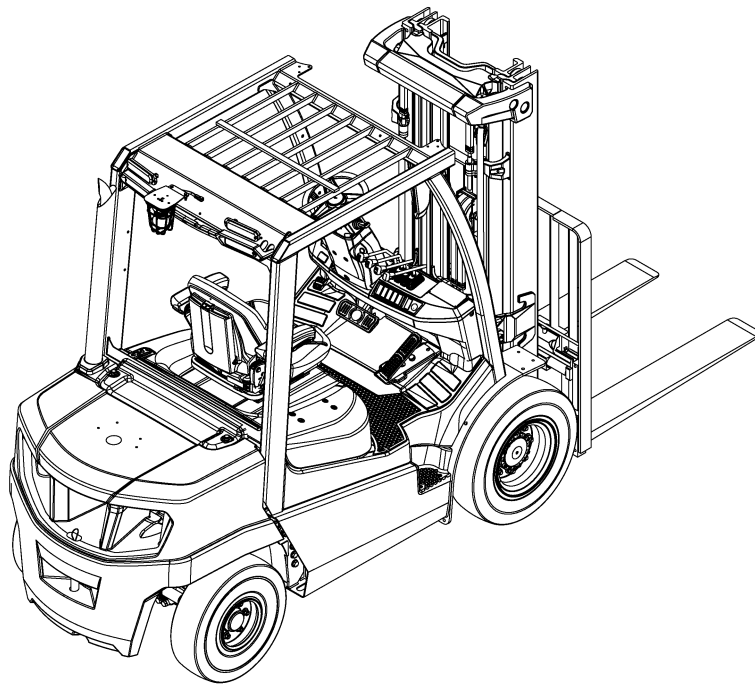


TRUCK SYSTEM DESCRIPTION

H2.0A, H2.5A6, H2.5A, H3.0A, H3.5A (H40A, H50A6,
H60A, H70A) [R177]



HYSTER

SAFETY PRECAUTIONS

MAINTENANCE AND REPAIR

- The Service Manuals are updated on a regular basis, but may not reflect recent design changes to the product. Updated technical service information may be available from your local authorized Hyster® dealer. Service Manuals provide general guidelines for maintenance and service and are intended for use by trained and experienced technicians. Failure to properly maintain equipment or to follow instructions contained in the Service Manual could result in damage to the products, personal injury, property damage or death.
- When lifting parts or assemblies, make sure all slings, chains, or cables are correctly fastened, and that the load being lifted is balanced. Make sure the crane, cables, and chains have the capacity to support the weight of the load.
- Do not lift heavy parts by hand; always use a lifting mechanism.
- Wear safety glasses.
- **DISCONNECT THE BATTERY** before doing any maintenance or repair on electric lift trucks. Disconnect the battery ground cable on internal combustion lift trucks.
- Always use correct blocks to prevent the unit from rolling or falling. See **HOW TO PUT THE LIFT TRUCK ON BLOCKS** in the **Operating Manual** or the **Periodic Maintenance** section of the service manual.
- Keep the unit clean and the working area clean and orderly.
- Use the correct tools for the job.
- Keep the tools clean and in good condition.
- Always use **HYSTER® APPROVED** parts when making repairs. Replacement parts must meet or exceed the specifications of the original equipment manufacturer.
- Make sure all nuts, bolts, snap rings, and other fastening devices are removed before using force to remove parts.
- Always fasten a **DO NOT OPERATE** tag to the controls of the unit when making repairs, or if the unit needs repairs.
- Strictly follow all **WARNING** and **CAUTION** notes in the operating manual, safety labels, service manual, and other instructions.
- Gasoline, Liquid Propane Gas (LPG), Compressed Natural Gas (CNG), Hydrogen Gas (H₂), and Diesel fuels are flammable and potentially explosive. Hydraulic, transmission, and other fluids and oils are also flammable. Be sure to follow the necessary safety precautions when handling these substances or working on systems containing these substances.
- Lead acid batteries generate flammable gas when they are being charged. Keep fire and sparks away from the area. Make sure the area is well ventilated.
- Lithium-ion batteries should only be used in working environments where the temperature is within the recommended operating range (typically between 0 - 40°C (32 - 104°F)). Extreme temperatures, moisture, improper charging or damage to the battery can cause a fire or explosion.
- Whenever Diagnostic tools are needed for engine, only licensed or certified persons can use Diagnostic tools.

NOTE: The following symbols and words indicate safety information in this manual:



WARNING

Indicates a hazardous situation which, if not avoided, could result in death or serious injury.



CAUTION

Indicates a hazardous situation which, if not avoided, could result in minor or moderate injury and property damage.

On the lift truck, the **WARNING** symbol (and word, if present) are on orange background. The **CAUTION** symbol (and word, if present) are on yellow background.



WARNING

Installing improper electrical accessories or installing an electrical accessory incorrectly can increase the risk of equipment damage, personal injury and fire. **DO NOT** install electrical accessories to the truck unless you have been trained and authorized to do so. Personnel installing the electrical accessories must document the changes made to the truck. **DO NOT** install accessories which affect the truck's compliance with standard ANSI/ITSDF B56.1, UL 558, or UL 583, or which otherwise affect the safe operation of the truck.



WARNING

Installing improper electrical accessories or installing an electrical accessory incorrectly can increase the risk of equipment damage, personal injury and fire. **DO NOT** install electrical accessories to the truck unless you have been trained and authorized to do so. Personnel installing the electrical accessories must document the changes made to the truck. **DO NOT** install accessories which affect the truck's compliance with standard EN 1175:2025.



WARNING

California Proposition 65 - Operating, servicing and maintaining a powered industrial truck can expose you to chemicals including engine exhaust, carbon monoxide, phthalates, and lead, which are known to the State of California to cause cancer and birth defects or other reproductive harm. For more information, go to www.P65Warnings.ca.gov.

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**"THE
QUALITY
KEEPERS"**

**HYSTER
APPROVED
PARTS**

Introduction

GENERAL

202001-001

NOTE: For any fasteners in this manual that feature standard torque specifications, please refer to **Metric and Inch (SAE) Fasteners 8000SRM0231** for correct specifications.

DISCHARGING THE CAPACITORS



WARNING

DO NOT make repairs or adjustments unless you have been properly trained and authorized to do so. Improper repairs and adjustments can create dangerous operating conditions. **DO NOT** operate a lift truck that needs repairs. Report the need for repairs to your supervisor immediately. If repair is necessary, attach a **DO NOT OPERATE** tag on the steering wheel and disconnect the battery.

Disconnect the battery and discharge the capacitors before opening any compartment covers or inspecting or repairing the electrical system. **DO NOT** place tools on top of the battery. If a tool causes a short circuit, the high current flow from the battery can cause personal injury or property damage.

Some check and adjustments are performed with the battery connected. **DO NOT** connect the battery until the procedure instructs you to do so. Never wear any metallic items on your fingers, arms, or neck. Metal items can accidentally make an electrical connection and cause injury. Before performing any tests or adjustments, block the lift truck to prevent unexpected movement.

The capacitors in the transistor controller(s) can hold an electrical charge for about 10 minutes after the battery is disconnected. To prevent an electrical shock and personal injury, discharge the capacitor(s) before inspecting or repairing any component in the drive unit compartment. Make certain that the battery had been disconnected.

DO NOT short across the motor controller terminals with a screwdriver or jumper wire.

Make certain the Emergency-Stop Switch has not been activated. This will isolate the controller and prevent the capacitors from discharging properly. The proper way to disconnect the battery is by separating the battery connectors.

DISCHARGING THE CAPACITORS: For trucks with rapid-charge option, the horn cannot be used to discharge capacitors prior to service. Disconnect the battery, then wait five minutes before performing any service on the truck.

1. Ensure the capacitors are discharged by performing Step 2 through Step 6 below.
2. Turn the key or keyless switch to **OFF** position.
3. Disconnect the battery by separating the connector on the battery cable from the connector on the lift truck.
4. Block the drive wheels to prevent the lift truck from moving.
5. Make sure the Emergency-Stop Switch **HAS NOT** been activated. If the Emergency-Stop Switch is activated, rotate the switch to the right until it pops up.
6. Press the horn button on the steering column. Wait 30 seconds to be sure capacitors are fully discharged. If the horn does not sound when the switch is actuated, wait 10 minutes before proceeding with service.
For lift trucks equipped with rapid-charge option, the horn cannot be used to discharge capacitors prior to service. Disconnect the battery, then wait five minutes before performing any service on the truck.

Frame

FRAME MODULAR DESIGN DESCRIPTION 202001-137

The frames for Hyster lift trucks are modular, bolt-together steel weldments. This is different from previous versions of Hyster counterbalance lift trucks, which had one-piece frames.

There are four modules that make up the lift truck frame.

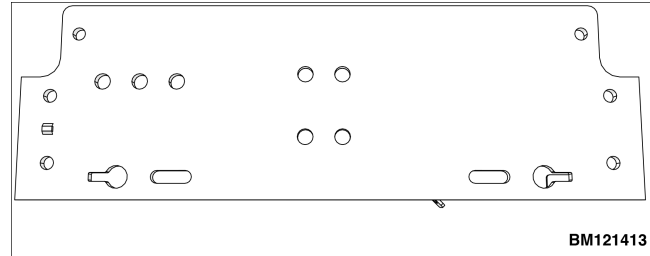


Figure 3. Front frame module

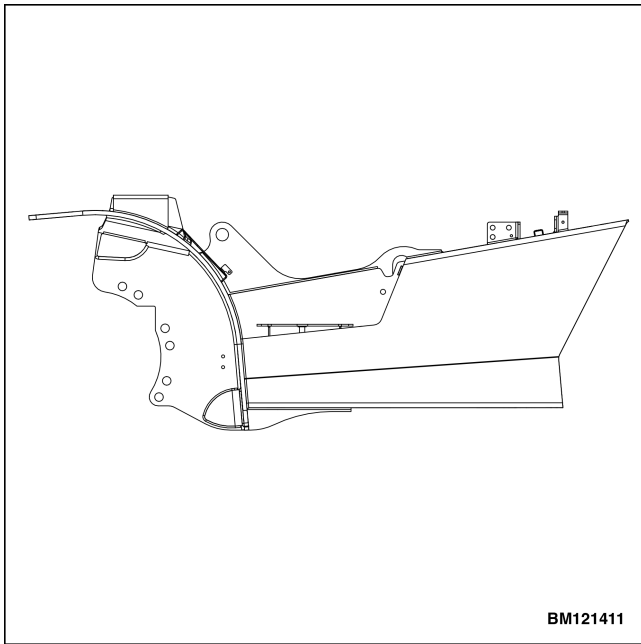


Figure 1. Left frame module

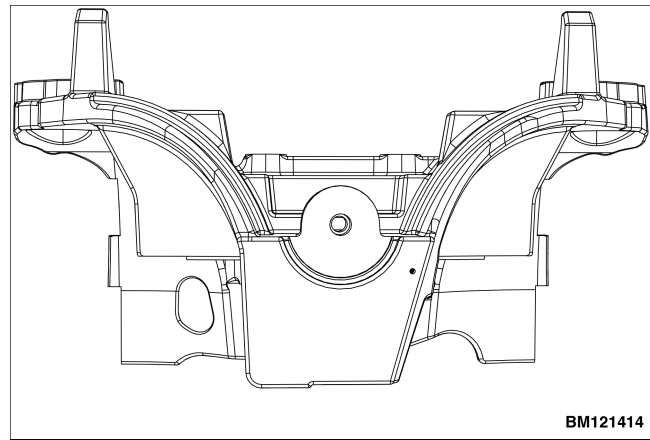


Figure 4. Rear frame module

The drive axle and the steer axle are also structural components of the truck. When the frame modules and axles are bolted together properly, the result is a complete frame with the required strength and rigidity to support truck systems.

