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500 — Terms and Abbreviations

CAN—Controller Area Network

CAN ID—The identifier for a specific message, which also contains the source address of the sending ECU communicating on the J1939 datalink.

ETPDM—Engine Transmission Power Distribution Module; also referred to as the power train power distribution module.

FMI—Failure Mode Indicator. The part of a J1587, J1939, and CAN fault code that identifies how part of a device, or item on a device, failed.

IMS—Integrated Magnetic Switch

MFJB—MEGA® Fuse Junction Block

MGJB—Main Ground Junction Block

Parameter—A parameter is a specific value that is assigned to a feature or function of the vehicle, and allows the customer to choose how that particular feature or function will work on the vehicle.

SA—Source Address; indicates numeric assignment for a device that communicates on J1939.

SAM—Signal Detect and Actuation Module

SOC—State of Charge

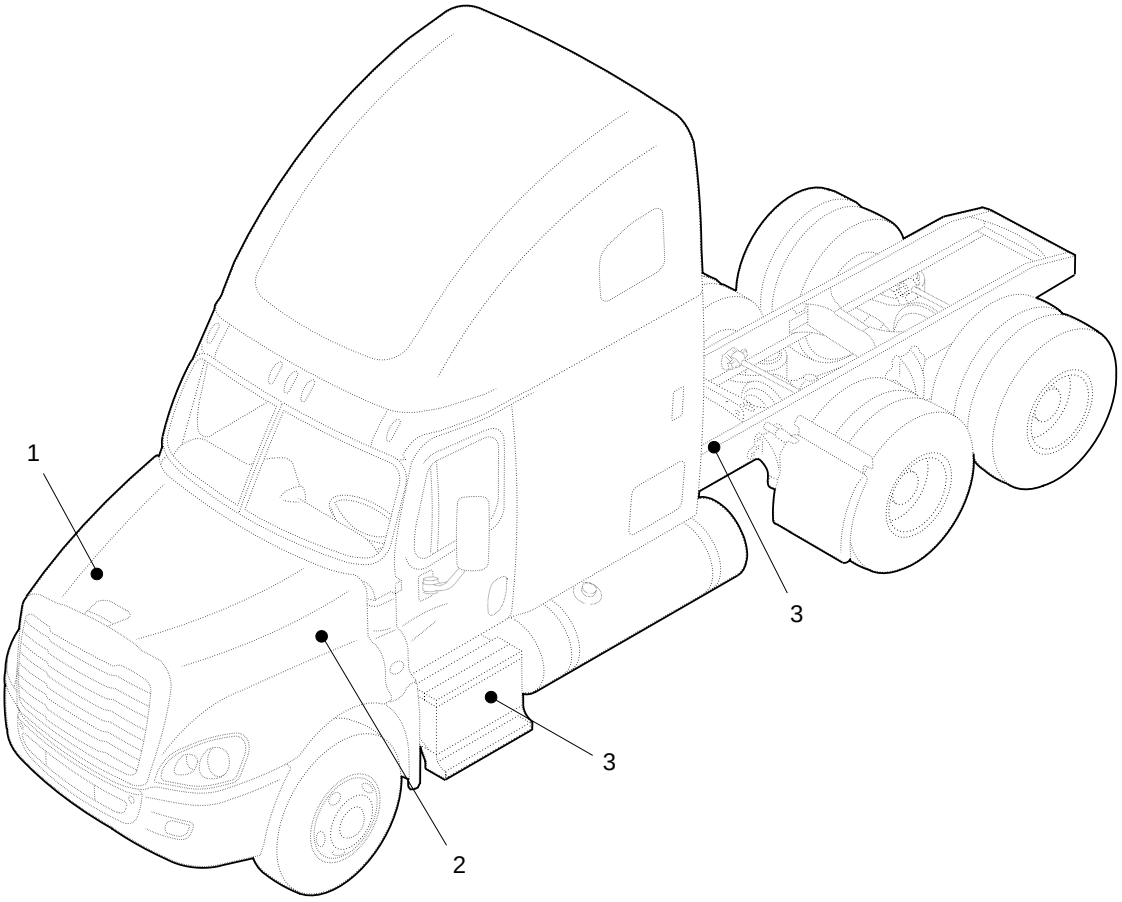
SPN—Suspect Parameter Number. The part of a J1939 or CAN fault code that identifies how part of a device, or item on a device, failed.

501 — General Information

The starting and charging system consists of three main elements: the battery system, the charging system, and the starting system. These systems provide the starting capability of the vehicle, and supply power to all of the electrical and electronic systems.

It is important that all three elements are well maintained for the overall health of the system. Poorly charged batteries, or bad connections, can cause premature failure to any or all of the elements of the starting and charging system.

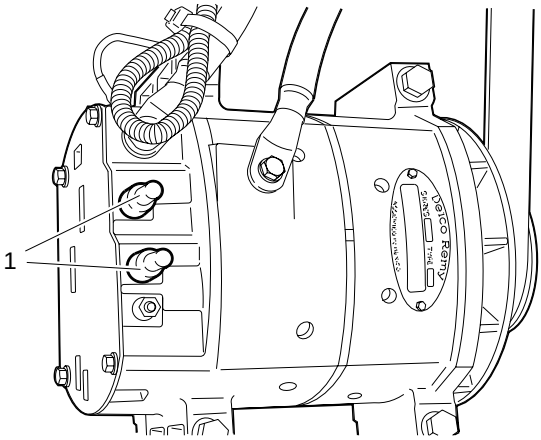
600 — Component Locations



1. Alternator
2. Starter
3. Batteries

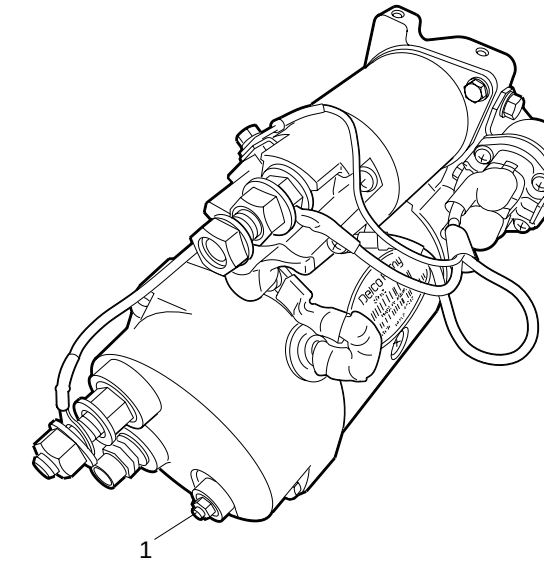
Fig. 1, Component Locations

601 — Component Details



1. Terminals

Fig. 2, Alternator



1. Terminal

Fig. 3, Planetary Gear Reduction Starter

700 — Battery System Diagnostics

Diagnostic Tools Required

- Approved Battery Tester

Possible Causes

Age—Batteries are perishable components, eventually wearing out through a process of sulfating.

Excessive Heat—If batteries are subjected to excessive temperatures, the positive plates quickly become corroded.

Cold Weather—The viscosity of engine oils decreases in cold temperatures, making engines harder to crank. This places a heavier and longer-lasting drain on the battery.

Vibration—If a battery is not securely fastened to the vehicle frame, the resulting vibration can shed the active material from the battery plate grids.

Fast Charging—Using a high charging rate to quickly charge batteries can be damaging, if the battery becomes overheated and begins gassing.

Deep Cycling—Repeated deep cycling eventually causes a battery to lose its ability to accept a charge.

Diagnostic Tests

1. **Check the battery pack state of charge (SOC).**

   1.1 Remove the surface charge from the battery pack.

   1.2 Shut down the engine.

   1.3 Turn on the headlights for 2 to 3 minutes or until the battery voltage is down to 12.6 volts.

   Is the battery pack at 75% SOC (12.4 volts) or higher? Refer to **800 — Battery State of Charge** to verify the voltage.

   YES → Go to test 2.

   NO → Charge the batteries until they are at least at 12.4 volts with the surface charge removed, then proceed to test 3.

2. **Check the condition of the batteries.**

   2.1 Disconnect the battery pack.

   2.2 Test the batteries individually using an approved tester.

   Do all of the batteries pass the battery test?

   YES → Go to test 4.

   NO → Replace the batteries.

3. **Reconnect the battery pack.**

   Were any of the batteries replaced, or corroded terminals repaired?

   YES → Re-evaluate the starting and charging system symptoms.

   NO → Go to test 4.

4. **Attempt to start the engine.**

   Does the engine start normally using only the onboard batteries?

   YES → Go to **701 — Charging System Diagnostics**.

   NO → Go to **702 — Starting System Diagnostics**.

701 — Charging System Diagnostics

Theory of Operation

The charging system consists of the alternator, drive belt, charging circuits, and sometimes sensing circuits. A current is sent through the slip rings on the alternator rotor, creating a magnetic field around the rotor. The drive belt then spins the rotor creating a rotating magnetic field that crosses the alternator stator. This creates a current that gets sent through the batteries to charge and maintain the battery system.

NOTE: Perform battery tests prior to testing the charging system. Defective or discharged batteries will cause invalid test results for the charging system.

Diagnostic Tools Required

- Approved alternator tester
- Volt/ohmmeter
- Clamp-on induction ammeter
- Carbon pile load tester
- Long test leads

Possible Causes

Excessive Heat: Alternators may become damaged if operated at excessive temperatures for an extended period of time. Modern heavy-duty alternators are designed to operate under the hood, where temperatures are high, however the alternator cooling capabilities need to be maintained. This means the alternator needs to be clean, and have adequate air flow.

Dirt or Oil Buildup: Charging system components operate less efficiently when a buildup of dirt or oil form around wire and cable connection points. Dirty connection points impair the flow of electrical current.

Vibration: If charging system components are poorly or loosely mounted, the resulting vibration can damage sensitive internal components. A loosely mounted component will also diminish the performance of the belt drives. This is very important on high-powered engines.

Diagnostic Tests

1. **Measure the voltage at the alternator output terminal.**

   1.1 Shut down the engine.

   1.2 Connect the alternator tester or voltmeter to the output and ground terminals of the alternator.

   1.3 Check for battery voltage at the alternator output.

   Is there battery voltage between the alternator output and ground terminals?

   YES → Go to test 2.

NO → Troubleshoot the alternator charging circuit. Inspect for loose, missing, or corroded connections between the alternator output to the un-fused side of the MFJB, then from the MFJB to the batteries. Continue checking the ground side from the alternator to the MGJB, then to the batteries.

2. **Measure the alternator's no load output voltage at 1500 rpm.**

   2.1 Start the engine and turn off all electrical loads.

   2.2 Run the engine at 1500 rpm for a few minutes to stabilize the charging system.

   2.3 Measure the alternator output voltage at 1500 rpm with no electrical loads on.

   Is the "no load" output voltage between 13.8 and 14.2 volts?

   YES → Go to test 3.

   NO → If undercharging, replace the alternator.

   If overcharging, check the remote sense fuse in the battery box (if equipped), and the remote sense circuit (123E). If overcharging continues, replace the alternator.

3. **Measure the alternator output voltage with loads applied.**

   3.1 Clamp the induction ammeter onto the alternator output cable, at least 6 inches (152 mm) from the alternator.

   3.2 With the engine running at 1500 rpm, turn on electrical loads (front and rear blower motors, headlights, road lamps) until the ammeter reads between 60 and 75 amps.

   3.3 Measure the output voltage of the alternator.

   Is the alternator output voltage 13.6 volts or above?

   YES → Go to test 4.

   NO → Replace the alternator.

4. **Perform an alternator amperage output test.**

   4.1 Connect a carbon pile load tester to the batteries.

   4.2 Run the engine at 1500 rpm.

   4.3 Adjust the carbon pile tester until the induction ammeter reads its maximum output current.

   4.4 Remove the carbon pile load tester from the batteries, and return the engine to idle.

   Is the maximum alternator output current at least 85% of its rated value?

   YES → Go to test 5.

   NO → Replace the alternator.

5. **Check for voltage drop from the alternator output to the batteries.**

   5.1 Connect a voltmeter between the alternator output terminal, and the battery positive terminal.

   5.2 With the engine running at 1500 rpm, turn on electrical loads (front and rear blower motors, headlights, road lamps).

   5.3 Measure the voltage drop from the alternator to the batteries.

   Is the voltage drop 0.5 volts or less?

YES → The charging system is working properly.

NO → Go to test 6.

6. **Check the charging system connections, cables, and terminals.**

   6.1 Check all connections between the batteries, MFJB, and alternator for tightness and signs of corrosion. Correct as necessary.

   6.2 Check all cables for breaks or partial breaks. Repair as necessary.

   6.3 Check each ring terminal for breakage at the point where it attaches to the cable or wire. Repair as necessary.

   6.4 Repeat test 5 after repairs are made to check for adequate voltage drop (less than 0.5 volt).

702 — Starting System Diagnostics

Fault Codes

CAN Fault — Starter Relay				
SA	**SPN**	**FMI**	**Fault Description**	**Fault Trigger**
33	522003	4	Starter relay — current above normal or grounded circuit.	This Fault is triggered when the ignition switch is in the "CRANK" position, and pin X19.3 senses greater then 7.0 amps. The fault becomes inactive when pin X19.3 senses less then 4.0 amps.

Theory of Operation

The starting system converts electrical energy from the batteries into mechanical energy to start the engine. The starter motor is a small but powerful electric motor that delivers a large amount of power in a short period of time. When the starter motor is energized, it engages the ring gear and produces torque, which turns the flywheel and cranks the engine.

When the ignition switch is released from the start position to the run position, the solenoid is deactivated. Its internal return springs cause the drive pinion to be pulled out of mesh with the flywheel, and the starter motor stops.

The starter relay control is a function of the SAM Cab. It is parameterized for transmission type, engine speed settings, and several time delay settings.

Starter Relay

On the Cascadia, the ignition switch is de-coupled from the starter relay. The SAM Cab activates an output to drive the starter relay. There may be other interlocks and control mechanisms between the SAM Cab and the starter relay depending on the make of the engine and transmission. On a vehicle with an Eaton automated transmission, a safety interlock relay is provided between the SAM Cab starter relay output and the starter relay.

Four criteria determine when the starter motor can be turned on:

- **Safety**: One of four conditions must be met before the starter motor can be activated. The bottom-of-clutch switch must be closed, the neutral switch must be closed, a CAN message from the transmission ECU indicates that it is safe to activate the starter motor, or, for natural gas vehicles only, the caps on the fuel fill

receptacle must be fully locked into place and completely tightened. The safety condition depends on which parameters are programmed on the vehicle.

- **User Control**: The driver requests an engine start by turning the ignition switch.
- **Reliability**: The SAM cab provides anti-grinding protection and thermal protection to the starter motor. When certain conditions exist that may damage the starter motor, the SAM Cab prevents cranking for a set period of time to protect the starter motor.

Anti-grinding Protection Rules:

- The engine speed must be less than 100 rpm to initiate a crank cycle.
- The crank cycle is terminated when the engine speed exceeds 300 rpm.

Thermal Protection Rules:

If the engine speed does not exceed 100 rpm during the crank cycle, cranking is terminated after a maximum of 5 seconds, even if the driver continues to hold the ignition key in the start (crank) position. Cranking can be initiated again after a 30-second cool-down period. This situation occurs when the engine is stalled due to a mechanical failure and excessive heat builds up in the starter motor.

When the engine speed exceeds 150 rpm but does not exceed 300 rpm during the crank cycle, cranking is terminated after a maximum of 10 seconds, even if the driver holds the the ignition key in the start (crank) position. Cranking can be initiated again after a 30-second cool-down period. This situation occurs when the engine is running and turning properly but cranking is still initiated. The termination of cranking protects the starter after the engine is fired.

Diagnostic Tools Required

- Approved alternator tester
- volt/ohmmeter
- carbon pile load tester
- long test leads

Possible Causes

Battery Charge: A battery having a low/poor SOC places abnormal stress on the starting system.

Operator Abuse: Engaging the starter into a running ring gear, starter overrun, and cranking the starter for too long are all extremely damaging to the starting system.

Excessive Heat: Excessive heat is generally due to continuous engagement of the starter. The starter should operate for 30 seconds maximum, then let it cool down for 2 minutes.

Excessive Vibration: If starting system components are poorly or loosely mounted to the vehicle's engine, the resulting vibration can damage sensitive internal components.

