Recommended Practice

RP 129A VMRS 031-001, 032-001

HEAVY-DUTY VEHICLE CRANKING AND CHARGING TROUBLESHOOTING: 12-VOLT SYSTEMS

PREFACE

The following Recommended Practice is subject to the Disclaimer at the front of TMC's *Recommended Maintenance Practices Manual*. Users are urged to read the Disclaimer before considering adoption of any portion of this Recommended Practice.

PURPOSE AND SCOPE

The purpose of this Recommended Practice (RP) is to provide a sequential procedure for evaluating or troubleshooting the electrical charging and cranking systems of heavy-duty vehicles during a pilot inspection, preventive maintenance (PM) inspection, or repair/diagnostic procedure.

Environmental and physical conditions—such as vibration, corrosion, temperature extremes, wiring or connector damage, etc.—can cause charging and cranking system deterioration that may not be noticeable to drivers or technicians. Problems in starter and alternator operation are often caused by defective or undersized wiring, corroded terminals and/or loose connections. Performing these tests out-of-sequence can also lead to misdiagnosis and the unnecessary removal and replacement of parts.

REQUIRED TROUBLESHOOTING CHECKS

There are two vehicle electrical systems that must be checked: cranking and charging.

⚠ CAUTION: Always follow all steps in their listed order to prevent unnecessary component removal or damage of starters, alternators, batteries, etc.

⚠ WARNING: Before conducting these procedures:

1. Be sure the transmission is in neutral or park.
2. Set the parking brake firmly.
3. Be sure to wear face or eye protection during testing.
4. Be cautious of fan, alternator, and other moving parts. Automatic fans will cycle on and off during engine operation.

A. CRANKING SYSTEM TEST

Step 1: Batteries

It is imperative that the batteries must be tested first and each pass an individual test before proceeding with the rest of the cranking system test. The minimum battery open circuit voltage (OCV) must be at or above 12.4 volts before continuing.

Step 2: Cranking Circuit

The cranking circuit consists of the large cables that carry the high starter current from the batteries to the starter. Some vehicles that do not have a pure copper crank circuit may use the frame rail as an electrical conductor. These circuits are typically single or dual circuits. Excessive loss here results in slow cranking speeds—especially in cold weather. An inability to start due to slow cranking can lead to reduced starter life or starter failure because of the heat generated from the prolonged start attempt.

NOTE: In the cranking circuit, the maximum allowable circuit voltage loss listed for in-service vehicle is somewhat higher than for new vehicles, due to normal deterioration of connections. The maximum allowable current loss as shown (0.5 volts) covers high-output 12-volt starters used on most medium- and heavy-duty on-highway vehicles with diesel engines. Consult the starter manufacturer for the allowable cable voltage loss for a specific starter model.

Step 3: Solenoid Circuit

The solenoid circuit consists of the wiring from the battery source, the contact disc of the magnetic switch and the wiring to the "SW" terminal of the solenoid. Excessive voltage drop in this circuit will cause the starter not to engage (only click) or the starter solenoid to shift in and out. Either case results in a no-start condition, leading to burned contact disc and terminals in the starter solenoid. Poorly maintained, discharged or defective batteries can cause the same problems. This magnetic switch could be

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mounted on the starter as an integrated magnetic switch (IMS) or external cab sheet metal. The type of starter will influence the current draw in this solenoid circuit. Most gear reduction starters require an IMS for optimal performance. Contact the component manufacture for recommendations.

Step 4: Control Circuit
(used with a magnetic switch)
The control circuit consists of the wiring from the battery source, the ignition key and/or the push button, the wiring from the key to the coil of the magnetic switch, the magnetic switch coil and the wiring back to the battery pack. In some cases, an over crank protection circuit is included in the starter motor or engine ECU. Excessive loss in this circuit can cause a "no start" complaint. Excessive loss and/or a deeply discharged battery pack can also cause the magnetic switch to open and close, which will cause the starter to shift in and out. A dead or completely discharged battery or an opening in this circuit will impede current flow, preventing cranking. A short in this circuit can also result in a blown fuse and/or an open circuit breaker—both of which will prevent starting.

B. CHARGING SYSTEM TEST

Step 1: Batteries
It is imperative that the batteries must be tested first and each pass an individual test before proceeding with the rest of the cranking system test. The minimum battery open circuit voltage (OCV) must be at or above 12.4 volts before continuing.

Step 2: Charging Circuit
The charging circuit consists of the wiring between the battery to the alternator (positive) and the alternator to the battery (negative). As with the cranking circuit, the frame may be part of the ground (negative) circuit. Excessive loss here can cause the batteries to not charge properly. Discharged batteries can cause the issues outlined in the cranking session and also result in misdiagnosis of the alternator (low-voltage output).

Step 3: Alternator Output Test
For exact results, alternator output (voltage and amperage) must be tested only after the battery pack has been tested and determined to be good, and the charging circuit has been tested and is within spec. Before conducting this test, be sure the alternator is securely mounted and that the belts are in good condition and proper tension. If these conditions are not met, the electrical test cannot be done correctly.

The voltage drop tests, as described in this RP, measuring circuit resistance using available shop tools. This resistance value is calculated by measuring the voltage loss (drop) when a specific amount of current is flowing within that circuit. The amount of resistance being measured is always near zero so the resistance value cannot be measured with a the type of ohmmeter typically found in shop multimeters.

To calculate the resistance of a specific circuit, the voltage drop at a specific current draw must be known. To determine the resistance of the circuit, use the following formula: $R = V/I$

where:
R = Circuit Resistance
V = Total Voltage Drop
I = Current Flow

Example:
0.5 volts / 500 amps = 0.001 ohms or 1 milliohm.

