PROFESSIONAL SERVICE TECHNICIAN WORKBOOK

Delco Remy

Diagnostics, Alternators and Starters

Peterbilt

CLASS PAYS

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New Intelli-Check2™ Systems Analyzer

The batteries, alternator, starter and cables make up the foundation of a heavy vehicle's electrical system. Without the batteries, the starter cannot work. Without the starter, the engine would not run. Without a running engine, the alternator could not charge the batteries. Each component depends on the other two for the vehicle to deliver the goods, and all of these components require cables in good condition with minimal voltage loss.

But each of these components can fail, often in ways that are difficult to diagnose. The challenge for the service technician is not only to find the problem and fix it, but to do it quickly and efficiently to satisfy the customer.

To shorten a customer's downtime, electrical system problems have to be detected and repaired before the vehicle leaves the service department. One solution is new diagnostic technology that identifies any weak link in a vehicle's electrical system by instantly testing alternators, starters, batteries and voltage drop.

This new diagnostic technology is now available to service departments. Remy, Inc., has developed the new Intelli-Check2 Systems Analyzer diagnostic tool, plus a new heat resistant alternator, to help get customers back on the road and keep them there.

Sequential Programming

With microprocessor control, Intelli-Check2 delivers more accurate and efficient data in one sweep than through the multiple, time-consuming methods of the past, boosting technician productivity.

It does this by being programmed to test in sequence:

- The analyzer automatically tests the system first. For example, if the charging system is being tested, the analyzer's programming runs the battery bank test before it tests the charging system.
- If the battery bank passes, the analyzer then tests the alternator cables.
- If the cables pass the test, the analyzer then tests the alternator.

With this sequential programming, Intelli-Check2 eliminates needless repetition and component replacement, saving the technician time and allowing him to work more efficiently.

J1708 Data Link

Unlike other analyzers, Intelli-Check2 is available with an optional J1708 data link to communicate with the electronic components on the vehicle. The analyzer does this in either of two ways: it transmits a message in computer code to the electronic control unit and waits for a response, or it monitors activity on the link without transmitting a message.

Testing Voltage Drop

Loose or corroded terminal connections and damaged or undersized wires can produce resistance, which causes a voltage drop between charging system or starter system components.

With Intelli-Check2, one technician can check voltage drop on multiple circuits. Determining starter voltage drop is important. Testing with heavy-duty straight drive and gear reduction starters shows that for every one volt of drop in a system, the cold-cranking engine loses 28 RPM – the difference between starting and not starting.

The Technology and Maintenance Council (TMC) specifies allowable voltage drop. For the cranking circuit with a 500-amp load, voltage drop must not exceed 0.5 volt. For the solenoid control circuit with an 80-amp load, voltage drop must not exceed one volt for a 12-volt system or two volts for a 24-volt system.

Voltage drop causes other problems besides failure to start. (1) The alternator cannot recharge batteries. (2) The starter suffers slow cranking speed and solenoid failures. (3) The starter's magnetic switch can cause

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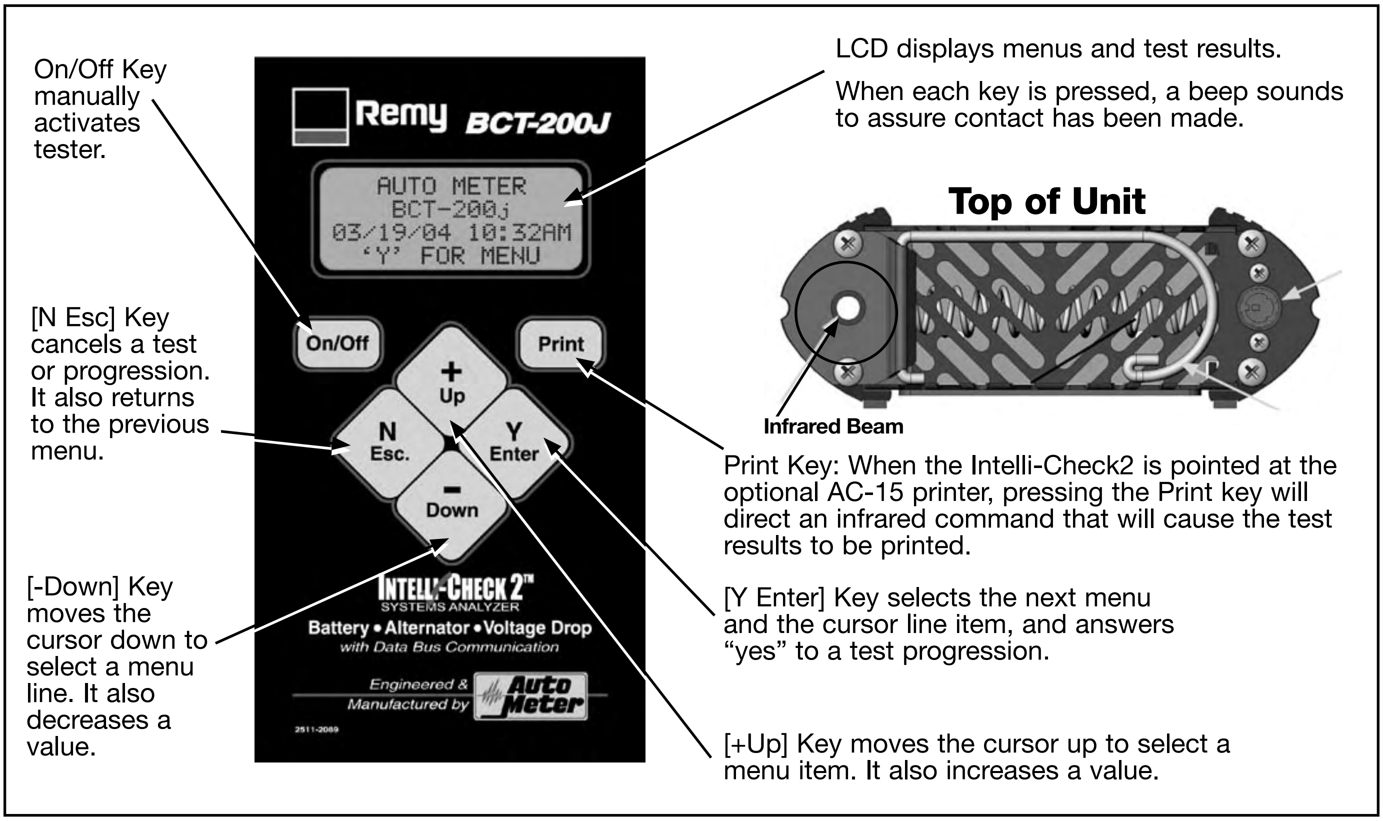


Figure 1. Intelli-Check2 Controls and Functions

premature starter or solenoid failure and possible ring gear milling. (4) The batteries cannot maintain a full state of charge.

Common causes of cranking circuit voltage drop include:

- Terminal or cable corrosion.
- Loose terminal or ground connections.
- Undersized cables.
- Over-long cables (batteries far away from the starter).

Individual Tests

Using Function and Control keys (Figure 1), Intelli-Check2 performs the tasks of three traditional tools:

- Carbon pile.
- Clamp-on ammeter.
- Voltmeter.

Initial Setup

IMPORTANT: Every time the analyzer is activated, setup should be run to assure that the unit has the information it needs for accurate data recording – air temperature or date/time, for example. The technician also can set these options:

- VIN.
- Technician ID number.
- Visual inspections needed.
- Battery date codes.

Next, the main menu will appear. Technicians choose which system test they want – charging, starting or battery – with the [+Up], [-Down], [Y Enter] or [N Esc] keys.

Battery Banks Test

No matter which system test – battery, charging or starting – is selected, the analyzer's sequential programming automatically tests the battery bank first to assure that it's delivering proper voltage.

Here's the procedure for testing only the battery bank:

1. Select SYSTEM TEST from the main menu.
2. Select BATTERY from the sub-menu.
3. Enter the number of batteries.
4. When prompted by the analyzer, connect the J1708 data cable. The analyzer screen will display optional data like the VIN, as well as oil temperature (to assure proper engine temperature if the starter is being tested).
5. Connect the large leads (Figure 2):
   a. Red to the main bank positive cable.
   b. Black to the main bank negative cable.

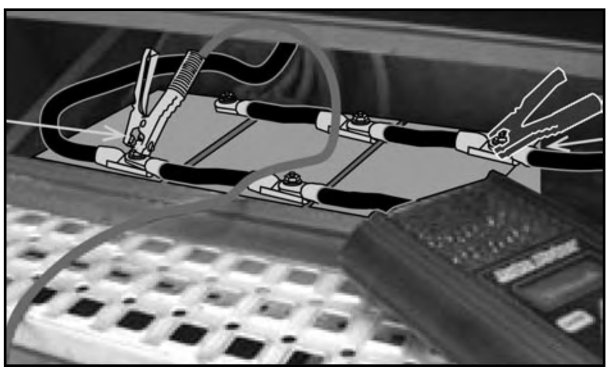


Figure 2. Connecting to Battery Bank

6. Press the [+Up] or [-Down] keys to enter:
   a. The approximate battery temperature in units of 10°F.
   b. The CCA rating of one battery.
7. Press [Y] to begin the test.
   a. If the analyzer screen displays "GOOD BATTERIES", the test is complete. Return to the main menu.

```
#211 12V BANK
GOOD BATTERIES
12.70V CHRG 100%
11.50V LOADED
```

   b. If the analyzer screen displays "TEST SEPARATELY", a low battery has been detected. Continue with the Individual Battery Test below.

```
#211 12V BANK
TEST SEPARATELY
12.38V CHRG 66%
```

Individual Battery Test

1. Select "BATTERY TEST" from the menu. Because the analyzer has already detected a battery problem, its sequential programming automatically selects the individual battery test.
2. When prompted by the analyzer, inspect each battery for:
   a. Dirt, cracks or leaking.
   b. Loose or contaminated post connections.

NOTE: In step 3 below, for group 31 threaded battery posts, screw on the top post adapters (Figure 3).

Figure 3. Top Post Adapters

3. When prompted by the analyzer, connect the large leads:
   a. Red to positive post.
   b. Black to negative post.
4. With the [+Up] and [-Down] keys, enter:
   a. Battery date code (only if requested in the initial setup).
   b. Battery temperature.
   c. CCA rating.

5. Press [Y Enter] to begin the individual battery test. The screen displays the results:
   a. **GOOD BATTERY** = a battery that is good and is charged.
   b. **GOOD NEEDS CHARGE** = a battery that is good but is low on charge.
   c. **MARGINAL BATTERY** = a battery that has passed the load test but the estimated CCA is getting low or the battery is near the end of its useful life.
   d. **CHARGE** and **RETEST** = a battery with insufficient charge to record accurate test results.
   e. **BAD BATTERY** = a battery that failed the load test or had an estimated CCA below about 70 percent of the rated value.

