INTRODUCTION

Every electrical component in a vehicle is supplied current from the battery. The primary purpose of an automotive battery is to provide a source of electrical power for starting, and for electrical demands that exceed alternator output.

The battery acts as a voltage stabilizer for the entire electrical system. It acts as a reservoir from where large amounts of current (amperes) can be delivered quickly during starting and replaced back gradually by the alternator during charging. Figure 1.

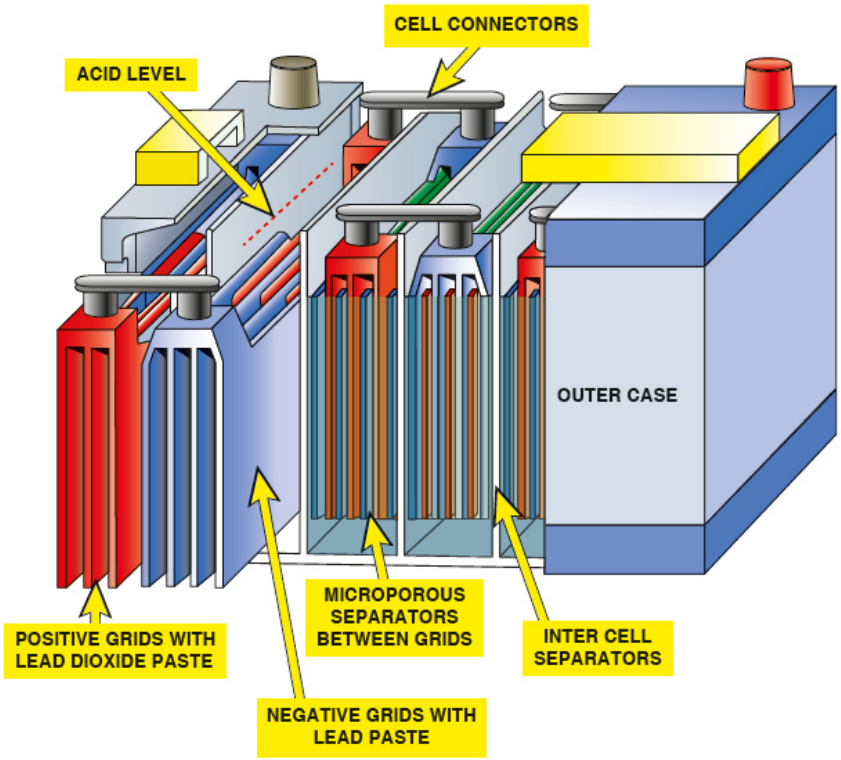

Figure 1. Batteries are constructed of plates grouped into cells and installed in a plastic case.

Most automotive battery cases are constructed of polypropylene, a thin, strong, and lightweight plastic. Inside the case are six cells (for a 12-volt battery). Each cell has positive and negative plates. The positive plates have lead dioxide (peroxide) placed onto the grid framework. The negative plates have grids that are pasted with a pure porous lead, called sponge lead. Figure 2.

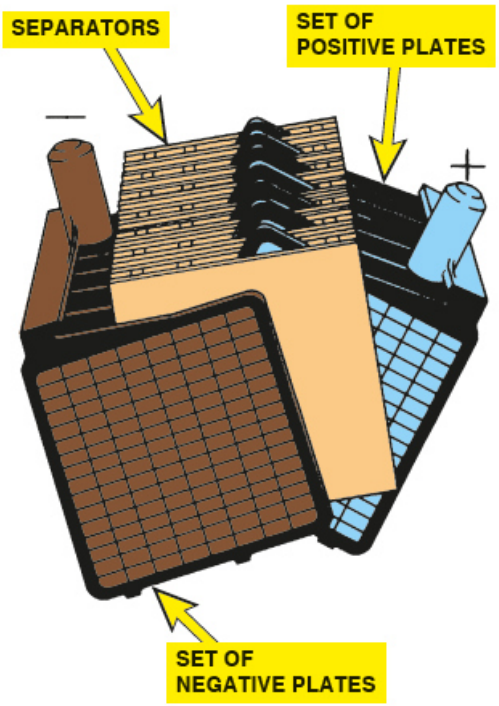

Figure 2. Two groups of plates are combined to form a battery element.