Corrosion, Dirt, and Dust: Starting system components operate less efficiently when corrosion forms or dirt particles build up around wire and cable connection points. Corroded and dirty connection points impair the flow of electrical current.

Diagnostic Tests

NOTE: While performing these tests, do not crank the starter for more then 30 seconds. Allow 2 minutes between each cranking of the starter to allow the starter to cool.

NOTE: Perform battery tests prior to testing the starting system. Inoperable or discharged batteries will cause invalid test results for the starting system.

1. **Verify complaint, and note symptoms.**

   1.1 Crank the engine using only onboard starting batteries.

   1.2 Note any symptoms related to the starting system.

   Does the starter crank normally?

   YES → Interview driver to determine the complaint. If the complaint involves the starting system, but the symptoms were intermittent, try allowing the engine to cool before testing the complaint again.

   NO → Go to step 2.

2. **Perform a visual inspection of the starting system cables, wires, and components.**

   2.1 Verify all connections to the magnetic switch, starter BAT, GND, and 'S' terminals.

   2.2 Inspect the starter, solenoid, and the magnetic switch for physical damage.

   Were any loose or missing connections found, or damaged starting system components found?

   YES → Repair as needed, and reevaluate the starting system complaint.

   NO → Go to appropriate tests based on the symptoms you experienced.

Starter Cranks Slowly

1. **Disable the engine ECM to allow cranking without starting the engine.**

   1.1 Locate the Engine Transmission Power Distribution Module (ETPDM) in the driver's side of the engine compartment.

   1.2 Remove the fuse(s) for the engine ECM.

2. **Check available cranking voltage at the starter.**

   2.1 Attach a long jumper lead from the battery negative post, to the negative lead of the voltmeter.

   2.2 Connect the positive lead of the voltmeter to the three locations listed below, measuring voltage at each point, one at a time while the starter is cranking.

   - starter solenoid battery terminal
   - starter solenoid motor terminal
   - starter ground terminal

3. **Check available cranking voltage at the battery pack.**

   3.1 Connect the positive lead of the voltmeter to the positive battery post.

   3.2 Have an assistant crank the starter.

   3.3 Measure the voltage at the battery pack while cranking the starter.

4. **Compare voltages from tests 2 and 3.**

   Is there more than one volt difference between the starter solenoid battery terminal voltage and battery voltage?

YES → There is a bad connection between the batteries and the starter. Refer to **703 — Battery Cable Voltage Drop Tests** to troubleshoot the connection.

NO → Go to the next question.

Is there more than one volt difference between solenoid motor terminal voltage and battery voltage?

YES → Replace the starter. The solenoid has failed.

NO → Go to the next question.

Is there more than one volt reading when measuring between the starter ground terminal and the battery ground terminal while cranking?

YES → There is a bad connection between the starter and battery negative terminal. Refer to **703 — Battery Cable Voltage Drop Tests** to troubleshoot the connection.

NO → The problem may be with the starter. Rule out other conditions such as cold start (thick oil) or engine problems prior to replacing the starter.

5. Install the engine ECM fuse(s) in the ETPDM.

Starter Will Not Turn, Starter Solenoid and Magnetic Switch Click

NOTE: If the engine is locked, the starter will be drawing a large amount of current even though the starter is not turning. If the starter solenoid makes a loud clunk and the starter cables become warm quickly or jump when the key is turned to the start position, check for a mechanical problem with the engine before continuing.

1. **Check available cranking voltage at the starter.**

   1.1 Attach a long jumper lead from the battery negative post, to the negative lead of the voltmeter.

   1.2 Connect the positive lead of the voltmeter to the three locations listed below, measuring voltage at each point, one at a time while the key is being held in the start position.

   - starter solenoid battery terminal
   - starter solenoid motor terminal
   - starter ground terminal

2. **Check available cranking voltage at the battery pack.**

   2.1 Connect the positive lead of the voltmeter to the positive battery post.

   2.2 Have an assistant turn the key to the start position.

   2.3 Measure the voltage at the battery pack while holding the key in the start position.

3. **Compare voltages from tests 1 and 2.**

   Is there more than one volt difference between the starter solenoid battery terminal voltage and battery voltage?

   YES → There is a bad connection between the batteries and the starter; conduct voltage drop tests. Refer to **703 — Battery Cable Voltage Drop Tests** to troubleshoot the connection.

   NO → Go to the next question.

   Is there more than one volt difference between solenoid motor terminal voltage and battery voltage?

YES → Replace the starter. The solenoid has failed.

NO → Go to the next question.

Is there more than one volt reading when measuring between the starter ground terminal and the battery ground terminal while the key is being held in the start position?

YES → There is a bad connection between the starter and battery negative terminal; conduct voltage drop tests. Refer to **703 — Battery Cable Voltage Drop Tests** to troubleshoot the connection.

NO → The problem may be with the starter. Rule out other conditions, such as engine problems, prior to replacing the starter.

Starter Will Not Turn, but the Magnetic Switch Clicks.

1. **Check available cranking voltage at the starter.**

   1.1 Attach a long jumper lead from the battery negative post, to the negative lead of the voltmeter.

   1.2 Connect the positive lead of the voltmeter to the three locations listed below, measuring voltage at each point, one at a time while the key is being held in the start position.

   - starter solenoid ‘S’ terminal
   - magnetic switch starter terminal
   - magnetic switch battery terminal

2. **Check available cranking voltage at the battery pack.**

   2.1 Connect the positive lead of the voltmeter to the positive battery post.

   2.2 Have an assistant turn the key to the start position.

   2.3 Measure the voltage at the battery pack while holding the key in the start position.

3. Compare voltages from tests 1 and 2.

   Is there more than one volt difference between the starter solenoid ‘S’ terminal voltage and battery voltage?

   YES → Go to the next question.

   NO → Move the lead to the starter ground terminal.

   Is there less than one volt while the key is in the start position?

   YES → Replace the starter.

   NO → Repair the starter ground circuit

   Is there more than one volt difference between magnetic switch starter terminal voltage and battery voltage?

   YES → Go to the next question.

   NO → There is a problem between the magnetic switch and the starter solenoid ‘S’ terminal. Repair the solenoid. Refer to the *Cascadia Workshop Manual* for instructions.

   Is there more than one volt difference between magnetic switch battery terminal voltage and battery voltage?

   YES → There is a bad connection between the battery supply and the magnetic switch. Check the connection from the magnetic switch battery terminal to the MFJB, and repair as required.

   NO → Replace the magnetic switch. Refer to the *Cascadia Workshop Manual* for instructions.

Starter Will Not Turn, No Clicking Noise

1. **Check voltage at the magnetic switch ignition and ground terminal.**

   1.1 Attach a long jumper lead from the battery negative post, to the negative lead of a voltmeter.

   1.2 Connect the positive lead of the voltmeter to the two locations listed below, measuring voltage at each point, one at a time while the key is being held in the start position.

   - magnetic switch ignition terminal
   - magnetic switch ground terminal

2. **Check available cranking voltage at the battery pack.**

   2.1 Connect the positive lead of the voltmeter to the positive battery post.

   2.2 Have an assistant turn the key to the start position.

   2.3 Measure the voltage at the battery pack while the key is being held in the start position.

3. **Compare voltages from tests 1 and 2.**

   Is there more than one volt difference between the magnetic switch ignition terminal voltage and battery voltage?

   YES → There is a problem in the ignition input circuit to the magnetic switch, or the starter interlocks. This signal comes from the SAM Cab. See **801 — Starter Crank Interlocks** for details about crank enable conditions. Use the "Starter Relay/Crank Enable" Datalink Monitor template to view the interlock signals to the SAM Cab.

   NO → Continue to the ground terminal.

   Is there more than 0.5 volts at the magnetic switch ground terminal?

   YES → The ground circuit has high resistance.

   NO → Replace the magnetic switch.

Starter Makes Clicking Noise, But Does Not Crank (or cranks intermittently)

1. **Check voltage at the starter solenoid ‘S’ terminal.**

   1.1 Attach a long jumper lead from the battery negative post, to the negative lead of the voltmeter.

   1.2 Connect the positive lead of the voltmeter to the solenoid "S" terminal.

   1.3 Have an assistant turn the key to the start position.

   1.4 Measure the voltage.

   Is there more than 6 volts at the solenoid ‘S’ terminal?

   YES → Go to test 2.

   NO → Troubleshoot the magnetic switch and circuitry.

2. **Inspect the pinion and ring gear.**

   2.1 Remove the starter.

   2.2 Visually inspect the pinion gear.

2.3 Visually inspect the ring gear.

NOTE: If a milled ring and/or pinion gear is the cause of the starting system problems, evaluate the root cause of this condition. Interview the driver to ensure proper starting procedures are being followed.

Is the pinion or ring gear milled or chipped?

YES → Replace the starter and/or ring gear as required.

NO → Install the starter, and reevaluate the starting system symptoms.

703 — Battery Cable Voltage Drop Tests

1. **Set-up the carbon pile tester.**

   1.1 Connect the positive lead of the carbon pile tester to the starter solenoid 'B' terminal.

   1.2 Connect the negative lead of the carbon pile tester to the starter 'G' terminal.

2. **Measure V1.**

   2.1 Connect the positive lead of the voltmeter to the battery positive terminal.

   2.2 Connect the negative lead of the voltmeter to the starter 'B' terminal.

   2.3 Turn the carbon pile tester to 500 amp load.

   2.4 Measure the voltage; record as V1.

   2.5 Turn off the carbon pile tester.

3. **Measure V2.**

   3.1 Connect the negative lead of the voltmeter to the battery negative terminal.

   3.2 Connect the positive lead of the voltmeter to the starter 'G' terminal.

   3.3 Turn the carbon pile tester to 500 amp load.

   3.4 Measure the voltage; record as V2.

   3.5 Turn off the carbon pile tester.

4. **Add voltage losses.**

   Is V1 + V2 greater than 0.50 volts?

   YES → Isolate the defective cables, and repair or replace.

   NO → Go to test 5.

5. **Measure voltages at each battery terminal.**

   5.1 Have one person turn the carbon pile tester to 500 amp load.

   5.2 A second person measures voltage across each battery.

   5.3 Turn the carbon pile tester off after voltages are measured.

   Is there a difference of more than 0.50 volts between any of the batteries?

   YES → Repair or replace defective interconnecting battery cables.

NO → Voltage loss on the battery cables is not the cause of the problem.

800 — Battery State of Charge

Open Circuit Voltage	State of Charge
12.6V	100%
12.4V	75%
12.2V	50%
12.0V	25%
11.8V	0%

Table 1, Battery State of Charge

801 — Starter Crank Interlocks

There are five different crank enable configurations depending on how the vehicle is programmed. These are all inputs to the SAM Cab, where the output is to the magnetic switch.

Starter Crank Interlocks					
Configuration	**Ignition**	**Bottom of Clutch Switch**	**Neutral Switch**	**J1939 Neutral Message**	**Engine rpm**
1	Crank	Closed	—	—	<= set parameter value
2	Crank	—	Closed	—	<= set parameter value
3	Crank	Closed	Closed	—	<= set parameter value
4	Crank	—	—	N	<= set parameter value
5	Crank	—	—	—	<= set parameter value

Table 2, Starter Crank Interlocks

802 — Parameters

Parameters				
Module Number	**Part Number**	**Description**	**Parameter**	**ECU**
12C	002 447 49 58	Alternator charging disabled.	PARM-CAB, ALC, NO CNT	SAM Cab
	002 447 50 58	Alternator charging enabled.	PARM-CAB, ALC, ENABLE	
156	002 447 24 58	Manual and Eaton AS transmission with bottom-of-clutch switch.	PARM-CAB, STR, MAN, BCS	
	002 447 27 58	Allison Automatic transmission with J1939 ETC7.	PARM-CAB, STR, AUT, ETC7	
	002 447 28 58	Eaton DM automatic transmission with transmission ECU interlock.	PARM-CAB, STR, AUT, DG	

Table 3, Parameters

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500 — Hydraulic Clutch Control System

The hydraulic clutch control system consists of a pedal unit and a slave cylinder, connected by a hydraulic hose and fastened with quick-disconnect clip. The components of the system have been specially designed to use DOT 4 brake fluid.

The pedal unit includes a hydraulic subassembly, composed of the master cylinder and reservoir, which can be removed from the pedal unit for service purposes.

When the clutch pedal is depressed, the fluid in the master cylinder is forced through a hydraulic line to the slave cylinder. The fluid pressure moves the slave cylinder piston, pushing the plunger rod and clutch release lever, which disengages the clutch.

The hydraulic system is self-adjusting.

501 — Clutches

The primary purpose of the clutch is to transfer the power of the engine from the engine flywheel to the transmission. At the point where the clutch engagement begins (clutch pedal partially released), the transmission input shaft may be stationary, as when the vehicle is not moving, or it may be rotating at a different speed than the flywheel, as in the case of upshifting or downshifting. Once the clutch is fully engaged (clutch pedal fully released), both the engine flywheel and the transmission input shaft will be rotating at the same speed.

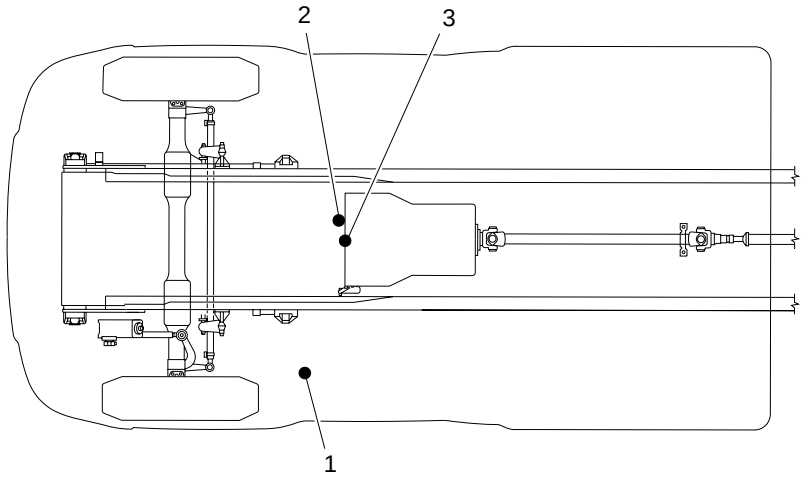
The secondary purpose of the clutch is to dampen unwanted vibrations that normally exist in the driveline system. The springs within each driven disc provide a flexible link between the friction surface and the disc hubs. Dampened clutch discs are specifically designed to prolong the life of the drivetrain components by reducing vibrations from the engine, non-uniform U-joint angles, and road dips and bumps.

When the vehicle is stationary, the clutch brake permits shifting into first gear or reverse gear without severe gear clash. The clutch brake is between the release bearing housing and the transmission bearing cap, and is engaged by tangs to the transmission input shaft. When the pedal is fully depressed, the clutch brake is squeezed between the release bearing housing transmission bearing cap, stopping the rotation of the main drive gear. The clutch brake may be a disc type or a torque-limiting type. To prevent overloads to it, the torque-limiting clutch brake is designed to slip when loads of 20 to 25 lbf·ft (27 to 24 N·m) are reached. The clutch brakes are not designed for upshifting.

502 — Eaton Solo 15.5-Inch Clutch

Eaton Fuller Solo clutches are adjustment-free. As the clutch wears, its wear-adjusting technology monitors clutch components and makes any necessary adjustments. The wear-adjusting technology comes from two sliding cams, which rotate to maintain the proper adjustment. Atop the upper cam, a wear indicating tab mirrors the cam’s movement, indicating when it is time to replace the clutch and showing how much clutch life remains.