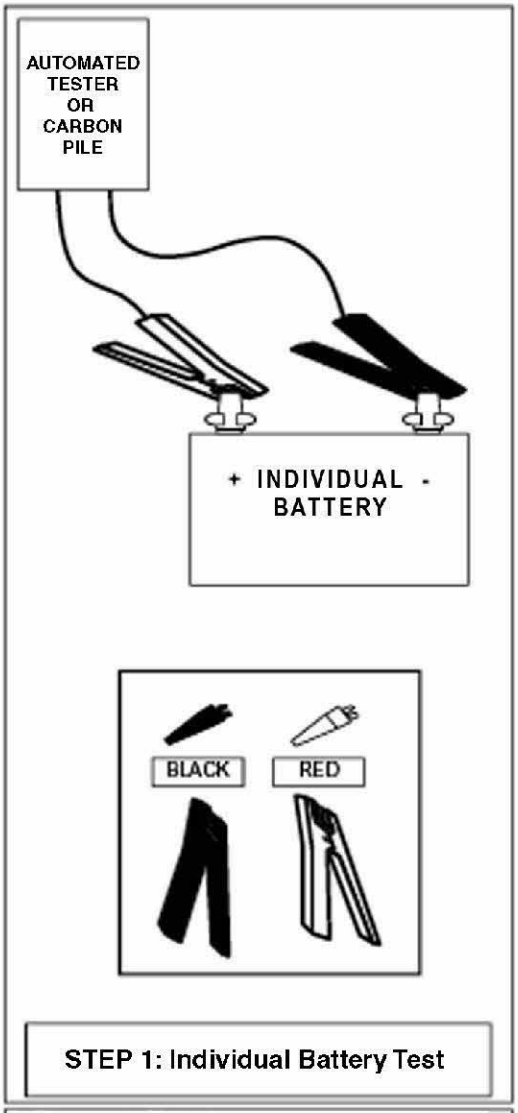
TEST EQUIPMENT OPTIONS
Automated Electronic Testers—A microprocessor-based device that incorporates a battery test, a voltage drop test, and an alternator output test (voltage and amperage), and calculates/displays the results. These testers are preferred because their high accuracy and repeatability, and they minimize the chance for human error.

Variable Load Carbon Pile Testers—These devices incorporate an ammeter with at least a 500 amp load. Also preferred would be a voltmeter, two sets of leads, one set that loads and connects to the battery and external leads that are connected various places as described. To read voltage at both locations, a switch is used to move from internal to external. If an external voltmeter is not available, a handheld voltmeter can be used. It is also preferable for the unit to have a clip-on ammeter. Whenever possible, a digital voltmeter is preferred for greater accuracy.

NOTE: In the following diagrams, when using an automated electronic tester to perform voltage drop tests, these units will—with one hook-up—offer overall voltage drop values as well as individual leg (positive and negative) voltage drop values. The variable load carbon piles testers require an overall test as well as a positive and negative test—thus, requiring three separate hook-ups.

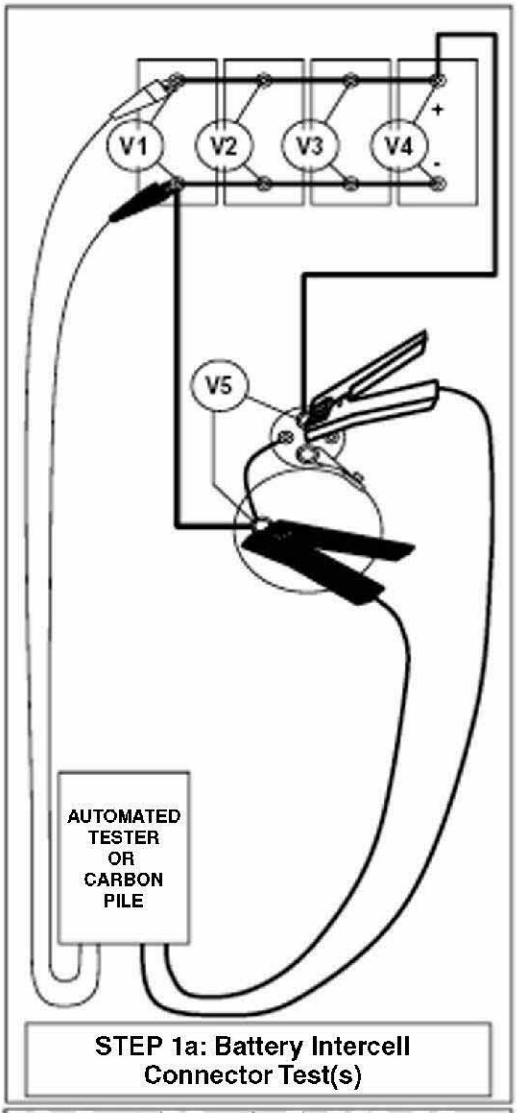
When testing the batteries, make sure that lead adapters are used and that the lead adapters make good contact with the lead pad of the battery.

CRANKING TEST PROCEDURE



STEP 1: Individual Battery Test

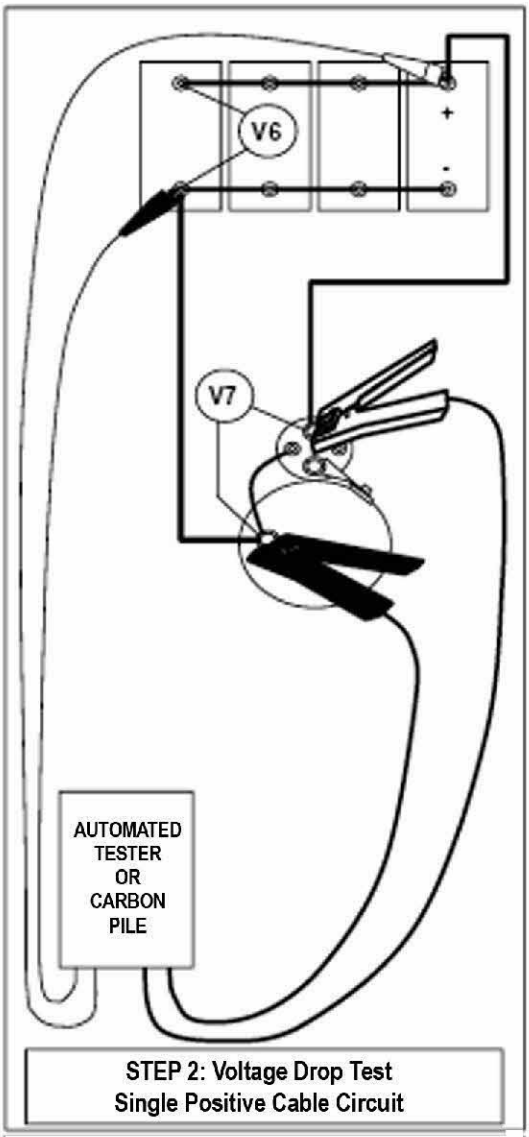
1. Disconnect all batteries.
2. Clean the lead pad area with a wire brush.
3. Use lead battery adapters on stud-type batteries.
4. Follow tester procedures and TMC RP 132A for testing instructions.
5. All batteries must either pass the individual testing or can be replaced with batteries that pass and have an open circuit voltage of 12.4 volts or higher before continuing to the next step.



