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500 — Terms and Abbreviations

ABS—Antilock Braking System

ATC—Automatic Traction Control

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

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

ESC—Electronic Stability Control

ESC Module—Electronic Stability Control System 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.

ICU—Instrumentation Control Unit

LBCU—Light Bar Control Unit

MSF—Modular Switch Field

RSA—Roll Stability Advisor

RSC—Roll Stability Control

SAE—Society of Automotive Engineers

SAS—Steering Angle Sensor

501 — General Information

Freightliner Cascadia™ vehicles are equipped with a Meritor WABCO E-Version Antilock Braking System (ABS) with a cab-mounted electronic control unit. The ABS is an electronic wheel speed monitoring and control system that works with the standard air brake system. It passively monitors vehicle wheel speed at all times, then controls wheel speed during emergency stops. As a result, the driver has full control of braking until the ECU senses that a lockup is about to occur.

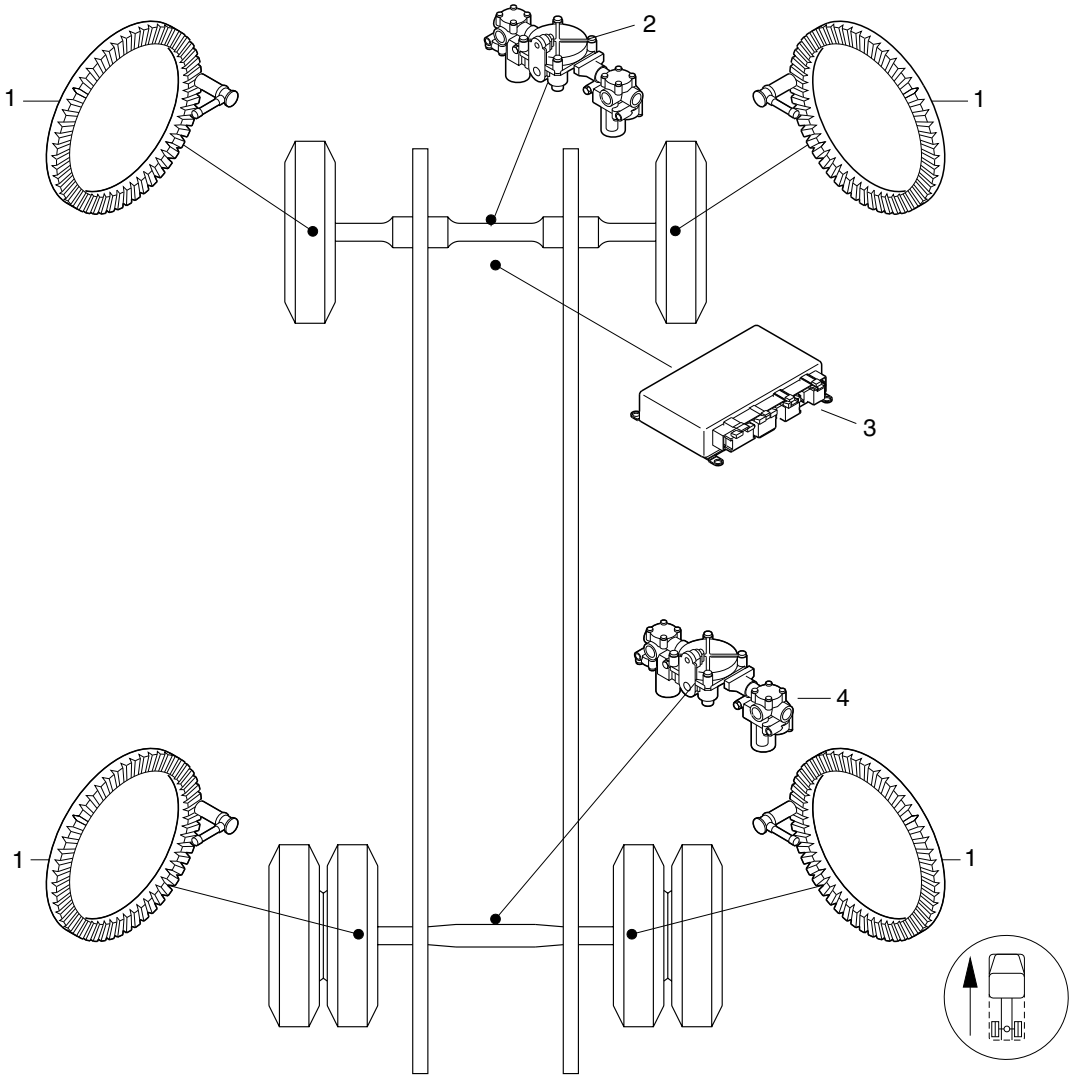
⚠ CAUTION

The size of the tires installed at the factory is programmed into the Antilock Braking System Electronic Control Unit (ABS ECU). Installing different size tires could result in a reduced braking force, leading to longer stopping distances and possibly resulting in personal injury or property damage.

The ABS includes signal-generating sensors activated by tone (tooth) wheels located on the hubs of the monitored wheels. See **Fig. 1**. The sensors transmit vehicle wheel speed information to the ECU. According to programmed specifications, the control unit signals the appropriate modulator valve to increase, reduce, or maintain air pressure in the brake chamber. This prevents front and rear wheel lockup, and enhances steering control during emergency braking situations.

Freightliner Cascadia™ vehicles come standard with four-channel ABS; four wheel speed sensors, and four modulator valves (4S/4M). Optional ABS systems are also available; 6S/4M and 6S/6M ABS. Automatic Traction Control (ATC) is optional with any of the standard or optional configurations.

During normal braking conditions, the standard air brake system is in effect. If the vehicle is equipped with ATC, wheel spin is controlled during reduced-traction startup and acceleration.



1. Tone Wheel and Sensor
2. Front Modulator Valve Assembly
3. Electronic Control Unit (ECU)
4. Rear Modulator Valve Assembly

Fig. 1, ABS Component Location (4-channel, 4S/4M system shown)

502 — Principles of Operation

The ABS has an electronic control unit (ECU) that serves as the information processing and command center for the antilock braking system. The ECU is a digital microcomputer that receives and processes vehicle wheel speed information from the sensors. During emergency brake applications, the control unit regulates the braking force applied to each wheel by sending control signals to the modulator valves.

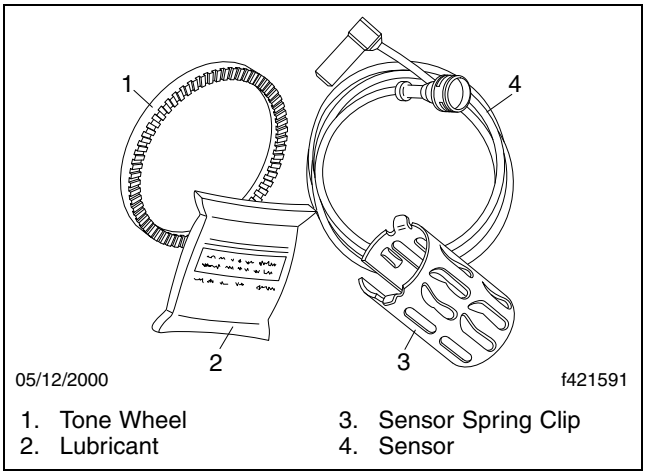
The major components of the Meritor WABCO pneumatic ABS system include the following:

- Wheel speed sensors

- An electronic control unit (ECU)
- Modulator valves (solenoid control valves)
- Automatic Traction Control (ATC) valve (optional)
- ABS warning and wheel-spin indicator lights

503 — Wheel Speed Sensors

The wheel speed sensor assembly is a signal generating device. The assembly includes a sensor (coil wrapped around a magnet), a tone wheel, and a sensor clip that holds the sensor in position near the tone wheel. See **Fig. 2**. Each ABS-controlled wheel has a wheel speed sensor assembly with its tone wheel mounted on the hub. When the vehicle is moving, the teeth on the tone wheel cause interruptions in the magnetic field created by the sensor. The interruptions create electrical pulses that are sent to the electronic control unit where they are used to determine the wheel speed.



1. Tone Wheel
2. Lubricant
3. Sensor Spring Clip
4. Sensor

Fig. 2, Wheel Speed Sensor Components

504 — ABS Electronic Control Unit (ECU)

The ECU is mounted inside the cab behind the lower center dash panel.

The ECU receives signals from the wheel speed sensors and uses them to calculate wheel speed and a vehicle reference speed. The unit is programmed to determine whether the wheels are slowing at a normal braking rate or at a higher rate, requiring ABS braking control. If the ECU senses wheel slip or lockup, the appropriate control circuit signals the modulator valve(s) to release, hold, or reapply braking pressure.

The ECU also shuts down the engine brake and the exhaust brake, if equipped, when a wheel approaches a slip or lockup condition. When the wheels return to a normal rate of speed, the engine and exhaust brakes are reactivated automatically.

The ECU constantly monitors the wheel sensors, modulator valves, automatic traction control valve (if equipped), and the electrical circuitry.

The ABS performs a self-test when the ignition is turned on. During the self-test, the modulator valves and the ATC valve cycle on and off, creating clicking noises that may be heard inside the cab. These clicking noises are

normal and do not indicate an ABS problem. If a problem is detected, the ECU will log a fault code and illumintate the warning lamp.

If, during vehicle operation, the safety circuit senses a failure in any part of the ABS system (such as a sensor, modulator valve, wiring connection, or short circuit), the ABS warning light comes on, a fault code is stored in ECU memory, and the control circuit where the failure occurred is switched to normal braking action. The remaining control circuit retains the ABS effect.

Even if the ABS system is completely inoperative, normal braking is maintained. An exception would be if a modulator valve or valve assembly is damaged and inoperative. These components are an integral part of the air brake system, so normal braking may be impaired or inoperative.

For troubleshooting purposes, the ECU can communicate with the Meritor WABCO PC Diagnostics (recommended), ServiceLink, or other tool capable of reading J1587 fault codes through the diagnostic connector.

IMPORTANT: Do not open the ECU. Opening the ECU to gain access to the internal components will void the warranty.

505 — Modulator Valves

Modulator valves control the air pressure in each affected brake chamber during an ABS operation. Depending on the signal received from the ECU, modulator valves prevent wheel lockup by reducing, maintaining, or increasing brake pressure.

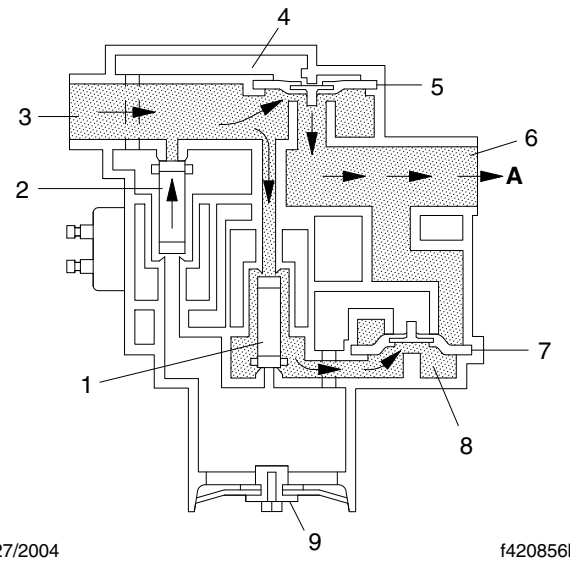
During normal braking applications, the ABS system is inactive and compressed air flows freely through the modulator valves to the brake chambers. Each ABS-monitored wheel has its own modulator valve. The front and rear modulator valve assemblies are mounted on a crossmember near the brake chambers. See **Fig. 1**. The assembly includes two modulator valves, one mounted on each side of a service relay valve.

If the vehicle has an ATC system, the ATC valve is mounted on the control port of the service relay valve. Vehicles with tandem rear axles and a 4S/4M ABS share modulator valves. One wheel is sensed but the modulator valve controls both wheels on a side.

Each modulator valve assembly includes two solenoid control valves (one supply and one exhaust) and two diaphragms. See **Fig. 3**.

- The supply diaphragm opens and closes an air passage between the supply port and delivery port. It is controlled by the supply solenoid valve.
- The exhaust diaphragm opens and closes an air passage between the exhaust port and the delivery port. It is controlled by the exhaust solenoid valve.

The ECU energizes different combinations of these solenoid valves to perform four functions: normal braking (without ABS control), ABS brake release (exhaust), ABS brake hold, and normal brake reapply.



NOTE: Both solenoid valves are closed (de-energized). The modulator valve is shown in the braking configuration with increased air pressure at the supply port (supply diaphragm unseated, exhaust diaphragm seated).

A. Air to brake chamber

1. Exhaust Valve (closed)
2. Supply Valve (closed)
3. Supply Port
4. Supply Pilot Chamber
5. Supply Diaphragm (unseated)
6. Delivery Port
7. Exhaust Diaphragm (seated)
8. Exhaust Chamber
9. Exhaust Port

Fig. 3, Modulator Valve, Normal Brake Control (brake applied)

506 — Normal Brake Control

The normal brake function (without ABS control) operates as follows:

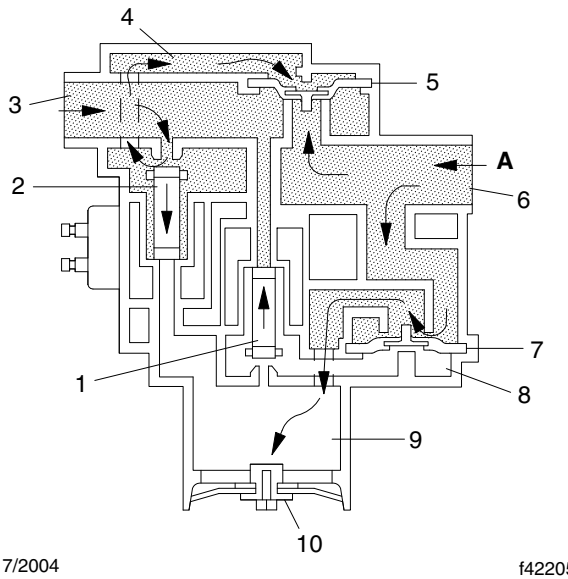
- Before braking, the supply pilot chamber is open to the atmosphere through the exhaust port.
- When the brakes are applied, both solenoid valves in the ABS modulator valve are closed (de-energized).
- Increased air pressure entering the supply port unseats the supply diaphragm by increasing the pressure under the diaphragm. This opens the passage to the delivery port and allows air to flow directly through the valve and into the brake chamber.
- Air also flows through the exhaust valve. The increased pressure under the exhaust diaphragm seats the diaphragm, which closes the passage between the exhaust port and the delivery port.

- When the brake pedal is released, air pressure at the supply port decreases and the higher pressure in the brake chamber reverses the flow of air in the modulator valve. Air now flows from the delivery port to the supply port until the pressure is balanced. This releases the supply diaphragm and closes the passage between the two ports.
- The reduced pressure unseats the exhaust diaphragm and air is vented through the exhaust port to the atmosphere.

507 — Brake Release (ABS Active)

The ABS brake release (exhaust) function is triggered when the ECU determines that the brakes are about to lock. It operates as follows:

- When a wheel is going to lock, the ECU opens (energizes) both solenoid valves in the ABS modulator valve. See **Fig. 4**.
- The open supply valve allows compressed air to enter the supply pilot chamber above the supply diaphragm. The increased pressure seats the diaphragm and stops air from entering the brake chamber.
- The open exhaust valve shuts off the supply of air entering the exhaust pilot chamber. It also creates an opening between the pilot and exhaust chambers.
- Air from the brake chamber enters through the delivery port. The pressure unseats the exhaust diaphragm, creating an opening between the delivery and exhaust chambers. Brake chamber air is then released through the exhaust port.



NOTE: Both solenoid valves are open (energized).

A. Air from brake chamber

1. Exhaust Valve (open)
2. Supply Valve (open)
3. Supply Port
4. Supply Pilot Chamber
5. Supply Diaphragm (seated)
6. Delivery Port
7. Exhaust Diaphragm (unseated)
8. Exhaust Pilot Chamber
9. Exhaust Chamber
10. Exhaust Port

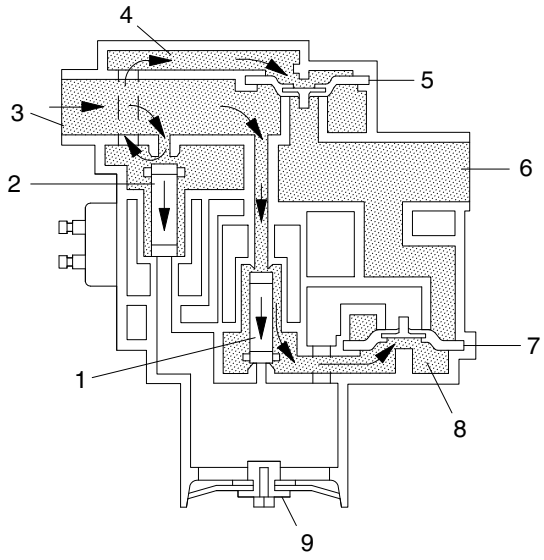
Fig. 4, Modulator Valve, Brake Release (exhaust)

508 — Brake Hold Control (ABS Active)

The ABS brake hold function takes control during an emergency stop when the pedal control valve delivers more air than the brakes can handle without locking.

- The hold function occurs after the ABS has started to control the pressure in the brake chamber by releasing some of the air.
- When enough air is released through the exhaust port to stop the wheel from locking (ABS brake release), the exhaust valve is closed and air pressure is allowed to flow into the exhaust pilot chamber. See **Fig. 5**.
- The increased pressure under the exhaust diaphragm seats the diaphragm, which closes the passage between the exhaust port and the delivery port. This stops the flow of air from the brake chamber to the exhaust port.
- The supply valve stays open to maintain pressure in the supply pilot chamber and keep the supply diaphragm seated. This prevents further buildup of pressure in the brake chamber.

- The remaining air pressure in the brake chamber is held and remains constant for stopping the vehicle in the minimum distance.



NOTE: The supply valve is open (energized); the exhaust valve is closed (de-energized).

1. Exhaust Valve (closed)
2. Supply Valve (open)
3. Supply Port
4. Supply Pilot Chamber
5. Supply Diaphragm (seated)
6. Delivery Port
7. Exhaust Diaphragm (seated)
8. Exhaust Pilot Chamber
9. Exhaust Port

Fig. 5, Modulator Valve, Brake Hold Control

509 — Reapply Brake Control (ABS Active)

The last ABS function is the reapply brake control. To achieve maximum braking, the ECU determines when to reapply the air pressure that the pedal control valve is delivering. When appropriate, both ABS solenoid valves are closed, which returns the system to the normal brake control state shown in **Fig. 11**.

During an ABS event, the ECU cycles the modulator valve(s) through the sequence of ABS valve states (brake release, hold, and reapply) very rapidly in order to control wheel speed. The effect is similar to manually pumping the brakes on a vehicle without an ABS.

NOTE: The driver always controls the maximum amount of pressure applied to the brakes. Pressure to the brake chamber can never be more than the driver applies with the foot pedal. The ABS can override the pedal pressure to provide less brake pressure, but not more.

510 — Automatic Traction Control (ATC)

If the vehicle is equipped with Automatic Traction Control (ATC), the ABS/ATC system automatically reduces wheel spin during low-traction startup or acceleration. If a drive wheel starts to spin faster than the steer axle wheels, the ATC system applies air pressure to brake that drive wheel. This transfers engine torque to the wheel or wheels that have better traction (differential braking).

If two or more drive wheels spin, the ATC reduces the engine torque to provide improved traction, overriding the throttle pressure from the driver.

The ATC valve controls only the brake chambers for the drive wheels. It is mounted on the service relay valve (rear modulator valve assembly).

The solenoid in the ATC valve controls an on/off air valve, which allows or prevents air flow to the control side of the service relay valve. If a wheel spin from one side of the vehicle is detected, the ECU signals the ATC valve to open. This allows compressed air to enter the service relay valve and the normal ABS control system determines which brake to apply.

The ATC function turns on and off automatically; drivers do not have to select this feature. If a drive wheel spins during startup or acceleration, the ATC indicator lamp comes on, indicating the ATC is active. It goes out when the drive wheel stops spinning.

511 — Roll Stability Advisor (RSA)

The roll stability advisor warns the driver when the risk of a rollover is moderate to high. These warnings come in the form of audible alerts as well as messages displayed on the ICU. The ABS ECU contains a sensor that measures lateral acceleration, and the ECU calculates an estimated load. The ABS ECU estimates turn severity relative to rollover limit. The ABS ECU then conveys the risk and severity of the maneuver information to the ICU display. No messages or audible alerts occur if the system determines the vehicle is being driven safely. RSA is not active below 13 mph or when there is a fault in the ABS.

If the vehicle operation reaches the initial threshold of rollover risk, the following message will display briefly, and self-extinguish. See **Fig. 6**.

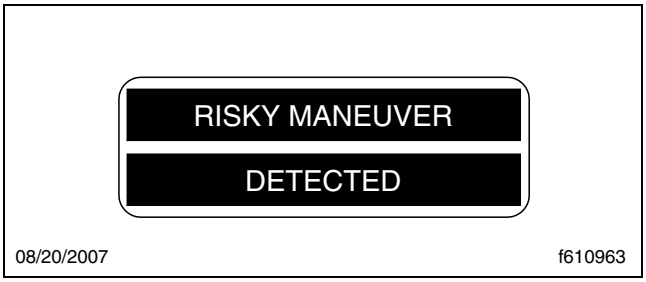


Fig. 6, Risky Maneuver Detected Warning

This is considered the "training point", with the goal to train drivers to avoid getting this message by operating the vehicle below this threshold. Beyond the initial rollover risk threshold, RSA has three levels of rollover-risk alert screens and sounds that can occur.

Level 1: Moderate Rollover Risk— A Level 1 alert includes a 2 second tone along with the alternating screens shown below. See **Fig. 7**. The screens will display for 8 seconds unless the driver acknowledges them sooner.

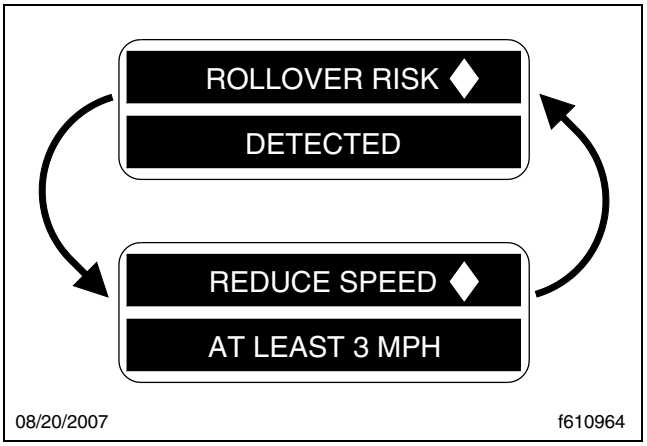


Fig. 7, Rollover Risk Detected Warning

Level 2: High Risk of Rollover— A Level 2 alert includes a 5 second tone along with the alternating screens shown below. See **Fig. 8**. The screens will display for 14 seconds unless the driver acknowledges them sooner.

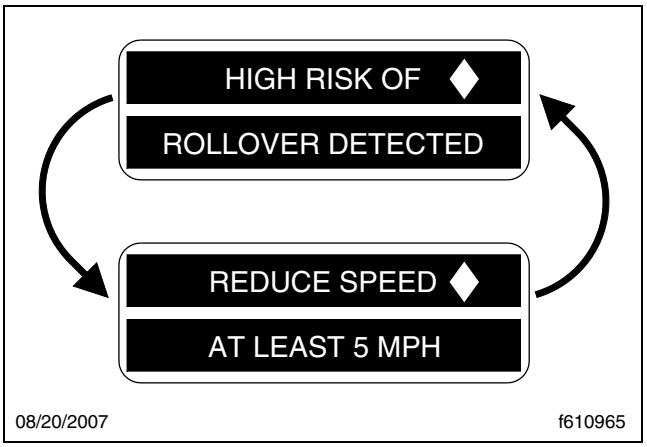


Fig. 8, High Risk of Rollover Warning

Level 3: Very High Risk of Rollover— A Level 3 alert includes a 10 second tone along with the alternating screens shown below. See **Fig. 9**. The screens will display for 20 seconds unless the driver acknowledges them sooner.

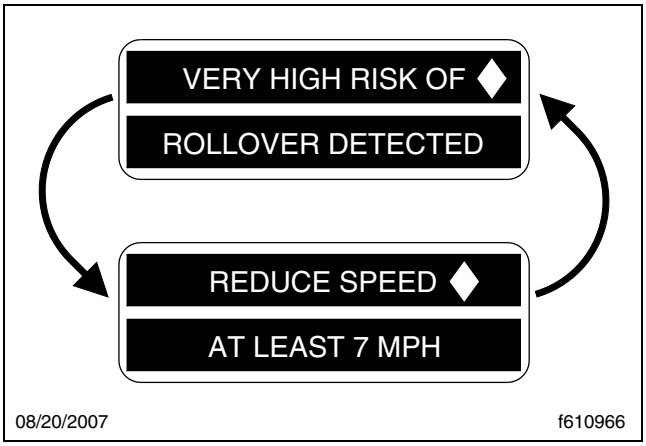


Fig. 9, Very High Risk of Rollover Warning

512 — Roll Stability Control (RSC)

Cascadia vehicles can be equipped with a Meritor WABCO Roll Stability Control (RSC) system in order to help prevent a roll over incident from occurring. The RSC system is an electronic system that passively monitors wheel speed and lateral acceleration, then controls drive axle and trailer axle braking, while decreasing engine torque and applying engine retarder (if equipped) in emergency roll over situations. As a result, the driver has full control over the vehicle until the ABS Electronic Control Unit (ECU) detects a potential roll over and intervenes accordingly.

By combining information on calculated load and turn severity with wheel speed differences (side to side) RSC sends a signal over the J1939 datalink to the engine controller causing the following:

- power to be reduced
- engine brake application and/or tractor rear axle service brake and trailer service brake application

When active, tractor rear brakes are applied using the ATC solenoid valve, while the trailer brakes are applied by the Roll Stability Control solenoid valve, which is the same type used for ATC, that is connected between the pneumatic brake system foot valve and the tractor protection valve. It has an independent air supply from the secondary air tank. In normal operation, the roll stability control valve does nothing and allows control of the trailer brakes from the foot valve. If a rollover is about to happen, the valve opens the air supply from the secondary air tank to the tractor protection valve, which causes the trailer brakes to apply.

The RSC system is automatic; it becomes active when it senses imminent rollover. Indicator lamps, chimes, and/or messages on the instrument cluster will notify the driver if the system became active.

The major components of the Meritor WABCO RSC system include the following:

- Accelerometer integrated into the ABS ECU
- ATC solenoid valve for full drive axle braking
- RSC solenoid valve for full trailer axle braking

513 — Roll Stability Advisor and Control (RAC) Fault Message

If a failure is detected in the roll stability advisor and control system, the following fault message will be displayed in the ICU until the problem is corrected. See **Fig. 10**. Check the ABS system for fault codes.