Starter Cable Test: Split Battery Systems

A split battery system (two banks of batteries having separate lines to the starter) must have each circuit tested separately. Disconnect one battery bank negative cable while testing the circuit of the other. Each side must be tested at one-half the amps required by the starter. The sum of the positive drop and the negative drop should not exceed 0.5V for each bank. Here is an example for a 500 amp starter:

Left Bank Test Results with Drop @ 250 Amps

0.20	Pos.
-0.10	Neg.
0.30V	Total Drop (PASSES TEST)

Right Bank Test Results with Drop @ 250 Amps

0.25	Pos.
0.30	Neg.
0.55V	Total Drop (FAILS TEST)

Charging System Tests

The analyzer's sequential programming first checks the battery bank, then charging system components and voltage drop. If the system passes, the technician connects the analyzer to test the alternator by itself. (The charging cables alone can be tested by selecting V DROP MENU and then CHARGING CABLES from the sub-menu.)

NOTE: During this test, the analyzer also checks connections and warns of problems by displaying one of these messages:

- Large leads not connected.
- Small leads not connected.
- Bad connection on large leads.
- Small leads reversed.
- Check large red lead.

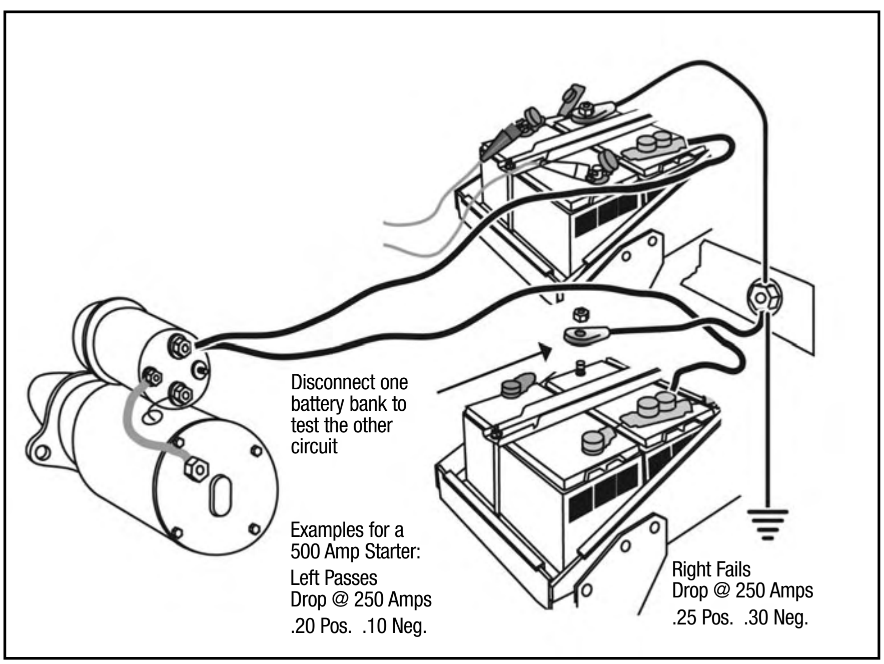


Figure 4. Split Battery Test Setup

- Check large black lead.
- Turn off engine and accessories (eliminate electrical “noise”).
- Electrical short or accessory draw.

CHARGING TEST “A” – Alternator Cables and Connections

With the leads connected as described below, the analyzer first tests the battery bank, and then tests for voltage drop.

Procedure:

1. Select SYSTEM TEST on the main menu and press [Y Enter].
2. Move to CHARGING with [+Up] and [-Down] keys and press [Y Enter].
3. If TEST INCOMPLETE appears, press [N Esc] to begin this new charging system test.
4. Enter the rated alternator output using the [+Up] and [-Down] keys, and then press [Y Enter].
5. Connect the leads when prompted by the analyzer, then press [Y Enter] to continue:
    a. Large leads to the alternator – red to positive, black to negative.
    b. Small leads to the battery bank – red on the positive main and black on the negative main. (Do not connect the small leads to an individual battery.) Using the small leads, the analyzer will check the battery bank first, and then the cables for voltage drop.
6. Press [Y Enter] to begin the test for the battery bank and cable voltage drop.
7. Wait for a load to be applied.
8. Results:
    a. Both positive and negative circuits will be displayed.
    b. If the results are not within specification, correct the connection or replace the cable, then re-test.

```
#8 CHRG CABLES
FAILED @ 200A
GOOD TO 183A
0.26POS 0.26NEG.
```

    c. If the results are within specification, the system has passed the test. Proceed with the alternator/regulator test.

```
#7 CHRG CABLES
PASSED @ 120A
GOOD TO 192A
0.15POS 0.15NEG
```

CHARGING TEST “B” – Alternator/ Regulator

After testing and passing the system, the analyzer automatically tests the alternator and regulator when directed by the technician.

1. Select ALTERNATOR TEST from the main menu and press [Y Enter].
2. If the analyzer is programmed to prompt visual inspection, check:
    a. Belt condition.
    b. Belt tension.
    c. Cables and connections.
3. When prompted by the analyzer, connect the single alligator clip from the optional J1708 cable to the alternator’s “R” terminal.
4. Press [Y Enter] to begin the test.
5. Start the engine.
6. Allow the voltage to stabilize until it stops rising.
7. Press [Y Enter] to begin.
8. When prompted by the analyzer, increase engine rpm to governed speed for 10 seconds.
9. If no results appear, press [Y Enter].
10. Results will be displayed for high or low output, as well as diode diagnosis.

```
#147 12V ALTER.
GOOD REG. 14.15V
GOOD DIODE
GOOD OUTPUT
```

NOTE: Remote sense alternators will show high readings if not connected properly. Reconnect the remote sensor and test again.

Starting System Tests

After connecting to test the battery bank and cable voltage drop, the technician changes connections to test the starting system magnetic and cranking circuits. If the system passes, the technician connects the analyzer to test the starter by itself.

STARTING TEST "A" – Battery Bank/ Voltage Drop

Loose or corroded terminal connections and damaged or undersized wires can produce resistance, which causes a voltage drop between starter system components.

As with other analyzer tests, voltage drop alone can be tested by selecting the VDROP menu and then STR MAIN CABLES from the sub-menu.

Procedure:

1. Connect the leads (Figure 5):
   a. The large leads to the starter – red on starter positive, black on starter negative (ground).
   b. The small leads to the battery bank – red on bank positive, black on bank negative. (Do not connect the small leads to an individual battery.) Using the small leads, the analyzer will check the cables for voltage drop.

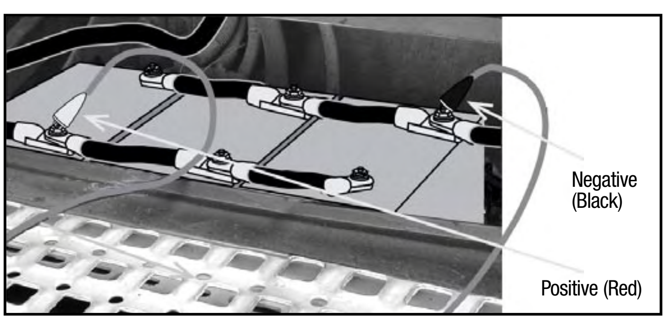


Figure 5. Starter and Battery Bank Lead Attachment

2. Wait for a load to be applied when prompted by the analyzer.
3. Results will depend on the condition of the cables:
   a. Both positive and negative circuits will be displayed with this single test.
   b. If the circuit does not pass, correct the connection or replace the cable, then re-test. (The analyzer will automatically resume the test after it is disconnected. When prompted by the analyzer, press [Y Enter].)

STARTING TEST "B" – Magnetic Circuit

The magnetic circuit supplies a path for current to the coils of the starter solenoid with minimum voltage drop. The test below has three steps.

- If the whole circuit passes the first test, there is no need to continue.
- If the circuit fails the first test, the next two tests are completed to obtain results of each leg and the magnetic switch itself.

NOTE: As in the charging system test, the analyzer checks connections and warns of problems by displaying messages.

As with all other analyzer testing, the magnetic circuit alone can be tested by selecting the VDROP menu and then MAG CIRCUIT from the sub-menu.

Procedure:

1. Assure that the battery banks are delivering proper voltage by testing as shown on page 4. Then proceed to step 2 below.
2. Select SYSTEM TEST on the main menu and press [Y Enter].
3. Move to STARTING with [+Up] and [-Down] keys and press [Y Enter].
4. If TEST INCOMPLETE appears, press [N ESC] to begin this new starting system test.
5. For safety:
   a. Disconnect the negative cable from the battery to avoid shorts or sparks during clamp/lead connecting.
   b. To avoid starting the engine during this test, disconnect the "S" terminal from the starter solenoid (Figure 6, page 8) when prompted by the analyzer, then press [Y Enter] to continue with the magnetic circuit test.

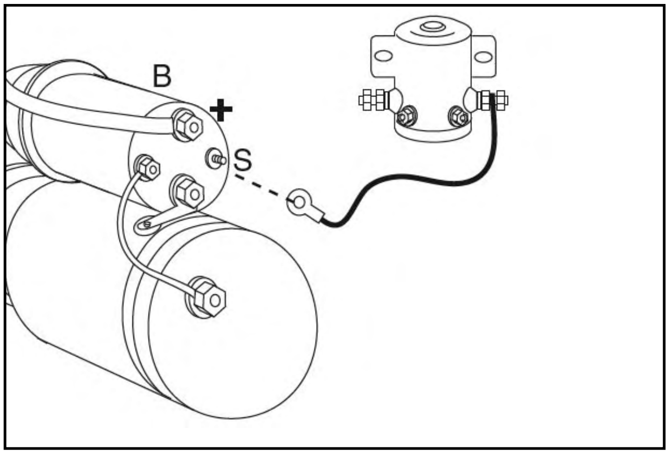


Figure 6. Disconnecting the "S" Terminal

6. From the VDROP sub-menu, select MAG CIRCUIT and press [Y Enter].
7. When prompted by the analyzer, connect the leads (Figure 7):
   a. The large red clamp (+) to the disconnected ring from the S-terminal magnetic circuit.
   b. The large black clamp (-) to the starter ground.
   c. The small red lead (+) to the "B" terminal (+) of the starter solenoid.
   d. The small black lead (-) to the starter ground.
8. Press [Y Enter].
9. When prompted by the analyzer, reconnect the battery's negative terminal for starter power.
10. When prompted by the analyzer, energize the magnetic switch for 3 to 5 seconds with a remote starter or an assistant in the cab.
11. Results:
    a. If the voltage drop is within specifications, the whole circuit passes.
    b. If the circuit failed the test, press [Y Enter] for the analyzer to advance to the next test. Failure is indicated by more than 1 volt drop at 80 amps.
12. To determine the faulty circuit component:
    a. When prompted by the analyzer, move the small red lead to the magnetic switch hot side connection from the battery (test position 2 in Figure 7).
    b. Press [Y Enter].
    c. Energize the switch again for 3 to 5 seconds.
    d. Move the small red lead to the negative (-) side of the magnetic switch (test position 3 in Figure 7).
    e. Press [Y Enter].
    f. Energize the switch again for 3 to 5 seconds.