600 — Component Locations



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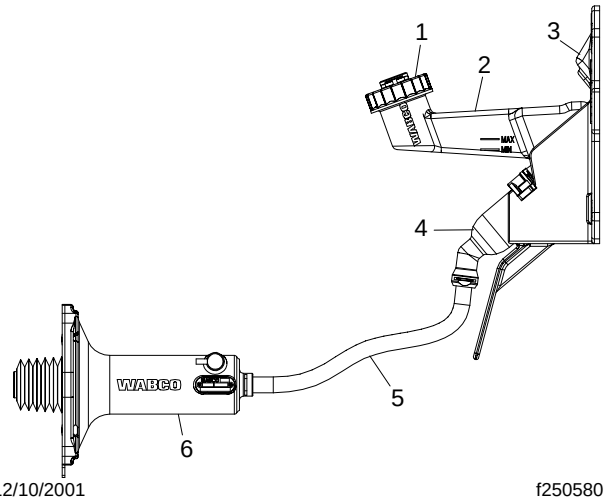
1. Pedal Unit
2. Slave Cylinder
3. Clutch

Fig. 1, Component Locations

601 — Component Details



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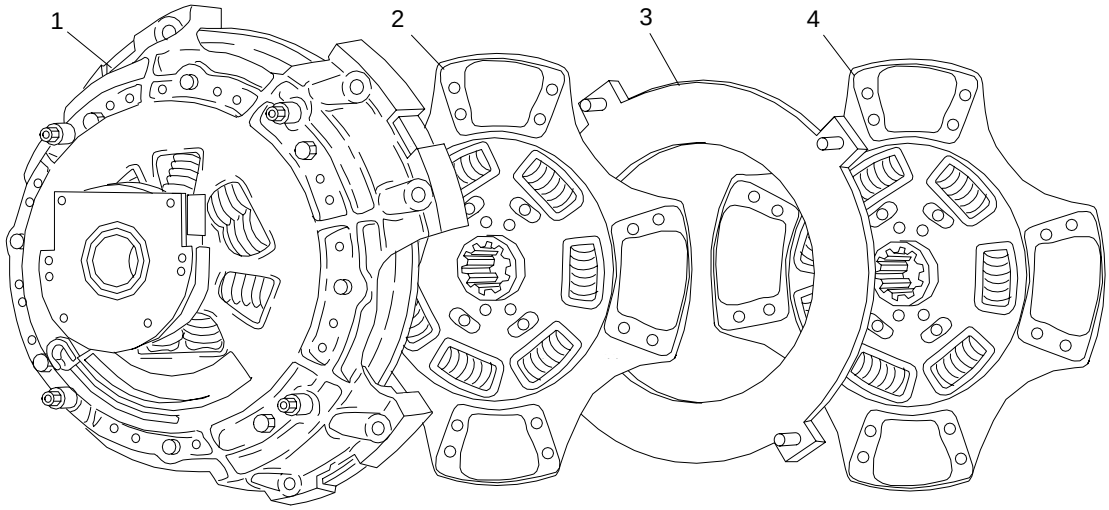
1. Reservoir Cap
2. Reservoir
3. Pedal Unit
4. Master Cylinder
5. Hydraulic Hose
6. Slave Cylinder

Fig. 2, Hydraulic Clutch Control Components



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1. Clutch Cover and Release Bearing
2. Rear Driven Disc
3. Intermediate Plate
4. Front Driven Disc

Fig. 3, Solo Clutch

700 — Clutch Troubleshooting

References

www.roadranger.com

701 — Clutch Control Switch Check

1. Check that the lower clutch-position switch registers at the SAM.

    1.1 Connect the vehicle to the ServiceLink diagnostic tool. Select the SAM Cab ECU, then go to the "Templates" tab and select "Starter Relay, Crank Enable." See **Fig. 4**.

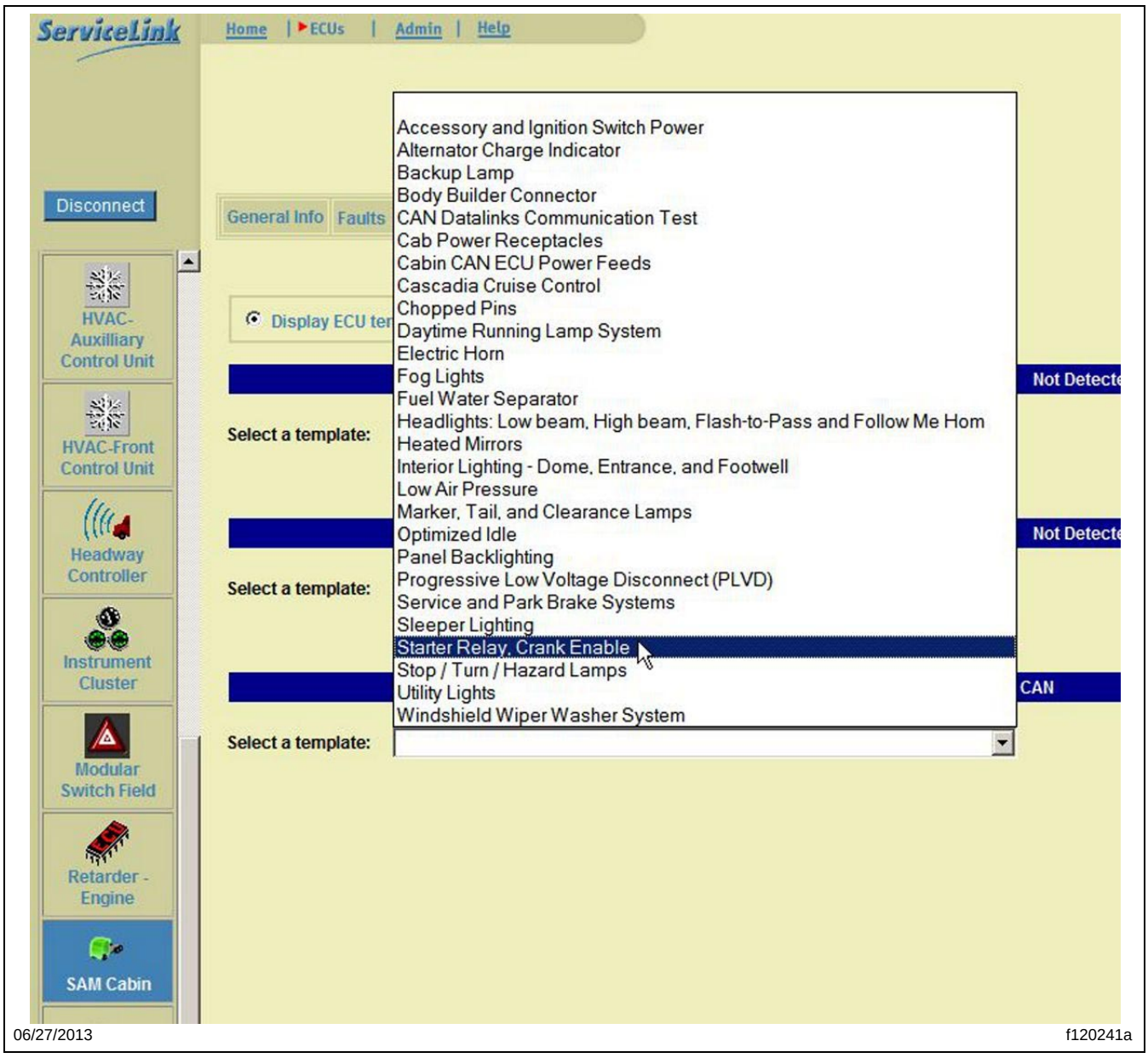


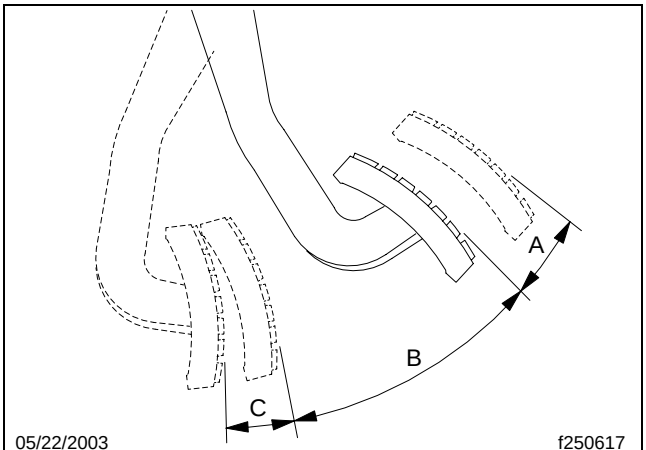
Fig. 4, Starter Relay, Crank Enable in ServiceLink Template Menu

1.2 While pushing the pedal to the point of clutch brake squeeze (**Fig. 5**), check the SAM Cab Template.

Does the actuation of the pedal switch register? The actuation of the pedal is registered when the "Bottom of Clutch Circuit" indicator turns green and reads "At Bottom," as shown in **Fig. 6**.

NO → Go to Test 1.3.

YES → Continue with normal diagnostics of the starting system; see **P01.01—Starting and Charging**.



A. Clutch Free-Pedal
B. Clutch Release-Pedal
C. Clutch Brake Squeeze

Fig. 5, Clutch Pedal Movement

1.3 Continue to monitor the SAM Cab ECU while pushing the clutch pedal with enough force (approximately 75 lbf [330 N]) to make the pedal travel all the way to the floor, opening the internal pressure relief valve in the clutch hydraulic system.

Does the actuation of the pedal switch register?

NO → Go to Test 1.4.

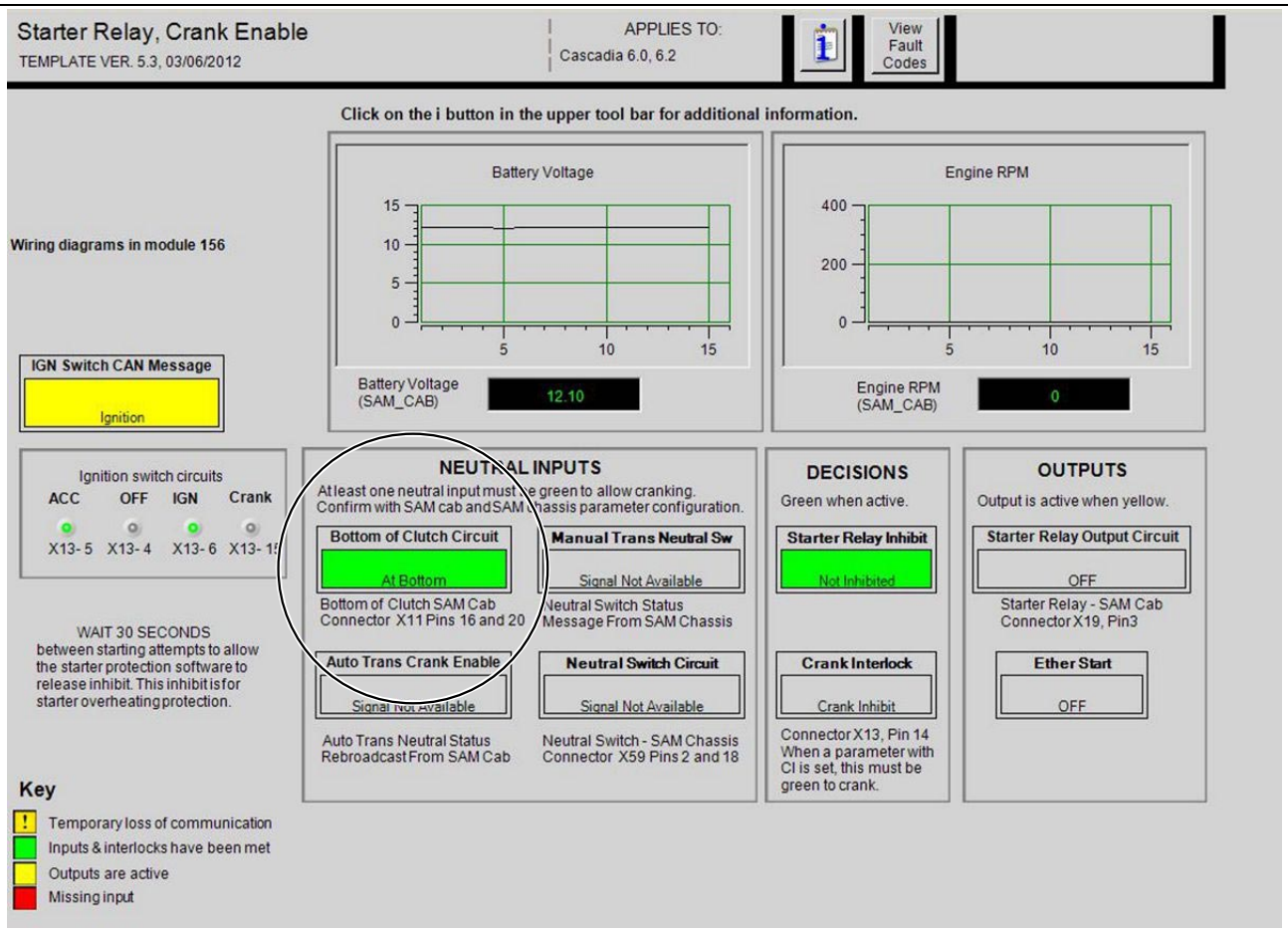
YES → Continue with mechanical diagnostics of the hydraulic pedal assembly and clutch adjustment. See *Cascadia Workshop Manual*, **Section 25.01**.

1.4 Disconnect the chassis harness from the clutch position combination switch. See **Table 5**. Use a jumper wire to close the clutch low position control circuit on the chassis side (between pins A and C in **Table 5**), and look for a response on the SAM Cab ECU template.

Does the response register on the template?

YES → Replace the switch. See *Cascadia Workshop Manual*, **Section 25.01, Subject 150**.

NO → Continue with normal diagnostics of the wiring and SAM.



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NOTE: Cascadia SAM versions 6.0 and 6.2 template shown. Version 5.4 template is similar.

Shown with "Bottom of Clutch Circuit" indicator (circled) registering pedal actuation.

Fig. 6, "Starter Relay, Crank Enable" Template

2. Check that the upper clutch position switch registers at the SAM.

   2.1 With the vehicle connected to the ServiceLink diagnostic tool, select the SAM Cab ECU, then go to the "Templates" tab and select "Cascadia Cruise Control." See **Fig. 7**.