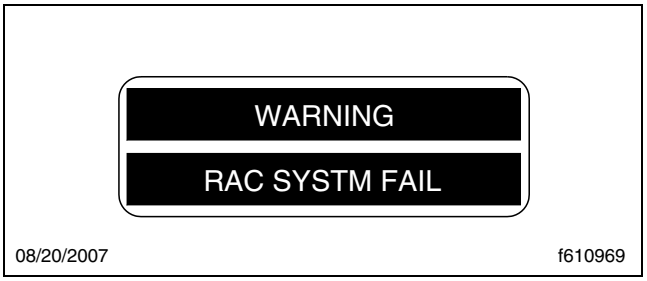


Fig. 10, RAC System Fail Warning

514 — Electronic Stability Control

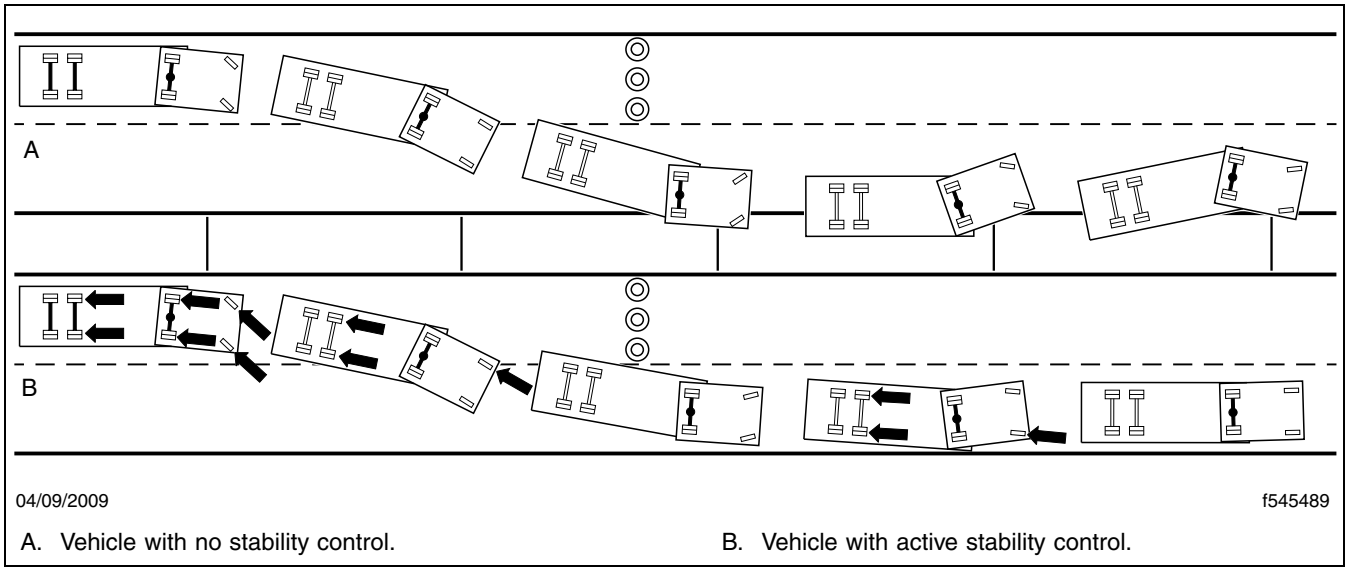
The Electronic Stability Control (ESC) system is a roll stability control system which offers the additional capability of complete directional stability (yaw control) in oversteer and understeer conditions, such as the ability to reduce the likelihood of drift-out or jackknife. The ESC system includes an additional solenoid valve for front axle braking, a brake pressure sensor, a steering angle sensor (SAS), and an Electronic Stability Control ECU (ESC module) with an integrated yaw rate sensor. The additional sensors allow the ECU to determine where the driver is attempting to steer the vehicle and how much brake demand they are requiring in order to more precisely control the vehicle in an emergency situation. The additional front solenoid valve allows for individual wheel braking on the steering axle to provide yaw control.

The ESC system includes the following:

- ATC solenoid valve for full drive axle braking
- RSC solenoid valve for full trailer braking
- Front solenoid valve for full steer axle braking
- Pressure sensor for driver brake demand
- Steering Angle Sensor (SAS)
- ESC module (with integrated yaw rate and accelerometer sensors)

On vehicles equipped with ESC, the ABS module does not house the accelerometer. The accelerometer is located in the ESC module. The ESC system becomes active when a potential rollover or loss of yaw stability is detected.

During a transition from a high to low traction surface, the ESC system may possibly activate if the vehicle is not responding to the drivers input. See **Fig. 11**.



A. Vehicle with no stability control.

B. Vehicle with active stability control.

Fig. 11, Vehicle Traction with Stability Control

Electronic Stability Control Module

The Electronic Stability Control (ESC) ECU is mounted on the chassis, as close to the vehicle horizontal center of gravity as possible.

The ESC module has two sensors, an accelerometer, and a yaw rate sensor. The accelerometer is used to measure lateral acceleration only. When cornering, lateral acceleration causes a force directed at the vehicles center of gravity, and, if high enough, may cause a vehicle to roll. The yaw rate sensor provides rotational sensing, which is used to detect and help prevent understeer, vehicle spinout, or a jackknife. The ESC module has one 4-pin connector that communicates with the ABS ECU.

IMPORTANT: The ESC Module must be mounted exactly as it was installed in production. The WABCO label must be right-side up. The ECU will be perpendicular to the frame rails, and the 4-pin connector on the ESC module will be facing towards the rear of the tractor. Make sure that the ESC Module is securely mounted and cannot move.

515 — ATC Switch (Deep Mud/Snow Switch)

An ATC function switch on the dash allows the driver to select from two levels of drive-axle traction control. In the default position, the ATC reduces drive-axle wheel spin on icy, wet, or sand-covered roads. Pressing the ATC switch increases the available traction on extra soft surfaces like snow, mud, or gravel by slightly increasing the permissible wheel spin. The greater wheel spin may also be used to help burn through a thin layer of ice.

The ATC switch overrides the ATC function. It must be manually selected by pressing the ATC spring-loaded switch briefly after the vehicle is started. The ECU indicates the activation by a constant flashing of the WHEEL SPIN lamp. This mode is disengaged by pressing the ATC switch again or turning the ignition switch off.

The ATC switch is located in a slave Modular Switch Field (MSF). It is hardwired to the tractor ABS ECU—it is not a multiplexed switch.

516 — Tractor ABS Warning Lamp

The tractor ABS warning light (TRACTOR ABS) receives power whenever the ignition switch is turned on. The ground path for this indicator is through the tractor ABS ECU. For the first three seconds after the ignition is turned on, the ABS performs a bulb check during the self test. The bulb will go out if no malfunctions are detected during the self test.

If a fault is detected in the ABS, it will illuminate the tractor ABS warning lamp as long as the fault remains active.

NOTE: If the stored faults are cleared, the tractor ABS warning light remains on until the vehicle is driven above a speed of 4 mph (6 km/h).

517 — ATC/RSC/ESC Indicator Lamp

The ATC/RSC indicator light also receives power whenever the ignition switch is on. If the drive-axle wheels spin or if RSC is active, the ATC/RSC indicator light turns on. See **Fig. 12**.

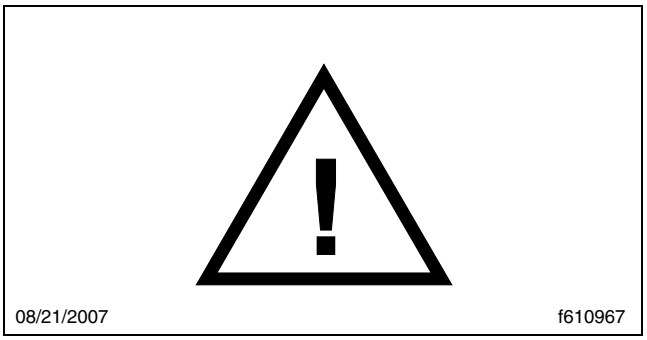


Fig. 12, ATC/RSC/ESC Indicator Light

If the ATC switch is activated, the ABS allows more wheel spin than normal and the ATC/RSC/ESC indicator blinks continuously until the switch is deactivated.

If the ATC/RSC/ESC indicator light stays on during normal vehicle operation, there is a malfunction in the system.

If the vehicle is equipped with ATC and not RSC/ESC, both the ABS and ATC lamps turn on for approximately 3 seconds when the ignition is turned to the ON position, then turn off simultaneously.

If the vehicle is equipped with both ATC and RSC/ESC, both the ABS and ATC/RSC/ESC lights turn on for approximately 3 seconds when the ignition is turned to the ON position, but the ATC/RSC/ESC light will stay lit longer than the ABS light.

518 — Trailer ABS Warning Light

The trailer ABS can be turned on one of two ways depending on whether the vehicle is towing a trailer with ABS capable of Powerline Carrier Communications (PLC).

A. Trailers ABS capable of PLC—When the trailer ABS detects a fault, it sends a message to command the warning light on through PLC to the tractor ABS. The tractor ABS then turns on the lamp by hardwire between the tractor ABS and the trailer ABS warning lamp in the ICU. For more information on PLC, see "Powerline Carrier Communications (PLC) and Trailer ABS Warning Light " below.

B. Trailer ABS not equipped with PLC—When the trailer ABS detects a fault, it turns the trailer ABS warning light on directly by hardwire between the trailer ABS and the ICU.

NOTE: For doubles and triples, the lamp does not distinguish between trailers. A system fault in any of the trailers will activate the trailer ABS warning light.

When the ignition is turned on, a three second bulb check will occur. If no faults are detected, the warning lamp should turn off.

NOTE: When a PLC equipped tractor is connected to a trailer without ABS, at start-up, the lamp will not come on for a bulb check.

519 — Powerline Carrier Communications (PLC) and Trailer ABS Warning Light

Truck and trailer ABS systems built since March 2001 are equipped with special internal electronics that can transmit and receive messages through the power line to each ECU. This method of communication is called powerline carrier communications or PLC.

Each ECU has a separate power supply that passes through a PLC filter. PLC messages are in the form of a frequency modulated signal superimposed over the direct current (DC) power supply. The PLC filter allows the DC power supplies to be separate, while allowing the PLC messages to pass from the trailer power line to the tractor ABS power line. It does this through a series of inductor coils and capacitors. The coils pass DC power while blocking the frequency modulated signal. The capacitors pass the frequency modulated signal from one powerline to the other while blocking the DC power. The filter shares the PLC signal on the separate power lines, while keeping the actual power supplies to the ECUs separate. The filter also prevents interference throughout the rest of the vehicle's electrical system.

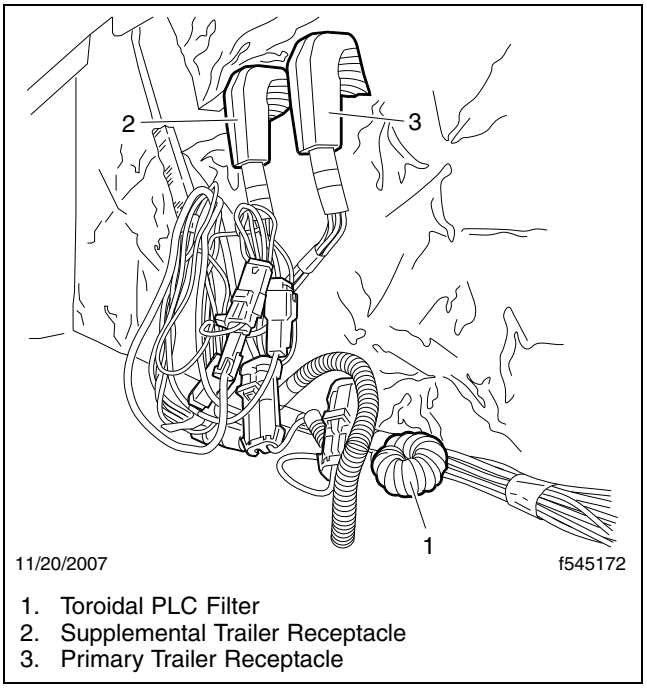
If the trailer ABS ECU detects a fault in the trailer's ABS system, the trailer ABS ECU transmits a message over the power line via PLC, which is received by the tractor ABS. The tractor ABS turns on the trailer ABS lamp on the dash.

When a PLC equipped tractor connects to a PLC equipped trailer, at start-up, the lamp should come on for a few seconds, then turn off if no trailer ABS faults exist.

520 — PLC Filter

As mentioned in the previous paragraphs, the PLC filter allows messages to transmit between the tractor ABS power line and the trailer ABS power line, while remaining separate. All Cascadia™ trucks are equipped with a PLC filter.

Trucks with trailer receptacles mounted directly to the back of the cab have a toroidal style PLC in the harness, on the back wall of the cab or sleeper, below and to the left of the receptacles. See **Fig. 13**. Trucks with trailer receptacles mounted on the chassis use a PLC filter contained in a module mounted to a bracket on the frame crossmember near the receptacles.



1. Toroidal PLC Filter
2. Supplemental Trailer Receptacle
3. Primary Trailer Receptacle

Fig. 13, PLC Filter Location

521 — Tire Size

For proper ABS/ATC operation with the standard ECU, the front and rear tire sizes must be within 14 percent of each other. When the tire-size range is exceeded, system performance can be affected and the warning lamp may come on. Call Meritor WABCO at 1-800-535-5560 if you plan a tire-size difference greater than 14 percent. Calculate the percentage difference of the tire sizes with the following equation:

Percentage Difference = {(steer-axle tire RPM ÷ drive-axle tire RPM) – 1} x 100,

where RPM equals tire revolutions per mile.

522 — Reconfiguration

E-version ECUs memorize the following components if they are connected at power-up:

- ESC Module
- RSC Valve
- Front Solenoid Valve
- Pressure Sensor
- Steering Angle Sensor
- ATC Valve
- Retarder Valve
- Datalink SAE J1939

Once these components have been memorized, the ECU will look for them at each power-up. If a memorized component is not present, the ECU will record a fault. For example, if an ATC valve is memorized, but is not present at the next power-up, the ECU records a fault. This can occur if an ECU is moved from one vehicle to another, and one or more of the memorized components are not available on the new vehicle. If this occurs, use Meritor Toolbox software to re-configure the ECU.

Refer to the Meritor WABCO End of Line (EOL) procedure for the initialization process when replacing major components such as an ECU. In addition, when the Steering Angle Sensor is replaced, or if work was performed on the steering system, it is important that the Steering Angle Sensor is re-calibrated. These procedures can be found in the latest version of the Meritor WABCO Maintenance Manual (MM-0112). This document is available at the Meritor WABCO website.

NOTE: For complete instructions for using TOOLBOX software, refer to the ArvinMeritor "TOOLBOX User's Manual, TP-99102."

523 — Electronic Stability Control Topology

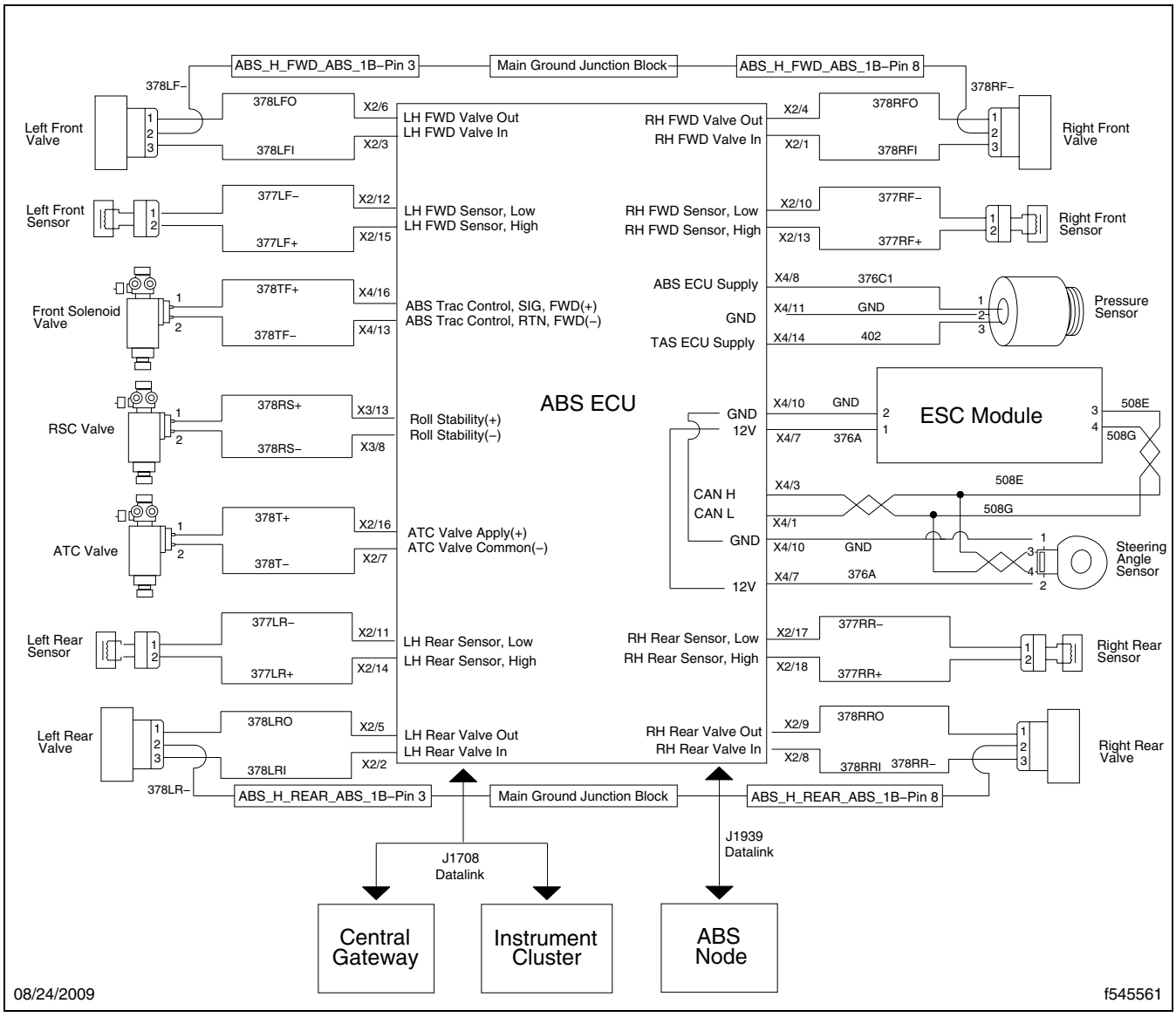
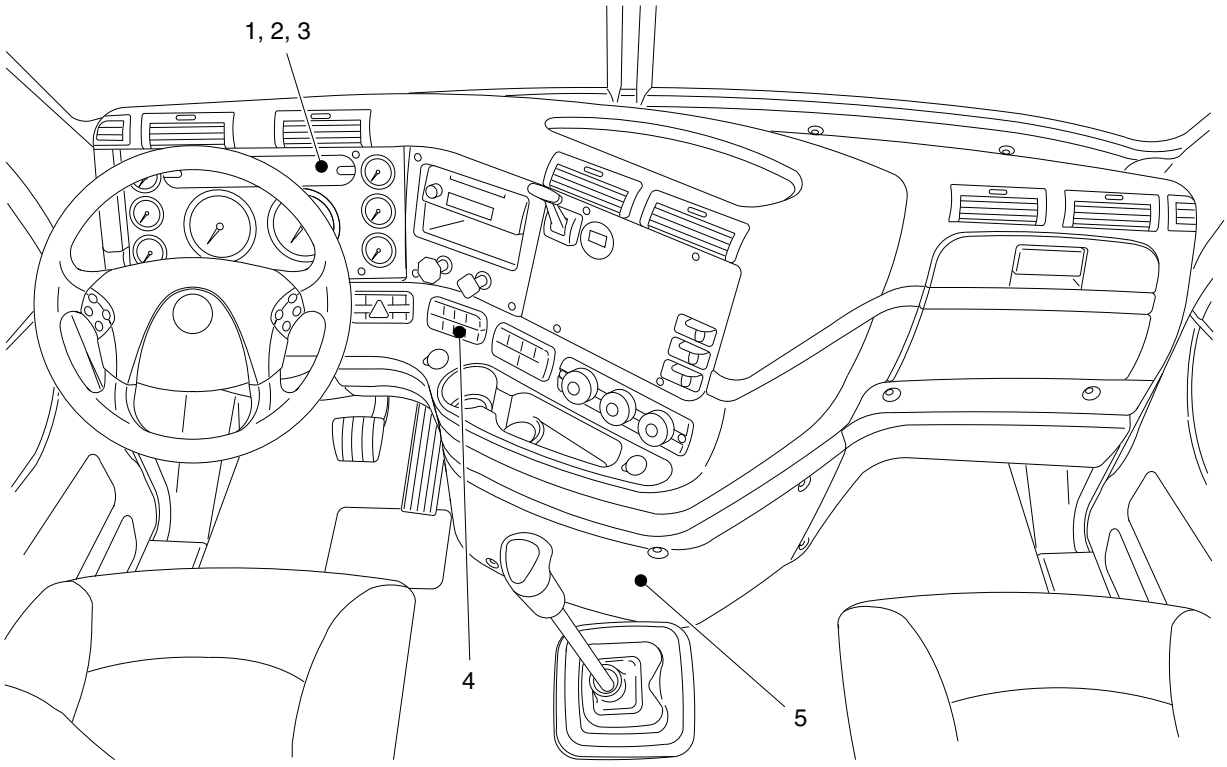


Fig. 14, Electronic Stability Control Topology

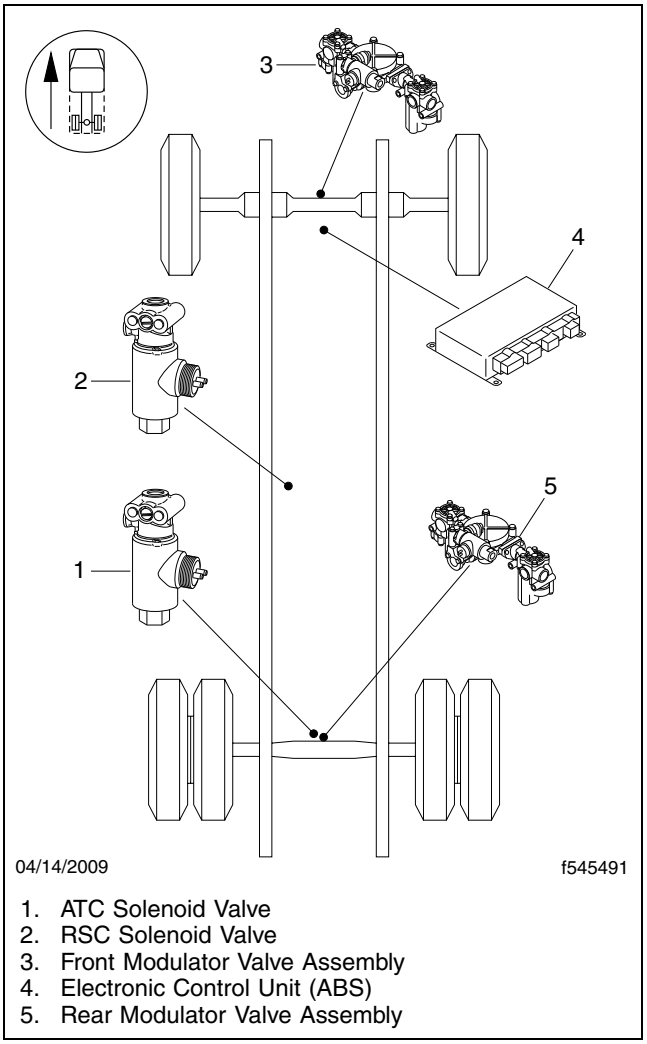
600 — Component Locations



08/21/2007 f610809a

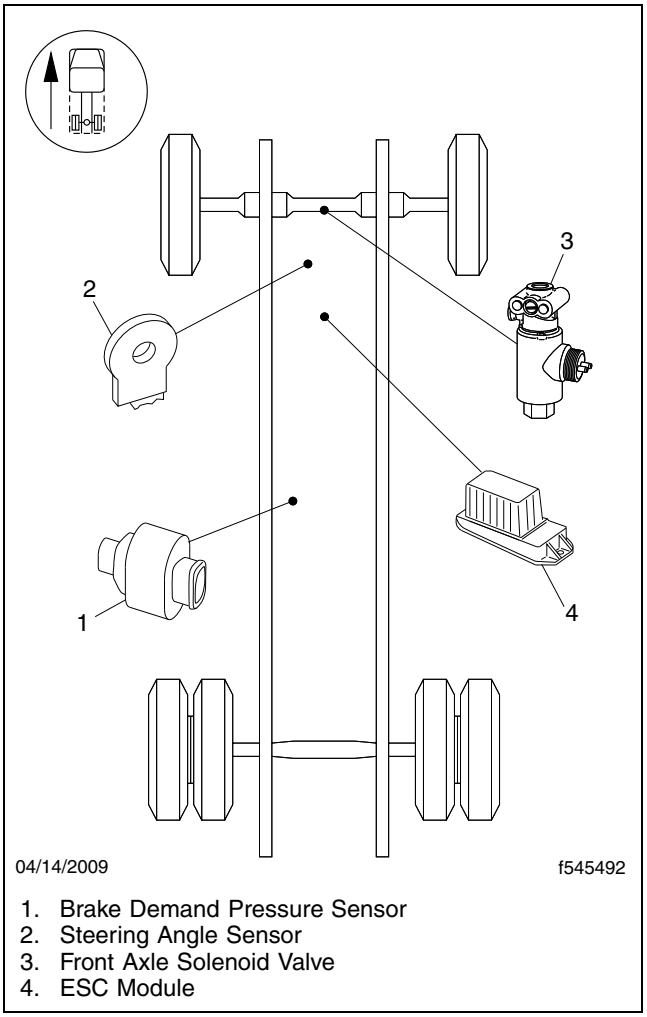
1. Tractor ABS Warning Lamp
2. Trailer ABS Warning Lamp
3. ATC Warning Lamp (Wheel Spin)
4. ATC Switch (Deep Mud/Snow Switch)
5. Tractor ABS ECU

Fig. 15, Component Locations



1. ATC Solenoid Valve
2. RSC Solenoid Valve
3. Front Modulator Valve Assembly
4. Electronic Control Unit (ABS)
5. Rear Modulator Valve Assembly

Fig. 16, Roll Stability Control Component Locations

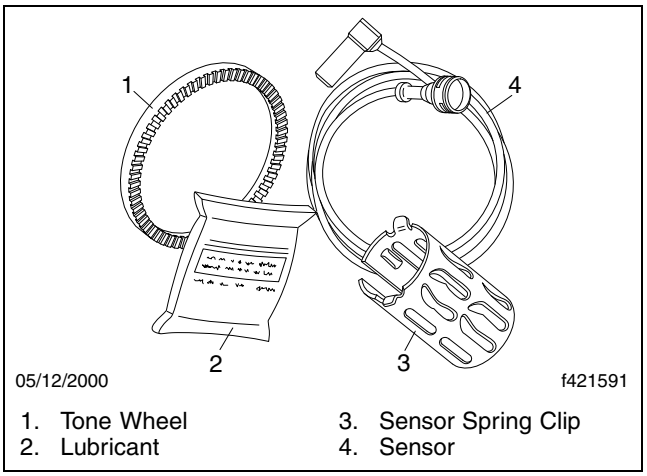


1. Brake Demand Pressure Sensor
2. Steering Angle Sensor
3. Front Axle Solenoid Valve
4. ESC Module

Fig. 17, Electronic Stability Control Component Locations

NOTE: The components in **Fig. 17** are needed in addition to the ones used in the RSC system

601 — Component Details



1. Tone Wheel
2. Lubricant
3. Sensor Spring Clip
4. Sensor

Fig. 18, Wheel Speed Sensor Components

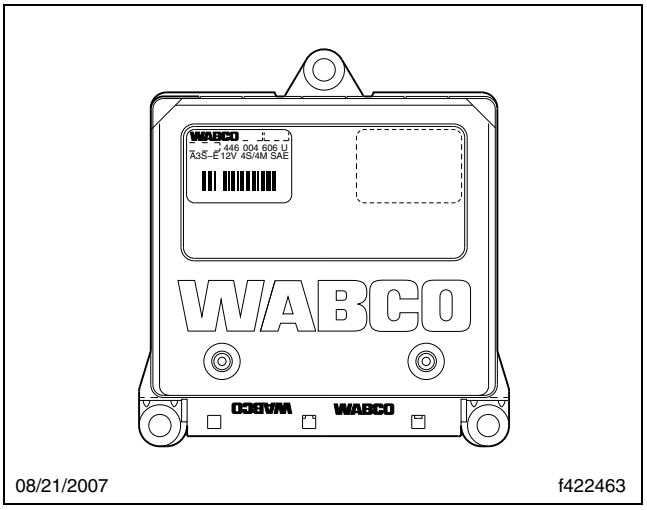
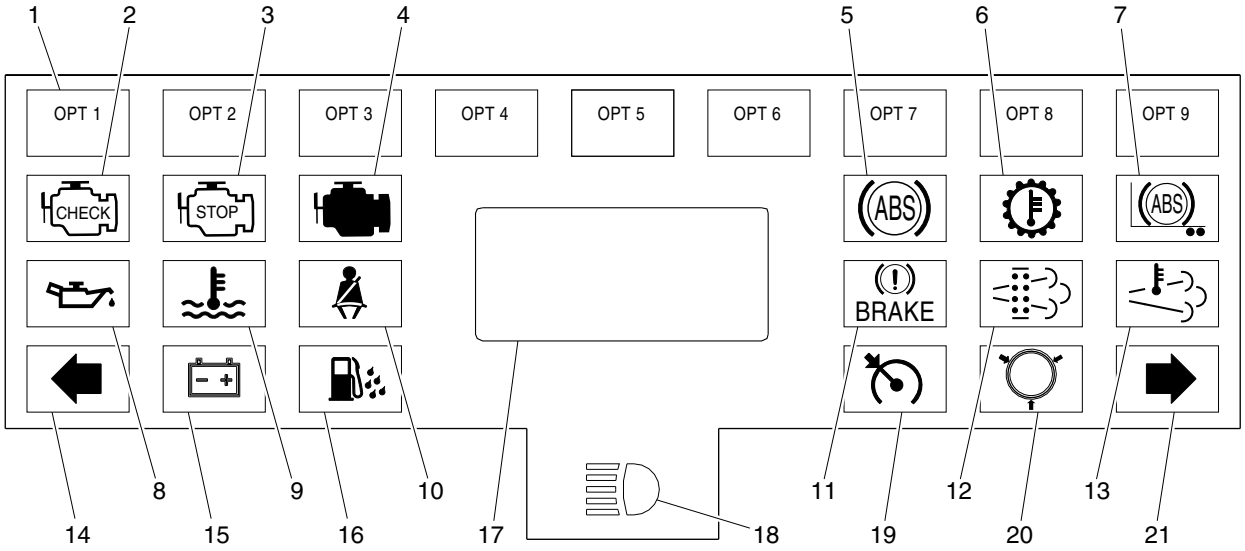
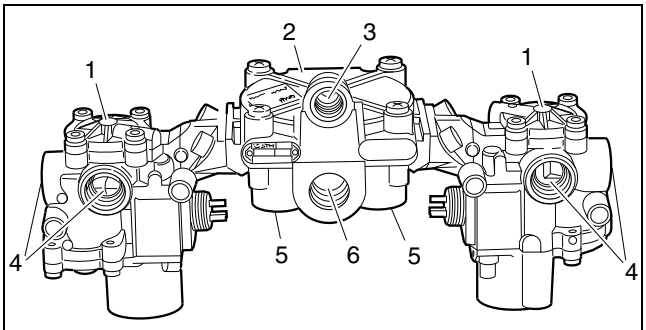