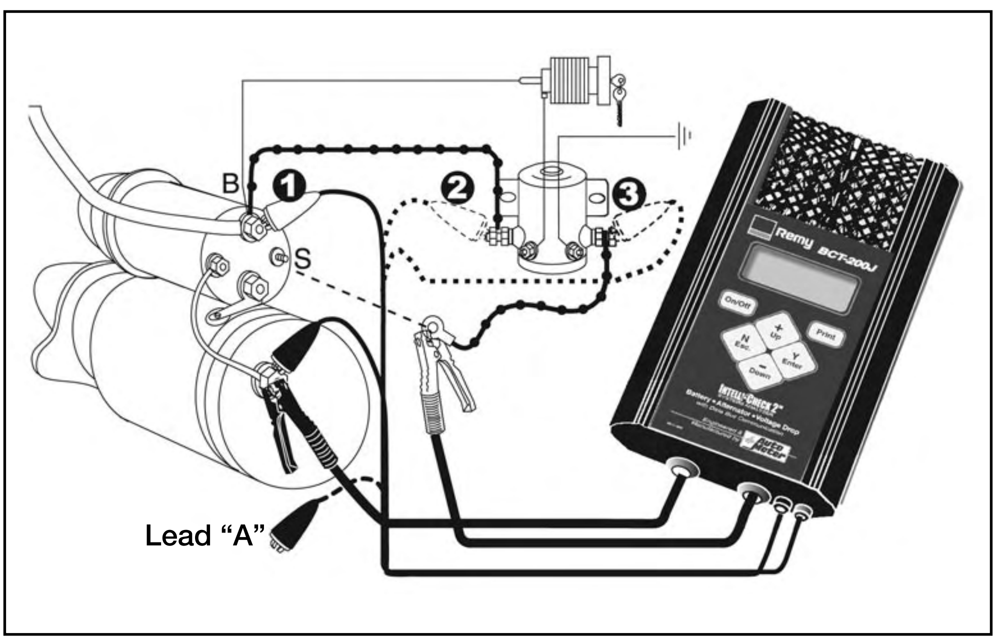


Figure 7. Magnetic Circuit Test Lead Attachment (Positions for Three Tests). Small black lead ("A") must be connected to the starter ground on 24-volt systems, but can be disconnected or grounded for 12-volt systems.

g. The final results will show the circuit component needing repair.

```
#337 MAG/CIRCUIT
PASSED!
DROP WITHIN SPEC
DROP @80A. 0.65V
```

```
#338 MAG/CIRCUIT
FAILED!
DROP @80A: 1.54V
'Y' TO CONTINUE
```

Starter Draw Test

While this test is a continuation of the system test, it can also be run individually be selecting STARTER TEST and pressing [Y Enter].

NOTE: The Intelli-Check2™ analyzer will recognize any significant electrical draw, including glow plugs, a computer or accessories. Therefore, heat the glow plugs before beginning the starter draw test. Make sure the engine is warm so it starts quickly with the proper draw. (Cold engine oil will significantly increase starter drag.)

Procedure:

1. If prompted by the analyzer, inspect all cables and connections.
2. Press [Y Enter].
3. Connect the leads as prompted by the analyzer, pressing [Y Enter] after each to continue:
   a. The large leads to the starter – red on starter positive, black on starter negative (ground).
   b. The small leads to the battery bank – red on bank positive, black on bank negative. (Do not connect the small leads to an individual battery.)
4. Press [Y Enter] to begin the test.
5. When prompted by the analyzer, start or crank the engine.
6. Wait for the analyzer to display results:
   a. With J1708 data link.

```
#216 12V STARTER
NORMAL DRAW
OIL TEMP: 58F
CURRENT: 1240A
```

```
#217 12V STARTER
HIGH DRAW
OIL TEMP: 58F
CURRENT: 1240A
```

```
#217 12V STARTER
BEG VOLTS: 12.56
END VOLTS: 9.48
CURRENT: 1240A.
```

   b. Without J1708 data link.
7. If the results are outside of specifications, perform the following and re-test:
   a. Check connections for looseness or corrosion that would cause voltage drop.
   b. Repair or replace defective cables or connectors.
   c. Check the starter for:
      1) Shorted windings.
      2) Bent armature.
      3) Broken housing.
      4) Bad bearings.

Generic Voltage Drop Test

The generic setup (Figure 8) can be used to test the entire circuit, or individual sections of any circuit that includes battery, cables and any load.

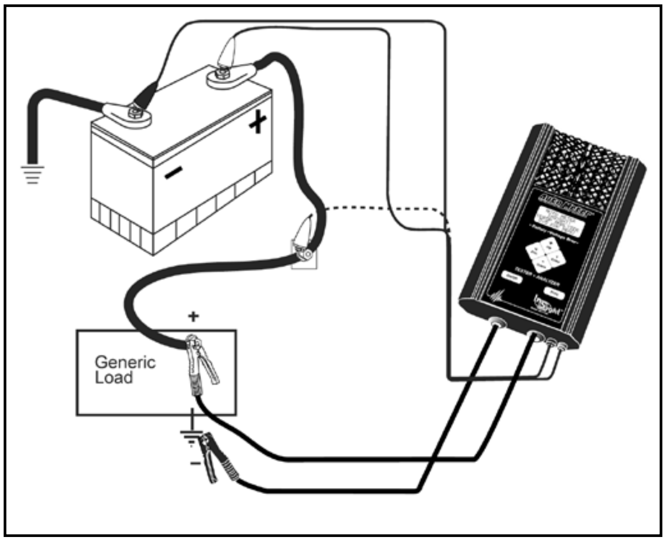


Figure 8. Setup for Generic Voltage Drop Test

Procedure:

1. Select VDROP from the main menu and press [Y Enter].
2. Select GENERIC VDROP from the sub-menu and press [Y Enter].
3. Using the [+] or [-] keys, adjust the amp rating to match the load and press [Y Enter].
4. Connect the leads:
   a. The large leads to the load.
   b. The small leads to the battery or along the circuit being tested.
5. Press [Y Enter].
   a. If all connections are correct, wait for a load to be applied.
   b. The results will vary depending upon the condition of the cables. Both the positive and negative circuit results will be indicated from this single test.

```
#28 GEN. VDROP
VOLTAGE DROPS
AT 250 AMPS
0.33 POS 0.32 NEG
```

   c. Results:
      1) If the overall voltage drop is not within the desired specifications, move the small leads closer along the line being tested and run the test again.
      2) If the results are desirable, it is the section included in the previous test that is bad.
      3) If the results are not desirable, the problem is most likely in the section being tested. Repair and test the entire section again.

Printing Results

Intelli-Check2 can store the results of 180 different tests, ready for printing to show the customer (Figure 9).

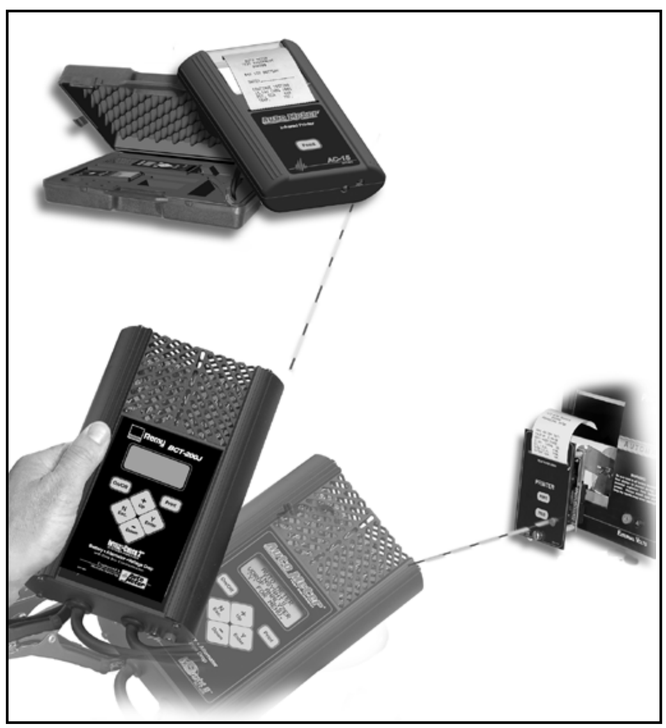


Figure 9. Using Optional AC15 Infrared Printer

Procedure:

1. Make sure the infrared printer is properly set up within 40 feet of Intelli-Check2.
2. Select REVIEW/PRINT. The last test will be displayed.
3. Press:
   a. [+Up] or [-Down] key to select the desired test.
   b. [N Esc] to select MAIN MENU.
4. Point the Intelli-Check2 at the printer (in or out of the case) with the printer's infrared receiver pointed at Intelli-Check2.
5. Press [Print].
6. Wait for the screen to clear before moving the Intelli-Check2. Depending upon the test made, the printer will sometimes yield more information than the LCD.
7. Printing options:
   a. For a single test printing, wait until the printer stops printing before you press [Print] again.
   b. For multiple test printing, pressing the print button repeatedly (up to six times) will automatically print the test in review and the previous tests.

Caring for Intelli-Check2™

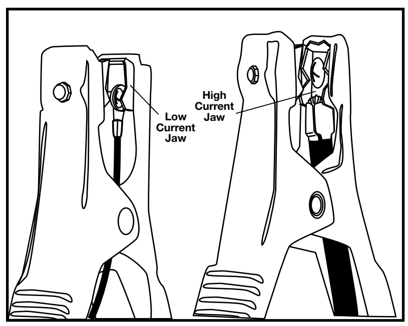
This hand-sized tester is designed for long life in a service department environment. However, the unit does require care as follows:

Clamp Inspection and Replacement

IMPORTANT: Both jaws of each clamp must firmly engage all terminals. The copper jaw contains the smaller gauge wire that reads the voltage and the silver jaw contains the larger conducting wire that draws the load in each test. Jaw insulation is necessary for accurate readings. Damaged clamps or loose wires will affect the readings. Keep clamps clean and in good repair.

Over time, the battery clamps will need to be replaced if the following situations arise:

- Battery CCA values seem to be badly wrong.
- Electrical continuity exists between the silver and copper jaw.
- The cables or clamps are excessively damaged or corroded.



Battery Clamps

Clamp replacement is easy:

1. Disconnect the back cover.
2. Remove the battery to prevent shorting.
3. Disconnect the two small wires from the PC board.
4. Remove the large cables from the copper busses.

CAUTION: In step 5 below, make sure the red clamp wires are attached to the positive buss and the black clamp is attached to the negative buss. Putting a little mineral spirits on the new cable ends will increase ease of insertion through the grommet.

5. Carefully pull each wire through the grommets.
6. Reverse the procedure in replacing new clamps.

Internal 9V Battery Replacement

Replace the 9-volt alkaline battery when the message "REPLACE INTERNAL BATTERY SOON" appears. Remove the back cover and insert a new 9-volt alkaline battery.

Connection Warning!

Never attach the Intelli-Check2 to a battery connected to any other tester or charging unit. Damage to Intelli-Check2 may result.

Vehicle Batteries

Batteries are perishable and wear out, but that does not mean the battery is always at fault when it is found discharged and weak. Often, the battery has been weakened by some other failed component in the system.

Check and Double-Check

Accurate vehicle electrical system testing depends on all the components being in good operating condition. In particular, the battery MUST have sufficient charge for testing. Check the following before attempting electrical diagnosis:

- Inspect the battery itself for terminal corrosion, loose, broken posts, cracks in the case or swelling, loose hold-down brackets, low electrolyte level, moisture and dirt around the terminal.
- Check:
  - Cables for proper tightness and problem areas: corrosion, cracking or brittleness.
  - Ground wire for clean, secure fastening to vehicle frame.
  - Fluid level, adding clean soft water or distilled water. NOTE: Do not add premixed electrolyte solution, which will make the sulfuric acid too strong and cause interior damage.
- Charging:
  - Leave the battery charger unplugged until its cables are connected to the battery.
  - Charge each battery separately.
  - Use the proper charger.
  - Charge batteries in a well-ventilated area.
- A known defective battery must be replaced before proceeding with any test on the charging and starting system.

