inoperative or missing hold-downs

NORMAL AGING

Any lead-acid battery will eventually wear out, due to normal cycling, overcharging, or undercharging.

A new battery that has never been in service has not yet developed its full power potential, although normal cycling soon brings the battery to its capacity.

Load testing a new battery at its rated capacity may result in false test failures.

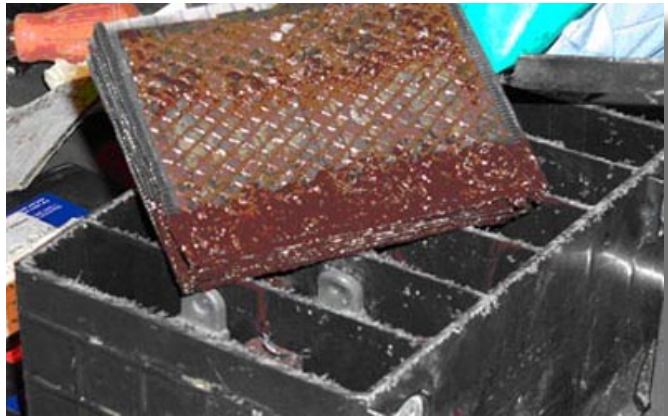
The voltage difference between cells in a new battery is zero or negligible. As a battery ages, the voltage difference increases. When the voltage difference reaches .05 volts between cells, the battery must be replaced since the cell with the lowest voltage will drain the other cells.

Years of cycling will ultimately take their toll on any battery. During cycling, small amounts of the active material on the positive plates are shed and fall to the bottom of the battery. If the sediment at the bottom of the battery builds up enough to connect the positive plates to the negative plates, a shorted cell will result.

OVERCHARGING

Overcharging, either from a vehicle's charging system or an external battery charger, speeds the shedding of plate materials which shortens battery life. Excessive gassing also carries water away from the electrolyte. In a sealed battery, the water cannot be replaced and the battery will fail prematurely. In a conventional battery the water can be replaced, but if the water level is far enough below the tops of the plates they can become dry, hard, chemically inactive.

Overcharged Lead Plates from One Cell of a Battery and Shedding of Plate Material

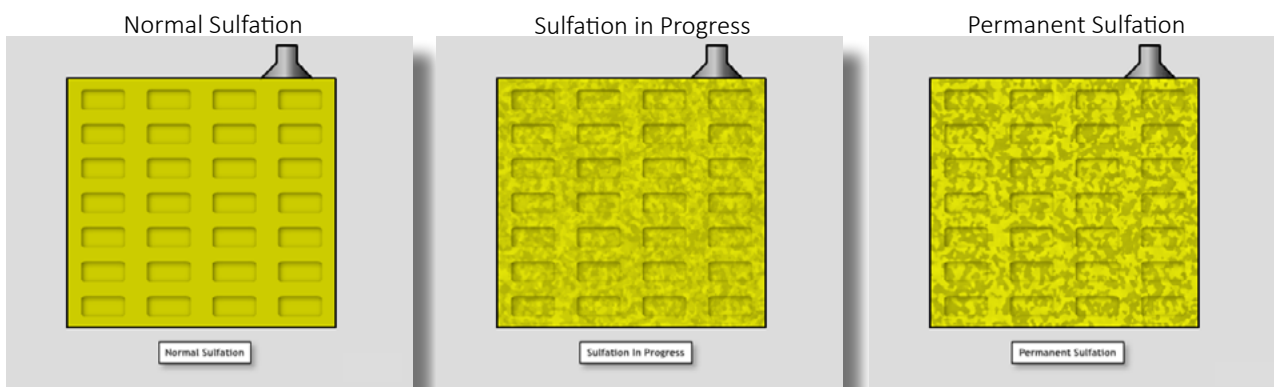


Overcharging also promotes corrosion on the plates, and may cause the battery to overheat. Severe overcharging can cause a battery to swell, puffing the ends out noticeably. A strong acidic or sulfurous smell may also be noticed.

Use care when working around a battery that has been overcharged as an overflow or residue of concentrated electrolyte is likely to be present. The battery tray and hold down should be cleaned and treated to prevent deterioration. A mixture of baking soda and water, or a commercially available treatment, are effective for this purpose.

UNDERCHARGING AND THE RESULT: A SULFATED BATTERY

A battery that is less than fully charged is obviously not storing its maximum capacity of energy. More importantly, it will be permanently damaged if left in this condition very long.



Batteries can be permanently damaged when stored without a full charge. This and other charging factors can lead to sulfation of the battery.

A battery that remains in a discharged condition for longer than approximately 30 days will begin to sulfate. Sulfating occurs when the lead sulfate on the plates crystallizes, becoming dense and hard, and difficult to break down. If the process has not gone too far, a battery may be restored to a serviceable condition by recharging at a reduced rate. A long, slow charge at half the normal rate may succeed in recharging the battery. A battery in this condition will not accept a normal charging rate and will simply overheat.

In the same manner, a battery that remains in service in a partially charged condition, due to poor connections, abnormally high electrical demands, or a low charging rate, will become partially sulfated. As a result, battery performance will be diminished which will result in premature failure.

PARASITIC LOADS

In modern vehicles, batteries are constantly being discharged by very small current loads needed to power the memory circuits of electrical devices such as Electronic Control Modules and digital clocks. These are known as parasitic loads, because the circuits involved are always connected to the battery and continue to operate, even when the ignition is turned off. One or more control modules may, at some time, exhibit a failure mode that causes a high parasitic drain. The total parasitic draw for a particular vehicle will vary according to the level of electrical equipment on the automobile. For example, a fully equipped luxury car will normally have a much greater parasitic draw than an economy car. The following table shows examples of typical parasitic draws, measured in milliamps (mA), for various automotive components.

Some special applications may have a high parasitic draw - up to .06 amps or 60 milliamps.

Parasitic draw can be measured by connecting an ammeter in series with the battery.

Current draw from 5 to 30 milliamps is typically considered to be a normal parasitic draw, however, some applications such as luxury cars, may have a normal parasitic load of up to 60 milliamps.

To properly test for parasitic loads with an ammeter in series requires a special tool typically called a Parasitic Load Tool. The tool is installed between the terminal of a battery (usually ground) and the cable that normally connects to that terminal. Once in place, it will maintain continuity through the system until you are ready to take readings. This procedure is necessary because current drain may not occur after the battery is disconnected to install an ammeter. Cycling the ignition key to the RUN and then to the OFF position may cause the drain to recur, but there may be drains that will not recur unless the vehicle systems are reactivated on a road test. **The key must not be turned to the START position with an ammeter installed, otherwise the meter fuse may blow.** The special tool will also allow the vehicle to be driven, if needed, to insure that all systems are ready for testing.

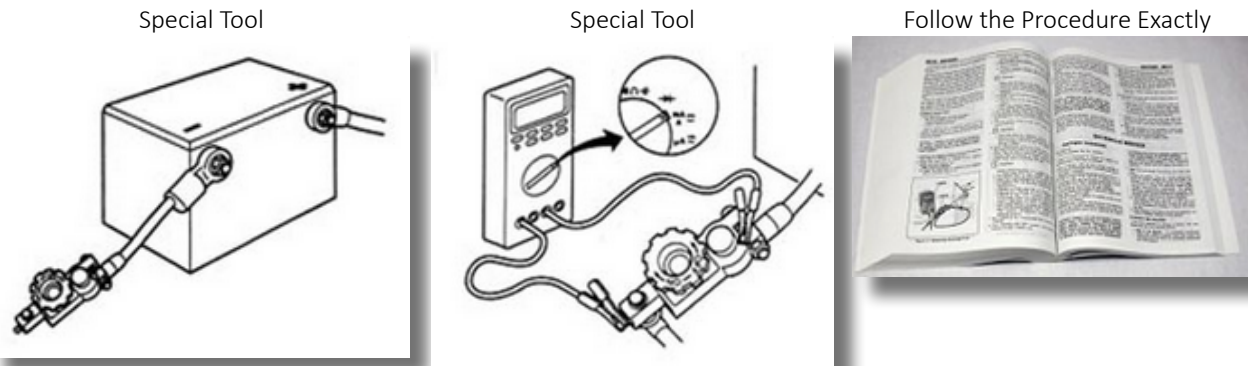
COMPONENT	TYPICAL MILLIAMPS (mA) DRAW
Adaptive Lamp Motor	0.5
Blower Control Module	1.0
ELC (After 7 Minute Time Out)	0 to 1.0 max
Electronic Brake (& Traction) Control Module After 4 Minute Time Out	1.0
Generator	2.0
Heated Seat Control Module (LH/RH)	0.5
HVAC Programmer	0.5
Instrument Panel	
Digital Cluster	
Gages Cluster	4.0
4.0	
Lamp Control Module	0.5
Oil Level Module	0 to 0.1 max
PCM	5.0
Pull-Down Unit	1.0
RAC Module	
(Retained Accessory Power)	
(Illuminated Entry)	
(Remote Keyless Entry)	0 to 3.8 max
Radio	
CD	7.0
1.8	

When using a hand-held DVOM, be sure to use the highest amperage range available to prevent blowing the meter's fuse. Furthermore, be sure not to cause a current overload by opening a door (and activating the courtesy lights), or by any other means, with the Load Tool in the OFF position. After testing is complete, turn the special Load Tool to the ON position (continuity through battery cable) to guard against current overload, and never turn the tool to the **OFF position with the vehicle's engine running**. To do so could damage the vehicle's electrical system.

Using a memory saver is helpful for retaining programmed information.

Any time a battery is disconnected from the system, it is a good idea to use a **memory saver** to avoid losing information such as radio settings, clock settings, and ECM adaptive learn values. A Memory Saver device will plug into a vehicle's cigarette lighter receptacle, and provide voltage to the system while the battery is disconnected. Failure to retain those memories could require that you conduct a number of time-consuming Relearn Procedures after fixing the Parasitic Drain problem.

Service manuals provide the procedures for Battery Electrical Drain/Parasitic Load testing using an ammeter in series with the Special Load Tool. Follow the procedure exactly to avoid damage to the vehicle or meter.



PHANTOM DRAINS

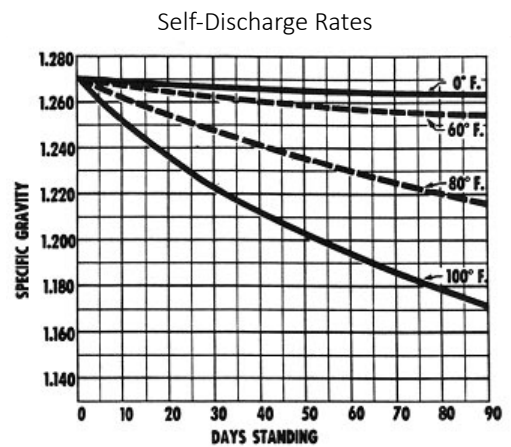
A phantom drain is an abnormal parasitic load caused by a component such as a trunk or glove box light bulb that stays on all the time. This can be caused by misadjustment, a bad switch, or a short. A phantom drain such as this can draw several amps, and will discharge a battery much faster than a normal parasitic load.

Stored batteries self-discharge over time.

Once it has been established that there is an excessive parasitic load, the problem can be isolated by pulling fuses, or disabling circuits, until the circuit causing the drain is identified.

SELF-DISCHARGING

Anytime a battery is stored, a slow chemical reaction will cause it to self-discharge. After just one month, a significant amount of power will already be lost, and after four months of storage at 80° F, a battery can be as much as 50% discharged. For this reason, stored batteries need to be recharged periodically, before they become significantly discharged and permanently damaged.



SELF-DISCHARGE RATES

Cold temperatures, during storage, will slow the rate of self-discharge. In fact, a battery can be stored at 0° F for an extended period without self-discharging at all.

Contrary to popular myth, setting a battery on a cement or concrete floor has no effect on the rate of self-discharge.

CORROSION

Corrosion forms on and around the battery cable ends, between the cable ends, on the battery terminals, and inside the battery. The positive terminal is particularly susceptible to corrosion build-up, which can creep down the cable where it is not visible. Look for a swollen cable or discolored insulation.

The positive terminal of the battery to the right corroded so badly it became fused to the cable and broke. Note the internal corrosion on the strap and plates.

An Internal Look at a Severely Corroded Battery



When corrosion builds up between the points of contact, it creates excessive resistance to current flow and can prevent starting and proper charging. This type of bad connection may allow small amounts of current to pass, but not the larger current needed for starting.

Note: Avoid replacing corroded cable ends with “universal” clamps that splice to the end of the cable. These clamps are especially susceptible to corrosion at the splice point, and they also tend to loosen, which causes a poor connection. If a battery cable has failed due to corrosion, or any other type of damage, replace the entire cable.

"Universal" Clamps are Not Recommended



BATTERY TESTING AND SERVICE

There are several methods for determining the condition of a battery. Any battery that fails these tests can often be condemned immediately.

Numerous Electronic Battery Testers are available that will run a series of tests on automotive batteries. These testers are simple to use and can determine the condition of a battery without having to recharge it first. However, electronic testers may also return a result of “Charge and Retest.” This message indicates that the battery is insufficiently charged to be tested.

Note: A battery must be fully charged in order to be accurately ‘Load Tested’.

INITIAL ASSESSMENT

Battery testing begins with a visual inspection of the battery, connections, and cables. A battery with a cracked case, broken or loose posts, or a sealed battery with insufficient electrolyte must be replaced. **Do not even attempt to test a battery with these kinds of obvious problems.** During your visual inspection, also note the general condition and age of the battery.

BATTERY LIFE

Despite marketing claims, many batteries do not last the length of their extended, prorated warranty period. The normal lifetime of most batteries is from three to five years.