Fig. 19, ECU



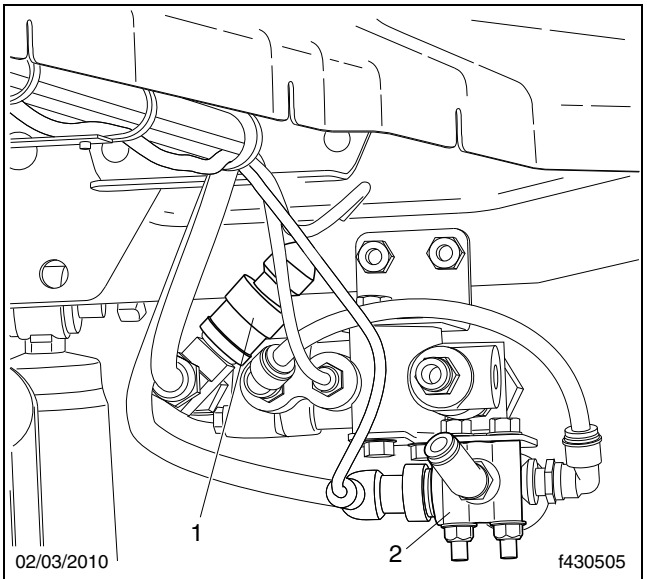
1. Optional
2. Check Engine (yellow)
3. Stop Engine (red)
4. Malfunction Indicator Lamp (yellow)
5. Tractor ABS (yellow)
6. Trans High Temp (yellow)
7. Trailer ABS (yellow)
8. Low Oil Pressure (red)
9. High Coolant Temp (red)
10. Fasten Seat Belt (red)
11. Parking Brake (red)
12. REGEN (yellow)
13. High Exhaust Temp (yellow)
14. Left Turn Signal (green)
15. Low Battery Voltage (red)
16. Water in Fuel (yellow)
17. Driver Display (green)
18. High Beam (blue)
19. Cruise Control (green)
20. Low Air Pressure (red)
21. Right Turn Signal (green)

Fig. 20, LBCU



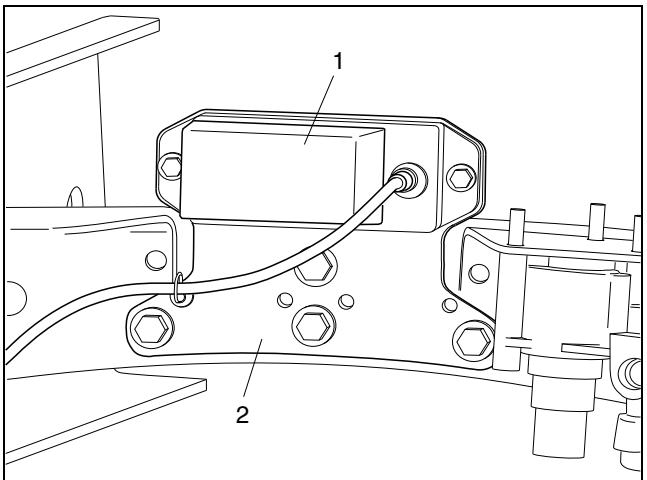
1. ABS Modulator Valve
2. Relay Valve
3. Control Port
4. Modulator Valve Delivery Ports
5. Relay Valve Delivery Ports
6. Supply Port

Fig. 21, Modulator Valve Assembly



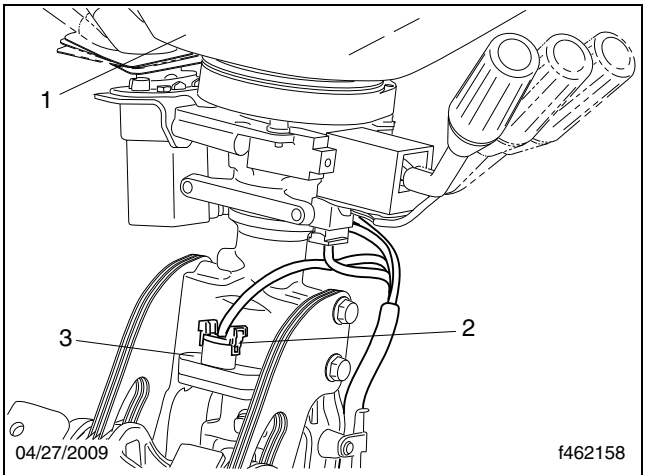
1. Brake Demand Pressure Sensor
2. Roll Stability Control Valve

Fig. 22, Pressure Sensor (mounted on trailer protection valve)



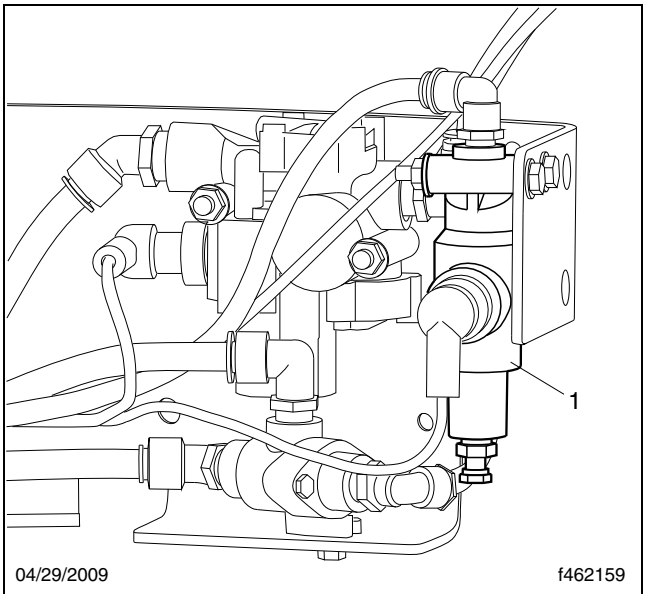
1. ESC Module
2. Crossmember

Fig. 23, Electronic Stability Control Module



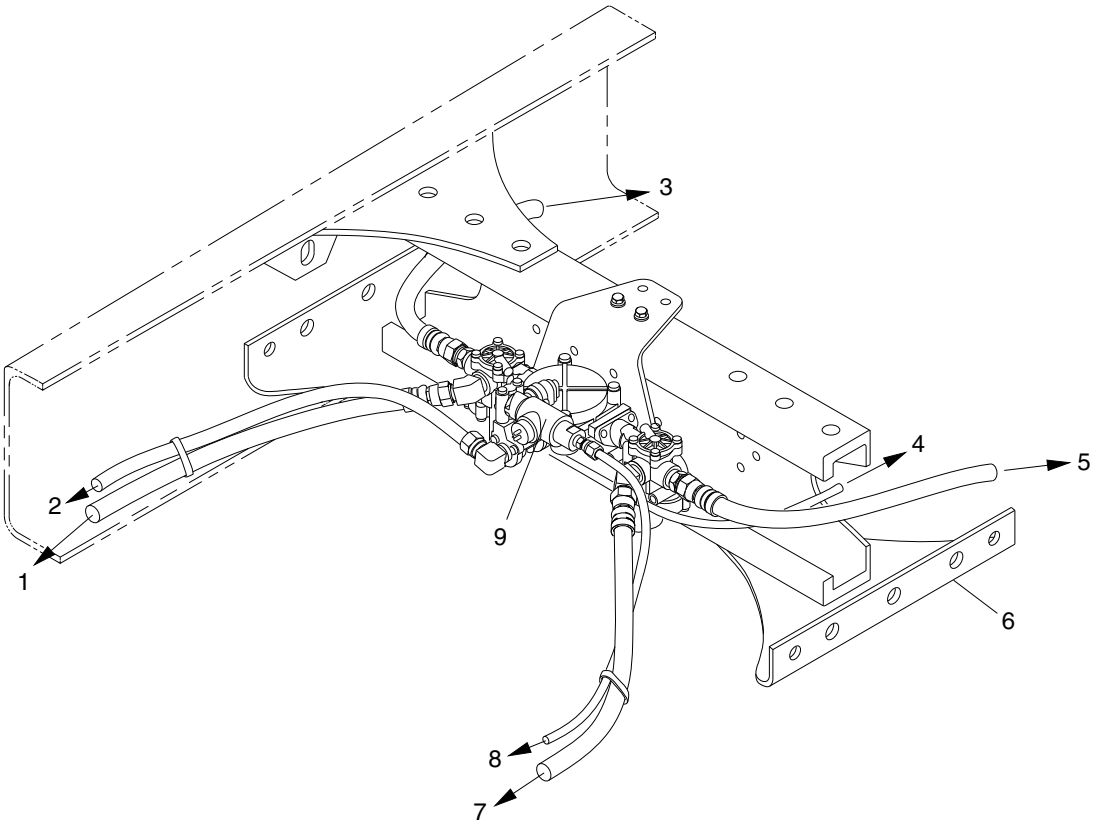
1. Steering Wheel
2. Steering Angle Sensor Connector
3. Steering Angle Sensor

Fig. 24, Steering Angle Sensor



1. Front Solenoid Valve

Fig. 25, Front Modulator Valve Assembly



1. Right Forward Brake Chamber Hose
2. Primary Air Tank Hose
3. Right Rear Brake Chamber Hose
4. Park Brake Quick-Release Hose
5. Left Rear Brake Chamber Hose
6. Crossmember
7. Left Forward Brake Chamber Hose
8. Hose to Foot Valve
9. ATC Valve

Fig. 26, Rear Modulator Valve Assembly with ATC Valve

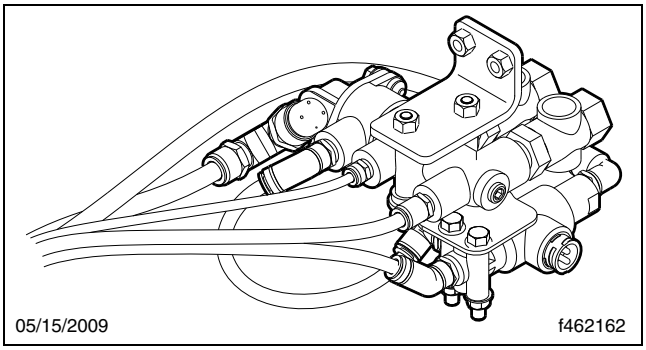


Fig. 27, Roll Stability Control Solenoid Valve mounted to Trailer Protection Valve

602 — Connector Pinout Details

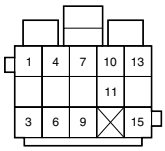
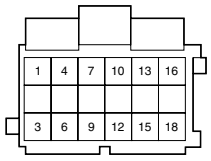
15-Pin X1 ABS ECU Connector			
			
Pin	**Circuit #**	**Wire Color**	**Circuit Description**
1	1939–A	Dark Green	J1939 datalink (–)
2	376F	Orange	Trailer ABS
3	1939+A	Yellow	J1939 datalink (+)
4	GND1	Black	Ground
5	—	—	Not used
6	376T	Orange	ATC switch input
7	376C or 376C4	Orange	+12V ignition
8	376A	Orange	+12V battery
9	GND	Black	Ground
10	1587–A	Orange	J1587 datalink (–)
11	1587+A	Dark Green	J1587 datalink (+)
12	—	—	Ground jumper between pins 9 and 15
13	376S	Orange	ATC/RSC lamp signal
14	—	—	Not used (retarder relay)
15	376L	Orange	Tractor ABS lamp signal (to ICU)

Table 1, 15-Pin X1 ABS ECU Connector

18-Pin X2 ABS ECU Connector			
			
Pin	**Circuit #**	**Wire Color**	**Circuit Description**
1	378RFI	Orange	Right front modulator valve in
2	378LRI	Orange	Left rear modulator valve in
3	378LFI	Orange	Left front modulator valve in

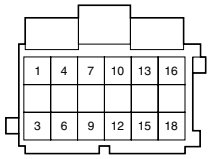
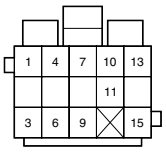
18-Pin X2 ABS ECU Connector			
			
Pin	**Circuit #**	**Wire Color**	**Circuit Description**
4	378RFO	Orange	Right front modulator valve out
5	378LRO	Orange	Left rear modulator valve out
6	378LFO	Orange	Left front modulator valve out
7	378T–	Orange	ATC valve common
8	378RRI	Orange	Right rear modulator valve in
9	378RRO	Orange	Right rear modulator valve out
10	377RF–	Black	Right front wheel speed sensor (–)
11	377LR–	Black	Left rear wheel speed sensor (–)
12	377LF–	Black	Left front wheel speed sensor (–)
13	377RF+	Brown	Right front wheel speed sensor (+)
14	377LR+	Brown	Left rear wheel speed sensor (+)
15	377LF+	Brown	Left front wheel speed sensor (+)
16	378T+	Orange	ATC valve apply
17	377RR–	Black	Right rear wheel speed sensor (–)
18	377RR+	Brown	Right rear wheel speed sensor (+)

Table 2, 18-Pin X2 ABS ECU Connector

15-Pin X3 ABS ECU Connector			
			
Pin	**Circuit #**	**Wire Color**	**Circuit Description**
1	—	—	Not used
2	377LA–	Black	Left third wheel speed sensor (–)
3	378LAI	Orange	Left third modulator valve in
4	—	—	Not used

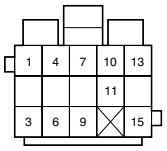
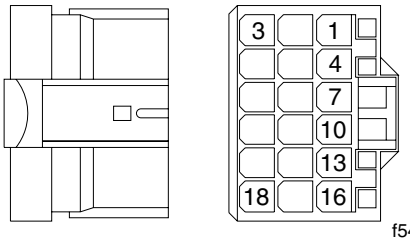
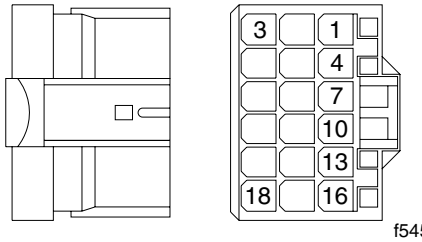
15-Pin X3 ABS ECU Connector			
			
Pin	**Circuit #**	**Wire Color**	**Circuit Description**
5	377LA+	Brown	Left third wheel speed sensor (+)
6	378LAO	Orange	Left third modulator valve out
7	—	—	Not used
8	378RS–	Orange	Roll stability control valve (–)
9	—	—	Not used
10	—	—	Not used
11	377RA–	Black	Right third wheel speed sensor (–)
12	378RAI	Orange	Right third modulator valve in
13	378RS+	Orange	Roll stability control valve (+)
14	377RA+	Brown	Right third wheel speed sensor (+)
15	378RAO	Orange	Right third modulator valve out

Table 3, 15-Pin X3 ABS ECU Connector

18-Pin X4 ABS ECU Connector			
 f545494			
Pin	**Circuit**	**Wire Color**	**Description**
1	50G	Brown/White	ESC CAN-Low
2	—	—	Not Used
3	50E	Brown/ Light Blue	ESC CAN-High
4	—	—	Not Used
5	—	—	Not Used
6	—	—	Not Used
7	376A	Orange	+12V Ignition
8	376C1	Orange	ABS ECU Ignition Supply

18-Pin X4 ABS ECU Connector

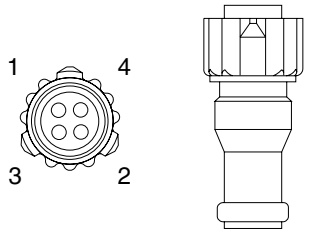


f545494

Pin	Circuit	Wire Color	Description
9	—	—	Not Used
10	GND	Black	Ground
11	GND	Black	Ground
12	—	—	Not Used
13	378TF-	Orange	ABS, ESC Front Solenoid Return
14	402	Pink/White	TAS ECU Supply
15	—	—	Not Used
16	378TF+	Orange	ABS, ESC Front Solenoid Signal
17	—	—	Not Used
18	—	—	Not Used

Table 4, 18-Pin X4 ABS ECU Connector

ESC Module Connector



f545493

Pin	Circuit	Wire Color	Description
1	376A	Orange	+12V Ignition
2	GND	Black	Ground
3	508E	Brown/Light Blue	ESC CAN-High
4	508G	Brown/White	ESC CAN-Low

Table 5, ESC Module Connector

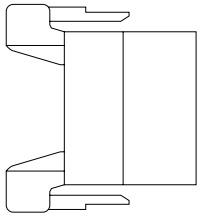
Steering Angle Sensor Connector			
 04/21/2009 f545517			
Pin	**Circuit**	**Wire Color**	**Description**
1	GND	Black	Ground
2	576A	Orange	+12V Ignition
3	508E	Brown/Light Blue	J1939 Datalink (+) Proprietary
4	508G	Brown/White	J1939 Datalink (–) Proprietary
5	—	—	Not Used
6	—	—	Not Used
7	—	—	Not Used

Table 6, Steering Angle Sensor Connector

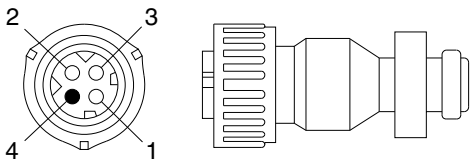
Driver Demand Brake Pressure Sensor Connector			
 04/21/2009 f545515			
Pin	**Circuit**	**Wire Color**	**Description**
1	376C1	Orange	ABS ECU Ignition Supply
2	GND	Black	Ground
3	402	Pink/White	Pressure Signal
4	—	—	Not Used

Table 7, Driver Demand Brake Pressure Sensor Connector

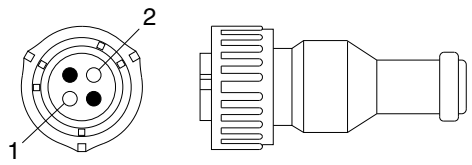
ATC Valve Connector			
 04/21/2009 f545516			
Pin	**Circuit**	**Wire Color**	**Description**
1	378T+	Black	ABS Traction Control Solenoid Signal (+)
2	378T-	Brown	ABS Traction Control Solenoid Signal (–)
3	—	—	Not Used
4	—	—	Not Used

Table 8, ATC Valve Connector

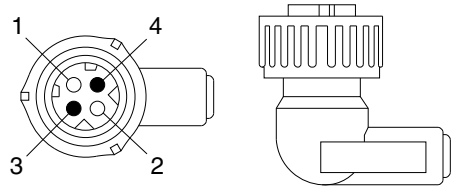
RSC Valve Connector			
 04/21/2009 f545495			
Pin	**Circuit**	**Wire Color**	**Description**
1	378RS+	Black	Roll Stability Control Valve Signal (+)
2	378RS-	Brown	Roll Stability Control Valve Return (–)
3	—	—	Not Used
4	—	—	Not Used

Table 9, RSC Valve Connector

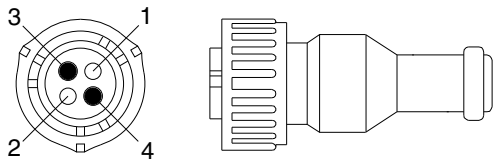
Front Solenoid Valve Connector			
 04/21/2009 f545518			
Pin	**Circuit**	**Wire Color**	**Description**
1	378TF+	Orange	Front Solenoid Valve Signal (+)
2	378TF-	Orange	Front Solenoid Valve Return (–)
3	—	—	Not Used
4	—	—	Not Used

Table 10, Front Solenoid Valve Connector

603 — Brake System Modules

ABS, RSC, and ESC System Modules	
Description	**Module**
ABS Control Unit	49A
Vehicle Stability Control	49b
Wiring, Vehicle Stability Control	49e
MGJB, Electrical System	280
Wiring, Dash Harness, SAS	320
Wiring, ABS/RSC/ESC	330
Wiring, Chassis, ABS/RSC/ESC	332
Valve, Front Brakes, ESC	413
Trailer Protection Valve, RSC	482
Steering Column	532
ABS Sensor, Front	414
Rear Modulator Valve Assembly	490
Instrument Panel	732
Miscellaneous Module References	
Description	**Module**
Wiring, Chassis, Modulator Valve	333
Front Brakes, Disc	402
Front Brakes, Rotors	419
Rear Brakes	423

ABS, RSC, and ESC System Modules	
Description	**Module**
Air Line Overview	871
Wiring, Service/Park Brake	877
Air Piping Pass Through	880
Front, Brake Hardware	43E

Table 11, ABS, RSC, and ESC System Modules

Before electrical troubleshooting, read all active fault codes through Service Link. This could verify an intermittent problem, such as a loose connection, that is accidently fixed by shifting and moving wires while troubleshooting.

- Perform general electrical troubleshooting tests first, like checking for wiring continuity and connections.
- Refer to any fault codes reported on CAN in ServiceLink.

700 — Troubleshooting Tips

Before electrical troubleshooting, read all active fault codes through Service Link. This could verify an intermittent problem, such as a loose connection, that is accidently fixed by shifting and moving wires while troubleshooting.

- Perform general electrical troubleshooting tests first, like checking for wiring continuity and connections.
- Refer to any fault codes reported on CAN in ServiceLink.

701 — Diagnostic Tools Required

The following tools are required to perform troubleshooting procedures.

- Servicelink or Meritor Toolbox
- Digital Multimeter

702 — Wheel Sensor Troubleshooting (SIDs 001 through 006)

J1587 Wheel Speed Sensor Fault Codes—Identifying SIDs With Specific Sensors			
MID	**PID**	**Description**	**FMIs**
136	001	Left front wheel speed sensor	01, 02, 03, 04, 05, 06, 07, 08, 09, 10, 11, 12
	002	Right front wheel speed sensor	
	003	Left rear wheel speed sensor	
	004	Right rear wheel speed sensor	
	005	Left 3rd wheel speed sensor	
	006	Right 3rd wheel speed sensor	

Table 12, J1587 Wheel Speed Sensor Fault Codes

J1587 Wheel Speed Sensor Fault Codes – Troubleshooting					
MID	**SIDs**	**FMI**	**Fault Description**	**Fault Trigger**	**Action**
136	001–006	01	Incorrect air gap	Sensor output voltage too low but just exceeds trigger level.	Perform WHEEL SPEED SENSOR OUTPUT VOLTAGE TEST.
136	001–006	02	Incorrect tire size	Wheel speed difference within front axle >10% or difference within wheels of different axles is >19%.	Check for correct tire size and mixed tire sizes. Check for correct number of tone wheel teeth. Repair as necessary.
136	001–006	03	Sensor shorted to power	DC voltage detected.	Perform WHEEL SPEED SENSOR CIRCUIT SHORT TO POWER TEST.
136	001–006	04	Short to ground	Short to ground detected.	Perform WHEEL SPEED SENSOR CIRCUIT RESISTANCE TEST.
136	001–006	05	Open circuit	Open circuit detected.	Perform WHEEL SPEED SENSOR CIRCUIT RESISTANCE TEST.
136	001–006	06	Short circuit	Short between sensor wires detected.	Perform WHEEL SPEED SENSOR CIRCUIT RESISTANCE TEST.
136	001–006	07	Damaged tone ring	Cyclic drop out detected at speed higher than 10 km/h. Several wheel revolutions necessary to trigger.	Inspect tone ring for damage and missing teeth. Make sure correct tone ring is installed (100-tooth is normal application). Repair as necessary.
136	001–006	08	Excessive wheel slip	Excessive tire spin for more than 16 seconds detected.	Check sensor adjustment.
136	001–006	09	Wire mismatch	Wire from another sensor detected.	Check sensor wiring.
136	001–006	10	Speed signal drop out	Temporary loss of wheel speed signal.	Perform WHEEL SPEED SENSOR SIGNAL TEST.
136	001–006	11	Abnormal speed	Brake squeezes or chatters.	Perform WHEEL SPEED SENSOR SIGNAL TEST.
136	001–006	12	Frequency too high	Non-plausible sensor frequency measured.	Check sensor wiring and connections. If OK, replace ECU.

Table 13, J1587 Wheel Speed Sensor Fault Codes-Troubleshooting

703 — Wheel Speed Sensor Tests

NOTE: Meritor WABCO PC Diagnostics can be used for this test to compare speed signal output of all sensors. A problem will be indicated by low or erratic output.

1. **Measure the sensor output voltage.**

   1.1 Park the vehicle on a level surface and set the parking brake.

   1.2 Chock the tires of the axle not being tested. Raise the vehicle and put jack stands under the axle so the wheels can rotate.

   1.3 Disconnect the applicable connector from the ABS ECU for the sensor being tested.

   1.4 Set a digital multimeter to the AC voltmeter mode. Connect the probes to the cable connector terminals for the sensor being tested.

   1.5 Rotate the wheel by hand at a speed of 30 rpm (one-half revolution per second) and read the voltage output.

   Is the AC voltage greater than 0.2V?

YES →Voltage output is within normal range. No problem found.

NO →Push the sensor into its holder until it touches the tone ring, then repeat this test. If voltage is still below 0.2V, replace the sensor.

2. **Check sensor circuit for short to ground.**

   2.1 Disconnect the ECU connector that contains the sensor wires for the sensor being tested.

   2.2 Check the resistance between each of the two sensor circuits (at the ECU connector) and ground. If the reading for either circuit is less than 10,000 Ohms, a short to ground is detected.

   Is a short to ground detected?

   YES →Sensor wiring is shorted to ground. Repair as necessary.

   NO →Go to Test 3

3. **Check the sensor circuit resistance.**

   3.1 Disconnect the ECU connector that contains the sensor wires for the sensor being tested.

   3.2 Measure the resistance between the two circuits for the sensor being tested.

   Is the resistance 900 to 2000 Ohms?

   YES →Sensor circuit resistance is within specifications. Verify fault and repeat tests. If problem persists, ECU may be faulty.

   NO →Go to Test 4.

4. **Check the sensor resistance.**

   4.1 Disconnect the sensor being tested.

   4.2 Measure the resistance between the sensor terminals.

   Is the resistance 900 to 2000 Ohms?

   YES →Sensor wiring is shorted or open, depending on results of Test 2 above. Repair as necessary.

   NO →Replace wheel speed sensor.

5. **Check for voltage in sensor wiring.**

   5.1 Disconnect the ECU connector that contains the sensor wires for the sensor being tested.

   5.2 Check for voltage between each of the two sensor circuits (at the ECU connector) and ground. If the reading for either circuit is more than 0.2V, a short to power is detected.

   Is a short to power detected?

   YES →Sensor wiring is shorted to power. Repair as necessary.

   NO →Verify fault and repeat test. If problem persists, ECU may be faulty.

6. **Check the sensor output signal.**

   6.1 Adjust the wheel speed sensor.

   6.2 Connect Meritor WABCO PC Diagnostics to the vehicle.

6.3 Observe the sensor output graph in PC Diagnostics while spinning the wheel or driving the vehicle. Observe if the signal drops out or is erratic.

Is the signal erratic or does it drop out?