Why Batteries Fail

Incorrect Application: The wrong-sized battery may have been adequate for original vehicle specifications, but added “creature comforts” now make it inadequate.

Incorrect Installation: Loose battery hold-downs cause excessive vibration, which can damage the plates.

Improper Maintenance: Low electrolytic fluid and corrosion on battery connections can greatly reduce battery life and affect battery performance.

Internal Connections: Components of the charging system may not meet proper specifications.

Battery Age: An old date code on the battery indicates a need for replacement.

Overcharging: Caused by a high voltage regulator setting or incorrect battery charging, overcharging can cause excessive gas, heat and water loss.

Undercharging: Caused by a low voltage regulator setting or incorrect battery charging, undercharging can cause lead sulfate to gradually build up and crystallize on the plates, greatly reducing the battery’s capacity and ability to be recharged.

Cycling: When the alternator is not operating, repeated battery usage causes an excessive drain.

Alternators

How an Alternator Works

When a wire is moved through a magnetic field, voltage is produced in the wire. Alternators use this function to produce electricity. In an alternator equipped with brushes, an electromagnet (the rotor) is created by passing a small electrical current from the truck's batteries through the brushes to the field coil inside the rotor. The alternator generates current as the magnetized rotor turns inside a stationary set of wire windings (called the stator). Carbon brushes wear as they rub against the slip ring. When they wear excessively, they fail to touch the rotor, so the alternator ceases to produce electricity.

To increase the brush life, Delco Remy incorporates in its heavy duty alternators brushes that have greater volume. These brushes are larger and longer than brushes used in any competitive alternator of comparable size.

Brushless alternators are designed to eliminate brush wear problems and extend the life of the alternator. In a brushless alternator, the field coil is stationary and connects directly to the regulator, thus eliminating the need for brushes.

An alternator is more accurately called a generator. It generates an alternating current (with the same sine wave as household electricity) and then changes that alternating current into direct current. That AC-to-DC change is completed by "rectification," allowing the generated alternating current to travel in only one direction. This rectification is necessary because the truck's batteries and the rest of the electrical circuitry are designed to operate on direct current. A built-in regulator limits the voltage to about 14.0 volts.

What Causes Alternator Failure?

Today's heavy duty vehicle engine compartments are smaller, tighter and hotter. One obvious reason is aerodynamics. But another is emissions, which engine makers control either with exhaust gas recirculation (EGR) or, in the case of Caterpillar®, with Advanced Combustion Emissions Reduction Technology (ACERT™). Both emissions control systems significantly raise engine temperatures.

Still another problem is the heat created by the alternator itself. Traditional alternators are not designed to throw off such heat.

Heat isn't the only plight suffered by the alternator. For years, engines have put out more horsepower and torque. That means the alternator has to survive higher vibration and more.

Maintenance intervals are extended, so the alternator has to be built to live longer.

The alternator has to endure more workload as "creature comforts" are added – demand that the standard unit can't handle. Many aftermarket alternators are ill-equipped, as well.

High output at idle often is overlooked in alternator selection, but it's very important. An underrated alternator cannot meet the vehicle's power needs and also rejuvenate batteries.

Durability is needed because truck operators have an "install and forget" philosophy. Most customers need an alternator that's maintenance-free and designed for long life.

The result is a higher-temperature operating environment, both inside and outside the alternator, plus vibration and perhaps incorrect installation, all causing lower alternator output and sometimes premature failure. With the constant addition of new electric and electronic devices to trucks, this lower output cannot be tolerated in today's trucking industry.

22SI

The 22SI (Figure 10) was introduced in 1998 with advanced features delivering high performance and long life.

- "Auto-Start" immediately energizes the alternator below engine idle rpm so it's charging immediately.

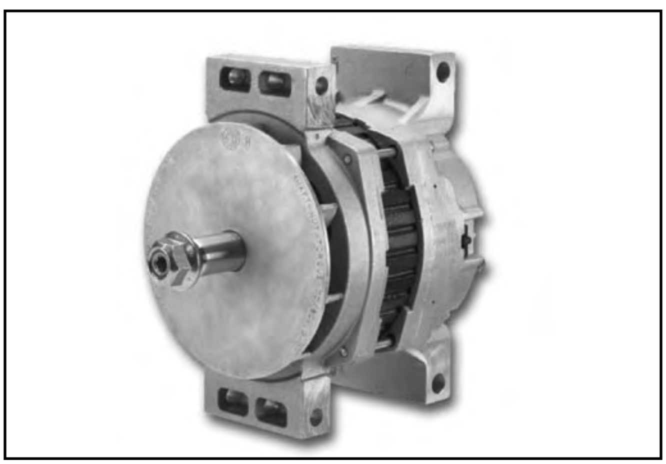


Figure 10. 22SI

- Brushes are high-volume radial construction with a constant-tension pulling spring for 3 times longer brush life.
- “Avalanche” diodes in the rectifier bridge drain power from electrical spikes, preventing damage to the unit or other electronics.
- Terminals are easily accessible for quick installation and excellent radio frequency interference suppression for radio and other electronic systems.
- Machined slip-ring and rotor eliminates brush bounce and electrical arcing, reducing brush erosion and wear.
- Cooling lightweight fan is made of die-cast aluminum.
- Rigid frame case and grade 8 fasteners withstand greater vibration.
- Sealed polyacrylate bearings resist heat transfer and stress from severe belt loads.
- Internal driven shaft is high-strength steel.
- Large lube reservoir contains high-temperature grease.

The 22SI delivers the performance and reliability that customers need. So why replace it? The answer is engine heat. The 22SI can operate efficiently at up to 200°F, which is about the temperature limit for engines meeting 2002 emissions regulations. But 2007-built engines will run at 10 percent higher temperatures – as much as 220°F. Steady operation in this kind of heat can overstress stator winding insulation and cause short circuits that would drastically reduce performance.

So a different alternator is needed for the future – not just an upgraded 22SI, but a completely new design with the same (or higher) performance, plus radically improved cooling air flow for reliability and long life.

Delco Remy’s answer to these demands is the 24SI.

24SI

Even a casual glance at this new alternator (Figure 11) tells the onlooker that this is a new approach.

Figure 11. 24SI

Cooling is radically redesigned (Figure 12):

- Not one, but two fans increase cooling air flow.
- Fans are internal, pulling air in from both ends for uniform cooling throughout the unit.

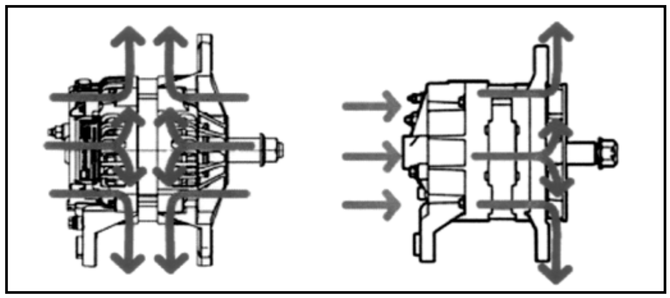


Figure 12. 24SI Cooling (L) vs. 22SI (R)

- The vented frame creates unobstructed airflow. Ribs cast into the frame dissipate heat more quickly and evenly.

Internal Protection of components is achieved by these design features:

- Dual spacers and slingers create built-in protection from water and other contaminants.
- The regulator’s packard connector (Figure 13) is environmentally sealed.
- A semi-rigid epoxy cover protects electronics while managing airflow.

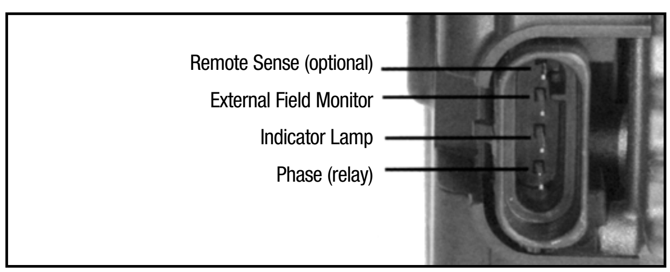


Figure 13. 24SI Packard Connector

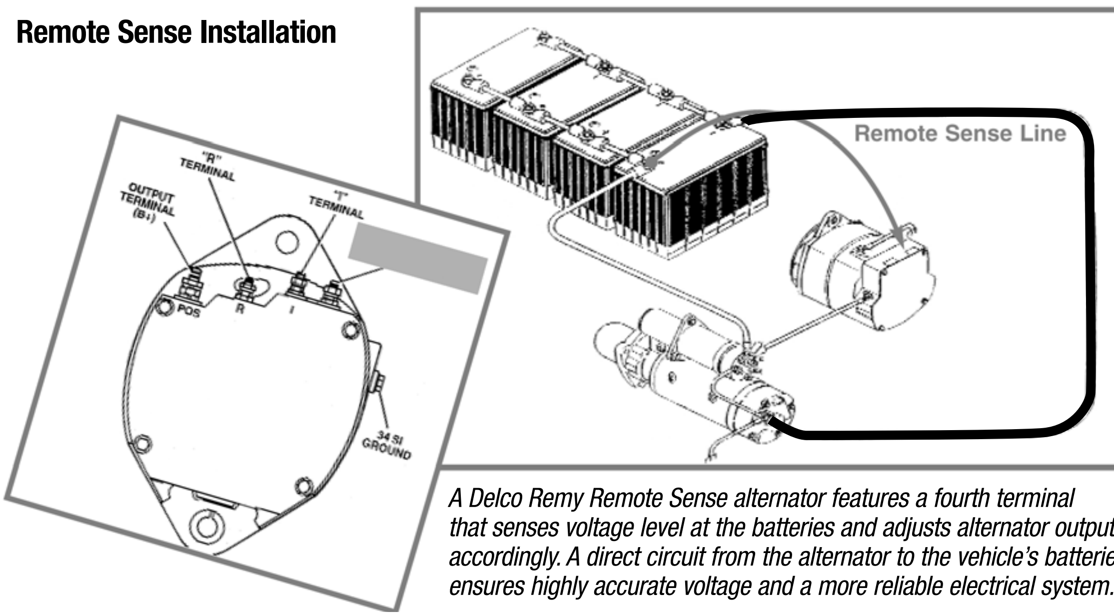
Performance Features are enhanced:

- "Auto-Start" creates instant charging.
- Optional "Remote Sense" monitors voltage level at the batteries and adjusts alternator output accordingly.
- Smaller slip rings resist brush bounce to extend service life.
- Installation is simplified with one-wire connection and accessible terminals.
- Advanced design "avalanche" diodes drain destructive energy from electrical spikes for long component life.

Remote Sense Keeps Output High

"Remote Sense" technology allows the alternator to automatically adjust voltage output based on the voltage measured at the battery terminals.

Remote Sense Installation



A Delco Remy Remote Sense alternator features a fourth terminal that senses voltage level at the batteries and adjusts alternator output accordingly. A direct circuit from the alternator to the vehicle's batteries ensures highly accurate voltage and a more reliable electrical system.

Traditional alternators have an internal sensor that attempts to keep alternator voltage at the required level. Such a design only works for vehicles with little or no electrical demand because the electrical cables lose voltage ("voltage drop"), reducing battery terminal voltage. An alternator set at 14.2 volts and charging the batteries through such voltage-losing cables may deliver only 13.7 volts at the battery terminals under full output.

