SPECIFICATIONS

General Specifications

Item	Specification
Generator amps	80/135 amps (max) @ 1,800-6,000 generator rpm, approximately 500-2,000 engine rpm

General Specifications (Continued)

Item	Specification
Voltage	12 volts

DESCRIPTION AND OPERATION

Charging System

The charging system consists of the following components:

- Generator
- Charging system warning indicator
- Necessary wiring and cables

The charging system is a negative ground system. The generator (including an internal voltage regulator) is belt-driven by the engine accessory drive system. When the engine is started, the generator begins to generate AC, which is internally converted to DC. This current is then supplied to the vehicle electrical system through the output (B+) terminal of the generator.

Vehicles equipped with a 4.6L (3V) have a one way clutch (OWC) in the generator pulley. The OWC pulley temporarily disengages the generator rotor from the front end accessory drive (FEAD) system during high deceleration rates on the engine. This may decrease noise, vibration and harshness (NVH) (belt chirp) and may increase belt life. The OWC pulley and generator/regulator must be installed as an assembly.

Battery

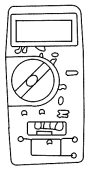
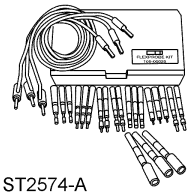
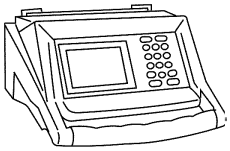
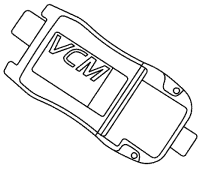
The battery is a 12-volt DC source connected in a negative ground system. The battery case is sealed with 2 vent holes to release gases. The battery has 3 major functions:

- Engine cranking power source
- Voltage stabilizer for the electrical system
- Temporary power source when electrical loads exceed the generator output current

DIAGNOSIS AND TESTING

Charging System

Special Tool(s)

 ST1137-A	73III Automotive Meter 105-R0057 or equivalent
 ST2574-A	Flex Probe Kit 105-R025B
 ST2173-A	SABRE Premium Battery and Electrical System Tester 010-00736 or equivalent
 ST2834-A	Vehicle Communication Module (VCM) and Integrated Diagnostic System (IDS) software with appropriate hardware, or equivalent scan tool

Principles of Operation

The PCM controlled charging system determines the optimal voltage setpoint for the charging system and communicates this information to the voltage regulator. This system is unique in that it has 2 communication lines between the PCM and the generator/regulator. Both of these communication lines are pulse-width modulated (PWM). The generator communication (GENCOM) line communicates the desired setpoint from the PCM to the voltage regulator. The generator monitor (GENMON) line communicates the generator load and error conditions to the PCM. The third pin on the voltage regulator, the A circuit pin, is a dedicated battery voltage sense line.

The generator charges the battery and at the same time supplies power for all of the electrical loads that are required. The battery is more effectively charged with a higher voltage when the battery is cold and a lower voltage when the battery is warm. The PCM is able to adjust the charging voltage according to the battery temperature by using a signal from the intake air temperature (IAT) sensor. This means the voltage setpoint is calculated by the PCM and communicated to the regulator by the GENCOM circuit.

The PCM simultaneously controls and monitors the output of the generator. When the current consumption is high or the battery is discharged the PCM raises engine speed to increase generator output.

To minimize the engine drag when starting the engine, the PCM does not allow the generator to produce any output until the engine has started. The PCM turns off the generator during cranking to reduce the starter load and improve cranking speed. Once the engine starts, the PCM slowly increases generator output to help establish a stable engine speed.

The PCM controls the charging system warning indicator by sending a message over the high-speed controller area network (HS-CAN) to the instrument cluster (IC). The PCM turns the charging system warning indicator off when generator output begins. The charging system warning indicator is also illuminated by the PCM whenever the key is ON with the engine OFF.

This is a System 4 charging system, which uses the GENMON and GENCOM lines to control and monitor the charging system through the PCM. System 4 charging systems are virtually identical in design and therefore, share the same diagnostics. The circuit numbers and colors may be different, but the functions are the same.

DIAGNOSIS AND TESTING (Continued)

Inspection and Verification

⚠ WARNING: Batteries contain sulfuric acid and produce explosive gases. Work in a well-ventilated area. Do not allow the battery to come in contact with flames, sparks or burning substances. Avoid contact with skin, eyes or clothing. Shield eyes when working near the battery to protect against possible splashing of acid solution. In case of acid contact with skin or eyes, flush immediately with water for a minimum of 15 minutes, then get prompt medical attention. If acid is swallowed, call a physician immediately. Failure to follow these instructions may result in serious personal injury.

⚠ WARNING: Always lift a plastic-cased battery with a battery carrier or with hands on opposite corners. Excessive pressure on the battery end walls may cause acid to flow through the vent caps, resulting in personal injury and/or damage to the vehicle or battery.

NOTICE: **Do not make jumper connections except as directed. Incorrect connections may damage the voltage regulator test terminals, fuses or fusible links.**

NOTICE: **Do not allow any metal object to come in contact with the generator housing and internal diode cooling fins. A short circuit may result and burn out the diodes.**

NOTE: While carrying out any pinpoint test, disregard the DTCs set while following a specific pinpoint test. After the completion of any test, be sure to clear all DTCs in the PCM.

NOTE: All voltage measurements are referenced to the negative (-) battery post unless otherwise specified.

NOTE: When the battery has been disconnected and reconnected, some abnormal drive symptoms may occur while the PCM relearns its fuel trim. The vehicle may need to be driven to relearn the strategy.

1. Verify the customer concern.
2. Visually inspect for obvious signs of mechanical or electrical damage.

Visual Inspection Chart

Mechanical	Electrical
• Battery • Generator drive belt • Generator pulley	• Bussed electrical center (BEC) fuse 43 (10A) • Battery charge • Circuitry • Cables • PCM • Charging system warning indicator

3. If an obvious cause for an observed or reported concern is found, correct the cause (if possible) before proceeding to the next step.
4. Verify the battery condition. Refer to Section 414-01.
5. Check the operation of the charging system warning indicator in the instrument cluster (IC) as follows:
   - With the key in the OFF position, the charging system warning indicator should be off.
   - With the key in the ON position and the engine OFF, the charging system warning indicator should be on.
   - With the engine running, the charging system warning indicator should be off.
6. Turn off the headlamps and the A/C system (if equipped). Turn the climate control blower to low/off. Check the battery voltage before and after starting the engine to determine if the battery voltage increases.
7. If the cause is not visually evident, connect the scan tool to the data link connector (DLC).
8. **NOTE:** The vehicle communication module (VCM) LED prove-out confirms voltage and ground from the DLC are provided to the VCM.

   If the scan tool does not communicate with the VCM:
   - check the connection to the vehicle.
   - refer to Section 418-00 to diagnose no communication with the scan tool.
9. If the scan tool does not communicate with the vehicle:
   - verify the ignition key is in the ON position.
   - verify the scan tool operation with a known good vehicle.

DIAGNOSIS AND TESTING (Continued)

- refer to Section 418-00 to diagnose no response from the PCM.

10. Carry out the network test.
    - If the scan tool responds with no communication for one or more modules, refer to Section 418-00.
    - If the network test passes, retrieve and record continuous memory DTCs.
11. Clear the continuous DTCs and carry out the self-test diagnostics for the PCM.
12. If the DTCs retrieved are related to the concern, go to the DTC Chart. For all other DTCs, refer to Section 419-10.
13. If no DTCs related to the concern are retrieved, GO to Symptom Chart.

NOTE: DTC P0622 may be set by the loss of the communication lines between the generator and the PCM. The charging system warning indicator then illuminates until the engine is operated at greater than 4,500 rpm (approximately wide open throttle [WOT]) for a minimum of 3 seconds. At this time, the generator self-excites. The charging system warning indicator remains illuminated and the generator operates in a default mode (approximately 13.5 volts) until the engine is turned off.

DTC Chart

DTCs	Description	Source	Action
B1317	Battery Voltage High	Various Modules	GO to Pinpoint Test B.
B1318	Battery Voltage Low	Various Modules	GO to Pinpoint Test F.
B1676	Battery Voltage Out of Range	Various Modules	GO to Pinpoint Test F.
P0622	Generator Field Term Circuit	PCM	GO to Pinpoint Test B.
All other DTCs	—	—	REFER to Section 419-10.

Symptom Chart

Symptom Chart

Condition	Possible Sources	Action
• The battery is discharged or battery voltage is low	• High key-off current drain(s) • Engine, generator and battery grounds • Positive battery cable • Circuitry • Battery • Generator	• GO to Pinpoint Test A.
• The charging system warning indicator is on with the engine running and no charging system DTCs present	• Circuitry • PCM • Generator • Instrument cluster (IC)	• GO to Pinpoint Test C.
• The generator is noisy	• Accessory drive belt • Loose bolts/brackets • Generator/pulley	• GO to Pinpoint Test D.
• Radio interference	• Generator • Circuitry • In-vehicle entertainment system	• GO to Pinpoint Test E.

DIAGNOSIS AND TESTING (Continued)

Pinpoint Tests

NOTICE: **Electronic modules are sensitive to electrostatic discharge. If exposed to these charges, damage can result.**

Refer to Inspection and Verification, the DTC Chart and the Symptom Chart for direction to the appropriate pinpoint test.

Pinpoint Test A: The Battery is Discharged or Battery Voltage is Low

Refer to Wiring Diagrams Cell 12, Charging System for schematic and connector information.

Normal Operation

The generator output voltage is supplied through the positive battery output (B+), circuit 2037 (RD) terminal on the rear of the generator to the battery and electrical system. During normal operation the charging system warning indicator is off with the key in the ON position and the engine running. The charging system warning indicator is on with the key ON engine OFF.

This pinpoint test is intended to diagnose the following:

- High key-off current drain(s)
- Engine, generator and battery grounds
- Positive battery cable
- Wiring, terminals or connectors
- Battery
- Generator

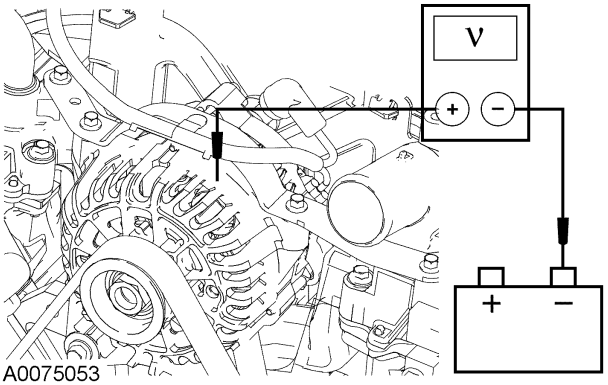
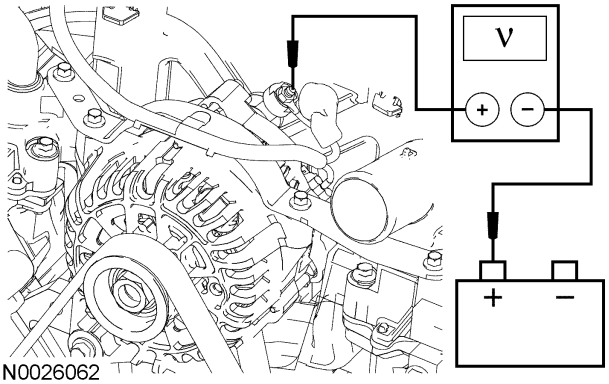
PINPOINT TEST A: THE BATTERY IS DISCHARGED OR BATTERY VOLTAGE IS LOW

Test Step		Result / Action to Take
A1	**CHECK THE BATTERY CONDITION**	
	• Carry out the Battery — Condition Test to determine if the battery can hold a charge and is OK for use. Refer to Section 414-01. • **Does the battery pass the condition test?**	**Yes** GO to **A2**. **No** INSTALL a new battery. REFER to Section 414-01. TEST the system for normal operation.
A2	**CHECK THE GENERATOR OUTPUT**	
	• Carry out the Generator On-Vehicle Load Test and No Load Test. Refer to the Component Tests in this section. • **Does the generator pass the component tests?**	**Yes** GO to **A3**. **No** GO to Pinpoint Test B.
A3	**CHECK FOR CURRENT DRAINS**	
	• Carry out the Battery — Drain Testing. Refer to the Component Tests in this section. • **Are any circuits causing excessive current drains?**	**Yes** REPAIR as necessary. TEST the system for normal operation. **No** GO to **A4**.
A4	**CHECK THE VEHICLE GROUNDS**	
	• Start the engine.	

(Continued)

DIAGNOSIS AND TESTING (Continued)

PINPOINT TEST A: THE BATTERY IS DISCHARGED OR BATTERY VOLTAGE IS LOW (Continued)

Test Step		Result / Action to Take
A4	CHECK THE VEHICLE GROUNDS (Continued)	
• With the engine running, measure the voltage drop between the generator housing and the negative battery terminal.  A0075053 • **Is the voltage drop less than 0.1 volt?**		**Yes** GO to **A5**. **No** CHECK the engine ground, generator ground and the battery ground for corrosion. TEST the system for normal operation.
A5	CHECK THE VOLTAGE DROP IN THE B+ CIRCUIT 2037 (RD)	
• With the engine running, measure the voltage drop between generator B+ C102b, circuit 2037 (RD) and the positive battery terminal.  N0026062 • **Is the voltage drop less than 0.5 volt?**		**Yes** CHECK if the customer left any electrical system(s) on or if there is an intermittent excessive battery draw. TEST the system for normal operation. **No** CHECK for any corrosion in the B+ 2037 (RD), positive battery cable and/or connections. REPAIR as necessary. TEST the system for normal operation.