YES →Check sensor and harness wiring. Also, check brakes—the cause could be from brake chatter.

NO →Sensor adjustment corrected the problem.

704 — Modulator Valve Troubleshooting (SIDs 007 through 010)

J1587 Modulator Valve Fault Codes—Identifying SIDs With Specific Valves			
MID	**SID**	**Description**	**FMIs**
136	007	Left front modulator valve	03, 05, 06
	008	Right front modulator valve	
	009	Left rear modulator valve	
	010	Right rear modulator valve	

Table 14, J1587 Modulator Valve Fault Codes

J1587 Modulator Valve Fault Codes—Troubleshooting					
MID	**SID**	**FMI**	**Fault Description**	**Fault Trigger**	**Action**
136	007–010	03	Short to power	Short to power detected in Inlet or outlet solenoid circuit.	Perform Modulator Valve Voltage Test
		05	Open circuit	Open detected in inlet or outlet solenoid circuit.	Perform Modulator Valve Test
		06	Short to ground	Short to ground detected in inlet or outlet solenoid circuits.	

Table 15, J1587 Modulator Valve Fault Codes

705 — Modulator Valve Tests

1. **Check for voltage in the modulator valve circuit wiring for a short to power.**

   1.1 Disconnect the ECU connector that contains the modulator valve wires for the modulator being tested.

   1.2 Check for voltage between each of the three valve circuits (at the ECU connector) and ground. If the reading for any circuit is more than 0.2V, a short to power is detected.

   Is a short to power detected?

   YES →Modulator valve wiring is shorted to power. Repair as necessary.

   NO →Verify fault and repeat test. If problem persists, ECU may be faulty.

2. **Check the modulator valve inlet and outlet coil resistance.**

   2.1 Disconnect the connector at the modulator valve.

   2.2 Measure resistance between modulator "in" and "ground" pins.

   Measure resistance between modulator "out" and "ground" pins. See **Fig. 28**.

Is there between 4 and 8 Ohms?

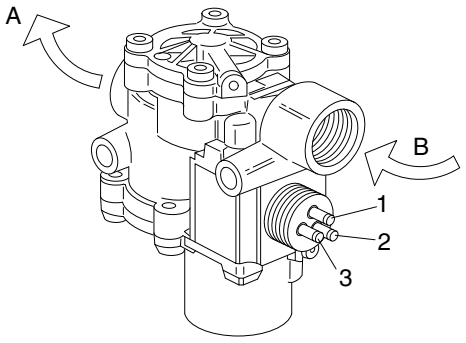
YES →The modulator is good. Check the modulator valve circuit wiring.

NO →Clean the terminals on the modulator valve and check the resistance again. If the resistance is still not correct, replace the valve.

706 — Retarder Relay Faults (SID 013)

J1587 Retarder Relay Fault Codes (SID 013)—Troubleshooting					
MID	**SID**	**FMI**	**Fault Description**	**Fault Trigger**	**Action**
136	013	03	Retarder relay circuit—short to power	This vehicle does not use the retarder relay circuit.	Check if a circuit has been connected to pin X1/14 by mistake. Re-configure the ECU.
		05	Retarder relay circuit—open circuit		
		06	Retarder relay circuit—short to ground		

Table 16, J1587 Retarder Relay Fault Codes (SID 013)



A. Delivery Port B. Supply Port

1. Ground (Common)
2. Exhaust Solenoid (Out)
3. Supply Solenoid (In)

Fig. 28, Modulator Valve Terminals

707 — ECU Power and Ground Faults (SID 014)

Power and Ground Faults Troubleshooting (SID 014) (Cab Mounted ECU)							
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**	**Blink Code**
136	014	04	Low voltage or open circuit.	1. Disconnect the 15-pin X1 connector from the ABS ECU. With the ignition ON, measure the voltage between pins 8 and 9.	Voltage is 9.5 to 14 volts.	System voltage is acceptable. Check for intermittent low voltage. Check the batteries and charging system. Voltage may have been temporarily too low. Repair as necessary.	8-1
					Voltage is less than 9.5 volts.	Check vehicle batteries and charging system. Check ABS ECU power and ground circuits for open or high resistance. Repair as necessary.	
136	014	05	Ground circuit open or high resistance.*NOTE: Make sure the batteries are disconnected or shut off, otherwise results may be misleading.*	2. Disconnect the 15-pin X1 connector from the ABS ECU. Measure the resistance in the ground circuit between pin 9 and the negative battery terminal.	Ground is okay.	Verify fault. Check ground circuit for open or high resistance. Repair as necessary.	8-5
					Ground is open or has high resistance.	Repair ground circuit as necessary.	
136	014	06	Internal relay does not open.			If fault repeats, replace the ABS ECU.	8-3

Table 17, Power and Ground Faults Troubleshooting (SID 014) (Cab-Mounted ECU)

708 — J1587 Fault Codes

J1587 Fault Codes						
MID	**SID**	**FMI**	**Fault Description**	**Test**	**Result**	**Action**
136	88	1	ESC – Initialization Not Complete	—	—	Important: Refer to Meritor WABCO's End of Line (EOL) procedure for the initialization process. This procedure can be found in Meritor WABCO's Maintenance Manual MM-0112. This document is available through Meritor WABCO or their website.
136	88	2	ESC – System Configuration	—	—	The ESC module is not compatible with the ABS ECU. Contact OEM or Meritor WABCO for ECU combinations.

J1587 Fault Codes						
MID	**SID**	**FMI**	**Fault Description**	**Test**	**Result**	**Action**
136	88	5	ESC – CAN Datalink Loss	Remove the 4-pin connector from the ESC Module. Turn the ignition ON. Measure the voltage between pins 1 and 2 of the 4-pin connector.	Voltage	Verify fault. Check ESC Module wiring for intermittent connection. Check for open connection on ESC Module and insure it is tight and clear of debris/ corrosion. Repair as necessary. If fault persists, ESC module or ABS ECU may be faulty.
					No Voltage.	Check wiring in circuit 376A from ESC Module to ABS ECU unit. Repair as necessary.
136	88	9	ESC – CAN Datalink Incorrect or Missing	Remove the 4-pin connector from the ESC Module. Measure the resistance between pins 3 and 4 on the 4-pin connector.	Resistance is approximately 90 ohms.	Verify fault. Check ESC Module wiring for intermitent connection and insure it is tight and clear of debris/ corrosion. Repair as necessary. Measure the resistance from the ABS ECU X4 18-pin connector and insure approximate 90 ohms is measured. If fault persists, ESC module or ABS ECU may be faulty.
					Resistance is much less or much greater than 90 ohms.	Check wiring between the ESC Module and ABS ECU. Repair as necessary. If fault persists, the ESC Module or ABS ECU may be faulty.
136	88	12	ESC – Internal Fault	Check the ESC Module and its mounting location. Verify that the ESC module is mounted horizontally and properly secured to the cross member. Check the 4-pin connector on the ESC Module and insure it is tight and clear of debris and corrosion. Check the wiring between the ESC module and the ABS ECU.	—	Verify fault. Clear code from ECU memory. Check for other fault codes that may have occurred with this fault, as this could indicate faulty wiring or poor connection at ESC module. If fault persists, the ESC module may be faulty.
136	88	13	ESC – Initialization Required	—	—	Important: Refer to Meritor WABCO's End of Line (EOL) procedure for the initialization process. This procedure can be found in Meritor WABCO's Maintenance Manual MM-0112. This document is available through Meritor WABCO or their website.

J1587 Fault Codes						
MID	**SID**	**FMI**	**Fault Description**	**Test**	**Result**	**Action**
136	88	14	ESC – Module Mounting Fault	Check the ESC Module and its mounting location. Verify the ESC module is mounted horizontally and properly secured to the crossmember. Check the 4-pin connector on the ESC Module and insure it is tight and clear of debris and corrosion. Check wiring between the ESC module and the ABS ECU.	—	Verify fault. Clear code from ECU memory. If fault persists, the ESC module may be faulty.
136	89	1, 2, 7 or 8	SAS – Steering Angle Sensor various faults	—	—	Visually check the installation of the steering sensor and mount to ensure it is properly seated. If any vehicle work related to the steering system has been performed, the SAS must be calibrated and the ESC module initialized. Refer to Meritor WABCO's End of Line (EOL) procedure for the initialization process. This procedure can be found in Meritor WABCO's Maintenance Manual MM-0112. This document is available through Meritor WABCO or their website.
136	89	9	SAS – Commutation Fault	Remove the 7-pin connector from the Steering Angle Sensor. Measure the resistance between pins 3 and 4 of the 7-pin connector.	Resistance is approximately 90 ohms.	Verify fault. Check Steering Angle Sensor wiring. Check for open connection between the ABS ECU and Steering angle sensor. Ensure connection is tight and clear of debri/corrosion. Repair as necessary. If fault persists, the SAS or ABS ECU may be faulty.
					Resistance is much less or much greater than 90 ohms.	Check wiring between the SAS and ABS ECU. Repair as necessary. If fault persists, the SAS Sensor or ABS ECU may be faulty.

J1587 Fault Codes						
MID	**SID**	**FMI**	**Fault Description**	**Test**	**Result**	**Action**
136	89	12	SAS – Sensor Defective	Disconnect the 7-pin connector from the steering angle sensor. Turn ignition ON. Measure the voltage between pins 1 and 2 of the 7-pin connector.	Voltage	Check Steering Angle Sensor wiring. Check for intermitent connection between the ABS ECU and Steering angle sensor. Ensure conenction is tight and clear of debri/corrosion. If fault persists, the ABS ECU may be faulty.
					No Voltage.	Check the wiring in circuit 576A between the SAS and the ABS ECU. Repair as necessary.
136	89	13	SAS – Not Calibrated	—	—	Refer to Meritor WABCO's SAS calibration procedure. This procedure can be found in Meritor WABCO's Maintenance Manual MM-0112. This document is available through Meritor WABCO or their website.
136	89	14	SAS – Internal Fault	—	—	Check SAS and its mounting location. Verify the SAS is securely mounted and the connector is free of debris and corrosion. SAS may be faulty.
136	16	5	BLS/Pressure Sensor	Disconnect the 18-pin X4 connector from the ABS ECU. Measure the voltage between pin 8 of the 18-pin (X4) connector and ground.	Voltage.	Wire shorted to power, check wiring and repair as necessary.
					No voltage.	Open circuit or shorted to ground. Check wiring and repair as necessary.
136	19	2	Front Axle Brake Valve – Open	Disconnect connector X4 from the ABS ECU. Measure the resistance between pins 16 and 13 of the 18-pin (X4) connector.	Open circuit, or high resistance.	Check Front solenoid valve wiring for corrosion or open connection. Repair as necessary. See **709 — Solenoid Valve Tests**. If fault persists, replace the front solenoid valve.
					Resistance is 7-14 ohms.	Correct resistance is measured. Check wiring for intermitent connection. Repair as necessary. If fault persists, see **709 — Solenoid Valve Tests**. If Front valve passes test, ABS ECU may be faulty.

J1587 Fault Codes						
MID	**SID**	**FMI**	**Fault Description**	**Test**	**Result**	**Action**
136	19	5	Trailer Brake Valve (RSC) Open	Disconnect connector X3 from the ABS ECU. Measure the resistance between pins 13 and 8 of the 15-pin (X3) connector.	Open circuit, or high resistance.	Check RSC valve wiring for corrosion or open connection. Repair as necessary. See **709 — Solenoid Valve Tests**. If fault persists, replace the RSC valve.
					Resistance is 7-14 ohms.	Correct resistance is measured. Check wiring for intermitent connection. Repair as necessary. If fault persists, see **709 — Solenoid Valve Tests**. If RSC valve passes test, ABS ECU may be faulty.
136	19	12	SAS and ESC Module – Shorted to Ground	Disconnect connector X4 from the ABS ECU. Measure the resistance between pin 7 of the 18-pin (X4) connector and ground.	Low Resistance	Wire shorted to ground, check wiring and repair as necessary.
					High Resistance	Verify fault. Check for intermitent fault in circuit 376A or open circuit. If fault persists, ABS ECU may be faulty.
136	55	3	Brake Pressure Sensor – Shorted to Battery	Disconnect the 4-pin connector from the Brake Pressure Sensor. Measure the resistance between pin 3 of the 4-pin connector and power.	Low Resistance	Wire shorted to power, check wiring and repair as necessary.
					High Resistance	Verify fault. Check for intermitent fault in circuit 402. If fault persists, sensor may be faulty.
136	55	5	Brake Pressure Sensor – Open or shorted to ground.	Disconnect the 4-pin connector from the Brake Pressure Sensor. Measure the resistance between pin 2 of the 4-pin connector and ground.	Low Resistance	Wire shorted to ground, check wiring and repair as necessary.
					High Resistance	Verify fault. Check for intermitent fault in ground circuit or open circuit. If fault persists, sensor may be faulty.

Table 18, J1587 Fault Codes

709 — Solenoid Valve Tests

1. **Test the voltage on the affected solenoid valve connector.**

   1.1 Disconnect the 4-pin connector from the solenoid valve.

   1.2 Switch the ignition to the ON position

   1.3 Measure the voltage between all pins in the solenoid connector and a good ground.

   Is voltage present on any pin?

YES →Check the wiring for a short to power. Repair as necessary.

NO → Go to test 2.

2. **Measure the voltage between all pins in the solenoid connector and +12V power.**

   Is voltage present on any pin?

   YES →The wire shorted to ground. Repair as necessary.

   NO → Go to test 3.

3. **Measure the resistance between pins 1 and 2 on the solenoid valve.**

   Is the resistance between 7 and 14 ohms?

   YES →Go to test 4.

   NO → Clean the electrical contacts on the solenoid and test again. If the resistance is still not correct, replace the solenoid valve.

4. **Measure the resistance of the solenoid valve through the wiring to the ABS ECU.**

Refer to **601 — Component Details**for the solenoid valve being tested.

Is the resistance between 7 and 14 ohms?

YES →Check for other electrical faults. The ABS ECU or the solenoid valve may be faulty.

NO → Clean the electrical contacts and check wiring between the ABS ECU and solenoid valve. Repair as necessary. If the resistance is still not correct, replace the solenoid valve.

710 — ATC Power and Ground Faults (SID 015)

ATC Valve Ground Circuit Faults Troubleshooting (SID 015) (Cab-Mounted ECU)							
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**	**Blink Code**
136	015	03	ATC valve ground circuit shorted to power.	1. Disconnect the 18-pin X2 connector from the ABS ECU. With the ignition ON, check for voltage between pin 7 and ground.	Voltage at pin 7.	Circuit 378T– is shorted to power. Locate fault and repair as necessary.	8-5
					No voltage at pin 7.	Verify fault. Check for intermittent fault in circuit 378T–and repair as necessary.	
136	015	05	ATC Valve—High Impedance.			Replace ABS ECU if fault persists.	
136	018	06	ATC Valve ground circuit shorted to ground.	2. Disconnect the 18-pin X2 connector. Check resistance between pin 7 and a good ground.	Resistance is less than 10,000 Ohms.	Circuit 378T– is shorted to ground. Locate fault and repair as necessary.	
					Resistance is greater than 10,000 Ohms.	Verify fault. Check for intermittent fault in circuit 378T–and repair as necessary.	

Table 19, ATC Valve Ground Circuit Faults Troubleshooting (SID 015) (Cab-Mounted ECU)

711 — ATC Valve Faults (SID 018)

ATC Valve Power Circuit Faults Troubleshooting (SID 018) (Cab Mounted ECU)							
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**	**Blink Code**
136	018	03	Short to power.	1. Disconnect the 18-pin (X2) connector from the ABS ECU. Measure the voltage between pin 16 of the 18-pin (X2) connector and a good chassis ground.	Voltage.	Circuit 378T+ is shorted to power. Repair as necessary.	7-2
					No voltage.	Verify fault. Check for intermittent fault in circuit 378T+. If fault persists, replace ABS ECU.	
136	018	05	Open circuit.	2. Disconnect the ATC Valve connector. Measure the resistance across the two pins of the ATC valve. *NOTE: If the vehicle does not have an ATC valve, re-configure the ECU.*	Resistance is 7 to 14 Ohms.	Perform Test 3.	7-2
					Resistance is not 7 to 14 Ohms.	Replace ATC Valve.	
				3. Reconnect the ATC valve connector. Disconnect the 18-pin X2 connector from the ECU. Measure the resistance across pins 7 and 16 of the 18-pin X2 connector.	Resistance is 7 to 14 Ohms.	Verify fault. Check for intermittent open circuit in 378T+ and 378T–. Repair as necessary.	
					Resistance is not 7 to 14 Ohms.	Repair circuit 378T+ or 378T–.	7-2
136	018	06	Short to ground.	4. Disconnect the 18-pin X2 connector, check continuity between pin 16 and a good ground.	Continuity.	Circuit 378T+ is shorted to ground. Repair as necessary.	
					No continuity.	Verify fault. Check circuit 378T+ for intermittent short to ground. Repair as necessary.	

Table 20, ATC Valve Power Circuit Faults Troubleshooting (SID 018) (Cab Mounted ECU)

712 — J1939 Datalink Faults (SID 231)

J1939 Datalink Troubleshooting (SID 231)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	231	02	J1939 speed plausibility error. NOTE: This fault indicates a discrepancy between vehicle speed reported on J1939 and ABS sensed vehicle speed.	—	—	Check speedometer calibration. Check for a tire size mismatch. The vehicle speed reported on the J1939 datalink does not agree with the wheel sensor speeds.
136	231	05	J1939 open/short.	Refer to Section **G03.02**for troubleshooting J1939.	—	Repair J1939 datalink as necessary.
136	231	06	J1939 open/short. Code 13s231 05 may be active as well.	Check the driveline retarder ECU and wires. Check the J1939 Datalink. Refer to Section **G03.02**	—	Repair J1939 datalink as necessary.
136	231	07	J1939 time out. NOTE: Fault occurs if engine retarder sends message incorrectly.	Check the driveline retarder ECU and wires. Refer to Section **G03.02**	—	Check J1939 datalink and driveline retarder ECU. Repair as necessary.
136	231	08	J1939 time out. NOTE: Fault occurs if engine retarder sends message incorrectly.	Check engine ECU and wires. Check J1939 datalink. Refer to Section**G03.02**	—	Check J1939 datalink and engine ECU. Repair as necessary.
136	231	09	J1939 time out. NOTE: Fault occurs if engine retarder sends message incorrectly.	Check engine and transmission ECUs and wires. Check J1939 datalink. Refer to Section **G03.02**	—	Check J1939 datalink, engine ECU, transmission ECU, and wiring. Repair as necessary.
136	231	10	J1939 time out. NOTE: Fault occurs if the exhaust retarder sends a message incorrectly.	Check the engine ECU and wires. Check the J1939 datalink. Refer to Section **G03.02**	—	Check J1939 datalink and engine ECU. Repair as necessary.
136	231	12	J1939 internal error.	—	—	Verify fault. Clear code from the ECU memory. If fault persists, replace the ABS ECU.

Table 21, J1939 Datalink Troubleshooting (SID 231)

713 — Voltage Faults (SID 251)

Voltage Troubleshooting (SID 251)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	251	03	Overvoltage. Voltage to ECU was too high for more than 5 seconds.	Using Meritor PC Diagnostics, check the diagonal voltages with the engine running at governed speed, or measure the voltage at the batteries with the engine running at governed speed.	Voltage is 9.5 to 14 volts.	Check for intermittent sources of high voltage. Check condition of charging system and batteries. Verify fault.
					Voltage is greater than 14 volts.	Check charging system. Repair as necessary.

Table 22, Voltage Troubleshooting (SID 251)

714 — Miscellaneous Faults (SID 254)

Miscellaneous Faults Troubleshooting (SID 254)					
MID	**SID**	**FMI**	**Problem**	**Fault Trigger**	**Action**
136	254	02	EEPROM, Wheel parameter incorrect.	Wheel parameters are out of tolerance.	Check wheel size and tire mismatch. If OK, replace ECU.
136	254	05	ABS/ATC ECU, no loads.	No modulator valve connected. Fault may have resulted from end of line test at factory.	Check modulator valve connections.
136	254	07	ABS missing.	This is a roll call fault generated by the ICU. It means the ICU does not detect the ABS on the J1587 datalink. Fault does not show up on datalink, only on ICU display.	Check power/ground to ABS, check ABS J1587 datalink wiring.
136	254	08	Excessive wheel slip.	One wheel was much faster than the other. May have been caused by testing vehicle on a dynamometer.	Check wheel speed sensor air gaps.
136	254	09	Modulator valve actuated too long.	Modulator valve was activated too long (more than 75% of 5 minutes).	After a delay, function will return to normal.
136	254	12	EEPROM Checksum/internal error.	—	If fault persists, replace the ABS ECU.
136	254	13	Accelerometer out of range.	Measured acceleration out of range.	If fault persists, replace the ABS ECU.
136	254	14	ECU Mounting/ accelerometer plausibility.	ECU not mounted correctly, or acceleration not plausible. Extreme banked road (measured acceleration not plausible). Accelerometer linearity (measured acceleration not plausible).	Check ECU mounting. Replace the ECU if fault persists.

Table 23, Miscellaneous Faults Troubleshooting (SID 254)

800 — Specifications

ABS and RSC Component Specifications			
Component	**Measurement**	**Normal Range**	**Notes**
Wheel Speed Sensor	Resistance	900–2000 Ohms	Measured across the two sensor terminals.
	Output voltage	0.2V AC (minimum)	Measured across the two sensor terminals while rotating the wheel 30 rpm.
Modulator Valve	Resistance	4–9 Ohms	Resistance between each coil pin and ground pin.
ATC/RSC/Front Solenoid Valve	Resistance	7–14 Ohms	Measured across the two valve terminals.
Accelerometer	Voltage	2.21 to 2.78 V	Measured with Meritor WABCO Toolbox software.

Table 24, ABS and RSC Component Specifications

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500 Terms and Abbreviations

Cabin CAN—A proprietary datalink connecting certain ECUs on the vehicle, specifically the CGW, MSF, SAM Cab, and SAM Chassis.

CAN—Controller Area Network

CGW—Central Gateway

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

LBCU—Lightbar Control Unit

Multiplexing—Sending multiple electronic messages through the same signal path at the same time—in this case, through the wiring.

MSF—Modular Switch Field

SAM Cab—Signal Detect and Actuation Module Cab ("SAM Cabin"); this ECU controls mainly cab-related functionality. See **G02.04 — SAM Cab** for more information.

SAM Chassis—Signal Detect and Actuation Module Chassis; this ECU controls mainly chassis-related functionality. See **G02.05 — SAM Chassis** for more information.

501 — General Information

Federal regulations require that the driver be alerted if the brake system air pressure drops below 60 psi (414 kPa). The low air pressure warning system uses a loud tone, and an indicator light on the lightbar, to alert the driver that the primary or secondary air system is below 65 psi (448 kPa). The system is activated when the key is in the ignition switch, and turned to the ON position. System components include the following:

- two pneumatically actuated, normally open, electrical switches, wired in series
- Lightbar Control Unit (LBCU) indicator light
- LBCU Speaker
- SAM Cab

The SAM Cab monitors the status of the switches via pin 10 and 11 on connector X13, where 11 is the output and 10 is the input. Unless both pneumatic switches register greater than 65 psi (448 kPa), the circuit will not be complete. If the circuit is not complete, SAM Cab activates the LBCU indicator and warning tone by applying high impedance to pin 6 of connector X11, which is connected directly to Pin A-3 on the instrument cluster. The LBCU also broadcasts the state of the low air warning system on the J1587 datalink.

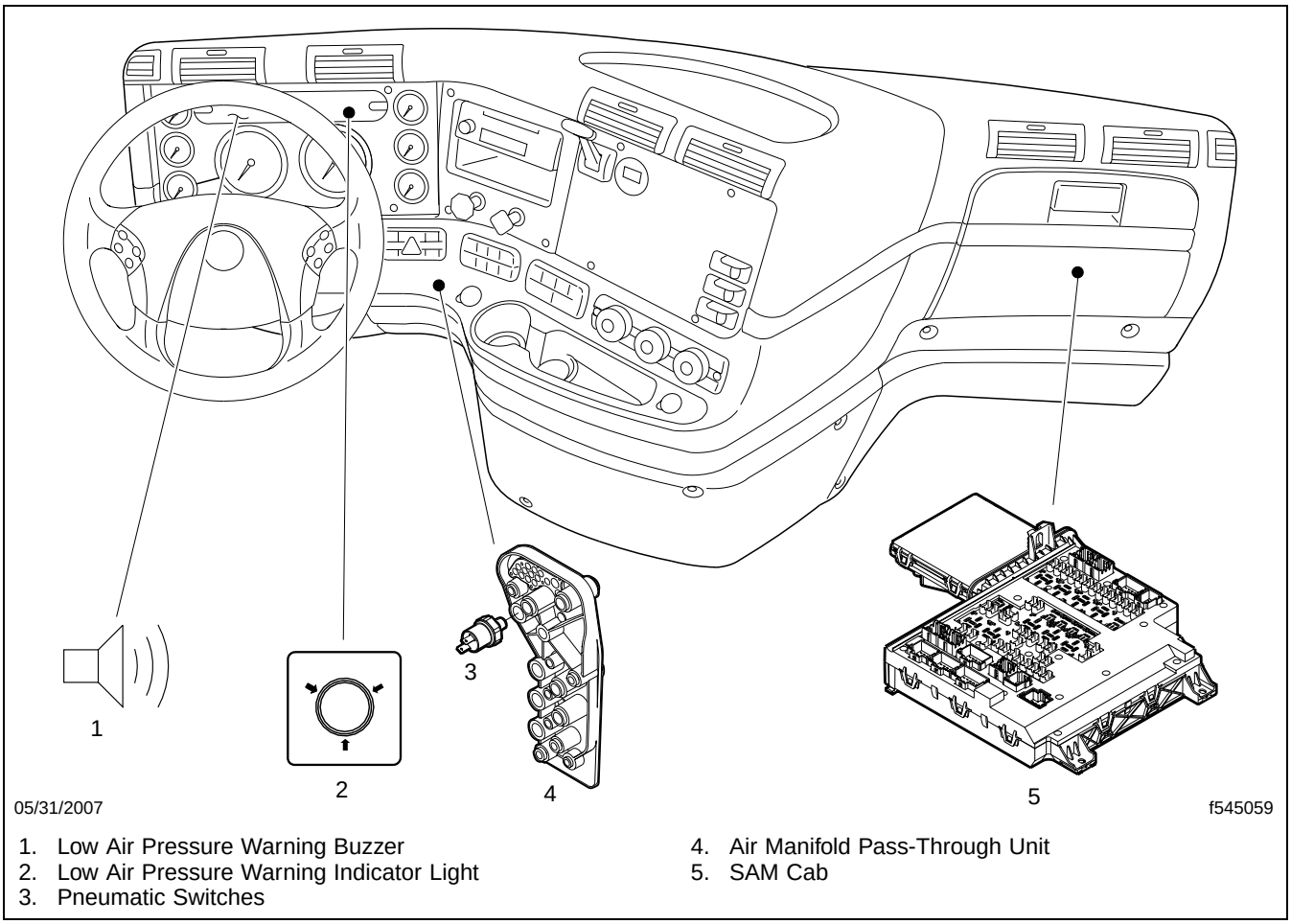
NOTE: The ICU3, ICU4, and ICU4M all function in the same manner in this system.