The date of manufacture is stamped into the battery case, and/or punched out of the label.

Most manufacturers use a date code with a letter corresponding to the month, and a number corresponding to the last digit of the year. For example, a date code of “A-1” means the battery was produced in January of 2001.

OPEN CIRCUIT VOLTAGE

Open Circuit Voltage is the voltage in a battery without any loads connected. Checking the Open Circuit Voltage will give you a quick check of a battery’s state of charge.

Remove the surface charge by turning on the headlights for one minute, then connect a voltmeter across the battery. The reading should be 12.6 volts or more for a fully charged battery.

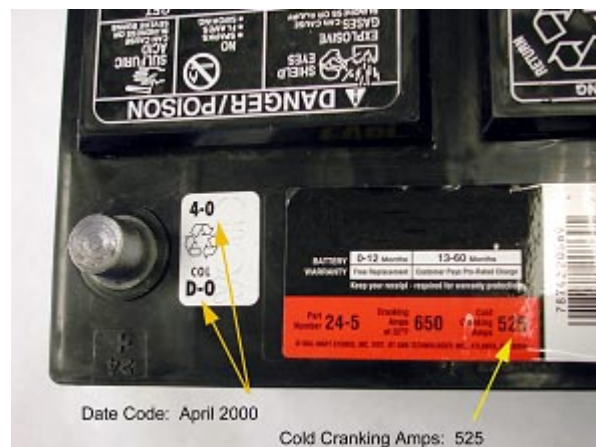
A weak or discharged battery is often a symptom of a problem elsewhere in the vehicle. Regardless of the testing method used, be sure the battery is bad, and not merely discharged, before recommending a replacement.

HYDROMETER TESTING

Hydrometers are used to measure the specific gravity of electrolyte. A hydrometer that has both a single float and a numerically graduated scale is typically recommended. This type of hydrometer also tends to have a built-in thermometer to make necessary temperature corrections. Smaller hydrometers that use multiple, colored balls are generally not as accurate or reliable and should be avoided. The hydrometer pictured here is a Snap-on BB4A.

Batteries are labeled with a date code.

Battery with Obvious Leakage Problem



Approximately 40% of condemned batteries are fit for recharging and continued service.



This chart shows the charge level and voltage for specific gravity readings taken with a hydrometer.

Charge Level, Specific Gravity, and Voltage

Charge Level	Specific Gravity	Voltage (12)	Voltage (6)
100%	1.270	12.60	6.3
75%	1.225	12.45	6.2
50%	1.190	12.24	6.1
25%	1.155	12.06	6.0
Discharged	1.120	11.89	6.0

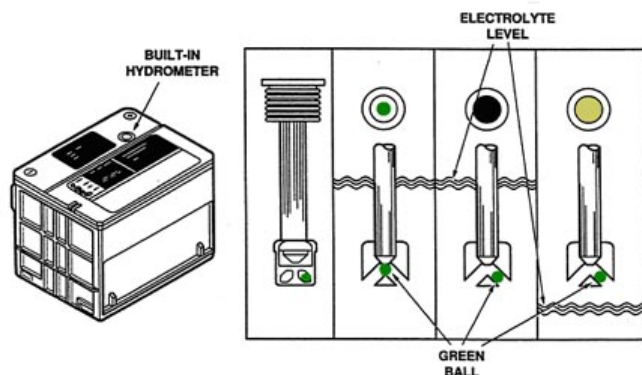
BUILT-IN HYDROMETERS

Some maintenance-free batteries have been equipped with a built-in hydrometer. These hydrometers, however, indicate the state of charge in only one cell of the battery, and therefore have limited diagnostic value. As such, those batteries should be tested in the same manner as conventional ones, and the built-in hydrometer ignored.

Keep in mind that a built-in hydrometer indicates the state of charge for only one cell.

Load testing, charging, or jump-starting a battery with insufficient electrolyte, or a loose post, poses an explosion risk!

Built-in Hydrometer



CONVENTIONAL HYDROMETERS

A conventional hydrometer works like an eyedropper or a turkey-baster. The battery caps are removed, and the bulb is squeezed before immersing the pick-up tube in the electrolyte. As the bulb is gently released, electrolyte fills the tube, and the float rises to a certain level, indicating the state of charge of that cell. The reading should be taken and noted, and compared to the checks of each of the remaining cells.

The float will rise higher in a fully charged battery because the electrolyte is heavier. The float will rise less or not at all in a discharged battery.

Conventional Hydrometer

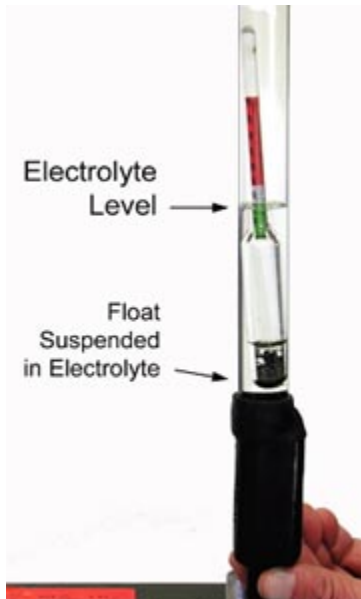


Here are some guidelines for using a hydrometer:

- Remember – electrolyte is acidic. Be careful, and avoid allowing the hydrometer to drip. Release the electrolyte back into the battery **slowly**.
- The float should be lifted free, and not touch the sides or bottom of the barrel.
- Take the reading with your eye level to the surface of the fluid.
- If there is a difference of .050 between the lowest and highest readings, or if all readings are below 1.225, recharge the battery.
- If, after recharging the battery, there is still a .050 difference between the highest and lowest reading, or there is still a reading below 1.225, replace the battery.
- If the battery passes this test, proceed with a load test.

Frequently, five cells will show good readings in the 1.250 to 1.270 range, with one cell showing a very low reading or not moving the float at all. Commonly called a "dead cell," this usually indicates a short. No further testing is necessary; the battery must be replaced.

Drawing Electrolyte into the Hydrometer



Buoyant Float



Notice how buoyant the float is in this fully-charged battery.

Buoyant Float



The next cell is checked, and also reads good: 1.265. But...

The float will rise higher in a fully charged battery because the electrolyte is heavier. The float will rise less or not at all in a discharged battery.

Keep in mind that hydrometer testing must be done while correcting for outside temperature.

Last Cell Doesn't Float



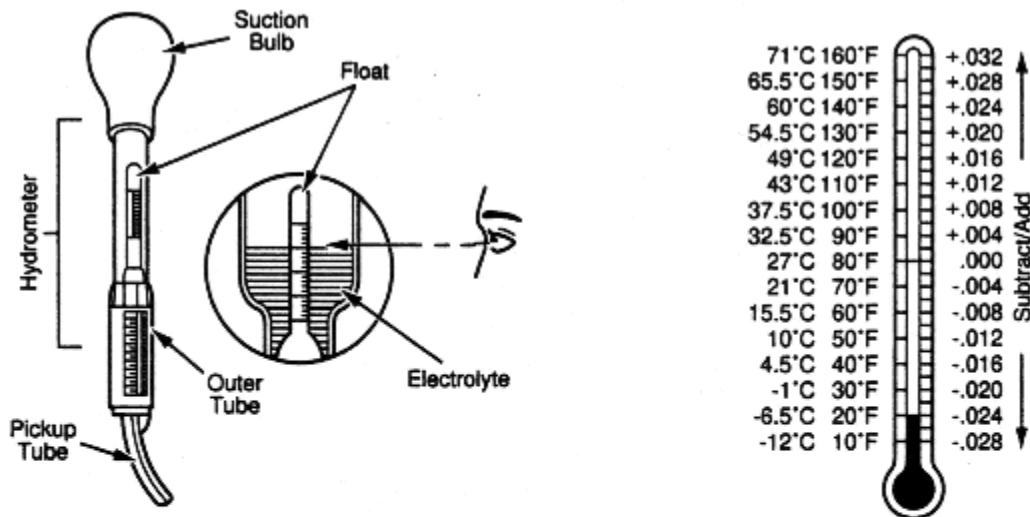
The last cell doesn't move the float at all.

Reading Below 1.100



The reading is below 1.100. When compared to the other readings, this indicates a bad cell.

Hydrometer and Temperature Correction



Example:

Electrolyte Temperature 40°F
 Hydrometer Reading 1.250
 Subtract Specific Gravity -0.016
 Corrected Specific Gravity Equals 1.234

Example:

Electrolyte Temperature 100°F
 Hydrometer Reading 1.240
 Add Specific Gravity +0.008
 Corrected Specific Gravity Equals 1.248

A Fully Charged Battery Has a Specific Gravity of 1.270.

CHAPTER 3: CHARGING AND REPLACEMENT

LOAD TESTING

Load testing a battery is an effective way to test its actual performance ability. During a Load Test, a specified current load is applied to the battery while its voltage is monitored. If the battery's voltage drops below a specified value, it fails the test. The battery should then be recharged, and retested, and replaced if it fails a second time.

For a load test to produce an accurate result, the battery must be fully, or near fully, charged.

To properly load test a battery, testing equipment that can apply a load of $\frac{1}{2}$ the battery's CCA is needed. This load value usually falls in the 200 to 500 amp range. The machine should also be equipped with a voltmeter, ammeter, heavy gauge clamps, and a load control knob. During testing, a load will be applied to the battery using a carbon pile, which is adjusted using the Load Control Knob. Many different types of Battery/Starting/Charging system testers are available on the market, and most are operated in a similar manner. Always refer to the manufacturer's instructions for proper use.

Volt-Amp Tester (VAT)/VAT



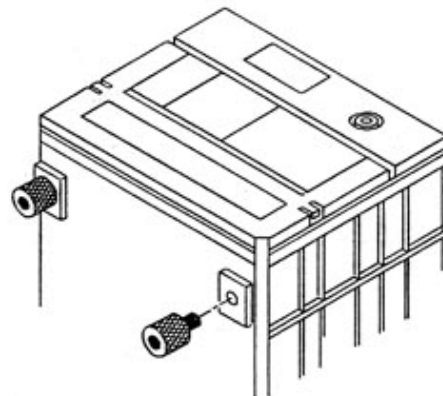
ADAPTERS

Adapters are screw-in connectors that allow Side Terminal batteries to be tested using standard Load Testing equipment. When testing, use only the side terminal adapters that are provided with the equipment and follow the equipment manufacturer's instructions regarding connection adapters and procedures.

Acceptable adapters are usually brass or steel.

Do not substitute standard bolts for proper adapters as they may damage the battery terminals.

Also, do not use adapters that consist of a post of lead poured around a steel stud that screw into the battery terminal. These adapters are a common cause of false test results.



Do not attempt to load test a battery with insufficient electrolyte. Observe all battery safety cautions.

THE LOAD TEST

To perform a Load Test:

1. Verify that the battery is sufficiently charged for testing by observing the hydrometer eye or performing a hydrometer check. An alternate method is to perform step 4 and then check for open circuit battery voltage of at least 12.4 volts.
2. Connect the test machine heavy clamps to the battery (Red to Positive and Black to Negative). If the battery is in a vehicle, connect to the battery clamps and rock the clamps back and forth to ensure a good “bite” on the terminals. If not in a vehicle, install the adapters (side terminal applications) and connect directly to the terminals or adapters.
3. Follow the equipment instructions for connecting the inductive amp probe. This usually involves installing the probe around the negative tester cable, with the probe arrow pointing in the direction of current flow (towards the machine). The instructions may also direct you to zero the ammeter.
4. Remove the surface charge by applying a 100 amp load for 10 seconds. Wait 15 seconds to let the battery recover before testing.
5. Apply a load of $\frac{1}{2}$ the battery’s CCA rating, using the tester’s carbon pile.
6. After 15 seconds, note the voltage and remove the load.
7. Measure or estimate the battery temperature and compare the voltage reading to the appropriate value on the chart. At 70° F, the voltage should not drop below 9.6 volts.

Minimum Voltages

VOLTAGE / TEMPERATURE TABLE		
Minimum Voltage	Temperature	
	'F	'C
9.6	70	21
9.5	60	16
9.4	50	10
9.3	40	4
9.1	30	- 1
8.9	20	- 7
8.7	10	- 12
8.5	0	- 18

USEFUL QUICK-CHECKS

To check for electrical leakage across the surface of the battery, touch the positive probe of a voltmeter to the surface of the battery between the terminals, and the negative probe to the negative battery terminal.

Checking for Electrical Leakage



Checking for Poor Connection



Any voltage reading indicates electrical leakage. This test is most useful with top post batteries.

To check for a poor connection between the battery post and the cable clamp, measure the voltage drop. First, disable the fuel system to prevent the engine from starting. Then, probe the top of the positive post with the positive probe, and probe the body of the clamp with the negative probe, while cranking the engine. A reading greater than .2 volts indicates the terminal and cable end need cleaning.

BATTERY CHARGERS

USING BATTERY CHARGERS

A discharged battery that is otherwise good can be restored to a charged condition with the use of a Battery Charger. The charger forces current through the battery and replaces the energy that has been drained.

The time required to bring a battery to full capacity depends on several factors:

- The condition of the battery
- State of charge of the battery
- Battery temperature
- Battery size and rating
- Rate of the charger/rate selected

Recharging at a lower rate is preferable to recharging at a higher rate.

A slow charge at a low rate of about 10 amps provides better results and less wear on the battery than a fast charge at high amperage. This is especially true of batteries that have been in service for an extended period. Generally, the lowest rate that time permits should be used.

BATTERY CONDITION

A battery that is sulfated will not accept a high current and attempting to fast-charge a sulfated battery will cause it to overheat. No battery should ever be allowed to reach a temperature of over 120° F, or a voltage of over 15.5 volts, during charging.