Pinpoint Test B: The Charging System Warning Indicator is On and Any Charging System DTC Stored

Refer to Wiring Diagrams Cell 12, Charging System for schematic and connector information.

Normal Operation

With the engine running, the charging system warning indicator is off. The Sense A circuit 35 (OG/LB) to the generator field coil is 13-15 volts. This voltage feedback is used by the regulator to maintain the battery voltage at the desired setpoint. The S (stator) circuit (internal to the generator) is used to monitor generator operation. This circuit and other regulator internal conditions are checked by the regulator to allow the PCM to turn off the charging system warning indicator by sending a message over the controller area network (CAN) bus to the instrument cluster (IC). The positive battery output (B+) circuit 2037 (RD) is the generator output voltage supplied to the battery and electrical system.

This pinpoint test is intended to diagnose

DIAGNOSIS AND TESTING (Continued)

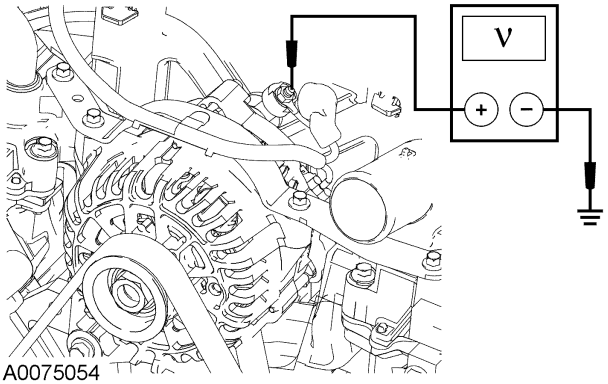
the following:

- Generator
- IC
- PCM

PINPOINT TEST B: THE CHARGING SYSTEM WARNING INDICATOR IS ON AND ANY CHARGING SYSTEM DTC STORED

NOTE: Make sure battery voltage is greater than 12.2 volts prior to carrying out this pinpoint test.

NOTE: Do not have a battery charger attached during vehicle testing.

Test Step		Result / Action to Take
B1	**CONFIRM THE BATTERY CONDITION**	
	• Carry out the Battery Condition Test. Refer to Section 414-01. • **Is the battery OK?**	**Yes** GO to **B2**. **No** CORRECT the battery condition and GO to **B2**.
B2	**CHECK THE BUSSED ELECTRICAL CENTER (BEC) FUSE 43 (10A)**	
	• Check fuse: BEC 43 (10A). • **Is BEC 43 (10A) OK?**	**Yes** GO to **B3**. **No** REPAIR circuit 35 (OG/LB) and INSTALL a fuse. INSPECT PCM and engine ground circuits and make sure they are securely attached. CLEAR the DTCs. REPEAT the self-test. TEST the system for normal operation.
B3	**CHECK THE GENERATOR B+ CONNECTION**	
	• Ignition OFF. • Inspect generator C102b, B+ circuit 2037 (RD) connection. Connection should be tight. • Measure the voltage between generator C102b, B+ circuit 2037 (RD) and ground.  A0075054 • **Is generator C102b connection tight and does the generator B+ measure battery voltage?**	**Yes** GO to **B4**. **No** TIGHTEN the generator B+ connection or REPAIR the circuit. CLEAR the DTCs. REPEAT the self-test. TEST the system for normal operation.
B4	**MONITOR THE PCM PID GENERATOR MONITOR WITH KOEO**	
	• Ignition ON. • Enter the following diagnostic mode on the scan tool: Clear the PCM DTCs.	

(Continued)

DIAGNOSIS AND TESTING (Continued)

PINPOINT TEST B: THE CHARGING SYSTEM WARNING INDICATOR IS ON AND ANY CHARGING SYSTEM DTC STORED (Continued)

Test Step		Result / Action to Take
B4	**MONITOR THE PCM PID GENERATOR MONITOR WITH KOEO (Continued)**	
	• Enter the following diagnostic mode on the scan tool: Select PCM PIDs. **NOTE:** Many of the PCM PIDs selected will be monitored later in this pinpoint test. Select and monitor the following PCM PIDs: — Generator Monitor (GENMON). — Generator Command Duty Cycle (GENCMD). — Generator Voltage Desired (GENVDSD). — Generator Fault Indicator Lamp (GENFIL). — Engine Revolutions Per Minute (RPM). — Module Supply Voltage (VPWR). • Monitor the GENMON PID. • **Does the GENMON PID read 0%?**	**Yes** GO to **B5**. **No** GO to **B8**.
B5	**MONITOR THE PCM PID GENERATOR MONITOR WITH KEY ON/ENGINE RUNNING (KOER)**	
	• Start the engine. • With the engine at idle, wait 15 seconds for the GENVDSD PID to increase to greater than 13 volts. • Monitor PID GENMON at idle and 3,000 rpm. • **Does the GENMON PID read between 3% and 98% at engine idle speed and at 3,000 rpm?**	**Yes** GO to **B6**. **No** GO to **B8**.
B6	**MONITOR THE PCM PIDs GENERATOR MONITOR, MODULE SUPPLY VOLTAGE AND GENERATOR DESIRED VOLTAGE WITH THE ENGINE AT 3,000 RPM**	
	• Turn all electrical accessories (lights, blower motor, etc.) off. • **NOTE:** If GENMON PID does not remain below 85%, make sure that the battery is at an acceptable state of charge and that all electrical accessories are off. Increase the engine speed to 3,000 rpm (or road test). • **Does the VPWR PID remain within ± 0.5 volt of the GENVDSD PID when the GENMON PID is less than 85%?**	**Yes** GO to **B7**. **No** GO to **B17**.
B7	**MONITOR THE PCM PIDs GENERATOR MONITOR, MODULE SUPPLY VOLTAGE AND GENERATOR DESIRED VOLTAGE WITH THE ENGINE AT IDLE**	
	• Return the engine speed to idle. • ***NOTICE:*** **On vehicles with low electrical loads, it may be necessary to add external loads (devices connected to power points, etc.) to determine the maximum GENMON value. GENMON value will not read between 95%-98% on a vehicle with minimal electrical accessories. As long as there is a significant increase in the GENMON PID following the procedure below, answer YES to the question.** **NOTE:** Manual transmission vehicles require the clutch pedal be depressed to operate the rpm active command. Determine the maximum GENMON PID value by lowering engine idle rpm to 500 rpm or less using the rpm active command and turn on all electrical accessories until the VPWR PID is less than the GENVDSD PID by at least 0.7 volt. Under this condition the GENMON PID should read between 95% and 98%. • **Does the GENMON PID read between 95% and 98%?**	**Yes** GO to **B19**. **No** GO to **B17**.
B8	**CHECK THE VOLTAGE OUTPUTS FROM THE PCM**	
	• Ignition OFF. • Disconnect: Generator C102a. • Ignition ON. • Measure the voltage of the following circuits:	

(Continued)

DIAGNOSIS AND TESTING (Continued)

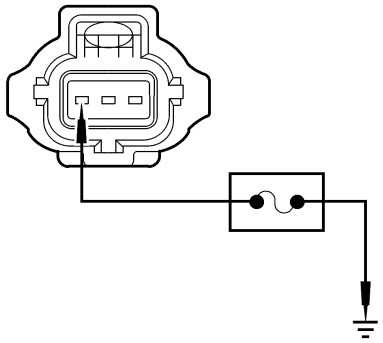
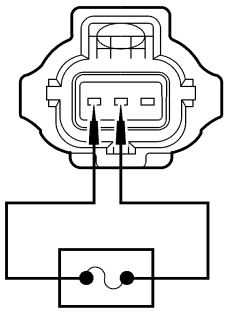
PINPOINT TEST B: THE CHARGING SYSTEM WARNING INDICATOR IS ON AND ANY CHARGING SYSTEM DTC STORED (Continued)

<table>
<tr><th colspan="2">Test Step</th><th>Result / Action to Take</th></tr>
<tr><td>B8</td><td>CHECK THE VOLTAGE OUTPUTS FROM THE PCM (Continued)</td><td rowspan="2">Yes
GO to B13.
No
If a fault is detected in the GENCOM circuit 1816 (YE/LB) or GENMON circuit 1817 (YE), GO to B9.
If a fault is detected in the A sense 35 (OG/LB) circuit, GO to B12.</td></tr>
<tr><td colspan="2">Expected Voltages
<table><tr><th>Generator Connector</th><th>Circuit</th><th>Expected Voltage (Approximate)</th></tr><tr><td>C102a-1</td><td>1817 (YE)</td><td>8-11 volts (should be less than battery voltage)</td></tr><tr><td>C102a-2</td><td>1816 (YE/LB)</td><td>0 volts</td></tr><tr><td>C102a-3</td><td>35 (OG/LB)</td><td>Battery voltage</td></tr></table>• Are the voltages as indicated for each circuit?</td></tr>
<tr><td>B9</td><td>CHECK CIRCUITS 1816 (YE/LB) AND 1817 (YE) FOR DAMAGE OR AN OPEN</td><td rowspan="2">Yes
GO to B10.
No
REPAIR the affected circuit. CLEAR the DTCs. REPEAT the self-test. TEST the system for normal operation.</td></tr>
<tr><td colspan="2">• Ignition OFF.
• Disconnect: Generator C102a.
• Disconnect: PCM C175b.
• Disconnect: PCM C175e.
• Inspect the following for damaged or pushed-out pins:
<table><tr><th>Component</th><th>Connector</th><th>Circuit</th></tr><tr><td>PCM</td><td>C175b-32</td><td>1816 (YE/LB)</td></tr><tr><td>PCM</td><td>C175e-5</td><td>1817 (YE)</td></tr><tr><td>Generator</td><td>C102a-2</td><td>1816 (YE/LB)</td></tr><tr><td>Generator</td><td>C102a-1</td><td>1817 (YE)</td></tr></table>• Measure the resistance between circuit C175b-32 and C102a-2 and circuit C175e-5 and C102a-1.
• Are the connectors and pins free of damage and are the resistances less than 5 ohms?</td></tr>
<tr><td>B10</td><td>CHECK CIRCUITS 1816 (YE/LB) AND 1817 (YE) FOR SHORT TO VOLTAGE</td><td rowspan="2">Yes
GO to B11.
No
REPAIR the affected circuits. CLEAR the DTCs. REPEAT the self-test. TEST the system for normal operation.</td></tr>
<tr><td colspan="2">• Ignition ON.
• Measure the voltage between circuits C102a-1, 1817 (YE) and C102a-2, 1816 (YE/LB).
• Are the voltages approximately 0 volt?</td></tr>
<tr><td>B11</td><td>CHECK CIRCUITS 1816 (YE/LB) AND 1817 (YE) FOR SHORT TO GROUND</td><td rowspan="2">Yes
GO to B24.
No
REPAIR the affected circuits. CLEAR the DTCs. REPEAT the self-test. TEST the system for normal operation.</td></tr>
<tr><td colspan="2">• Ignition OFF.
• Measure the resistance between circuit C102a-1, 1817 (YE) harness side and ground and C102a-2, 1816 (YE/LB) harness side and ground and also measure resistance. between each other:
• Are the resistances less than 5 ohms?</td></tr>
<tr><td>B12</td><td>CHECK CIRCUIT 35 (OG/LB) FOR DAMAGE OR AN OPEN</td><td rowspan="2">Yes
GO to B24.
No
REPAIR the affected circuit. CLEAR the DTCs. REPEAT the self-test. TEST the system for normal operation.</td></tr>
<tr><td colspan="2">• Ignition OFF.
• Disconnect: Generator C102a.
• Inspect C102a-3 for damaged or pushed-out pins.
• Measure the resistance of the circuit A sense circuit 35 (OG/LB) between the battery and C102a-3 generator connector.
• Are the connectors and pins free of damage and are the resistances less than 5 ohms?</td></tr>
</table>

(Continued)

DIAGNOSIS AND TESTING (Continued)

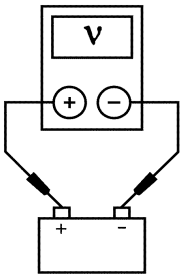
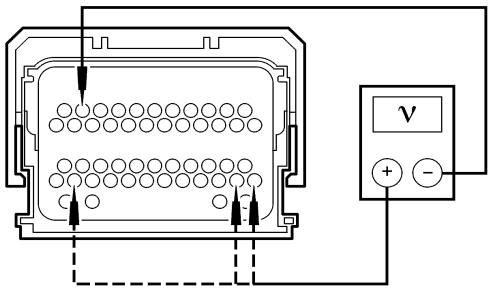
PINPOINT TEST B: THE CHARGING SYSTEM WARNING INDICATOR IS ON AND ANY CHARGING SYSTEM DTC STORED (Continued)

Test Step		Result / Action to Take
B13	**CHECK FOR SHORTED CIRCUITS**	
	• Ignition OFF. • Disconnect: Generator C102a. • Ignition ON. • Verify that PID GENMON reads 100%. • Carry out the Wiggle Test of wiring to determine if PID GENMON changes from 100%. • **Does PID GENMON change from 100%?**	**Yes** REPAIR short circuit on 1817 (YE) C102a-1. **No** GO to **B14**.
B14	**CHECK THE PCM PID GENERATOR MONITOR INPUT TO THE PCM**	
	• Connect a fused (10A) jumper wire between generator C102a-1, circuit 1817 (YE), harness side and ground.  N0074141 • Ignition ON. • Monitor the GENMON PID while performing a wiggle test on the wire harness. • **Does the GENMON PID read 0%?**	**Yes** GO to **B15**. **No** REPAIR open connection on circuit 1817 (YE). INSPECT generator C102a-1 and PCM C175e-5 for damage. CLEAR the DTCs. REPEAT the self-test. TEST the system for normal operation.
B15	**COMPARE THE PCM PIDS GENERATOR MONITOR AND GENERATOR FIELD DUTY CYCLE**	
	• Ignition OFF. • Disconnect: Fused (10A) Jumper Wire. • Connect a fused (10A) jumper wire between generator C102a-1, circuit 1817 (YE), harness side and generator C102a-2, circuit 1816 (YE/LB), harness side.  N0074142 • Ignition ON. • Monitor the GENMON and GENCMD PIDs while performing a wiggle test on the harness. • **Does the GENMON PID read within 2% of the GENCMD PID?**	**Yes** GO to **B16**. **No** INSPECT C175b-10, circuit 1205 (BK), PCM ground circuit. CLEAR the DTCs. REPEAT the self-test. TEST the system for normal operation.