When the vehicle key is turned to the ON position, a test of the ICU will occur, which will illuminate several indicator lights on the LBCU and activate the buzzer for 3 seconds. If the pneumatic switch circuit is not complete, SAM Cab will activate the low air pressure warning system, and the LBCU indicator light and buzzer will remain on after the LBCU self-test. For more information on individual components, see the following subjects:

- **C01.01 — ICU3 Instrument Cluster**
- **C01.02 — ICU4/ICU4M Instrument Cluster**

- **G02.03 — Central Gateway**
- **G02.04 — SAM Cab**

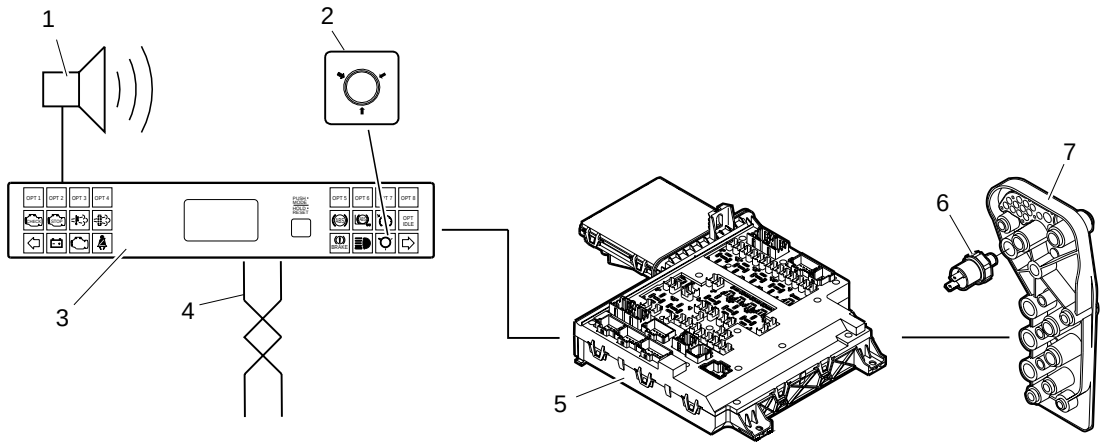
600 — Component Locations



1. Low Air Pressure Warning Buzzer
2. Low Air Pressure Warning Indicator Light
3. Pneumatic Switches
4. Air Manifold Pass-Through Unit
5. SAM Cab

Fig. 1, Low Air Pressure Warning System Components

601 — Component Details



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1. Low Air Pressure Warning Buzzer
2. Low Air Pressure Warning Indicator Light
3. LBCU
4. J1587 Datalink
5. SAM Cab
6. Pressure Switch
7. Air Manifold Pass-Through Unit

Fig. 2, Low Air Pressure Warning System Components (ICU4 shown)

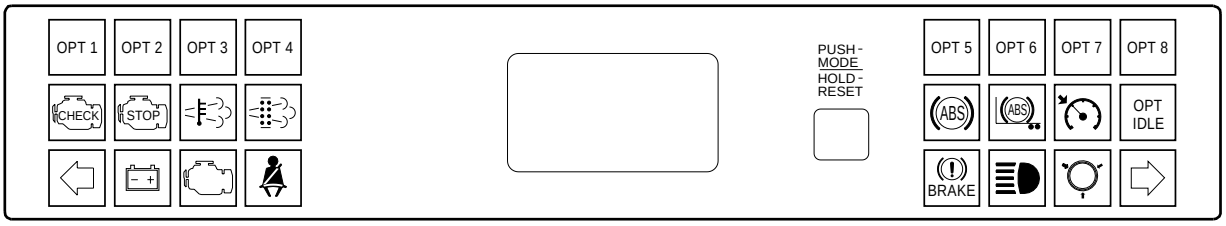

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Fig. 3, Lightbar Control Unit (ICU4 shown)

Part of the Instrumentation Control Unit, the LBCU communicates over the J1587/J1708 datalink. The buzzer is activated for 3 seconds during the ICU self-test, and when there is low air pressure, low oil pressure, high coolant temperature, or the parking brake is set and the vehicle is moving at a speed of at least 2 mph (4 km/h).

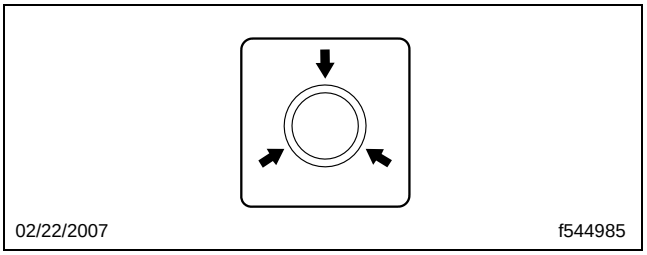

Fig. 4, Low Air Pressure Warning Indicator Light

The low air pressure warning indicator light is located next to the right turn indicator light on the bottom row of the LBCU; it is illuminated for 3 seconds during the ICU self-test, and any time the low air pressure warning system is activated. It is a nonreplacable red LED.

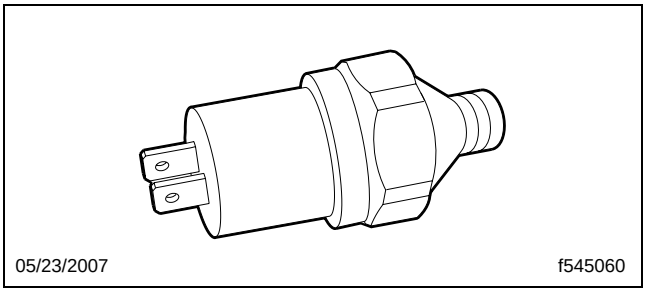

Fig. 5, Pneumatic Switches

The pneumatic switches are pneumatically actuated, normally open, electrical switches, with a 65 to 75 psi (448 to 517 kPa) trigger. The two switches are mounted on the air manifold pass-through unit, on the cab side of the frontwall, just above the throttle pedal. They are connected to the primary air system and are wired in series. Both switches must be closed for the circuit to be complete.

The SAM Cab monitors the status of the pneumatic switches, and broadcasts it over the Cabin CAN.

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500 — Terms and Abbreviations

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

ICU—Instrumentation Control Unit

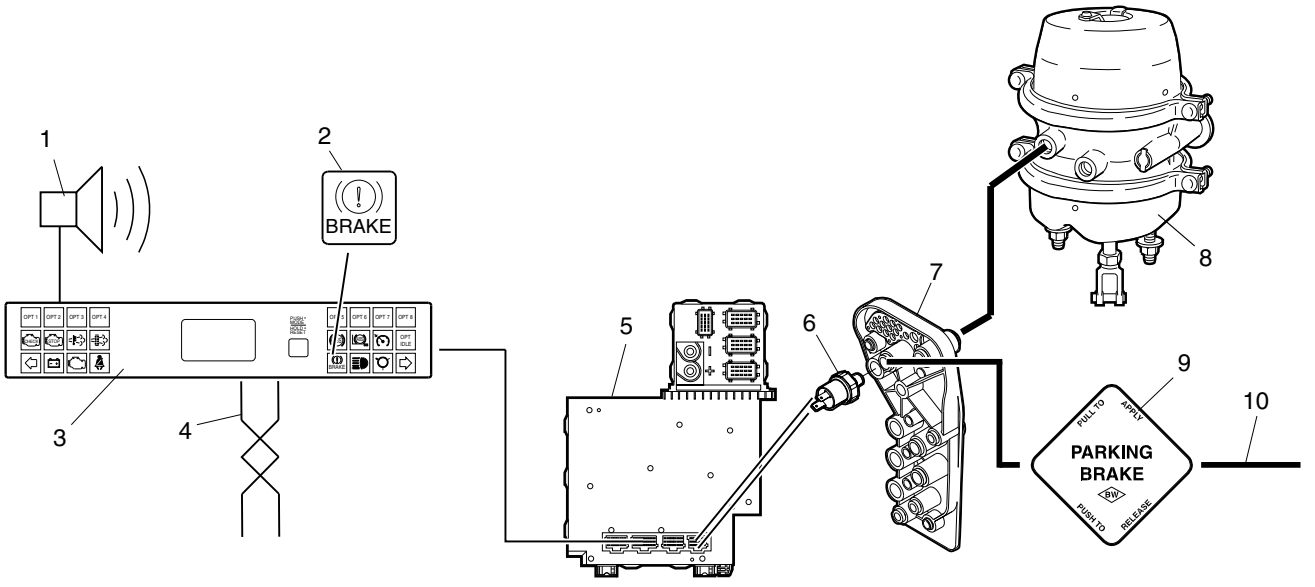
LBCU—Light Bar Control Unit

SAM—Signal Detect and Actuation Module

SAM Cab—Signal Detect and Actuation Module Cab ("SAM Cabin"); this ECU controls mainly cab-related functionality. See **G02.04 — SAM Cab** for more information.

501 — General Information

The parking brake warning system activates a warning light on the dash if the parking brake is engaged, and activates an audible alarm if the vehicle speed is greater than 2 mph (3.2 km/h) with the parking brake engaged. For more information on the parking brake system, see **H01.09 — Park Brake System**.



1. LBCU Buzzer
2. LBCU Brake Indicator LED
3. LBCU With One Wire from Pin X11/14
4. ICU Connection to J1587/ J1708
5. SAM Cab
6. Pressure Switch
7. Air Manifold Pass-Through Unit
8. Parking Brake Unit
9. Parking Brake Control Valve
10. Air From Primary or Secondary Air System

Fig. 1, Parking Brake Warning System

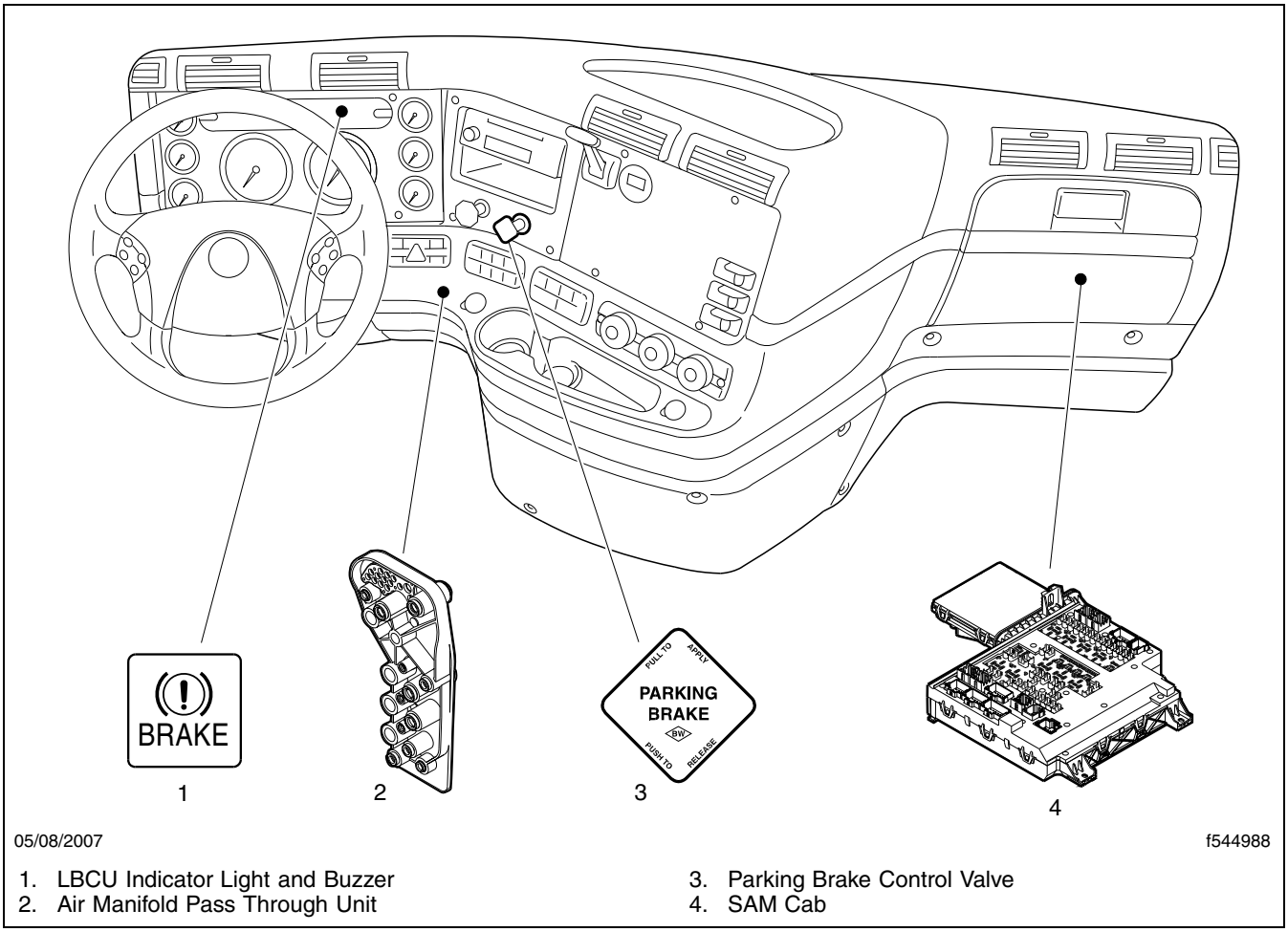
The SAM Cab monitors the status of the parking brake control valve by a small electrical switch integrated into the valve. A 0.04 amp current sent from pin 9 on connector X13 is monitored by pin 8 on the same connector. If the parking brake is set and the switch is closed, the SAM Cab grounds pin 14 on connector X11 and illuminates

the park brake warning LED, which is powered by the LBCU. If the vehicle speed is greater than 2 mph (3.2 km/h), the LBCU warning buzzer is also activated by the ICU.

502 — Related Subjects

- **C01.01 — ICU3 Instrument Cluster**
- **C01.02 — ICU4/4M Instrument Cluster**
- **G02.04 — SAM Cab**
- **H01.04 — Low Air Pressure Warning System**

600 — Component Locations



1. LBCU Indicator Light and Buzzer
2. Air Manifold Pass Through Unit
3. Parking Brake Control Valve
4. SAM Cab

Fig. 2, Component Locations

601 — Component Details

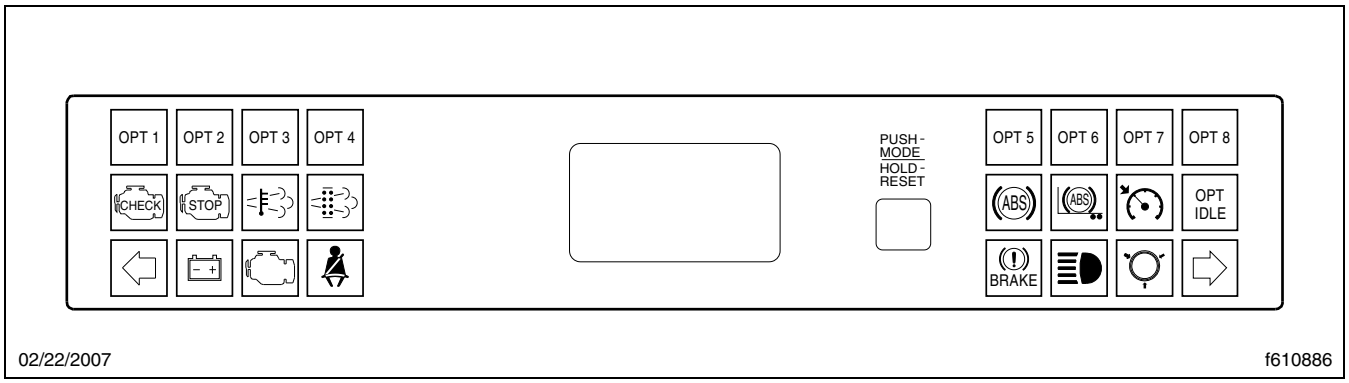


Fig. 3, Light Bar Control Unit

The LBCU is part of the instrumentation control unit. It communicates over the J1587/J1708 datalink. A buzzer is activated for 3 seconds during the ICU self-test, and when there is low air pressure, low oil pressure, high coolant temperature, or the parking brake is set and the vehicle is moving at a speed of at least 2 mph (3.2 km/h).

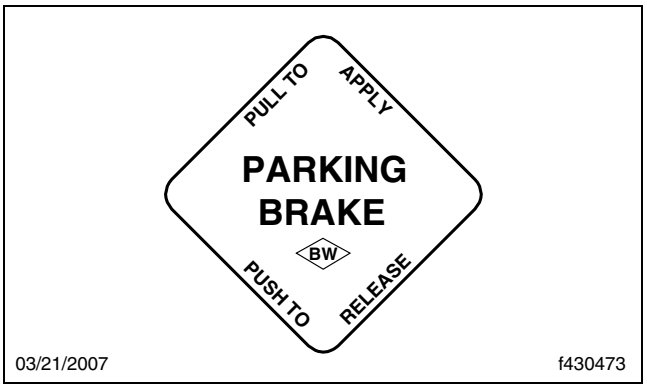


Fig. 4, Parking Brake Control Valve

The parking brake control valve engages the brake when pulled, and releases the brake when pushed.

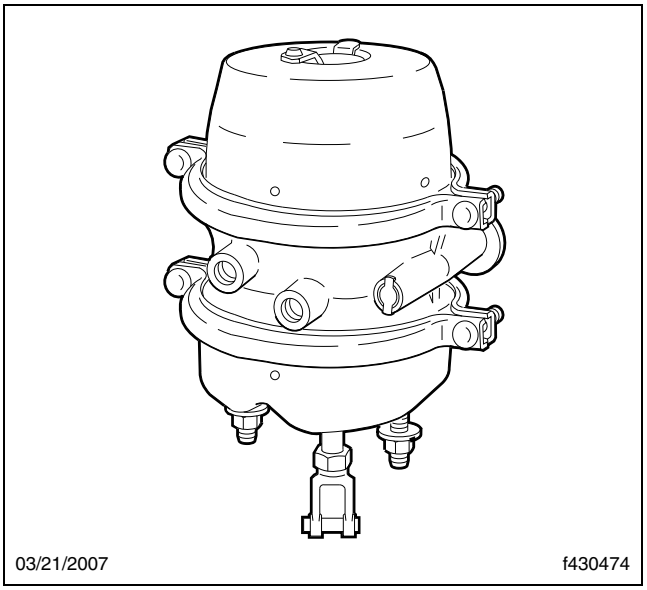


Fig. 5, Parking Brake

The parking brake is a spring powered brake and a pneumatically powered release.

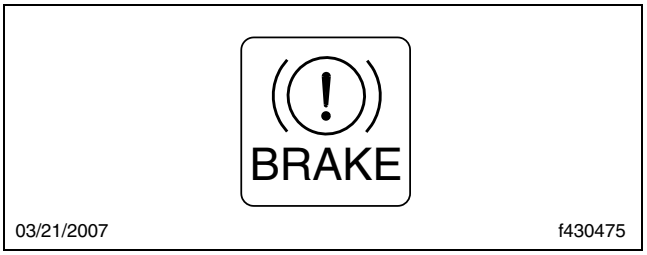


Fig. 6, LBCU Parking Brake Indicator Light

The parking brake indicator light is located immediately to the right of the LBCU LCD screen on the bottom row. It is illuminated when the parking brake is set and the key is in IGN position. It is a non-replaceable red LED.

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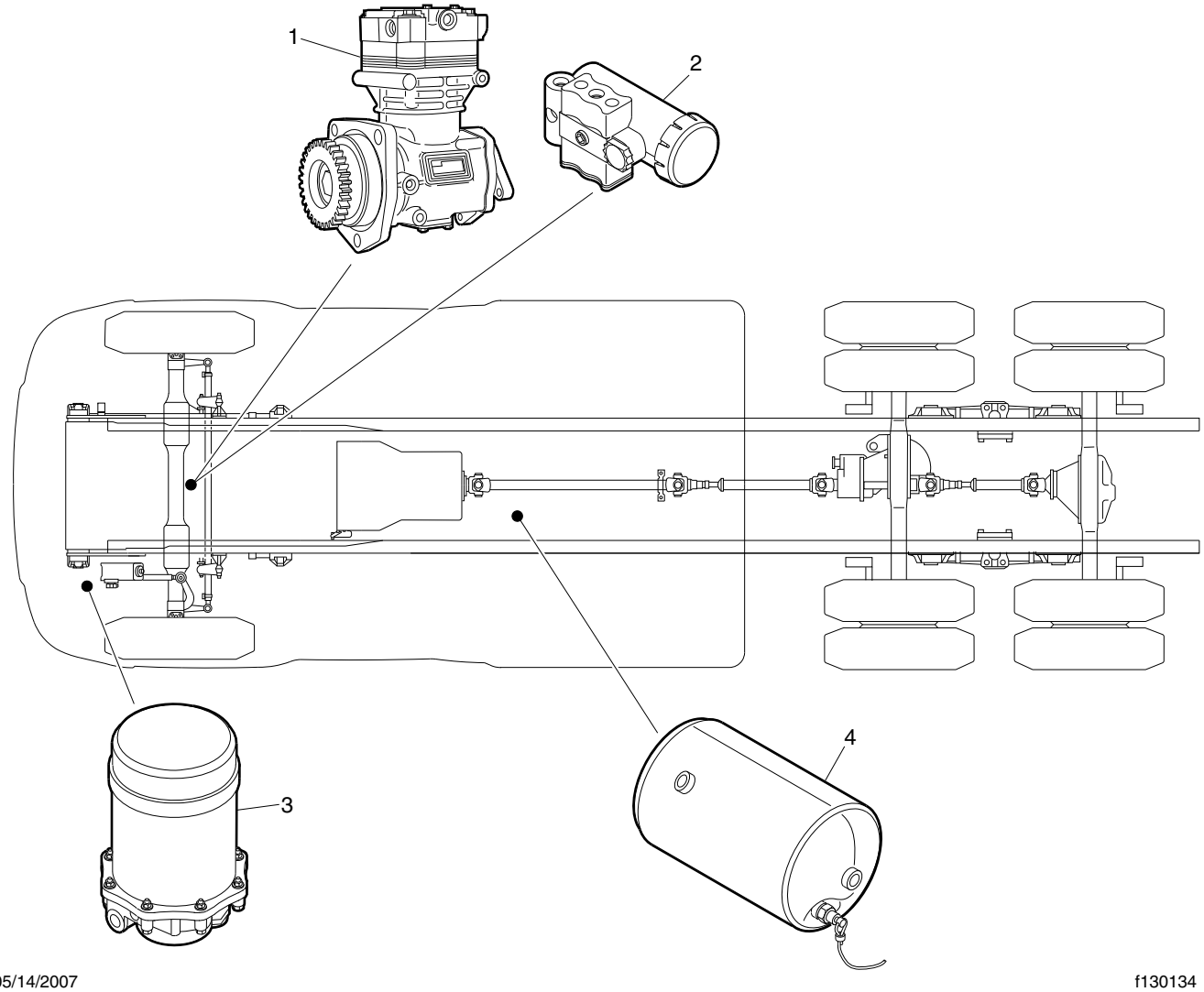
501 — General Information

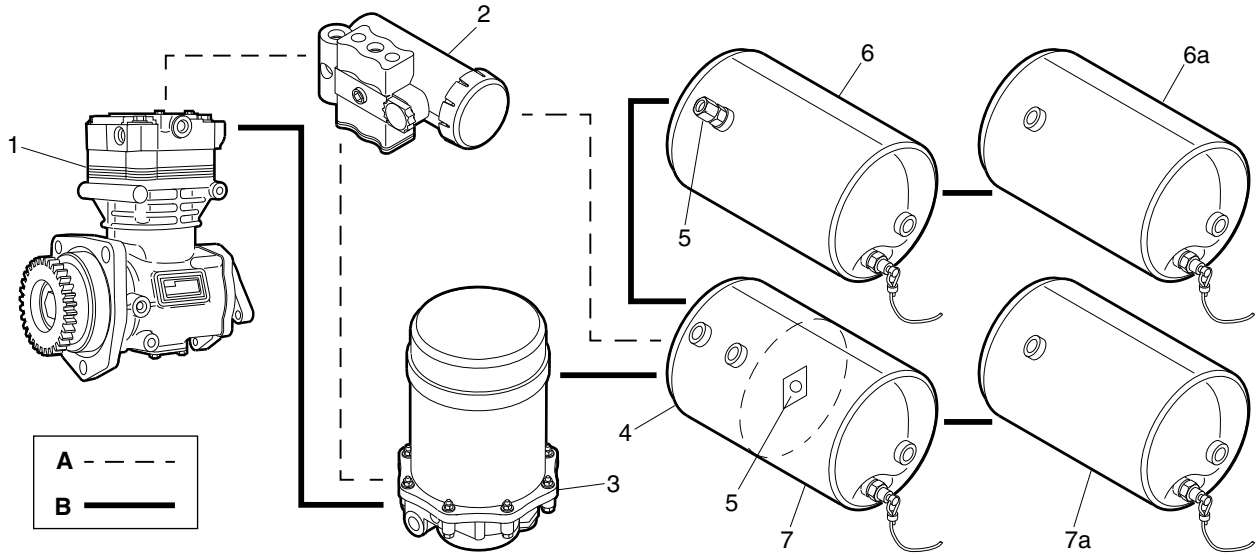
The air supply system generates pressurized, dried, air to be used by various systems of the vehicle, including the air brakes, suspension, and trailer air supply system. **Figure 2** shows a basic schematic of the air supply system components, and how they are connected. The diagram is only a general representation of the components. In most cases the governor is attached directly to the compressor and there is an air passage between the two, eliminating the need for an air line.

600 — Component Locations



1. Air Compressor (attached to engine)
2. Air Governor (usually attached to compressor)
3. Air Dryer (usually attached to left forward frame rail)
4. Air Tanks (location varies, depending on vehicle configuration)

Fig. 1, Component Locations



A. Air Signal Lines
B. Air Flow Lines

1. Air Compressor (attached to engine)
2. Air Governor (usually attached to compressor)
3. Air Dryer
4. Supply (Wet) Tank
5. Check Valves
6. Primary Air Tank
6a. Additional Primary Air Tank (if equipped)
7. Secondary Air Tank
7a. Additional Secondary Air Tank (if equipped)

Fig. 2, Air Supply System Components

601 — Component Details

Air Intake

The air is captured through the air intake system of the vehicle. It passes through the air filter to remove water and debris. The air compressor on the Cascadia™ is naturally aspirated; the air passes from the vehicle air filter directly to the air compressor intake.

Air Compressor

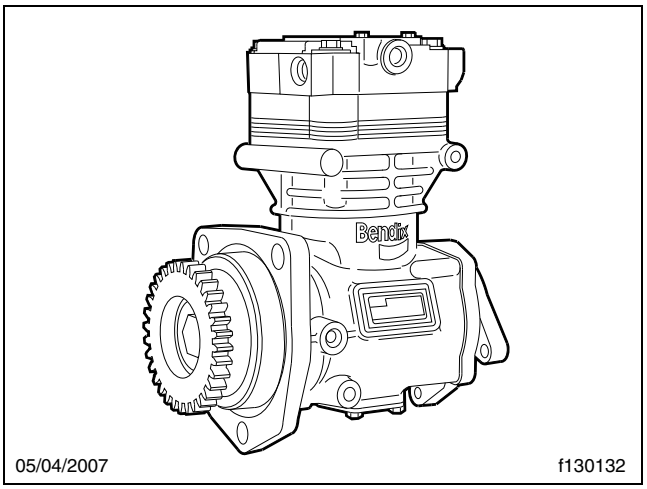


Fig. 3, Air Compressor

The air compressor is attached directly to the engine. The compressor operates in either the loaded or unloaded condition, which is controlled by a pneumatic signal from the governor. In the loaded condition, the compressor is actively compressing air. In the unloaded condition, the compressor's valves stay closed, and the compressor does not work to compress air for the air system. The air compressor is gear-driven by the engine, and is lubricated with engine oil. The piston rings will always pass small amounts of oil into the air system, and as the piston ring seals degrade, more oil will pass through. For air compressor applications for the engines offered in the Cascadia, see **Table 1**. From the compressor, the compressed air goes through a braided hose to the air dryer.

Cascadia Air Compressors		
Engine	**Standard Compressor**	**High-Flow Compressor**
Detroit Diesel Series 60	Bendix BA-921	Bendix BA-922
Caterpillar C-15	CAT 270	
Mercedes-Benz MBE4000	WABCO 15.5	WABCO 28.1

Table 1, Cascadia Air Compressors

Air Dryer

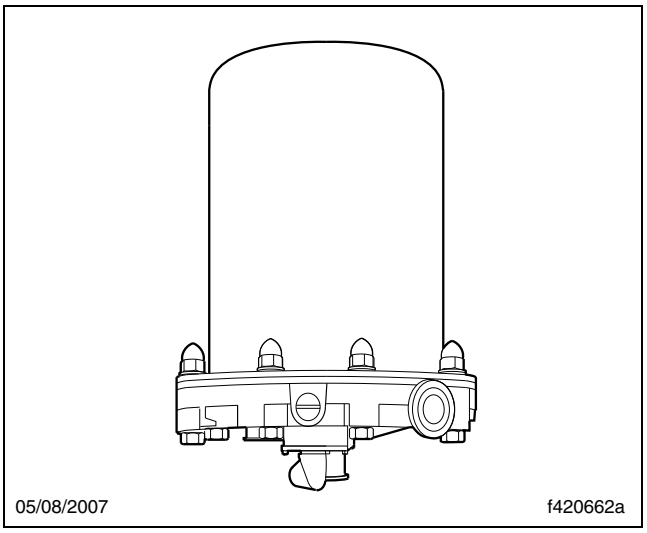


Fig. 4, Air Dryer

The air dryer is usually located on the front left frame rail. Most air dryers have some kind of oil filter before a bed of moisture-absorbing desiccant. The air dryer removes water that has condensed as a by-product of the compression process, and also removes oil that gets passed through from the compressor. When the compressor reaches the high-pressure limit, and the governor signals for the compressor to turn OFF (cutout), the dryer also momentarily purges the desiccant bed of any collected moisture. The air dryers used are the Bendix models AD-9, AD-IP, AD-IS, and a WABCO System Saver 1200. The Bendix AD-IS, is attached directly to the supply tank. From the air dryer, the air goes through a black air hose into the wet tank (also called the supply tank).