When charging a partially sulfated battery, a lower charging rate may allow the sulfate to break down, permitting the battery to be recharged and returned to service.

Similarly, a battery that is severely discharged will not accept a high current. As a result, a completely discharged battery will take more than twice as long to charge as a half-charged battery of the same size. However, as a battery's state of charge increases, it will accept more current, and the remaining time required for recharging will be reduced.

A completely discharged battery may not have sufficient voltage to activate the polarity protection circuits on some chargers. These circuits are designed to prevent accidentally reversing the charger leads at the battery, and usually require at least two volts from the battery before they can operate properly. Carefully follow the manufacturer's instructions on bypassing or overriding this circuitry when charging a completely drained battery.

Using a high charging rate to fast-charge a battery will not damage a battery that is in **good condition**; however, it will not bring the battery to as full a state of charge as a slower rate will. To recharge a severely discharged battery in a reasonably short period of time, start with a high charging rate of around 20 to 35 amps. As time permits, switch to a lower charging rate of around 5 to 10 amps to finish. Higher beginning charge rates may be used, but they do not promote extended battery life. Some chargers automatically reduce the charging rate as the battery's state of charge increases.

BATTERY TEMPERATURE

We have said previously that cold temperatures slow the chemical reactions inside batteries, which increases the time required for recharging. The current accepted by a cold battery will therefore be very low at first but, as the battery warms up, it will accept a higher charging current. As such, a deeply discharged battery may take quite a long time to recharge, if it is charged in cold temperatures. A temperature of 70° to 80° F (21° to 27° C) is typically considered optimal.

BATTERY SIZE AND RATING

Larger, higher-rated batteries will take longer to recharge than lower rated ones. In fact, a battery with a high CCA rating may take more than twice as long to recharge as one with a low CCA rating. The reason is that the battery with the higher rating is denser, and has more plate material.

CHARGING RATE

The more amps a charger can supply, the faster it can recharge a battery. Recharge times for chargers are typically measured in ampere-hours (AH). Notice the differences in this comparison of recharging times for a battery that has been discharged at a rate of 20 amps for one hour (20 ampere-hours).

- A charging rate of 20 amps will recharge the battery in one hour
 $20 \text{ amperes} \times 1 \text{ hour} = 20 \text{ ampere hours}$
- A charging rate of 10 amps will recharge the battery in two hours
 $10 \text{ amperes} \times 2 \text{ hours} = 20 \text{ ampere hours}$
- A charging rate of 5 amps will recharge the battery in 4 hours
 $5 \text{ amperes} \times 4 \text{ hours} = 20 \text{ ampere hours}$

When fast charging a battery at a high rate (20 to 50 amps), to bring it to a serviceable level of charge in the fastest possible time, it must be checked frequently. Monitor the battery to insure that the terminal voltage never exceeds 15.5 volts, that electrolyte doesn't spew from the vent holes, and that it does not feel excessively hot.

Carefully monitor batteries when charging at a high rate.

BATTERY CHARGING

CHARGING A SINGLE BATTERY

Charging a single battery with a fast charger is a simple operation. First, ensure that there is sufficient electrolyte before charging the battery. Remove the cell caps (on non-sealed batteries), add clean distilled water to bring the electrolyte level to the bottom of the filler necks, then replace the caps.

- If the battery is out of the vehicle, install the appropriate adapters (side terminal batteries), as described in the section on Load Testing. If it is installed in the vehicle, ensure that the cable ends and battery terminals are clean and in good condition, and that the ignition is OFF.
- Considering the above factors, decide how long and at what rate to charge the battery.
- Ensure that the charger is unplugged, or turned OFF, before connecting the charger leads to the battery.
- Check the battery at least every hour for excessive heat or spewing of electrolyte. High charging rates require checking more frequently. After the battery is charged, recheck the electrolyte level and perform a Load Test.

THREE-MINUTE CHARGE TEST

The three-minute charge test, or “quick charge” test can be used to determine if a battery will accept a charge. A battery that fails this test usually has sulfated plates.

To perform a three-minute charge test, connect a battery charger as previously outlined. Connect and observe a voltmeter while charging the battery at a rate of 30 to 40 amps. If the voltage rises above 15.5 volts, replace the battery.

CHARGING MULTIPLE BATTERIES

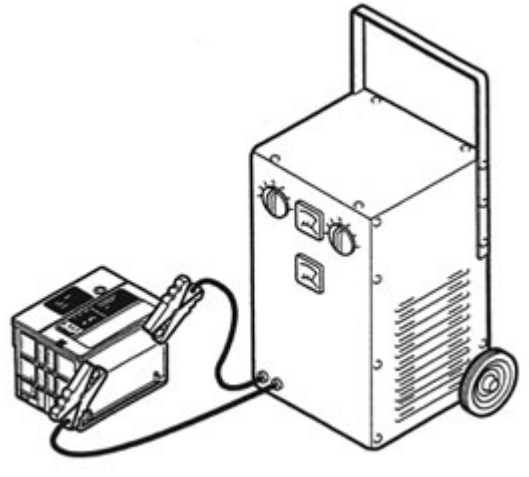
Larger service centers may have a battery charger for charging multiple batteries at the same time. These chargers are usually maintained at a low charging rate of three to ten amps per battery, and are used for slow, “trickle charging”. The charger and batteries are collectively referred to as the “**charging line**,” or “**charging rack**.” The charging line should be carefully monitored throughout the day.

Two different types of chargers can be used for group charging batteries. These are:

- Current-Limiting (constant current or series chargers)
- Voltage-Limiting (constant voltage or parallel chargers)

Series chargers have the batteries connected in a single row, so that each battery receives the same amount of current.

Charging a Single Battery



Parallel chargers have each of the batteries connected directly to the charger, so that each battery receives the same amount of voltage.

Regardless of which type of charger is used, the procedures outlined here must be followed closely to prevent undercharging, overcharging, or battery damage on the charging line.

SERIES CHARGING

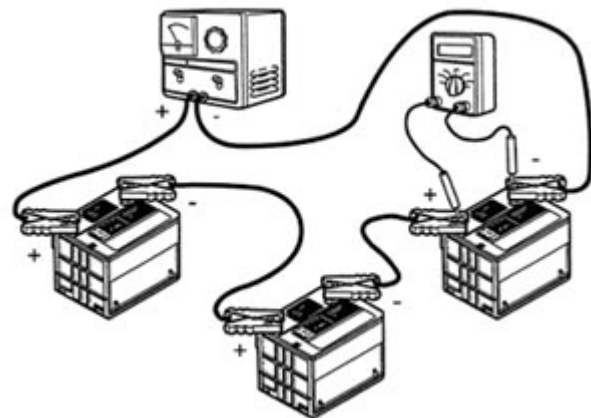
Batteries on a charging line may vary in age, capacity or size, state of charge, and type. **For this reason and other considerations, series charging is not recommended.** The procedure has been included for your information, and in case you are ever required to use a series charger.

Batteries on a series charger should be closely monitored for spewing, gassing, high temperature, or voltages greater than 15.5 volts.

To charge batteries in series:

- Connect all the batteries, negative terminal to positive terminal, using single jumper cables
- Connect the charger to the unused positive terminal on the first battery and the remaining negative terminal on the last battery to complete the series circuit, as shown in the illustration.
- Connect the charger to a power source
- Set the charger to maintain a charging rate of 5 to 10 amps
- Monitor each battery and the charging rate every 30 minutes
- Turn off the charger, and disconnect any recharged battery, when charging is complete

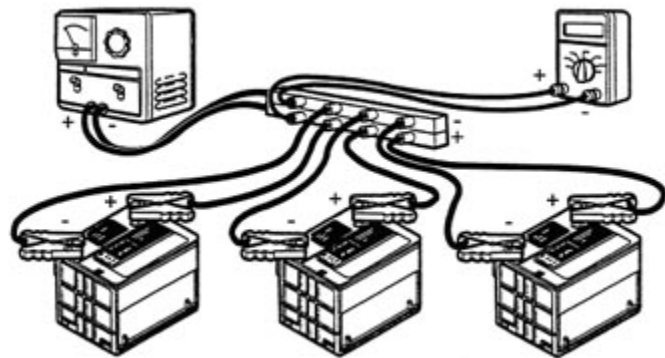
Series Charging



Parallel Charging

PARALLEL CHARGING

When charging batteries in parallel, the current rate is dependent on the voltage setting. Most parallel chargers have a number of switches that adjust the charging rate. The switches are adjusted to obtain the desired voltage, and the ammeter reading indicates the amount of current being accepted by the charging line.



To charge batteries in parallel:

- Connect all the batteries to the buss bars, positive terminals to the positive bar, and negative terminals to the negative bar, as shown.
- Connect the charger to a power source and turn it ON
- Adjust the voltage to the desired setting (between 14.2 and 15.5 volts)
- Monitor each battery every hour
- Disconnect any battery that has finished recharging. It is not necessary to turn the charger OFF as long as there is at least one battery on the line, however, the line voltage will increase as batteries are removed, so it will need to be monitored and possibly reduced

Parallel chargers rated at 300 amps are common.

If the bus bar clamps are normally connected to their respective bus bars when not in use, double-check for proper polarity before returning them to the bus bar. Crossing the polarity of the clamps can cause a fire and possible explosion.

Keep in mind that even if the charger is turned OFF, any batteries connected to the bus bars are connected electrically, and the line contains the amperage potential of all of the batteries combined!

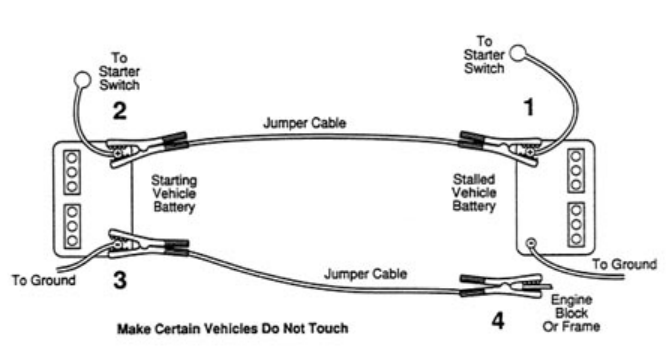
JUMP-STARTING

Always observe all safety precautions when jump-starting a vehicle. To jump-start a vehicle:

1. Set the Parking Brake in both vehicles and place the transmissions in Park, if the vehicle has an automatic transmission, or Neutral for vehicles with manual transmissions. Start the engine of the vehicle providing the jump.
2. Turn off the lights, heater, or other electrical loads.
3. Attach one end of the Red jumper cable to the **positive** terminal of the stalled vehicle battery, and the other end of the same cable to the **positive** terminal of the donor (good) vehicle battery (as shown).
4. Attach one end of the Black jumper cable to the negative terminal of the donor vehicle battery, and the other end of that cable to a ground at least 12 inches from the battery of the stalled vehicle.

This procedure is used in order to reduce the chance of a battery explosion since there is likely to be a spark when making the final connection. That spark is due to the difference in voltage between the two systems. If the spark occurs near a battery, it could ignite explosive gasses. Do not make the final connection to the negative battery terminal, to metal tubing, or anywhere gasoline fumes may be present.

Jumper Cable Hookup



Keep your face away from both batteries and always wear safety glasses.

BATTERY REPLACEMENT

REPLACING A BATTERY

Replacing a battery is typically a simple job although there are some things you need to keep in mind.

After installing a new battery, the vehicle's starting and charging system should be checked to ensure satisfactory performance from the battery.

Battery terminals are made of lead, a very soft metal, and are easy to damage. Listed here are the **torque specifications** for battery connections.

Terminal Type	Torque Measured in:		
	Pound / Inch	Pound / Foot	Newton Meters
Tapered terminal posts (SAE)	50 - 70 lb-in	4 - 6 lb-ft	5.4 - 8.1 N•m
Side terminals	90 - 180 lb-in	7.5 - 15 lb-ft	10.0 - 20.0 N•m
Stud terminals	120 - 180 lb-in	10 - 15 lb-ft	13.5 - 20.0 N•m

UNIT 2 STARTING SYSTEMS

The following topics are addressed in this unit:

STARTING SYSTEM OVERVIEW

- Starting System
- Motor Drive Mechanism
- Gear Reduction
- Starter Solenoids
- Reduction Starters
- Starting Circuit
- Current Draw and Torque

STARTING SYSTEM DIAGNOSIS AND SERVICE

- Starting System Diagnosis
- Testing
- Wires and Cables
- Abnormal Noises
- Starter Replacement and Repair

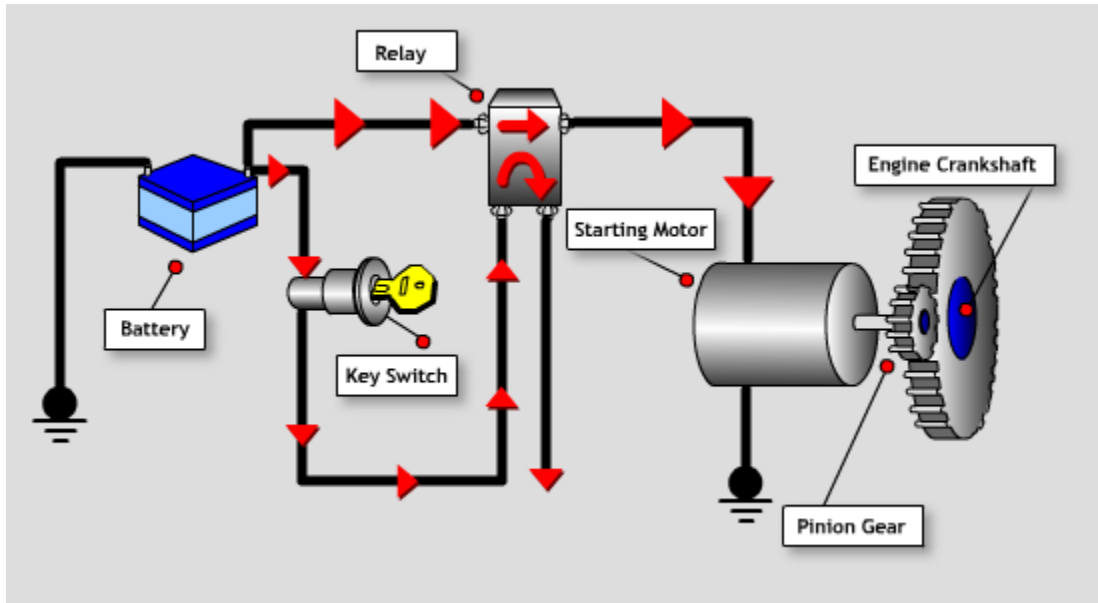
CHAPTER 1: STARTING SYSTEM OVERVIEW

STARTING SYSTEM

An automotive starting system uses power from one or more batteries to spin a cranking motor (starter). When the starting circuit is energized, a pinion gear mounted to the shaft of the cranking motor engages with teeth on the flywheel, and the engine is cranked for starting. The components involved in the starting system include:

- **Battery** – provides power to the cranking motor and Ignition system
- **Ignition Switch** – permits operator to control starting system operation
- **Starter Relay** – A high-current relay that connects the battery to the cranking motor.
- **Solenoid** – An electromagnetic device that provides the lateral movement which engages the pinion gear with the flywheel.
- **Starter** – A high-torque electric motor used for cranking the engine. Starters also include the drive mechanism for engaging the pinion gear with the flywheel.
- **Battery Cables**, wiring, starter relay, fusible links, etc.