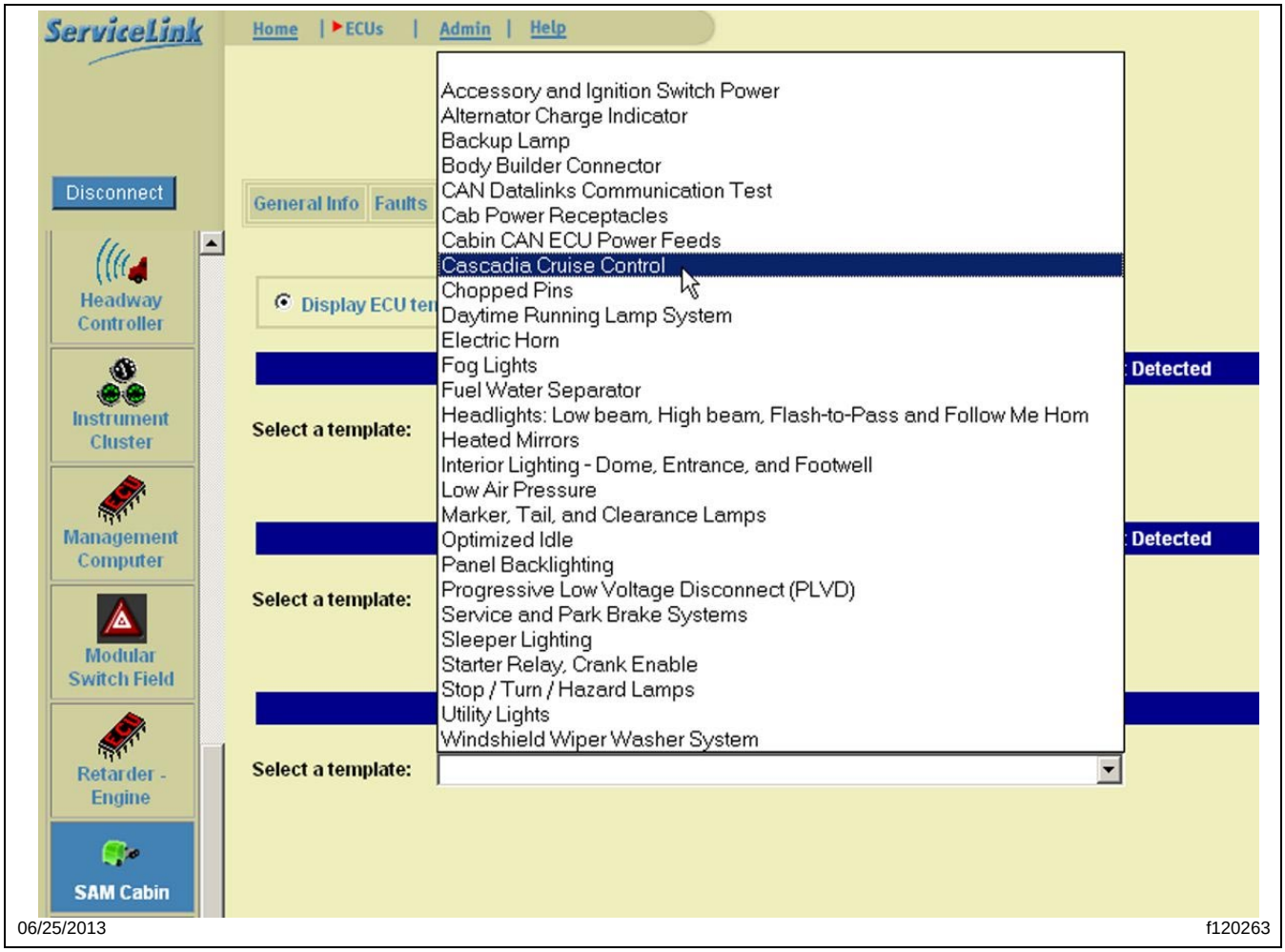


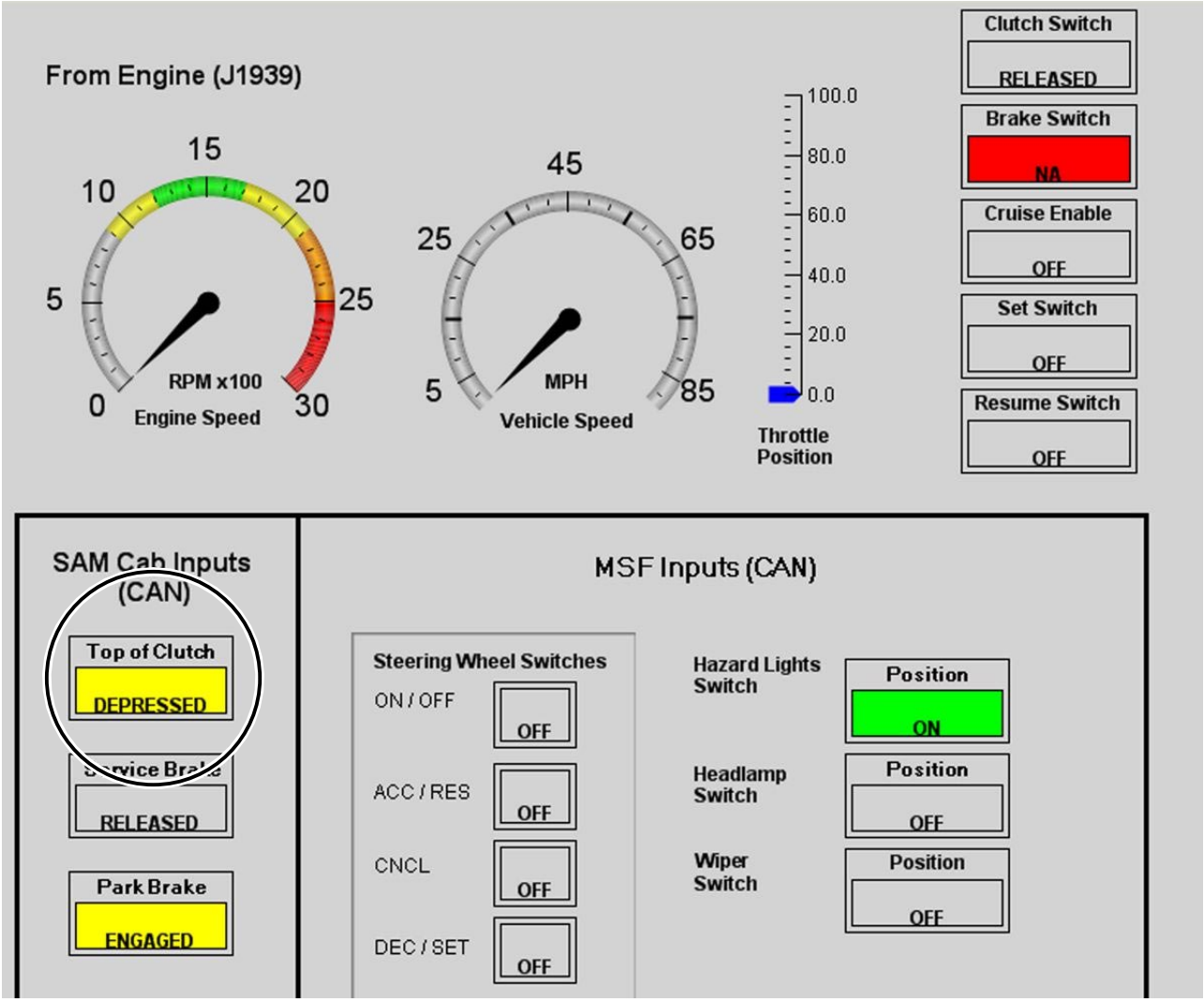
Fig. 7, Cascadia Cruise Control in ServiceLink Template Menu

2.2 While pushing the pedal to the point of clutch brake squeeze (**Fig. 5**), check the SAM Cab Template.

Does the actuation of the pedal switch register? The actuation of the pedal is registered when the "Top of Clutch" indicator turns yellow and reads "DEPRESSED," as shown in **Fig. 8**.

NO → Go to Test 2.3.

YES → The switch is functioning properly.



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NOTE: Cascadia SAM versions 6.0 and 6.2 template shown. Version 5.4 template is similar.

Shown with "Top of Clutch" indicator (circled) registering pedal actuation.

Fig. 8, "Cascadia Cruise Control" Template

2.3 Disconnect the chassis harness from the clutch position combination switch. See **Table 5**. Use a jumper wire to close the clutch low position control circuit on the chassis side (between pins B and C in **Table 5**), and look for a response on the SAM Cab ECU template.

Does the response register on the template?

YES → Replace the switch. See *Cascadia Workshop Manual*, **Section 25.01, Subject 150**.

NO → Continue with normal diagnostics of the wiring and SAM.

702 — Clutch Actuation System Leak Check

Shut down the engine, if not already done. Then, have an assistant press down on the clutch pedal while you check the clutch hydraulic system for signs of leaks.

Were any hydraulic leaks discovered in the clutch actuation system?

YES → Repair any hydraulic leaks as needed.

NO → Continue to "Clutch Actuation System Check."

703 — Clutch Actuation System Check

1. Check the action of the clutch pedal, as follows.

   1.1 Shut down the engine, if not already done.

   1.2 Press the pedal with firm pressure (approximately 60 lbf [270 N]) several times, and check the action of the pedal.

   The pedal should be easy to operate, and should return without difficulty to its original position. It should feel firm and responsive, not soft or spongy.

   Does the clutch pedal feel firm and responsive, and not soft or spongy?

   YES → Go to Test 2.

   NO → There may be air in the hydraulic system, or possibly a hydraulic fluid leak. Fill and bleed the hydraulic system. Check for fluid leaks, and repair or replace any leaking components.

2. Check the operation of the clutch, as follows.

   2.1 With both the clutch and brake pedals depressed, attempt to start the engine.

   IMPORTANT: If the starter will not operate, follow the "Clutch Control Switch Check" instructions above.

   2.2 Test drive the vehicle.

   2.3 Check for proper clutch function while shifting gears.

   IMPORTANT: If cruise control does not deactivate when the clutch pedal is depressed, follow the "Clutch Control Switch Check" instructions above.

   2.4 With cruise control on, press the clutch pedal down.

   Does the clutch operate properly?

   YES → There are no detectable problems with the clutch, re-evaluate the complaint or possibly interview the driver to determine where the problem may be.

   NO → Locate the description of the problem in the following tables to correct the defect.

Problem: The Clutch Pedal is Unusually Hard to Operate	
Possible Cause	**Remedy**
The clutch is damaged.	Remove the clutch and inspect if for damage. Replace the clutch if damaged, or make any necessary repairs.
The return or assist spring is broken.	Replace the pedal unit.
The pedal assembly is worn or jammed.	Replace the pedal unit.
The master cylinder has components that are jammed or broken.	Replace the hydraulic subassembly.

Table 1, The Clutch Pedal is Unusually Hard to Operate

Problem: The Clutch Does Not Completely Disengage; Shifting is Difficult and Noisy	
Possible Cause	**Remedy**
There is air in the hydraulic system.	Bleed the hydraulic system.
There is a hydraulic fluid leak.	Check the fluid level. Check for leakage and replace any components found to be leaking. Fill and bleed the hydraulic system.
Components of the pedal unit are defective.	Replace the pedal unit.
The slave cylinder is defective.	Replace the slave cylinder.
The slave cylinder is loose.	Inspect the slave cylinder mounting and fasteners.
The wrong type of brake fluid was used.	Replace the complete hydraulic system. Fill only with approved DOT 4 brake fluid.

Table 2, The Clutch Does Not Completely Disengage; Shifting is Difficult and Noisy

Problem: The Clutch is Slipping	
Possible Cause	**Remedy**
The clutch is worn.	Replace the clutch.
Contamination (e.g. oil, grease).	Replace the clutch.

Table 3, The Clutch is Slipping

800 — Clutch Control Switch

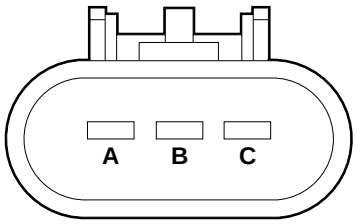
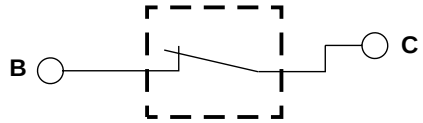
Connector	Clutch Control Switch Diagram	A	B	C
 03/19/2007 f545004	 03/19/2007 f545005	—	Yellow	Black

Table 4, Clutch Control Switch, Top of Clutch Control

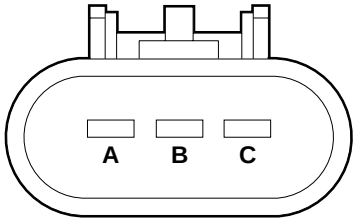
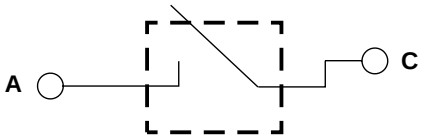
Connector	Clutch Control Switch Diagram	A	B	C
 03/19/2007 f545004	 03/19/2007 f545006	Blue	—	Black

Table 5, Clutch Control Switch, Bottom of Clutch Control

801 — Hydraulic Slave Cylinder

Hydraulic Slave Cylinder Specifications	
Hydraulic Fluid	DOT 4 (SAE J1703)
Temperature Range	–40 to 212°F (–40 to 100°C)

Table 6, Hydraulic Slave Cylinder Specifications

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500 — General Information

The transmission must efficiently transfer the engine's power, in terms of torque, to the vehicle's drive wheels. Torque is the twisting force delivered by the engine's flywheel. The transmission's gear ratio increases or decreases torque depending on the requirements needed to move or start the load. Gearing also increases or decreases speed. The gear ratios are correctly spaced so that the engine will operate in its most efficient rpm range with progressive speed changes.

To meet the vehicle's requirements, the transmission must have ratios low enough to start the vehicle moving, maintain movement up grades, and keep the engine operating in its peak efficiency range. The transmission must also provide an easy method for gear selection.

Refer to the transmission vendor for specific troubleshooting and service information. Look for the serial tag on the transmission to identify which specific model transmission you have, then use this model number to reference the appropriate troubleshooting and service information. See **Fig. 1**.

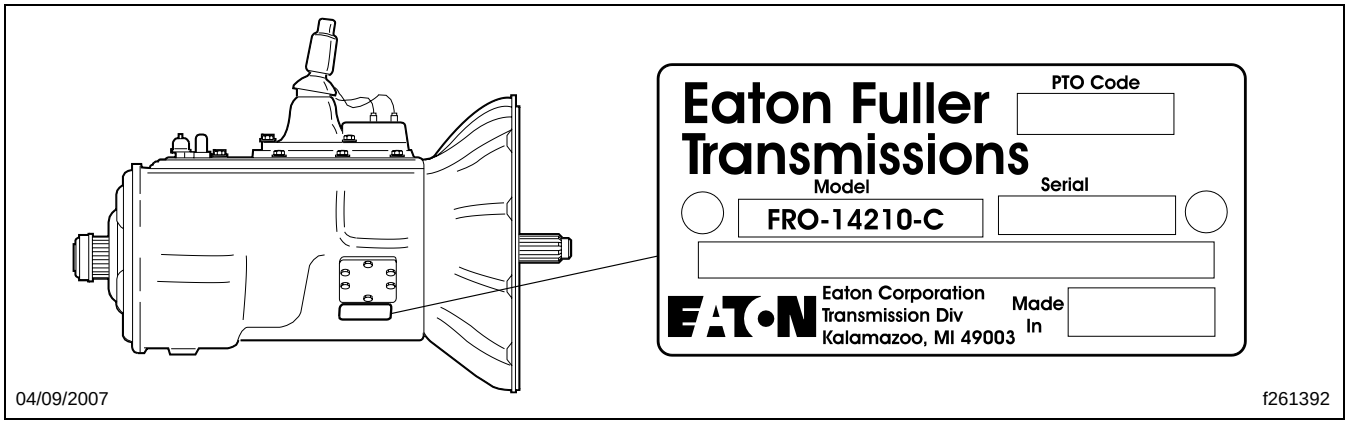
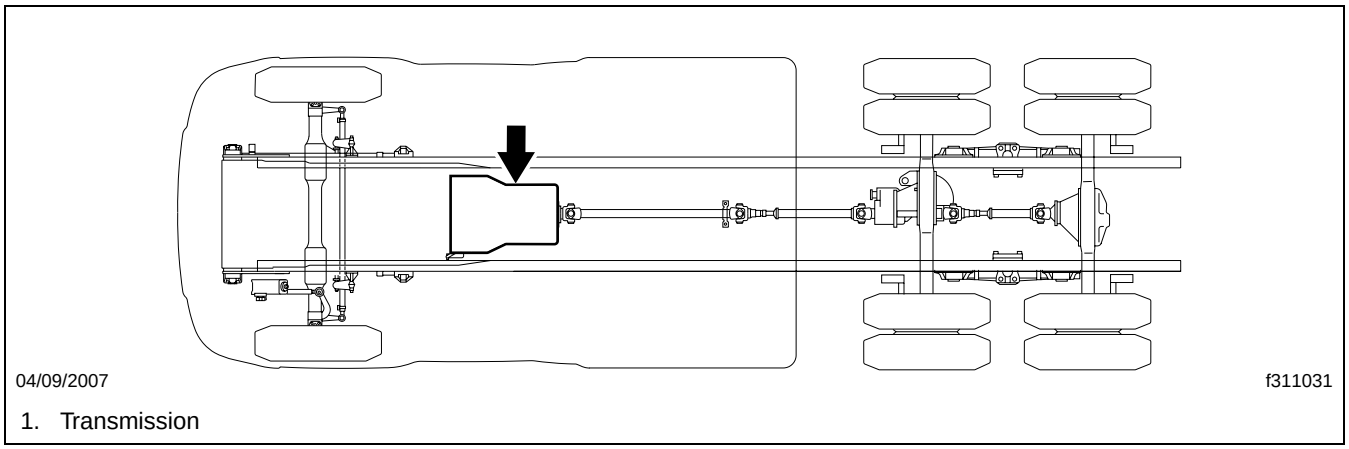


Fig. 1, Transmission Serial Tag

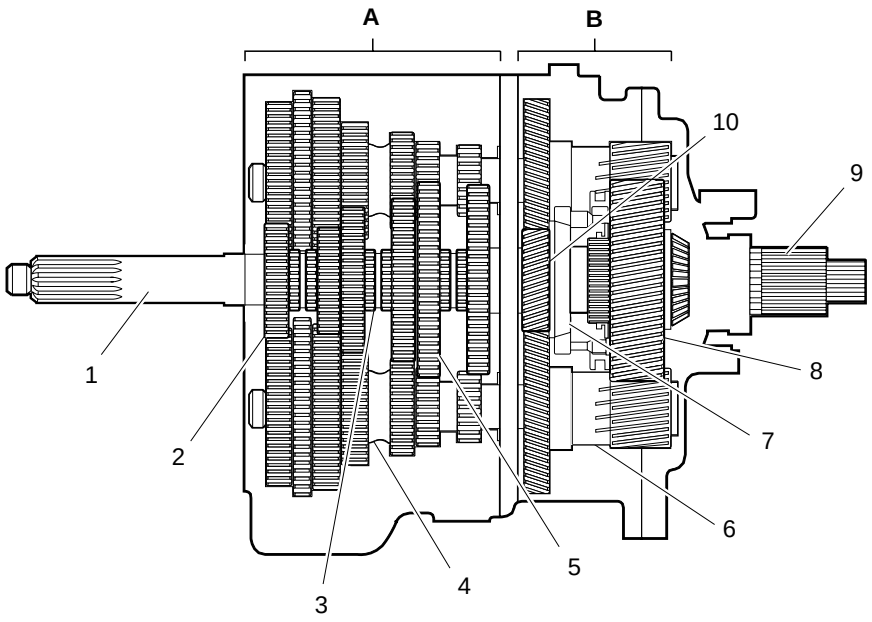
600 — Component Locations



1. Transmission

Fig. 2, Transmission

601 — Component Details



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A. Front Section
B. Auxiliary Section

1. Input Shaft
2. Main Drive Gear
3. Sliding Clutch
4. Countershaft
5. Mainshaft Gear
6. Auxiliary Countershaft
7. Range Sliding Clutch
8. Auxiliary Mainshaft Reduction Gear
9. Output Shaft (Auxiliary Mainshaft)
10. Auxiliary Drive Gear

Fig. 3, Transmission Components

700 — Diagnosis

Refer to the transmission vendor's literature for specific troubleshooting and service information. This information can be viewed or downloaded from the internet, or paper manuals can be ordered from the vendor.