(Continued)

DIAGNOSIS AND TESTING (Continued)

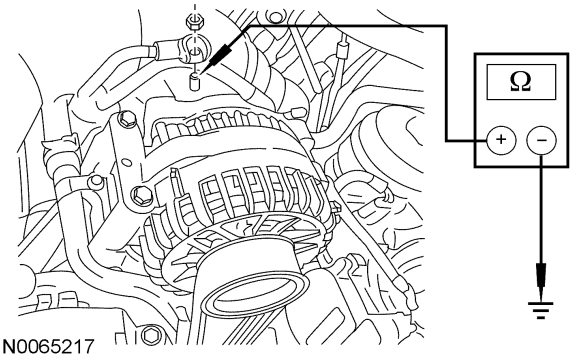
PINPOINT TEST B: THE CHARGING SYSTEM WARNING INDICATOR IS ON AND ANY CHARGING SYSTEM DTC STORED (Continued)

Test Step		Result / Action to Take
B16	**A SENSE CIRCUIT LOAD TEST**	
	NOTE: This step puts a load on the A sense circuit. If there are corroded or loose connections, loading the circuit may help show the fault. • Ignition ON. • Using a 12-volt test lamp, check for voltage at C102a-3, circuit 35 (OG/LB). • **Does the test lamp illuminate?**	**Yes** GO to **B23**. **No** REPAIR connection on circuit 35 (OG/LB). INSPECT generator C102a-3 for damage. CLEAR the DTCs. REPEAT the self-test. TEST the system for normal operation.
B17	**CHECK THE PCM VPWR PID**	
	• With the engine running, measure the battery voltage.  AJ0210-A • Monitor the VPWR PID. • **Are the battery voltage and VPWR PID within 0.5 volt of each other?**	**Yes** GO to **B19**. **No** GO to **B18**.
B18	**MEASURE THE PCM INPUT VOLTAGE**	
	• Ignition OFF. • Disconnect: PCM C175b. • Connect a fused (10A) jumper wire between C175b-37 circuit 1769 (BN/PK) and ground. • Ignition ON. • Measure the voltage between PCM input voltage pins 35, 36 and 45 to PCM ground pin 10.  N0065215 • **Are voltages within 0.5 volt of PID VPWR?**	**Yes** GO to **B24**. **No** REPAIR high resistance or loose connections between C175b-35 circuit 1118 (RD) 4.0L or circuit 1856 (GY/OG) 5.4L, C175b-36 circuit 1118 (RD) 4.0L or circuit 1856 (GY/OG) 5.4L, C175b-45 circuit 1683 (DG) PCM power circuits or C175b-10, circuit 1205 (BK), PCM ground circuit.
B19	**CHECK THE GENERATOR B+ RESISTANCE**	
	• Ignition OFF. • Disconnect: Battery. • Disconnect: Generator C102b.	

(Continued)

DIAGNOSIS AND TESTING (Continued)

PINPOINT TEST B: THE CHARGING SYSTEM WARNING INDICATOR IS ON AND ANY CHARGING SYSTEM DTC STORED (Continued)

<table>
<tr><th colspan="2">Test Step</th><th>Result / Action to Take</th></tr>
<tr><td>B19</td><td>CHECK THE GENERATOR B+ RESISTANCE (Continued)</td><td rowspan="2">Yes
GO to B20.
No
INSTALL a new generator. REFER to Section 414-02. CLEAR the DTCs. REPEAT the self-test. TEST the system for normal operation.</td></tr>
<tr><td colspan="2">• Measure the resistance between generator C102b, component side and the generator housing.
 

N0065217
• Is the resistance greater than 125K ohms?</td></tr>
<tr><td>B20</td><td>CHECK THE RESISTANCE OF THE VOLTAGE REGULATOR INTERNAL CIRCUITS TO GROUND</td><td rowspan="2">Yes
GO to B21.
No
INSTALL a new generator. REFER to Section 414-02. CLEAR the DTCs. REPEAT the self-test. TEST the system for normal operation.</td></tr>
<tr><td colspan="2">• Measure the resistance between generator C102a, component side and ground. Refer to the following table.
<table><tr><th>Pin</th><th>Expected Resistance</th></tr><tr><td>1</td><td>Greater than 1,000K ohms</td></tr><tr><td>2</td><td>Greater than 125K ohms</td></tr><tr><td>3</td><td>Greater than 125K ohms</td></tr></table>• Are the resistance values as indicated?</td></tr>
<tr><td>B21</td><td>ROAD TEST IN AN ATTEMPT TO VERIFY THE FAULT</td><td rowspan="2">Yes
GO to B2.
No
If a road test did not cause the fault to occur, intermittent fault condition may be present. GO to B22.</td></tr>
<tr><td colspan="2">• Connect: Generator C102b.
• Connect: Generator C102a.
• Connect: Battery.
• Carry out a road test and monitor the following PIDs:
— Generator monitor (GENMON).
— Generator voltage desired (GENVDSD).
— Module supply voltage (VPWR).
• Does the GENMON PID read either 0% or 100% during the road test?</td></tr>
<tr><td>B22</td><td>USE THE VEHICLE DATA RECORDER (VDR) TO CAPTURE INTERMITTENT FAULT CONDITION</td><td rowspan="2">Yes
RECORD any values from the VDR that may have been captured. If no charging system DTCs are present, GO to Pinpoint Test C. If any charging system DTCs are present, GO to B3.
No
No problem found at this time. CLEAR the DTCs. REPEAT the self-test. TEST the system for normal operation.</td></tr>
<tr><td colspan="2">• Connect a VDR to the vehicle and setup to capture the following PIDs:
— Generator monitor (GENMON).
— Generator command duty cycle (GENCMD).
— Generator voltage desired (GENVDSD).
— Generator fault indicator lamp (GENFIL).
— Engine revolutions per minute (RPM).
— Module supply voltage (VPWR).
• Set the VDR to trigger if any of the following events occur during vehicle operation (waiting 15 seconds after start):
— VPWR PID reads greater than 15.2 volts.
— GENMON PID reads 0% or 100%.
• Road test the vehicle.
• Was a fault captured by the VDR?</td></tr>
<tr><td>B23</td><td>CHECK THE CHARGING SYSTEM CIRCUITS FOR INTERMITTENT FAULTS</td><td rowspan="2"></td></tr>
<tr><td colspan="2">• Ignition OFF.</td></tr>
</table>

(Continued)

DIAGNOSIS AND TESTING (Continued)

PINPOINT TEST B: THE CHARGING SYSTEM WARNING INDICATOR IS ON AND ANY CHARGING SYSTEM DTC STORED (Continued)

Test Step		Result / Action to Take
B23	**CHECK THE CHARGING SYSTEM CIRCUITS FOR INTERMITTENT FAULTS (Continued)**	
	• Connect: Generator C102b. • Connect: Generator C102a. • Connect: PCM C175b. • Connect: PCM C175e. • Connect the scan tool. • Start the engine. • With the engine running, monitor the charging system warning indicator lamp and the scan tool for DTCs. • **Does the charging system warning indicator lamp illuminate and does any charging system DTC get stored into memory?**	**Yes** INSTALL a new generator. REFER to Section 414-02. CLEAR the DTCs. REPEAT the self-test. TEST the system for normal operation. **No** The fault is not present and cannot be recreated at this time. This may indicate an intermittent fault. GO to **B19**.
B24	**CHECK THE CHARGING SYSTEM CIRCUITS FOR INTERMITTENT FAULTS**	
	• Ignition OFF. • Connect: Generator C102b. • Connect: Generator C102a. • Connect: PCM C175b. • Connect: PCM C175e. • Connect the scan tool. • Start the engine. • With the engine running, monitor the charging system warning indicator lamp and the scan tool for DTCs. • **Does the charging system warning indicator lamp illuminate and does any charging system DTC get stored into memory?**	**Yes** INSTALL a new PCM. REFER to Section 303-14. **No** The fault is not present and cannot be recreated at this time. This may indicate an intermittent fault. GO to **B19**.

Pinpoint Test C: The Charging System Warning Indicator is On With the Engine Running and No Charging System DTCs Present

Refer to Wiring Diagrams Cell 12, Charging System for schematic and connector information.

Normal Operation

With the engine running, the charging system warning indicator is off. The A circuit 35 (OG/LB) from the battery B+ to the generator regulator is 13-15 volts. This voltage feedback is used by the regulator to maintain the battery voltage at the desired setpoint. The S (stator) circuit (internal to the generator) is used to monitor generator operation. This circuit and other regulator internal conditions are checked by the regulator to allow the PCM to turn off the charging system warning indicator by sending a message over the controller area network (CAN) bus to the instrument cluster (IC). The positive battery output (B+) circuit 2037 (RD) is the generator output supplied to the battery and electrical system.

This pinpoint test is intended to diagnose the following:

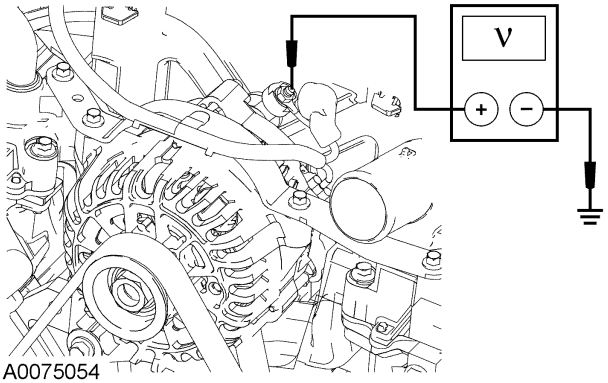
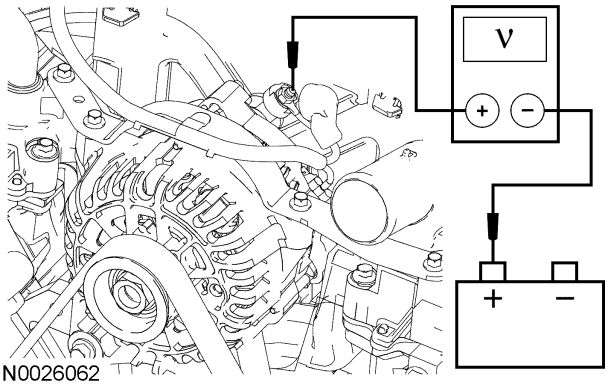
- Generator
- Circuitry
- IC
- PCM

DIAGNOSIS AND TESTING (Continued)

PINPOINT TEST C: THE CHARGING SYSTEM WARNING INDICATOR IS ON WITH THE ENGINE RUNNING AND NO CHARGING SYSTEM DTCs PRESENT

NOTE: Make sure battery voltage is greater than 12.2 volts prior to carrying out this pinpoint test.

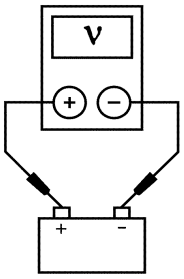
NOTE: Do not have a battery charger attached during vehicle testing.

Test Step		Result / Action to Take
C1	**CHECK THE BATTERY CONDITION**	
	• Carry out the Battery — Condition Test to determine if the battery can hold a charge and is OK for use. Refer to Section 414-01. • **Does the battery pass the condition test?**	**Yes** GO to C2. **No** INSTALL a new battery. REFER to Section 414-01. TEST the system for normal operation.
C2	**CHECK THE GENERATOR B+ CONNECTION**	
	• Ignition OFF. • Inspect generator C102b connection. Connection should be tight. • Measure the voltage between generator C102b, circuit 2037 (RD) and ground.  A0075054 • **Is generator C102b connection tight and does the generator B+ measure battery voltage?**	**Yes** GO to C3. **No** TIGHTEN the generator B+ connection or REPAIR the circuit. CLEAR the any DTCs. REPEAT the self-test. TEST the system for normal operation.
C3	**CHECK THE VOLTAGE DROP IN THE B+ circuit 2037 (RD)**	
	• With the engine running, measure the voltage drop between generator B+ C102b, circuit 2037 (RD) and the positive battery terminal.  N0026062 • **Is the voltage drop less than 0.5 volt?**	**Yes** GO to C4. **No** CHECK for any corrosion in the B+ C102b, circuit 2037 (RD), positive battery cable and/or connections. REPAIR as necessary. TEST the system for normal operation.