When the ignition key is turned to the START position, a circuit to the Starter Relay Coil is completed to ground. That circuit current causes the solenoid contacts to close, completing the high current cranking motor's circuit to ground, and connecting the battery to the starter. The starting system circuit will be covered in more detail later, but first let's examine some starter engagement components.

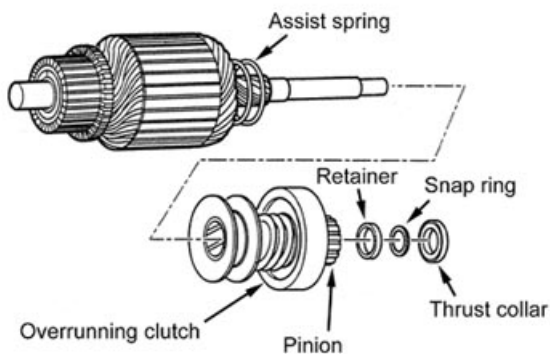


Note that in the system shown here, used on many Fords, there is no solenoid to engage the pinion with the flywheel. Rather, it is the spinning motion of the starter which moves the pinion gear by centrifugal force. Although the component that connects the high current to the starter is often (incorrectly) referred to as a solenoid, it is really just a high-current relay. It is not actually a true solenoid because it does not produce any linear movement.

MOTOR DRIVE MECHANISM

The motor drive mechanism is the component through which power is transmitted from the starter armature, to the engine flywheel, during cranking. The main components of the drive mechanism are the pinion gear and the overrunning clutch. These components work together to engage the pinion with the flywheel.

Typical Motor Drive Mechanism



Internal Starter Components



When the Ignition Key is held in the START position, voltage is applied to the starter motor. This applied power causes the pinion gear to push out and mesh with teeth on the flywheel, and it turns the armature. As the armature spins, it rotates the pinion gear. When the Ignition Key is released from the START position, a return spring disengages the pinion from the flywheel.

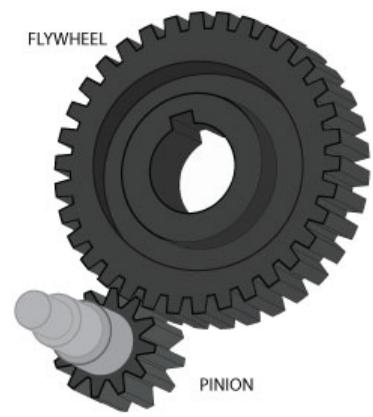
GEAR REDUCTION

PINION AND GEAR REDUCTION

Several different types of drive mechanisms are used on starting motors, but in all cases, gear reduction occurs between the pinion and the flywheel. The amount of gear reduction designed into an application is a balance between the torque required from the starter, and the cranking speed required for reliable engine starting.

Proper disengagement of the pinion is critical to cranking motor operation. Because of the gear ratios, if the pinion were to remain engaged after the engine started, the flywheel would drive the armature at speeds that could damage the cranking motor. This is where the overrunning clutch comes into play. When the flywheel begins to drive the pinion, the overrunning (or “one way”) clutch freewheels to prevent damage to the starter.

Pinion to Flywheel Engagement

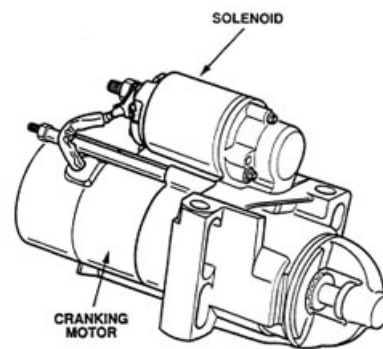


STARTER SOLENOIDS

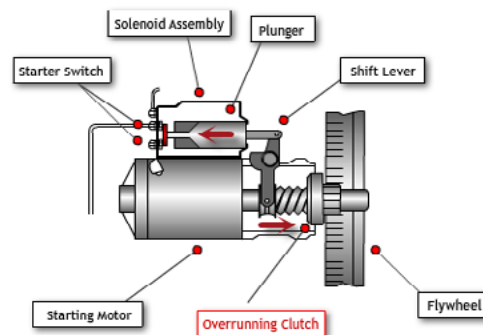
The starter-mounted solenoid is a powerful electromagnetic coil that is designed to both activate the pinion gear and supply power to the starter. As the ignition switch is turned to the START position, a relatively low amount of current energizes the solenoid, causing it to draw a plunger into itself and hold it there.

As the magnetic field created by the coil pulls the plunger in, a shift lever moves the pinion outward toward the flywheel. When the plunger reaches the end of its throw, a contact disk in the solenoid's opposite end, is pushed into firm contact with two terminals. One terminal is connected to the battery and the other is connected to the starter, thus completing the circuit. At this point, the pinion is fully engaged with the starter, and cranking begins.

Solenoid and Starter Motor



Shift Lever



Solenoid and Drive Operation

SOLENOID PULL-IN WINDING AND HOLD-IN WINDING

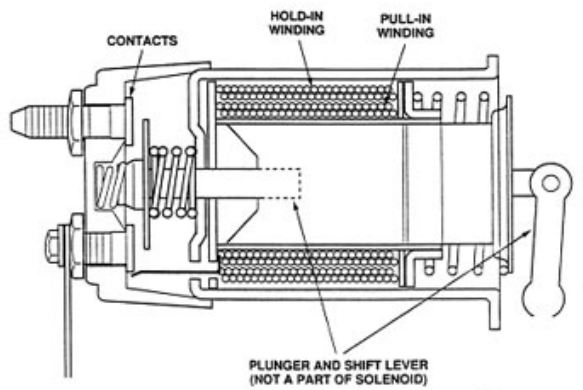
Some solenoids have two separate windings: a pull-in winding, and a hold-in winding. The illustration shows both windings.

As the ignition is turned to START, current flows from the battery to the S (solenoid) terminal on the solenoid, and through the two windings to ground.

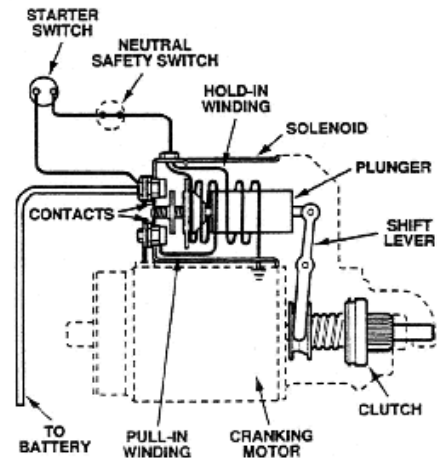
In short, the pull-in winding works only long enough to activate the solenoid and supply current to the starter motor. After that, the hold-in winding continues to keep the solenoid engaged until the ignition key is released.

Diagnostically, if a hold-in winding fails, the pinion will engage repeatedly but it will not remain engaged. Likewise, a pull-in winding failure will prevent the pinion from engaging at all. On some starters, a pull-in winding failure will allow the motor to run, even if the pinion is not engaged.

Solenoid Windings



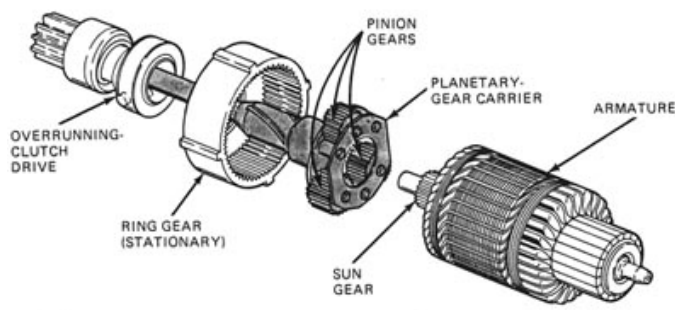
Typical Solenoid-Type Starter



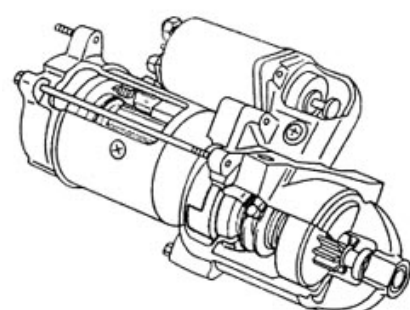
REDUCTION STARTERS

On some starters, called reduction starters, extra gears are used to achieve 'secondary reduction', and develop higher torque. Typically a planetary gearset will be used to produce a reduction from the starter armature shaft speed to the pinion gear speed. This second reduction, plus the pinion/flywheel reduction, permits both increased torque and the use of a smaller starter.

Permanent Magnet Reduction Starter

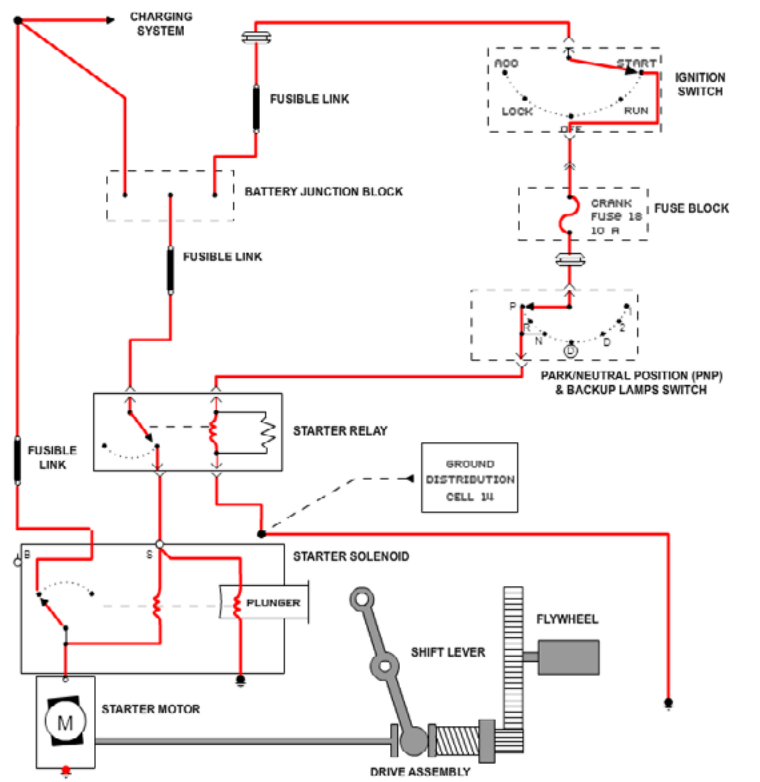


Planetary Gearset in a Reduction Starter



STARTING CIRCUIT

In a typical starting circuit the ignition switch is powered from a battery junction block and protected by a fusible link. When the ignition switch is turned to the start position, a current of less than 10 amps travels through a fuse. The current then flows through the park neutral position and back-up lamp switch PNP. Proved the switch is in the park or neutral position. The PNP is a safety feature to prevent cranking with the vehicle in gear. Manual transmission equipped vehicles have a clutch/pedal position or CPP switch. From the PNP switch, current flows through the starter relay coil and to ground. Energizing the relay coil causes the contacts to close, supplying current from the junction block to the solenoid. The hot at all times portions of the relay and solenoid circuits are protected with fusible links.

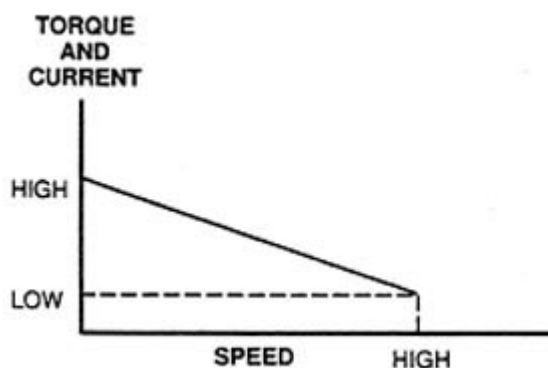


The hot at all times portions of the relay and solenoid circuits are protected with fusible links. Energizing the solenoid causes the plunger to move engaging the pinion gear with the flywheel and the contact disc connects the solenoid's battery and starter terminals. High current then flows from the battery cable, through the solenoid to the starter motor. The starter motor case completes the circuit to ground and cranking begins.