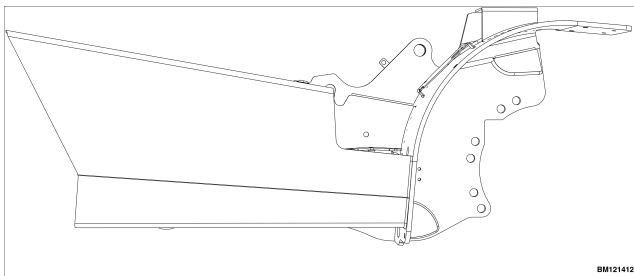
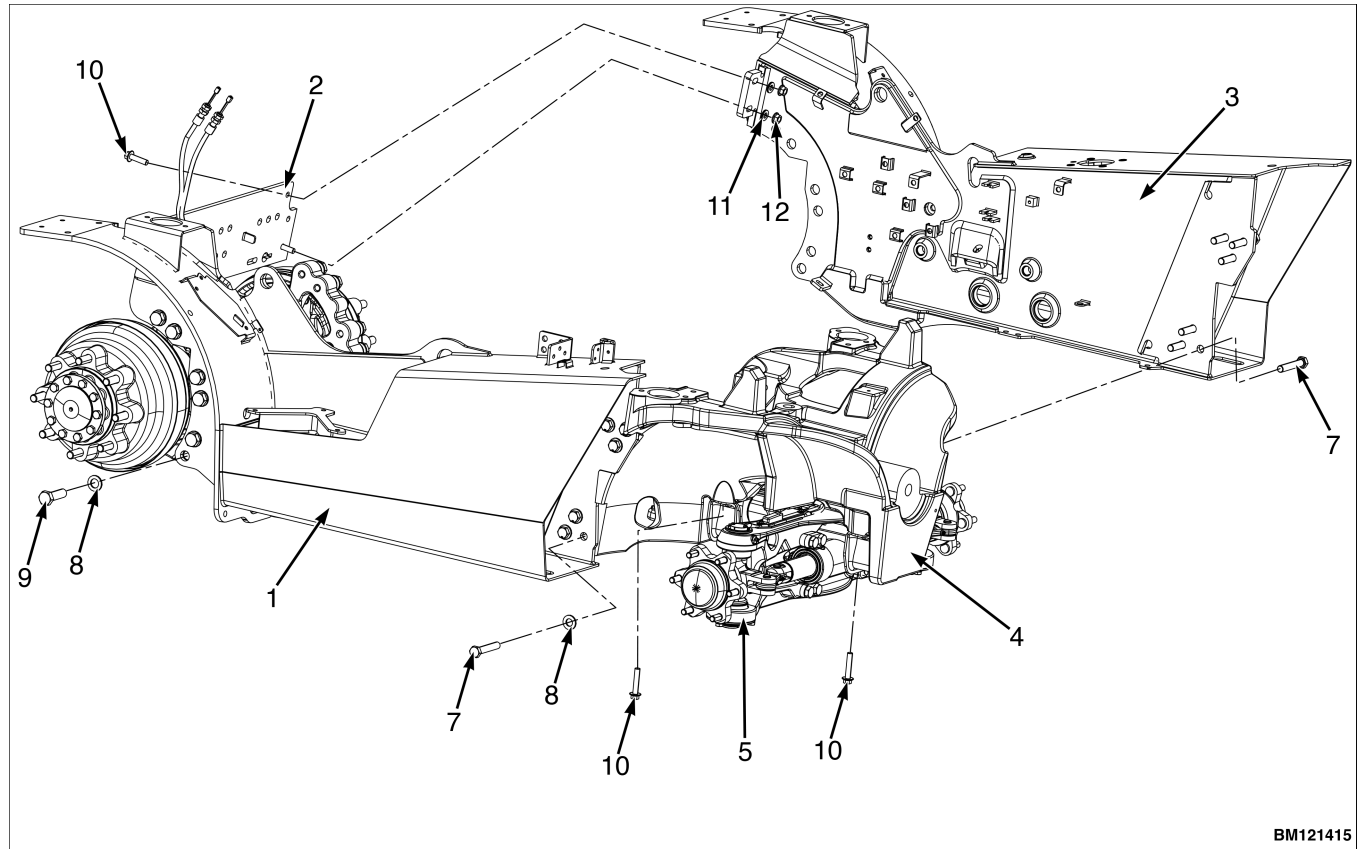


Figure 2. Right frame module



BM121415

- | | |
|---------------------|--------------------|
| 1. LEFT HAND FRAME | 7. CAPSCREW (M16) |
| 2. FRONT FRAME | 8. LOCKWASHER |
| 3. RIGHT HAND FRAME | 9. CAPSCREW (M20) |
| 4. REAR FRAME | 10. CAPSCREW (M12) |
| 5. STEER AXLE | 11. WASHER |
| 6. DRIVE AXLE | 12. NUT |

Figure 5. Frame assembly

The frame has removable panels and cutouts in it to allow access to maintenance areas.

The frame can have optional tie-down slots or D-rings to facilitate lifting or securing the truck. It can also include optional fender extensions for some applications.

For service needs, approved configuration changes, or in case of damage, contact **Hyster** Service.

Paint on the surfaces of the joints between frame modules will affect fit and tightness. Paint that is too thick can cause the joints to relax over time, leading to looseness. Always follow the instructions in General painting concerns in the Frame and Main Components manual when painting.

FRAME ATTACHING HARDWARE

DESCRIPTION

202001-138

NOTE: Frame weldments are not service parts in normal operation. If a frame is damaged, consult with **Hyster** Service before attempting to perform any maintenance or repair on the frame.

Modular frames require hardware to fix one module to another.

To ensure the frame is firmly fixed together and that the frame dimensions are within tolerances, it is important to use hardware that is the correct size, material, and hardness, and to maintain the hardware according to periodic maintenance intervals.

The frame attaching hardware is salt spray and rust resistant.

Bolts for attaching the front frame module to the side frame modules are M12 x 1.75 x 45 hex flange bolts, class 8.8. The nuts used with these bolts are M12 x 1.75 hex flange nuts, class 8.

Bolts for attaching the drive axle to the side frame modules are M20 x 2.5 x 70 hex head capscrews, class 10.9. The washers used with these bolts are 20 x 37 hardened washers.

Bolts for attaching side frame modules to the rear frame module are M16 x 2.0 x 90 hex head capscrews. The washers used with these bolts are 16 x 34 hardened washers.

Bolts for attaching the steer axle to the rear frame module are M12 x 1.75 x 60 hex flange bolts, class 8.8.

Only use approved Hyster parts when replacing hardware. Never use hardware of a different material, hardness, for finish, or that deviates from the Hyster-approved hardware in any way. Consult the Parts Manual for relevant hardware part numbers.

Do not reuse hardware once it has been removed from a frame module. Always discard frame attaching hardware after disassembling the frame, and replace frame attaching hardware during reassembly.