(Continued)

DIAGNOSIS AND TESTING (Continued)

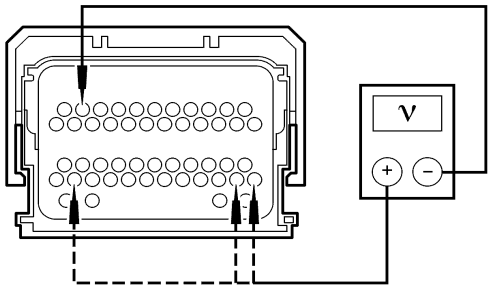
PINPOINT TEST C: THE CHARGING SYSTEM WARNING INDICATOR IS ON WITH THE ENGINE RUNNING AND NO CHARGING SYSTEM DTCs PRESENT (Continued)

Test Step		Result / Action to Take
C4	**CHECK THE DTCs IN THE PCM**	
	• Ignition OFF. • Connect the scan tool. • Start the engine. • Enter the following diagnostic mode on the scan tool: Retrieve PCM DTCs. • Use the recorded PCM DTCs from the continuous and on-demand self tests. • **Are any PCM DTCs recorded?**	**Yes** For all DTCs EXCEPT charging system DTCs, REFER to the Powertrain Control/Emissions Diagnosis (PC/ED) manual. If any charging system DTCs are present, GO to Pinpoint Test B. If referred here by the PC/ED, GO to **C5**. **No** GO to **C5**.
C5	**MONITOR PID GENFIL**	
	• With the engine running, monitor PID GENFIL. • **Does PID GENFIL show fault?**	**Yes** GO to **C6**. **No** REPAIR/INSTALL a new IC, IC-to-PCM connection or the PCM. TEST the system for normal operation.
C6	**MONITOR PID VPWR**	
	• With the engine running, monitor PIDS VPWR, GENFIL, GENVDSD. • **Is PID VPWR greater than 15.6 volts?**	**Yes** GO to **C7**. **No** GO to **C8**.
C7	**CHECK PCM VPWR PID**	
	• With the engine running, measure the battery voltage.  AJ0210-A • Monitor the VPWR PID. • **Are the battery voltage and VPWR PID within 0.6 volt of each other?**	**Yes** GO to **C8**. **No** GO to **C9**.
C8	**MEASURE PCM INPUT VOLTAGE**	
	• Ignition OFF. • Disconnect: PCM C175b. • Ignition ON. • Connect a fused (10A) jumper wire between C175b-37 circuit 1769 (BN/PK) and ground.	

(Continued)

DIAGNOSIS AND TESTING (Continued)

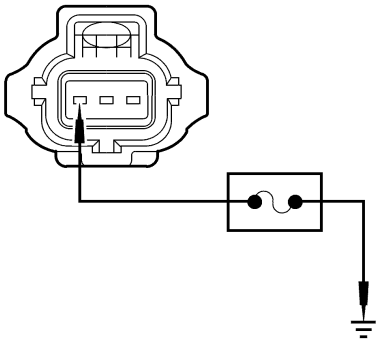
PINPOINT TEST C: THE CHARGING SYSTEM WARNING INDICATOR IS ON WITH THE ENGINE RUNNING AND NO CHARGING SYSTEM DTCs PRESENT (Continued)

Test Step		Result / Action to Take
C8	**MEASURE PCM INPUT VOLTAGE (Continued)**	**Yes** INSTALL a new PCM. **No** REPAIR high resistance or loose connections between C175b-35 circuit 1118 (RD) 4.0L or circuit 1856 (GY/OG) 5.4L, C175b-36 circuit 1118 (RD) 4.0L or circuit 1856 (GY/OG) 5.4L, C175b-45 circuit 1683 (DG) PCM power circuits or C175b-10, circuit 1205 (BK), PCM ground circuit.
	• Measure the voltage between PCM input voltage pins 35, 36 and 45 to PCM ground pin 10.  N0065215 • **Are voltages within 0.5 volt of PID VPWR?**	
C9	**MONITOR THE PCM PID GENERATOR MONITOR (GENMON) WITH KEY ON/ENGINE RUNNING**	**Yes** GO to **C10**. **No** GO to **C11**.
	• Start the engine. • With the engine at idle, wait 15 seconds for the GENVDSD PID to increase to greater than 13 volts. • Monitor PID GENMON at idle and 3,000 rpm. • **Does the GENMON PID read between 3% and 98% at engine idle speed and at 3,000 rpm?**	
C10	**MONITOR PID GENVDSD**	**Yes** REPAIR connection on circuit 35 (OG/LB). INSPECT generator C102a-3 for damage. CLEAR the DTCs. REPEAT the self-test. TEST the system for normal operation. If no problems are found, INSTALL a new generator. REFER to Section 414-02. TEST the system for normal operation. **No** REFLASH or INSTALL a new PCM.
	• With the engine running, monitor PID GENVDSD. • **Is PID GENVDSD greater than 15.2 volts?**	
C11	**CHECK FOR SHORTED CIRCUITS**	**Yes** REPAIR short circuit on C102a-1 1817 (YE). **No** GO to **C12**.
	• Ignition OFF. • Disconnect: Generator C102a. • Verify that PID GENMON reads 100%. • Carry out the Wiggle Test of wiring to determine if PID GENMON changes from 100%. • **Does PID GENMON change from 100%?**	

(Continued)

DIAGNOSIS AND TESTING (Continued)

PINPOINT TEST C: THE CHARGING SYSTEM WARNING INDICATOR IS ON WITH THE ENGINE RUNNING AND NO CHARGING SYSTEM DTCs PRESENT (Continued)

Test Step		Result / Action to Take
C12	**CHECK THE PCM PID GENERATOR MONITOR INPUT TO THE PCM**	
	• Connect a fused (10A) jumper wire between generator C102a-1, circuit 1817 (YE), harness side and ground.  N0074141 • Ignition ON. • Monitor the GENMON PID while carrying out a Wiggle Test on the wire harness. • **Does the GENMON PID read 0%?**	**Yes** REPAIR open connection on circuit 1817 (YE) C102a-1, and PCM C175e-26. CLEAR the DTCs. REPEAT the self-test. TEST the system for normal operation. **No** INSTALL a new generator. REFER to Section 414-02. CLEAR the DTCs. REPEAT the self-test. TEST the system for normal operation.

Pinpoint Test D: The Generator is Noisy

Refer to Wiring Diagrams Cell 12, Charging System for schematic and connector information.

Normal Operation

The generator is belt-driven by the engine accessory drive system.

This pinpoint test is intended to diagnose the following:

- Accessory drive belt
- Loose bolts/brackets
- Generator/pulley

PINPOINT TEST D: THE GENERATOR IS NOISY

Test Step		Result / Action to Take
D1	**CHECK FOR ACCESSORY DRIVE BELT NOISE AND LOOSE MOUNTING BRACKETS**	
	• Ignition OFF. • Check the accessory drive belt for damage and correct installation. Refer to Section 303-05. • Check the accessory mounting brackets and generator pulley for looseness or misalignment. • **Is the accessory drive OK?**	**Yes** GO to **D2**. **No** REPAIR as necessary. REFER to Section 303-05 for diagnosis and testing of the accessory drive system. TEST the system for normal operation.
D2	**CHECK THE GENERATOR MOUNTING**	
	• Check the generator mounting for loose bolts or misalignment. • **Is the generator mounted correctly?**	**Yes** GO to **D3**. **No** REPAIR as necessary. TEST the system for normal operation.
D3	**CHECK THE GENERATOR FOR ELECTRICAL NOISE**	
	• Disconnect: Generator C102b. • Start the engine. • With the engine running, use a stethoscope or equivalent listening device to probe the generator. • **Is the noise still present?**	**Yes** GO to **D4**. **No** INSTALL a new generator. REFER to Section 414-02. TEST the system for normal operation.

(Continued)

DIAGNOSIS AND TESTING (Continued)

PINPOINT TEST D: THE GENERATOR IS NOISY (Continued)

Test Step		Result / Action to Take
D4	**CHECK THE GENERATOR FOR MECHANICAL NOISE**	
	• With the engine running, use a stethoscope or equivalent listening device to probe the generator and the accessory drive area for unusual mechanical noise. • **Is the generator the noise source?**	**Yes** INSTALL a new generator. REFER to Section 414-02. TEST the system for normal operation. **No** REFER to Section 303-00 to diagnose the source of the engine noise.

Pinpoint Test E: Radio Interference

Refer to Wiring Diagrams Cell 12, Charging System for schematic and connector information.

Normal Operation

The generator radio suppression equipment reduces interference transmitted through the speakers by the vehicle electrical system.

This pinpoint test is intended to diagnose the following:

- Generator
- Circuitry
- In-vehicle entertainment system

PINPOINT TEST E: RADIO INTERFERENCE

Test Step		Result / Action to Take
E1	**VERIFY THE GENERATOR IS THE SOURCE OF THE RADIO INTERFERENCE**	
	NOTE: If the OEM audio unit has been replaced with an aftermarket unit, the vehicle may not pass this test. Return the vehicle to OEM condition before following this pinpoint test. • Start and run the engine. • Tune the audio unit to a station where the interference is present. • Ignition OFF. • Disconnect: Generator C102b. • Start the engine. • With the engine running, determine if the interference is still present. • **Is the interference present with the generator disconnected?**	**Yes** REFER to Section 415-00 for diagnosis and testing of the in-vehicle entertainment system. **No** INSTALL a new generator. REFER to Section 414-02. TEST the system for normal operation.

Pinpoint Test F: DTC B1318 or B1676 - Battery Voltage Low or Battery Voltage Out of Range

Refer to Wiring Diagrams Cell 12, Charging System for schematic and connector information.

Normal Operation

Various control modules within the vehicle operate at a voltage between 10-17 volts. Voltage to these modules is supplied through the vehicle harness to the module(s). Ground for the modules is provided by the modules ground circuit(s). If voltages to these modules rise above 17 volts, DTC B1317 or B1676 may set or if voltage drops below 10 volts, DTC B1318 or B1676 may set.

This pinpoint test is intended to diagnose the following:

- Battery
- Charging system
- Module voltage supply
- Module ground

DIAGNOSIS AND TESTING (Continued)

NOTE: DTC B1317 or B1318 can be set if the vehicle has had a discharged battery, has been recently jump started or has had the vehicle battery charged.

PINPOINT TEST F: DTC B1318 OR B1676 - BATTERY VOLTAGE LOW OR BATTERY VOLTAGE OUT OF RANGE

Test Step		Result / Action to Take
F1	**CHECK FOR DTCs**	
	• Ignition OFF. • Connect the scan tool. • Enter the following diagnostic mode on the scan tool: Retrieve all continuous DTCs. • **Is DTC B1318 or B1676 present in only one module?**	**Yes** If DTC B1317 or B1676 are recorded in only one module, GO to **F2**. **No** If DTC B1318 or B1676 are recorded in more than one module, GO to Pinpoint Test B.
F2	**CHECK THE BATTERY VOLTAGE**	
	• Measure the battery voltage between the positive and negative battery posts with the key ON engine OFF (KOEO), and with the engine running, all accessory loads OFF. • **Is the battery voltage between 10 and 13 volts with KOEO, and between 11 and 17 volts with the engine running?**	**Yes** GO to **F3**. **No** CHECK and/or REPAIR the charging system as necessary. GO to Pinpoint Test B. TEST the system for normal operation. CLEAR the DTCs. REPEAT the self-test.
F3	**CHECK THE VOLTAGE TO THE MODULE**	
	• Ignition OFF. • Disconnect: Affected Module Which Recorded DTC B1317 or B1676. • Ignition ON. • Measure all of the affected module's power circuits, harness side to ground. Refer to affected module Wiring Diagrams Cell for schematic and connector information. • **Is the voltage greater than 10 volts?**	**Yes** GO to **F4**. **No** REPAIR the module power circuit(s). CLEAR the DTCs. REPEAT the self-test.
F4	**CHECK THE MODULE GROUNDS**	
	• Ignition OFF. • Measure the resistance between all of the affected module's ground circuits, harness side to ground. Refer to affected module Wiring Diagrams Cell for schematic and connector information. • **Is the resistance less than 5 ohms?**	**Yes** GO to **F5**. **No** REPAIR the module ground circuit(s). CLEAR the DTCs. REPEAT the self-test.
F5	**CHECK THE MODULE FOR CORRECT OPERATION**	
	• Ignition OFF. • Disconnect: All of the Affected Module Connectors.. • Check the connector and module for: — corrosion. — pushed-out or damaged pins. — connector or module damage. • Connect: All of the Affected Module Connectors. • Clear all DTCs. • Operate the system and verify the concern is still present. • **Is the concern still present?**	**Yes** INSTALL a new module. REFER to the removal and installation procedure in the affected module's section. CLEAR the DTCs. REPEAT the self-test. **No** The system is operating correctly at this time. The concern may have been the result of a loose connection, may recently have had a discharged battery or may have been jump started. CLEAR the DTCs. REPEAT the self-test.

