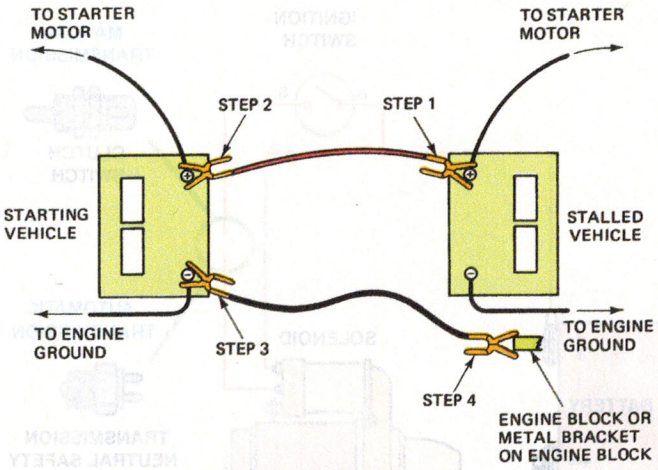

FIGURE 23–7 Jumper cable usage guide. Note that the last connection should be the engine block of the disabled vehicle to help prevent the spark that normally occurs from igniting the gases from the battery.

JUMP STARTING To safely jump-start a vehicle without doing any harm, use the following procedure.

STEP 1 Be certain the ignition switch is off on both vehicles.

STEP 2 Connect good-quality copper jumper cables as indicated in **FIGURE 23–7.**

STEP 3 Start the vehicle with the good battery and allow it to run for 5 to 10 minutes. This allows the alternator of the good vehicle to charge the battery on the disabled vehicle.

STEP 4 Start the disabled vehicle and, after the engine is operating smoothly, disconnect the jumper cables in the reverse order of step 2.

NOTE: To help prevent accidental touching of the jumper cables, simply separate them into two cables and attach using wire (cable) ties or tape so that the clamps are offset from each other, making it impossible for them to touch.

BATTERY CHARGING If the **state of charge** of a battery is low, it must be recharged. It is best to slow-charge any battery to prevent possible overheating damage to the battery. Remember, it may take eight hours or more to charge a fully discharged battery. The initial charge rate should be about 35 amperes for 30 minutes to help start the charging process. Fast-charging a battery increases the temperature of the battery and can cause warping of the plates inside the battery. Fast-charging also increases the amount of gassing (release of hydrogen and oxygen), which can create a health and fire hazard. The battery temperature should not exceed 125°F (hot to the touch). Most batteries should be charged at a rate equal to 1% of the battery's CCA rating. **SEE FIGURE 23–8.**

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

FIGURE 23–8 A typical industrial battery charger. Be sure that the ignition switch is in the off position before connecting any battery charger. Connect the cables of the charger to the battery before plugging the charger into the outlet. This helps prevent a voltage spike and spark that could occur if the charger happened to be accidentally left on. Always follow the battery charger manufacturer's instructions.

CRANKING CIRCUIT

PARTS INVOLVED The cranking circuit includes the mechanical and electrical components required to crank the engine for starting. The cranking force in the early 1900s was the driver's arm. Cranking circuits include the following:

1. **Starter motor.** The starter is normally a 0.5 to 2.6 hp (0.4 to 2 kilowatts) electric motor that can develop nearly 8 hp (6 kilowatts) for a very short time when first cranking a cold engine. **SEE FIGURE 23–9.**
2. **Battery.** The battery must be of the correct capacity and be at least 75% charged to provide the necessary current and voltage for correct operation of the starter.
3. **Starter solenoid or relay.** The high current required by the starter must be able to be turned on and off. A large switch would be required if the current were controlled by the driver directly. Instead, a small current switch (ignition switch) operates a solenoid or relay that controls the high starter current.

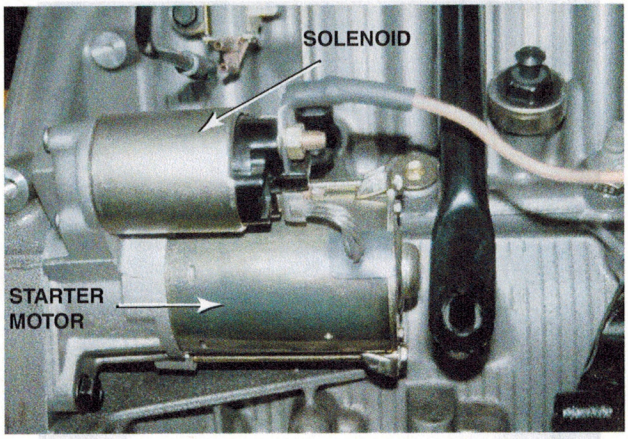

FIGURE 23–9 A typical solenoid-operated starter.