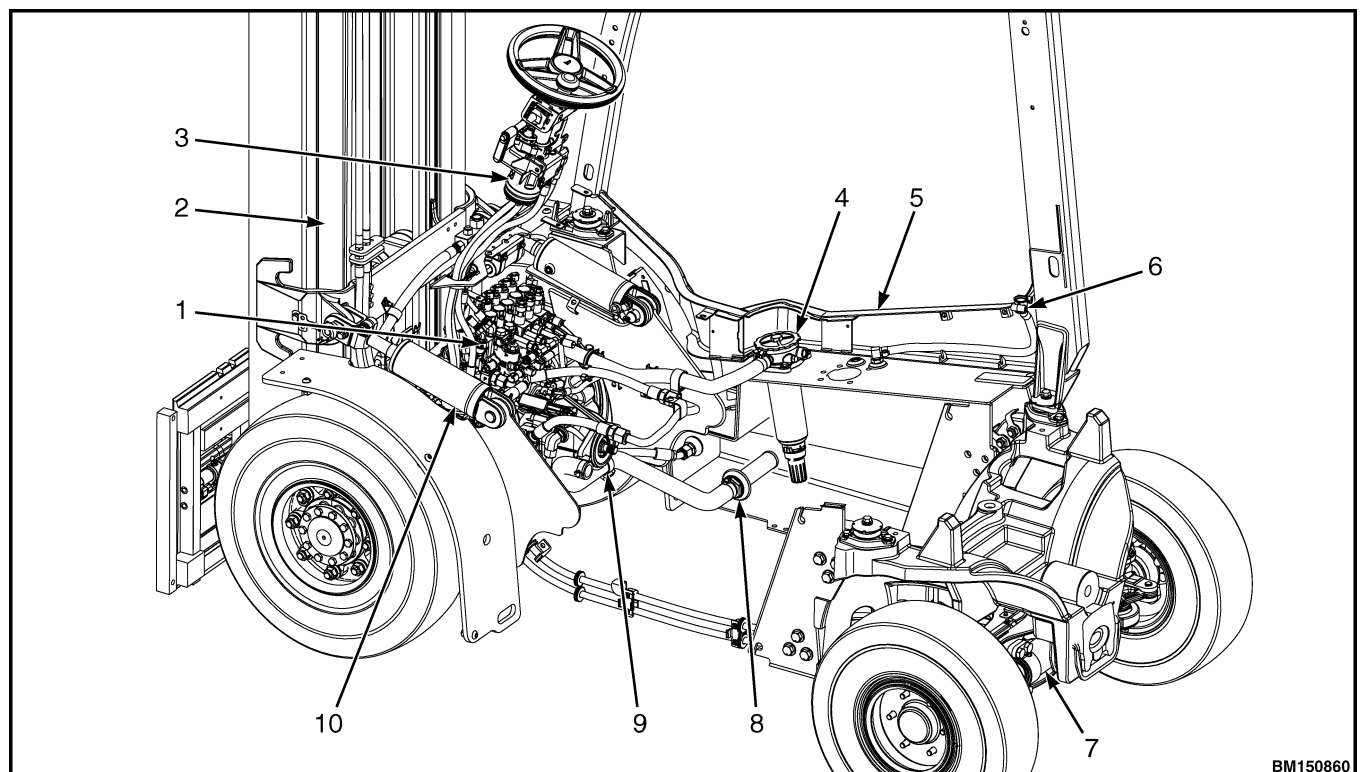
Hydraulics

HYDRAULIC SUPPLY AND RETURN DESCRIPTION 202001-139

HYDRAULIC SUPPLY AND RETURN

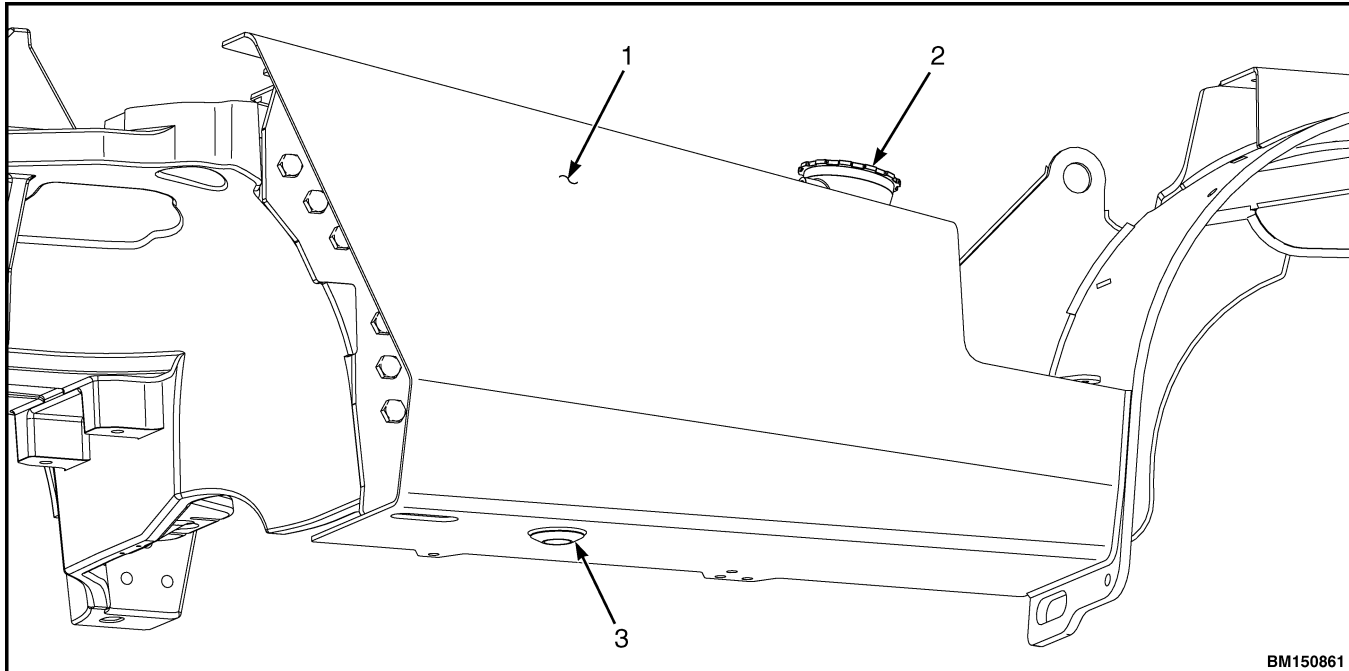
A typical hydraulic system uses compressed fluid to transfer force applied at one point to another point. The hydraulic system on the lift truck consists of the following components: hydraulic tank, pump assembly, steering control unit, main control valve (manual or electric), lift cylinders, tilt cylinders,

steering cylinder, filter assembly, suction strainer, and breather. The hydraulic tank is integrated into the right side of the frame channel. The hydraulic filter assembly and breather are mounted to the top of the tank and an oil dipstick is located near the filter assembly. All hydraulic oil flow is eventually returned to the hydraulic tank through the hydraulic return filter. An internal bypass circuit protects the hydraulic return filter. Two types of hydraulic pumps are available, either a gear-type or a Variable Displacement Pump (VDP).



- | | |
|---------------------------------|--------------------------------------|
| 1. MAIN HYDRAULIC CONTROL VALVE | 7. STEERING CYLINDER |
| 2. LIFT CYLINDERS (2 USED) | 8. SUCTION HOSE AND STRAINER |
| 3. STEERING CONTROL UNIT (SCU) | 9. PUMP (GEAR OR VDP) |
| 4. RETURN FILTER ASSEMBLY | 10. TILT CYLINDERS (2 USED) |
| 5. HYDRAULIC TANK | 11. OPTIONAL ACCUMULATOR (NOT SHOWN) |
| 6. BREATHER ASSEMBLY | |

Figure 6. Hydraulic Component Locator



BM150861

1. HYDRAULIC TANK
2. RETURN FILTER ASSEMBLY
3. DRAIN PLUG

Figure 7. Hydraulic Tank

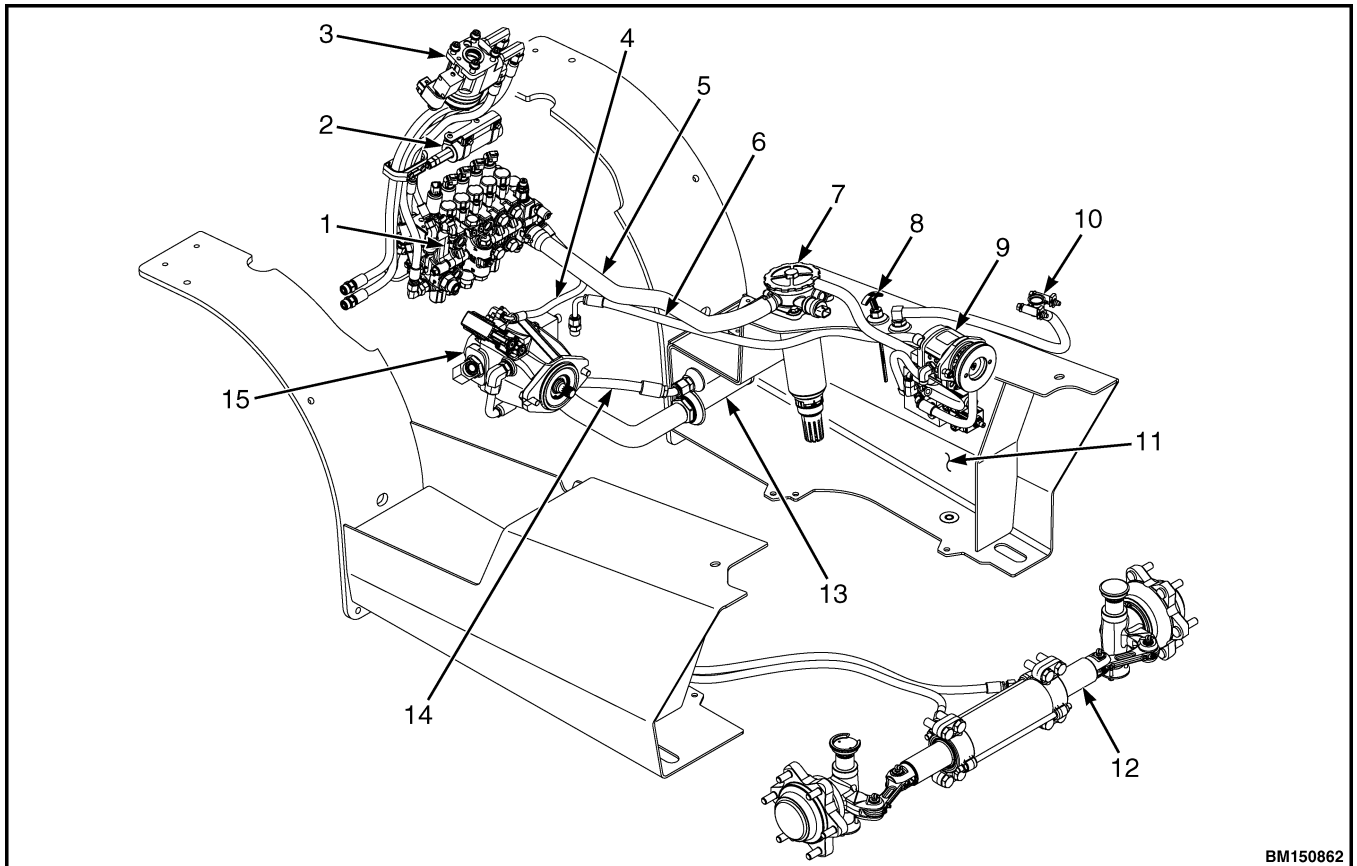
The hydraulic system provides a means of actuating the front end equipment, steering the truck, and in some cases actuating the park brake system by directing the flow and pressure of hydraulic fluid. On some lift trucks the hydraulic system will also power an optional on-demand, hydraulic-driven, reversible, engine cooling fan. This variable speed fan is an alternative to the conventional engine belt-driven design.

The system may be equipped with an optional mast accumulator. The mast accumulator is a hydraulic container that is attached on the side of the outer mast channel in line with the main lift hydraulic circuit. The nitrogen, pre-charged accumulator

provides a shock absorbing effect which translates into smooth carriage movements when driven over uneven surfaces or fast lifts/lowers. This reduces noise and wear to the mast components.

In addition, the lift truck may be equipped with an accumulator in the hydraulic circuit near the main control valve to help maintain pilot pressure that otherwise may drop during low engine RPM or lowering the mast.

Numerous hydraulic hose groups perform the function of transferring hydraulic fluid from the hydraulic tank to the various hydraulic components and back to the tank.

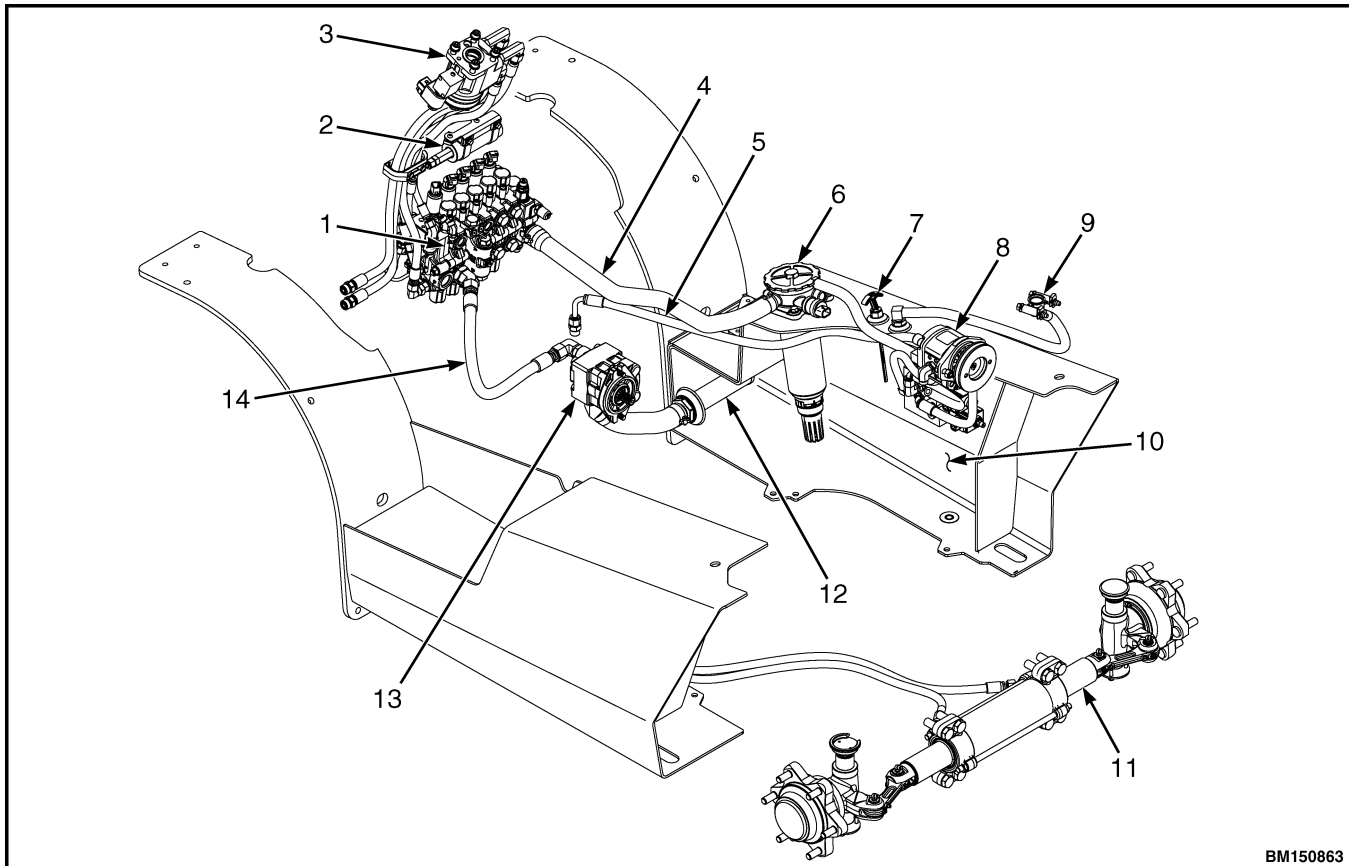


BM150862

- | | |
|---------------------------------|-------------------------------|
| 1. MAIN HYDRAULIC CONTROL VALVE | 9. HYDRAULIC FAN |
| 2. ACCUMULATOR | 10. BREATHER ASSEMBLY |
| 3. STEERING CONTROL UNIT (SCU) | 11. HYDRAULIC TANK |
| 4. VDP LOAD SENSE HOSE | 12. STEERING CYLINDER |
| 5. RETURN HOSE | 13. SUCTION HOSE AND STRAINER |
| 6. HYDRAULIC FAN SUPPLY HOSE | 14. VDP CASE DRAIN HOSE |
| 7. RETURN FILTER ASSEMBLY | 15. VDP |
| 8. OIL TANK DIPSTICK | |

Figure 8. Hydraulic System with VDP

NOTE: Some components in the above graphic may be optional equipment.