The electrolyte used in automotive batteries is a solution of 36% sulfuric acid and 64% water. This electrolyte is used for both lead–antimony and lead–calcium (maintenance free) batteries. The chemical symbol for this sulfuric acid solution is H2SO4.

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

The cranking circuit includes those mechanical and electrical components that are required to crank the engine for starting. The control circuit includes those wires and components that carry a relatively small current such as the ignition switch, safety switch, and solenoid or relay. The power circuit carries the heavy current needed to crank the engine and includes the battery itself, plus the battery cables, solenoid, and starter motor.

The engine is cranked by an electric motor that is controlled by a key-operated ignition switch. The ignition switch will not operate the starter unless the automatic transmission is in neutral or park. Figure 3.

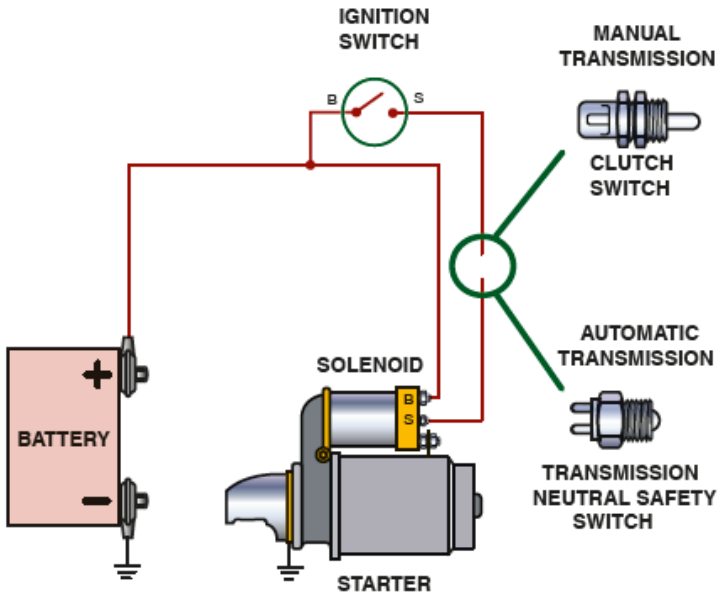

Figure 3. Basic cranking system and safety switches, as found on older vehicles..

Most key-operated ignition systems and pushbutton-to-start systems are now using the body control module (BCM) and the engine control module (ECM) to crank the engine. The ignition switch start position, or the push-to-start button is used as an input signal to the BCM. The BCM uses the vehicle data network to request starting from the ECM. Figure 4.