4. **Starter drive.** The starter drive uses a small gear that contacts the engine flywheel gear and transmits starter motor power to rotate the engine.
5. **Ignition switch.** The ignition switch and safety control switches control the starter motor operation.

The engine is cranked by an electric motor that is controlled by a key-operated ignition switch or the PCM on vehicles equipped with electronic starting. The ignition switch will not operate the starter unless the automatic transmission is in neutral or park or if the clutch pedal is not depressed on most vehicles equipped with a manual transmission. This is to prevent an accident that might result from the vehicle moving forward or backward when the engine is started. Many automobile manufacturers use a **neutral safety switch** or a **clutch switch** that opens the circuit between the ignition switch and the starter to prevent starter motor operation unless the gear selector is in neutral or park. The safety switch can be attached either to the steering column inside the vehicle near the floor or to the side of the transmission/transaxle. According to vehicle manufacturing engineers, starters can be expected to start an engine 25,000 times during the normal life of the vehicle. **SEE FIGURE 23–10.**

VISUAL INSPECTION For proper operation, all starters require that a known good battery is used and that both power-side and ground-side battery cables are clean and tight. **SEE FIGURE 23–11.**

- Check to see if the starter motor heat shield (if equipped) is in place.
- Check for any non-stock add-on accessories or equipment that may drain the battery, such as a cell phone charger.
- Crank the engine. It should crank and start normally. If the starter motor acts as if it is turning slower than normal, then additional tests may need to be performed to determine the root cause.

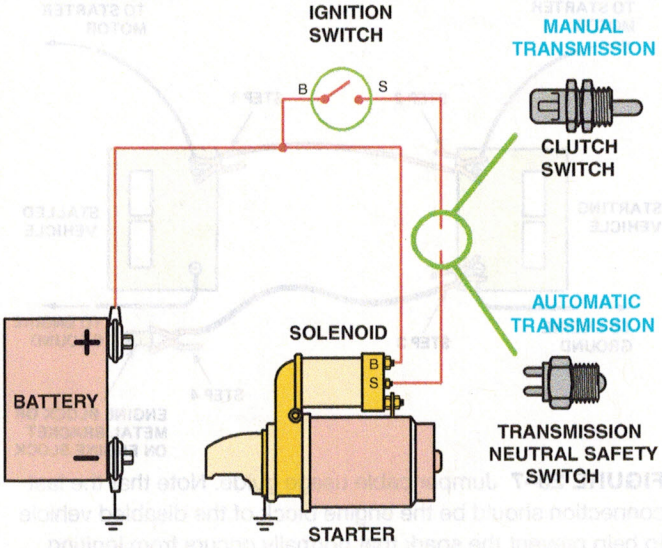

FIGURE 23–10 To prevent the engine from cranking, an electrical switch is usually installed to open the circuit between the ignition switch and the starter solenoid.

FIGURE 23–11 All battery cables and connections have to be clean and tight for the starter to be able to operate correctly.

CHARGING CIRCUIT

ALTERNATOR CONSTRUCTION An alternator is constructed of a two piece cast-aluminum housing. Aluminum is used because of its light weight, nonmagnetic properties, and heat transfer properties that are needed to help keep the alternator cool. A front ball bearing is pressed into the front housing (called the **drive-end [DE]** housing) to provide the support and friction reduction necessary for the belt-driven rotor assembly. The rear housing (called the **slip-ring-end [SRE]**) usually contains a bearing support for the rotor and mounting for the brushes, diodes, and internal voltage regulator (if the alternator is so equipped). **SEE FIGURE 23–12.**

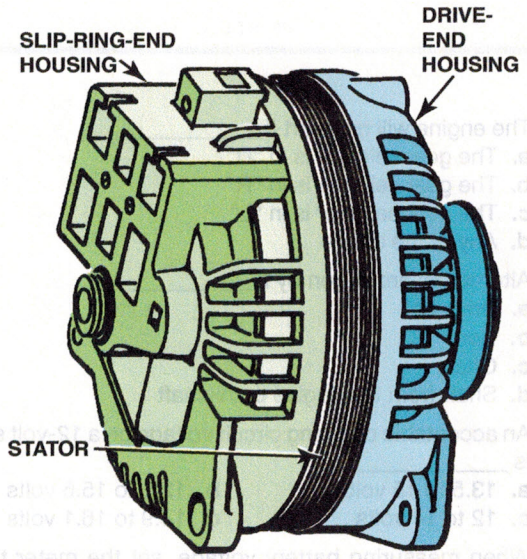

FIGURE 23–12 The end frame toward the drive belt is called the drive-end housing and the rear section is called the slip-ring-end housing.