BM150863

- | | |
|---------------------------------|-------------------------------|
| 1. MAIN HYDRAULIC CONTROL VALVE | 8. HYDRAULIC FAN |
| 2. ACCUMULATOR | 9. BREATHER ASSEMBLY |
| 3. STEERING CONTROL UNIT (SCU) | 10. HYDRAULIC TANK |
| 4. RETURN HOSE | 11. STEERING CYLINDER |
| 5. HYDRAULIC FAN SUPPLY HOSE | 12. SUCTION HOSE AND STRAINER |
| 6. RETURN FILTER ASSEMBLY | 13. GEAR-TYPE PUMP |
| 7. OIL TANK DIPSTICK | 14. SUPPLY HOSE |

Figure 9. Hydraulic System with Gear-Type Pump

NOTE: Some components in the above graphic may be optional equipment.

HYDRAULIC PUMP DESCRIPTION 202001-140

HYDRAULIC PUMP

The hydraulic pump is the component of the hydraulic system that takes mechanical energy and converts it into fluid energy in the form of oil flow. This mechanical energy is taken from what is called the prime mover (a turning force) such as the power take-off or directly from the truck engine. The working of any hydraulic pump is based on the displacement principle. Any object, wholly or partially immersed in a fluid, is buoyed up by a force equal to the weight of the fluid displaced by the object. Simply stated, a hydraulic pump converts mechanical energy into hydraulic energy.

A power source (electric motor or other device) energizes the pump and begins its action by forcing the liquid to move. When the hydraulic pump operates, it performs two functions. First, its mechanical action creates a vacuum at the pump inlet which allows atmospheric pressure to force liquid from the reservoir into the inlet line to the pump. Second, its mechanical action delivers this liquid to the pump outlet and forces it into the hydraulic system. A pump produces liquid movement or flow: it does not generate pressure. It produces the flow necessary for the development of pressure which is a function of resistance to fluid flow in the system. For example, the pressure of the

fluid at the pump outlet is zero for a pump not connected to a system (load). Further, for a pump delivering into a system, the pressure will rise only to the level necessary to overcome the resistance of the load. Both the inlet and outlet of the hydraulic pump contain check valves. The check valve located at the inlet will push the fluid from the tank/reservoir into the pump and the one located at the outlet will pump fluid to other parts of the system. The hydraulic pump will carry oil or any other fluids from the reservoir/tank to other parts of the system.

Two popular pump designs, gear and Variable Displacement Pump (VDP), are discussed/illustrated below.

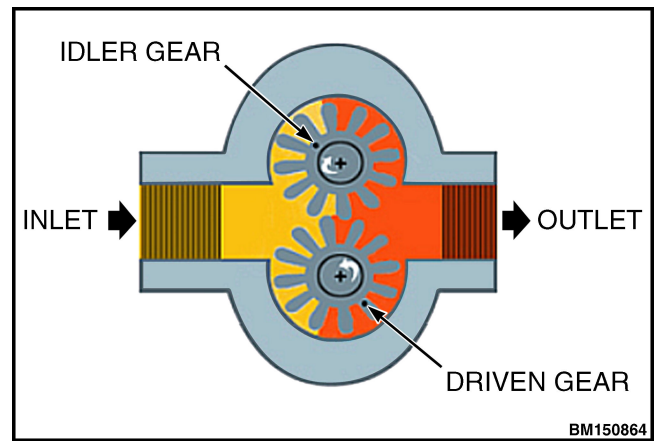
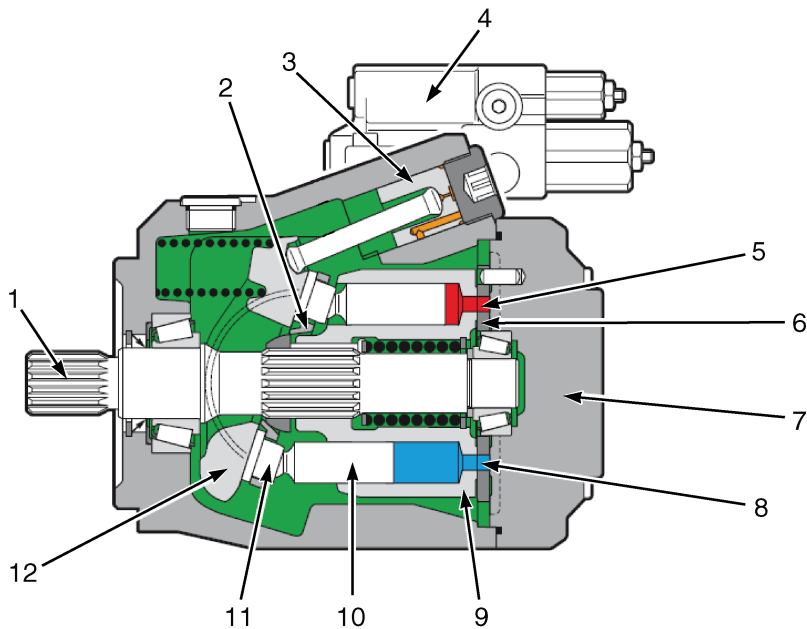


Figure 10. Basic Gear Pump Cross Section



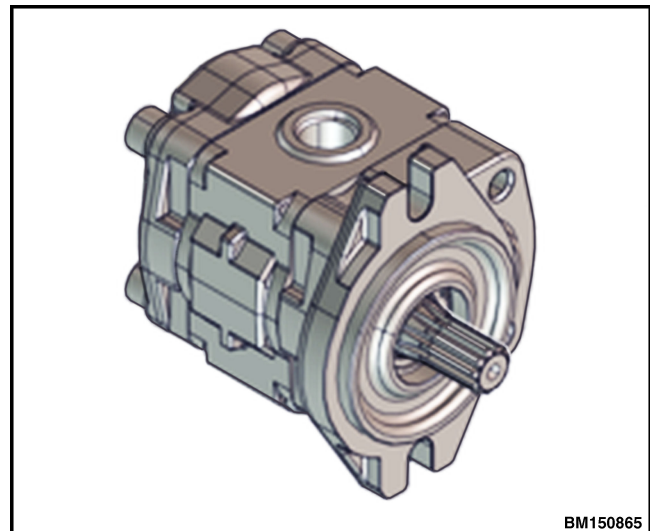
BT150091

- | | |
|-------------------------------|-----------------|
| 1. DRIVE SHAFT | 7. PORT BLOCK |
| 2. RETAINING PLATE | 8. SUCTION SIDE |
| 3. STROKE PISTON | 9. CYLINDER |
| 4. COMPENSATOR VALVE ASSEMBLY | 10. PISTON |
| 5. PRESSURE SIDE | 11. SLIPPER PAD |
| 6. CONTROL PLATE | 12. SWASH PLATE |

Figure 11. Basic Variable Displacement Pump

The hydraulic pump provides system flow and pressure for the hydraulic system. It is driven by the engine/transmission on internal combustion engine trucks and by an electric motor on the electric rider trucks.

Two different hydraulic pumps are available for use, a gear pump and a Variable Displacement Pump (VDP) which is an axial piston type pump.



BM150865

Figure 12. Gear Pump

A gear pump is a fixed displacement pump and provides hydraulic flow that rises and falls with engine RPM.

The gear pump is a cast iron body fixed output pump mounted on the transmission housing and provides flow for the hydraulic system. A meshing gear set develops oil pressure from the inlet to the outlet. The gear pump receives oil from the hydraulic tank through either a single or dual screen at the outlet(s) of the tank.

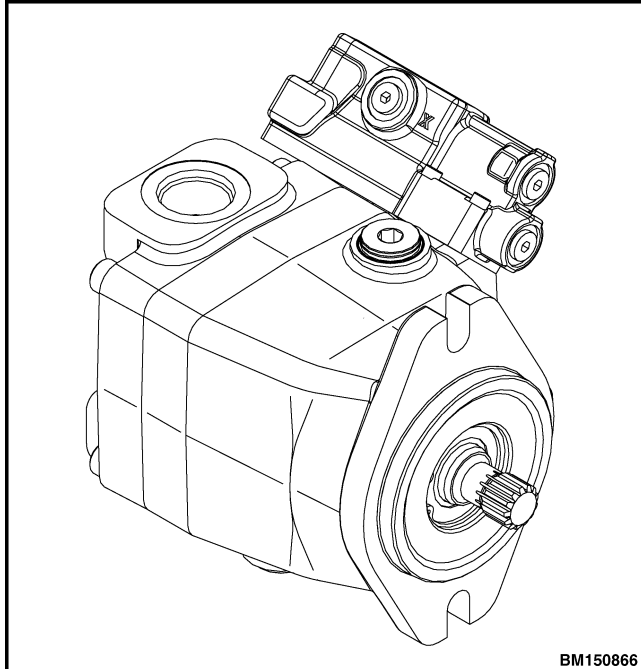
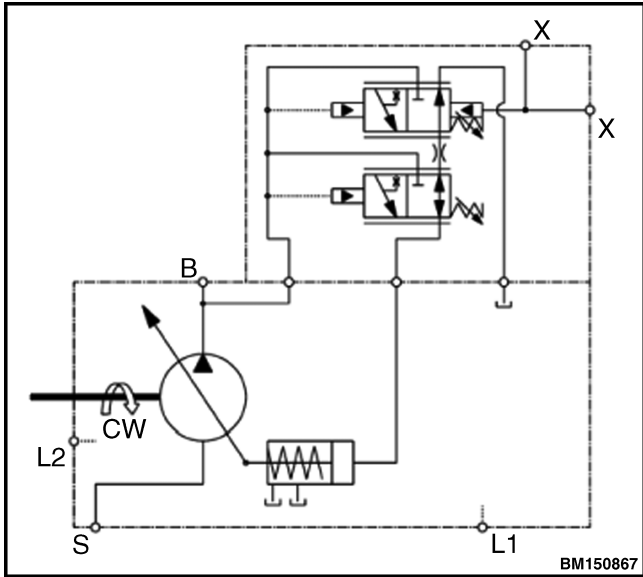


Figure 13. Variable Displacement Pump

The Variable Displacement Pump (VDP) in the 1-3.5 ton series is an axial piston pump. The axial piston pump consists of a swash plate design. The pistons are arranged axially with respect to the drive shaft. They are guided in the rotating cylinder and support themselves with slipper pads on the non-rotating swash plate. Torque is applied to the drive shaft by the engine. The cylinder and pistons turn with the drive shaft while the swash plate remains stationary. For each rotation of the drive shaft, the pistons perform a stroke movement which is defined by the pitch of the swash plate. The splined drive shaft is connected to the cylinders. Inside the case the pistons are arranged in an array around the input shaft. The bases of all the pistons are attached to a swash plate. The swash plate is attached to the input shaft mounted at an offset rather than 90 degrees to the input shaft.