STEP 1a: Battery Intercell Connector Test(s)

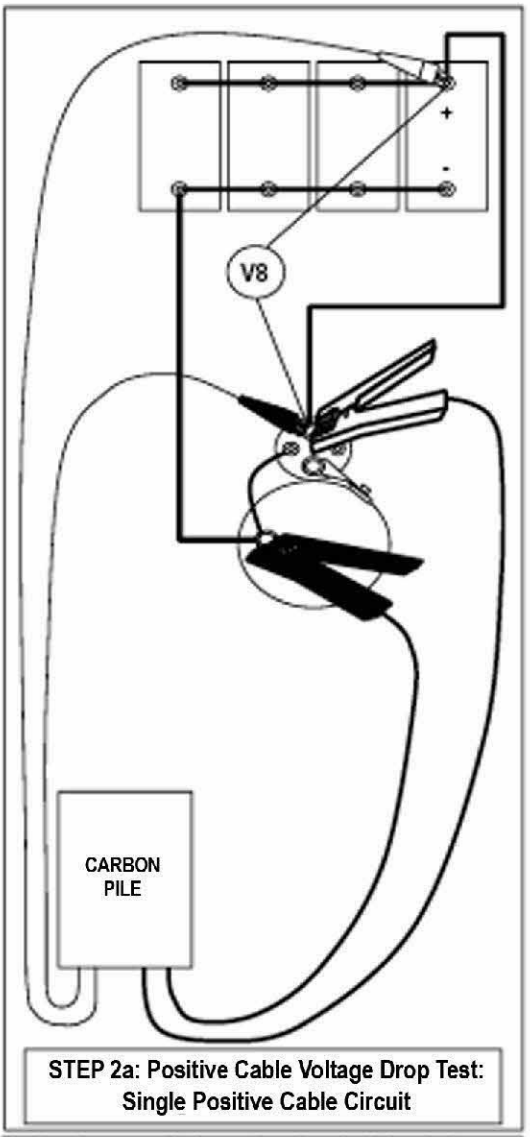
1. Conduct test with the engine off and all electrical loads off.
2. Connect tester as shown.
3. Automated Tester
   A. Follow tester instructions and review results.
   B. Repeat test and move small clamps for V2, V3 & V4.
   C. V1, V2, V3 & V4 should all be within 0.1 volts.
4. Carbon Pile Tester
   A. Apply 500 amp load with tester.
   B. Repeat test and move small clamps for V2, V3 & V4.
   C. V1, V2, V3 & V4 should all be within 0.1 volts.
   D. If more than 0.1 volts, repair or replace cables and retest.

CRANKING TEST PROCEDURE (CONTINUED)



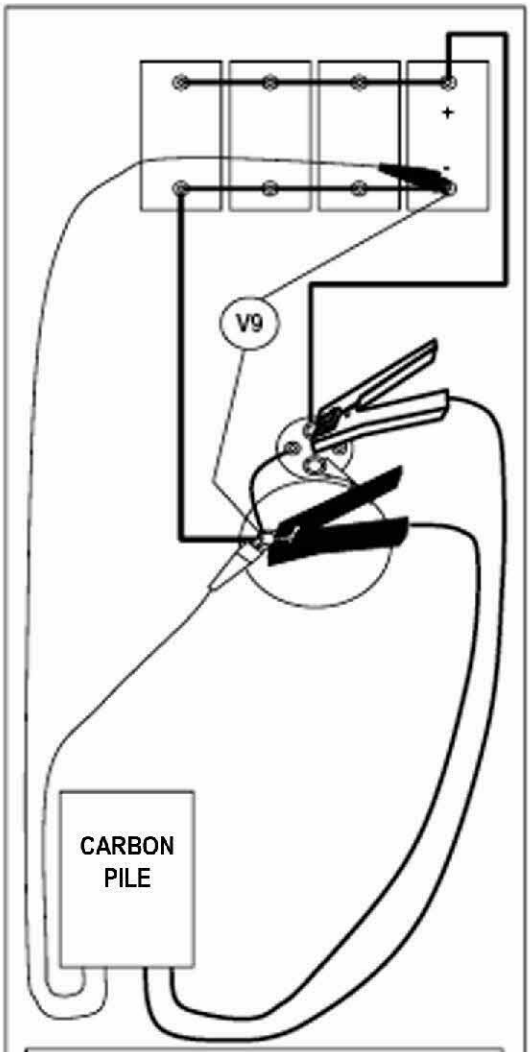
STEP 2: Voltage Drop Test
Single Positive Cable Circuit

1. Conduct test with the engine off and all electrical loads off.
2. Determine if the cranking circuit is a single positive or dual positive cable circuit.
3. Connect tester as shown.
4. Automated Tester
   A. Follow tester instructions and review results.
5. Carbon Pile Tester
   A. Apply 500 amp load with tester.
   B. V6-V7 should be less than 0.5 volts.
   C. If more than 0.5 volts, proceed to the positive and negative side of the test to determine the problem area.
6. If the circuit passes or has been repaired and passes, continue to the next step.



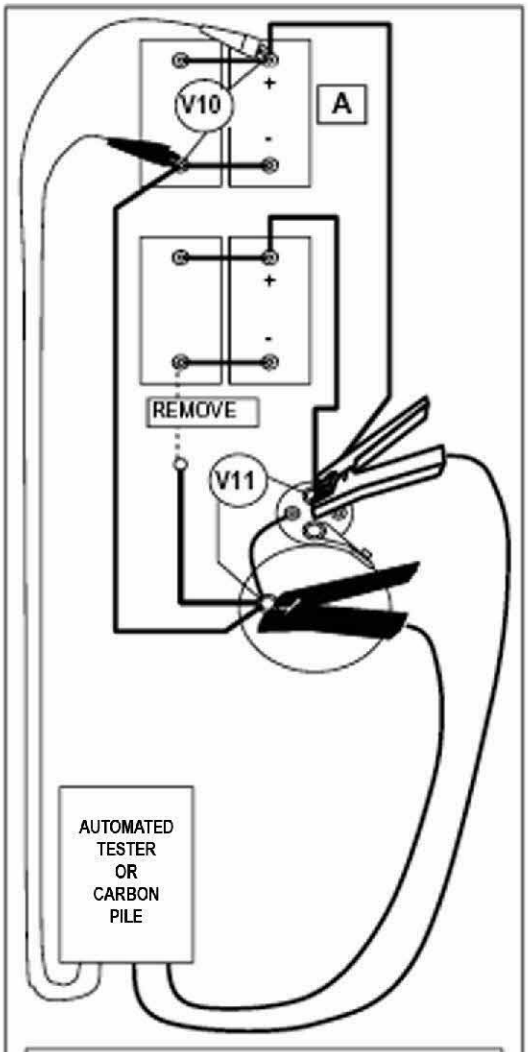
STEP 2a: Positive Cable Voltage Drop Test:
Single Positive Cable Circuit

1. Conduct test with the engine off and all electrical loads off.
2. Connect large alligator clips as shown.
3. Connect small red external clamp to battery positive.
4. Connect small black external clamp to starter B+ terminal.
5. External voltmeter will read zero (static).
6. Apply 500 amp load with carbon pile and read external voltmeter V8. This reading is the voltage drop in the positive cable.
7. V8 (Step 2a) + V9 (Step 2b) must equal less than 0.5 volts. Always repair or replace the side of the circuit that has the higher voltage drop. These (V8 & V9) do not have to be equal, just less than 0.5 volts together.