Supply or Wet Tank

The purpose of the supply (wet) tank is to collect moisture, so that it does not easily pass on to the other tanks, or the rest of the air system. A small black hose connects the wet tank to the air governor, so the governor can monitor system pressure. From the wet tank, the air goes through a check valve into another air tank, either the primary or secondary air tank, depending on the vehicle configuration. In many cases, the wet tank will be a small compartment of one of the other tanks. In these cases a weld line is visible on the exterior of the tank. Each tank is protected by a check valve that prevents flow back into the wet tank.

Air Governor

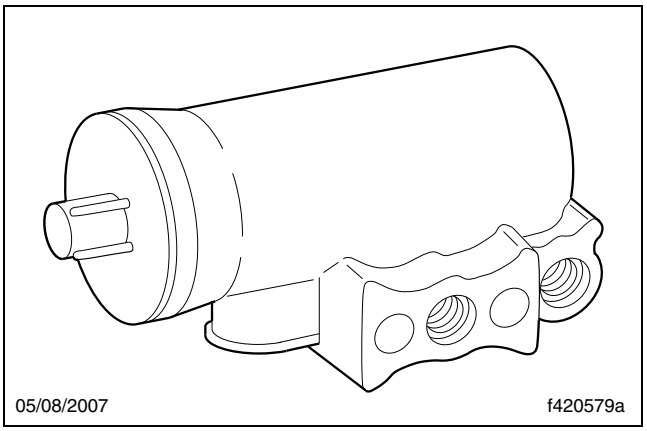


Fig. 5, Air Governor

The air governor is attached directly on the compressor on all engines except for the Mercedes-Benz MBE4000, where it is located on the engine block. The air governor cut-in pressure is 110 psi (758 kPa), and the cutout pressure is 130 psi (896 kPa). When the governor senses that the pressure in the wet tank has reached the cut-out level (130 ± 5 psi [896 ± 34kPa]), the compressor turns OFF (unloaded). As air is used, or depleted, from the tanks, the pressure in the supply/wet tank falls. When it reaches the cut-in pressure level (110 ± 5 psi [758 ± 34kPa]), the compressor turns ON (loaded), and starts pumping air again. Once the cutout pressure has been reached, the governor sends a signal (through a direct connection if the governor is attached directly to the compressor) to the compressor to move to the unloaded condition. The governor also sends a pressure signal, through a small silver hose, to the air dryer to purge. The model used is a Bendix D-2A.

Dual Air System

The air in the supply or wet tank passes through single check valves to fill the two separate air tank systems known as the primary and secondary air systems. The check valves, or in some cases pressure protection valves, are used to isolate these two independent air systems from each other. If there is a leak in one system, which may drain it down to zero pressure, the other air system will remain unaffected.

Air Brake System

Normally, the steering axle service brakes are plumbed into the secondary air system, and the drive axle service brakes are plumbed into the primary air system. The trailer service brakes, and parking brakes, receive air from either the primary or secondary air system, depending on which system has the higher pressure. The truck/tractor parking brake control is also supplied by the higher of either the primary or secondary system. Neither the service brakes nor the parking brakes are pressure-protected. The total air reservoir volume, of all the air tanks on the vehicle (including the wet/supply tank) available for use by the brake system, must exceed a volume of 12 times the total brake chamber volume, at maximum brake chamber stroke.

Air Accessories

The vehicle air accessories are generally the non-service/parking-brake related, air-powered features, that are required to be pressure-protected from the rest of the air systems. Air accessories include, but are not limited to: engine fan control, engine brake control, engine performance control, interaxle lock control, differential lock control, front axle air suspension, rear axle air suspension, cab suspension, air seats, air horns, transmission

control, rear air suspension dump, fifth wheel slide, fifth wheel kingpin lock, and PTO control. Generally, all air accessories are plumbed to the secondary air system.

Pressure Protection

Pressure protection valves (PPV) are installed between the secondary air tank(s) and all air accessory devices. The PPV "protects" the air reservoir from being completely drained if there is a leak in an air accessory device(s). In an emergency, when there is a leak or the pressure is falling, the PPV reserves the air tank pressure for the higher priority brake system, and shuts off the lower priority air accessory device(s). The PPV is a simple spring-piston device. If the pressure in the air tank is rising from 0 psi (0 kPa), at a designated opening pressure, the PPV opens and delivers air to the air accessory device(s). If there is a leak in the air accessory device(s), as the pressure is falling, the PPV will close at a designed pressure level, and let the air accessory device go to 0 psi (0 kPa), while retaining air pressure in the air tanks. The rear suspension is typically supplied through an 85 psi (586 kPa) (open) PPV, which closes at about 67 psi (462 kPa). All the other air accessory devices are typically supplied through a 55 psi (379 kPa) (open) PPV, that closes at about 45 psi (310 kPa). The 55 psi (379 kPa) PPV often feeds a junction block, from which several air accessory devices are plumbed. Although the purpose of pressure protection is to protect the brake air from a leak in an air accessory, there is also a kind of protection for the air accessory in the event that there is a leak in the air tank or brake system. In that case, the tank pressure (and air accessory pressure) will fall until it reaches the closing point of the valve, and then it will trap or hold that pressure in the air accessory device.

For more information on individual components, see the following:

- C01.02 — ICU4/4M Instrument Cluster
- G02.03 — Central Gateway
- G02.04 — SAM Cab Module
- G02.05 — SAM Chassis Module

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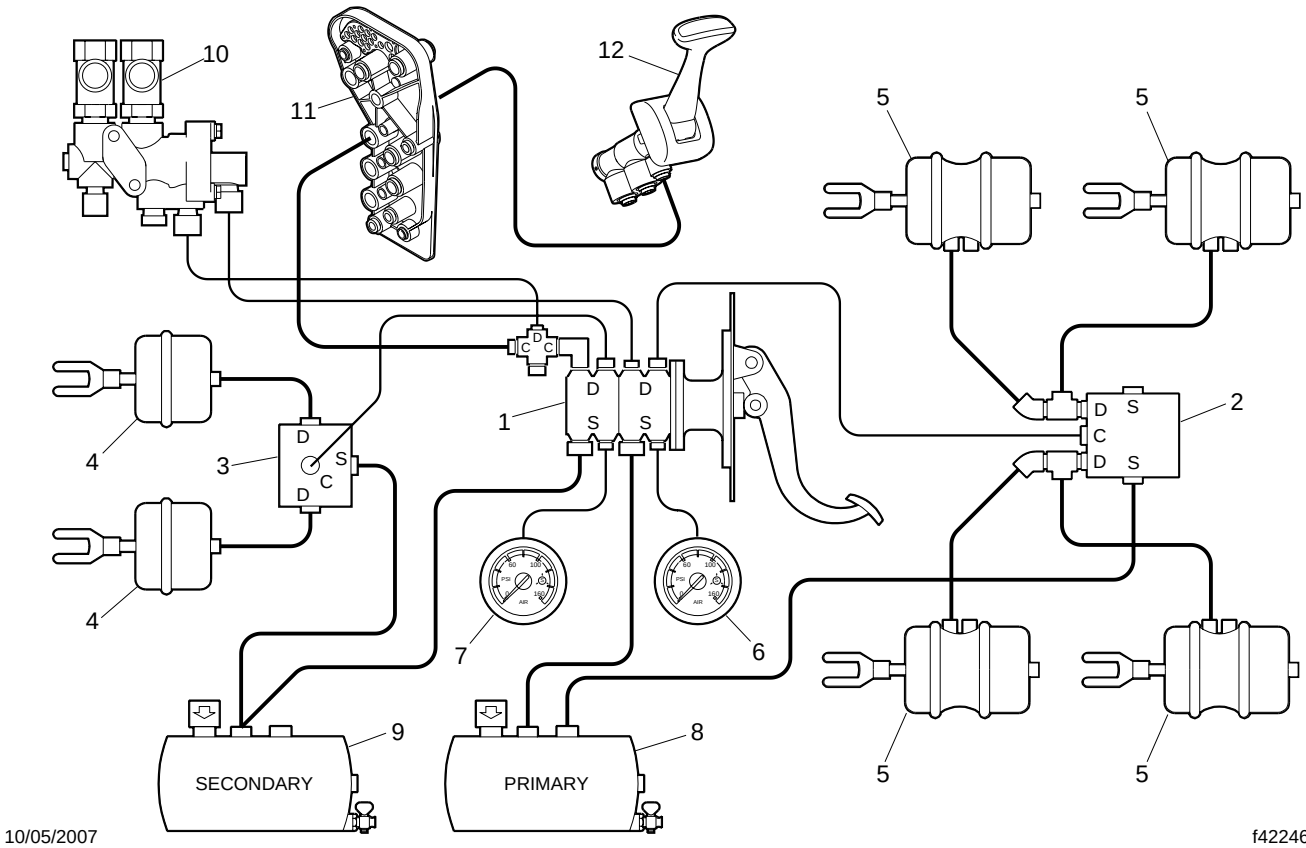
500 — General Information

The service brake system uses pressurized air to actuate the service brakes. The service brake system applies gradual pressure to the brake chambers proportional to the pressure applied to the brake foot pedal. For more information on the service brakes, refer to *Service Brakes, Mechanical System*, H01.07. For vehicle specific air system plumbing diagrams, refer to EZWiring™.

The service brake air system includes the following components:



1. Service Brake Control Valve
2. Rear Air Brake Valve
3. Front Air Brake Valve
4. Front Air Brake Chamber
5. Rear Air Brake Chamber (dual chambered, Includes parking brake)
6. Primary Air System Pressure Gauge
7. Secondary Air System Pressure Gauge
8. Primary Air System
9. Secondary Air System
10. Trailer Air Valve
11. Air Manifold Pass-Through Unit
12. Trailer Hand Brake

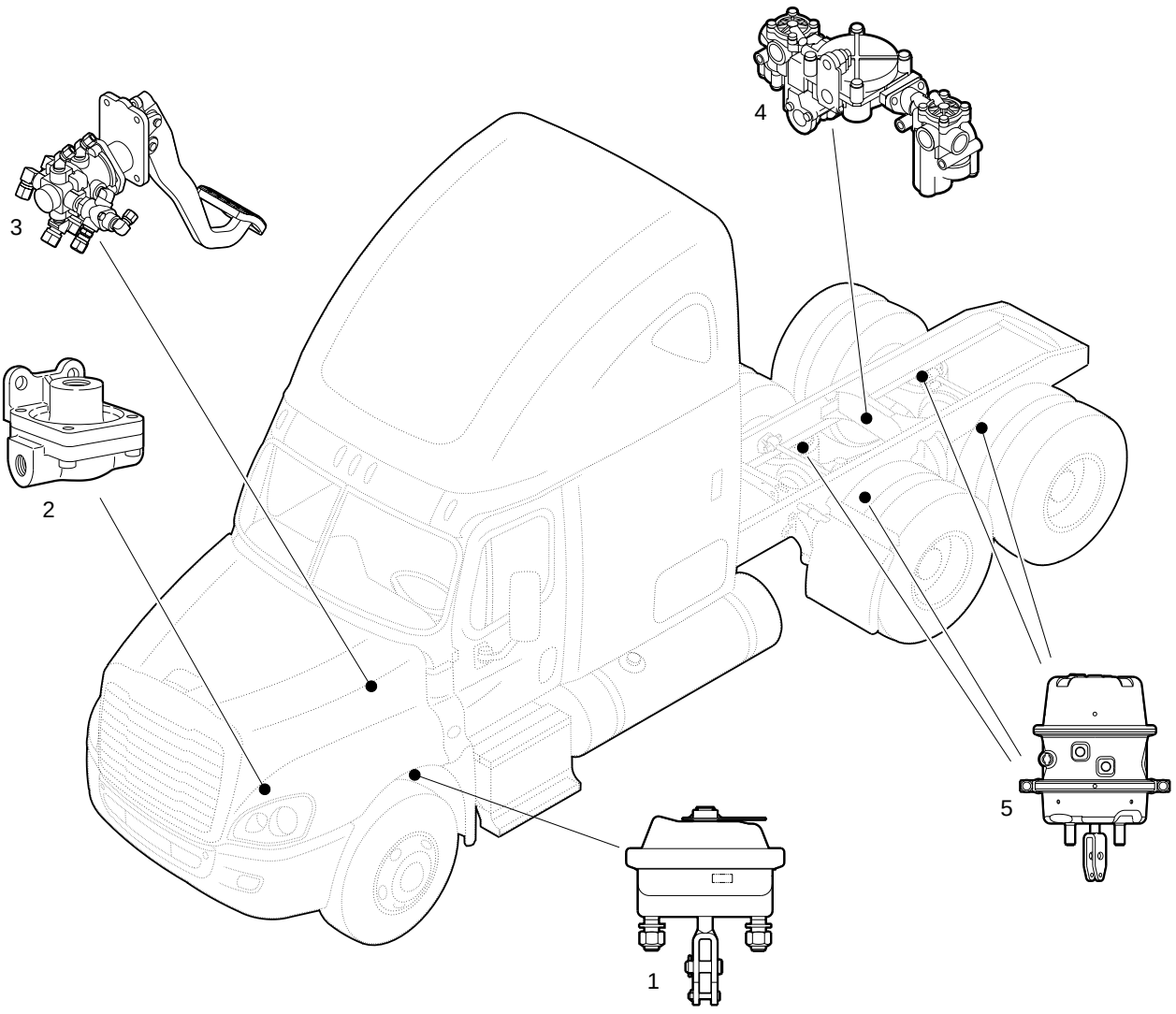
Fig. 1, Service Brake System Components (typical)

When the brake pedal is pressed, air from the secondary air system pressurizes the line to the control port of the front brake valve. The front brake valve opens proportionally to the pressure in the control line, and air from the secondary air system connected to the supply port of the valve is routed to the delivery port, where it pressurizes the brake canisters and applies the brakes. This same process occurs for the rear brakes, except the rear brakes use air from the primary air system. Additionally the trailer brake is actuated in the same way, but the

trailer brake can also be operated independently of the tractor brakes, using the trailer hand brake located on the dash. The air pressure gauges located in the ICU are connected to the supply port of the service brake control valve through the air manifold pass-through unit. For more information on individual components see the following subjects:

- H01.06 – Air Supply System
- H01.07 – Service Brakes, Mechanical System
- H01.09 – Parking Brake System

600 — Component Locations



1. Front Air Brake Chamber
2. Quick Release Valve
3. Service Brake Control Valve
4. Rear Air Brake Combination Valve (relay valve and two ABS modulator valves)
5. Rear Air Brake Chamber (dual chambered, includes parking brake)

Fig. 2, Component Locations

610 — Component Details

Service Brake Control Valve

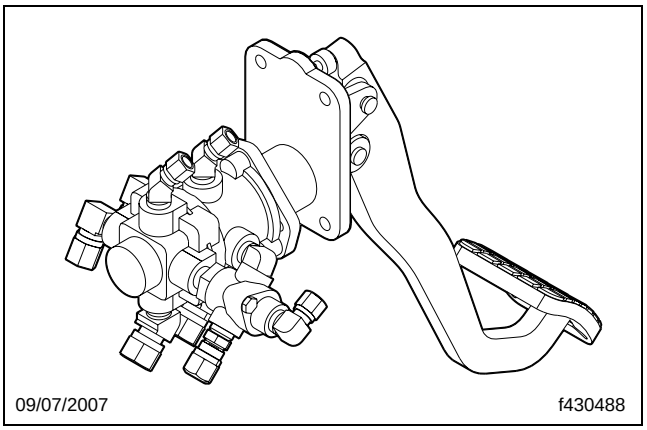


Fig. 3, Service Brake Control Valve

The service brake control valve is actually two separate valves, the half closer to the front wall is supplied by the primary air system (port is indicated with “SUP 11”). The delivery ports go to the rear brakes and trailer brakes (both horizontal unmarked ports). The top port is directly linked to the supply port, and the Primary air gauge is connected here. The second half of the brake control valve is supplied by the secondary air system, and the delivery ports (with the marks "DEL 21") lead to the front brakes, with an additional double check valve that allows for either the trailer hand valve, or brake control valve, air application to the trailer air valve. The top port is directly linked to the supply port, and the secondary air gauge is connected here.

Rear Air Brake Combination Valve

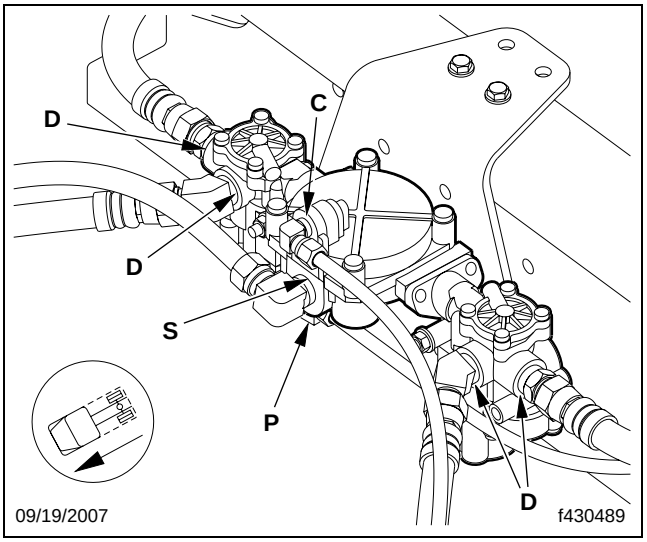


Fig. 4, Rear Air Brake Combination Valve

The rear air brake combination valve is mounted on the crossmember beneath the fifth wheel (if equipped). The combination valve consists of a relay valve, and two ABS modulation valves. The combination valve is labeled with an "S" indicating supply port for the relay valve, "C" indicating the control port for the relay valve and "D" indicating the delivery ports of the modulator valves. The "P" indicates a delivery port from the relay valve and leads to the parking brake control valve.

Front Brake Air Valve

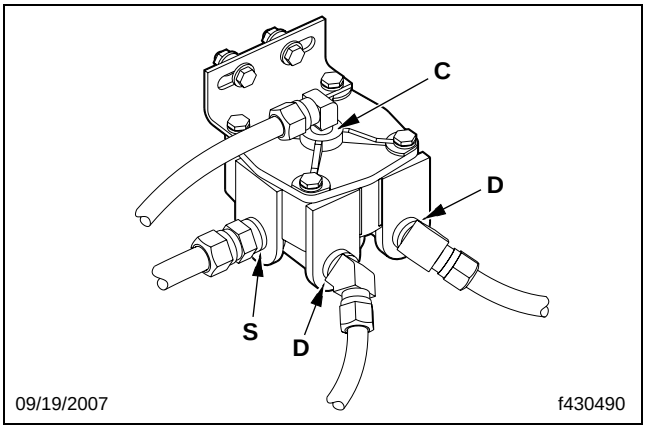


Fig. 5, Front Brake Relay Valve

The front brake air valve is mounted on the front of the left frame rail. "S" indicates the supply port, "C" indicates the control port, "D" indicates delivery ports. "E" indicates the exhaust port. Depending on vehicle configuration, it will be either a quick release valve (>90%) or a relay valve.

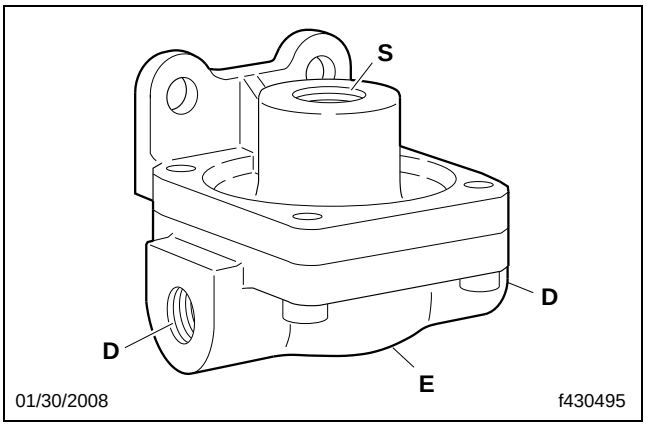


Fig. 6, Front Brake Quick Release Valve

Front Air Brake Chamber

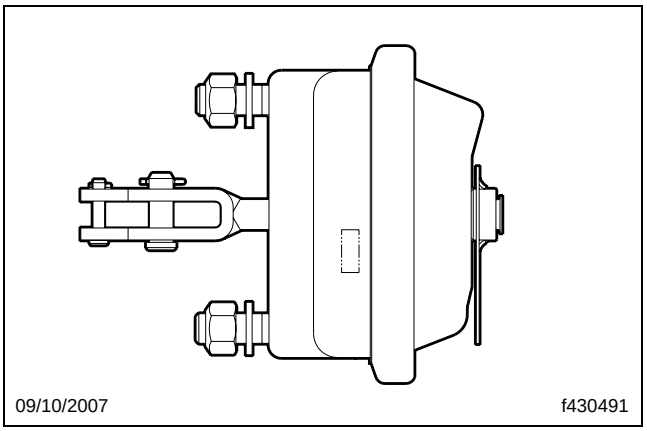


Fig. 7, Front Air Brake Chamber

The front air brake chambers are single chamber units. They only apply the vehicle service brakes.

Rear Air Brake Chamber

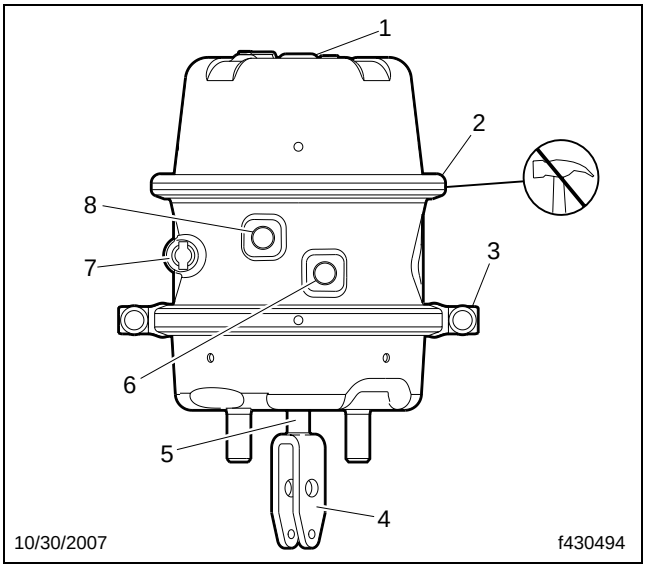


Fig. 8, Rear Air Brake Chamber

The rear air brake chambers, on at least one of the rear axles, are a two-chambered design, with a service brake chamber, and a parking brake chamber. "P" indicates the parking brake port, and "S" indicates the service brake port. Normally, the forward rear axle will have the parking brakes, and the rear rear axle will have single chamber brake chambers similar to those on the front brakes. In some applications, both rear axles will have parking brake chambers installed.

700 — Quick Release Valve Operation and Leakage Tests

The following tests should be performed after repairing or replacing the quick release valve to ensure that it is functioning properly.

1. Park the vehicle on a level surface and set the parking brakes. Shut down the engine. Chock the tires.
2. Drain the air system.
3. Release the parking brakes.
4. On QR-1C valves, remove the air line from the valve balance port. Build system air pressure to 120 psi (827 kPa). Coat the exhaust and balance ports with a soap solution; leakage of no greater than a 1-inch (2.5-cm) bubble in 5 seconds at either port is allowable. Install the air line at the balance port.
5. Apply the parking brakes. Step on the foot brake; the valve should exhaust air at the exhaust port when the foot brake is released.
6. Drain the air system.
7. Remove the air line from the valve supply port. Build system air pressure to 120 psi (827 kPa). With the foot valve depressed, coat the supply port and the seam between the body and cover with a soap solution; leakage of no greater than a 1-inch (2.5-cm) bubble in 5 seconds at the supply port is allowable. No leakage between the body and cover is permitted. Install the air line at the supply port.
8. If the valve does not function properly, or if leakage is excessive, repair or replace it following the instructions in this section.

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502 — System Overview

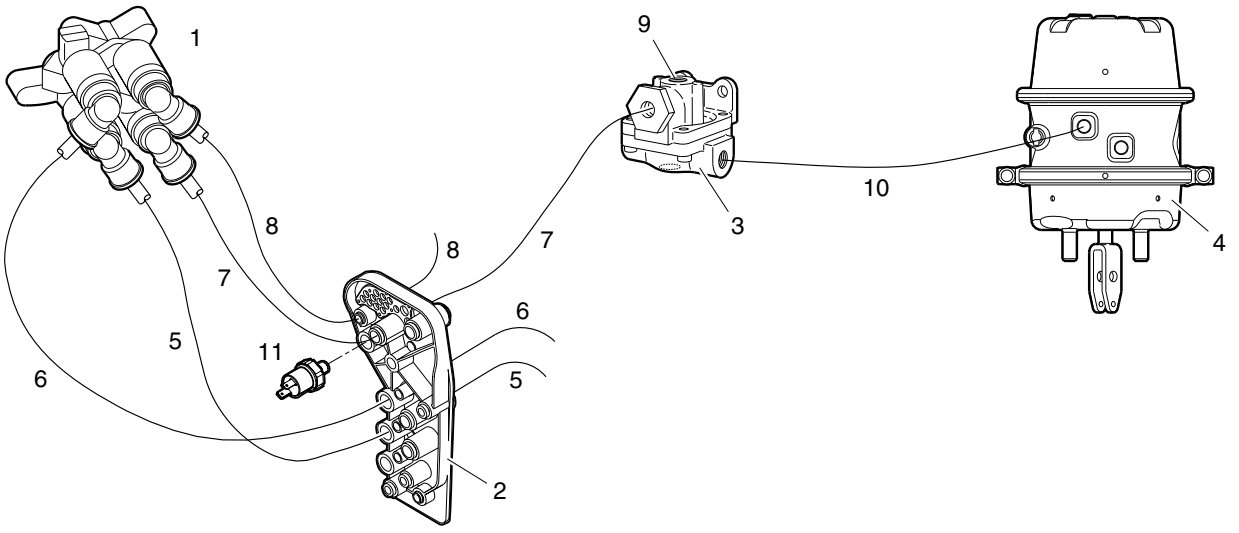
⚠ DANGER

Do not attempt to remove the factory-sealed clamp ring of a dual chamber brake chamber for any purpose, at any time. The parking/emergency brake section is not intended to be serviced. Serious injury or death may result from the sudden release of the power spring.