The pump has an adjustable Pressure Compensator (PC) and Load Sensing (LS) or flow compensator valve body attached to the pump case. PC control is designed to maintain constant pressure as flow varies. LS control is designed to match pump flow with system demand. The two valves can be identified by their size as the larger is the PC and smaller is the LS flow compensator.

For efficiency under varying load conditions the pump displacement is variable. The variable displacement pump uses load sensing pressure to adjust flow output by adjusting the swash plate angle. Flow is controllable and adjustable, making the pump quieter and reducing fluid noise. When pressure and flow demand increases the pump is able to compensate within the limit of the equivalent relief setting of the pressure compensator. When demand on the hydraulic system is low the load sense flow compensator can also enable the VDP, unlike a fixed output gear pump, to reduce flow resulting in pressure less than the low limit setting of the pressure compensator. With reduced flow, less energy is consumed to drive the pump during these conditions. Another benefit to flow compensation is the reduction of heat during idle or standby. Excess heat is not created from excess flow over relief as oil builds up behind and passes the relief valve.



- B - OUTLET PORT
- S - INLET PORT
- L1 - CASE DRAIN PORT
- L2 - CASE DRAIN PORT
- X - SIGNAL

Figure 14. VDP Hydraulic Circuit Diagram

CONTROL VALVE DESCRIPTION
202001-141

CONTROL VALVE

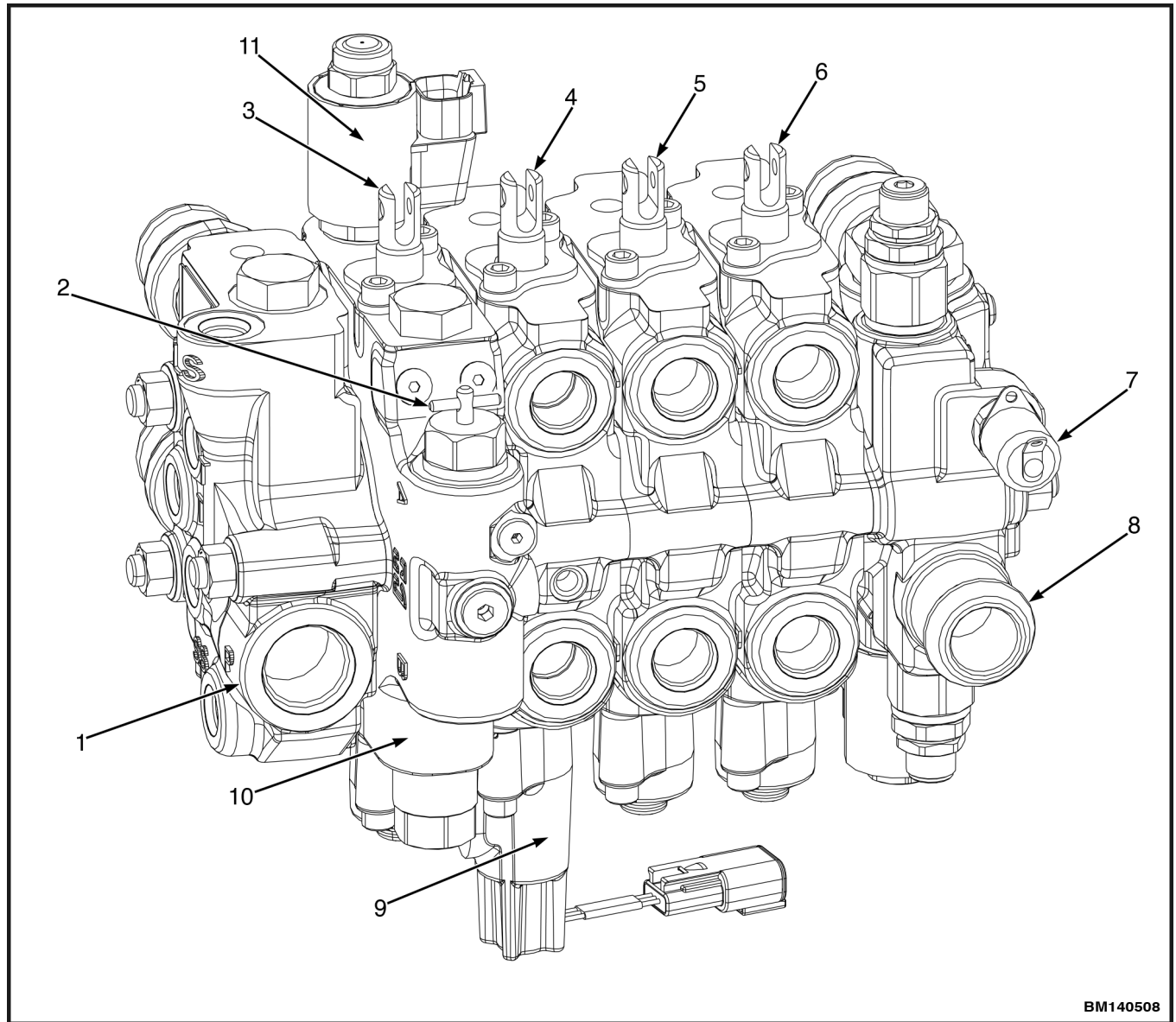
The hydraulic control valve is a modular, stackable section of valve bodies held together with tie-rod bolts. The hydraulic control valve uses operator feedback/electrical signals to control the flow and direction of hydraulic fluid to various hydraulic

components and will have between 2 and 5 functions on a single valve assembly. The control valve controls the operation of the lift/lower, forward/reverse tilt, and auxiliary functions of the lift truck. The unit will be either a manual control valve or an Electro-Hydraulic (E-Hydraulic or EH) control valve. Manual control valves have manual control levers for actuation. The E-Hydraulic type replaces the manual control levers with simple, single-handed integrated electronic controls, (joystick or a finger operated lever module), typically located on the right-hand armrest. Both types of control valve are designed to be load sensing closed center (load compensated) meaning internal feedback capability is built into the valve that compensates for the flow based on the load placed on the hydraulic system. In other terms, the operator will have consistent lowering regardless of load on the forks.

Manual Control Valve

The manual control valve in the 1-3.5 ton series is a hydraulic valve based on common valve architecture. Hydraulic levers are linked directly to the spools on the control valve that open and close flow to the hydraulic circuits. Circuits do not open/close unless operator input is given directly. The spools in this hydraulic valve have a closed center so that when hydraulic functions are neutral there is no excess flow of hydraulic oil from the valve back to the tank when no work is performed. Without excess flow, no excess heat is produced during idle or standby conditions.

NOTE: The graphic shown below is a 4-function valve.



BM140508

- | | |
|---------------------------|--------------------------|
| 1. INLET SECTION | 7. DIAGNOSTIC FITTING |
| 2. EMERGENCY RELIEF VALVE | 8. OUTLET SECTION |
| 3. HOIST SECTION | 9. SPOOL POSITION SENSOR |
| 4. TILT SECTION | 10. OPS SOLENOID |
| 5. AUXILIARY #1 SECTION | 11. RTST SOLENOID |
| 6. AUXILIARY #2 SECTION | |

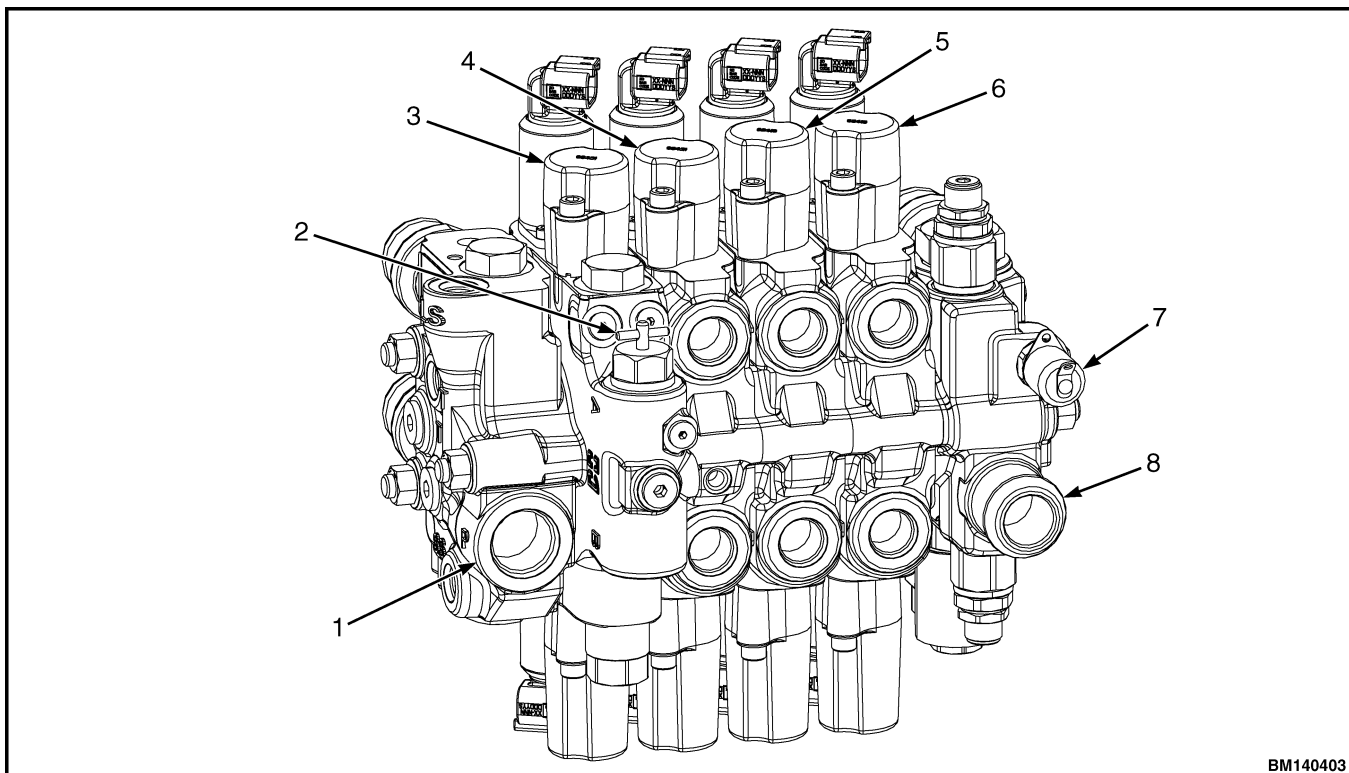
Figure 15. Typical Manual Control Valve with VDP

Electro-Hydraulic Control Valve

The E-Hydraulic (or EH) control valve in the 1-3.5 ton series is a hydraulic valve also based on common valve architecture. Spool opening is controlled via a proportional solenoid that is controlled by the truck Vehicle System Manager (VSM). Signal for the movement comes from the operator moving a finger control or joystick, but functions can be locked out or adjusted via the control system. The spools in

this hydraulic valve have a closed center so that when hydraulic functions are neutral there is no excess flow of hydraulic oil from the valve back to the tank when no work is performed. Without excess flow, no excess heat is produced during idle or standby conditions.