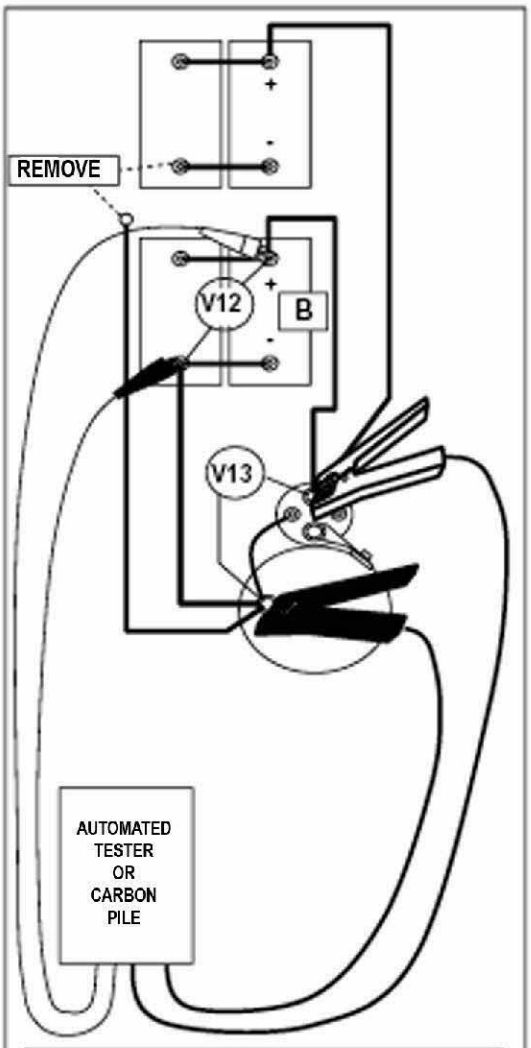
STEP 2b: Negative Cable Voltage Drop Test
Single Negative Cable Circuit

1. Conduct test with the engine off and all electrical loads off.
2. Connect large alligator clips as shown.
3. Connect small black external clamp to battery negative.
4. Connect small red external clamp to starter ground terminal.
5. External voltmeter will read zero (static).
6. Apply 500 amp load with carbon pile and read external voltmeter V9. This reading is the voltage drop in the negative cable.
7. V8 (Step 2a) + V9 (Step 2b) must equal less than 0.5 volts. Always repair or replace the side of the circuit that has the higher voltage drop. These (V8 & V9) do not have to be equal, just less than 0.5 volts together.



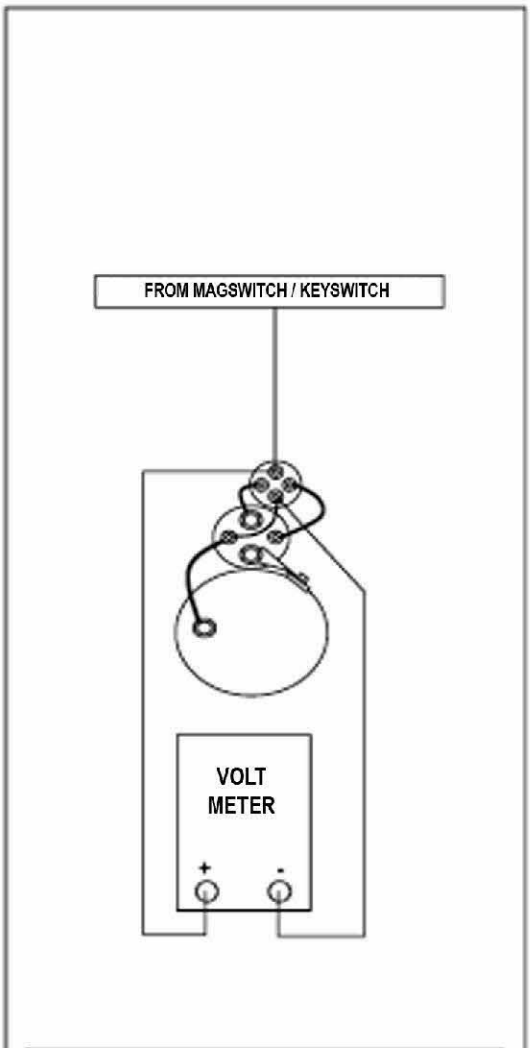
STEP 2c: Voltage Drop Test
Split System A

1. Conduct test with the engine off and all electrical loads off.
2. Disconnect the ground (-) cable from battery bank B.
3. Connect tester as shown.
4. Automated Tester
   A. Follow tester instructions and review results.
5. Carbon Pile Tester
   A. Apply 250 amp load with tester.
   B. V10-V11 should be less than 0.5 volts.
   C. If more than 0.5 volts, proceed to the positive and negative side of the test to determine the problem area in 2a; use 250 amps as the load.
6. If the circuit passes, or has been repaired and passes, continue to the next step.



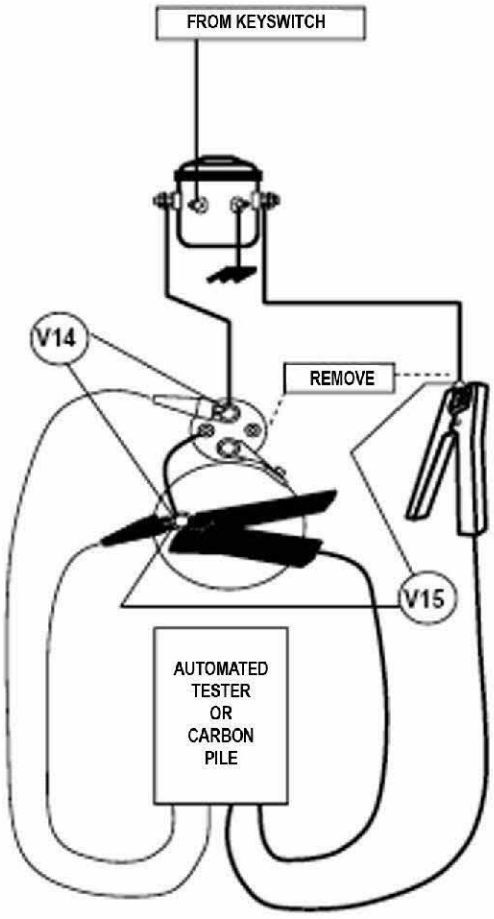
STEP 2d: Voltage Drop Test Split System B

1. Conduct test with the engine off and all electrical loads off.
2. Disconnect the ground (-) cable from battery bank A.
3. Connect tester as shown.
4. Automated Tester
   A. Follow tester instructions and review results.
5. Carbon Pile Tester
   A. Apply 250 amp load with tester.
   B. V12 - V13 should be less than 0.5 volts.
   C. If more than 0.5 volts, proceed to the positive and negative side of the test to determine the problem area in 2a or 2b ; use 250 amps as the load.
6. If the circuit passes, or has been repaired and passes, continue to the next step.