CURRENT DRAW AND TORQUE

A direct relationship exists between the current draw of a starter motor and the torque it produces. Torque and current flow are both greatest when the armature is at zero speed or 'stalled'. Electric motor stall occurs either at that point when voltage has first been applied, but the motor has not yet begun to turn, or if the motor is running and hits a stop (such as an electric window reaching the end of its travel).

Current and Torque vs. Motor Speed



CHAPTER 2: STARTING SYSTEM DIAGNOSIS AND SERVICE

DIAGNOSIS

STARTING SYSTEM DIAGNOSIS

Diagnosis of starting system failures is rather straightforward. Some of the common causes of starting system problems include:

- Dead battery
- Poor battery cable connections
- Burned solenoid contacts
- Burned fuse or fusible link
- Loose starter or solenoid mounting bolts
- Loose starter cable connection(s)
- Bad or misadjust Park/Neutral Position (PNP) or Clutch Pedal Position (CPP) switch
- Ignition switch problems (tumbler, actuator, or contacts)
- Theft deterrent system active
- Bad cranking motor

The service manual provides detailed diagnostic flow charts, procedures, and specifications. We will present some general testing guidelines here.

COMMON STARTING SYSTEM PROBLEMS

This chart addresses some common starting system problems.

Common Starting Problems

Result	Possible Cause	Problem Source
1. Engine cranks slowly but does not start	• Battery discharged	Check Battery.
	• Very low temperature	Battery must be fully charged; engine wiring and starting motor in good condition. Install proper cables.
	• Undersized battery cables	Install proper cables
	• Cranking motor defective	Test cranking motor.
	• Mechanical trouble in engine	Check engine.
2. Solenoid plunger chatters	• Low battery, loose or corroded terminals	Check battery, clean and tighten terminals.
	• Hold-in winding of solenoid open	Replace solenoid.
3. Pinion disengages slowly after starting	• Sticky solenoid plunger	Clean and free plunger.
	• Overrunning clutch sticks on armature shaft	Clean armature shaft and clutch sleeve.
	• Overrunning clutch defective	Replace clutch.
	• Shift-lever return spring weak	Install new spring.
	• Tight alignment between flywheel and pinion	Realign cranking motor to flywheel.
4. Cranking motor turns but engine doesn't	• Pinion not engaged	Realign cranking motor to flywheel
	• Pinion slips	Replace defective drive.

TESTING

CURRENT DRAW TESTING

A starter current draw test can quickly tell you the condition of a starter motor and other system components. Current draw values should not be any higher, or much lower, than specifications.

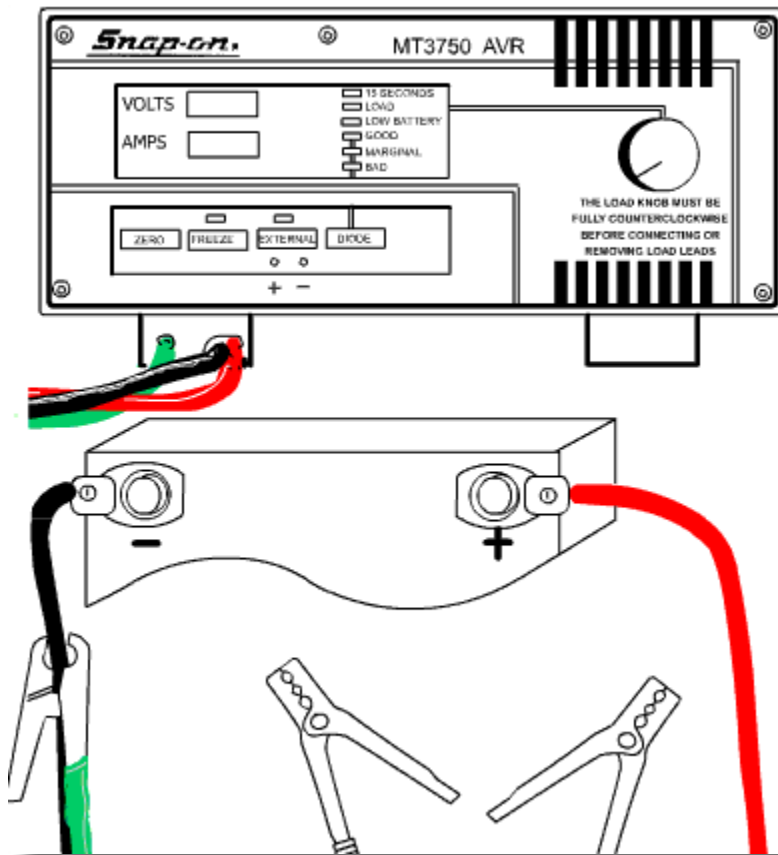
To perform a current draw test:

1. **Disable the fuel delivery system** to prevent the engine from starting. Refer to the service manual to find the best procedure for the vehicle you are working on.
2. **Connect a Volt-Amp tester's** inductive pickup around the negative battery cable. A tester rated from 500 to 600 amps is recommended, making sure to never exceed its meter's range.

Volt-Amp Tester (VAT)VAT



Current Draw Testing Setup



HEADLIGHTS QUICK CHECK

Attempting to crank an engine with the headlights or dome light on, while observing what happens, may quickly point you in the right direction. This chart lists some of the possible conditions, related causes, and problem sources you may encounter.

Headlights Quick Check Chart

Result	Possible Cause	Problem Source
1. No cranking, lights stay bright.	• Open circuit in switch	Check switch contacts and connections
	• Cranking motor	Check commutator, brushes, and connections.
	• Open in control in circuit	Check solenoid, switch, and connections
	• High resistance at battery connection	Clean and tighten terminal connections.
	• Theft deterrent system active	Check theft deterrent system for proper operation.
2. No cranking, lights dim significantly.	• Battery discharged or malfunctioning	Recharge and test battery.
	• Very low temperature	Check wiring circuit and battery.
	• Pinion jammed	Poor alignment between cranking motor and flywheel – free pinion, check gear teeth.
	• Stuck armature	Frozen bearings, bent shaft, loose pole shoe.
	• Short in cranking motor	Repair or replace as necessary.
	• Engine malfunction	Check engine for loss of oil, mechanical interference.
3. No cranking, lights dim slightly.	• Loose or corroded battery terminals	Remove, clean, and reinstall.
	• Pinion not engaging	Clean drive and armature shafts, replace damaged parts.
	• Solenoid engages but no cranking	Clean commutator, replace brushes, repair poor connections.
	• Excessive resistance or open circuit in cranking motor	Clean commutator, replace brushes, repair poor connections.
4. No cranking, lights out.	• Poor connection, probably at battery	Clean cable clamp and terminal, tighten clamp.
5. No cranking, no lights.	• Open circuit	Clean and tighten connections, replace wiring.
	• Discharged or malfunctioning battery	Recharge and test battery.

VOLTAGE DROP TESTING

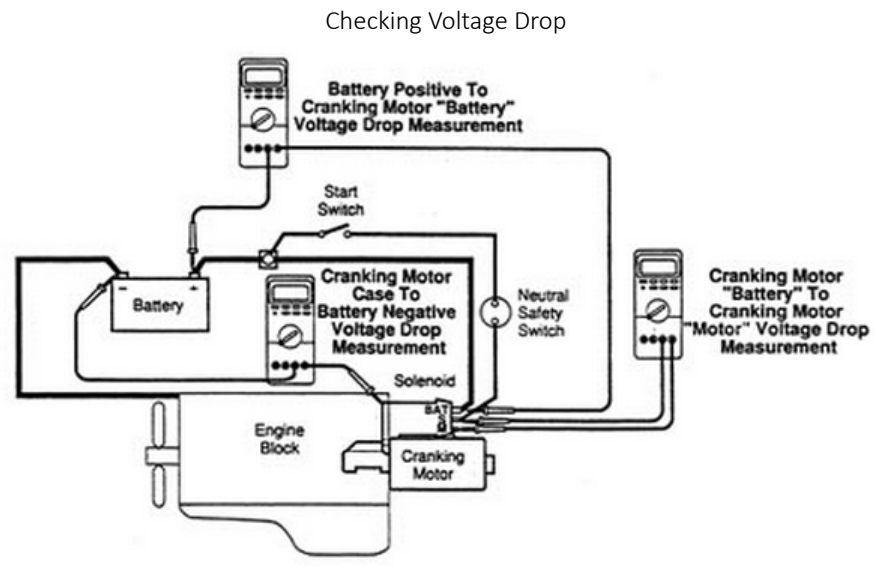
Voltage drop tests are useful for quickly finding sources of high resistance in a circuit. Either the positive side or the ground side can introduce excessive resistance to a circuit, and both can be checked with a voltmeter. If the battery is known to be in good condition, and excessive voltage drop is indicated, continue on to test the circuit components.

To check the voltage drop of the positive battery cable, measure the drop from the positive battery terminal to the battery terminal on the solenoid, while cranking the engine (with the fuel system disabled). This reading indicates the voltage drop and the rest of the circuit can be checked in a similar manner.

The illustration below shows meter connections for all three of the common voltage drop tests. If you use the starting and charging system tester's external volts leads, the load clamps must be connected to the battery in order to power the meter's display.

Do not crank the engine for more than 30 seconds at a time. Five to ten seconds should be adequate to obtain the necessary reading.

In general, a .2 volt drop is the maximum acceptable for each cable, or for the solenoid. If a higher voltage drop is indicated, clean the connections and retest. If the voltage drop is still high, replace the component. Starter relays and other small components are generally also allowed a maximum voltage drop of .2 volts. The total starting system voltage drop, however, should not exceed .5 volts.



NO-LOAD TEST

When removed from a vehicle, the starter can be no-load, or “bench tested.” First, you should attempt to turn the pinion gear with a screwdriver. If the pinion does not turn freely, the motor may have binding bearings, a bent armature shaft, or other internal problems, and should be replaced. If the pinion does turn freely, the starter can be no-load tested.

Wear safety glasses when performing this test.

A no-load test may point to specific defects in the motor, and is also useful for testing new or rebuilt units for proper operation prior to installation on a vehicle. To perform a no-load test, make the connections as shown in the image to the right. When the switch is closed, compare the current and voltage readings to the specifications.

An even simpler form of this test can be used to verify that a unit will operate correctly.

With the starter motor held firmly by a suitable means, connect it to a battery using jumper cables, while a second jumper wire is connected across the solenoid. Connect the positive cable to the solenoid battery terminal **first**, and then connect the negative cable to a suitable ground on the starter (otherwise arcing may damage the threads on the terminal). The solenoid should kick the pinion out, and the motor should spin. With experience, the sound and pitch of a starter at free speed can be used to evaluate starter condition.

WIRES AND CABLES

When checking wiring, ensure the following conditions are met:

- Cables are routed to avoid heat, abrasion, and vibration
- Grommets are in place where cables pass through holes in sheet metal
- Insulation is intact
- Cables are supported every 24 inches
- A strain relief or anchor point is provided a short distance from the battery terminal

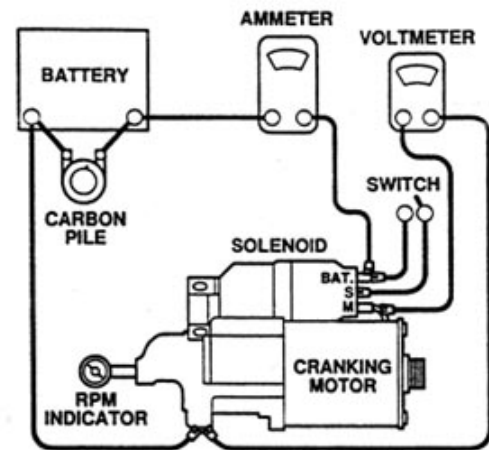
Keep in mind that the longer a cable is, the greater its voltage drop will be. Make sure that adequately sized cable is used. For example, a cable 22 feet long that is required to carry 150 amps should be 00 AWG, which has a conductor approximately 3/8 of an inch in diameter. Rope stranded core is recommended.

Minimum gauge size for 12 volt, high-output systems must be 00 while dual-path circuitry is preferred.

ABNORMAL NOISES

Some conditions can produce abnormal noises during or after cranking.

No-Load Test



Connection Points

When testing an electrical circuit, never pierce an electrical wire with any type of probe. Doing so will allow moisture to enter the circuit, causing corrosion and high resistance. Always test circuits at connection points.

Refer to the chart below for some of the symptoms and their possible causes.

SYMPTOMS	PROBABLE CAUSE
1. High-pitched “whine” during cranking (before engine fires) but engine cranks and fires okay.	Distance too great between starter pinion and flywheel.
2. High-pitched “whine” after engine fires, as key is being released. Engine cranks and fires okay. This intermittent complaint is often diagnosed as “cranking motor hang-in” or solenoid weak.	Distance too small between starter pinion and flywheel. Flywheel runout contributes to the intermittent nature.
3. A loud “whoop” after the engine fires but while the cranking motor is still held engaged. Sounds like a siren if the engine is revved while cranking motor is engaged.	Most probable cause is a defective clutch. A new clutch will often correct this problem.
4. A “rumble, growl” or (in severe cases) a “knock” as the cranking motor is coasting down to a stop after starting the engine.	Most probable cause is a bent or unbalanced motor armature. A new armature will often correct this problem.