Possible Causes / General Complaints

Gear Jumpout— Jumpout usually occurs with the splitter gear set. If torque is not sufficiently broken during splitter shifts, the sliding clutch gear may not have enough time to complete the shift before torque is reapplied to the gears. As torque is reapplied, the partially engaged clutch gear "jumps" out of the splitter gear. Since the gears have torque applied to them, damage will be done to the clutching teeth of the mating gears.

Gear Slipout— When a sliding clutch is moved to engage with a main shaft gear, the mating teeth must be parallel. Tapered or worn clutching teeth will try to "walk" apart as the gears rotate.

Hard Shifting— Shift linkage is a common cause of hard shifting complaints. Another common cause is the splines of a sliding clutch gear binding on the main shaft as a result of a twisted main shaft key, bent shift yoke, or bowed main shaft key. Also, yoke bars binding in the bar housing as a result of cracked housing,

over-torqued shift block lock-screw, sprung yoke bar, or swelled areas of the yoke bar may cause hard shifting.

Heat— Excessive heat may be caused by improper lubrication, operating consistently under 20 mph, high engine rpm, high horsepower, overdrive operation, or coasting downhill with the clutch depressed.

Transmission Noise, Growling— A growling noise may be audible if there is an error in tooth spacing, which can be caused by improper timing of the transmission during reassembly, or improper timing due to gear turning on the countershaft.

Transmission Noise, High Pitched Whine or Squeal— High-pitched whining or squealing can be caused by normal gear wear, including gear tooth pitting from excessive use (in advanced deterioration, a howl will result), mismatched gear sets (identifiable by an uneven wear pattern on the face of the gear teeth), or pinched bearings (insufficient axial or radial clearance).

Transmission Noise, Knocking, or Thudding— Bumps or swells are present on gear teeth. Generally this noise is more predominant when the gear is loaded; thus, the problem can be located as the noise occurs in a specific gear position. Bumps or swells are caused by improper handling of gears before or during assembly. Also, a gear cracked or broken by shock loading or by pressing on the shaft during installation will produce this sound at low speeds (at high speeds a howl may be audible). Bearing noise comes in at low shaft speeds in any position. It is caused by bearings with damaged balls or rollers, or with pitted and spalled raceways.

Vibration— Although the effects of vibration will show up in the transmission, vibration usually originates somewhere else in the drivetrain. Vibration can usually be felt or heard by the driver; however, in some cases, transmission damage caused by vibration will occur without the driver's knowledge.

Diagnostic Tests

Refer to vendor literature for diagnostic tests.

References

See the following for additional diagnostic information:

- **G05.01 — Vibration**
- **C01.06 — Air Supply System**
- Eaton's website, www.roadranger.com
- Meritor's website, www.meritorhvs.com

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500 — Terms and Abbreviations

AMT—Automated Manual Transmission

Databus—No longer used; replaced by "datalink."

Datalink—A collection of wires, connecting system components, through which data is transmitted.

ECU—Electronic Control Unit, typically connected to a datalink.

ICU—Instrumentation Control Unit

TCU—Transmission Control Unit

501 — Automated Transmission

An automated manual transmission (AMT) combines the best features of manual and automatic transmissions. Manual transmissions are lighter than conventional automatic transmissions and suffer fewer energy losses. However, many drivers prefer the convenience of an automatic.

An automated transmission operates similarly to a manual transmission except that it does not require clutch actuation or shifting by the driver. Shifting can either be performed automatically, or the driver may shift manually using the slide switch on the Freightliner SmartShift control.

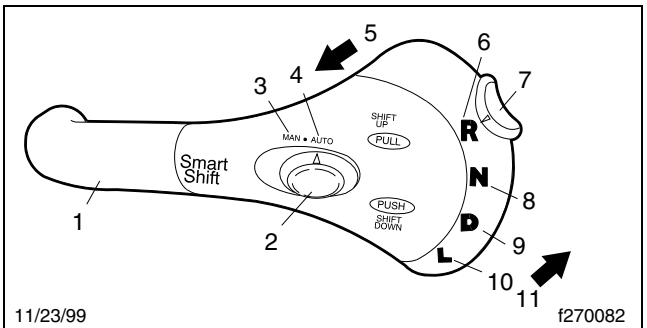
502 — Freightliner SmartShift Transmission Shift Control

The following information is provided to help determine whether a problem is the transmission or the Freightliner SmartShift Transmission Shift Control.

Resistance checks at the SmartShift connector can help determine connection problems. DataLink Software can be used to test the SmartShift control. Some of these tests require a ServiceLink computer connected to the vehicle.

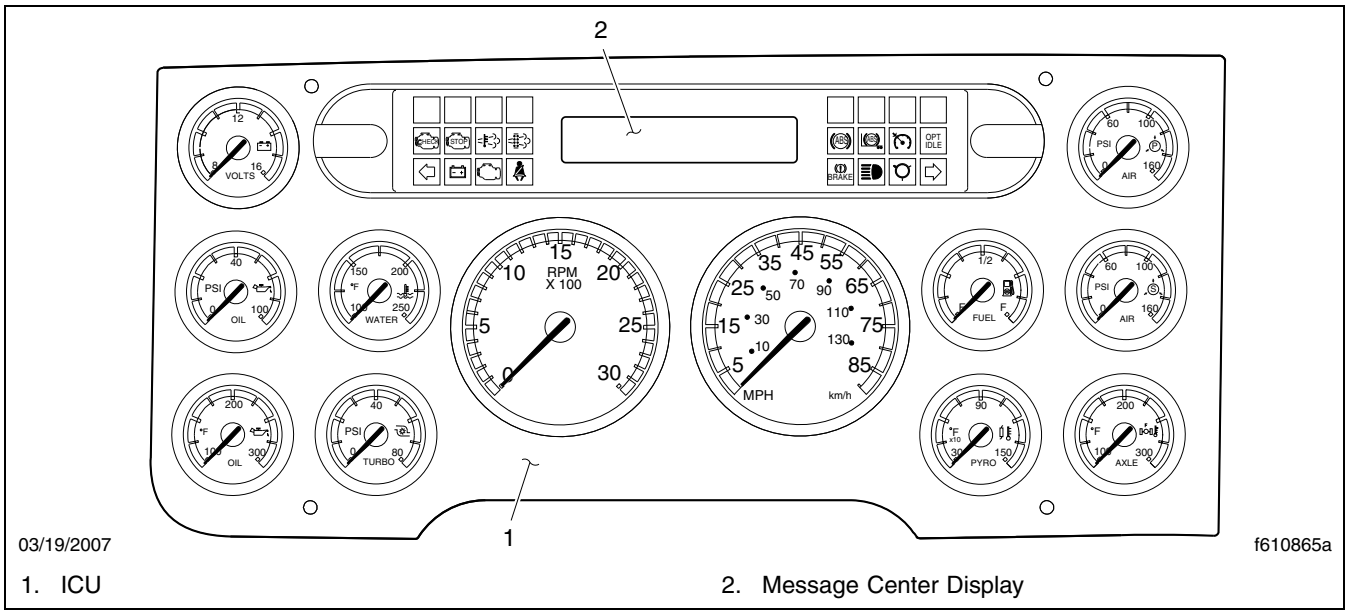
The ICU will display current gear information for vehicles with automated transmissions. This information is sent to the ICU through the datalink from the TCU. The last three digits at the far right on the lower line of the ICU message center is reserved for this display information. If there is a need to shift, one digit displays an arrow, either up or down depending on the shift direction. The other two digits display the current gear.

600 — Component Details



1. SmartShift Control
2. Slide Switch (forward driving mode switch)
3. MAN Position (on slide switch)
4. AUTO Position (on slide switch)
5. Upshift Direction
6. Reverse Position (on selector switch)
7. Selector Switch
8. Neutral Position (on selector switch)
9. Drive Position (on selector switch)
10. Low Position (on selector switch)
11. Downshift Direction

Fig. 1, SmartShift Control



1. ICU
2. Message Center Display

Fig. 2, ICU Message Center

700 — Troubleshooting an Automated Transmission

Refer to the vendor's literature for specific troubleshooting of the automated transmission. This information can be viewed or downloaded from the internet, and paper manuals can be ordered from the vendor.

Fault Codes

Refer to the vendor's literature for a detailed fault code list.

References

See the following for additional diagnostic information:

- **G05.01 — Vibration**
- **H01.06 — Air Supply System**
- **C01.02 — ICU4M**
- Eaton's website, www.roadranger.com

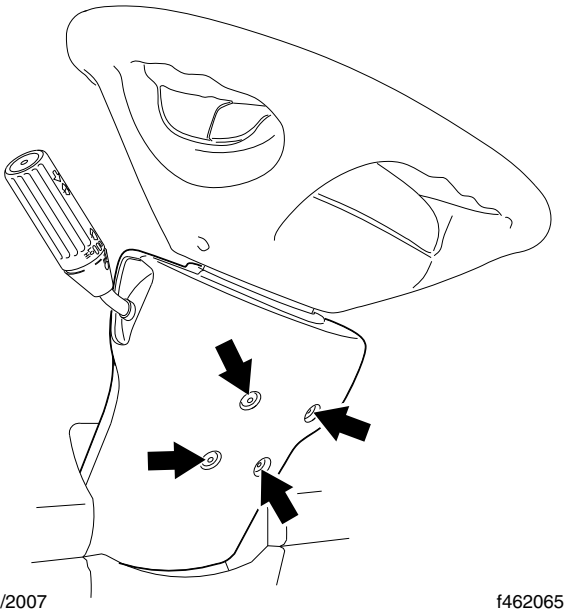
Diagnostic Tools

Use the following diagnostic tools when troubleshooting an automated transmission:

- ServiceLink
- digital multimeter
- wire extension (assembly instructions are provided later in this subject)
- diagnostic software supplied by transmission OEM
- DataLink Monitor Template (SmartShift with Eaton Fuller automated transmissions only)

701 — Shift Control Resistance Test

1. Inspect the SmartShift electrical connector.
   1.1 Remove the screws that secure the steering column trim panels. See **Fig. 3**.



Remove the screws that secure the steering column trim panels.

Fig. 3, Steering Column Screws

1.2 Separate the forward and rear panels to access the shift control.

1.3 Disconnect the electrical connector from the plug on the shift control unit.

1.4 Visually inspect the connector and pins for damage and corrosion, and, if needed, add a dielectric grease.

Are the connector and pins free from damage?

YES → Go to test 2.

NO → Repair any damaged pins or connectors as needed. Then, if needed, go to test 2.

2. Assemble and install a wire extension kit, then use it to check the resistance on the SmartShift control. See **Table 1**for a list of parts for a wire extension kit.

Parts for Wire Extension*		
Part Number	**Description**	**Qty.**
PAC 12110847 L	Metri-Pack Terminal	3
PAC 12047767 L	Connector Terminal	3
48-02493-184	18GA GTX Wire, Yellow	3 ft x 3
PAC 12047781 B	3-Pin Connector	1
PAC 12047783 B	Connector Lock	1

* Parts are available through the PDCs.

Table 1, Parts for Wire Extension

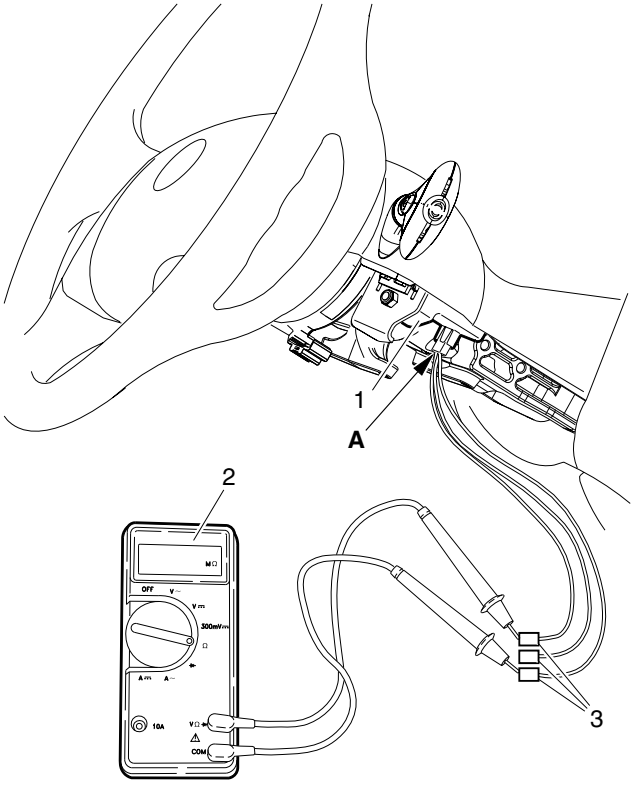
NOTE: Using a wire extension prevents needing to remove the shift control.

2.1 Crimp the connector terminals at the end of each 3-foot (1-meter) wire.

2.2 Assemble the 3-pin connector with the connector terminals and connector lock.

2.3 Crimp the Metri-Pack terminals on the other end of the wires.

2.4 Plug the wire extension into the plug on the shift control unit. See **Fig. 4**.



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A Plug the newly assembled wire extension into the plug on the shift control unit.

1. Shift Control Unit
2. Digital Multimeter (set to ohms)
3. Metri-Pack Terminals (at wire ends)

Fig. 4, Resistance Checking at Shift Control

2.5 If the wire extension fits snugly into the SmartShift control, proceed to the next step. If not, ensure the extension terminals are fully seated in the plug; reseat the terminals as needed. If a connector is not available, you may plug the terminals into the individual pins on the shift control—just be sure the terminals do not touch one another when performing the resistance checks.

2.6 Check the resistance at the end of the wires. See **Fig. 4**. To identify terminal positions, see **Fig. 5**. For resistance values, see **Table 2**and **Table 3**.

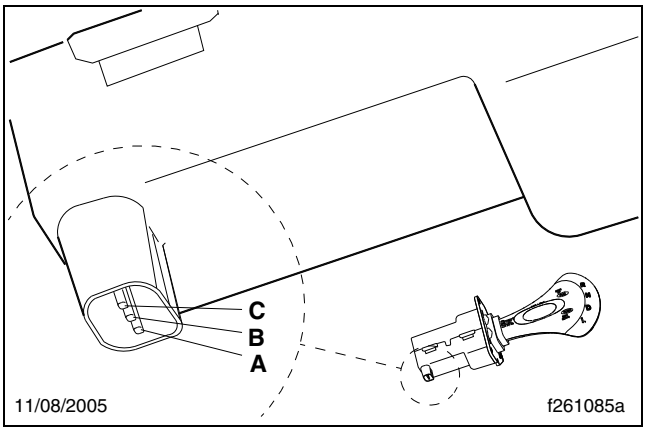

Fig. 5, SmartShift Terminal Positions

Resistance on SmartShift Controls at B and C	
Selector Switch Position	**Reading: kOhm**
R	2.947–3.067
N	0.347–0.361
D	0.606–0.630
L*	1.65–1.72

* Applies to four-position (R-N-D-L) controls only.