STEP 3: Control Circuit Test With Integral Control Switch

1. Make sure parking brake is set and transmission is out of gear.
2. Use a voltmeter, automated tester, or carbon pile tester that has a voltmeter that will operate without the large clamps being connected.
3. Connect as shown.
4. Turn the ignition key to start and observe the voltage reading. Voltage should be at least 12.0 volts and engine should start.
5. If the voltage is 12.0 or higher and the starter does not engage, replace the starter.
6. If the voltage is less than 12.0 volts, continue to the next session.

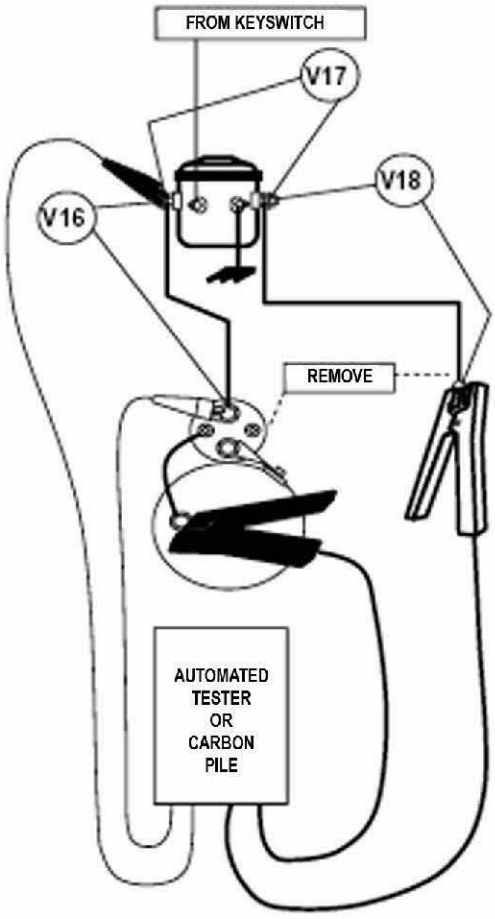


STEP 3: Control Circuit Test External Mag Switch - Complete Circuit

1. Conduct test with the engine off and all electrical loads off.
2. Disconnect the ground (-) cable(s) from batteries.
3. Remove the s-terminal or 50 terminal from the starter solenoid.
4. Connect the tester as shown. A bolt and washer may need to be used for an easier connection at the s-terminal wire.

⚠ CAUTION Do not let the large red clamp touch ground since it will see positive voltage during the test.

5. Reconnect the ground (-) cable(s) to the batteries.
6. Automated Tester
   A. Follow tester instructions, turn key to start for three seconds and review results. This test must be completed three times.
7. Carbon Pile Tester
   A. With ignition key turned to start, apply 100 amp load and review V14 and V15.
   B. V14-V15 shows voltage drop. (See your starter manufacturer's specifications for maximum voltage drop allowed.
   C. If out of spec, proceed to test (Step 3a) individual legs.
   D. If within spec, continue test.

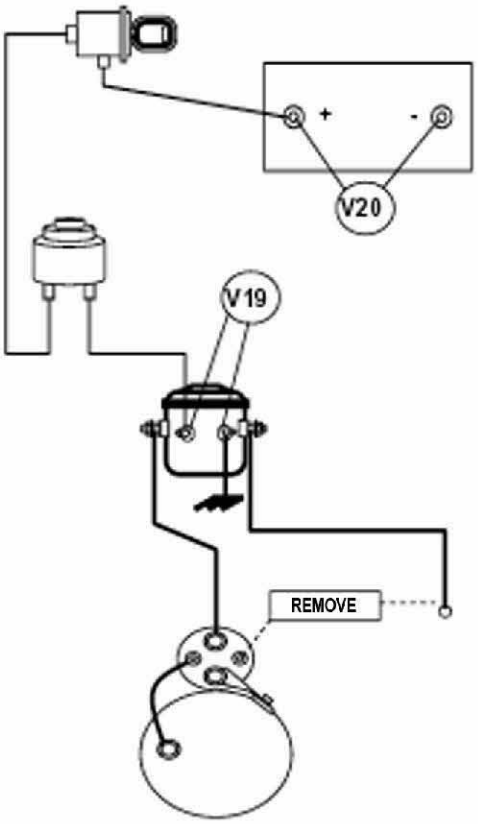


STEP 3a: Control Circuit Test External Mag Switch - Individual Legs

1. Conduct test with the engine off and all electrical loads off.
2. Disconnect the ground (-) cable(s) from batteries.
3. Remove the s-terminal or 50 terminal from the starter solenoid.
4. Connect the tester as shown. A bolt and washer may need to be used for an easier connection at the s-terminal wire.

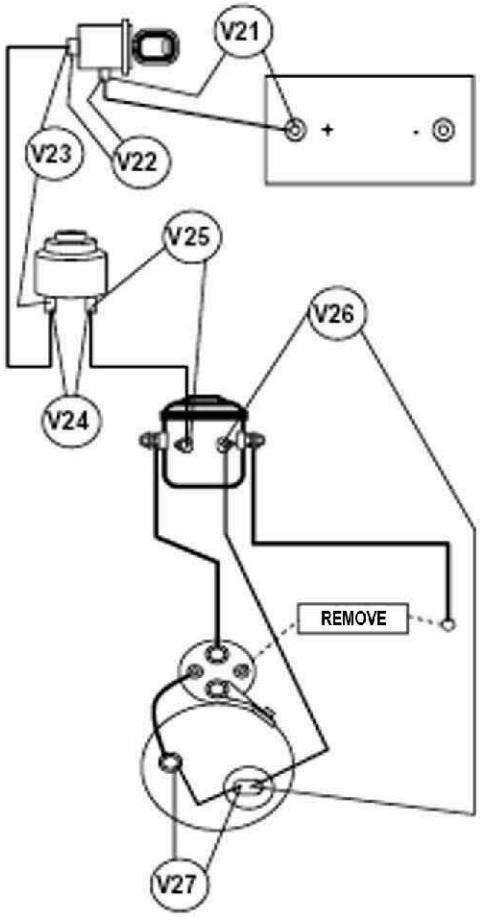
⚠ CAUTION Do not let the large red clamp touch ground since it will see positive voltage during the test.