PINION CLEARANCE

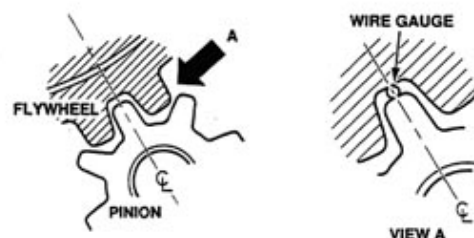
Insufficient clearance between the pinion and flywheel may cause a grinding sound during cranking. If improper clearance is suspected of causing an abnormal noise do the following:

- **Remove the flywheel housing cover** and check for obvious problems such as broken or damaged teeth on the flywheel and pinion, a bent flywheel, cracked starter housing, or unusual tooth wear.
- **Mark the flywheel** to identify the high point of tooth runout. To do this, start the engine and carefully touch the outside diameter of the rotating flywheel with chalk or a crayon.
- Turn off the engine and **disconnect the negative battery terminal** to prevent inadvertent cranking of the engine.
- **Rotate the flywheel** so that the marked teeth are in the cranking motor pinion gear area.
- **Move the pinion** into mesh with the flywheel. Some applications provide a hole in the bottom of the starter housing for inserting a screwdriver to do this (first illustration).

Moving the Pinion into Mesh with the Flywheel



Flywheel to Pinion Clearance

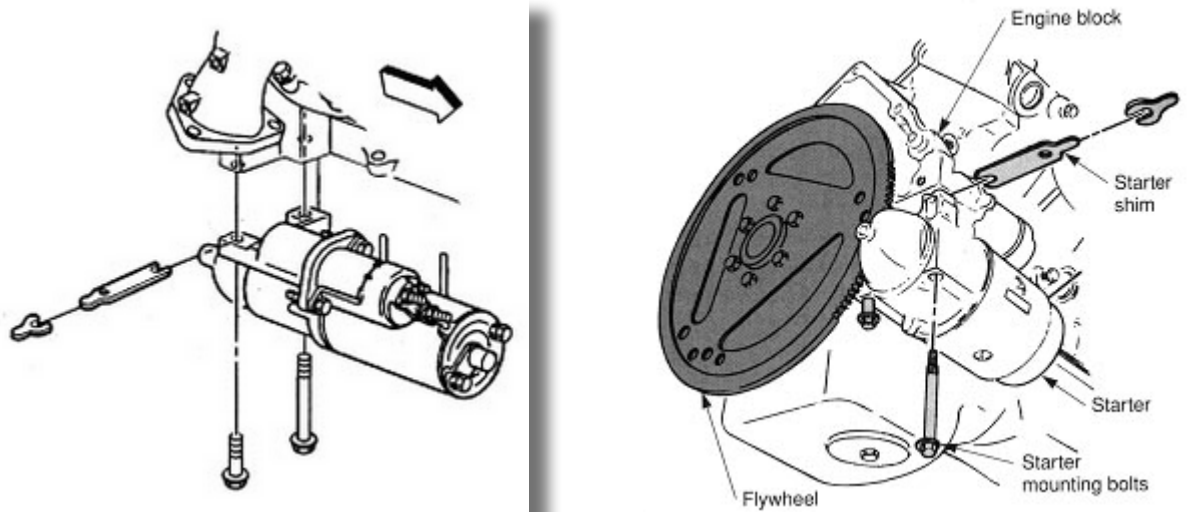


- **Turn the flywheel** if necessary, so that a pinion tooth is centered directly between two flywheel teeth (second illustration).
- **Check the clearance** with a wire gauge or an Allen wrench and compare to specs. Clearance is generally between .020 to .125 inches.

On some applications, pinion gear clearance can be corrected with shims. To increase the clearance, install shim(s) to contact both starter motor mounting pads, as shown in the illustrations.

- When replacing a starter motor, always re-install any original shims.
- Shimming is not recommended on diesel applications.

Shimming a Starter During Installation



REPLACEMENT AND REPAIR

Starter replacement is a straightforward affair. Procedures will be in the service manual, however, these are some general items to keep in mind:

- Make sure to always disconnect the negative battery cable before you begin.
- Re-install any heat shields or support brackets.
- Starter mounting bolts are hardened to withstand the repeated torque produced by the starter motor. Do not replace them with standard hardware.
- It is much easier to make the solenoid connections before mounting the starter to the engine.
- Do not allow the starter to hang from its cables.

In many cases, it may be more practical, for both you and the customer, to replace a starter and solenoid as a unit. This is a good preventive-maintenance practice, because trouble with one component often precedes trouble with the other.

Starter Motor Repair

Service manuals typically contain detailed procedures and specifications for the repair and rebuilding of starter motors. However, this requires a judgment call and may not be practical in terms of cost. With some units, rebuilding is not recommended. Again, check the service manual.

UNIT 3 CHARGING SYSTEMS

The following topics are addressed in this unit:

CHARGING SYSTEM OVERVIEW

- System Components
- Generator Functions
- Generator Components
- Rotor and Brushes
- Stator
- Diodes and Diode Bridges
- Voltage Regulators

CHARGING SYSTEM DIAGNOSIS AND SERVICE

- Inspection
- Electrical Testing
- Scan Tools and Scopes
- Waveforms
- Tests
- Generator Repair

CHAPTER 1: CHARGING SYSTEM OVERVIEW

The charging system uses power from the engine to keep the battery fully charged and supply the vehicle's electrical needs when the engine is running.

SYSTEM COMPONENTS

The primary components of a charging system include:

- **Generator*** – Produces electrical power to recharge the battery and supply the needs of a vehicle's electrical systems.
- **Voltage Regulator** – An electronic control device that limits the amount of generator voltage output and protects the system from electrical damage.
- **Battery** – Receives electric power from the generator and supplies the initial current needed to energize the generator. It also provides for the vehicle's electrical needs when the generator output is insufficient. As such it helps to stabilize the generator output.
- **Drive belt** – Transmits mechanical power from the engine to the generator pulley.
- **Charge Indicator** – A voltmeter, ammeter, and/or generator warning lamp to inform the driver of possible charging system problems.

* - The term 'generator' is used throughout this course to refer to the device that produces electrical power in automotive applications. However, students will more often find the term 'alternator' used instead of generator. The difference is that 'alternators' produce Alternating Voltage and Current (AC) while 'generators' can be either Alternating Current or Direct Current (DC). As such, all 'alternators' are 'generators' but not all 'generators' are 'alternators'. However, for current automotive applications, the terms can be used interchangeably.

GENERATORS FUNCTIONS

Generators are the primary components of charging systems. Just as motors use conductors and electromagnetic fields to convert electrical energy into rotary motion, generators use those same principles to convert rotary mechanical (belt-driven) energy into electrical energy.

However, even though both motors and generators use the principle of **electromagnetic induction**, they can actually be thought of as electrical opposites. Where one uses electric power to turn a motor (such as a starter), the other uses mechanical power to turn a generator, which produces electricity.

The increased output possible with newer AC generators (alternators), compared to the older DC generators (1960s and earlier), is due to a fundamental difference in design. All generators in current automotive use are AC types.

CHARGING SYSTEM MODES OF OPERATION

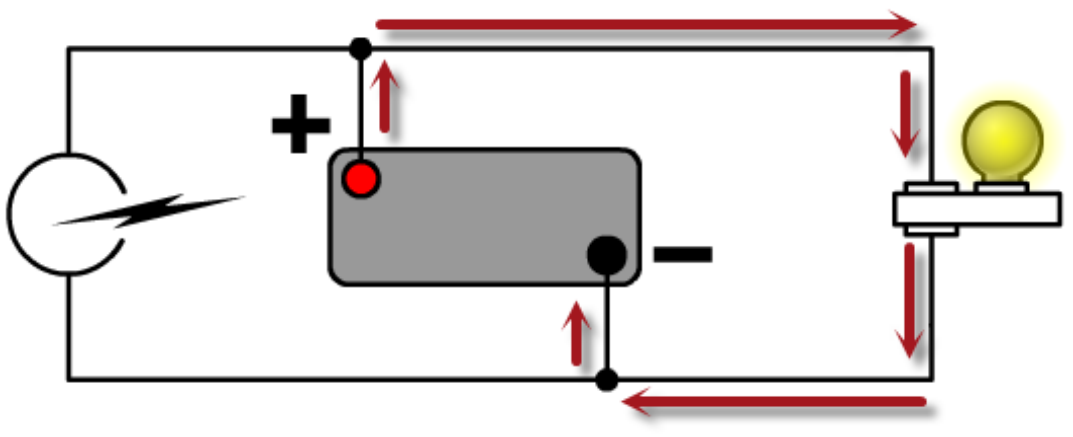
This illustration shows a typical battery, generator, and electrical load configuration. In this mode, the generator is not producing current and the battery is supplying all of the system's electrical needs. This condition occurs when accessories are operating without the engine running, and or during a charging system failure.

If this situation were allowed to continue for an extended period, the battery would become discharged.

Generators use the principle of electromagnetic induction to produce electric power.

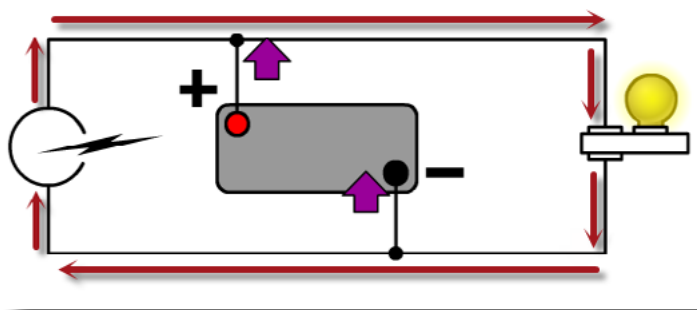
Some AC Generators now in use can produce up to 300 amps.

Modern AC Generator (Alternator)



BATTERY AND GENERATOR SUPPLYING CURRENT

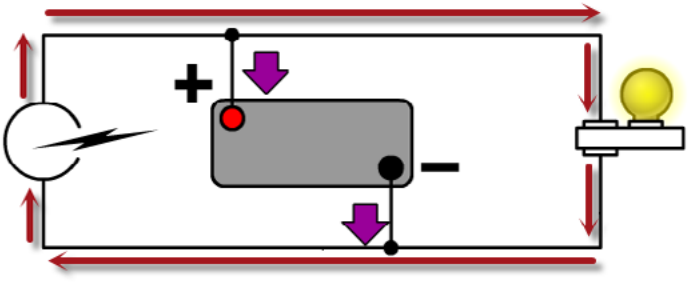
This illustration shows both the battery and generator supplying current. This situation occurs when the generator is not operating at a sufficient speed to meet the electrical demand, and the battery is required to make up the difference. A high electrical demand at idle could cause this condition.



This condition will also cause the battery to become discharged but over a longer period of time than in the first example.

GENERATOR SUPPLYING CURRENT

In this illustration, the generator is operating at a sufficient speed to supply both adequate operating current and to recharge the battery. The generator recharges the battery by creating a voltage high enough to send current through the battery in the opposite direction as during discharge.



This is the normal, desired operation.

GENERATOR VOLTAGE OUTPUT

A generator's output can be varied three ways:

- Alter the number of turns, or windings, in the stator (stationary winding)
- Change the speed of rotor rotation
- Vary the strength of the rotor's magnetic field

The first two ways are determined by the generator's design, and the third is used by the voltage regulator to control a generator's voltage output during operation.

If the rotation **speed** of the rotor is increased, the **voltage** produced by the generator will increase. Rotor speed, which increases with engine rpm, is determined by the generator's pulley size.

Altering a rotor's **magnetic field strength** will control the generator's **voltage** output. The stronger the magnetic field, the greater the voltage induced in the stator.

Voltage regulators control generator output by varying the amount of current to the rotor, which controls its magnetic field, and limits the voltage output of the generator.

GENERATOR COMPONENTS

A generator is made up of four primary components:

- Rotor and Brushes
- Stator
- Diode Bridge
- Voltage Regulator

Let's examine each of these components in detail

ROTOR AND BRUSHES

ROTOR

A generator rotor is a rotating magnetic field assembly, mounted on a shaft, that rides in bearings located in the front and rear of the generator case.

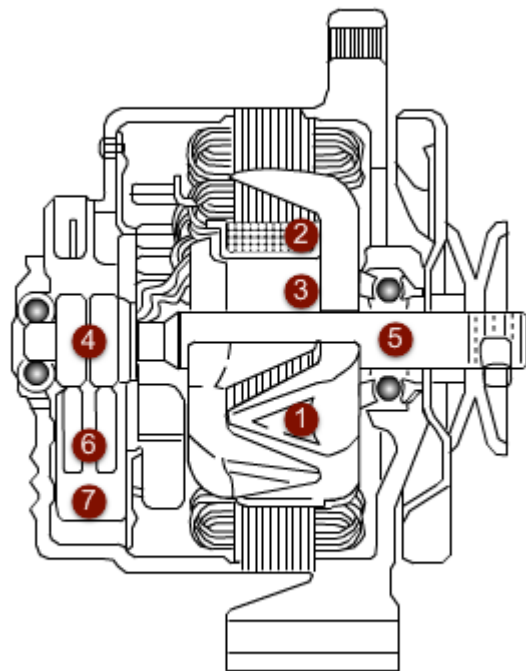
1. Two pole pieces with Interlacing Fingers or "Claws"
2. A Rotor Core of Field Windings
3. An Iron Core
4. Two Copper Slip Rings
5. A Shaft
6. Brushes
7. A Brush Holder

BRUSHES

In order for a generator to operate, its rotor must be turned into an electromagnet. This is achieved by supplying a current to the rotor through spring-loaded, carbon brushes that are in constant contact with slip rings. The slip rings are insulated from the rotor shaft and are connected to opposite ends of the rotor windings. One of the brushes is connected to system voltage and the other to an alternating ground.