DIAGNOSIS AND TESTING (Continued)

Component Tests

Battery — Drain Tests

⚠ **WARNING: Do not attempt to service, charge, recharge or jump start a battery unless the following information has been read and understood. Failure to follow this instruction may result in serious personal injury.**

NOTICE: **To prevent damage to the meter, do not crank the engine or operate accessories that draw more than 10A.**

NOTE: No factory-equipped vehicle should have more than a 50 mA (0.050 amp) draw.

NOTE: Many electronic modules draw 10 mA (0.010 amp) or more continuously.

NOTE: Use an in-line ammeter between the negative battery post and its respective cable.

NOTE: Typically, a drain of approximately 1 amp can be attributed to an engine compartment lamp, glove compartment lamp or an interior lamp staying on continually. Other component failures or wiring shorts are located by selectively pulling fuses to pinpoint the location of the current drain. When the current drain is found, the meter reading will fall to an acceptable level. If the drain is still not located after checking all of the fuses, it is due to the generator.

NOTE: To accurately test the drain on a battery, an in-line ammeter must be used. Use of a test lamp or voltmeter is not an accurate method due to the number of electronic modules.

Check for current drains on the battery in excess of 50 mA (0.050 amp) with all of the electrical accessories off and the vehicle at rest for at least 40 minutes. Current drains can be tested with the following procedure:

1. Make sure the battery junction box (BJB) and the smart junction box (SJB) are accessible without turning on the interior lights.
2. Drive the vehicle for at least 5 minutes and over 48 km/h (30 mph) to turn on and activate the vehicle systems.
3. Allow the vehicle to sit with the key OFF for at least 40 minutes to allow the modules to time out/power down.
4. Connect a fused (30A) jumper wire between the negative battery cable and the negative battery post to prevent the modules from resetting and to catch capacitive drains.
5. Disconnect the negative battery cable from the negative battery post without breaking the connection of the jumper wire.
6. **NOTE:** It is very important that continuity is not broken between the negative battery cable and the negative battery post when connecting the meter. If this happens, the entire procedure must be repeated.

   Connect the battery tester between the negative battery cable and the post. The meter must be capable of reading milliamperes and should have a 10A capability.
7. **NOTE:** If the meter settings need to be switched or the test leads need to be moved to another jack, the jumper wire must be reinstalled to avoid breaking continuity.

   NOTE: Amperage draw varies from vehicle to vehicle depending on the equipment package. Compare to a similar vehicle for reference.

   NOTE: No factory-equipped vehicle should have more than a 50 mA (0.050 amp) draw.

   Remove the jumper wire.
8. Note the amperage draw. Draw varies from vehicle to vehicle depending on the equipment package. Compare to a similar vehicle for reference. No factory-equipped vehicle should have more than a 50 mA draw (0.050 amp).
9. If the draw is found to be excessive, remove the fuses from the SJB one at a time and note the current drop. Do not reinstall the fuses until you are finished testing. To properly isolate each of the circuits, all of the fuses may need to be removed. After removal of all of the fuses, install a fuse, note the amperage draw, then remove the fuse and install the next fuse until each circuit is tested. When the current level drops to an acceptable level after removing a fuse, the circuit containing the excessive draw has been located.

DIAGNOSIS AND TESTING (Continued)

10. If the current draw is still excessive, remove the fuses from the BJB one at a time and note the current drop. Do not reinstall the fuses until you have finished testing. To correctly isolate each of the circuits, all of the fuses may need to be removed. After removal of all of the fuses, install a fuse, note the amperage draw, then remove the fuse and install the next fuse until each circuit is tested. When the current level drops to an acceptable level after removing a fuse, the circuit containing the excessive draw has been located.
11. Check the wiring schematic in the wiring diagram for any circuits that run from the battery without passing through the junction boxes. If the current draw is still excessive, disconnect these circuits until the draw is found. Also disconnect the generator electrical connections if the draw cannot be located. The generator may be internally shorted, causing the current drain.

Generator On-Vehicle Tests

NOTICE: **To prevent damage to the generator, do not make the jumper wire connections except as directed.**

NOTICE: **Do not allow any metal object to come in contact with the housing and the internal diode cooling fins with the key in the ON or OFF positions. A short circuit may result and burn out the diodes.**

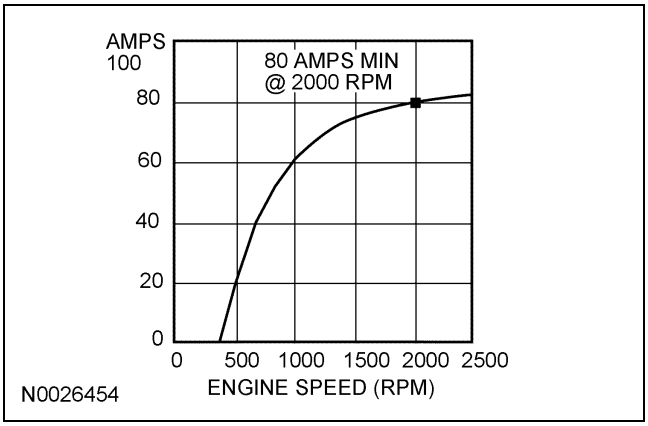
NOTE: Battery posts and cable clamps must be clean and tight for accurate meter indications.

NOTE: Refer to the battery tester manual for complete directions for testing the charging system.

1. Turn off all of the lamps and the electrical components.
2. Place the transmission in NEUTRAL and apply the parking brake.
3. Carry out the Load Test and No Load Test according to the following component tests:

Generator On-Vehicle Tests — Load Test

1. Switch the tester to the ammeter function.
2. Connect the positive and negative leads of the tester to the corresponding battery terminals.
3. Connect the current probe to the generator B+ output terminal, circuit 2037 (RD).
4. With the engine running at approximately 2,000 rpm, adjust the tester load bank to determine the output of the generator. The generator output should be greater than the graph shown below. If not, refer back to the pinpoint test or GO to Symptom Chart.



Generator On-Vehicle Tests — No Load Test

1. Switch the tester to the voltmeter function.
2. Connect the voltmeter positive lead to the generator B+ terminal, circuit 2037 (RD) and the negative lead to ground.
3. Turn all of the electrical accessories off.
4. With the engine running at approximately 2,000 rpm, check the generator output voltage. The voltage should be between 13.2 and 15.5 volts. If not, refer back to the pinpoint test or GO to Symptom Chart.

SPECIFICATIONS

Material

Item	Specification	Fill Capacity
Threadlock and Sealer TA-25	WSK-M2G351-A5	—

General Specifications

Item	Specification
Battery	
Battery amps rating	56 amp/hr
Cold cranking amps (CCA) measured at -18°C (0°F)	590 CCA
Voltage	12 volts

Torque Specifications

Description	Nm	lb-ft	lb-in
Battery cable harness bracket bolt (4.0L)	27	20	—
Battery cable terminal bolts	5	—	44
Battery ground cable body bolt	10	—	89

Torque Specifications (Continued)

Description	Nm	lb-ft	lb-in
Battery ground cable engine terminal bolt (4.0L)	27	20	—
Battery ground cable engine terminal nut (4.6L, 5.4L)	25	18	—
Battery ground cable terminal nut	8	—	71
Battery hold-down bolt	8	—	71
Battery tray bolts	11	8	—
Bussed electrical center (BEC) terminal bolt	10	—	89
Generator B+ terminal nut (4.0L)	8	—	71
Generator harness terminal nut (4.6L, 5.4L)	8	—	71
Starter solenoid positive cable terminal nut	12	9	—
Starter solenoid wire terminal nut (4.0L)	5	—	44

DESCRIPTION AND OPERATION

Battery and Cables

Vehicles are equipped with a 12V, maintenance-free battery.

The battery and cable system consists of the following components:

- Battery
- Battery cable assembly
- Battery tray

Ford Motor Company strongly recommends that lead-acid batteries be returned to an authorized recycling facility for disposal.

N0026431

DIAGNOSIS AND TESTING

Battery

Special Tool(s)

 ST2442-A	Micro 490 Digital Battery Analyzer 162-00004 or equivalent

Principles of Operation

Battery Eye Operation

The purpose of the battery eye is to indicate the state of charge of the battery in the assembly plant and while on the dealership lot. The battery eye can also indicate the state-of-charge when the vehicle is delivered to the dealership and during the pre-delivery inspection process. The battery eye is made up of a viewing plate, 2 balls and a small passage. The balls indicate the specific gravity of the electrolyte by floating higher or lower in the passageway. It is important to note that the battery eye checks the specific gravity on only a single battery cell.

The color of the battery eye indicates the approximate state of charge.

- Red usually indicates the battery state-of-charge is at 40% or less.
- Yellow indicates the battery state-of-charge is between 40% and 57%.
- Green indicates the battery state-of-charge is above 57%.
- No color/black can occur after the battery has been in service for several years and some of the plate material has coated the balls.
- A clear battery eye can occur if the battery case becomes damaged and the electrolyte has fallen below the plates.

NOTE: The battery eye may remain red for a period of time (up to several days), even after the battery is fully charged, because the acid is not yet fully mixed.

Do not install a new battery based solely on the indication of the battery eye. The battery eye color simply indicates the battery state-of-charge, not its condition. For example, a red or yellow battery eye usually indicates the battery is discharged, not defective. If the battery eye indicates the battery may be discharged, it is necessary to recharge the battery before testing its condition.

Charging a Battery

Batteries discharge while the vehicle is on the dealer lot or parked by the customer for an extended period of time due to normal parasitic key-off loads. Also, vehicles still in dealer inventory or in long-term storage may be driven short distances with heavy electrical loads. Over a period of time (30 days or more), this could result in vehicles having shallow or deeply discharged batteries.

- Deeply discharged — A battery that is drained over a prolonged period of time, such as an unsold vehicle or a vehicle in storage, to the point the battery is dead.
- Shallow discharge — A battery that is drained by leaving an accessory on for several hours or a few days and has a very low charge.

The vehicle's charging system is designed to supply the electrical power needed to maintain the battery near full charge during normal vehicle use. The charging system is not capable of bringing a deeply discharged battery back near full charge in a short amount of time such as allowing the vehicle to idle for 15 minutes to ''recharge the battery.'' Discharged batteries should be charged using an external charger.

DIAGNOSIS AND TESTING (Continued)

NOTE: Battery chargers have improved greatly with the addition of the new generation pulse chargers. These chargers pulse current into the battery, breaking down the sulfation layer on the battery plates and generally reduce charging times to less than an hour.

NOTE: Cold batteries will not readily accept a charge. Therefore, batteries should be allowed to warm to approximately 5°C (41°F) before charging. This may require 4 to 8 hours at room temperature.

The following chart summarizes 2 recommended methods of charging.

Type of Battery Discharge	Pulse Charger	Standard Charger
Deeply discharged	Follow directions supplied with the pulse charger	2 to 8 hours and may take up to an hour to accept initial charge
Shallow discharge	45 minutes to an hour charge	2 hours (40A) on manual setting or medium automatic setting

Inspection and Verification

1. Verify the customer concern.
2. Visually inspect for obvious signs of mechanical or electrical damage.

Visual Inspection Chart

Mechanical	Electrical
• Battery • Battery mounting	• Battery cables • Battery posts

3. If an obvious cause for an observed or reported concern is found, correct the cause (if possible) before proceeding to the next step.
4. If the fault is not visually evident, GO to Pinpoint Test A.

Pinpoint Tests

Pinpoint Test A: Battery Condition Test

Normal Operation

Battery condition is determined by measuring battery terminal voltage after a specific discharge current is applied for a specified time period.

This pinpoint test is intended to diagnose the following:

- Battery charge
- Battery

PINPOINT TEST A: BATTERY CONDITION TEST

Test Step		Result / Action to Take
A1	**TEST THE BATTERY CONDITION** **NOTE:** No battery with a red test-eye should be replaced. The red eye only means the battery is discharged, not necessarily defective. **NOTE:** Failure to fully charge the battery before retesting may cause false readings. • Verify the battery condition using the battery analyzer. • **Is the battery OK?**	**Yes** If the meter reads GOOD BATTERY, RETURN the battery to service. If the meter reads GOOD-RECHARGE, CHARGE the battery and RETURN it to service. If the meter reads CHARGE & RETEST, fully CHARGE and RETEST the battery. **No** If the meter reads REPLACE BATTERY, INSTALL a new battery. If the meter reads BAD CELL-REPLACE, INSTALL a new battery.

GENERAL PROCEDURES

Battery Disconnect

⚠ WARNING: Batteries contain sulfuric acid and produce explosive gases. Work in a well-ventilated area. Do not allow the battery to come in contact with flames, sparks or burning substances. Avoid contact with skin, eyes or clothing. Shield eyes when working near the battery to protect against possible splashing of acid solution. In case of acid contact with skin or eyes, flush immediately with water for a minimum of 15 minutes, then get prompt medical attention. If acid is swallowed, call a physician immediately. Failure to follow these instructions may result in serious personal injury.

⚠ WARNING: Always deplete the backup power supply before repairing or installing any new front or side air bag supplemental restraint system (SRS) component and before servicing, removing, installing, adjusting or striking components near the front or side impact sensors or the restraints control module (RCM). Nearby components include doors, instrument panel, console, door latches, strikers, seats and hood latches.

Refer to the Description and Operation portion of Section 501-20B for location of the RCM and impact sensor(s).