NOTE: The graphic shown below is a 4-function valve.

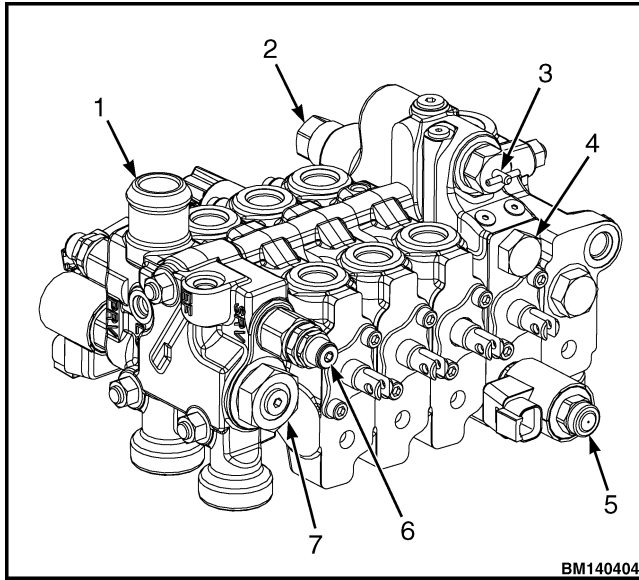


1. INLET SECTION
2. EMERGENCY RELIEF VALVE
3. HOIST SECTION
4. TILT SECTION

5. AUXILIARY #1 SECTION
6. AUXILIARY #2 SECTION
7. DIAGNOSTIC FITTING
8. OUTLET SECTION

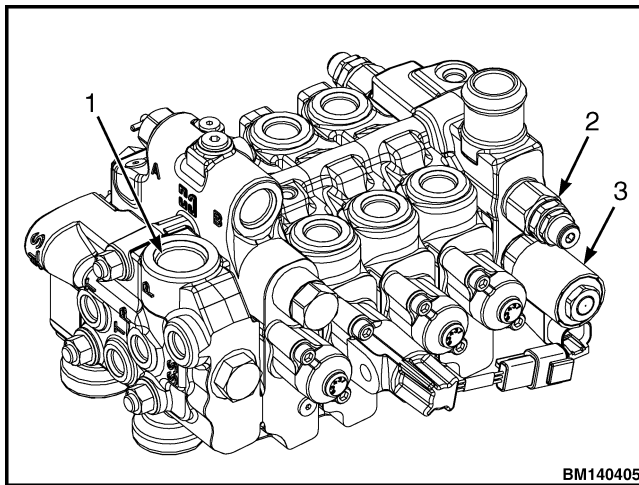
Figure 16. Typical Electro-Hydraulic Control Valve with VDP

Manual Valve Main Components



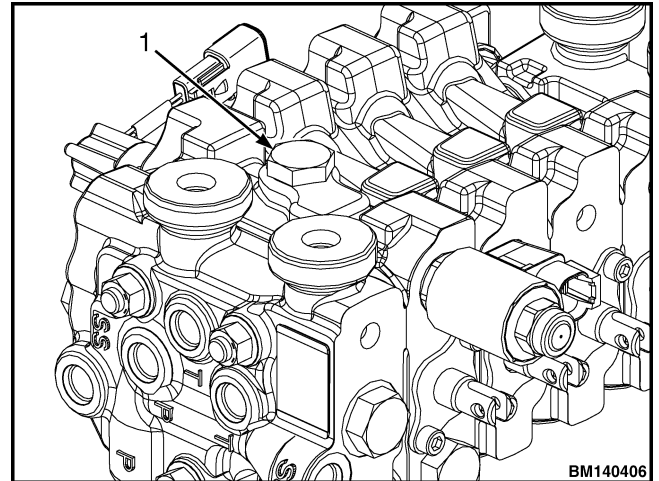
- 1. TANK
- 2. COMP LOWER
- 3. EMERGENCY LOWER
- 4. LLC
- 5. OPS
- 6. SRV
- 7. SHUT OFF (UNLOADER)

Figure 17. Main Components, View 1



- 1. INLET
- 2. PRV
- 3. ANTI-STALL SOLENOID

Figure 18. Main Components, View 2



- 1. PUMP DUMP POPPET

Figure 19. Main Components, View 3

Control Valve Schematic

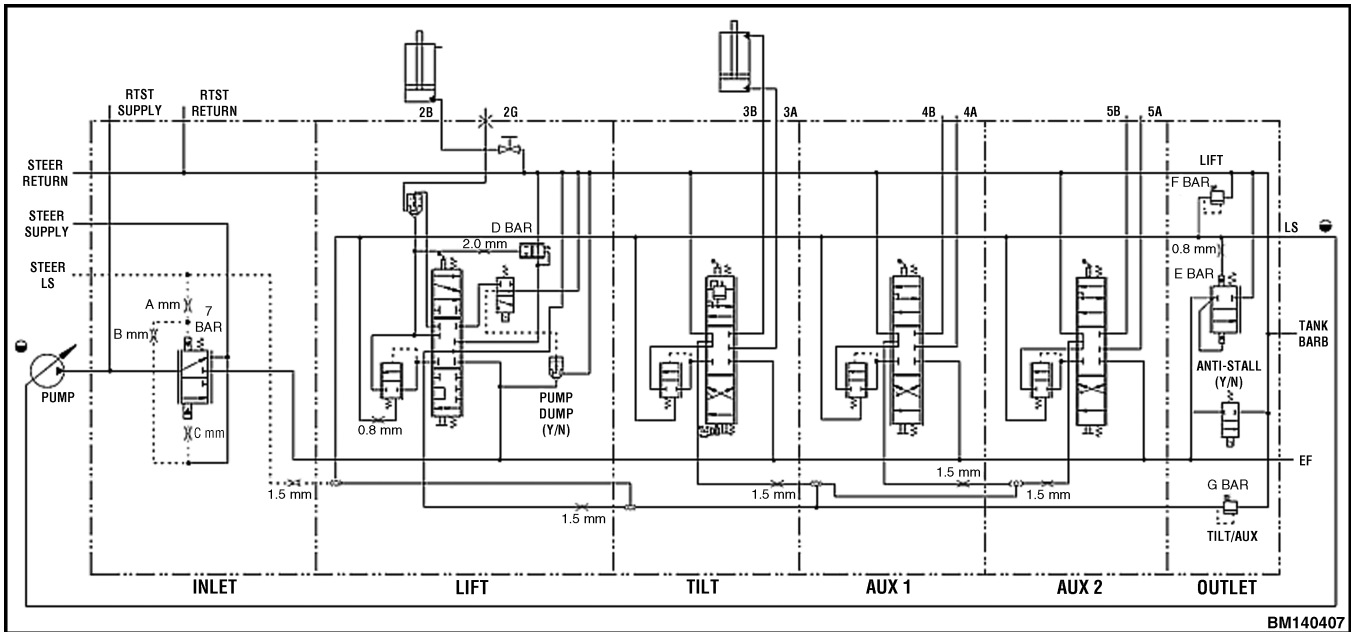


Figure 20. Control Valve Schematic

Valve Section Breakdowns

The following sections illustrate the different valve sections and functions.

Inlet/Steer Section – Neutral/Steering Idle

Steer supply pressure shifts steer spool against spring as Steer LS is zero and flow goes to downstream functions.

Steer LS connected to tank. No steer supply.

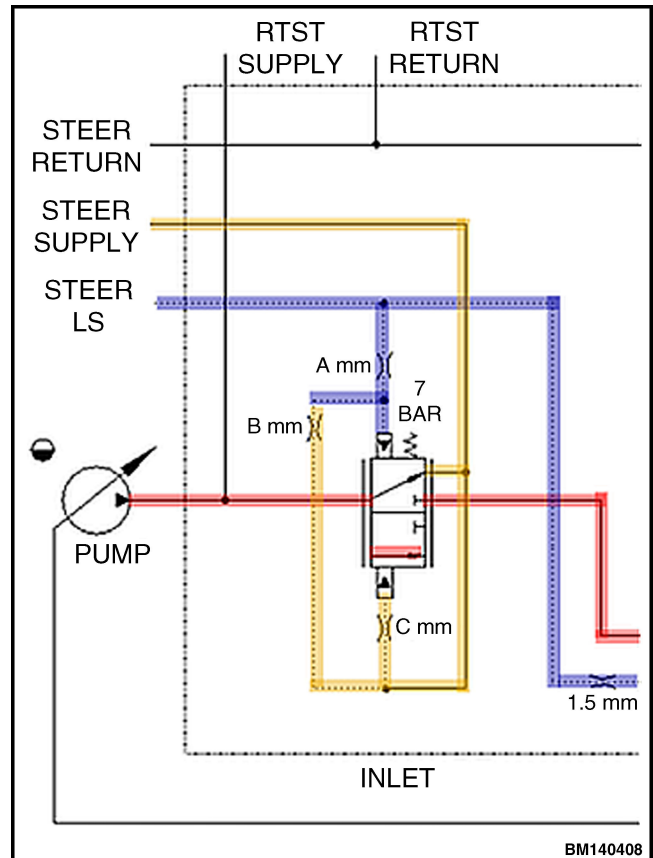


Figure 21. Neutral/Steering Idle

Inlet Section – Steering

When steering operated, Steer LS acts on left side of spool and shifts spool to right side.

This blocks the pump flow to downstream functions and diverts flow to steering.

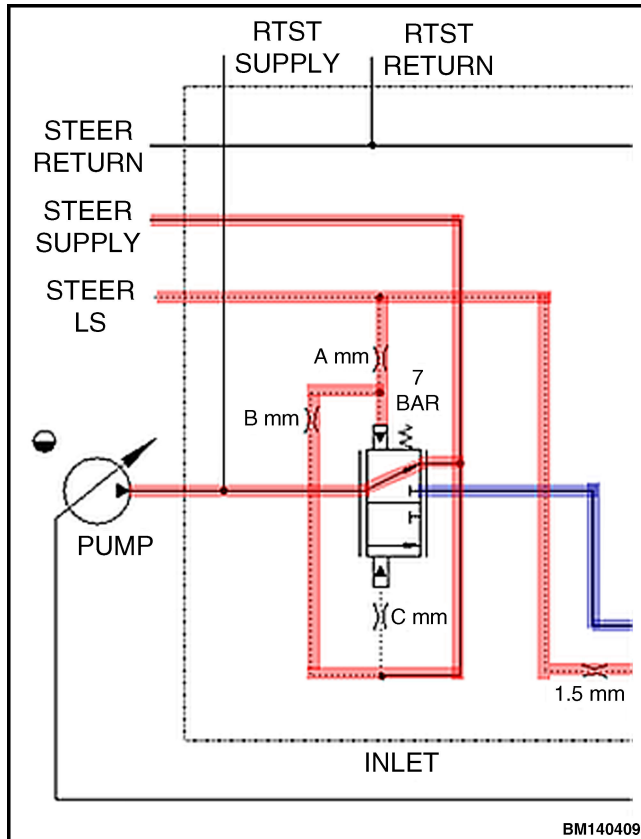


Figure 22. Steering

Lift Section - Neutral

OP Solenoid (OPS) Off

LLC Poppet Vent to tank blocked.