Table 2, Resistance on SmartShift Controls at B and C

Resistance on SmartShift Controls at A and C	
Slide Switch + Lever Position	**Reading: kOhm**
Manual	2.865–2.981
Manual + Up	0.531–0.553
Manual + Down	1.150–1.197
Auto	11.27–11.73

Table 3, Resistance on SmartShift Controls at A and C

2.7 Are the resistance values within the correct ranges specified in **Table 2**and **Table 3**?

YES → The Freightliner SmartShift control is working properly. Continue with this troubleshooting subject.

NO → Replace the Freightliner SmartShift control.

702 — SmartShift Control Testing for Eaton Fuller Automated Transmissions

The DataLink Monitor Template for Eaton Fuller automated transmissions (with SmartShift control) displays the current vehicle status and will reflect changes in status. Vehicle information is retrieved from the transmission ECU on the datalink. This DataLink Monitor Template can also be used to verify readings on the instrument panel.

To test the shift control using the datalink, place the vehicle into a mode that allows the gears to be shifted without the engine running. Using ServiceLink, open the DataLink Monitor Template (SmartShift with Eaton Fuller automated transmissions), and put the TCU in "Engine ON" mode.

Diagnostic Tests

1. Verify whether the transmission will shift gears.

   1.1 Start the engine.

   1.2 Turn the ignition *off*, and then, without starting the engine again, turn the ignition back *on*.

   1.3 Using the SmartShift control, verify whether the TCU will allow shifting.

   Will the transmission shift gears?

   YES → Go to test 2.

   NO → There may be a problem with the transmission. Refer to vendor literature for specific troubleshooting information.

2. Using the SmartShift control, try shifting the transmission. Does information on the DataLink Monitor Template correspond to commands input at the SmartShift control and the dash display?

   YES → The SmartShift control is providing the correct input to the TCU. The problem is likely with the automated transmission. Refer to vendor literature for specific troubleshooting information for the automated transmission.

   NO → There may be a problem with the harness between the SmartShift control and the TCU. Check for common wiring problems. If there are no problems with this harness, refer to the vendor literature for specific troubleshooting information for the automated transmission.

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500 — Terms and Abbreviations

Datalink—A collection of wires connecting system components through which data is transmitted.

Planetary Gear—An outer gear that revolves around an inner sun gear.

Parameter—A parameter is a predetermined variable in a set, each of which restricts or defines the specific capabilities of the system as a whole. Parameters are used to customize the configuration of the system.

TCU—Transmission Control Unit

501 — Automatic Transmission

The primary purpose of the transmission is to allow the engine to operate in a limited speed range, while allowing the output speeds to vary greatly. The transmission uses gears to make effective use of the engines torque while keeping the engine at optimal speeds.

The key difference between manual and automatic transmissions is that manual transmissions lock and unlock different sets of gears to the output shaft, and automatic transmissions use the same gear sets to produce the various gear ratios. This is accomplished by use of a planetary gear set.

The transmission fluid is an important aspect to maintain in automatic transmissions. The fluid cools, lubricates, and transmits hydraulic power between the engine and transmission. The fluid needs to be maintained at proper levels, if it's too low, the torque converter and clutches do not receive an adequate supply of fluid, causing the transmission to overheat. If the level is too high, the fluid aerates, causing the transmission to shift erratically and overheat. The fluid may also be expelled through the dipstick tube, or breather. Damage due to excessive heat may be key to diagnosing transmission related issues.

For detailed diagnostics information of the Allison Automatic transmission, including troubleshooting transmission fault codes, refer to Allison's own publications and use Allison approved diagnostic service tools. This will ensure you are using the most up to date and accurate information available.

For datalink related issues, refer to section **G02.02 — Datalink Communication Structure**.

600 — Component Locations

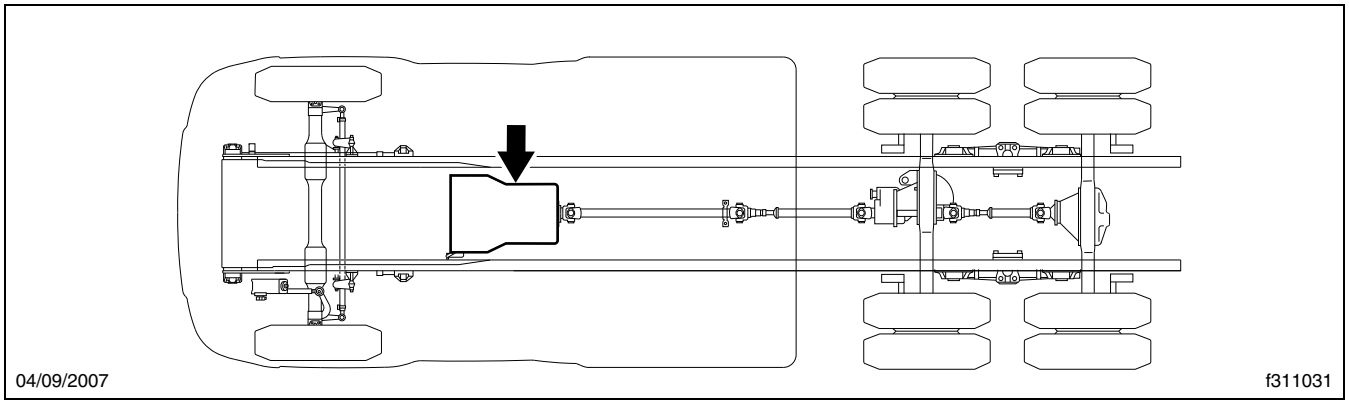


Fig. 1, Transmission

700 — Automatic Transmission Troubleshooting

Reference: www.allisontransmission.com

Diagnostic Tools Required:

- Allison DOC™
- Other diagnostic tools specified by the transmission OEM

701 — Fluid Leak Diagnosis

1. Find the source of the leak.

   1.1 Identify the fluid (engine oil, automatic transmission fluid, hydraulic fluid from the power steering system, etc.).

   1.2 Operate the vehicle to reach normal operating temperature.

   1.3 Inspect the vehicle to identify the source of the leak. See **Table 1** for possible points of transmission fluid leak and their causes.

Transmission Fluid Leaks, Locations and Causes	
Leak Location	**Possible Causes**
Transmission mating surfaces	Attaching bolts not correctly aligned.
	Improperly installed/damaged gasket.
	Mating surface(s) damaged or dirty.
Housing	Fill tube or plug seal damaged or missing.
	Fill tube bracket dislocated.
	Oil cooler connector fittings loose or damaged.
	Output shaft seal worn-out or damaged.
	Pressure port plugs loose.
	Porous casting.
At the converter end	Converter seal damaged.
	Seal lip cut (check converter hub for damage).
	Garter spring missing from seal.
	Converter leak in weld area or O-ring seal.
	Porous casting.
Fluid comes out of the fill tube	Overfilled.
	Incorrect dipstick.
	Plugged vent.
	Coolant in the fluid.
	Incorrect electronic fluid indication.
	Drain-back holes plugged.

Table 1, Transmission Fluid Leaks, Locations and Causes

1.4 Inspect both the suspected area and the gasket mating surfaces for leaks.

1.5 Clean the suspected area if the leak still cannot be identified. Dry the area when finished.

1.6 Operate the vehicle for several miles at varying speeds, and inspect for leaks.

Has the source of the leak been found?

YES → Go to step 4 for repairs.

NO → Go to either step 2 to use the power method of leak detection, or step 3 for the dye and black light method, depending on your shop practices.

2. Leak Detection, Power Method

2.1 Clean the suspected area.

2.2 Apply an aerosol-type white power to the suspected area.

2.3 Operate the vehicle under normal conditions.

2.4 Inspect the area and trace the leak path over the white power.

Has the source of the leak been found?

YES → Go to step 4 for repairs.

NO → Repeat step 2 until the source is found.

3. Leak Detection, Black Light and Dye Method

NOTE: If a black light and dye kit are available, use the kit instructions.

3.1 Pour the specified amount of dye into the transmission fill tube.

3.2 Operate the vehicle under normal conditions.

3.3 Shine the black light toward the suspected area. The dyed fluid will appear as a brightly colored trace leading to the leak.

Has the source of the leak been found?

YES → Go to step 4 for repairs.

NO → Repeat step 3 until the source is found.

4. Once the leak has been traced back to its source, inspect the leaking part for the conditions listed in **Table 2**, and repair as needed.

Transmission Fluid Leaks, Components	
Component	**Possible Causes**
Gaskets	Fluid level or pressure is too high.
	Plugged vent or drain-back holes.
	Improperly tightened fasteners or damaged threads.
	Warped flanges or seals surfaces.
	Scratches, burrs, or other damage to sealing surfaces.
	Damaged or worn-out gasket.
	Cracked or porous casting.
	Improper sealant used, where applicable.
Seals	Fluid level or pressure is too high.
	Plugged vent or drain-back hole.
	Damaged seal bore.
	Damaged or worn-out seal.
	Improper seal installation.
	Cracks in components.
	Output shaft surface scratched, nicked, or damaged.
	Loose or worn-out bearing causes excessive seal wear.
Sealing Flange	Bent sealing flange. Replace sealing flange if bent.

Table 2, Transmission Fluid Leaks, Components

702 — Automatic Transmission Diagnostics

Refer to the vendor literature for detailed transmission diagnostics.

800 — Specifications

Transmission Fluid Contamination	
Contaminant	**Limit**
Water	0.2% Maximum
Glycol	No trace allowed.
Unapproved Fluids*	If detected, change transmission fluids.

* Any fluid not on an Allison-approved fluid list must not be used. A list of approved automatic transmission fluids can be found at the Allison website, www.allisontransmission.com.

Table 3, Transmission Fluid Contamination

Table of Contents

500 — Terms and Abbreviations

CSC—Customer Support Center

ECM—Engine Control Module

ECU—Electronic Control Unit

FMI—Failure Mode Indicator. The part of a J1587, J1939, and CAN fault code that identifies how part of a device, or item on a device, failed.

GPS—Global Positioning System

GSM—Global System for Mobile Communications; the cellular telephone network.

HU—Hardware Update

LED—Light-Emitting Diode

OTA—Over the Air; OTA refers to software updates made to the Virtual Technician system over the GPS system.

Parameter—A parameter is a specific value that is assigned to a feature or function of the vehicle, and allows the customer to choose how that particular feature or function will work on the vehicle.

SA—Source Address, indicates any device that communicates on J1939.

SPN—Suspect Parameter Number. The part of a J1939 or CAN fault code that identifies how part of a device, or item on a device, failed.

VT—Virtual Technician

501 — General Information

The Virtual Technician (VT) generates diagnostic information to aid Detroit™ and the technician in diagnosing complex engine control issues. The system creates sensor log files, captures fault codes, and sends alert messages and other advanced diagnostic information to the Detroit Customer Support Center. The Virtual Technician utilizes GPS navigation, GSM (cellular telephone) communication, and a J1939 connection for databus monitoring. Virtual Technician does not require any driver input to function. The unit is located behind the sunglass holder on the passenger side of the overhead console, and is mounted to a bracket via hook and loop tape. See **Fig. 1** and **Fig. 2** . The unit can safely be removed from the mount while remaining wired into the vehicle for visual diagnostic purposes.

600 — Component Locations

NOTE: The Virtual Technician is located in the overhead console, behind the sunglass holder.

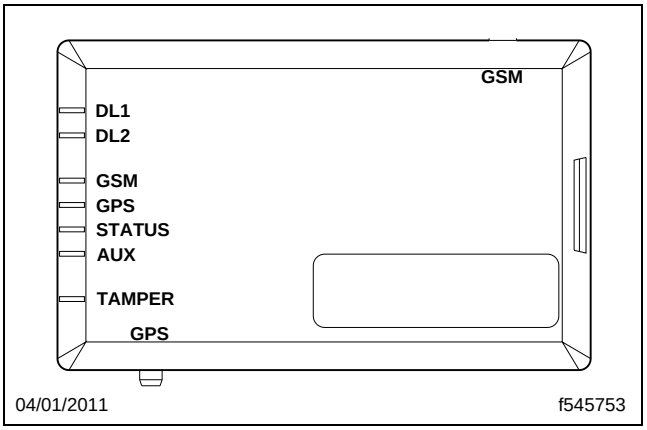


Fig. 1, Virtual Technician ECU

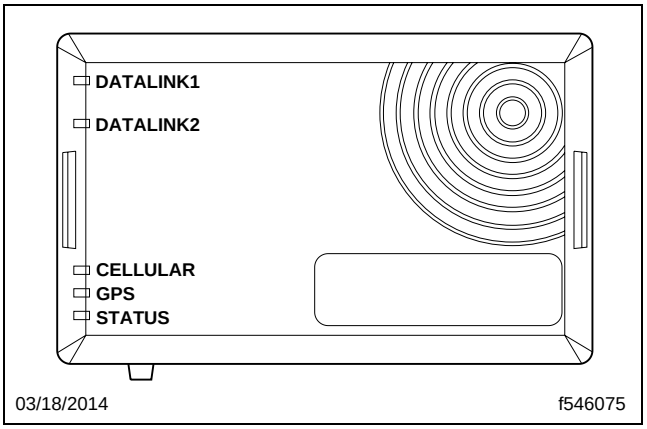


Fig. 2, Virtual Technician HU

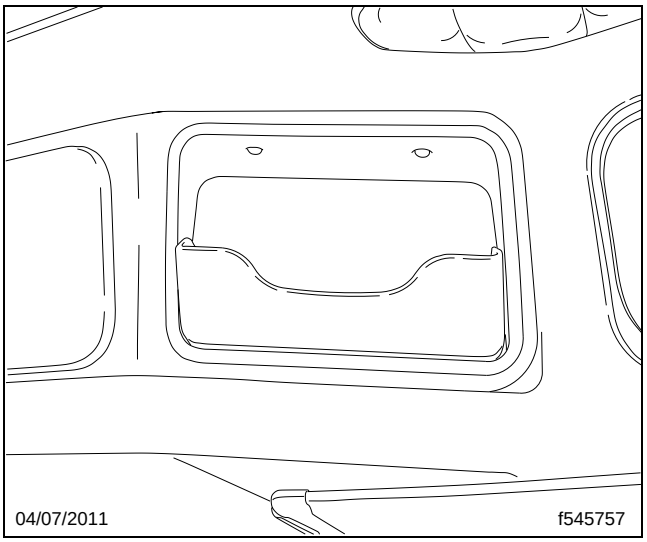
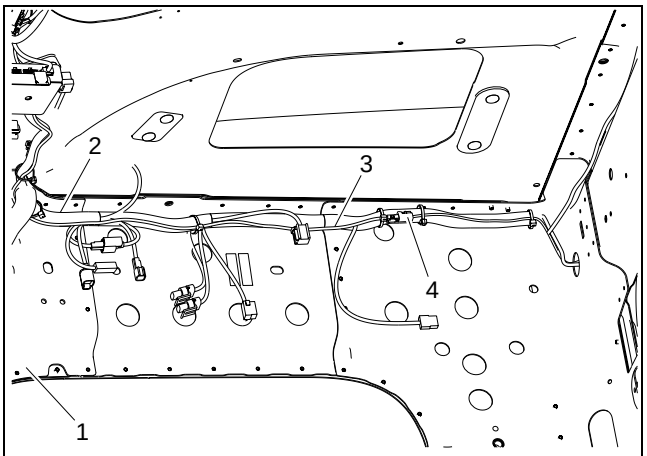


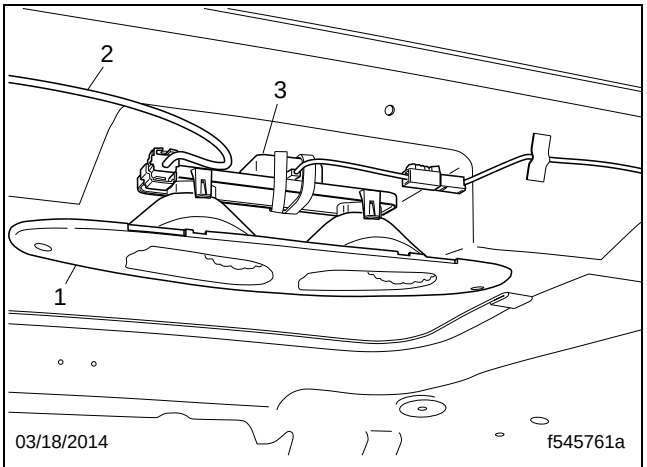
Fig. 3, Sunglass Holder

601 — Component Details



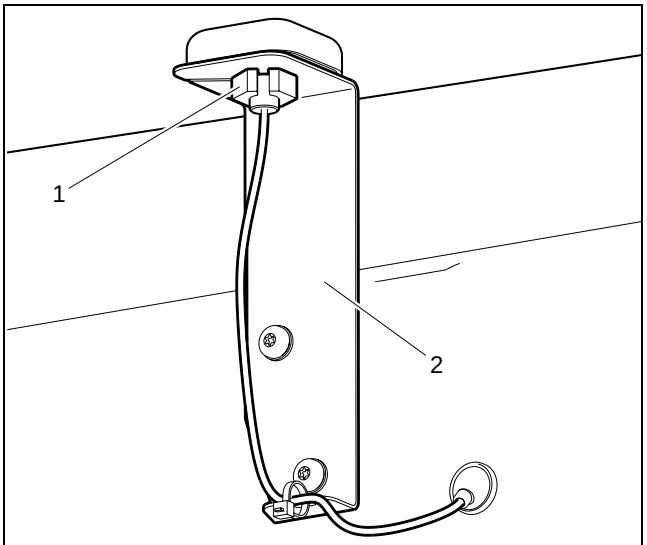
1. Passenger-Side Cab Door
2. Overhead Commodity Harness
3. Antenna Cable
4. Antenna Pigtail Connector

Fig. 4, Antenna Connector (daycab)



1. Right-Hand Sleeper Dome Light
2. Interior Wiring
3. GPS Antenna

Fig. 5, Dome Light Connections



1. Antenna Mounting Nut
2. Antenna Bracket

Fig. 6, External Antenna (daycab)

700 — Diagnostic Overview

All testing of the GPS and cellular reception must be done outside, and at a distance of at least 40 feet (12 meters) from any buildings. This ensures adequate GPS signal strength and good cellular reception.