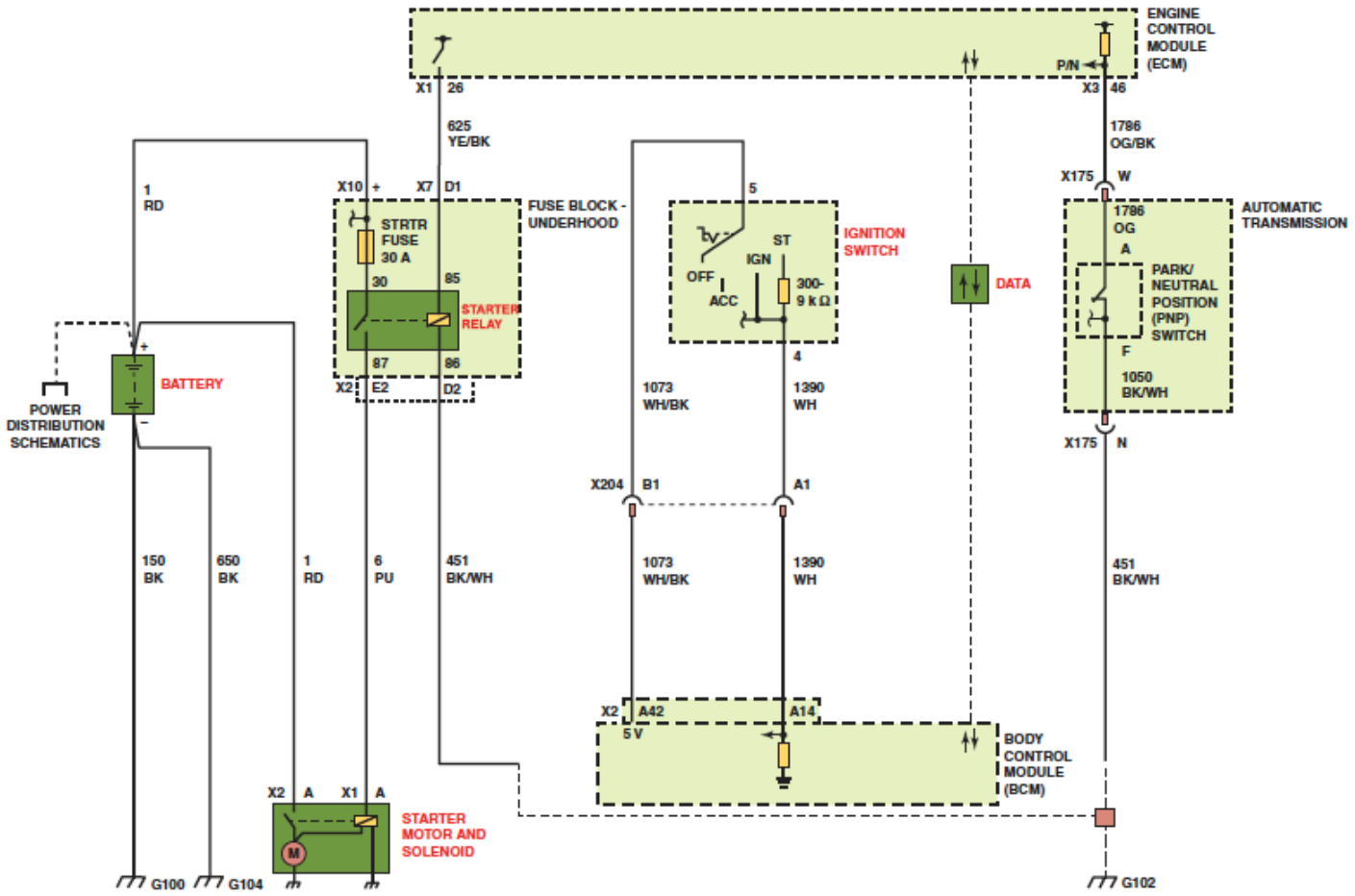

Figure 4. Cranking circuit using the BCM and PCM for control.

ASE TEST TOPICS

1. Identify low-voltage energy storage system type, voltage, and system configuration (to include non-traditional chemistry, voltages, multi-battery grouping, and incorporation of boost capacitors); test and repair as needed.

Flooded Batteries. Conventional batteries use a liquid electrolyte and are called flooded lead acid (FLA) batteries. In this design, vents are used to allow the gases (hydrogen and oxygen) to escape. It is this loss of the hydrogen and oxygen that results in a battery using water during normal use.

Maintenance-free batteries, also known as sealed lead-acid (SLA) or valve-regulated lead-acid (VRLA) batteries, are designed to minimize the need for regular maintenance. Unlike traditional batteries that have removable caps or vents, maintenance-free batteries are designed with a sealed housing and pressure-relief valves. Maintenance-free batteries are engineered to minimize electrolyte evaporation by trapping the water vapor within the battery case.

Enhanced Flooded Batteries. An enhanced flooded battery (EFB) is a flooded battery that is optimized to work with stop/ start vehicle systems.

Absorbed Glass Mat. The electrolyte used in an absorbed glass mat (AGM) battery is totally absorbed into the separator, making the battery leak proof and spill proof. Absorbed glass mat batteries are used as the low-voltage battery in many hybrid-electric vehicles. The sealed maintenance-free design uses a pressure release valve in each cell. This allows for installing inside the vehicle, rather than in the engine compartment. Figure 5.