The parking brake system uses powerful springs to apply the rear brake chambers when parking. The parking brake can only be released if there is air pressure greater than the pressure of the parking brake spring (approximately 65 psi [448 kPa]). If the primary air system loses pressure, the parking brakes will gradually start applying pressure at about 65 psi (448 kPa), and will be fully applied when there is no longer any pressure in the primary air system. For more information on the parking brake system, see the following:

- H01.05 — Parking Brake Warning System
- H01.08 — Service Brake, Air System

The parking brake system includes the following components:



1. Parking Brake Control Valve
2. Air Manifold Pass-Through Unit
3. Parking Brake Air Valve (valve type may vary)
4. Air Brake Chamber
5. Air Line From the Primary Air System
6. Air Line From the Secondary Air System
7. Air Line to Parking Brake Air Valve
8. Exhaust Line
9. Air Line From Brake Valve to Parking Brake Valve
10. Air Line to Parking Brake Port on Brake Chambers
11. Parking Brake Pressure Switch

Fig. 1, Parking Brake System Components

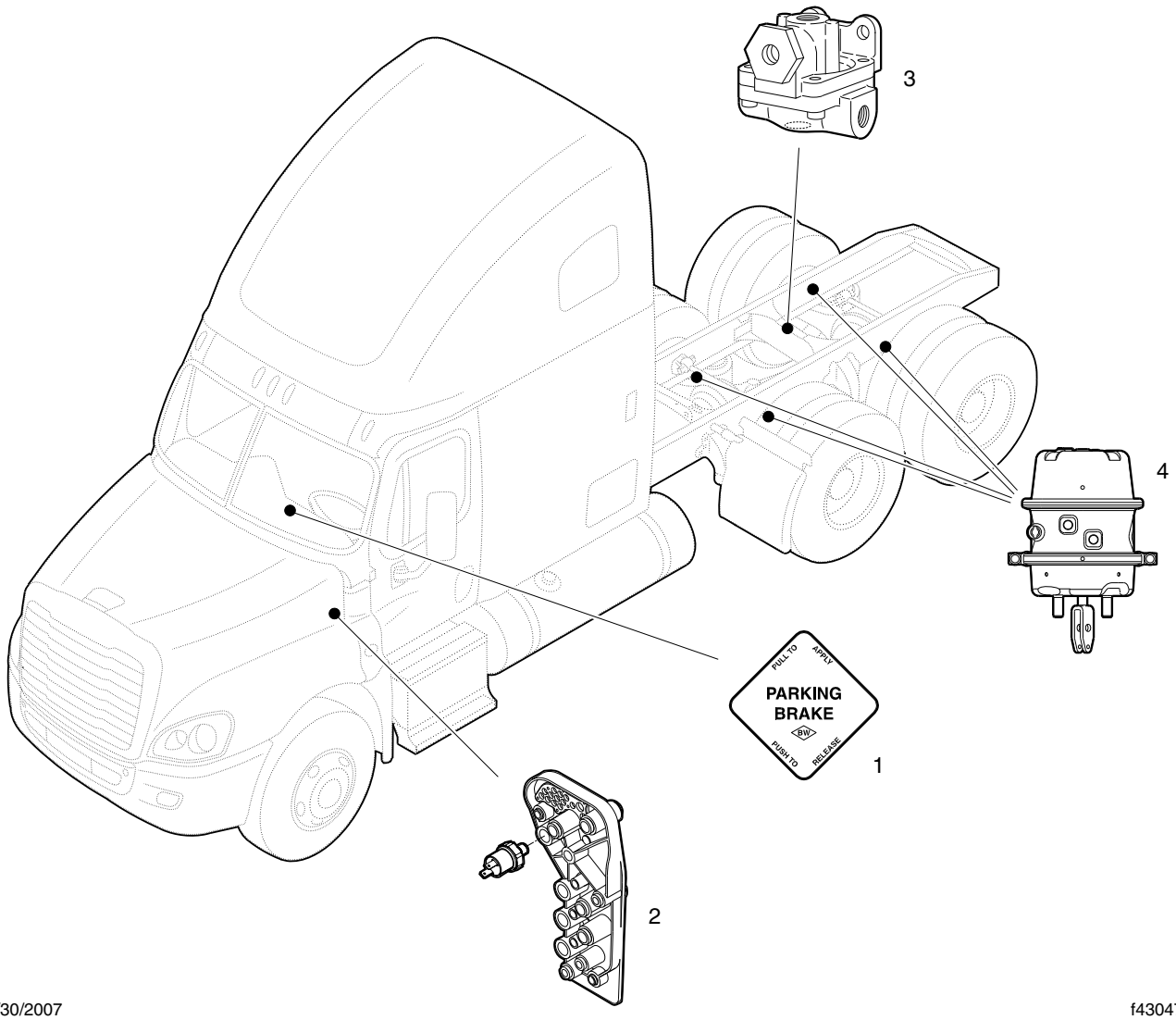
When the parking brake knob is pushed to release the parking brake, air from either the primary or secondary air system (whichever is greater) pressurizes the black delivery line that runs back through the air manifold pass-through unit to the control port on the parking brake air valve. When the control port is pressurized, it allows air

to flow from the supply port to the delivery ports, which lead to the parking brake port on the air brake chambers. The supply air to the parking brake air valve is supplied by the air brake valve, which in turn is supplied by the primary air system.

For more information on individual components, see the following chapters:

- H01.05 — Parking Brake Warning System
- H01.06 — Air Supply System
- H01.08 — Service Brakes, Air System

600 — Component Locations



1. Parking Brake Control Valve
2. Air Manifold Pass-Through Unit
3. Parking Brake Air Valve (valve type may vary)
4. Air Brake Chamber

Fig. 2, Component Locations

601 — Component Details

Parking Brake Control Valve

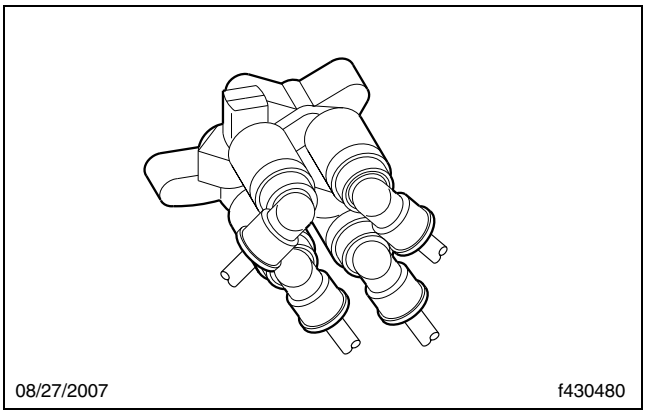


Fig. 3, Parking Brake Control Valve

The parking brake control valve has four air hoses connected to the back of it. The green line is primary air supply, the red line is secondary air supply, the black line is for the control signal to the parking brake air valve, and the yellow line is the exhaust port, which leads to the engine side of the front wall to eliminate the control valve from exhausting into the dash area.

Air Manifold Pass-Through Unit

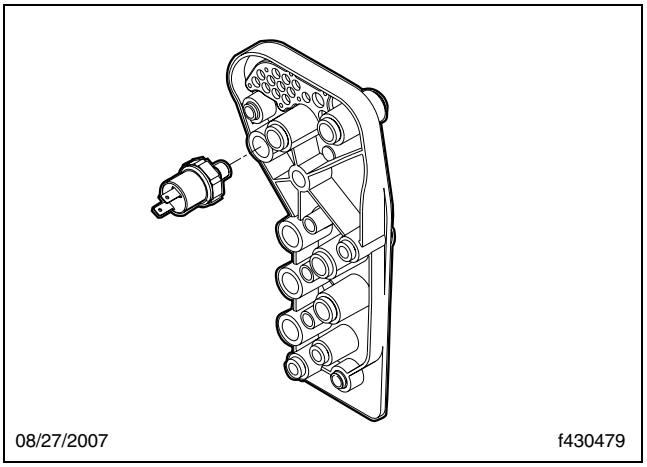
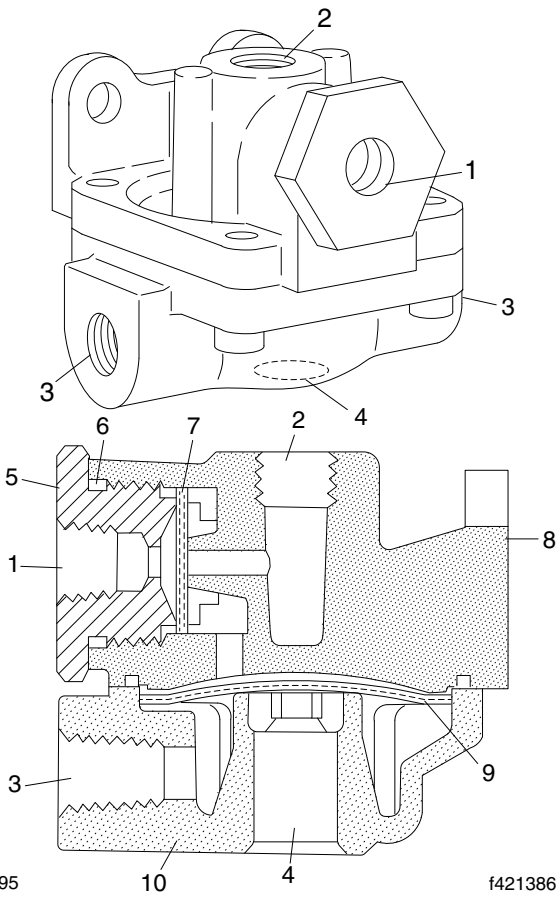


Fig. 4, Air Manifold Pass-Through Unit

The air manifold pass-through unit is located on the front wall above the throttle pedal. The pressure switch shown is part of the Parking Brake Warning System (H01.05).

Parking Brake Air Valve

Tractor Applications



1. Supply Port
2. Balance Port
3. Delivery Port
4. Exhaust
5. Cap Nut
6. Sealing Ring
7. Double Check Diaphragm
8. Body
9. Quick Release Diaphragm
10. Cover

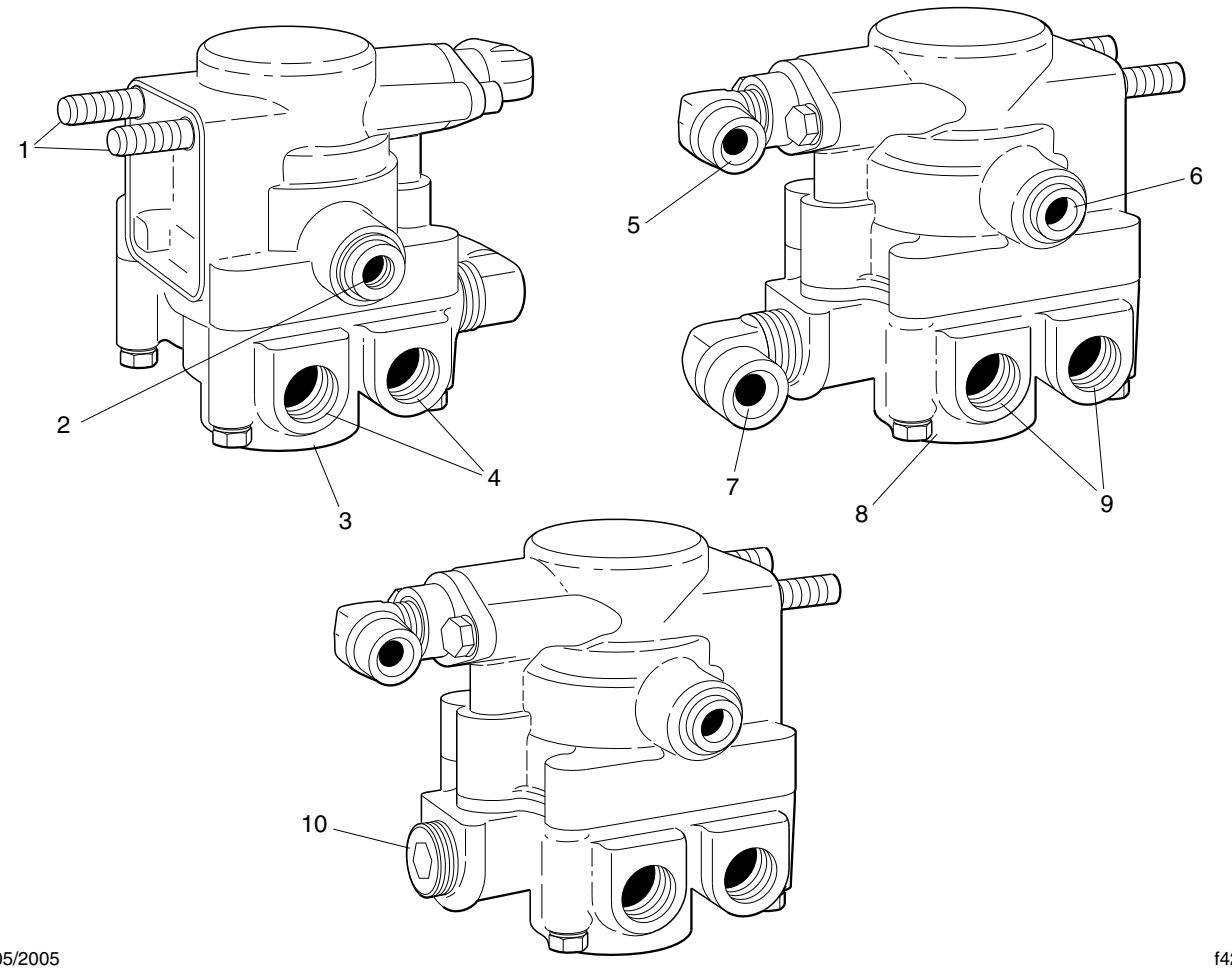
Fig. 5, Parking Brake Air Valve (QR-1C cross-section shown)

On a tractor application, the parking brake air valve is mounted near the rear axle, generally on the fifth wheel rear horizontal crossmember. This quick release valve is a dual function valve. Its primary function is to speed up the release of air pressure from the parking brake chambers. Additionally, the valve works as an anticompound

device. The double check valve feature prevents a service and parking brake application from occurring at the same time. A balance line from the relay valve delivery port (port 2 on the WABCO combination valve) is connected to the balance port on the quick release valve; the two side ports are for brake chamber connections; the supply port is connected to the delivery port of the parking brake control valve, and the exhaust port is located at the bottom of the valve.

Straight Truck Applications

On straight truck applications, the parking brake air valve is mounted near the rear axle, generally on a horizontal crossmember. The Bendix SR-7™ spring brake modulating valve is used in conjunction with a dual air brake system and spring brake actuator, and performs the following functions:



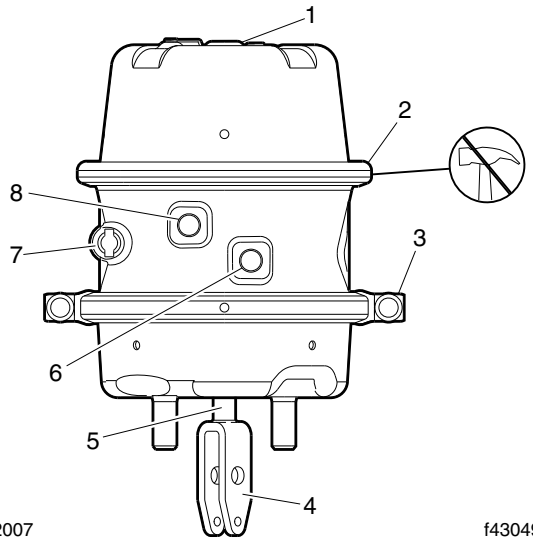
1. Mounting Studs
2. 42 Control Port
3. Exhaust
4. Delivery
5. 41 Park Control (from dash valve)
6. 41 Balance Port
7. Supply Port
8. Exhaust
9. Delivery
10. Pipe Plug (QRV applications only)

Fig. 6, SR-7 Spring Brake Modulating Valve (exterior views)

- Modulates the spring brake actuator application using the dual brake valve should a primary failure occur in the service brake system.
- Prevents compounding of service and spring brake forces.

The SR-7 valve has one park control, one service control, one supply, one balance, four delivery NPT ports, and an exhaust port protected by an exhaust diaphragm. The valve incorporates two mounting studs for mounting the valve to the frame rail or crossmember.

Dual Air Brake Chamber



Do not remove the factory-sealed clamp ring.

1. End Cover Cap
2. Factory-Sealed Parking Brake Clamp Ring
3. Service Brake Clamp Ring
4. Clevis
5. Piston Rod
6. Spring Brake Air Inlet
7. Release Bolt Storage Pocket
8. Parking Brake Air Inlet

Fig. 7, Dual Air Brake Chamber

The air brake chambers are a standard 2 chambered design.

700 — Operating and Leakage Tests

The following tests should be performed if the parking brake system is not operating properly, and/or after repairing or replacing the valve, to ensure that it is functioning properly.

Quick Release Valve, Bendix QR-1C

1. Make sure the tires are properly chocked.

2. Build system air pressure to 120 psi (827 kPa).
3. Release the parking brakes.
4. Remove the air line from the valve balance port. Coat the exhaust and balance ports with a soap solution; leakage of a 1-inch (25-mm) bubble in five seconds at either port is allowable. Install the air line at the balance port.
5. Apply the parking brakes; the valve should exhaust air at the exhaust port.
6. Build system air pressure to 120 psi (827 kPa).
7. Remove the air line from the valve supply port. With the foot valve depressed, coat the supply port and the seam between the body and cover with a soap solution; leakage of a 1-inch (25-mm) bubble in five seconds at the supply port is allowable. No leakage between the body and cover is permitted. Install the air line at the supply port.
8. If the valve does not function properly, or if leakage is excessive, repair or replace it following the instructions in **Group 42** of the *Cascadia™ Workshop Manual*.

Modulating Valve, Bendix SR-7

⚠ CAUTION

Do not attempt to disassemble the SR-7 valve. The valve contains high spring forces that could result in personal injury if disassembly is attempted.

NOTE: The SR-7 valve is not serviceable. If the valve does not function as described, or if leakage is excessive, replace it following the instructions in **Group 42** of the *Cascadia™ Workshop Manual*.

Operational Check

1. Make sure the tires are properly chocked.
2. Charge the air brake system to governor cut-out pressure.
3. Place the parking control valve in the PARK position. Observe that the spring brake actuators apply promptly.
4. Remove one line from a delivery port of the SR-7 valve and install a test gauge that is known to be accurate. See **Fig. 6** for the port locations.
5. Place the parking control valve in the RELEASE position. Observe that the spring brake actuators fully release.
6. With the parking control valve still in the RELEASE position, note the gauge pressure reading. Correct spring brake actuator hold-off pressure is 107 psi (737 kPa) nominal.
7. Place the parking control valve in the PARK position. The gauge reading should drop to zero promptly. A lag (more than 3 seconds) in the drop of pressure would indicate faulty operation.
8. With the parking control valve still in the PARK position, gradually apply the foot brake valve and note a pressure reading increase on the gauge installed in the SR-7 valve delivery port.
9. Place the parking control valve in the RELEASE position.
10. Drain the reservoir that supplies the rear service brake circuit; apply the foot brake valve several times and note that the pressure reading on the gauge decreases each time the foot brake valve is applied (spring

brake modulation). After the foot brake valve has been applied several times, the pressure reading on the gauge will drop to the point where release of the spring brake actuators will no longer occur.

Leakage Test

Place the parking control valve in the RELEASE position; using a soap solution, coat all ports including the exhaust port. A 1-inch (25-mm) bubble in three seconds is permitted.

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500 — Terms and Abbreviations

Bellow—A rubber or polypropylene "boot" that is clamped over the ends of the rack and inner tie rods on the rack and pinion steering gear

I-Shaft—Intermediate Steering Shaft.

Poppet—A rising and falling valve consisting of a disk at the end of a vertically set stem. The poppet reduces power steering hydraulic pressure just before full right or left turns.

PSSA—Power Steering System Analyzer

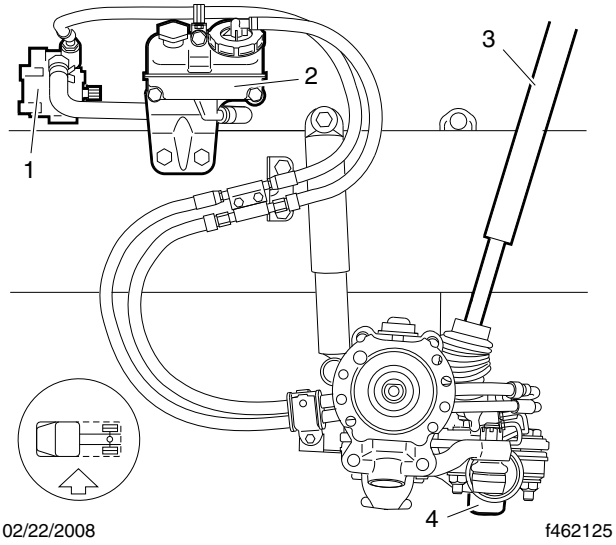
501 — General Information

The power steering pump converts the rotational energy of the engine into hydraulic energy, flow, and pressure. The steering gear then uses this hydraulic energy to steer the vehicle.

The power steering pump creates a partial vacuum at the inlet, which causes atmospheric pressure to force the fluid into the pump from the reservoir. The pump then pushes the fluid into the system for use by the steering gear.

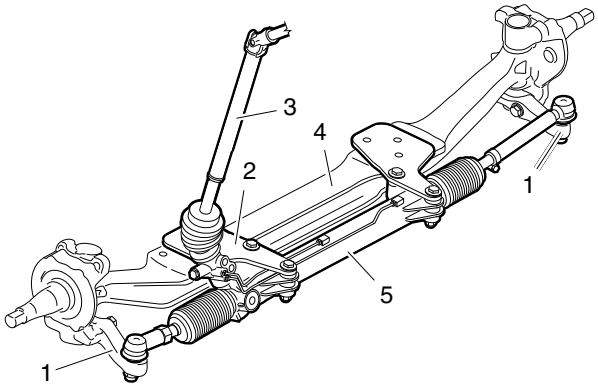
Pump output flow relates to steering gear speed, and the pump output pressure relates to steering gear force.

600 — Component Locations



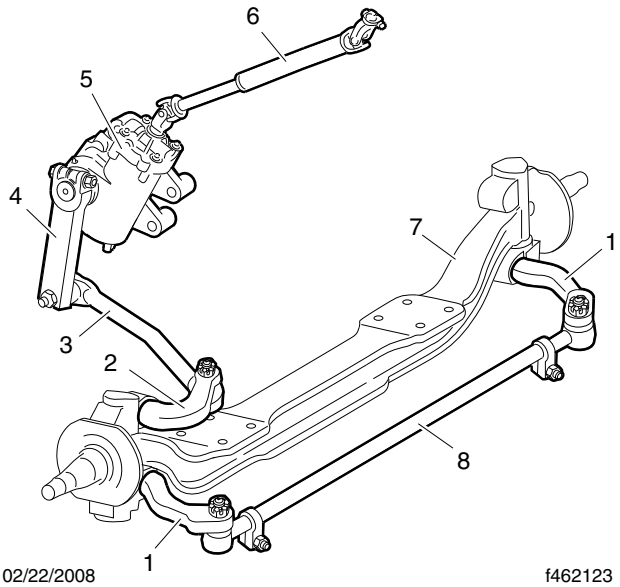
1. Power Steering Pump (DDC60 location shown)
2. Fluid Reservoir
3. Steering I-Shaft
4. Rack and Pinion Steering Gear

Fig. 1, Rack and Pinion Steering System



1. Tie Rod Arm
2. Gear Mounting Bracket
3. I-Shaft
4. Axle
5. Rack and Pinion Steering Gear

Fig. 2, Rack and Pinion Steering Gear



1. Tie Rod Arm
2. Steering Arm
3. Drag Link
4. Pitman Arm
5. Integral Steering Gear
6. I-Shaft
7. Axle
8. Tie Rod

Fig. 3, Integral Steering Gear

700 — Possible Causes

- Excessive Heat
- Contaminated Fluid
- External Damage
- Misaligned or Improperly Adjusted Components
- Excessive System Restriction

701 — Diagnostic Tools Required

- Power Steering System Analyzer (PSSA)
- Low Pressure Gauge, 200–300 psi (1380–2070 kPa) maximum
- Temperature Gauge
- Steering Stop Spacer, 1-inch

702 — Checklist for Troubleshooting Power Steering Problems

A Checklist for Troubleshooting Power Steering Problems, form STI-492, has been developed to accompany the procedure in **703 — Steering System Troubleshooting**. To access Form STI-492, follow the steps below.

1. Log into www.AccessFreightliner.com.
2. Under Applications, click on **WarrantyLit**.
3. Click on **Forms**.
4. Select "**Checklist for Troubleshooting Power Steering Problems (STI492)**."
5. Save or print form STI-492.

Each test in **703 — Steering System Troubleshooting** corresponds to a step on form STI-492. Use **Table 1** to determine which steps should be completed, based on the customer's complaint. For example, if complaints include "Pulling to one side" and "Noisy steering," steps 1, 3, 4, 5, and 6 will be the tests for the most likely failure modes.

Start with the lowest test number and work up to the highest. For example, when completing steps 1, 3, and 6 to determine the cause of a vehicle pulling to one side, start with test 1 and finish with test 6.

Steering Complaint and Troubleshooting Steps Checklist													
LH	RH	Both	Complaint	Troubleshooting Steps								
				1	2	3	4	5	6	7	8	9
			Hard or heavy steering	•	•		•	•	•	•	•	•
			Low assist									
			Binding									
			Locking									
			Occasional loss of assist									
			Reduced wheel cut								•	

Steering Complaint and Troubleshooting Steps Checklist												
LH	RH	Both	Complaint	Troubleshooting Steps								
				1	2	3	4	5	6	7	8	9
			Pulling to one side*	•		•			•			
			Darting/oversteering	•	•	•	•		•			
			Wandering									
			Noisy steering				•	•	•			
			External seals leaking					•	•			•
			Excessive heat									

* If there is consistent pull to one side, a braking issue could feel like a steering assist problem. Refer to **Group 42** in the *Cascadia Workshop Manual* to ensure the brake system is functioning properly.

Table 1, Steering Complaint and Troubleshooting Steps Checklist

703 — Steering System Troubleshooting

Tests 1 through 4 may have been performed by the customer. Verify the vehicle service history with the customer to prevent redundant testing.

1. **Check the tire pressure and load.**

   1.1 Check the tires for damage.

   1.2 Check that the front tires are inflated to the correct pressure, and the tire pressure is equal on both sides.

   1.3 Check that the rear tires are inflated to the correct pressure, and the tire pressure is equal on both sides.

   1.4 Check that the tire sizes are correctly matched, and whether duplex or oversized tires (that were not originally specified for the vehicle) have been installed.

   1.5 Make sure the vehicle is being operated within rated capacities.

   Were any problems found with tire pressure and load?

   YES → Fix the problem and re-evaluate the steering system complaint.

   NO → Go to the next appropriate test.

2. **Check fifth wheel condition.**

   2.1 Check fifth wheel lubrication.

   2.2 Check the plate surface for burrs, gouges, and irregularities.

Were any problems found with the fifth wheel?

YES → Fix the problem and re-evaluate the steering system complaint.

NO → Go to the next appropriate test.

3. **Check vehicle alignment and wheel bearing adjustment.**

   3.1 Check the vehicle service history for the last known alignment, and inspect tire wear for indications that an alignment needs to be completed.

3.2 Check front axle caster and camber measurements.

3.3 Ensure wheel bearings and rear axle are in good condition, and that toe is set correctly.

3.4 Ensure the rear axle is properly aligned.

Were any problems found with vehicle alignment and wheel bearing adjustment?

YES → Fix the problem and re-evaluate the steering system complaint.

NO → Go to the next appropriate test.

4. **Check for loose and binding components. Check whether any steering components need maintenance or adjustment.**

4.1 Check for proper lubrication of the drag link, tie rods, and knuckle pins. Lubricate as needed.

4.2 Check the steering driveline U-joints for looseness or binding. Lubricate as needed.

4.3 Check the sector shaft adjustment.

- With the vehicle on the ground, the engine idling, and the front tires pointed straight ahead, turn the steering wheel until slight motion is observed at the front wheels.
- Align a reference mark on the steering wheel to a rule, then, with the engine running, slowly turn the steering wheel in the opposite direction until motion is again detected at the wheels.
- Measure the lash (free play) at the rim of the steering wheel. Excessive lash exists if steering wheel movement exceeds 2-1/2 inches (64 mm) with a 20-inch (508-mm) steering wheel, or 2-1/4 inches (57 mm) with an 18-inch (457-mm) steering wheel.

4.4 Check that the front wheels self-return without binding.

- With the engine off, chock the rearmost tires and place the front tires on radius plates (turntables).
- Disconnect the drag link from the steering arm.
- By hand, pull one tire to the axle stop and release. The tire should self-return to almost straight ahead. Repeat with the opposite tire.
- If a tire does not return to near straight ahead, check for binding or lack of lubrication in the steering axle kingpin bushings or tie rod linkage.
- Connect the drag link and tighten the castle nut, then install a new cotter pin.

4.5 Inspect all suspension fasteners and components for wear or looseness.

Were any problems found with loose or binding components?

YES → Fix the problem and re-evaluate the steering system complaint.

NO → Go to the next appropriate test.

5. **Check the steering system for leaks or restrictions, and test the system back pressure.**

5.1 Inspect hoses, fittings, and seals for damage or leaks.

- With the engine idling, inspect for kinked or collapsed hoses. Ensure the steering system is filled with the correct automatic transmission fluid.
- Inspect fittings for leaks.

- Inspect all external seals.
- Inspect the seal bores and sealing surfaces for scrapes or burrs. Make sure the seals are installed correctly using the recommended tools.
- If you replaced the steering gear input shaft seal and found it to be excessively hard, test the system operating temperature in test 6.

5.2 Inspect the steering gear for external leakage.

- Clean the area around the input shaft and inspect the input shaft for signs of leakage after operating the vehicle under normal conditions through steering maneuvers.
- Inspect the sector shaft for signs of leakage.
- Inspect the vent plug in the trunnion housing for signs of leakage.