Pump vented to Tank thru pump dump poppet.

No flow is available for downstream sections.

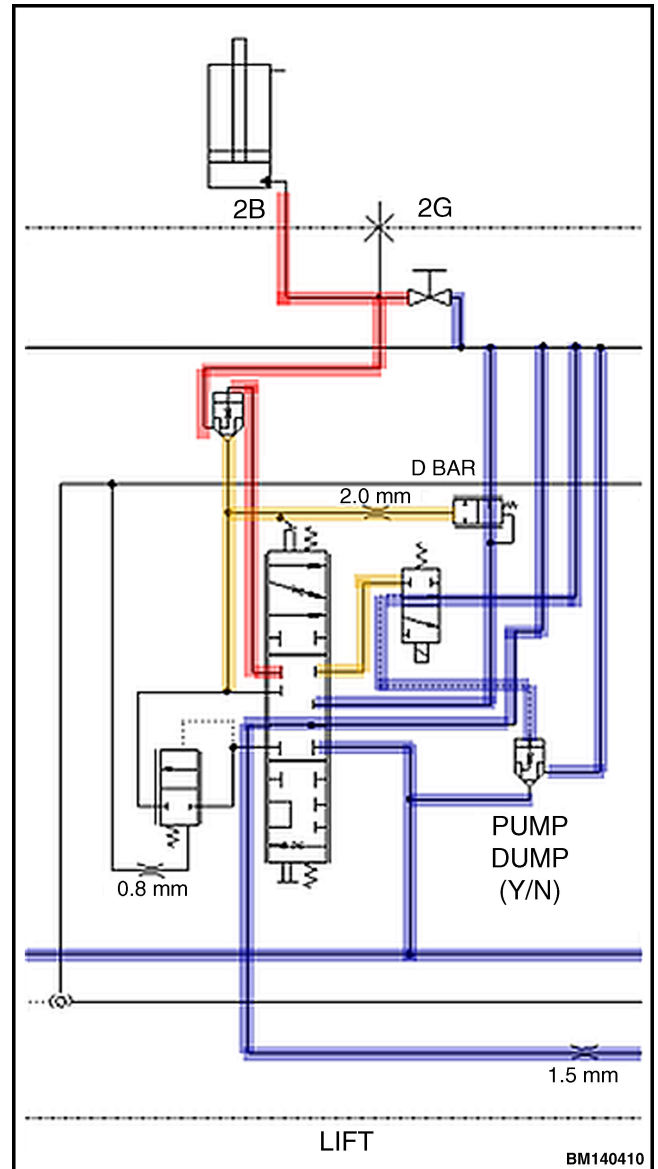


Figure 23. Neutral - OPS Off

Lift Section - Neutral

OP Solenoid (OPS) On

Pump dump poppet blocked.

Flow goes to downstream functions.

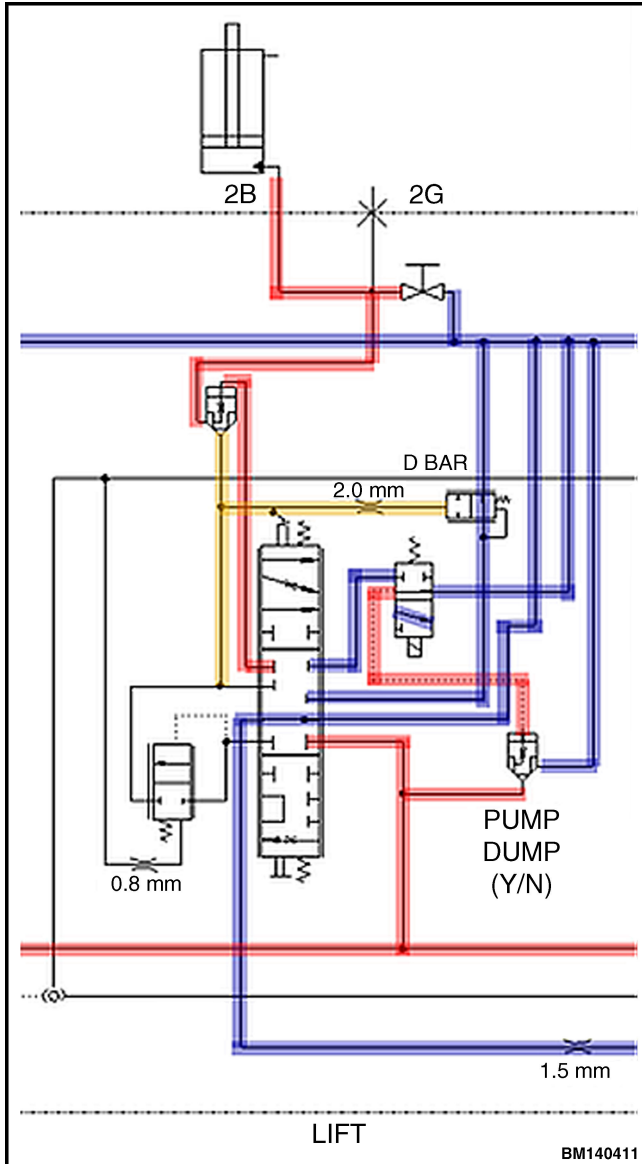


Figure 24. Neutral - OPS On

Lift Section - Lower

OPS Off and Spool IN

OPS - Solenoid Off

LLC poppet vent to tank blocked.

EF vented to tank through pump dump poppet.

Spool IN to connect WP-Tank, but LLC poppet will not lift as vent to tank blocked by OPS.

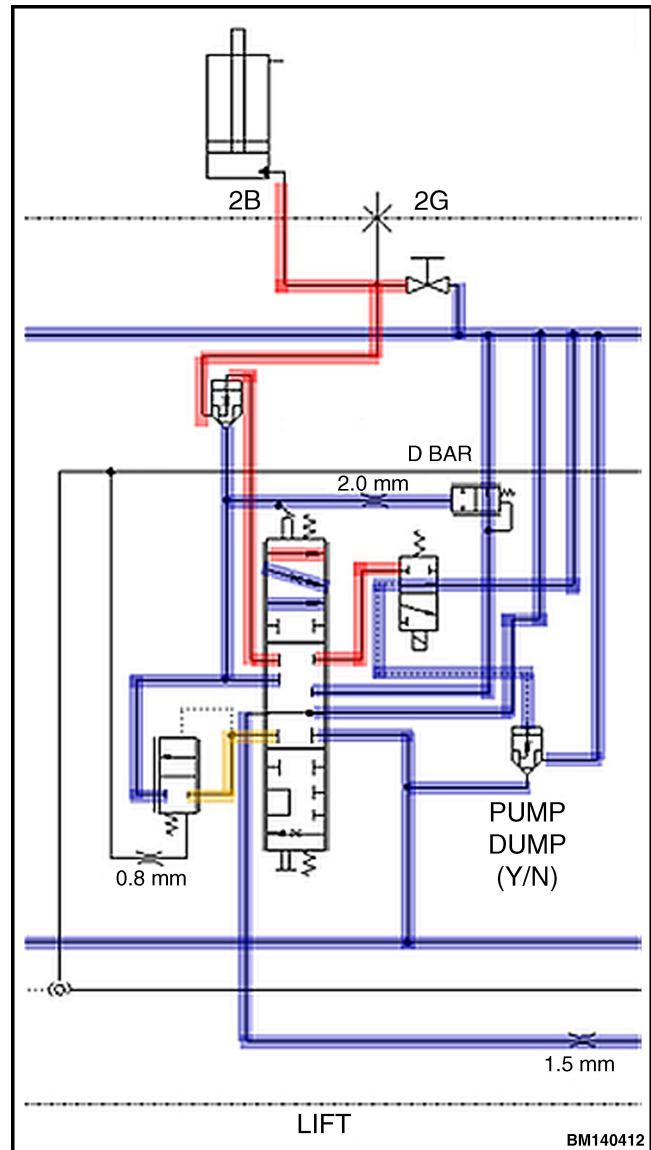


Figure 25. Lower - OPS Off, Spool IN

Lift Section - Lower

OPS On

OPS - Solenoid On

Spool IN, work port is connected to tank.

LLC vent connect to tank. WP flow will return to tank through compensator lower notches from Pre-Tank gallery.

Lower compensator will adjust position based on WP load to ensure constant flow and dP across spool notches.

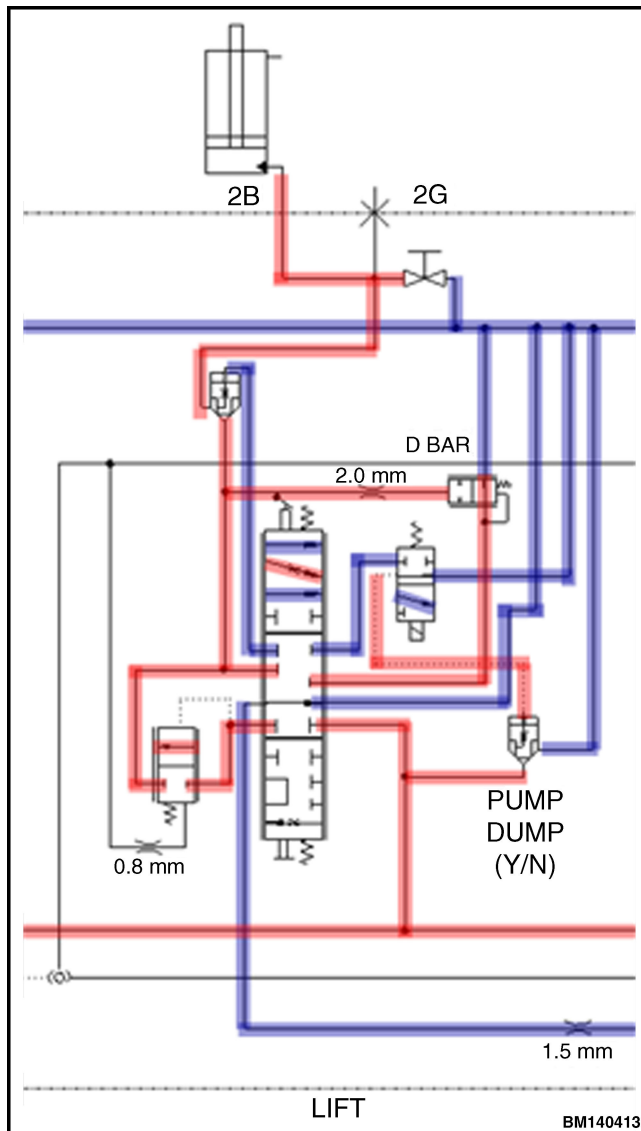


Figure 26. Lower - OPS On Spool IN

Lift Section – Raise

OPS OFF and Spool Out

OPS Solenoid OFF

Spool Out, EF is connected to bridge.

Low pressure below pump dump poppet.

Pressure in EF gallery pushes pump dump poppet down draining all flow to tank.

Load can not be raised – LLC remains shut.