To deplete the backup power supply energy, disconnect the battery ground cable and wait at least 1 minute. Be sure to disconnect auxiliary batteries and power supplies (if equipped).

Failure to follow these instructions may result in serious personal injury or death in the event of an accidental deployment.

⚠ WARNING: Always lift a plastic-cased battery with a battery carrier or with hands on opposite corners. Excessive pressure on the battery end walls may cause acid to flow through the vent caps, resulting in personal injury and/or damage to the vehicle or battery.

NOTE: When the battery (or PCM) is disconnected and connected, some abnormal drive symptoms may occur while the vehicle relearns its adaptive strategy. The charging system setpoint may also vary. The vehicle may need to be driven to relearn its strategy.

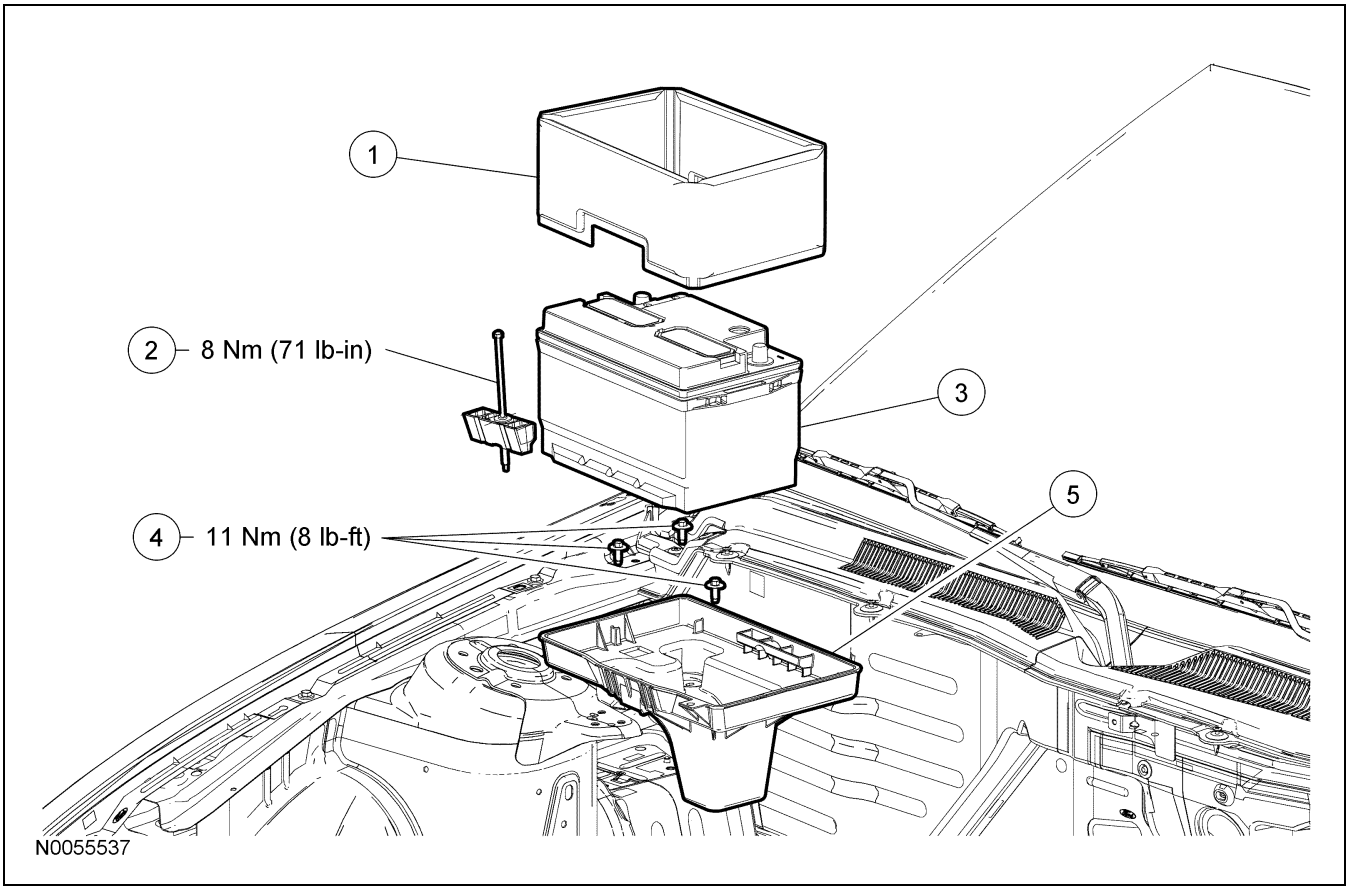
1. Disconnect the battery ground terminal.
   - To connect, tighten to 5 Nm (44 lb-in).

GENERAL PROCEDURES (Continued)

2. Disconnect the positive battery terminal.
   - To connect, tighten to 5 Nm (44 lb-in).
3. To connect, reverse the disconnect procedure.

REMOVAL AND INSTALLATION

Battery and Battery Tray — Exploded View



Item	Part Number	Description
1	10A687	Battery heat shield
2	10756	Battery hold-down bolt/clamp
3	10655	Battery
4	W503923	Battery tray bolts (3 required)
5	10723	Battery tray

1. For additional information, refer to the procedures in this section.

REMOVAL AND INSTALLATION

Battery

Removal and Installation

⚠ WARNING: Batteries contain sulfuric acid and produce explosive gases. Work in a well-ventilated area. Do not allow the battery to come in contact with flames, sparks or burning substances. Avoid contact with skin, eyes or clothing. Shield eyes when working near the battery to protect against possible splashing of acid solution. In case of acid contact with skin or eyes, flush immediately with water for a minimum of 15 minutes, then get prompt medical attention. If acid is swallowed, call a physician immediately. Failure to follow these instructions may result in serious personal injury.

⚠ WARNING: Always lift a plastic-cased battery with a battery carrier or with hands on opposite corners. Excessive pressure on the battery end walls may cause acid to flow through the vent caps, resulting in personal injury and/or damage to the vehicle or battery.

1. Disconnect the battery. For additional information, refer to Battery Disconnect in this section.
2. Remove the battery heat shield.
3. Remove the bolt and the battery hold-down clamp.
   - To install, tighten to 8 Nm (71 lb-in).
4. Remove the battery.
5. To install, reverse the removal procedure.

REMOVAL AND INSTALLATION

Battery Tray

Material

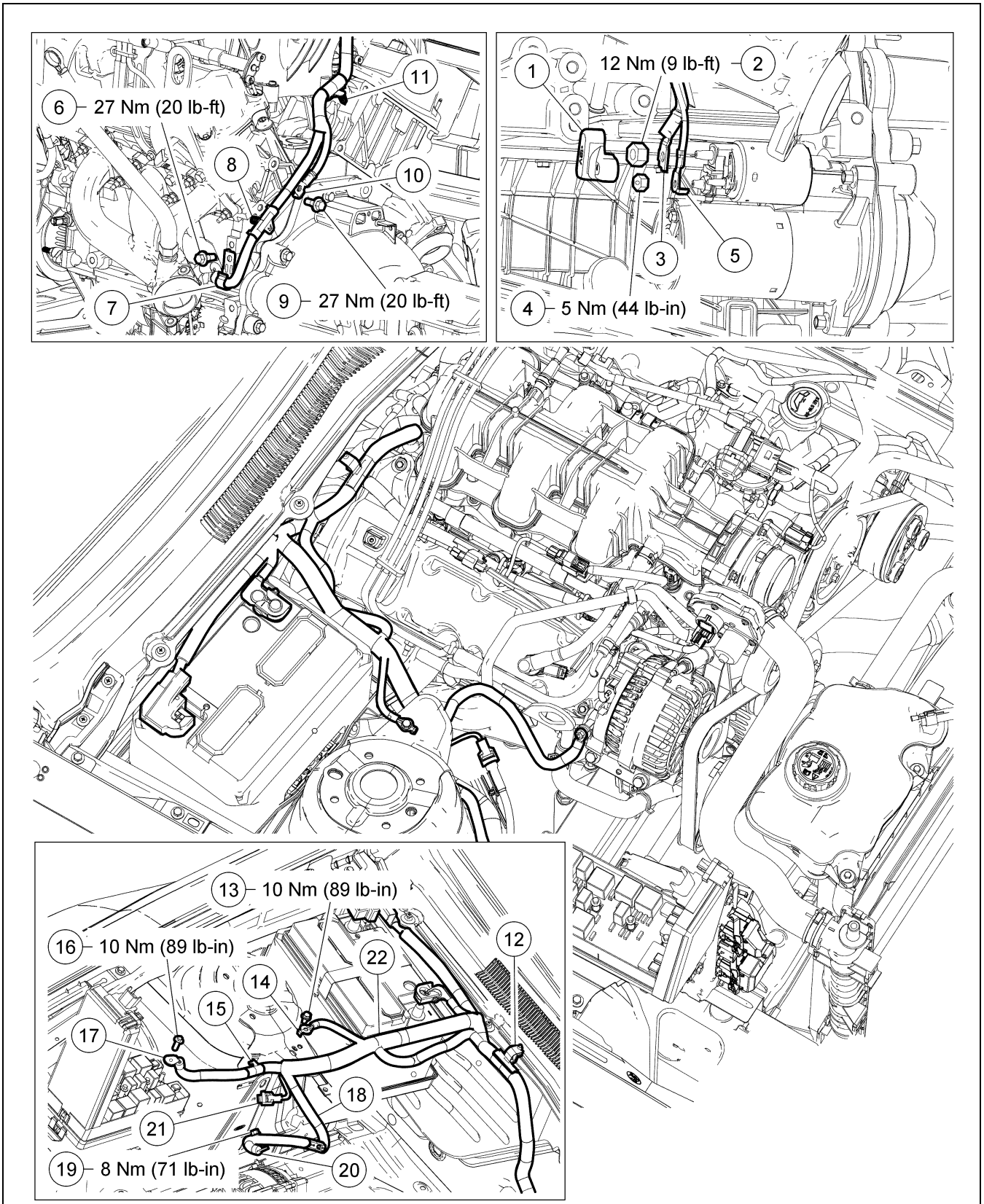
Item	Specification
Threadlock and Sealer TA-25	WSK-M2G351-A5

Removal and Installation

1. Remove the battery. For additional information, refer to Battery in this section.
2. Remove the 3 bolts and the battery tray.
   - To install, tighten to 11 Nm (8 lb-ft).
3. To install, reverse the removal procedure.
   - For GT500 models, apply threadlock and sealer to the battery tray bolt threads.

REMOVAL AND INSTALLATION

Battery Cables — 4.0L SOHC



REMOVAL AND INSTALLATION (Continued)

Item	Part Number	Description
1	11N087	Starter solenoid terminal cover
2	W706414-S413	Starter solenoid positive cable terminal nut
3	—	Starter solenoid positive cable terminal (part of 14300)
4	W705790-S901	Starter solenoid wire terminal nut
5	—	Starter solenoid wire terminal (part of 14300)
6	W506031	Battery cable harness bracket bolt
7	—	Battery cable harness bracket (part of 14300)
8	—	Battery cable harness locator (LH) (part of 14300)
9	W506031	Battery ground cable engine terminal bolt
10	—	Battery ground cable engine terminal (part of 14300)
11	—	Battery cable harness locator (RH) (part of 14300)
12	—	Battery cable harness locator (part of 14300)
13	W712583	Battery ground cable body terminal bolt
14	—	Battery ground cable body terminal (part of 14300)
15	—	Battery cable harness locator (part of 14300)
16	—	Bussed electrical center (BEC) terminal bolt
17	—	BEC terminal (part of 14300)
18	—	Battery cable harness locator (part of 14300)
19	W705790-S901	Generator B+ terminal nut
20	—	Generator B+ terminal (part of 14300)
21	—	Battery cable in-line connector (part of 14300)
22	14300	Battery cable