NOTICE

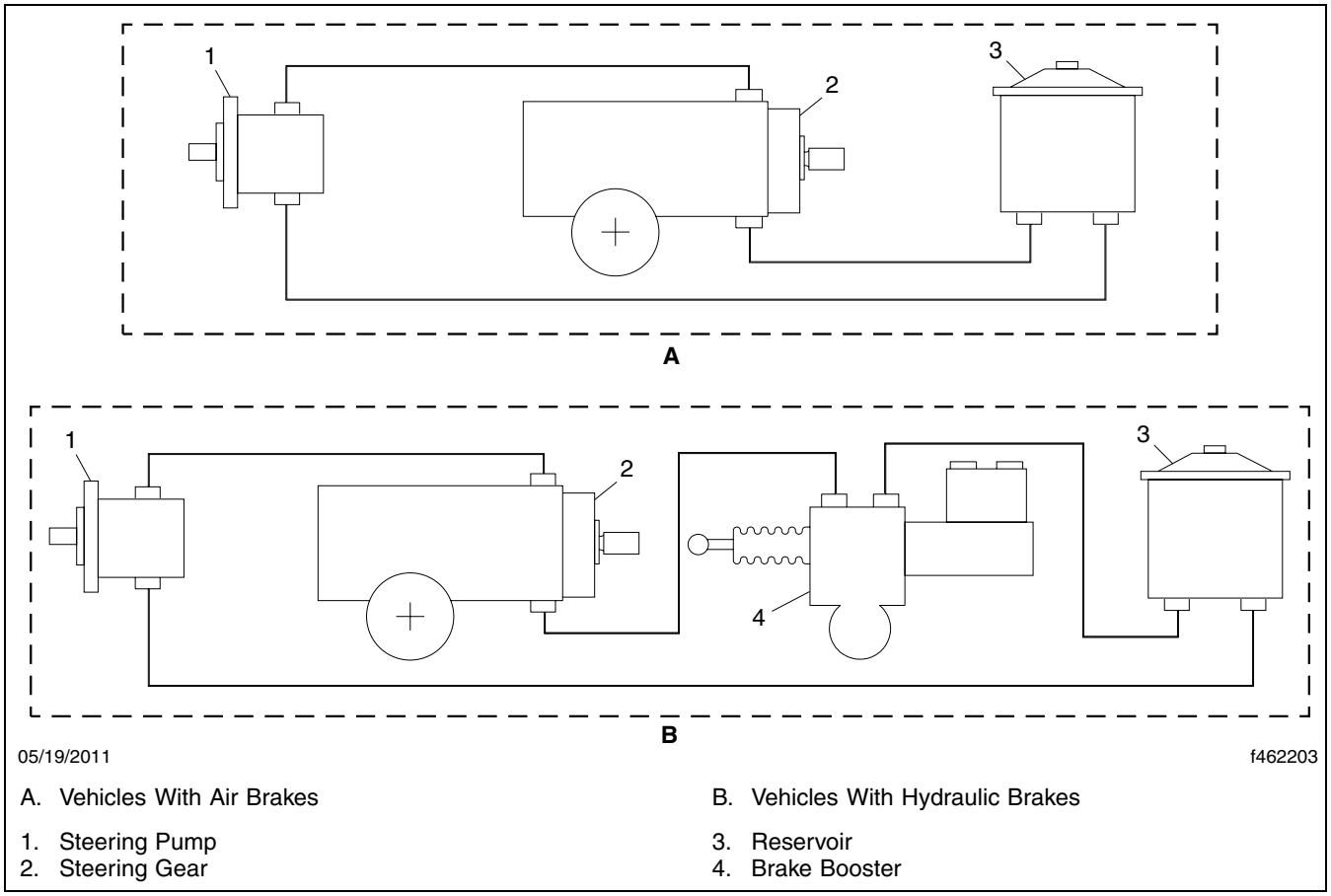
Do not turn the steering wheel or allow system pressure to exceed the rating of the gauge during the following test. Damage to the gauge could occur.

5.3 Check total steering system back pressure.

- Install a low pressure gauge—300 psi (2068 kPa) maximum—between the steering pump and the steering gear.
- Check for correct fluid level. If necessary, add fluid. If bubbles or foam appear in the reservoir, check hose fittings for looseness or leaks.
- With the engine idling, read the total system back pressure on the pressure gauge.
- If the total system back pressure is greater than 100 psi (689 kPa), or 140 psi (965 kPa) for a vehicle with hydraulic brakes, replace the steering fluid filter and re-test the system. If the system back pressure is still excessive, go to the next substep.
- If the total system back pressure is less than 100 psi (689 kPa), or 140 psi (965 kPa) for a vehicle with hydraulic brakes, restriction is not a problem—go to test 6.

5.4 Leave the low pressure gauge in place and check individual steering system components for excessive restriction. See **Fig. 4** for a plumbing diagram.

- Bypass the steering gear by disconnecting the steering gear input and output lines from the gear and coupling them together. See **Fig. 5** for an example. If the drop in system pressure from the value found in substep 5.3 is greater than 55 psi (379 kPa), the steering gear has excessive restriction. If the drop in pressure is less than 55 psi (379 kPa), reconnect the gear input and output lines to the gear and continue with this substep.
- If the vehicle is equipped with hydraulic brakes, bypass the brake booster by disconnecting the booster input and output lines and coupling them together. If the drop in system pressure from the value found in substep 5.3 is greater than 40 psi (276 kPa), the brake booster has excessive restriction. If the drop in pressure is less than 40 psi (276 kPa), reconnect the booster input and output lines and continue with this substep.
- Test each hydraulic line in the power steering system individually by bypassing them one at a time, as was done with the steering gear and brake booster, if equipped. If the drop in system pressure from the value found in substep 5.3 is greater than 12 psi (83 kPa) for any one line, replace the line and test total system back pressure again.



A. Vehicles With Air Brakes
B. Vehicles With Hydraulic Brakes

1. Steering Pump
2. Steering Gear
3. Reservoir
4. Brake Booster

Fig. 4, Plumbing Diagrams

Were any problems found with leaks or system restriction?

YES → Fix the problem and re-evaluate the steering system complaint.

NO → Go to the next appropriate test.

6. **Check steering pump performance.**

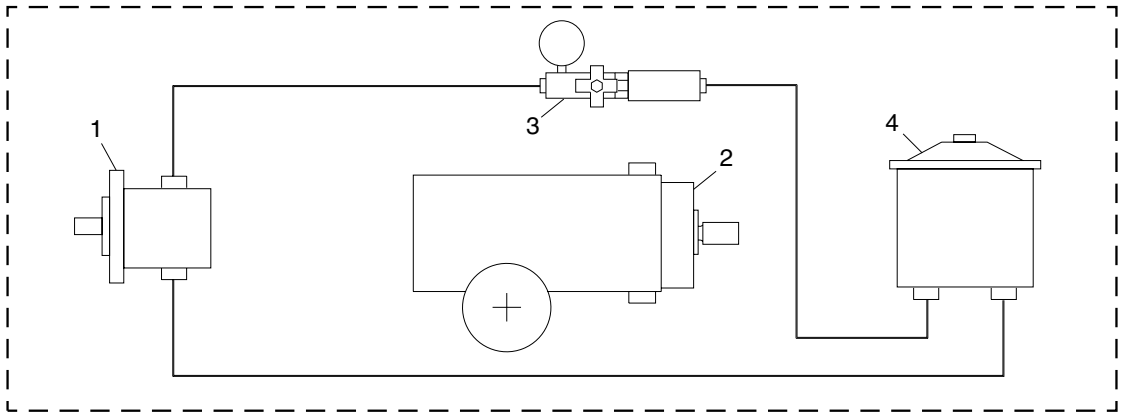
If the system fails the tests in the following substeps, replace the pressure relief valve (PRV) and complete the tests again. If the system fails again, replace the pump.

Power steering fluid temperature should be approximately 180°F (82°C) to best replicate fluid temperatures under normal driving conditions. Install the PSSA between the steering pump and the gear for the following substeps.

NOTICE

Do not leave the load valve closed for longer than five seconds during the following test. Doing so could damage the power steering system.

6.1 Check for erratic pump response.



1. Steering Pump
2. Steering Gear
3. Low Pressure Gauge
4. Reservoir

Fig. 5, Testing Steering Gear Restriction

- Slowly close the load valve and watch the pressure and flow readings as the valve closes, then open the valve immediately.
- If the pressure rises rapidly or appears uncontrolled, open the load valve immediately.
- If the response was erratic, replace the PRV or pump, as required. If the response was smooth and controlled, go to the next substep.

6.2 Check the pump relief pressure.

- Slowly close the load valve. When the valve is completely closed, read the pressure gauge, then open the valve.
- If the pump relief pressure does not exceed the typical relief pressure listed in **801 — Steering Gear Relief Pressures**, replace the PRV or pump, as required.
- If the pump relief pressure exceeds the typical relief pressure listed in **801 — Steering Gear Relief Pressures**, it is acceptable. Go to the next substep.

6.3 Test the pump relief valve reaction at idle.

- Run the engine at idle and note the flow rate with the load valve open.
- Close the load valve until the pump relief pressure is reached. Smoothly and quickly open the load valve and note the flow rate. Repeat this action three times. The flow rate should return to the flow rate first noted with the load valve open.
- If the flow rate does not return smoothly and quickly, the pump relief valve is not working correctly.
- If the flow rate returns smoothly and quickly, the pump relief valve is acceptable. Go to the next substep.

6.4 Test the pump relief valve reaction at 1500 rpm.

- Run the engine at 1500 rpm and note the flow rate with the load valve open.

- Close the load valve until the pump relief pressure is reached. Smoothly and quickly open the load valve and note the flow rate. Repeat this action three times. The flow rate should return to the flow rate first noted with the load valve open.
- If the flow rate does not return smoothly and quickly, replace the PRV or pump, as required.
- If the flow rate returns smoothly and quickly, the pump relief valve is acceptable. Go to the next substep.

IMPORTANT: For vehicles with high-pressure steering gears, use 1000 psi (6900 kPa) and 2300 psi (15 860 kPa) as the testload pressures.

6.5 Test the flow of the pump at idle with a load applied.

For vehicles with low-pressure steering gears, run the engine at idle and slowly close the load valve until the pressure gauge reads 1000 psi (6900 kPa). Read the flow rate on the gauge, then set the pressure to 1800 psi (12 400 kPa). Read the flow gauge, then open the load valve. Compare the values to those in **800 — Minimum Steering Pump Flow Rates**.

6.6 Test the flow of the pump with no load applied.

- Run the engine at 1500 rpm, make sure the load valve is completely open, and read the flow gauge.
- If the flow rate is below the minimum indicated in **800 — Minimum Steering Pump Flow Rates**, replace the PRV or pump, as required.
- If the flow rate is above 5.5 gpm (20.8 L/min) on a vehicle with a single steering gear, or 7.7 gpm (28.8 L/min) on a vehicle with an assist cylinder installed, replace the pump.

Were any problems found with pump performance?

YES → Replace the pump or PRV and re-evaluate the steering system complaint.

NO → Go to the next appropriate test.

7. **Test the steering gear internal leakage.**

Select TRW integral steering gears are equipped with an internal PRV that significantly limits maximum supply pressure to protect the steering gear. These gears, unlike gears on vehicles fitted with hydraulic brake boosters, cannot be tested for internal leakage by plugging the internal PRV in the gear. The pump output must be limited to prevent excessive pressure from damaging the gear, and the internal PRV passage must be blocked to direct oil flow through the gear.

Use PartsPro® for the specific VIN to determine if the steering gear is equipped with an internal PRV, which will be listed as a serviceable part under module 536.

If a TRW steering gear has an internal PRV but no hydraulic brake booster, see the following heading, **Internal Leakage Test Setup, TRW Steering Gears With an Internal PRV**, for instructions on setting up the necessary test components before proceeding with the following substeps.

ThyssenKrupp rack and pinion steering gears are also equipped with an internal PRV, but cannot be tested for internal leakage.

IMPORTANT: Make sure the fluid temperature is approximately 180°F (82°C) and the vehicle is stationary with the front wheels pointing forward.

7.1 Run the engine at idle with the load valve open.

⚠ WARNING

Keep fingers clear of the stop bolt and spacer block during the following test. Make sure that the spacer block contacts the axle stop squarely. Contact that is not square could break the stop bolts or eject the spacer block, which could cause serious personal injury.

7.2 Place an unhardened steel spacer, 1-inch (25-mm) thick, between the axle and the stop bolt on one side of the axle.

NOTICE

While running the following test, do not hold the steering wheel in the full-turn position for more than five seconds. Doing so could damage the pump.

7.3 Have someone turn the steering wheel, applying enough force to completely close the rotary valve.

Complete closure of the rotary valve requires approximately 20 lbf (27 N) pull on the steering wheel, and will be indicated by a pressure reading nearly equal to the system relief pressure (tested in substep 6.2).

7.4 Hold the steering wheel in the full-turn position. Note the steering gear internal leakage on the PSSA.

7.5 Repeat the previous substeps for the opposite turn.

The maximum permissible internal leakage for a single gear is 1.0 gpm (3.8 L/min). If leakage is greater in either turning direction, replace the steering gear components as needed.

For systems with two or more steering gears and/or linear cylinders, the total acceptable internal leakage is 1.0 gpm (3.8 L/min) for each steering gear/ram in the system. If the leakage is more than 2.0 gpm (7.6 L/min) on a dual-gear system, isolate the auxiliary cylinder from the system using the substeps that follow.

7.6 Disconnect the auxiliary cylinder hydraulic lines at the main gear auxiliary ports.

7.7 Plug the main steering gear ports with suitable steel or high-pressure plugs or caps.

7.8 Repeat the internal leakage test.

If the internal leakage is less than 1 gpm (3.8 L/min), repair or replace the auxiliary gear or linear cylinder. If the internal leakage is greater than 1 gpm (3.8 L/min), repair or replace the main gear.

Were any problems found with steering gear internal leakage?

YES → Fix the problem and re-evaluate the steering system complaint.

NO → Go to the next appropriate test.

8. **Check the steering gear poppet relief valve and stop bolt adjustment.**

8.1 Check the steering system for stop bolt adjustment.

Make sure the stop bolt settings limit the steering travel so there is $\frac{1}{2}$ -inch (13-mm) clearance from all stationary components, and 3/4-inch (19-mm) clearance from all moving components.

8.2 Make sure the pitman arm is situated on the steering gear sector shaft correctly. Check that the pitman arm and sector shaft timing marks are aligned.

NOTICE

If power steering pump relief pressure is reached while the steering wheel is at full lock, release the steering wheel from this position. Do not allow the pump relief pressure to be maintained for longer than five seconds or damage to the pump may result.

8.3 Check the poppet relief pressure.

- Install the PSSA between the steering pump and the steering gear.
- Run the engine at idle with the load valve open. Turn the steering wheel to either full-lock position. Note the pressure gauge reading, then repeat for the opposite turn.
- The pressure should drop slightly before the stop bolts are contacted. If the pressure increases (from contact with the stop bolts), reset the poppets.
  If the pressure is relieved and assist is lost when the wheel is too far from the axle stop bolts, refer to the *Cascadia Workshop Manual* for gear-specific information.

8.4 Check for normal hissing sound at full turn.

8.5 Check for abnormal power steering noise. See **Table 2** for possible causes and remedies for common noises associated with the power steering system and power steering pump.

Listen for a hissing sound at less than full turn. If a hissing sound is heard, check the steering gear poppet and the axle stop adjustment.

Power Steering System Noise	
Noise	**Remedy**
Growling or other abnormal steering noise	Check the fluid level. Check for air bubbles and foam. Check for hose and fitting leaks. If there is air in the fluid, check for inlet tube and hose leaks. Correct all leaks.
A change from the usual pump sound	Check the steering fluid reservoir for air bubbles and foam. If there is air in the fluid, check for inlet tube and hose leaks. Correct all leaks.
Clicking noise during a turn	Check for loose steering components. Tighten any loose steering components. Check the front suspension for insufficient spring pin shims. Add front spring pin shims if needed.
Hissing when the steering wheel is at or near full turn	This is normal; no action is needed.
Steering Pump intake line is plugged	Drain the system. Clear the intake line if needed. Fill the system.
Air leak at the pump or reservoir connections, fittings, or shaft seal	Check all the connections by pouring power steering fluid over them, and listening for a reduction in sound. Tighten all connections as needed.
Pump input shaft is misaligned	Replace the pump.

Table 2, Power Steering System Noise

Were any problems found with the poppet valves?

YES → Fix the problem and re-evaluate the steering system complaint.

NO → Go to the next appropriate test.

NOTICE

If the system temperature exceeds 250°F (121°C), damage to hoses, seals, and other components may result if the vehicle continues to operate at excessive steering system temperatures. If this temperature is exceeded, stop the test and record the last noted temperature on STI-492.

9. **Test the system operating temperature.**

   9.1 Run the engine at governed speed.

   9.2 Observe the power steering fluid temperature until it stabilizes.

   9.3 Record the power steering fluid temperature in 10-minute intervals until 40 minutes have passed.

   9.4 If the temperature does not exceed 250°F (121°C) during the test, excessive heat is probably not the cause of the complaint.

   If the temperature exceeds 250°F (121°C), excessive steering system back pressure or excessive pump flow may be the cause of the high temperature problem.

   If system back pressure or restriction values found in substeps 5.3 and 5.4 above were close to the maximum allowable, complete test 5 again. If steering pump flow and relief pressures found in test 6 above were close to the maximum allowable, complete test 6 again.

Did system temperature exceed 250°F (121°C)?

YES → Fix the problem and re-evaluate the steering system complaint.

NO → Go to the next appropriate test.

Internal Leakage Test Setup, TRW Steering Gears With an Internal PRV

Select TRW steering gears are equipped with an internal PRV that limits maximum supply pressure to protect the steering gear. These gears cannot be tested for internal leakage using the standard procedure. The pump output must be limited to prevent excessive pressure from damaging the gear, and the internal PRV passage must be blocked to direct oil flow through the gear.

Use PartsPro® to determine if a specific TRW steering gear is equipped with an internal PRV, which will be listed as a serviceable part under module 536.

If your TRW steering gear has an internal PRV, complete the following steps to set up the necessary internal leakage test components. See **Table 3** for a list of recommended leakage test components.

Internal Leakage Test Components

Part	Available From	Part Number (Vendor P/N)	Item #, Fig. 6
Power Steering System Analyzer (PSSA)	SPX Kent-Moore	J-26487	5
PSSA Adaptor Kit	SPX Kent-Moore	J-28593	—
Relief Valve Plug	SPX Kent-Moore	J-37130	—
Connector, Straight Thread with O-Ring	Daimler Trucks PDC	23-11470-088	6
Power Steering Hose, 42"	Daimler Trucks PDC	14-12694-042	8
Connector, 3/8" Male NPT to 5/8" Beaded Hose Barb	Daimler Trucks PDC	23-11321-001	9
Pipe Coupling, 3/8" NPT	Parker Hannifin	PH 3/8 GG S (3/8 GG-S)	10

Internal Leakage Test Components			
Part	**Available From**	**Part Number (Vendor P/N)**	**Item #, Fig. 6**
Tee, Male JIC with Male NPT Branch *	Parker Hannifin	PH 8STXS (8 STX-S)	11
Swivel Adaptor, 3/8" Male NPT to Female 37 degree JIC (qty 2)	Weatherhead	WH 9100X8X6 (9100x8x6)	12
Swivel Nut Run Tee	Parker Hannifin	PH 8 R6X S (8 R6X-S)	13
3/8" Female NPT Aluminum Relief Valve Threaded Cartridge Body	Parker Hannifin	B10-2-A6P (PH B102A6P)	14
Aluminum Hydraulic Threaded Cartridge Relief Valve with Knob	Parker Hannifin	PH RAH101K30 (RAH101K30)	15

* Use steel 37 degree JIC fittings only.

Table 3, Internal Leakage Test Components

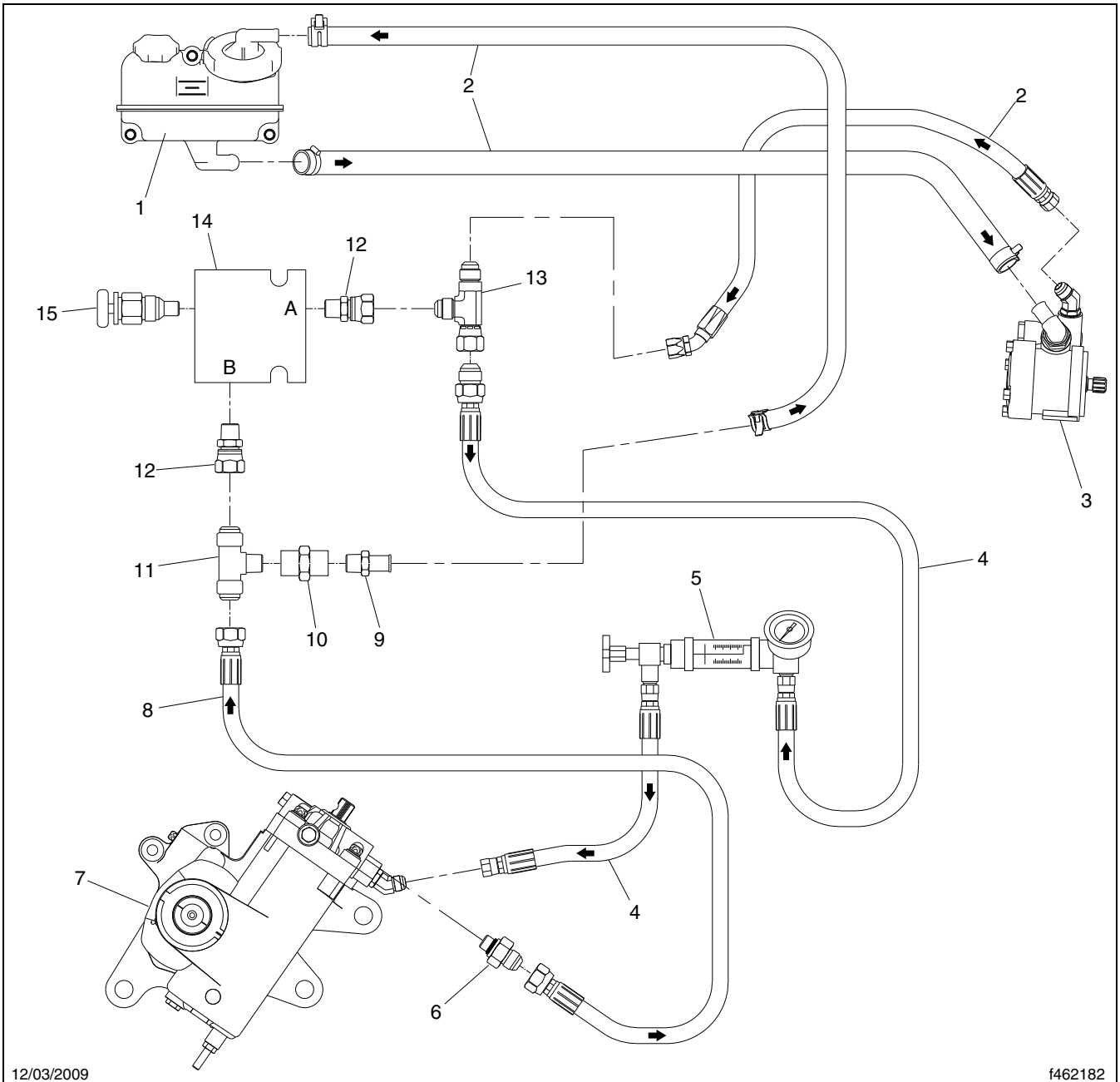
IMPORTANT: The front wheels must be raised or on turnplates during this procedure.

1. Turn the engine off. Remove the relief valve cap, O-ring, and relief valve from the steering gear. See **Fig. 6**.
2. Install the relief valve plug, J-37130, in the internal PRV hole. Install the relief valve cap and O-ring over the plug.
3. Assemble the relief valve cartridge body, relief valve, and tee fittings as shown in **Fig. 6**.
4. Install the PSSA and other test components as shown in **Fig. 6**.
5. Open the external relief valve on the relief valve cartridge. Ensure the PSSA shutoff valve is fully open.
6. Raise the front wheels off the ground and turn the steering wheel to the right and left full-lock positions five times to bleed air from the system.
7. Start the engine and bleed the remaining air out of the system by continuing to turn the wheel from side to side.

NOTICE

Do not leave the PSSA shutoff valve fully closed for longer than five seconds. Doing so could damage the power steering system.

8. With the engine on, close the shutoff valve on the PSSA.
9. Set the system relief pressure by closing the external relief valve until the gauge on the PSSA reaches 2,000 psi (13 790 kPa), then fully open the shutoff valve on the PSSA.
10. Continue with the steering gear internal leakage test (test 7 above).



A. High-Pressure Input Port
B. Low-Pressure Output Port

1. Power Steering Fluid Reservoir
2. Existing Power Steering Fluid Lines (Qty 3)
3. Power Steering Pump
4. PSSA Fluid Lines (Qty 2)
5. PSSA
6. Connector, Straight Thread with O-Ring
7. Power Steering Gear (TAS85 shown)
8. Power Steering Hose, 42"
9. Connector, Male NPT to Beaded Hose Barb
10. Pipe Coupling
11. Tee, Male JIC with Male NPT Branch
12. Swivel Adaptor (Qty 2)
13. Swivel Nut Run Tee
14. Relief Valve Threaded Cartridge Body
15. External Relief Valve, Threaded Cartridge Type

Fig. 6, Internal Leakage Test Component Installation

800 — Minimum Steering Pump Flow Rates

Minimum Measured Pump Flow Rates			
Steering Gear	**Flow at 1500 rpm, No Load: gpm (L/min)**	**Flow at 1000 psi (6900 kPa): gpm (L/min)**	**Flow at 1800 psi (12 400 kPa): gpm (L/min)**
Sheppard HD94	3.7 (14.0)	2.6 (9.8)	1.8 (6.8)
Sheppard M100		2.8 (10.6)	2.3 (8.7)
ThyssenKrupp LZS5 Rack and Pinion		3.3 (12.5)	2.8 (10.6)
TRW TAS40		2.1 (7.9)*	1.6 (6.1)
TRW TAS55		2.4 (9.1)*	1.9 (7.2)
TRW TAS65		2.8 (10.6)*	2.3 (8.7)
TRW TAS65 With C28 or C32 Linear Cylinder	5.8 (22.0)	4.9 (18.5)	4.4 (16.7)
TRW TAS65 With RCS65			
TRW TAS85	3.7 (14.0)	3.3 (12.5)	2.8 (10.6)
TRW TAS85 With C28 or C32 Linear Cylinder	5.8 (22.0)	5.4 (20.4)*	4.9 (18.5)
TRW TAS85 With RCS65			
TRW THP45	3.7 (14.0)	2.2 (8.3)	1.4 (5.3)
TRW THP60 or PCF60		2.6 (9.8)	1.8 (6.8)
TRW THP60 With Linear Cylinder	5.8 (22.0)	4.1 (15.5)	3.3 (12.5)
TRW THP60 With RCH45			

* Approximate value based on flow at 1800 psi (12 400 kPa).

Table 4, Minimum Measured Pump Flow Rates

801 — Steering Gear Relief Pressures

Typical Steering Gear Relief Pressure at Engine Idle	
Steering Gear	**Typical Relief Pressure: psi (kPa)**
Sheppard HD94	2683 ± 100 (18 500 ± 700)
Sheppard M100	2175 ± 100 (15 000 ± 700)
ThyssenKrupp LZS5 Rack and Pinion	2300 ± 116 (15 500 ± 800)
TRW TAS40	2175 ± 100 (15 000 ± 700)*
TRW TAS55	
TRW TAS65	
TRW TAS85	
TRW TAS65 With C28 or C32 Linear Cylinder	
TRW TAS65 With RCS65	
TRW TAS85 With C28 or C32 Linear Cylinder	
TRW TAS85 With RCS65	

Typical Steering Gear Relief Pressure at Engine Idle	
Steering Gear	**Typical Relief Pressure: psi (kPa)**
TRW THP45	2683 ± 100 (18 500 ± 700)
TRW THP60 or PCF60	
TRW THP60 With Linear Cylinder	
TRW THP60 With RCH45	

* On vehicles with TRW TAS steering gears and hydraulic brakes, typical relief pressure is 2375 ± 100 psi (16 375 ± 690 kPa).

Table 5, Typical Steering Gear Relief Pressure at Engine Idle