A remote sense alternator is more effective. The regulator automatically adjusts output voltage to compensate for voltage "drop" – an improved 14.2 volts at the battery and 14.7 volts at the alternator output terminals.

If, for example, the alternator senses that less-than-ideal current is reaching the batteries (possibly due to voltage drop in the cable, improper wiring or a loose connection), it will automatically increase output to compensate for the loss. This important feature operates through a separate circuit that connects to the alternator's fourth terminal.

Such advanced technology significantly improves the electrical system, reducing the need for jump starts, battery charging and maintenance expense, while extending battery life.

35SI

Delco Remy's 35SI (Figure 14) is the first brushless alternator engineered specifically to operate in higher underhood temperatures, delivering the current that powers "creature comforts."

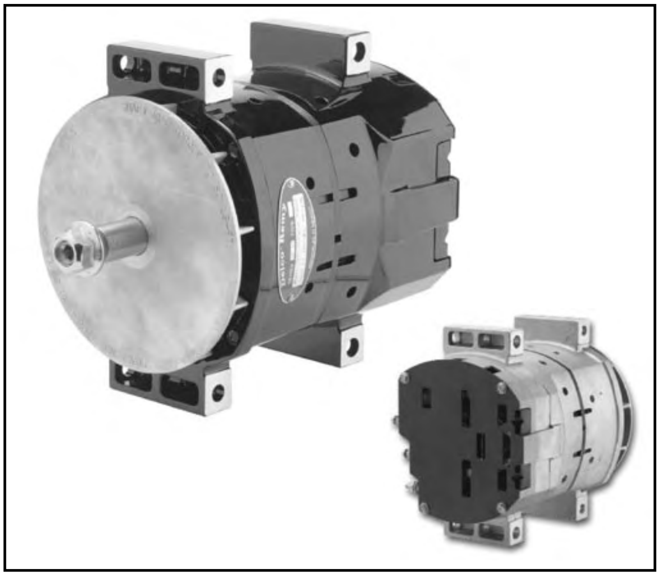


Figure 14. 35SI

The 110- and 135-amp 35SI models produce maximum current at the highest underhood temperatures of 221°F. They have been tested for more than 2,000 hours at 3,000 rpm, the hottest operating conditions for any heavy-duty alternator, thanks to these features that result in high output but reduced heat:

- Heat-radiating casting and back-plate vents to maximize heat transfer.
- Advanced-design, high-efficiency stator windings.
- Improved rotor design and materials.
- Oversized rectifier bridge.

The Wrong Diagnosis

A working alternator may seem to be not working. When a service technician makes such a misdiagnosis, it's costly. Not only may you lose a service customer over it, but the dollar cost of a rejected warranty return is very high!

Problem: Drained Batteries

This kind of alternator misdiagnosis usually occurs when discharged batteries are discovered, making the technician think that the alternator is defective, especially if it was replaced recently. In many cases, the real cause is that the replacement alternator is working fine, but its output is too low for the vehicle's load demand. The real problem may have one of several other causes, too:

- Defective battery.
- Loose or corroded connections in the charging system.
- Undersized wiring.
- Improper alternator output caused by (1) the wrong alternator belt tension, (2) a cracked mounting bracket or loose bolts or (3) misaligned pulleys.
- Alternator mounted too close to heat-generating components.

But that's not the only result. Misdiagnosing the alternator creates two additional situations, both bad. One is a customer relations problem. The customer comes back because the real problem hasn't been fixed. The other is a cost problem. It occurs when the alternator manufacturer rejects the dealership's warranty claim on an alternator that's working perfectly.
(About 45 percent of all alternator warranty claims are rejected for this reason, which the industry calls "No Trouble Found/NTF".)

Table 1. Alternator Problems and Causes

PROBLEMS	CAUSES
Engine running - indicator light dim	• Inoperative diodes • High resistance in wire connections
Engine running - indicator light bright	• Inoperative diodes • Broken drive belt • Inoperative brush assembly • Open circuit in rotor or stator
Ignition switch on – engine not running – indicator light out	• Bulb burned out or open circuit from main harness connector to alternator
Ignition switch off - indicator light bright	• Inoperative diodes • Inoperative ignition switch
Noise in alternator	• Worn bearings • Loose or misaligned pulley • Shorted diode (high-pitched whine)

Troubleshooting

Keep these warnings and cautions in mind when troubleshooting alternators (Table 1).

WARNINGS:

A skin burn can result if a tool accidentally shorts across the alternator's BAT terminal.

Some alternator tests bypass the regulator, allowing high voltage to hit other electric/electronic components, which can cause severe damage.

CAUTION: Check for correct mounting.

- The mounting bracket must be strong enough to support the alternator's weight, with no cracks or rust-through.
- The adjusting strap should only adjust belt tension. It should not bear any of the alternator's weight.
- Pulleys should be correctly aligned. (Look carefully. Even a little deviation can reduce alternator output.)
- Belt should be tensioned to prevent:
  - Slipping that wears out belt, cuts current output and builds up heat to damage bearings.
  - Over-tightening that wears belt and puts high loads on bearings.

Alternator Maintenance

An alternator is not an "install and forget" component. It needs to be maintained.

At every oil change, check the alternator for:

- Surfaces cleaned of grease or dirt.
- Air passages clear for good air flow through the unit.
- Connections tight and cleaned of corrosion, grime or dirt.
- Auto-tensor for proper belt tension – Belt tension must be tight enough so the alternator fan cannot be turned by hand. NOTE: A new belt loses 60 percent of its tension in the first few hours. After installing the new belt, run the belt with several electrical accessories on for 15 minutes, and then readjust the tension. Tension may need readjusting twice after installation.
- Belt condition for cracking, glazing or dryness.
- Belt matching on multi-belt drives.
- Mounting brackets for bending, cracking or rusting. (NOTE: Always replace mounting hardware when installing new brackets.)
- Drive pulley alignment (especially "poly V" types).

Alternator Wiring Test

Following battery testing, this is the next step in evaluating charging system performance (Figure 15). Any voltage loss slows the battery charge rate and may partially discharge the batteries. Discharged batteries can result in starter damage. Low output voltage can cause improper performance of other vehicle electrical components.

NOTE: If the alternator wiring passes this test, follow the steps in Figures 16 and 17 to determine if the alternator is over- or under-charging, and whether it should be replaced.

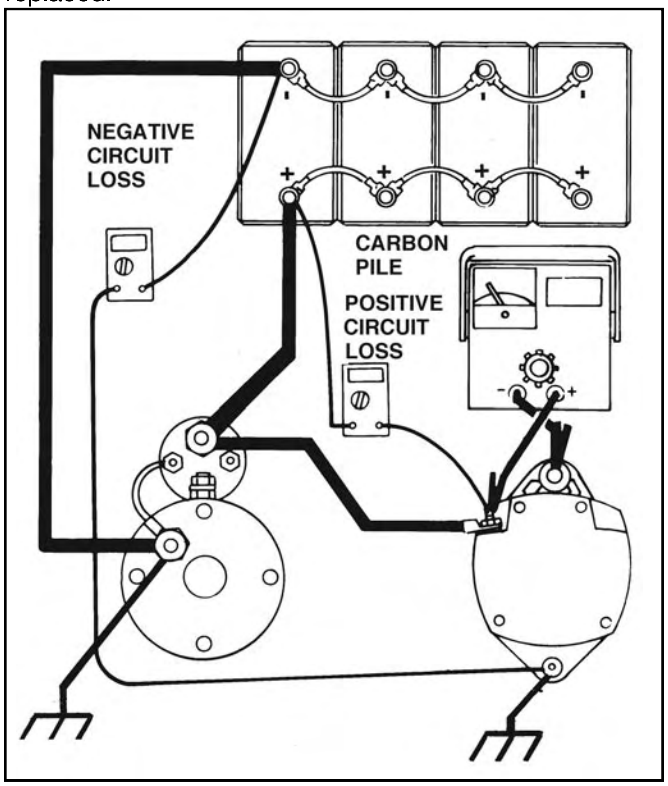


Figure 15. Connections for Alternator Wiring Test

Instead of using the alternator output, this test uses the same current but draws it from the batteries. Using a carbon pile load, current flows in reverse through the circuit with the engine off.

NOTES:

- A 24-volt vehicle system must be connected into a temporary 12-volt configuration. Connect only one 12-volt battery to the system (disconnect all other batteries). Test at 12 volts but use the amperage specified for a 24-volt system. Immediately upon completion of tests, reconnect batteries in the approved manner for a 24-volt system.
- Alternator output terminal is at battery voltage. Engine must be off for this test.

Procedure to calculate total system voltage drop:

1. Turn vehicle's engine off.
2. Test the batteries to assure adequate charge.
3. Assure battery connections are clean and tight.
4. Assure carbon pile is turned off.
5. Connect carbon pile to:
   a. Alternator output terminal.
   b. Ground.

NOTE: In step 6a below, extend the voltmeter leads with jumper wires if necessary.

6. To check positive circuit voltage:
   a. Connect digital voltmeter set on low scale from alternator output terminal to positive battery terminal.
   b. Turn on and adjust carbon pile to alternator's rated amperage output.
   c. Record voltmeter reading, which is positive circuit voltage.
   d. Immediately turn off carbon pile.
7. To check negative circuit voltage:
   a. Connect digital voltmeter set on low scale from alternator ground terminal to negative battery terminal.
   b. Turn on and adjust carbon pile to alternator's rated amperage output.
   c. Record voltmeter reading, which is negative circuit voltage.
   d. Immediately turn off carbon pile.
8. Add positive circuit voltage loss and negative circuit voltage loss to get total system loss, which must not exceed:
   a. 12-volt system – 0.500 volt maximum.
   b. 24-volt system – 1.000 volt maximum.
9. Replace cables or repair circuits with excessive voltage loss.

NOTE: For 24-volt systems after test completion:

1. Reconnect temporary 12-volt system back to 24-volt system.
2. Conduct the Magnetic Switch Circuit Test if delayed.
3. After completing Magnetic Switch Circuit Test, be sure to reconnect lead to “S” starter solenoid terminal.

Is the Alternator Overcharging?