Diagnosing Virtual Technician requires access to the unit to view the LEDs. The LEDs provide diagnostic information needed by the technician and the CSC (Customer Support Center). To access the unit, remove the sunglass holder from the passenger side of the overhead console and detach the VT box from the hook and loop tape mounting. To diagnose the unit, turn the ignition to the ON position.

There are seven LEDs visible on the module. If no LEDs light up with the ignition ON, diagnose supplied power and ground to the unit. See **Table 1** for the Virtual Technician ECU, and **Table 2** for Virtual Technician HU.

Diagnostic LEDs, Virtual Technician ECU			
Name	**Color**	**Function**	**Action**
DL1	Red	**Red Blink (1Hz)**: J1708 connectivity (disabled).	Red is the normal and expected state. There is no J1708 databus connection.
DL2	Red and Green	**Red Blink (1Hz)**: J1939 connectivity. No J1939 activity detected (device is awake). **Green Blink (1Hz)**: J1939 activity detected (device is awake).	Green blink is expected. If LED is blinking red diagnose J1939 connectivity issue at the terminals. The LED will blink red when the VT is awake but the ignition is OFF. The VT remains awake for 2 minutes after the ignition is turned OFF and will flash red during this time.
GSM	Green	**Solid**: GPS connection successful. **One Blink**: Initializing. **Two Blinks**: Acquiring time zone information. **Three Blinks**: Attempting to make a GPS connection.	Solid is expected – if otherwise call the Customer Support Center for further instruction.
GPS	Green and Amber	**Solid**: Satellites acquired. **One Blink**: Acquiring satellites.	Solid green when the satellite is acquired with the external antenna, and solid amber when the satellite is acquired with the internal antenna. Amber when no external antenna is connected.
Status	Green	**Solid**: Engine running. **One Blink**: Engine not running; no data to send. **Two Blinks**: Data is available to be sent. **Four Blinks**: GPS storage log is full.	Refer to J1939 fault codes if a problem is suspected.
AUX	Red	**Solid**: GSM Modem Comm. Error, or panic line is active. **Two Blinks**: Not Used. **Three Blinks**: GSM modem is not starting up. **Four Blinks**: SIM Card read error. **Five Blinks**: GSM CTS (clear-to-send) line is active.	Refer to J1939 fault codes if a problem is suspected.
Tamper	Red	Disabled	N/A

Table 1, Diagnostic LEDs, Virtual Technician ECU

Diagnostic LEDs, Virtual Technician ECU			
Name	**Color**	**Function**	**Action**
DL1	Red and Green	**One Red Blink (1Hz)**: J1708 connectivity (disabled).	Red is the normal and expected state. There is no J1708 databus connection.
DL2	Red and Green	**One Red Blink (1Hz)**: J1939 connectivity. No J1939 activity detected (device is awake). **One Green Blink (1Hz)**: J1939 activity detected (device is awake).	Green blink is expected. If LED is blinking red diagnose J1939 connectivity issue at the terminals. The LED will blink red when the VT is awake but the ignition is OFF. The VT remains awake for 2 minutes after the ignition is turned OFF and will flash red during this time.
GSM	Green	**Solid**: Connected. **One Blink**: Initializing.	Solid is expected – if otherwise call the Customer Support Center for further instruction. NOTE: The VT must be in a 2G network service area.
GPS	Red and Green	**Solid Green**: Satellites acquired. **One Green Blink**: Acquiring sattelites using external GPS antenna. **One Red Blink**: Acquiring sattelites using internal GPS antenna.	Solid green when the satellite is acquired with the external antenna, and solid amber when the satellite is acquired with the internal antenna. Amber when no external antenna is connected.
Status	Green	**Solid**: Engine running. **One Blink**: Engine not running; no data to send. **Two Blinks**: Data is available to be sent.	Refer to J1939 fault codes if a problem is suspected.

Table 2, Diagnostic LEDs, Virtual Technician ECU

701 — Fault Codes

NOTE: The VT ECU source address (SA) is usually 74. Due to the addition of other telematics devices, SA 74 may be taken by another ECU. In this case the VT ECU will be assigned another source address. To reset the VT back to address 74, the 4 pin power connector must be disconnected for 5 seconds then reconnected.

Fault Codes				
Fault	**SPN**	**FMI**	**Details**	**Action**
GPS Antenna Shorted	524286	4	Center lead shorted to ground or cable ground.	Check the antenna cable; replace GPS Antenna if necessary
GPS Not Connected	524286	5	Antenna open or cut.	Attach GPS Antenna. Replace Antenna if wiring damaged
NAND Full	524285	0	Full	Contact CSC/ Replace ECU
NAND ++Checksum Error	524285	2	Error	Contact CSC/ Replace ECU
NAND I/O Error	524285	11	Cannot read/write.	Contact CSC/ Replace ECU
RTC Error (real time clock)	524282	11	VTECU RTC out of range	Contact CSC/ Replace ECU

Table 3, Fault Codes

702 — DL1 and DL2 Alternate Functionality

These LEDs indicate other behavior than those indicated at startup:

- **Fast alternating red DL1 and DL2 blinks**: indicates that the device is booting.
- **Fast-alternating green DL1 and DL2 blinks**: indicates that a new firmware file is detected and is being loaded.
- **Solid red DL1 and OFF (dark) DL2**: indicates that the device is updating the vehicle interface firmware.

703 — External Antennas

There are two SMA connectors on the VT ECU module. One connector is for an external GPS antenna, and the other is for an external GSM antenna. The GSM antenna is mounted directly to the ECU.

704 — Vehicle Fault Monitoring

When the VT ECU receives a new fault code, it compares the received message to a list stored internally. If the fault code is less than 24 hours from the last occurrence, it will be ignored. New fault codes are added to the list and the appropriate information is uploaded to the Zonar server.

705 — Ring Buffer Files

The VT ECU is capable of generating diagnostic ring buffer files. A ring buffer file is a recording of J1939 databus activity over a predefined period. This information is sent directly to the CSC for analysis.

800 — Virtual Technician ECU Connector Reference

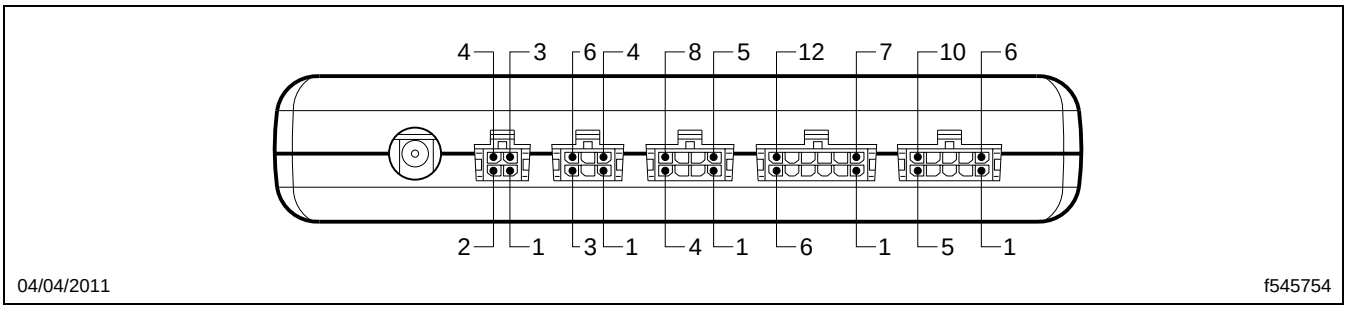


Fig. 7, Connector Reference, Virtual Technician ECU

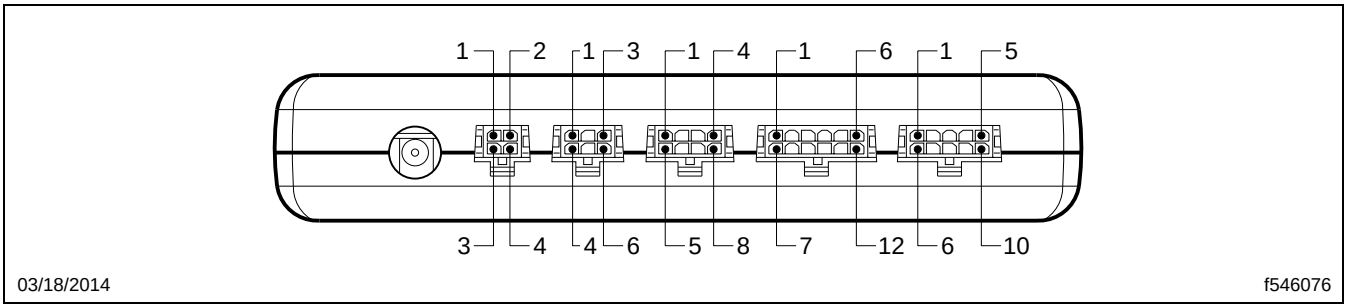


Fig. 8, Connector Reference, Virtual Technician HU

Power Connector			
Connector	**Pin**	**Name**	**Notes**
4-Pin	1	Battery	Circuit 433 from PNDB F3
	2	Ignition	Circuit 81C from splice pack in the dash.
	3	Ground	From splice pack in the dash.
	4	—	—

Table 4, Power Connector

Vehicle Communication Connector		
Connector	**Pin**	**Name**
10-Pin	1	J1939 –H
	2	NC
	3	—
	4	NC
	5	NC
	6	J1939 –L
	7	NC
	8	NC
	9	NC
	10	NC

Table 5, Vehicle Communication Connector

Table of Contents

500 — Terms and Abbreviations

CNG—Compressed Natural Gas

FMM—Fuel Management Module

PRD—Pressure Relief Device

ECU—Electronic Control Unit

PRV—Pressure Relief Valve

psi—Pounds per Square Inch (pressure measurement)

501 — General Information

The CNG block diagram shows major components of the system from the tank to the engine.

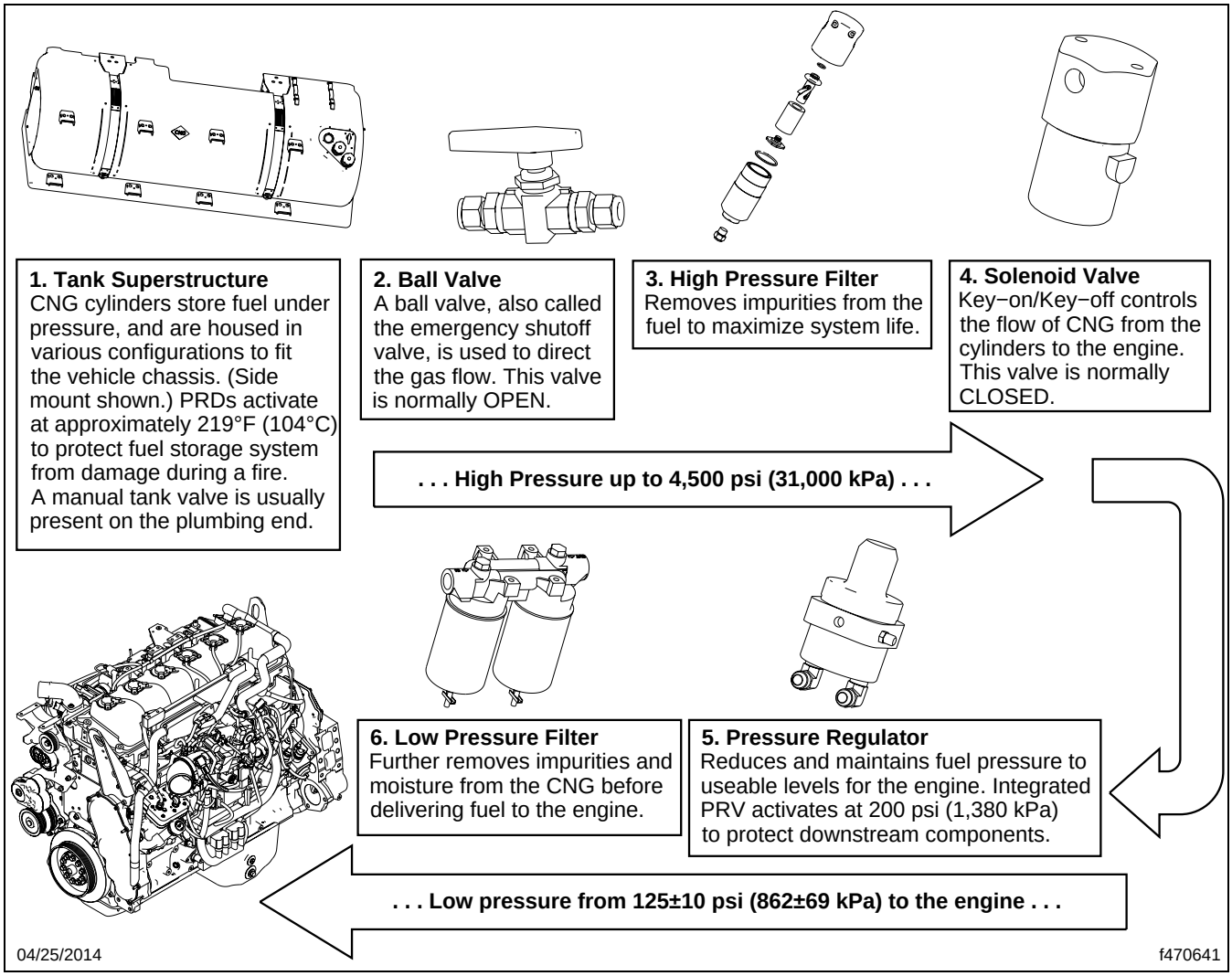
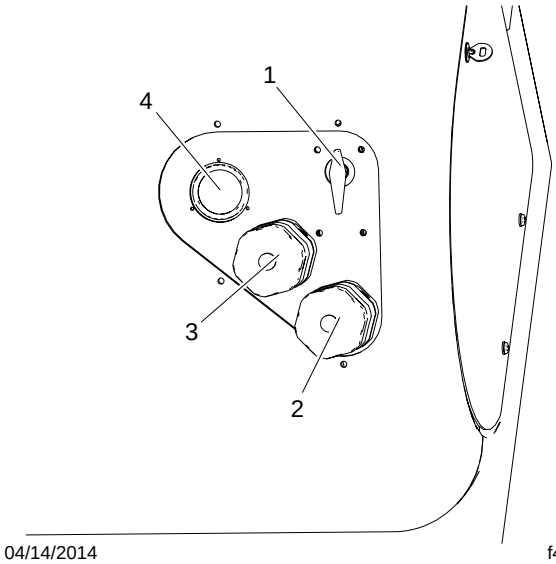


Fig. 1, Basic CNG Block Diagram

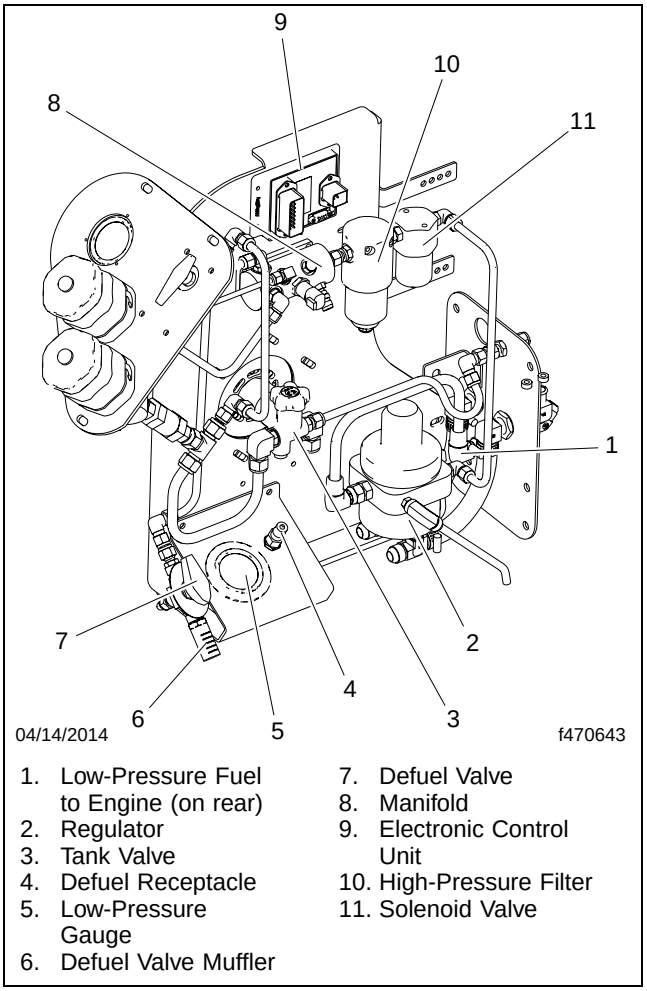
600 — Component Locations

An integrated fuel management module (FMM) unit is used for side-of-rail mounted CNG tanks.