5. Reconnect the ground (-) cable(s) to the batteries.
6. Automated Tester
   A. Follow tester instructions. Review results.
7. Carbon Pile Tester
   A. With ignition key turned to start, apply 100 amp load and review external voltage reading.
   B. V16 shows voltage drop for leg 1. Record drop.
   C. Move the small clips to V17, and repeat test. Record drop for V17, leg 2.
   D. Move the small clips to V18, and repeat test. Record drop for V18, leg 3.
   E. Repair or replace the leg of the circuit with the highest voltage drop.



STEP 3b: Keyswitch Circuit Test Complete Circuit Without OCP

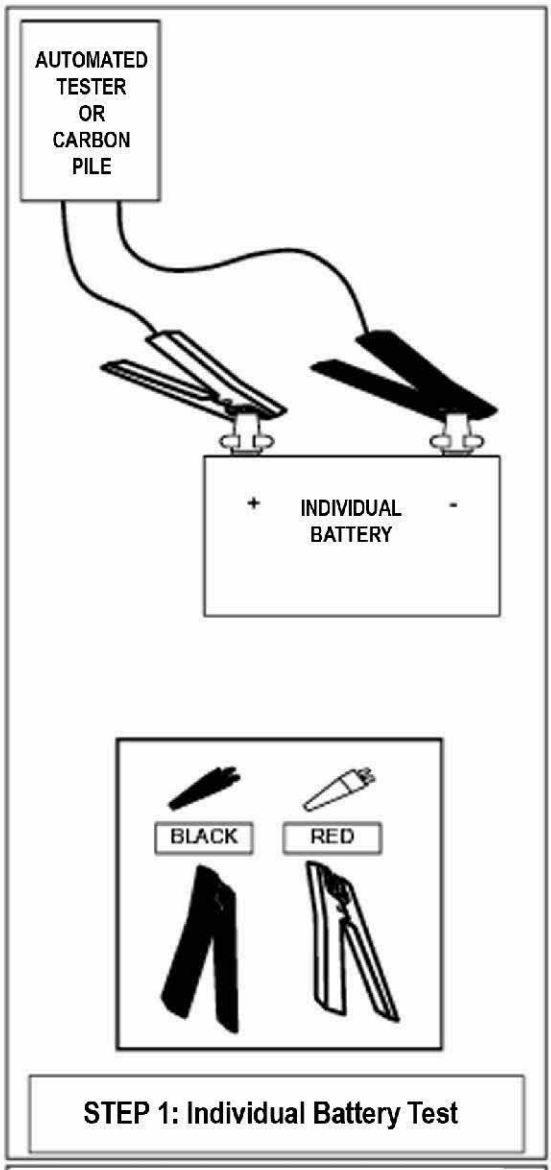
1. Conduct test with the engine off and all electrical loads off.
2. Leave the s-terminal wire disconnected.
3. With ignition key turned to start, push and hold push button. Note voltage readings V19 and V20.
4. If V20-V19 shows voltage drop, must be less than 0.5 volts.
5. If out of spec, proceed to test (Step 3c) individual legs.



STEP 3c: Keyswitch Circuit Test Individual Segments with OCP

1. Conduct test with the engine off and all electrical loads off.
2. Leave the s-terminal wire disconnected.
3. With ignition key turned to start, push and hold push button. Note voltage reading V21.
4. Repeat, recording readings V22 through V27.
5. Repair or replace the leg of the circuit with the highest voltage drop.
6. V22 + V23 + V24 + V25 + V26 + V27 must equal less than 0.5 volts.