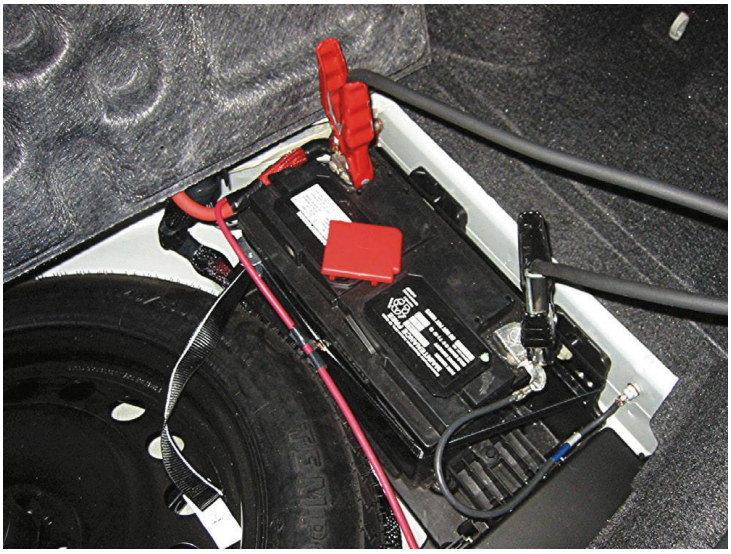

Figure 5. An AGM battery under the floor next to the spare tire in a hybrid-electric vehicle. A vent tube is used to route battery fumes to the outside of the vehicle.

Some vehicles, usually trucks, are equipped with more than one battery. Two 500 ampere, 12 volt batteries connected in parallel are capable of supplying 1,000 amperes at 12 volts, which is needed to start many diesel engines. Figure 6.

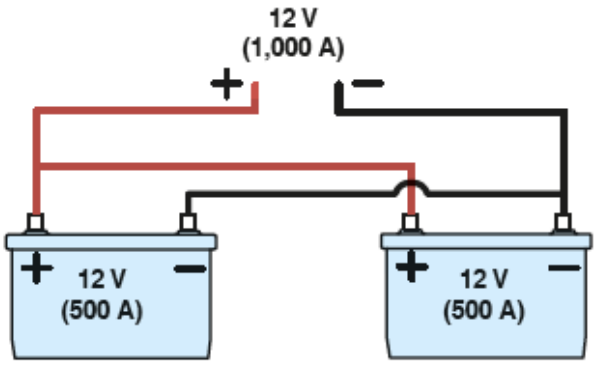

Figure 6. Batteries connected in parallel.

Many heavy-duty trucks and buses use two 12 volt batteries connected in series to provide 24 volts. Figure 7.

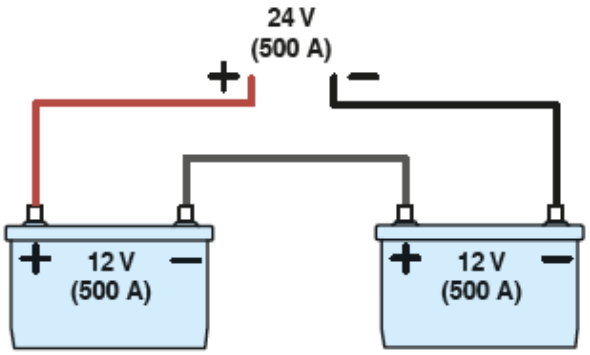

Figure 7. Batteries connected in series.

2. Test and diagnose problems resulting from low-voltage battery system failures; determine needed action.

Some symptoms and causes of a vehicle battery failure are:

- Slower than normal engine cranking. When the capacity of the battery is reduced due to damage or age, it is less likely to be able to supply the necessary current for starting the engine, especially during cold weather.
- Dash indicators flicker when cranking. The heavy load on the battery may cause the voltage to drop below the point where the BCM or PCM may cut off and reset.
- Solenoid clicks and engine does not crank. Check for loose or corroded connections at the battery posts.

3. Perform low-voltage battery state-of-charge test; determine needed service.

Testing the battery voltage with a voltmeter is a method for determining the state of charge of any battery. This test is commonly called an open circuit battery voltage test because it is conducted with an open circuit, no current flowing, and no load applied to the battery.

- If the battery has just been charged or the vehicle has recently been driven, it is necessary to remove the surface charge from the battery before testing.
- To remove the surface charge, turn the headlights on high beam (brights) for one minute, then turn the headlights off and wait two minutes.
- With the engine and all electrical accessories off, and the doors shut (to turn off the interior lights), connect a voltmeter to the battery posts.
- Read the voltmeter and compare the results with the chart. Figure 8.