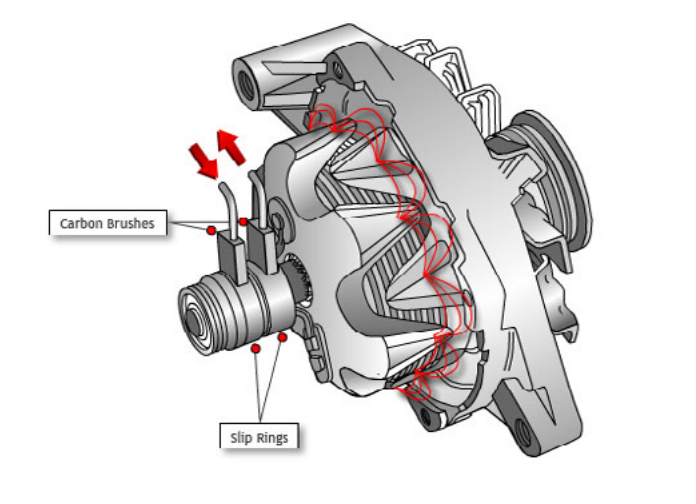
As a result of the applied voltage (from the regulator), a variable current flows through the field windings which creates a variable magnetic field. That variable magnetic field creates changing North and South poles on the rotor. Note the alternating N and S fingers of the pole pieces in the illustration.

Alternator Rotor and Stator



The brushes in an AC generator tend to be much smaller than brushes in starter motors since they carry only field current to the rotating field, instead of the much higher starter current.

Carbon Brushes in Contact with Slip Rings and Alternating Poles on a Rotor



STATOR

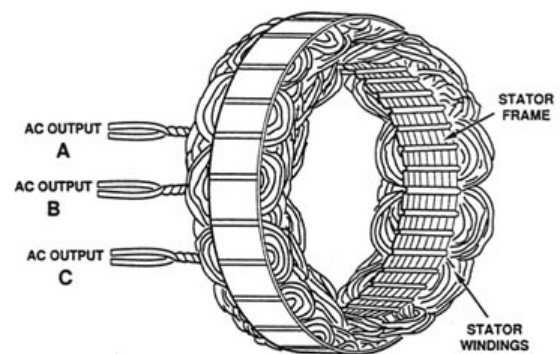
In an alternator, the stationary winding assembly is called a stator. A stator consists of three windings, called phases, assembled onto an iron frame. The currents that are induced in each winding, by the spinning rotor, are added to produce the alternator's total output current. As the alternating North and South poles of the rotor pass next to the stator coils, three distinct AC voltage cycles are produced.

DIODES AND DIODE BRIDGES

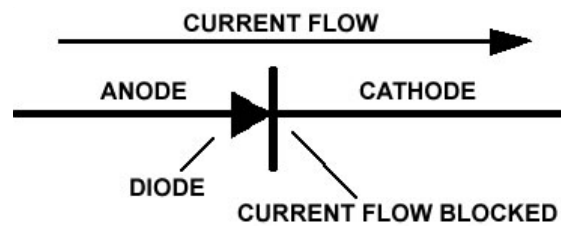
Automotive circuits operate on direct current (DC) while their generators produce alternating current (AC). As a result, the generator output current must be converted from AC to DC before it can be used. To accomplish this we use a series of diodes, or rectifiers to make the conversion.

Diodes are electronic devices that only allow current to flow through the device in one direction. By incorporating a series of six diodes, called a rectifier bridge, we can convert 3-phase AC to 3-phase DC.

Stator Assembly



Electrical Diode Symbol and Components



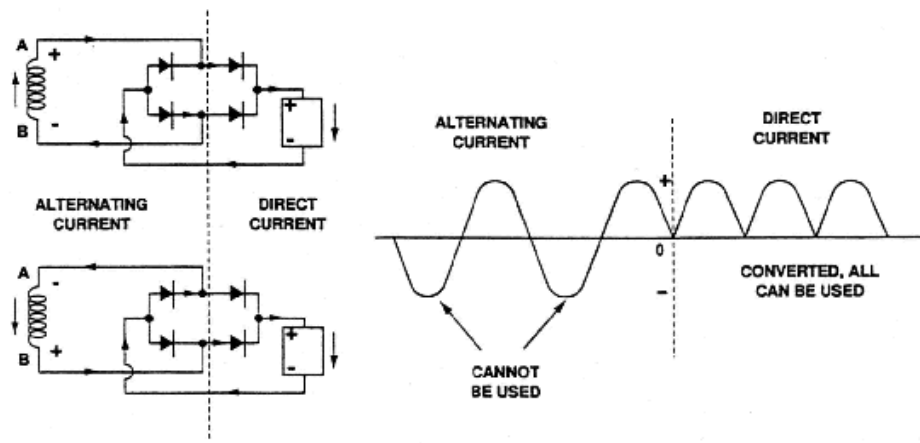
A diode is an electronic component that acts as an electrical check valve and allows current to flow through it in only one direction.

WAVEFORMS

A rectifier bridge, also referred to as a full-wave rectifier, commonly consists of six diodes, which convert AC voltage to DC. Although there are six diodes in a generator, only four are used to rectify each of the three AC voltage phases. That means that each of the diodes works with two of the three phases.

This illustration shows a four-diode bridge and its output waveform pattern.

Full-Wave Rectifier Using Four Diodes to Convert One Generator Phase from AC to DC

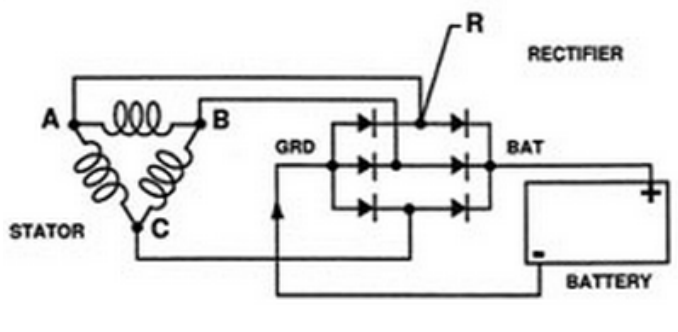


STATOR AND RECTIFIER BRIDGE

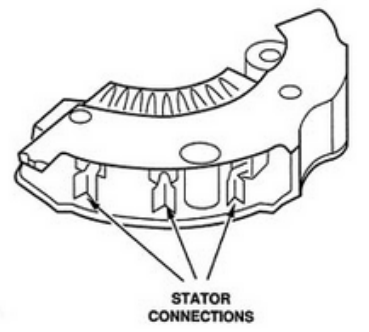
The diagram on the left shows a 3-phase stator wired to a six-diode bridge. Note that the current flow is blocked from the stator to the grounded side of the bridge.

The image on the right shows a typical diode bridge.

3-Phase Stator and Six Diode Bridge



Typical Diode Bridge



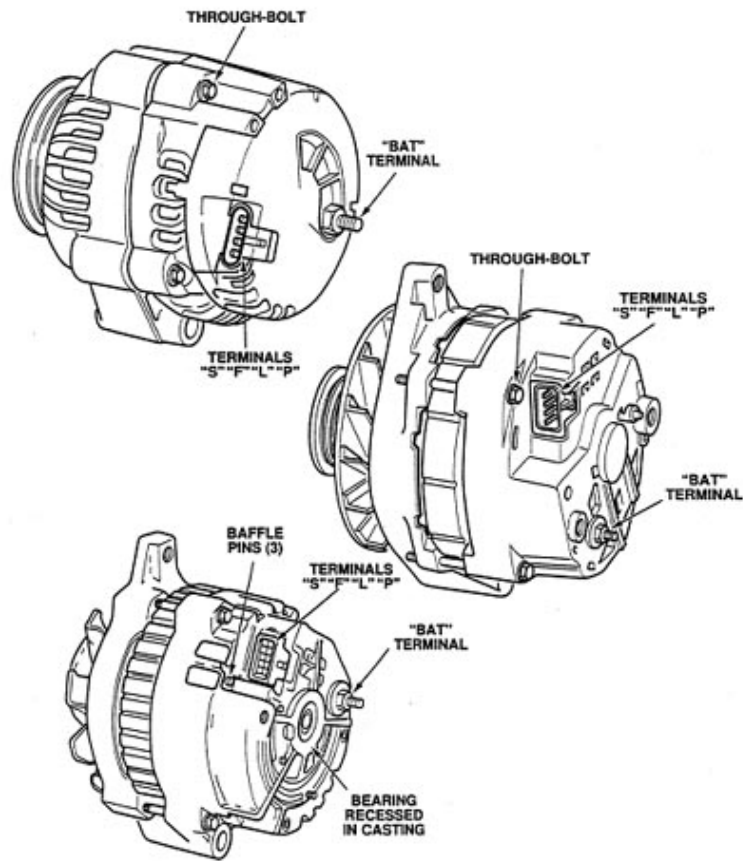
VOLTAGE REGULATORS

All alternators have a **voltage regulator**, and most are internally mounted as part of the unit. This illustration shows some typical alternators with internal regulators and with both internal and external cooling fans.

Alternator



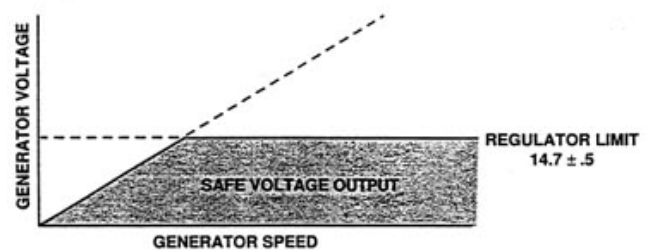
Various Alternator Electrical Connections and Configurations



LIMITING VOLTAGE

Voltage regulators limit generator output to a level approximately two volts higher than battery voltage. This higher voltage level provides the “push” necessary to force current through the battery, recharging it (when the engine is running at a sufficient speed and without excessive electrical loads). As shown in this illustration, system voltage must be kept to a safe level ($14.7\text{ V} \pm .5$) to prevent damage to electrical components.

Voltage Limiting



DUTY CYCLE

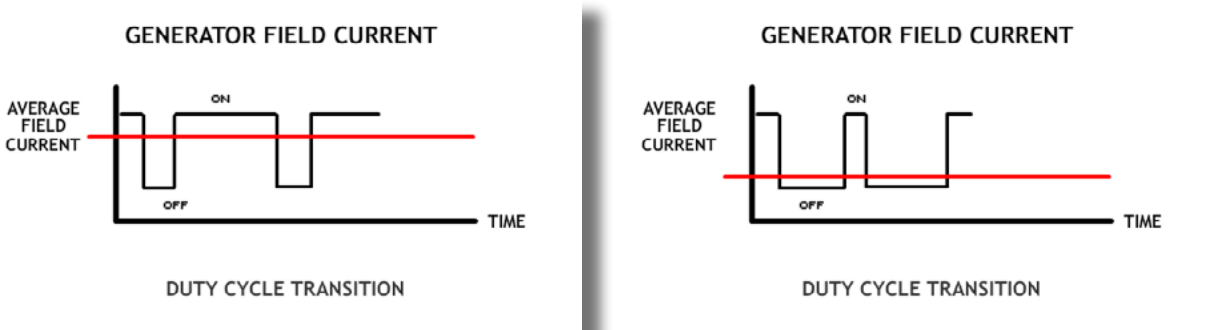
In order to achieve a regulated system voltage, voltage regulators switch the rotor current ON and OFF at a fixed frequency of about 400 cycles per second. The system voltage is then controlled by varying the ON/OFF time of the rotor (or Field) current.

The voltage regulator controls the magnetic field strength by rapidly turning the field current on and off.

For example, at low speeds, the field may be turned ON 90 percent of the time and OFF 10 percent of the time (a 90% duty cycle). This action yields a relatively high average rotor current which, when combined with the low generator speed or high electrical demand, produces the desired system output.

As generator speed increases, less rotor current (a lower Field current) may be needed to generate the desired system voltage, and the duty cycle drops to reduce the average rotor current. At high engine speeds, the regulator may be ON for only 10 percent of the time and OFF 90 percent of the time (a 10% duty cycle). Duty cycles constantly change as operating factors and loads change. In the images below, notice that the Average Field Current increases during On cycles and

ON/OFF Duty Cycle vs. Average Field (Rotor) Current



HIGH ELECTRICAL DEMANDS

Keep in mind that a voltage regulator only limits the **maximum** voltage output of a generator. When demands on the vehicle electrical system are such that the full output of the generator is insufficient, the regulator will provide continuous (full) field current in order to obtain the maximum possible output.

High electrical demands can cause the actual system voltage to be less than the regulator setting.