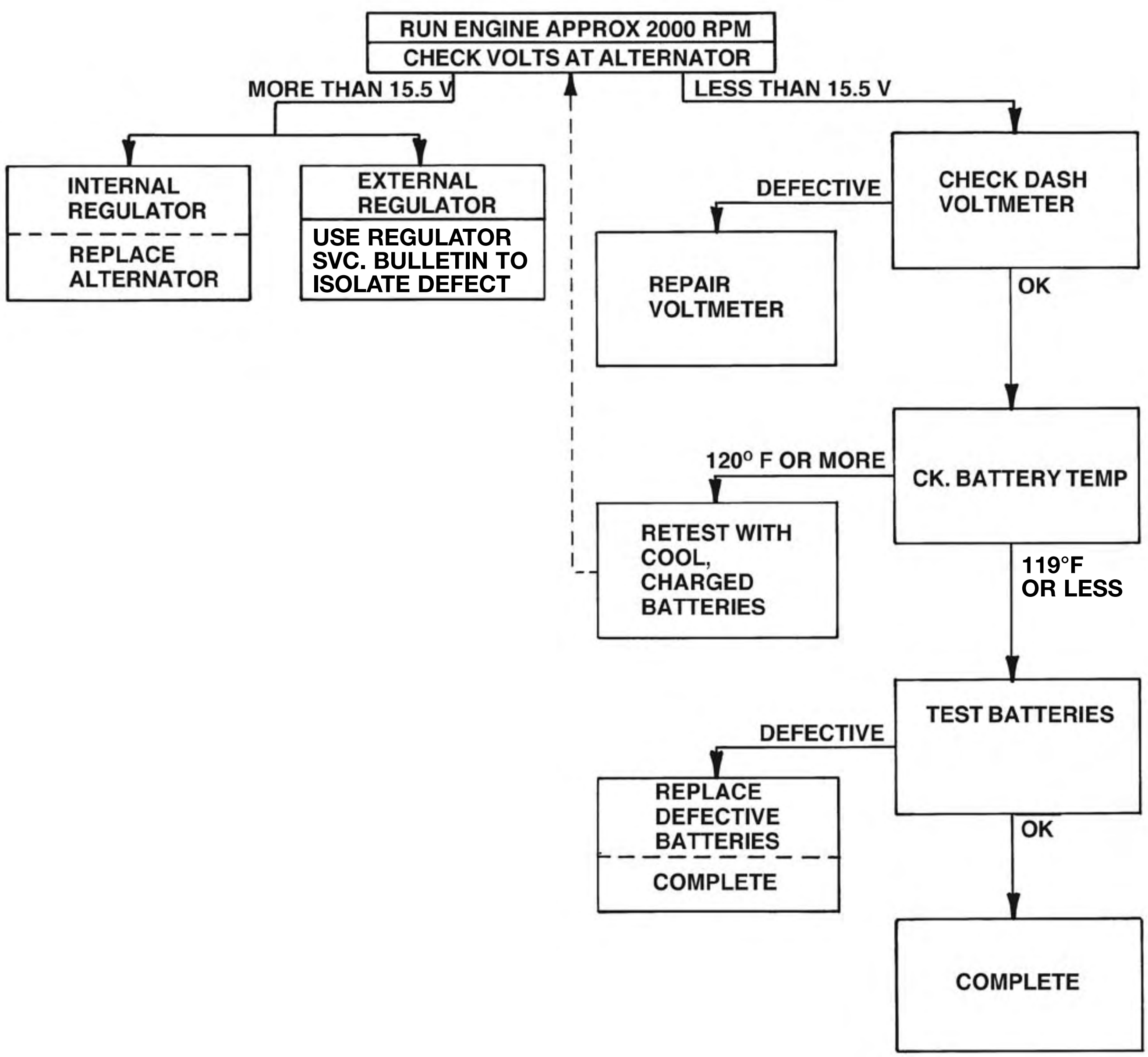


Figure 16. Alternator Overcharging Diagnosis

Is the Alternator Undercharging?

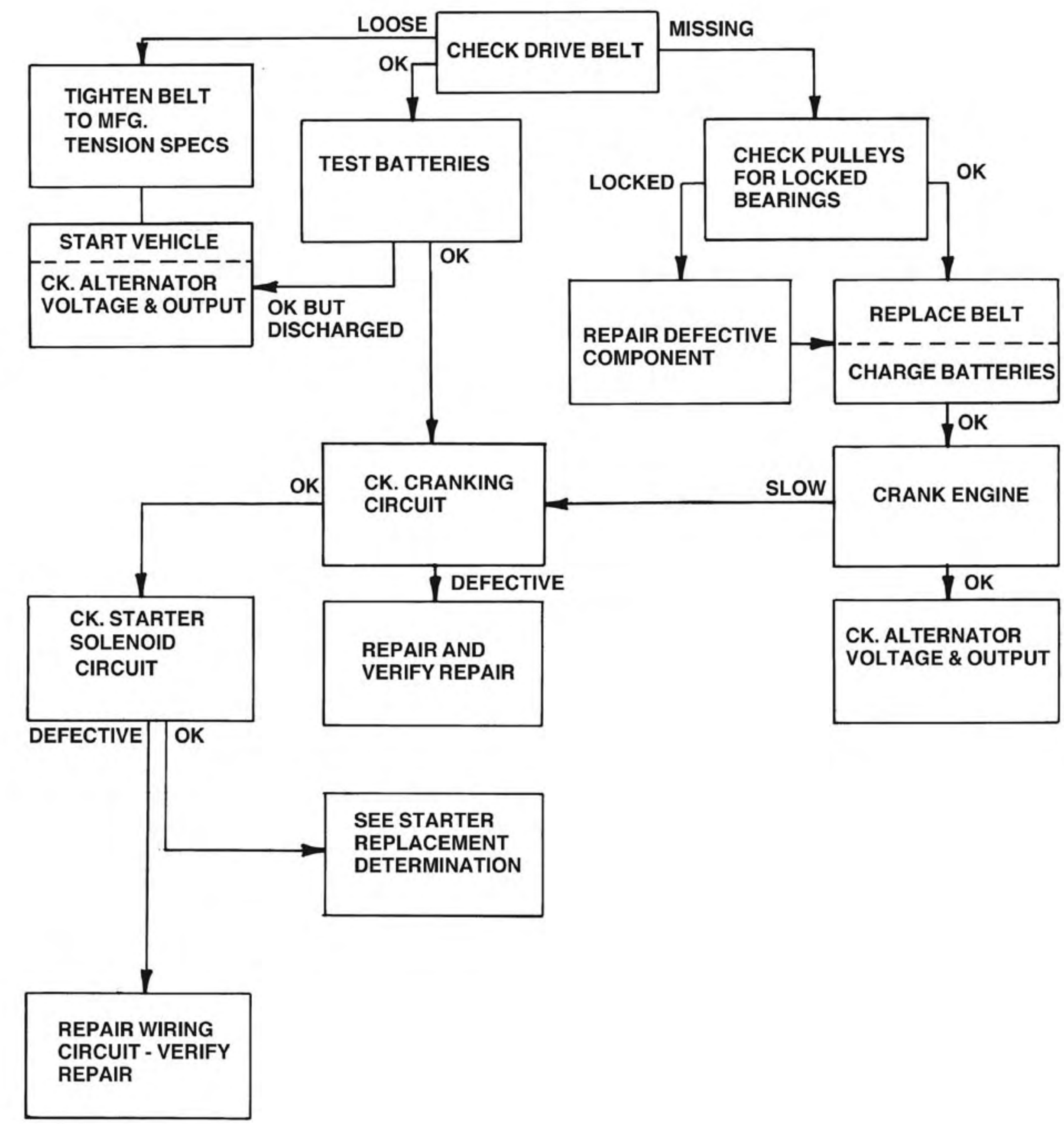


Figure 17. Alternator Undercharging Diagnosis

Alternator Voltage and Amperage Output Test

Conduct this test at shop temperature.

1. Before testing the alternator, make sure that:
   a. The vehicle engine is turned off.
   b. Alternator mounting hardware is secure.
   c. Belts are at correct tension and not worn or frayed.
   d. Batteries are satisfactorily load tested and near full charge with more than 12.4 volts at no-load voltage.
   e. All vehicle electrical loads are turned off.
2. To test alternator voltage output (Figure 18):

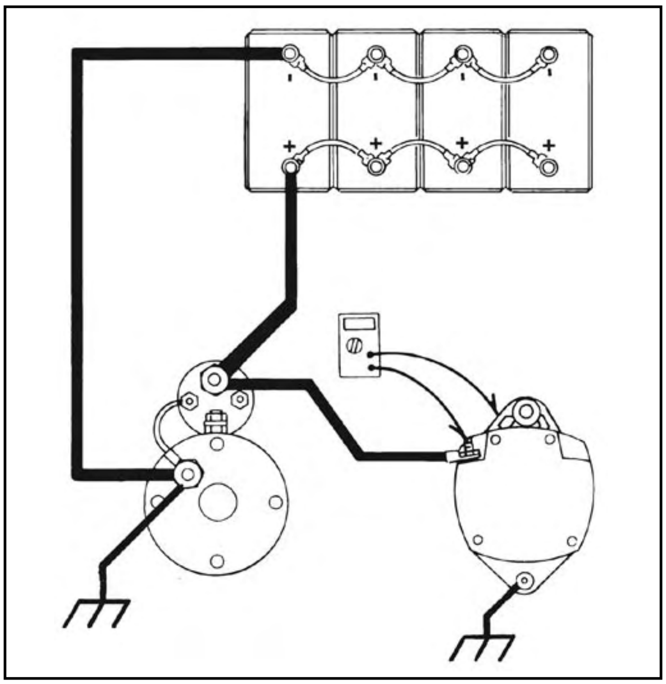


Figure 18. Voltage Output Test Setup

   a. Connect a digital voltmeter from positive alternator terminal to alternator ground.
   b. To test alternator output:
      1) Start the engine.
      2) Run the engine at high idle until voltage stabilizes (does not increase) for two minutes.
      3) Check that alternator output voltage does not exceed 15.5 volts (31 volts for 24-volt system).
      4) Turn engine off.
      5) Remove voltmeter.
3. To test alternator amperage output:
   a. Check alternator rated amps of specific alternator being tested.
   b. Connect:
      1) Carbon pile across the vehicle batteries in parallel.
      2) Induction ammeter, clamped around all wires connected to the alternator output terminal.
   c. Make sure all vehicle electrical loads are off.
   d. Start the engine.
   e. Assure that the alternator is turning at rated rpms. Most heavy-duty alternators are rated at 5000 rpm.
   f. Run the engine at high idle.
   g. Turn on and adjust carbon pile until the induction ammeter reads its highest value.
   h. Record this ammeter reading.
4. Turn off:
   a. Carbon pile.
   b. Engine.
5. If ammeter reading is zero (no output), magnetize the rotor with the alternator connected normally.
   a. Momentarily connect a jumper lead from the battery positive (+) to the alternator relay (R) or indicator (I) terminal. This procedure applies to both negative and positive ground systems, and will restore the normal residual magnetism.
   b. Repeat steps 3 and 4.
6. Replace the alternator:
   a. If output is still zero after repeating steps 3 and 4.
   b. If output voltage exceeds 15.5 volts. If alternator has separate regulator, use the appropriate regulator service bulletin to isolate the defect.
   c. If output amperage is not within 10 percent of alternator rated output stamped on alternator case.
7. After completion of all tests, make sure:
   a. All test instruments have been removed from the vehicle.
   b. The vehicle wiring, if altered, has been returned to the operational state.

Starters

NOTE: If the engine does not crank properly after making all tests specified below, the problem must be with the starter or the engine. Replace the starter and recheck to see if the engine cranks properly. If not, then look for a mechanical problem with the engine.

How a Starter Works

When the start switch is turned on, low current flows to the starter solenoid and the solenoid plunger is pulled magnetically into the solenoid. As the plunger is pulled into the solenoid:

1. The starter pinion, pushed towards the flywheel by the starter shift mechanism, engages the teeth on the outside edge of the flywheel.
2. The batteries send current to the starter.
3. The starter motor turns the flywheel, which turns the engine crankshaft, creating compression (and therefore heat) in the engine cylinders.
4. The injected fuel mixture in the engine cylinders ignites, starting the engine.
5. When the engine starts, the starter's over-run clutch allows the starter pinion to spin freely, preventing the engine from turning the starting motor at damaging high rpm.
6. When the start switch is released, the solenoid plunger returns to its original position and the starter shift mechanism disengages the pinion from the flywheel.
7. The electrical connection from the batteries to the starter motor is disconnected and the starter stops turning.