BATTERY VOLTAGE (V)	STATE OF CHARGE
12.6 or higher	100% charged
12.4	75% charged
12.2	50% charged
12.0	25% charged
11.9 or lower	Discharged

Figure 8. Battery state of charge.

4. Perform low-voltage battery tests (load and capacitance); determine needed service.

One test to determine the condition of any battery is the load test. Most automotive starting and charging testers use a carbon pile to create an electrical load on the battery. The amount of the load is determined by the original CCA rating of the battery, which should be at least 75% charged before performing a load test.

- The proper electrical load used to test a battery is half of the CCA rating, with a minimum 150 ampere load.
- Apply the load for a full 15 seconds. Observe the voltmeter during the load testing and check the voltage at the end of the 15 second period, while the battery is still under load. A good battery should indicate above 9.6 volts.

Some manufacturers specify that an electronic conductance tester be used to test batteries in vehicles still under factory warranty. Conductance is a measure of how well a battery can create current. Figure 9.

Figure 9. A conductance tester.

- Connect the unit to the positive and negative terminals of the battery. If testing a side-post battery, always use the lead adapters. Test results can be incorrectly reported on the display if proper, clean connections to the battery are not made.

- Enter the CCA rating (if known) and push the arrow keys.
- The tester determines and displays one of the following:
  - *Good battery*. The battery can return to service.
  - *Charge and retest*. Fully recharge the battery, drive the vehicle, and retest.
  - *Replace the battery*. The battery is not serviceable and should be replaced.
  - *Bad cell–replace*. The battery is not serviceable and should be replaced.

5. Follow manufacturer's procedure to restore (or maintain if applicable) electronic memory functions.

Whenever a battery is disconnected or replaced, many electrical/electronic modules may lose their memory and will have to be re-learned or set. To prevent having to reinitialize these modules, a "memory saver" can be used keep power applied to the electrical system when the battery is disconnected.

A commercially available memory saver connects a 12 volt auxiliary battery to terminals 4 and 16 of the data link connector (DLC). The applied voltage, which is connected the electrical system through the DLC, will keep all memory functions, so they do not need to be reset. Figure 10.

Figure 10. This memory saver connects a jumper box to the vehicle DLC pins 4 and 16.

6. Perform low-voltage battery charge in accordance with manufacturer's recommendations.

If the state of charge of a battery is low, it must be recharged. It is best to slow charge any battery to prevent possible overheating damage to the battery. The charge rate is based on the current state of charge. Figure 11.

OPEN CIRCUIT VOLTAGE	STATE OF CHARGE	CHARGING TIME TO FULL CHARGE AT 80°F**					
		at 60 amps	at 50 amps	at 40 amps	at 30 amps	at 20 amps	at 10 amps
12.6	100%	FULL CHARGE					
12.4	75%	15 min.	20 min.	27 min.	35 min.	48 min.	90 min.
12.2	50%	35 min.	45 min.	55 min.	75 min.	95 min.	180 min.
12.0	25%	50 min.	65 min.	85 min.	115 min.	145 min.	260 min.
11.8	0%	65 min.	85 min.	110 min.	150 min.	195 min.	370 min.

Figure 11. Charging rates.

Side-post batteries require that an adapter be used when charging the battery, if it is removed from the vehicle. Do not use steel bolts. Figure 12.

Figure 12. Side-post battery charging adapters.

Charging an AGM battery requires a different charger than is used to recharge a flooded type battery. The charging voltage has to be kept at or below 14.4 volts to prevent damage. Most conventional battery chargers use a charging voltage of 16 volts or higher.

7. Inspect, clean, repair and/or replace low-voltage battery(ies), battery cables, connectors, clamps, hold-downs, trays, and vent tubes.

Battery maintenance includes making certain that the battery case is clean and checking that the battery cables and hold-down fasteners are clean and tight. The battery should also be secured with a hold-down bracket to prevent vibration from damaging the plates inside the battery.

Many battery-related faults are caused by poor electrical connections at the battery. Battery cable connections should be checked and cleaned to prevent voltage drop at the connections. Check for the following conditions:

- Loose or corroded connections at the battery terminals (should not be able to be moved by hand)
- Loose or corroded connections at the ground connector on the engine block
- Wiring that has been modified to add auxiliary power for a sound system or other electrical accessory

Some vehicles require that a new battery be registered so that the powertrain control module (PCM) "knows" that the battery has been replaced. When a new battery is installed, the vehicle must have the new battery registered so that the system does not overcharge the new battery.