1. Main Valve
2. Transit Fill Receptacle with Cap Attached (tether not shown)
3. Fill Receptacle with Cap Attached (tether not shown)
4. High-Pressure Gauge

Fig. 2, Fuel Management Module



1. Low-Pressure Fuel to Engine (on rear)
2. Regulator
3. Tank Valve
4. Defuel Receptacle
5. Low-Pressure Gauge
6. Defuel Valve Muffler
7. Defuel Valve
8. Manifold
9. Electronic Control Unit
10. High-Pressure Filter
11. Solenoid Valve

Fig. 3, FMM Components

700 — Troubleshooting, "No Crank" Condition

Theory of Operation

The FMM is equipped with safety caps to prevent the vehicle from starting while fueling. After fueling, the fuel fill caps must be locked in place to allow the vehicle to start. Under normal operating conditions, the starter crank signal is passed through the ECU in the FMM when the fuel fill caps are properly installed. A "no crank" condition that is associated with the CNG fuel system can be a result of:

- the caps not being properly secured,
- a problem on the Agility Fuel Systems side with the driveaway protection feature, or a wiring fault to or from the FMM.

NOTICE

While performing these tests, do not crank the starter for more than 30 seconds. Allow 2 minutes between each cranking of the starter to allow the starter to cool. Allowing the starter to overheat may cause damage to the starter or wiring.

Diagnostic Tests

1. Check the installation of the fuel fill caps.

   Ensure that the caps are fully locked into place on the fuel fill receptacle, and completely tightened.

   Are the caps in place?

   NO → Put them on and completely tighten them.

   YES → Go to test 2.

2. Verify that the crank signal is being delivered to the Agility Fuel Systems ECU.

   Check pin "G" (Cir 472S) of the 8-pin connector on the FMM end of the chassis harness for a starter engage signal while the key is being held in the START position.

   Is the signal present on pin "G"?

   NO → Troubleshoot the starter relay signal on the chassis harness (Cir 472S).

   YES → Go to test 3.

3. Verify that the crank signal is passed through the Agility Fuel Systems ECU.

   Check pin "F" (Cir 49K) of the 8-pin connector on the FMM end of the chassis harness for a starter engage signal while the key is being held in the START position.

   Is the signal present on pin "F"?

   NO → Contact Agility Fuel Systems at 949-267-7745.

   YES → Go to Starting and Charging Troubleshooting in **P01.01** of the *Cascadia Troubleshooting Manual*.

IMPORTANT: To temporarily disable the driveaway protection feature in order to move the vehicle, locate and disconnect the single pin connectors inside the FMM by the fill receptacles, and connect the harness side green and black single pin connectors with a jumper wire.

701 — Troubleshooting, "Crank/No Run" Condition

Theory of Operation

For normal operation, adequate fuel delivery to the engine from the CNG storage and fuel management system is required. Delivery pressure from the FMM can be observed at the low-pressure gauge, and is regulated to a stable 125 psi (862 kPa). Insufficient delivery pressures can be caused by any of the following:

- Insufficient pressure in the CNG storage tanks (< 500 psi [3448kPa]).
- The shutoff valves at the tank, or the main shutoff valve (sometimes referred to as the quarter turn valve) are not opened.
- The solenoid shutoff valve is not functioning properly.

The solenoid valve is a normally closed shutoff valve that allows fuel to pass to the engine when energized under the following conditions:

- The solenoid is powered continuously when the key is in the ON position and the engine is running, or when the key is in the START position.
- The solenoid is powered for 30 seconds after the door is opened to prime the system. (The door must have been closed for long enough for the dome lights go out before this feature resets).

Diagnostic Tests

1. Verify that there is high-pressure fuel supplied to the FMM.

   Ensure that the shutoff valves at each tank and the main shutoff valve are open, and observe the high-pressure gauge.

   Is the tank pressure above 500 psi (3448 kPa)?

   NO → The tanks are empty.

   YES → Go to test 2.

2. Verify that the solenoid valve is receiving an energize signal.

   Measure the voltage on pin "C" (Cir 48C) of the 8-pin connector on the FMM end of the chassis harness while the key is being held in the START position.

   Is the signal (+12V) present on pin "C"?

   YES → Go to Test 3.

   NO → Troubleshoot for a wiring fault on Cir 48C.

   If a wiring fault is a blown fuse, check the solenoid coil resistance at room temp (normal range is 7.1 Ohm±0.5 Ohm). If it is out of range, contact Agility Fuel Systems at 949-267-7745.

3. Verify that the solenoid valve is operating properly.

   When the solenoid valve is energized (opened), fuel delivery, as measured at the low-pressure gauge, should be above 100 psi (690 kPa).

   Is the low-pressure gauge showing delivery pressure above 100 psi (690 kPa)?

   NO → Contact Agility Fuel Systems at 949-267-7745.

   YES → Check the low-pressure filter by opening the petcock on the bottom of the filter while the solenoid is energized (see above).

   Hissing indicates the delivery of fuel to the engine.

   If any liquid is expelled, it may be a sign of fuel contamination. Refer to Cummins engine troubleshooting.

702 — Poor Engine Performance

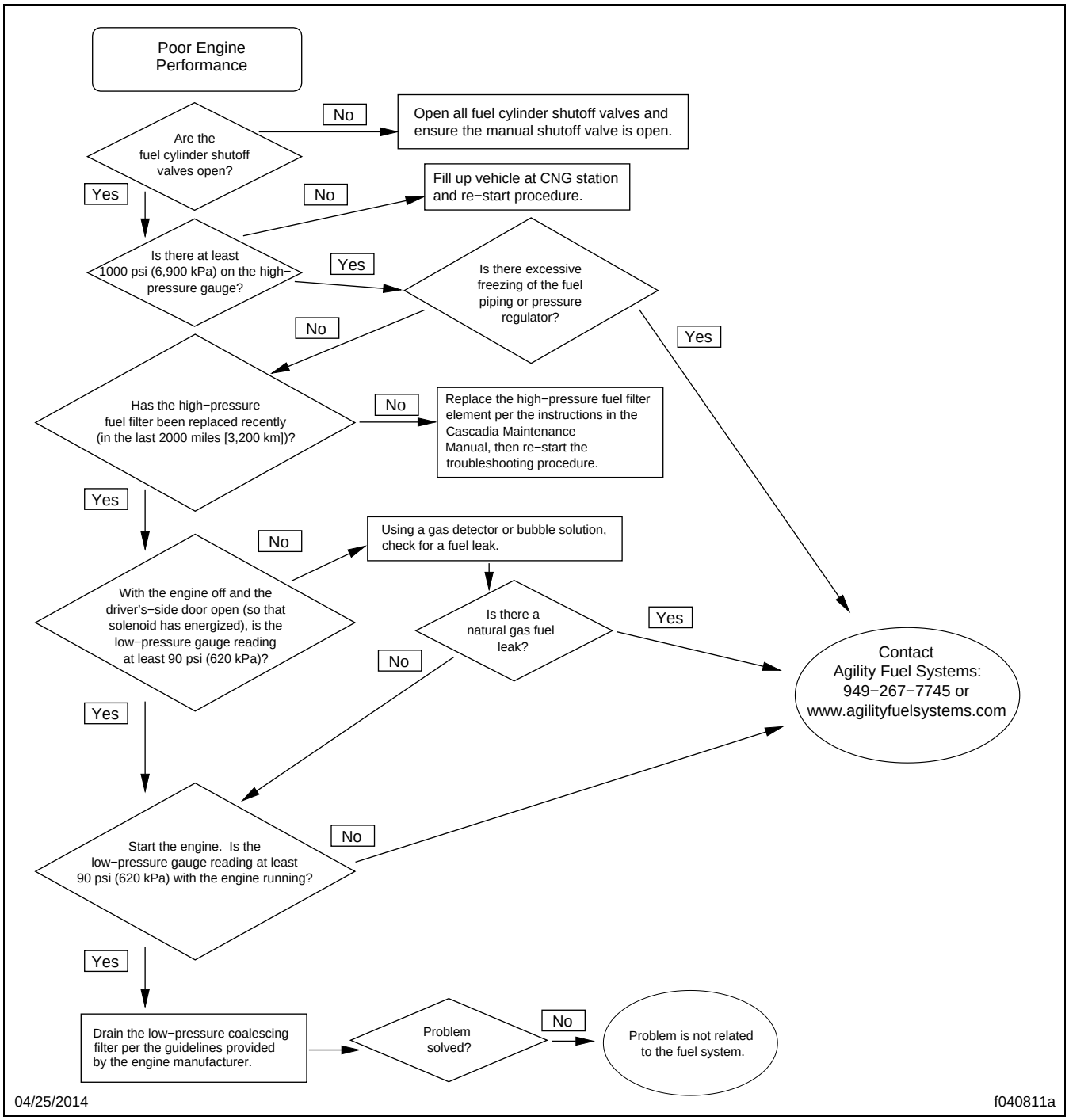


Fig. 4, Flow Chart: Poor Engine Performance

703 — Dash Mounted Gauge Reading Incorrectly

Theory of Operation

The fuel level sending unit senses pressure from a manifold in the FMM and sends an electrical signal to the ECU, which interprets pressure and temperature data and outputs the temperature-compensated fuel level signal to the dash display for the driver.

Diagnostic Tests

1. Check the chassis harness wiring using the "Fuel Level Sensor Problem" detection functionality.

   1.1 With the key in the ON position, unplug the 8-pin connector on the FMM end of the chassis harness.

   1.2 Observe the dash instrument cluster to see if the fuel gauge goes to empty and/or look for the following fault code in the driver message center. (Parked Screens/Menus > Diagnostics):

   - Fuel Level Sensor Problem Detected > Diagnostic Code SPN 96, FMI 55

   Does the fuel gauge go to empty and/or the fault code noted appear in the driver message center?

   NO → Troubleshoot the fuel gauge wiring.

   YES → Go to test 2.

2. Check for power from the chassis harness to the Agility Fuel Systems ECU.

   Check pin "D" (fuel level sender power) on the 8-pin connector, on the FMM side of the chassis harness, for +12V with key in the ON position.

   Is the power being supplied to the FMM on pin "D"?

   YES → Contact Agility Fuel Systems at 949-267-7745.

   NO → Troubleshoot Cir 81C for a wiring fault (and/or fuse 11 in the PDM).

704 — Leak Check

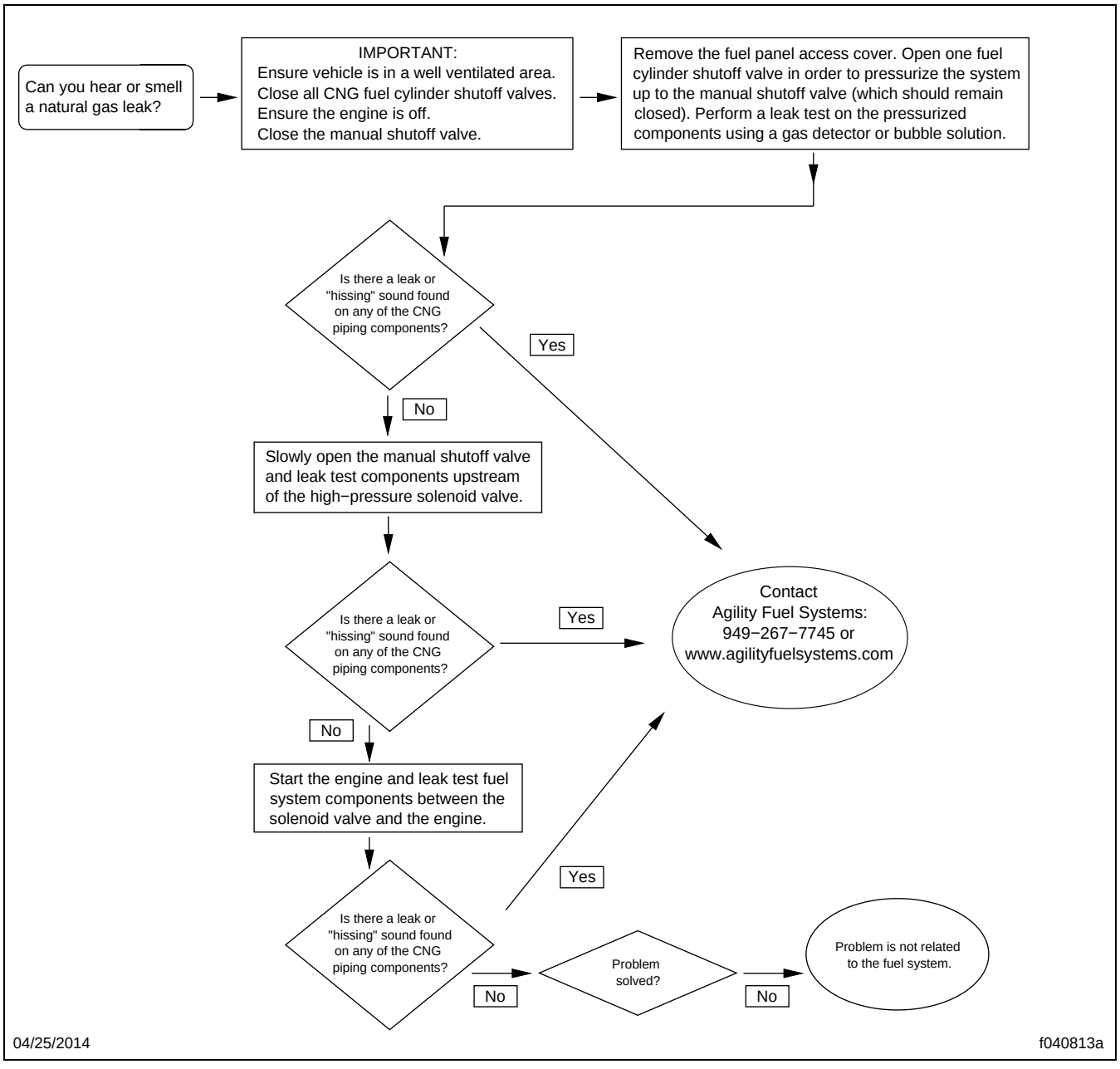


Fig. 5, Flow Chart: Gas Leak