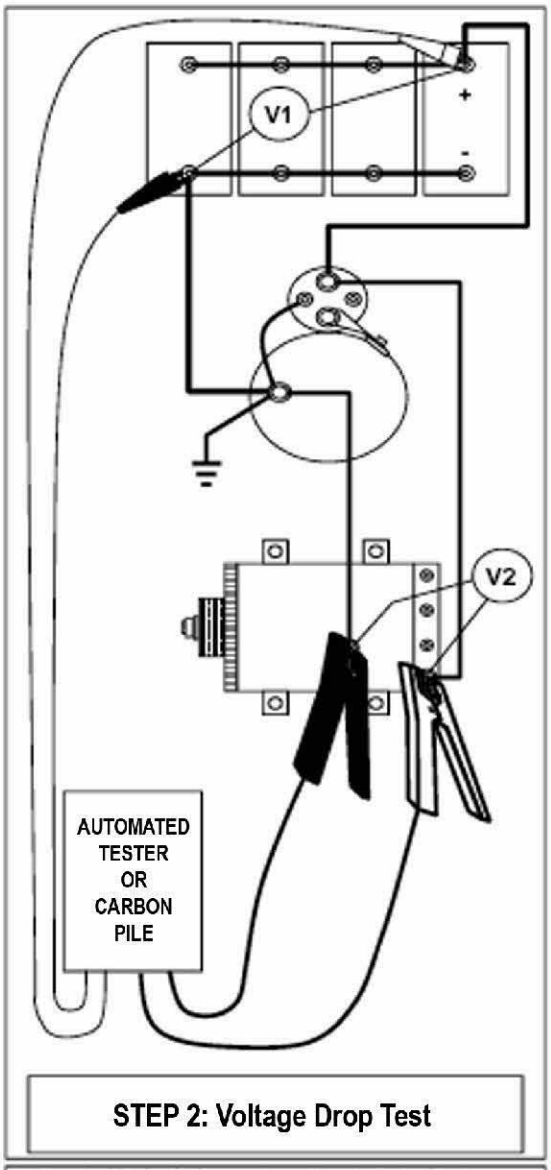
CHARGING TEST PROCEDURE



STEP 1: Individual Battery Test

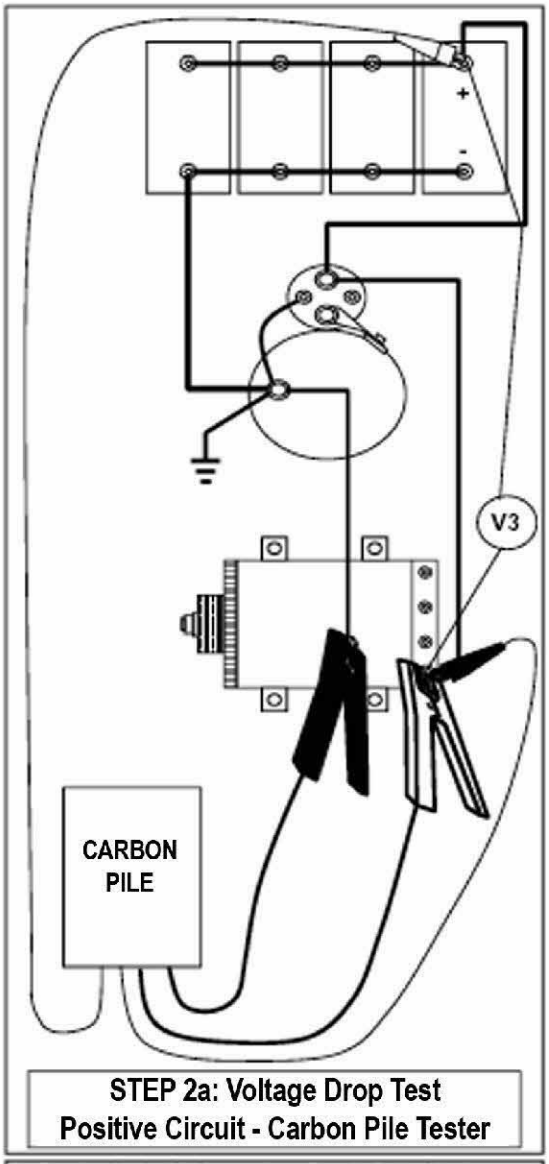
1. Clean the lead pad area with a wire brush.
2. Use lead battery adapters on stud-type batteries.
3. Follow tester procedures and TMC RP 132A for testing instructions.
4. All batteries must either pass the individual testing or be replaced with batteries that pass and have an open circuit voltage of 12.4 volts or higher before continuing to next step.

NOTE: For maximum battery life, all batteries must be from the same manufacturer and have the same ratings. These batteries should not vary in age more than six months.



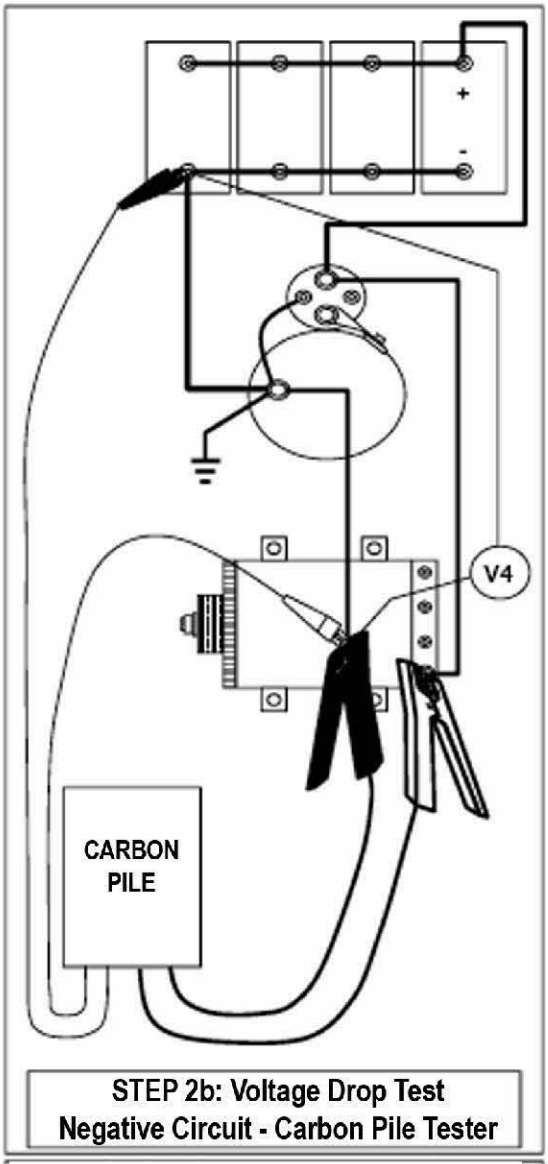
STEP 2: Voltage Drop Test

1. Conduct test with the engine off and all electrical loads off.
2. Using alternator adapters may help in making a good connection.
3. Connect tester as shown.
4. Automated Testers
   A. Follow tester instructions and review results.
5. Carbon Pile Testers
   A. Draw amp load equal to the alternator's rated output.
   B. V1-V2 should be less than 0.5 volts.
   C. If more than 0.5 volts, proceed to the positive and negative side of the test to determine the problem area.
   D. If the circuit passes or has been repaired and passes, continue to the next step.



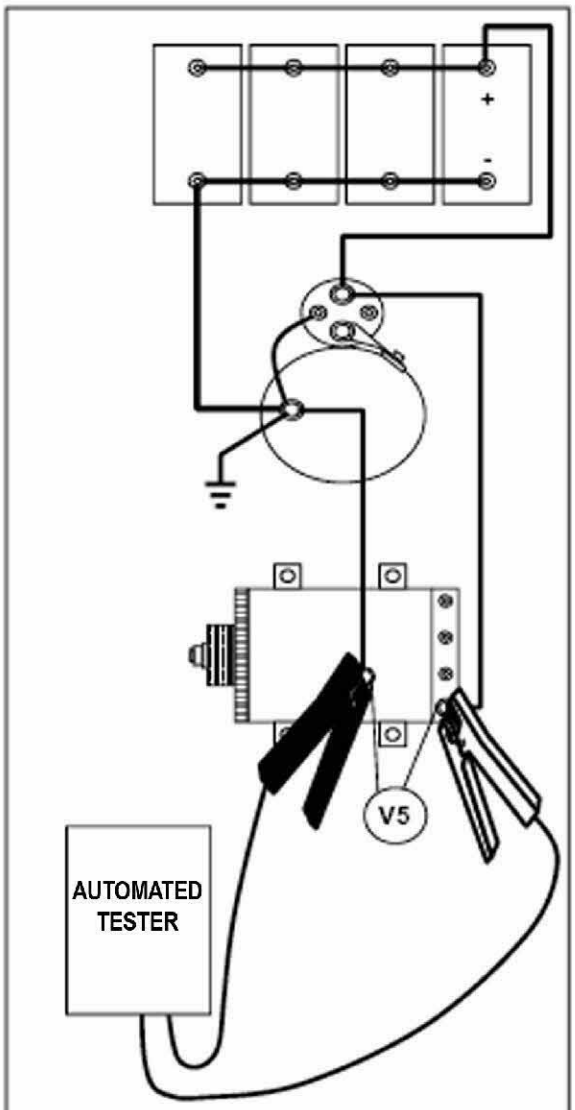
STEP 2a: Voltage Drop Test
Positive Circuit - Carbon Pile Tester

1. Conduct test with the engine off and all electrical loads off.
2. Connect large alligator clips as shown.
3. Connect small red external clamp to alternator output (B+) terminal.
4. External voltmeter will read zero (static).
6. Pull rated output of alternator with carbon pile and read external voltmeter.
   This reading is the voltage drop in the positive cable.
7. If the circuit passes or has been repaired and passes, continue to the next step.