The replacement battery must be the same type (flooded or AGM) as the original to avoid potential issues. Use a factory or factory level aftermarket scan tool to register the battery following the on-screen directions.

8. Jump-start a vehicle (when applicable) using jumper cables, a booster battery, or auxiliary power supply.

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

Many newer vehicles have special ground and/or positive power connections built away from the battery just for the purpose of jump starting. Check the owner's manual or service information for the exact location. Figure 13.

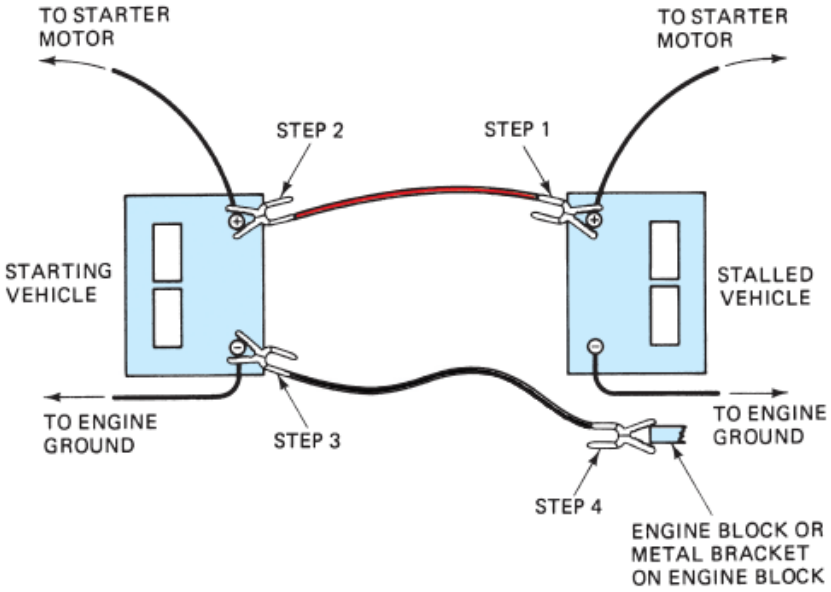

Figure 13. Jumper cable connections.

9. Test and diagnose problems resulting from starting system failures; determine needed action.

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

- The starter is the highest amperage draw device used in a vehicle and any faults , such as corrosion on battery terminals, can cause cranking system problems.

- Perform a battery load or conductance test on the battery to be sure that the battery is capable of supplying the necessary current for the starter.
- An open or high resistance anywhere in the control circuit can cause the starter motor to not engage. Items to check include:
    - "S" terminal of the starter solenoid.
    - Neutral safety or clutch switch.
    - Starter enable relay (if equipped).
    - Antitheft system fault. If the engine does not crank or start and the theft indicator light is on or flashing, there is likely a fault in the theft deterrent system. Figure 14.

Figure 14. A theft deterrent indicator lamp on the dash. A flashing lamp usually indicates a fault in the system, and the engine may not start.

10. Perform starter current draw test; determine needed repairs.

A starter amperage draw test determines if the starter motor is the cause of a no or slow cranking concern. Before performing a starter amperage test, be certain that the battery is sufficiently charged (75% or more). Connect a starter amperage tester following the tester's instructions. Figure 15.

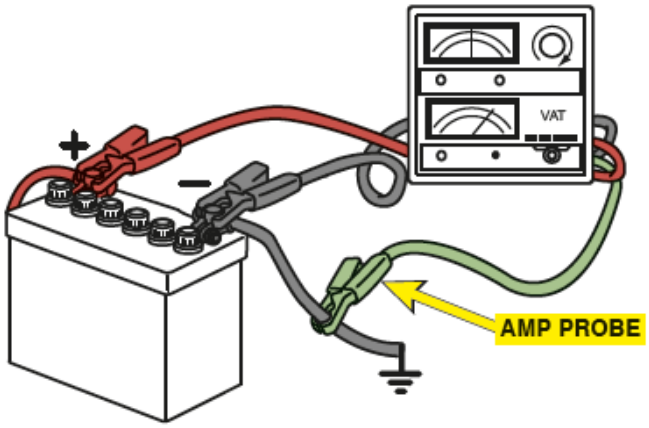

Figure 15. A starter amperage tester uses an amp probe around the positive or negative battery cables.