Removal and Installation

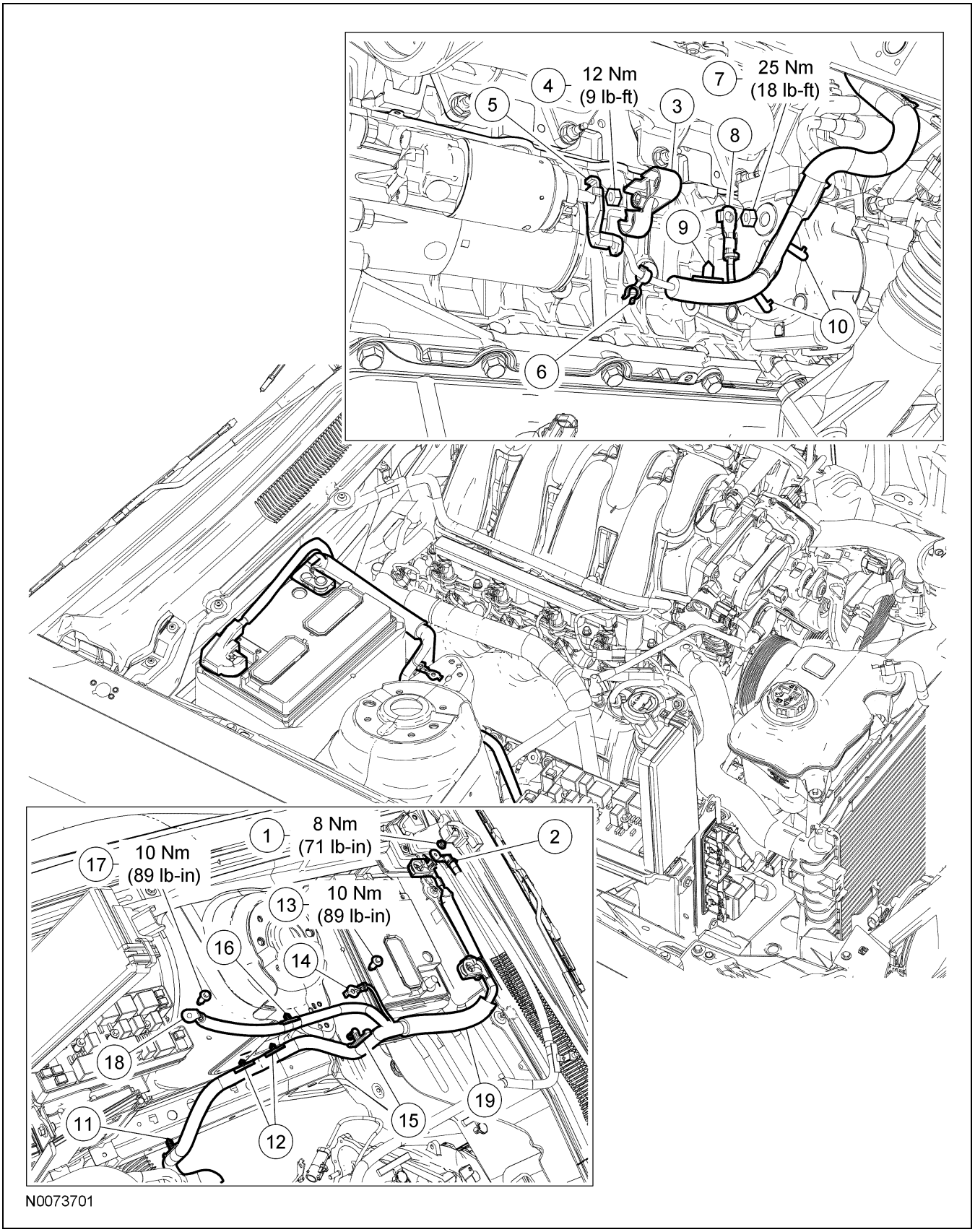
1. With the vehicle in NEUTRAL, position it on a hoist. For additional information, refer to Section 100-02.
2. Disconnect the battery. For additional information, refer to Battery Disconnect in this section.
3. Remove the starter solenoid terminal cover.
4. Remove the nut and position the starter solenoid positive cable terminal aside.
   - To install, tighten to 12 Nm (9 lb-ft).
5. Remove the nut and position the starter solenoid wire terminal aside.
   - To install, tighten to 5 Nm (44 lb-in).
6. Remove the bolt and position the battery cable harness bracket aside.
   - To install, tighten to 27 Nm (20 lb-ft).
7. Remove the battery cable harness locator from behind the LH cylinder head.
8. Remove the bolt and position the battery ground cable engine terminal aside.
   - To install, tighten to 27 Nm (20 lb-ft).
9. Remove the battery cable harness locator from behind the RH cylinder head.
10. Remove the battery cable harness locator from the bulkhead.
11. Remove the bolt and position the battery ground cable body terminal aside.
    - To install, tighten to 10 Nm (89 lb-in).
12. Remove the battery cable harness locator from the RH strut tower.
13. Open the bussed electrical center (BEC) cover, remove the bolt and position the BEC terminal aside.
    - To install, tighten to 10 Nm (89 lb-in).
14. Remove the battery cable harness locator from the engine bracket.
15. Position aside the generator B+ boot, remove the nut and position the generator B+ terminal aside.
    - To install, tighten to 8 Nm (71 lb-in).

REMOVAL AND INSTALLATION (Continued)

16. Disconnect the battery cable in-line connector.
17. Remove the battery cables.
18. To install, reverse the removal procedure.

REMOVAL AND INSTALLATION

Battery Cables — 4.6L (3V)



REMOVAL AND INSTALLATION (Continued)

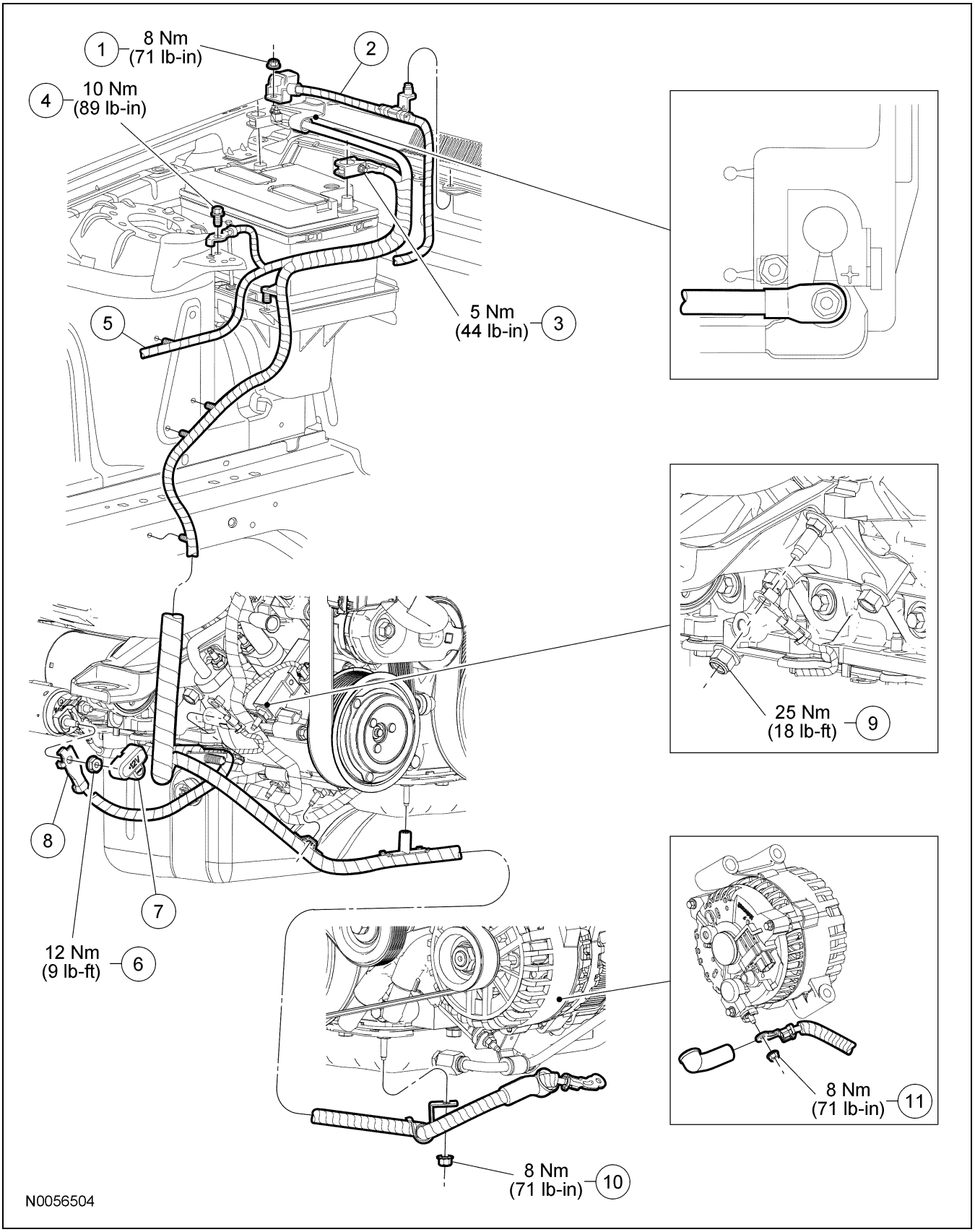
Item	Part Number	Description
1	W705790-S901	Generator harness terminal nut
2	—	Generator harness terminal (part of 14305)
3	11N087	Starter solenoid terminal cover
4	W706414-S413	Starter solenoid positive cable terminal nut
5	—	Starter solenoid positive cable terminal (part of 14300)
6	—	Battery cable clip (part of 14300)
7	W520213	Battery ground cable engine terminal nut
8	—	Battery ground cable engine terminal (part of 14300)
9	—	Starter solenoid wire harness locator
10	—	Battery cable harness locators (2 required) (part of 14300)
11	—	Battery cable harness locator (part of 14300)
12	—	Battery cable harness locators (2 required) (RH tower) (part of 14300)
13	W712583	Battery ground cable body terminal bolt
14	—	Battery ground cable body terminal (part of 14300)
15	—	Battery cable harness locator (part of 14300)
16	—	Bussed electrical center (BEC) harness locator (part of 14300)
17	—	BEC terminal bolt
18	—	BEC terminal (part of 14300)
19	14300	Battery cable

Removal and Installation

1. With the vehicle in NEUTRAL, position it on a hoist. For additional information, refer to Section 100-02.
2. Disconnect the battery. For additional information, refer to Battery Disconnect in this section.
3. Position the positive battery terminal cover aside, remove the nut and position the generator harness terminal aside.
   - To install, tighten to 8 Nm (71 lb-in).
4. Remove the starter solenoid terminal cover.
5. Remove the nut and position the starter solenoid positive cable terminal aside.
   - To install, tighten to 12 Nm (9 lb-ft).
6. Remove the battery cable clip from the transmission cooler lines.
7. Remove the nut and position the battery ground cable engine terminal aside.
   - To install, tighten to 25 Nm (18 lb-ft).
8. Remove the starter solenoid wire harness locator from the battery cable harness.
9. Remove the 2 battery cable harness locators from the subframe.
10. Remove the battery cable harness locator from the body.
11. Remove the 2 battery cable harness locators from the RH strut tower.
12. Remove the bolt and position the battery ground cable body terminal aside.
    - To install, tighten to 10 Nm (89 lb-in).
13. Remove the battery cable harness locator from the battery tray.
14. Remove the battery cable harness locator from the RH strut tower.
15. Open the BEC cover, remove the bolt and position the BEC terminal aside.
    - To install, tighten to 10 Nm (89 lb-in).
16. Remove the battery cables.
17. To install, reverse the removal procedure.

REMOVAL AND INSTALLATION

Battery Cables — 5.4L (4V)



REMOVAL AND INSTALLATION (Continued)

Item	Part Number	Description
1	W705790-S901	Generator harness terminal nut
2	—	Generator harness terminal (part of 14300)
3	—	Battery cable terminal bolt (part of 14300)
4	W712583	Battery ground cable body bolt
5	—	Battery harness-to-distribution box
6	W706414-S413	Starter solenoid positive cable terminal nut
7	11N087	Starter solenoid terminal cover
8	—	Starter solenoid positive cable terminal (part of 14300)
9	W520213-S440	Battery ground cable engine terminal nut
10	W705790-S901	Battery cable harness locator nut
11	W705790-S901	Battery cable terminal nut

Removal and Installation

1. With the vehicle in NEUTRAL, position it on a hoist. For additional information, refer to Section 100-02.
2. Disconnect the battery. For additional information, refer to Battery Disconnect in this section.
3. Position the positive battery terminal cover aside, remove the nut and position the generator harness terminal aside.
   - To install, tighten to 8 Nm (71 lb-in).
4. Remove the locator from the dash panel.
5. Remove the starter solenoid terminal cover.
6. Remove the nut and position the starter solenoid positive cable terminal aside.
   - To install, tighten to 12 Nm (9 lb-ft).
7. Remove the nut and position the battery ground cable engine terminal aside.
   - To install, tighten to 25 Nm (18 lb-ft).
8. Remove the starter solenoid wire harness locator from the A/C compressor.
9. Remove the battery cable harness locators from the body.
10. Remove the battery cable harness locators from the oil pan.
11. Remove the 2 battery cable harness locators from the RH strut tower.
12. Remove the bolt and position the battery ground cable body terminal aside.
    - To install, tighten to 10 Nm (89 lb-in).
13. Remove the battery cable harness locator from the battery tray.
14. Remove the battery cable harness locator from the RH strut tower.
15. Open the BEC cover, remove the bolt and position the BEC terminal aside.
    - To install, tighten to 10 Nm (89 lb-in).
16. Remove the battery cables.
17. To install, reverse the removal procedure.

SPECIFICATIONS

General Specifications

Item	Specification
Generator (4.0L)	
Generator pulley ratio	2.59:1
Rating	80/135 amp (max) @ 1,800-6,000 generator rpm, approximately 525-2,000 engine rpm
Voltage regulator type	Electronic internal with generator
Generator (4.6L, 5.4L)	
Generator pulley ratio	2.72:1
Rating	80/135 amp (max) @ 1,800-6,000 generator rpm, approximately 525-2,000 engine rpm
Voltage regulator type	Electronic internal with generator

Torque Specifications

Description	Nm	lb-ft	lb-in
Generator B+ terminal nut (4.0L and 4.6L)	8	—	71
Generator B+ terminal nut (5.4L)	12	9	—
Generator bolts (4.6L)	25	18	—
Generator bolts/stud nut (4.0L)	48	35	—
Generator bracket bolts (4.6L)	10	—	89
Lower generator stud nut (5.4L)	25	18	—
Stabilizer bar bracket nuts	70	52	—
Upper/lower generator bolts (5.4L)	48	35	—

DESCRIPTION AND OPERATION

Generator

The charging system consists of the:

- generator.
- internal voltage regulator.