CHARGING SYSTEM VOLTMETER TEST

- **Digital Multimeter Connections.** The charge indicator light on the dash should be on with the key on, engine off (KOEO), but should be off when the engine is running (KOER). If the charge light remains on with the engine running, check the charging system voltage. To measure charging system voltage, set the digital multimeter to read DC volts. Connect the test leads of a digital multimeter to the positive (+) and negative (−) terminals of the battery.
- **Charging System Voltage Specifications.** Most alternators are designed to supply between 13.5 and 15 volts at 2,000 engine RPM. Be sure to check the vehicle manufacturer's specifications.
- **Charging System Voltage Test Procedure.** Charging system voltage tests should be performed on a vehicle with a battery at least 75% charged. If the battery is discharged (or defective), the charging voltage may be below specifications. To measure charging system voltage, follow these steps.

1. Set the meter to read DC volts.
2. Connect the voltmeter to the positive and negative terminals of the battery.
3. Start the engine and raise to a fast idle (about 2,000 RPM).
4. Observe the voltmeter (a good reading should be between 13.5 and 15.0 volts). **SEE FIGURE 23–13.**

FIGURE 23–13 The digital multimeter should be set to read DC volts, with the red lead connected to the positive (+) battery terminal and the black meter lead connected to the negative (−) battery terminal.

SUMMARY

1. Batteries can be tested with a voltmeter to determine its state of charge. A battery load test loads the battery to one-half of its CCA rating. A good battery should be able to maintain above 9.6 volts for the entire 15-second test period.
2. Proper operation of the starter motor depends on the battery being at least 75% charged.
3. An open in the control circuit can prevent starter motor operation.
4. Charging system testing requires that the battery be at least 75% charged to be assured of accurate test results. The charge indicator light should be on with the ignition switch on, but should go out whenever the engine is running. Normal charging voltage (at 2,000 engine RPM) is 13.5 to 15 volts.

REVIEW QUESTIONS

1. What are the results of a voltmeter battery state-of-charge (SOC) test?
2. What are the steps for performing a battery load test?
3. How do you set the digital multimeter to read charging voltage?

CHAPTER QUIZ

1. Which battery rating is used mostly when testing a battery to see if it is performing normally?
   a. CA
   b. CCA
   c. MCA
   d. Reserve capacity
2. A battery high-rate discharge (load capacity) test is being performed on a 12-volt battery. Technician A says that a good battery should have a voltage reading higher than 9.6 volts while under load at the end of the 15-second test. Technician B says that the battery should be discharged (loaded to two times its CCA rating). Which technician is correct?
   a. Technician A only
   b. Technician B only
   c. Both technicians A and B
   d. Neither technician A nor B
3. When jump starting, _____.
   a. The last connection should be the positive post of the dead battery
   b. The last connection should be the engine block of the dead vehicle
   c. The alternator must be disconnected on both vehicles
   d. Both a and c
4. Starters rotate the engine by a _____.
   a. Drive belt
   b. Gear
   c. Chain
   d. Shaft from the engine crankshaft
5. The engine will not start if _____.
   a. The gear selector is in "D"
   b. The gear selector is in "R"
   c. The gear selector is in "L"
   d. Any of the above
6. Alternators are driven by a _____.
   a. Drive belt
   b. Gear
   c. Chain
   d. Shaft from the engine crankshaft
7. An acceptable charging circuit voltage on a 12-volt system is _____.
   a. 13.5 to 15 volts
   b. 12.6 to 15.6 volts
   c. 12 to 14 volts
   d. 14.9 to 16.1 volts
8. When measuring battery voltage, set the meter to read _____.
   a. DC volts
   b. AC volts
   c. Hertz (Hz)
   d. Amperes (A)
9. A type of electronic battery testing that does *not* place a load on the battery is called _____.
   a. VAT test
   b. Conductance tester
   c. Load tester
   d. Ammeter tester
10. A battery should be charged at what rate?
    a. High or fast depending on the capacity of the charger
    b. At a rate of 1% of the CCA rating of the battery
    c. At a rate that does not cause the battery to get hotter than 125°
    d. Both b and c are correct