The following can be used as general maximum amperage draw specifications for testing a starter on the vehicle.

- 4–cylinder engines = 150 to 185 amperes (normally less than 100 amperes) at room temperature
- 6–cylinder engines = 160 to 200 amperes (normally less than 100 amperes) at room temperature
- 8–cylinder engines = 185 to 250 amperes (normally less than 125 amperes) at room temperature

11. Perform starter circuit voltage drop tests; determine needed repairs.

Voltage drop is the drop in voltage that occurs when current is flowing through a resistance. The higher the voltage drop is, the greater is the resistance in the circuit. Even though voltage drop testing can be performed on any electrical circuit , the most common areas of testing include the cranking circuit and the charging circuit wiring and connections. Voltage drop testing should be performed on both the power side and ground side of the circuit .

A high-voltage drop (high resistance) in the cranking circuit wiring can cause slow engine cranking with less than normal starter amperage drain as a result of the excessive circuit resistance. If the voltage drop is high enough, such as that caused by dirty battery terminals, the starter may not operate. A typical symptom of high resistance in the cranking circuit is a “clicking” of the starter solenoid.

Voltage drop testing of the wire involves connecting a voltmeter set to read DC volts to the suspected high-resistance cable ends and cranking the engine. Figure 16.

- Disable the ignition or fuel injection system.
- Connect one lead of the voltmeter to the starter motor battery terminal and the other end to the positive battery terminal.
- Crank the engine and observe the reading while cranking. (Disregard the first higher reading.) The reading should be less than 0.20 volt (200 millivolts).
- Repeat the voltage drop on the ground side of the cranking circuit by connecting one voltmeter lead to the negative battery terminal and the other at the starter housing or engine block.

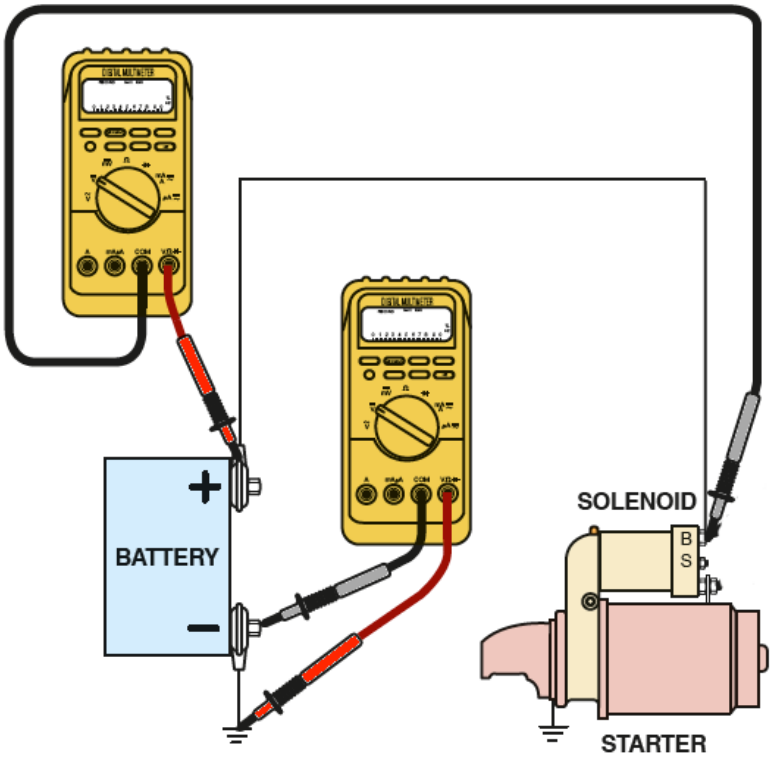

Figure 16. Voltmeter connections for a voltage drop test.

12. Inspect, test, repair and/or replace starter, relays, solenoids, modules, switches, connectors, and wires of starter circuits.