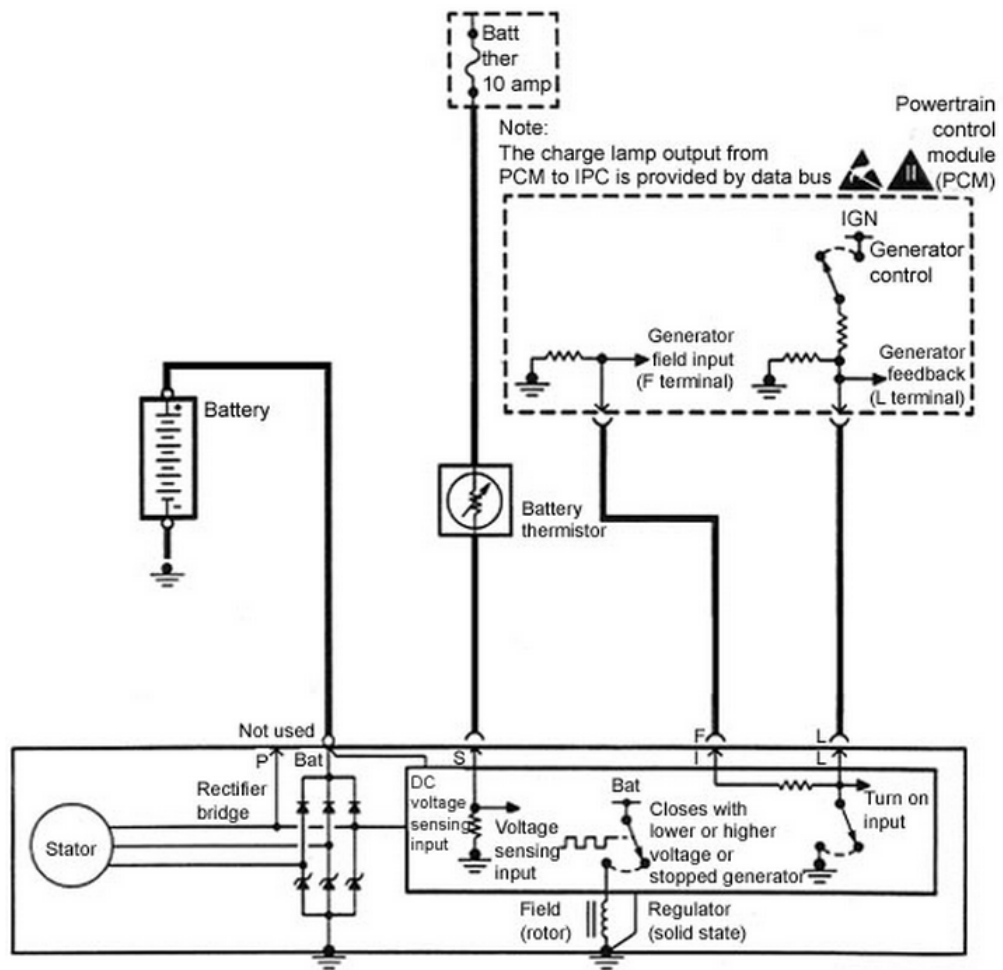
In other words, the regulator limits the maximum voltage a generator can produce. However, excessive electrical loads can exceed the capacity of a generator, which will result in a low system voltage.

METHODS OF REGULATING VOLTAGE

Historically, several different methods of regulating system voltage have been used, and late model vehicles often use electronic control modules (ECMs, PCMs, etc) to supplement or replace conventional voltage regulators. **Computerized ECM or PCM control of system voltage** offers several benefits, such as greater accuracy and consistency. Other advantages include the ability to set diagnostic codes, and to enhance driveability in cases such as turning off the alternator at full throttle to reduce engine load.

This diagram is an example of a system in which the voltage is controlled by a PCM. Carefully examine, and familiarize yourself, with this schematic and its components. Note especially the battery thermistor, which provides battery temperature information to the system for voltage corrections.

ON/OFF Duty Cycle vs. Average Field (Rotor) Current



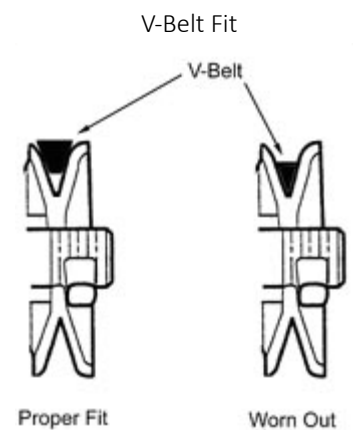
CHAPTER 2: CHARGING SYSTEM DIAGNOSIS AND SERVICE

While there are relatively few components involved in a charging system, they are interdependent, and troubleshooting should be systematic and methodical to ensure an accurate diagnosis. Refer to the appropriate service material for diagnostic flow charts, procedures, and specifications.

VISUAL AND MECHANICAL INSPECTION

Begin by checking that all battery terminal and alternator connections are clean and tight.

Check the drive belt condition and tension. Look for glazing or oil on the belt, which may cause slippage. **Even a small amount of slippage** can prevent the battery from receiving an adequate charge.



V-BELT APPLICATIONS

Although V-Belts are no longer installed on new vehicles, there are still many of them in use today. As such, it is important to understand the maintenance issues surrounding them.

On V-belt applications, always check first for proper fit and alignment. The belt should always be driven by the sides of the V in the pulley, and should not ride low in the pulley, or contact the bottom of the pulley, as shown in the illustration. Any belt that "bottoms out" must be replaced.

One method of checking for slippage is to firmly grasp the generator by the fan blades or pulley and attempt to rotate it. If the pulley can be rotated by hand, excessive slippage is present and must be corrected. Do **not** overtighten a worn-out or oily belt as this can ruin the bearings in the alternator or other accessories.

Listen for unusual noises from the alternator. A buzzing, grinding or rattling can indicate mechanical problems such as a bad bearing or broken internal parts. A loud whining can be caused by bad diodes or overcharging.

Checking for Belt Slippage



SERPENTINE BELT APPLICATIONS

Serpentine Belts or 'Flat Belts' are installed on all modern vehicles. Although a few applications use two belts, most have only one to operate all of the engine accessories including the Generator, Coolant Pump, Air Conditioning Compressor, Power Steering Pump, and possibly others. Unlike V-Belts, most serpentes also use a spring-loaded automatic tensioner to take up slack in the belt. This system insures that the belt's tension is always correct, and that it has not been over-tightened, as often happens with V-Belts.

When performing diagnosis or maintenance on a serpentine-equipped vehicle, it is important to take note of the operation of the tensioner. Most of the time when a tensioner is seen 'bouncing', the assumption is that it is just 'doing its job'. However, if the engine is operating correctly (no cylinder misses or imbalances causing it to run inconsistently, or 'shake'), then the tensioner should remain mostly stationary and not 'bounce'. If the tensioner does bounce, and the engine is operating correctly, then the tensioner has failed and should be replaced.

This illustration shows a system that uses a flat, serpentine belt with an automatic tensioner.

A Spring Applies Proper Tension



ELECTRICAL TESTING

For accurate electrical testing, a vehicle must have a known-good, sufficiently charged battery. A sulfated, shorted, or dead battery can cause misleading test results.

Connect a voltmeter across the battery with the engine running at about 2000 rpm for a quick functional check of the alternator. A no-load voltage, or open-circuit voltage, of approximately 13.2 to 14.7 volts indicates some output from the generator.

An output lower than 13.2 V indicates battery voltage only. If only battery voltage is indicated, check the wiring harnesses and generator connections. Jiggle the wires while observing the voltmeter and if the system begins charging, you will have located a wiring problem. There may also be a whining noise as the generator begins to charge, and a brief loading of the engine, before the PCM adjusts the idle speed.

WARNING: Never remove a battery from the charging circuit with the engine running! The resulting voltage spike may ruin the PCM or other electronic components. Also, **never short or ground any charging system terminal unless instructed to do so by the service manual!**

On older vehicles, a common diagnostic practice is to bypass the regulator and apply full system voltage to the field circuit. This is done in order to determine whether the alternator is even capable of charging. Bypassing in this manner forces the alternator into unregulated charging (maximum output), which can damage the electronic components on modern vehicles.

SCAN TOOLS AND SCOPES

For many vehicles a scan tool can be useful when diagnosing charging systems. Scan tools can display charging rates, battery temperatures, and other useful data. Always refer to the scan tool's user manual for operating instructions.

Open Circuit Voltage Test



Never short or ground any charging system terminal unless instructed to do so by the service manual. Never remove a battery from the charging circuit with the engine running!

Scan Tool



Oscilloscopes, on the other hand, can be used to display voltage waveforms when diagnosing diode failures that voltmeters cannot detect. Familiarizing yourself with some of the common waveform examples on the following screens may prove to be useful in future diagnosis

Digital Oscilloscope



WAVEFORMS

Normal Waveform

This is a typical normal output waveform. The alternator is charging correctly.

Normal Waveform



Waveform Under Heavy Load

This waveform is also normal, but indicates the alternator is under a heavy load.

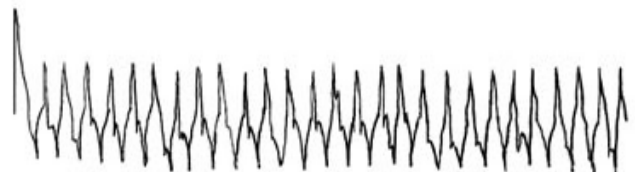
Waveform Under Heavy Load



Waveform with Inductive Spikes

This pattern is seen with some charging systems that use electronic regulators and duty cycles. The higher inductive spike is normal on these systems.

Waveform with Inductive Spikes



Duty-Cycle Waveform to Field Windings

This pattern shows a duty cycle from a control module to the field windings. This duty cycle is at about 50%.

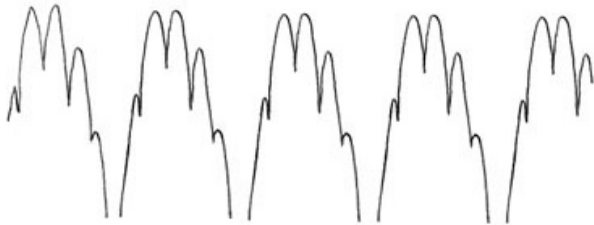
Duty-Cycle Waveform to Field Windings



Open Diode Waveform

This is an unacceptable waveform. The high spikes in this pattern indicate an open diode.

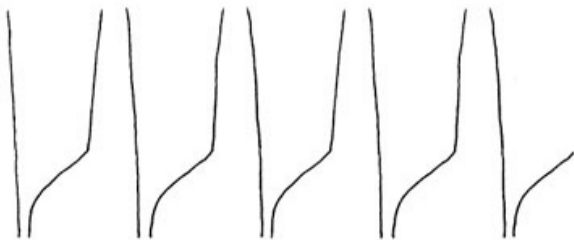
Open Diode Waveform



Waveform of Open and Shorted Diodes

This unacceptable waveform is showing one open diode and one shorted diode.

Waveform of Open and Shorted Diodes



Waveform Showing Shorted Diodes or Stator Windings

This waveform, also unacceptable, shows shorted diodes or stator windings.

Waveform Showing Shorted Diodes or Stator Windings



TESTS

CHARGING SYSTEM OUTPUT TEST

The load-testers used for checking batteries and starting systems also provide an effective means for testing charging systems. They can check for adequate current and voltage output, under varying loads, up to the rated capacity of the generator. Load-testers typically also have features for testing alternator diodes and stator windings.

In general, the procedure for testing a charging system's output consists of the following:

- Connect the tester's heavy clamps to the correct battery terminals (red to red and black to black), and clamp the inductive amp probe around the negative battery cable(s).
- Start and run the engine at approximately 2000 rpm.
- Gradually rotate the load control knob until the ammeter indicates the generator's specified current rating. Watch the appropriate display to make sure that the voltage remains in an acceptable range (13 to 15 volts), then remove the load.

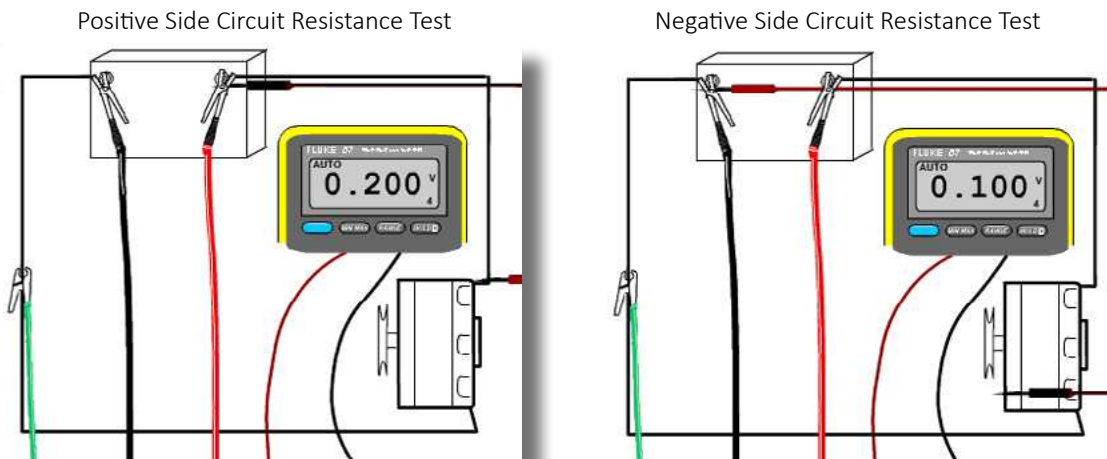
Note: Alternator current output should be within approximately 20 percent of its rated capacity.

- Press the DIODE key (or rotate the tester's function selector knob to the diode/stator test position) and observe the reading.

CIRCUIT RESISTANCE TESTS

If you suspect that poor test results are due to circuit/wiring problems, rather than alternator/regulator failure, circuit resistance tests can pinpoint problems in the wiring. Circuit Resistance Tests are merely voltage drop tests, similar to the starting system tests described in the Starting Systems section. To perform a circuit resistance test on the positive side of a circuit, follow these steps:

- Connect the positive probe of a voltmeter to the alternator output terminal, and the negative probe to the positive battery terminal, as shown.
- Start and run the engine at approximately 2000 rpm.
- Adjust the load control knob to approximately half of the alternator's rated output.
- Observe the voltmeter reading. The voltage drop should not exceed .5 volts in most cases.



Refer to the vehicle's service manual for applicable specs and exact procedures. Most applications will specify not more than a .6 volt drop total for both sides of the circuit.

GENERATOR REPAIR

Although some generator units are “serviceable”, it typically isn’t worth the time or money to repair one.

While it is useful for students to disassemble generators to familiarize themselves with the internal components, it is recommended that any actual repair of these units be left to electrical rebuild/repair facilities with the proper tools and test equipment.