The generator has an internal voltage regulator that is not installed separately. A new generator and voltage regulator must be installed as an assembly.

Vehicles equipped with 4.6L 3V have a one-way clutch (OWC) in the generator pulley. The OWC pulley temporarily disengages the generator rotor from the front end accessory drive (FEAD) system during high deceleration rates on the engine. This may decrease noise, vibration and harshness (NVH) (belt chirp) and may increase belt life. A new OWC pulley and generator/regulator must be installed as an assembly.

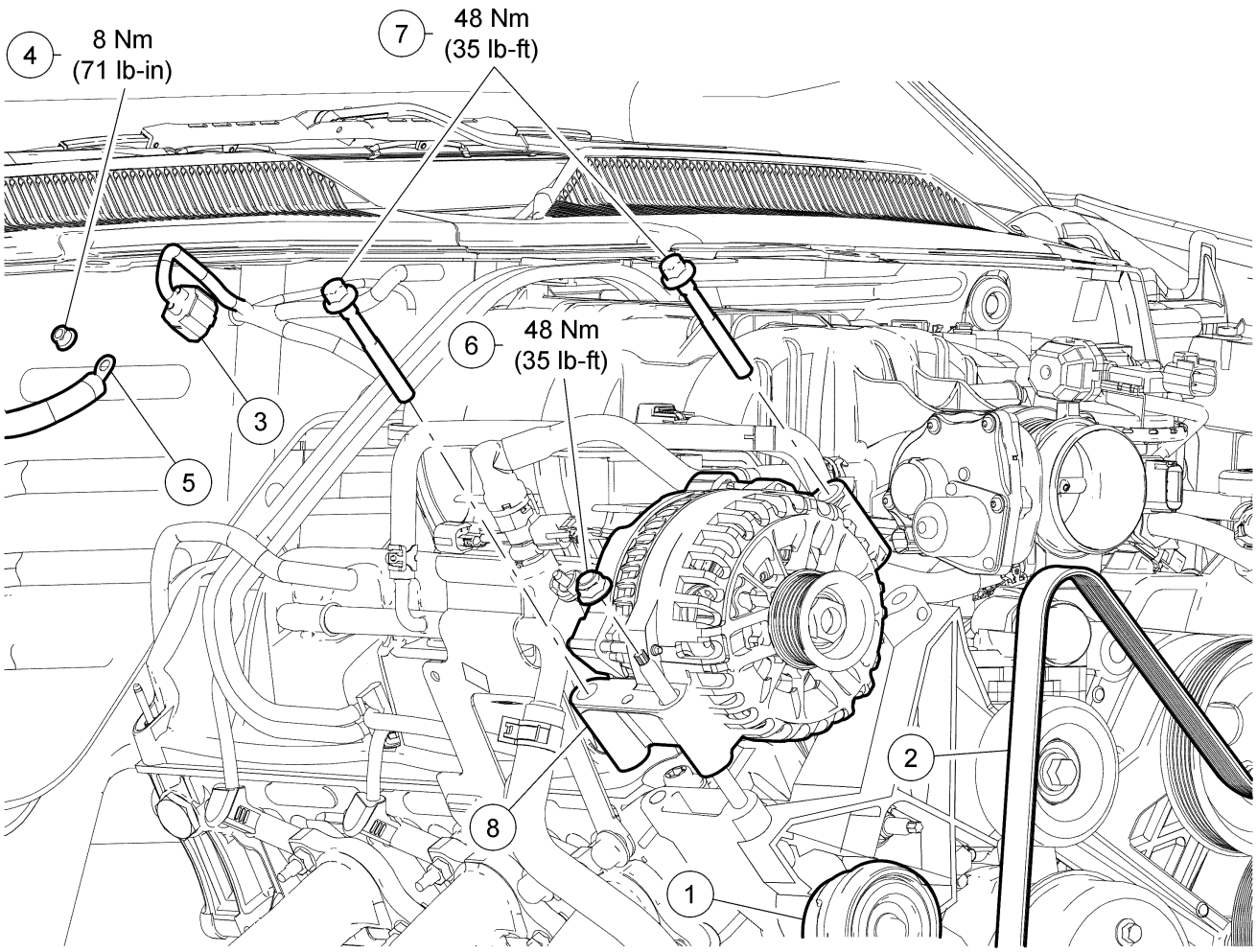
DIAGNOSIS AND TESTING

Generator

Refer to Section 414-00.

REMOVAL AND INSTALLATION

Generator — 4.0L SOHC



Item	Part Number	Description
1	6B209	Front end accessory drive (FEAD) belt tensioner
2	8620	FEAD belt
3	—	Generator electrical connector (part of 12B637)
4	W705790	Generator B+ terminal nut

(Continued)

Item	Part Number	Description
5	—	Generator B+ terminal (part of 14B060)
6	W520414	Generator stud nut
7	W606068	Generator bolts (2 required)
8	10300	Generator

REMOVAL AND INSTALLATION (Continued)

Removal and Installation

1. Disconnect the battery. For additional information, refer to Section 414-01.
2. Rotate the front end accessory drive (FEAD) belt tensioner counterclockwise and position the FEAD belt aside.
3. Disconnect the generator electrical connector.
4. Position the generator B+ protective boot aside, remove the nut and position the generator B+ terminal aside.
   - To install, tighten to 8 Nm (71 lb-in).
5. Remove the generator stud nut.
   - To install, tighten to 48 Nm (35 lb-ft).
6. Remove the 2 bolts and the generator.
   - To install, tighten to 48 Nm (35 lb-ft).
7. To install, reverse the removal procedure.

REMOVAL AND INSTALLATION

Generator — 4.6L (3V)

Item	Part Number	Description
1	6B209	Front end accessory drive (FEAD) belt tensioner
2	8620	FEAD belt
3	—	Generator bolts (2 required)
4	N807309-S	Generator bracket bolts (outer) (2 required)

(Continued)

Item	Part Number	Description
5	N807309-S	Generator bracket bolts (inner) (2 required)
6	—	Generator harness locator (part of 14305)
7	10153	Generator bracket
8	—	Generator electrical connector (part of 14305)

(Continued)

REMOVAL AND INSTALLATION (Continued)

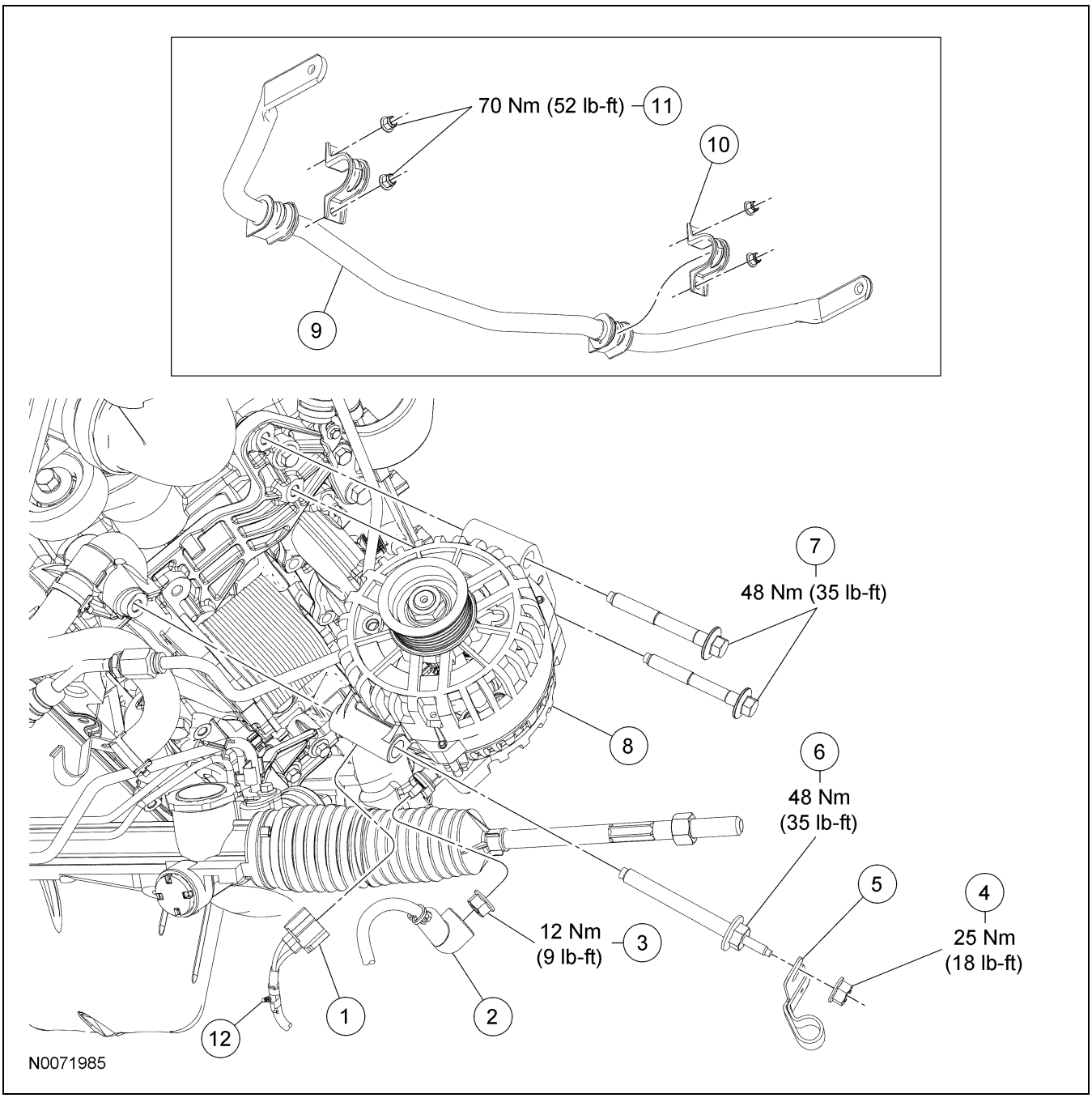
Item	Part Number	Description
9	W705790-S	Generator B+ terminal nut
10	—	Generator B+ terminal (part of 14305)
11	10300	Generator

Removal and Installation

1. Disconnect the battery. For additional information, refer to Section 414-01.
2. Press the lock tab, remove the crankcase vent tube from the air cleaner outlet pipe and position it aside.
3. Loosen the clamps, remove the air cleaner outlet pipe from the throttle body and remove it from the vehicle.
4. Rotate the front end accessory drive (FEAD) belt tensioner clockwise and position the FEAD belt aside.
5. Remove the generator harness locator.
6. Remove the 2 generator nuts.
   - To install, tighten to 25 Nm (18 lb-ft).
7. Remove the 2 outer generator bracket bolts and position the generator aside.
   - To install, tighten to 10 Nm (89 lb-in).
8. Loosen the 2 inner generator bracket bolts.
   - Pull the generator outward.
   - Remove the generator bracket.
   - To install, tighten to 10 Nm (89 lb-in).
9. Disconnect the generator electrical connector.
10. Position the generator B+ protective boot aside, remove the nut and position the generator B+ terminal aside.
    - To install, tighten to 8 Nm (71 lb-in).
11. Remove the generator.
12. To install, reverse the removal procedure.

REMOVAL AND INSTALLATION

Generator — 5.4L (4V)



Item	Part Number	Description
1	—	Generator electrical connector (part of 12B637)
2	—	Generator B+ terminal (part of 14B060)
3	W705790	Generator B+ terminal nut
4	W520111	Generator stud nut

(Continued)

Item	Part Number	Description
5	—	Power steering fluid line bracket
6	W704893	Lower generator bolt
7	N805424	Upper generator bolts (2 required)
8	10300	Generator
9	5482	Stabilizer bar

(Continued)

REMOVAL AND INSTALLATION (Continued)

Item	Part Number	Description
10	5486	Stabilizer bar bracket
11	W520213	Bracket nuts (4 required)
12	—	Wire harness retainer (part of 14305)

Removal and Installation

1. With the vehicle in NEUTRAL, position it on a hoist. For additional information, refer to Section 100-02.
2. Disconnect the battery. For additional information, refer to Section 414-01.
3. Rotate the front end accessory drive belt (FEAD) tensioner clockwise and position the FEAD belt aside.
4. Remove the air cleaner assembly. For additional information, refer to Section 303-12.
5. Remove the 2 upper generator bolts.
   - To install, tighten to 48 Nm (35 lb-ft).
6. Remove the power steering tube bracket nut and position the bracket aside.
   - To install, tighten to 25 Nm (18 lb-ft).
7. Remove and discard the 4 stabilizer bracket nuts, then remove the stabilizer bar brackets and position the sway bar aside.
   - To install, tighten to 70 Nm (52 lb-ft).
8. Disconnect the generator electrical connector and remove the harness retainer pushpin from the rear of the generator.
   - Position the harness aside.
9. Position the generator B+ protective boot aside, remove the nut and position the generator B+ terminal aside.
   - To install, tighten to 12 Nm (9 lb-ft).
10. Remove the lower generator bolt.
    - To install, tighten to 48 Nm (35 lb-ft).
11. Remove the generator.
12. To install, reverse the removal procedure.