After testing has confirmed that a starter motor may need to be replaced, most vehicle manufacturers recommend the following general steps and procedures, figure 17:

STEP 1 Disconnect the negative battery cable.

STEP 2 Hoist the vehicle safely.

STEP 3 Remove the starter retaining bolts and lower the starter to gain access to the wire(s) connection(s) on the starter.

STEP 4 Disconnect and label the wire(s) from the starter and remove the starter.

STEP 5 Inspect the flywheel (flexplate) for ring gear damage. Also check that the mounting holes are clean, and the mounting flange is clean and smooth.

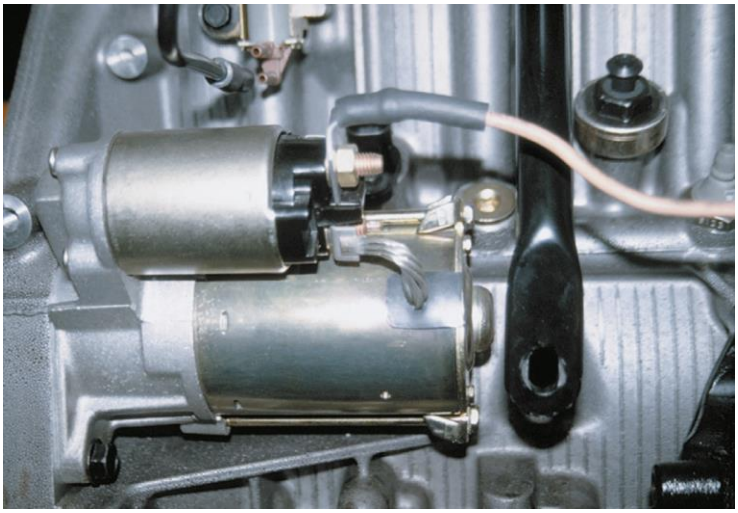

Figure 17. Starter and battery cable.

If the ignition switch is found to be faulty, partial disassembly of the steering column is necessary to replace it. Figure 18.

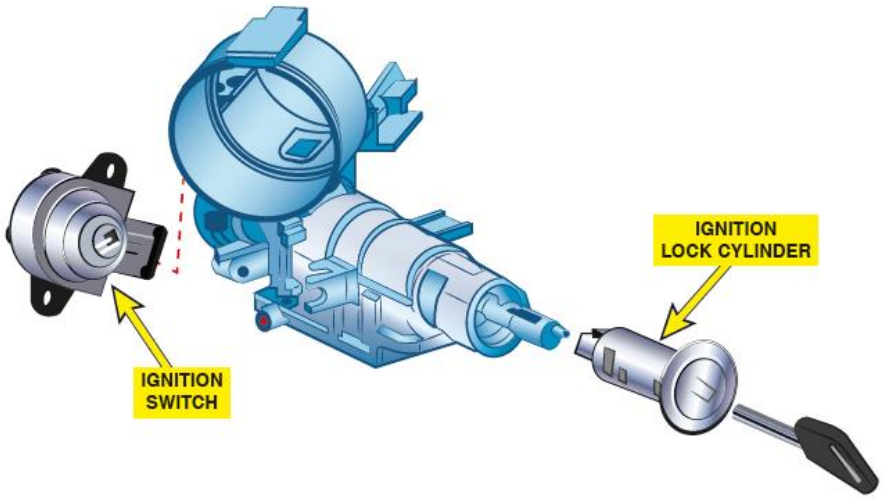

Figure 18. The ignition switch is mounted to the lock cylinder and is a separate part.

13. Differentiate between electrical and engine mechanical problems that cause a slow crank, no-crank, extended cranking, or a cranking noise condition.

Excessive current draw and/or slow cranking may indicate one or more of the following:

- Binding of starter armature as a result of worn bushings
- Oil too thick (viscosity too high) for weather conditions
- Tight or seized engine

Lower than normal amperage draw and slow or no cranking may indicate one or more of the following:

- Dirty or corroded battery connections
- High internal resistance in the battery cable(s)

- Poor ground connection between the starter motor and the engine block

Noise while cranking can be due to:

- Defective starter drive unit
- Defective flywheel
- Cracked or broken starter drive-end housing
- Worn or damaged flywheel or ring gear teeth