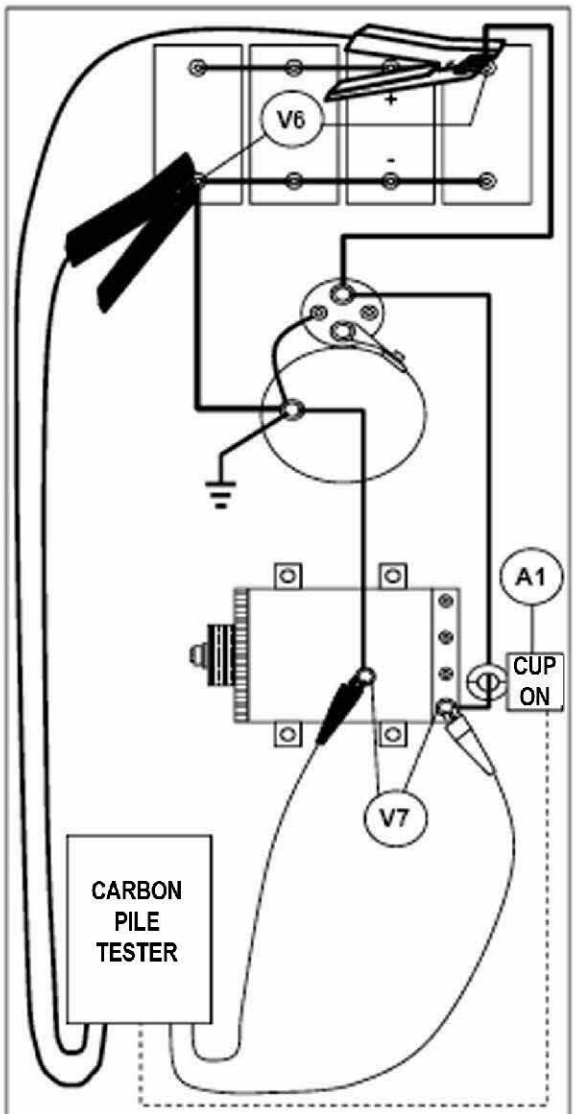
STEP 2b: Voltage Drop Test
Negative Circuit - Carbon Pile Tester

1. Conduct test with the engine off and all electrical loads off.
2. Connect large alligator clips as shown.
3. Connect small black external clamp to battery negative.
4. Connect small red external clamp to alternator ground.
5. External voltmeter will read zero (static).
6. Pull rated output of alternator with carbon pile and read external voltmeter. This reading is the voltage drop in the negative cable.
7. If the circuit passes or has been repaired and passes, continue to the next step.



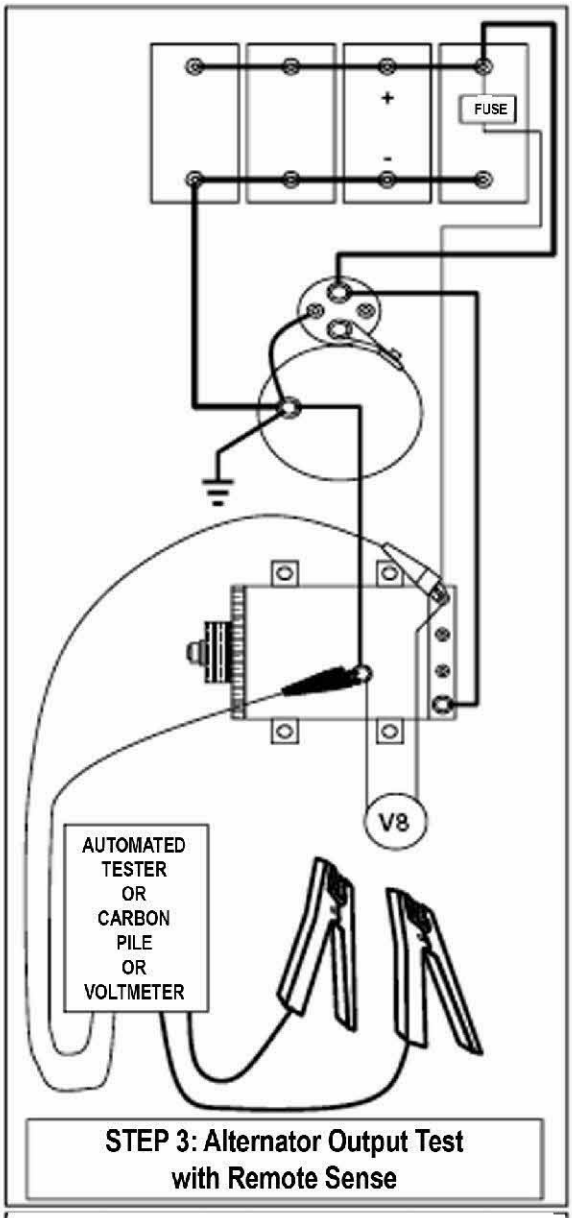
STEP 3: Automated Tester Alternator Output Test

1. Turn all electrical loads off. Make sure parking brake is set and transmission is out of gear.
2. Connect tester as shown.
3. Follow tester instructions.
4. Start engine and perform test.
5. Review test results.



STEP 3: Carbon Pile Tester Alternator Output Test

1. Turn all electrical loads off. Make sure parking brake is set and transmission is out of gear.
2. Connect tester as shown.
3. Install clip-on ammeter from tester or hand-held clip-on ammeter around all (+) cables (close to alternator).
4. Start engine and run at fast idle. Allow battery to stabilize.
5. Note external voltage reading at idle speed V7.
6. Run engine to governed speed and note external voltage reading V7. Voltage should not rise more than 0.2 volts.
7. While engine is still at governed speed, apply load with carbon pile until battery voltage drops to between 12.5 and 12.0 volts and note the ammeter reading A1. Should be within +/- 10 percent of alternator's rated output.



STEP 3: Alternator Output Test with Remote Sense

1. Check to see if alternator is equipped with remote sense terminal. If so, confirm that the terminal is being used (should be fused wire to batteries).
2. Check remote sense terminal of the alternator for battery voltage V8. If remove sense terminal shows battery voltage, continue to test per "Alternator Output Test" instructions.
3. If remote sense terminal shows voltage less than battery voltage or zero, check the lead to the battery for blown fuse or damaged wire. Repair circuit.
4. Continue to test per "Alternator Output Test" instructions.