Starter Problems and Solutions

Over-Cranking

Starters apply great torque for relatively short periods of time. When starters are constantly cranked because an engine is cold, water-soaked or has low batteries, the starter becomes hot. Excessive heat caused by prolonged cranking can destroy a starter. Continual cranking also rapidly discharges batteries.

Delco Remy's 42MT has optional overcrank protection (OCP). OCP prevents heat damage (common in adverse starting conditions) and automatically resets after the starter has cooled to a safe temperature.

Sticking Contacts

Stuck contacts, caused by low voltage, are perhaps the most common reliability problem in heavy-duty starters. When the contact disc sticks and cannot free itself from the battery and motor terminals, current continually flows through the starter and makes it spin freely.

Now the 42MT also is offered with the new Semi-Solid Link (SSL) solenoid (Figure 19, page 23). SSL technology overcomes a leading starter problem – sticking contacts caused by low voltage. The Semi-Solid Link (SSL) solenoid reduces sticking contacts by ensuring that the solenoid's contact disc is disconnected from the battery and motor terminals after starting.

Over-Powered Solenoid

Prolonged power to the starter motor solenoid can cause overheated solenoid windings, armature or pinion shaft. This results from high voltage drop in the control circuit, or from defective relays or switches.

High current can make relay switches arc and fail, and some are not suited to heavy starter applications. The failures occur whenever conditions like voltage drop put stress on the starter's solenoid control circuit.

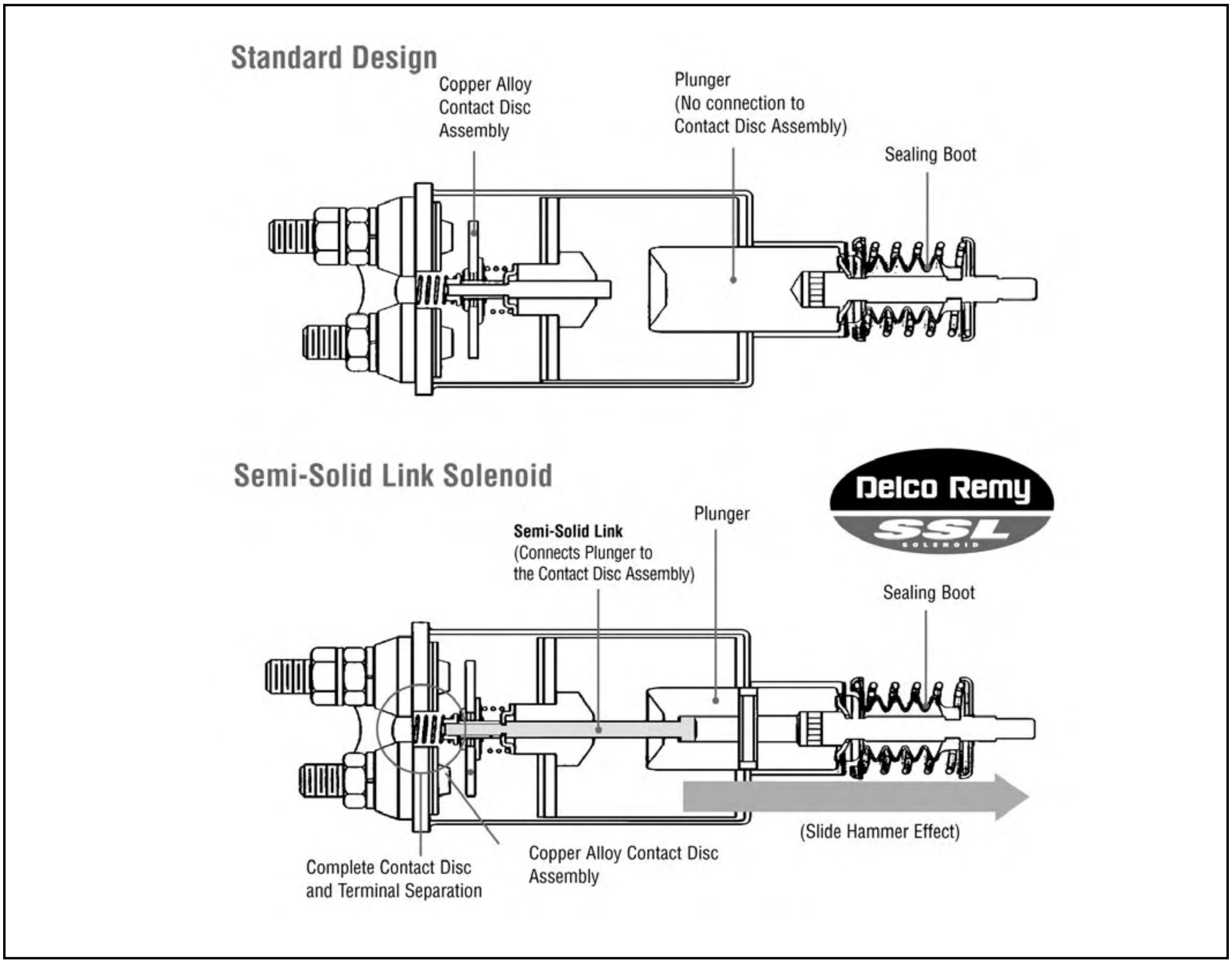


Figure 19. 42MT with Semi-Solid Link Solenoid (SSL)

Delco Remy's optional Integral Magnetic Switch (IMS) is an alternative for vehicles with light-duty relays not designed to supply this high solenoid current. The switch is matched to the starter motor and solenoid, minimizing voltage drop and maximizing solenoid voltage. This design allows:

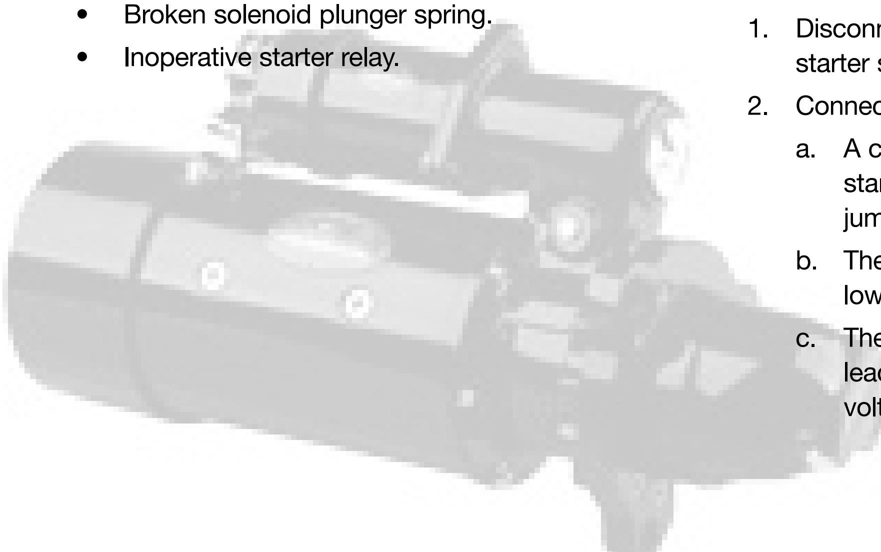
- The shortest possible length for heavy gage wire in the solenoid control circuit.
- The smallest possible wire gage from the ignition switch to the starter motor.
- No need for a vehicle magnetic switch.

Troubleshooting

Before beginning troubleshooting, inspect the starting system. Check the starter, solenoid and alternator for loose connections, loose mounts and frayed or cracked wires.

What kind of starter problems does your service customer face? Here's a list, with possible causes:

- ❑ Starter cranks engine slowly:
  - One or more discharged or defective batteries.
  - Extremely cold temperatures.
  - Excessive voltage loss in cables.
- ❑ Starter inoperative:
  - Loose or corroded battery terminals.
  - Discharged batteries.
  - Open starting circuit.
  - Inoperative solenoid or relay.
  - Inoperative ignition switch.
  - Inoperative starter.
  - Excessive voltage loss in cables.
- ❑ Starter turns but drive does not engage:
  - Broken teeth on flywheel ring gear.
  - Rusted/corroded starter drive shaft.
  - Inoperative starter drive.
  - Stuck solenoid contact disc.
- ❑ Starter does not disengage:
  - Faulty ignition switch.
  - Short circuit in solenoid.
  - Broken solenoid plunger spring.
  - Inoperative starter relay.



Starter Solenoid Circuit Test

The drive housing of a replacement starter must be identical or rotated to match the solenoid position of the original starter. The solenoid position must be 15° above horizontal when mounted to the engine.

High resistance in an electrical circuit can cause voltage drop. Such a drop in the starter solenoid circuit can cause the starter to (1) engage the flywheel completely but only for an extremely short period or (2) not completely engage the flywheel. If it does engage, it may disengage too soon when battery voltage drops.

NOTES:

- Two technicians are needed for this test – Technician #1 in the cab to engage the starter, and Technician #2 to listen to starter operation and read a digital voltmeter.
- For starters with an integral magnetic switch, use the test procedures specific to those starters.
- When testing 24-volt systems, use the temporary 12-volt connection.

Procedure:

1. Disconnect the lead to the “S” terminal on the starter solenoid.
2. Connect:
   a. A carbon pile to starter switch wire lead and to starter ground terminal (use a small clamp or jumper wire if needed).
   b. The positive lead of a digital voltmeter (set on low scale) to the solenoid “BAT” terminal.
   c. The voltmeter negative lead to the switch wire lead to which the carbon pile is connected. The voltmeter will show battery voltage.

NOTES: In step 3 below:

- If the magnetic switch does not close on a 12-volt vehicle, perform the Magnetic Switch Circuit Test, and then continue with the Starter Solenoid Circuit Test.
- When testing a 24-volt vehicle, if the temporary 12-volt connection will not close the magnetic switch, bypass it with a heavy jumper connected between the two large studs on the magnetic switch. This simulates engaging the starter switch and closing the magnetic switch. With no button to release or key to turn, the jumper must be disconnected after each voltage reading.

3. Test:
    a. Technician #1 engages the starter.
    b. Technician #2 listens for the sound of the magnetic switch closing. Voltmeter reading should be zero.
    c. Technician #2 adjusts a carbon pile to a 100-amp load (60-amps if 24-volt system).
    d. Read and record the voltage. Voltage loss shall not exceed:
        1) 12-volt system – 1.0 volt.
        2) 24-volt system – 2.0 volts.
4. If the circuit voltage loss:
    a. Is less than shown in step 3d above, the solenoid circuit is operating correctly. (Remember, this procedure tests only the circuit, not the solenoid itself. The solenoid is inoperative during this test because the "S" terminal is disconnected.) Turn off and disconnect carbon pile and conduct the Magnetic Switch Circuit Test.
    b. Exceeds the maximum, loss is excessive and may be caused by loose terminals, corrosion, too small wire gauge, a switch located too far from starter or a worn out magnetic switch. Perform the Wiring Test and Magnetic Switch Contactor Test to isolate the problem.

Wiring Test

1. Connect:
    a. A carbon pile:
        1) To the starter switch wire lead.
        2) To the starter ground terminal (use a small clamp or jumper wire if needed).
    b. The positive lead of a digital voltmeter set on low scale to the solenoid "BAT" terminal.
    c. The negative lead of the voltmeter to a large terminal on the magnetic switch. If voltage shows, reconnect the voltmeter lead to the other large terminal on the magnetic switch.

NOTE: When testing a 24-volt vehicle, if the temporary 12-volt connection will not close the magnetic switch, bypass it with a heavy jumper connected between the two large studs on the magnetic switch. This simulates engaging the starter switch and closing the magnetic switch. With no button to release or key to turn, the jumper must be disconnected after each voltage reading.

2. Test #1:
    a. Adjust the carbon pile to 100-amp load (60-amp load if 24-volt system).
    b. Engage the starter.
    c. Read and record the voltage.
    d. Turn off the carbon pile to free the system of the 100-amp load.
    e. Connect:
        1) The positive lead of a digital voltmeter set on low scale to the switch wire lead to which the carbon pile is connected.
        2) The negative lead of the voltmeter to the other large terminal on magnetic switch.
3. Test #2:
    a. Engage the starter.
    b. Adjust carbon pile:
        1) 100-amp load for 12-volt system.
        2) 60-amp load for 24-volt system.
    c. Read and record the voltage.

d. Add voltage loss to the voltage loss previously recorded with the 100-amp load to get total wire voltage loss. Total wire voltage loss shall not exceed:
    1) 12-volt system – 0.8 volt.
    2) 24-volt system – 1.8 volts.

4. Replace and repair wiring and connections if voltage loss is excessive.

Magnetic Switch Tests

Two technicians are needed for the following two tests. Technician #1 engages the starter, and Technician #2 listens to starter operation and reads a digital voltmeter.

Contact Test

NOTE: Perform the following test only if the magnetic switch closed in preceding tests.

1. Connect:
    a. A carbon pile:
        1) To the starter switch wire lead.
        2) To starter ground terminal (use a small clamp or jumper wire if needed).
    b. A digital voltmeter set on low scale across the large terminals of the magnetic switch. Battery voltage will show immediately.
2. Test:
    a. Technician #1 engages the starter while Technician #2 reads voltage. Voltage will read zero.
    b. Technician #2 adjusts the carbon pile to a 100-amp load (60-amp load if 24-volt system).
    c. While Technician #1 continues to engage the starter, Technician #2 reads and records the voltage across the magnetic switch on the voltmeter.
    d. Technician #1 disengages the starter.
3. Replace the magnetic switch if voltage loss exceeds 0.2 volts for 12- or 24-volt system.
4. Turn the carbon pile off.
5. Remove the carbon pile and the voltmeter from the electrical circuit.
6. Leave the solenoid “S” wire disconnected and temporarily taped for insulation at the terminal.

Circuit Test

NOTES:

- For starters which have a magnetic switch as part of the motor (39MT IMS, 42MT IMS), refer to Delco Field Service Bulletin DR7789.
- This test must be performed using full voltage of the system. If a 24-volt system was temporarily converted into a 12-volt system for the magnetic switch test, check the system with the Alternator Wiring Test. Test the system after the batteries have been reconnected back to a 24-volt system.
- The lead to the “S” terminal on the starter solenoid remains disconnected from previous tests.
- If the magnetic switch does not close or drops out too soon, look for high resistance or an open circuit in the control circuit.
- Leave the “S” lead disconnected to prevent engine from cranking during these tests.

Procedure:

1. Set a digital voltmeter on battery voltage scale.
2. Connect the voltmeter to two small terminals on the magnetic switch. If the magnetic switch has only one small terminal, connect the other voltmeter wire to the switch bracket.
3. Test:
    a. Technician #1 engages the starter.
    b. Technician #2 listens for the click that shows the magnetic switch is closing.
    c. Technician #2 notes and records the voltmeter reading.
        1) If the magnetic switch closed and voltage is within 1.0 volt (2.0 volts for 24-volt system) of battery voltage, this circuit is operating correctly.
        2) If the magnetic switch does not close and voltage is within 1.0 volt (2.0 volts for 24-volt system) of battery voltage, replace the magnetic switch and retest.

d. If the voltage is more than 1.0 volt (2.0 volts for 24-volt system) below battery voltage:
   1) Move the voltmeter lead on the magnetic switch ground to the frame or motor ground terminal.
   2) Engage the starter and read the voltage.
   3) If the voltage is within 1.0 volt (2.0 volts for 24-volt system) of battery voltage, repair the magnetic switch ground lead or connections.
   4) If the voltage is not within 1.0 volt (2.0 volts for 24-volt system) of battery voltage, replace the voltmeter ground lead at the magnetic switch ground terminal.

4. Repeat step 3d, moving voltmeter plus lead to the following locations and measuring the specified voltages with the key on and the starter engaged. If any voltage is not within 1.0 volt (2.0 volts for 24-volt system) of battery voltage, repair or replace the wire or component specified and retest. Test the following:
   a. The wire between the ignition key and the magnetic switch.
   b. The ignition switch.
   c. The wire between the ignition switch and the solenoid “BAT” terminal.
5. Remove voltmeter from vehicle.
6. If all tests have been completed satisfactorily, reconnect the lead to the “S” terminal on starter solenoid so the engine can be started.

Starter Replacement Determination

Cold Weather Cranking

Starter circuits with a magnetic switch also can fail to stay engaged during cold weather starting and low voltage, even though the switches and circuits tested OK at higher temperatures. This condition will sound as though the starter is failing to stay engaged with the engine. It is caused by the cold weather low voltage of the system releasing the electrical connection of the magnetic switch.

Two technicians are needed for the following tests. Technician #1 engages the starter, and Technician #2 performs underhood procedures.

Procedure:

CAUTION: In step 1 below, the large terminal studs on the magnetic switch are at battery voltage. The engine should crank when the jumper is connected.
Be prepared to remove the jumper immediately after engine begins cranking.

1. With the key switch on:
   a. Technician #1 engages the starter.
   b. Technician #2 clamps heavy battery jumper cables between the two large studs on the magnetic switch. Engine should crank.
   c. Technician #2 immediately removes the jumper cables to stop engine cranking.
2. If the engine starts with jumper in place, replace the magnetic switch.
3. If the vehicle now starts properly, make sure the starter mounting bolts are tight and proceed to the Alternator Wiring Test (page 18).

Available Cranking Voltage

If the batteries, switches and wiring have been checked and the starter still cranks slowly, check for available voltage at the starter while cranking.

Procedure:

1. Technician #1 engages the starter with the key switch.
2. Technician #2 measures the voltage across the solenoid “BAT” terminal and the starter ground terminal.
3. If voltage is 9.0 volts (18 volts for 24-volt system) or less while cranking, check the battery interconnecting cables.
4. Measure the voltage across each battery while cranking.
5. Touch the voltmeter leads to the terminals of every battery.
6. Check or replace interconnecting cables as required:
    a. If the difference between any two battery readings in the same battery box is more than 0.5 volt.
    b. If any cable or connection feels warm to the touch.

Ring Gear and Pinion Check

One final check before replacing the starter is to inspect the pinion and ring gear (Figure 20).

Procedure:

1. Technician #1 visually inspects the pinion and ring gear while Technician #2 turns the engine with a bar. Be sure to check the entire ring gear.
2. Replace:
    a. The starter if the pinion is damaged.
    b. The ring gear if it is damaged, noting that if ring gear is damaged, the pinion may also be damaged.

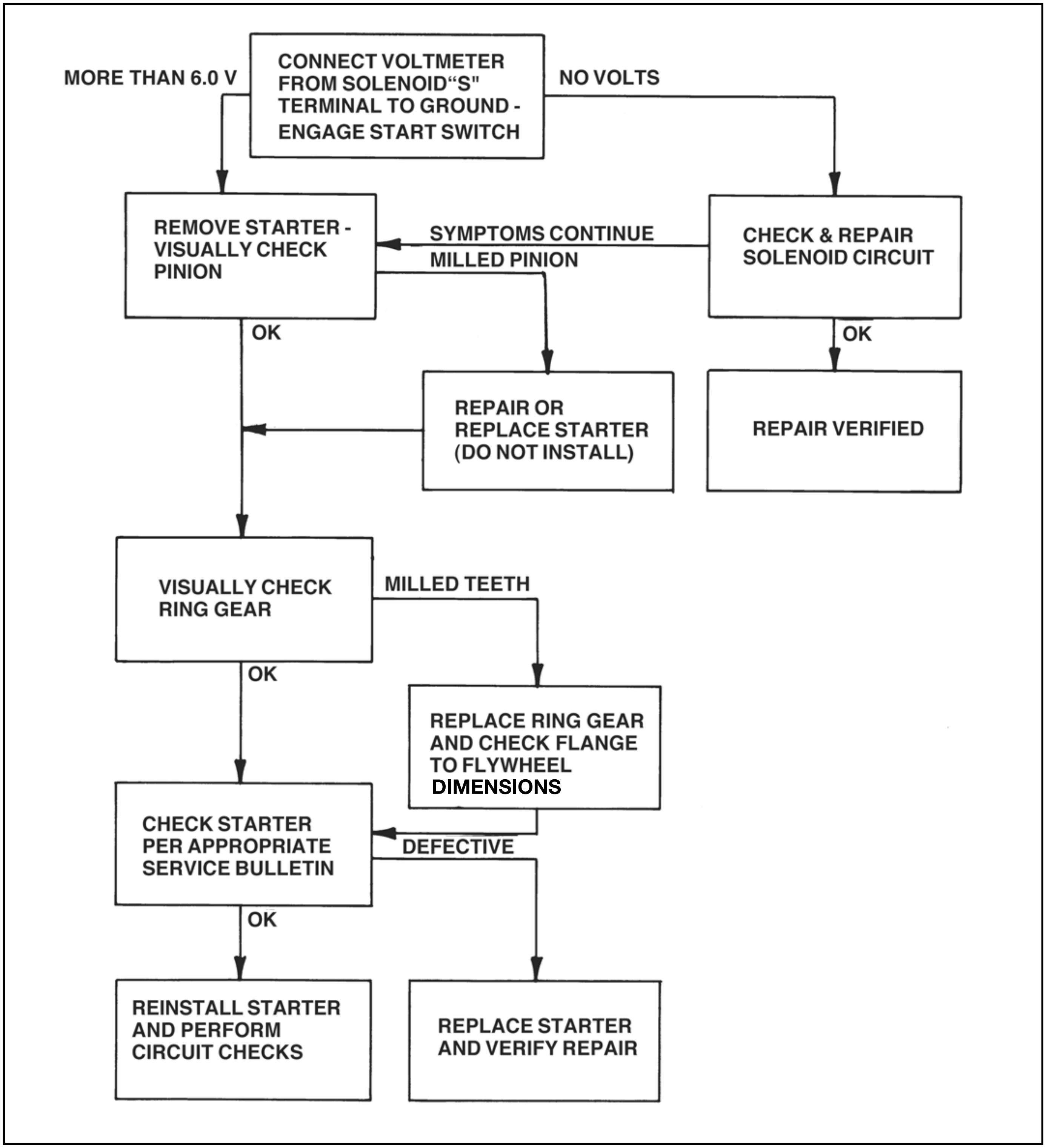


Figure 20. Milled Pinion Diagnosis