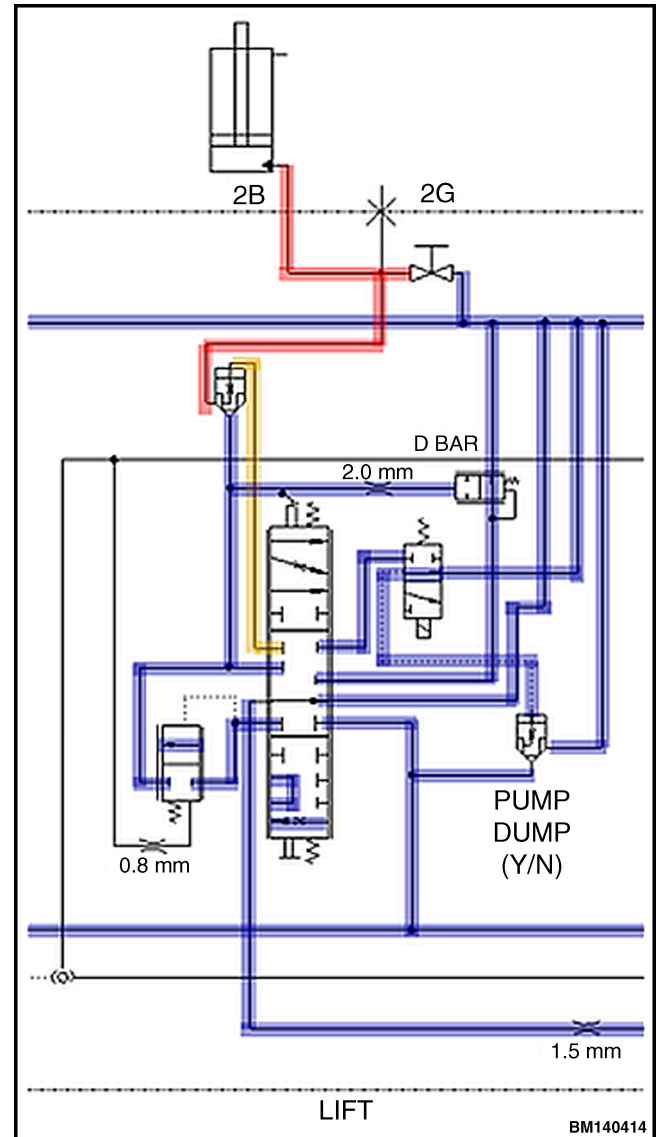


Figure 27. Raise - OPS Off, Spool OUT

Lift Section – Raise

OPS ON and Spool Out

OPS Solenoid ON

Spool Out, EF is connected to work port.

OPS holds the pump dump poppet to ensure bridge to WP connection.

Bridge is connected to LS and communicated to pump (unloader).

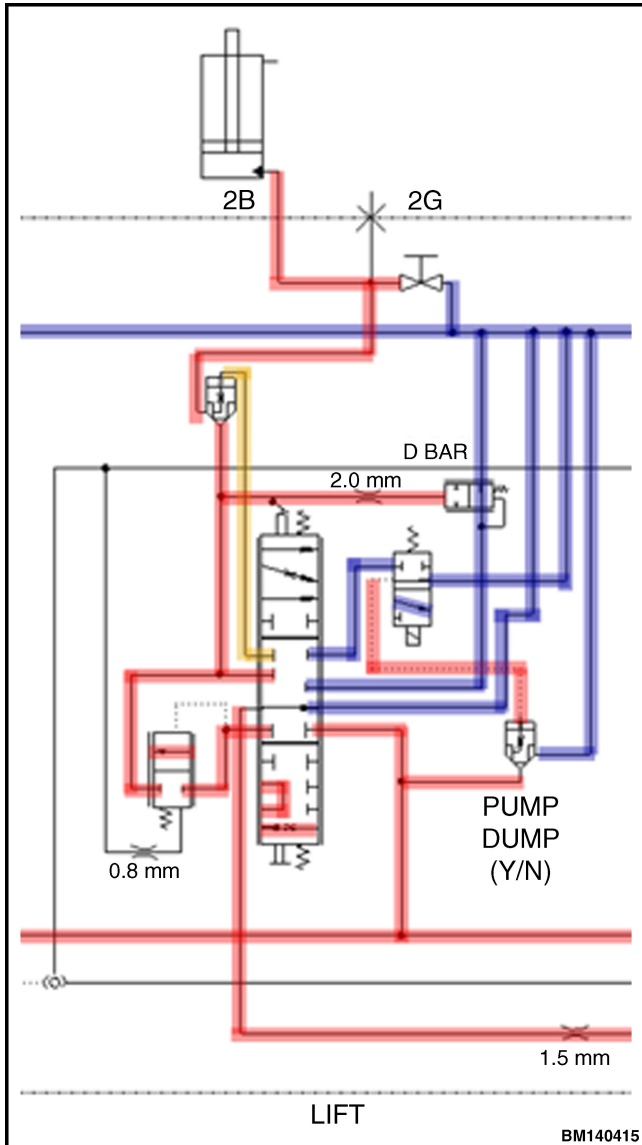


Figure 28. Raise - OPS On, Spool OUT

Tilt Section - Neutral

Work Port with trapped pressure.

Bridge drained to tank.

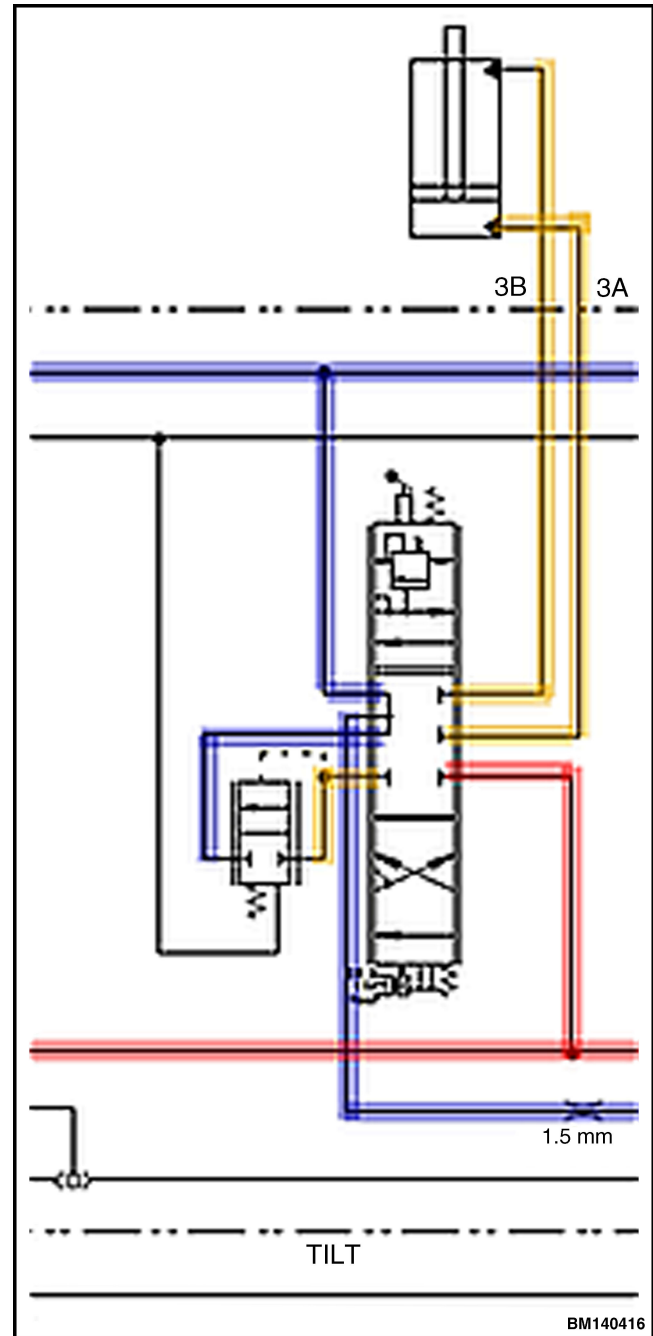


Figure 29. Tilt Section - Neutral

Tilt Section - Spool IN

Spool IN, EF connected to WP A (High Pressure) and WP B connected to tank. (Low Pressure).

Tilt Forward: Bridge pressure lifts the tilt lock poppet from seat and delivers flow to tank through orifice.

Tilt Lock: Tilt lock piston will remain shut if OPS is off and bridge pressure is low or if the machine is off.

Bridge is connected to LS and communicated to pump (unloader).

Position sensor voltage decreases proportionally with stroke.

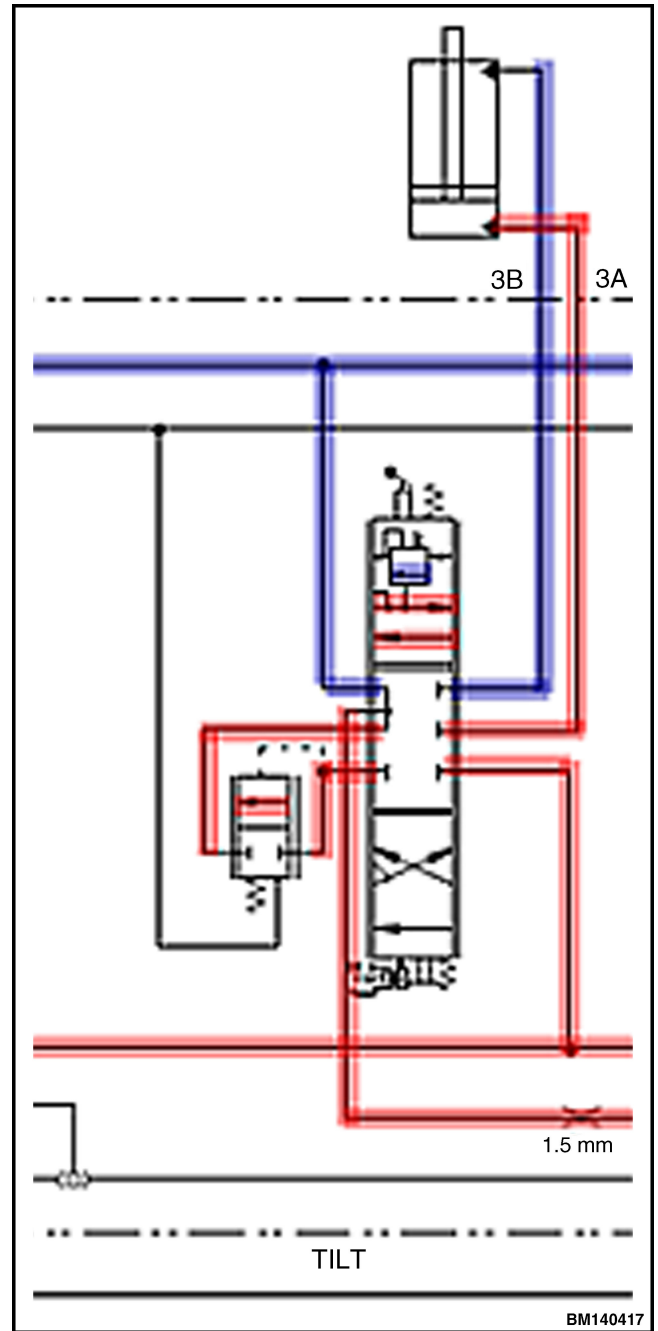


Figure 30. Tilt Section - Spool IN

Tilt Section - Spool OUT

Spool OUT, EF connected to WP B (High Pressure) and WP A connected to tank. (Low Pressure).

Bridge is connected to LS and communicated to pump (unloader).

Position sensor voltage increases proportionally with stroke.

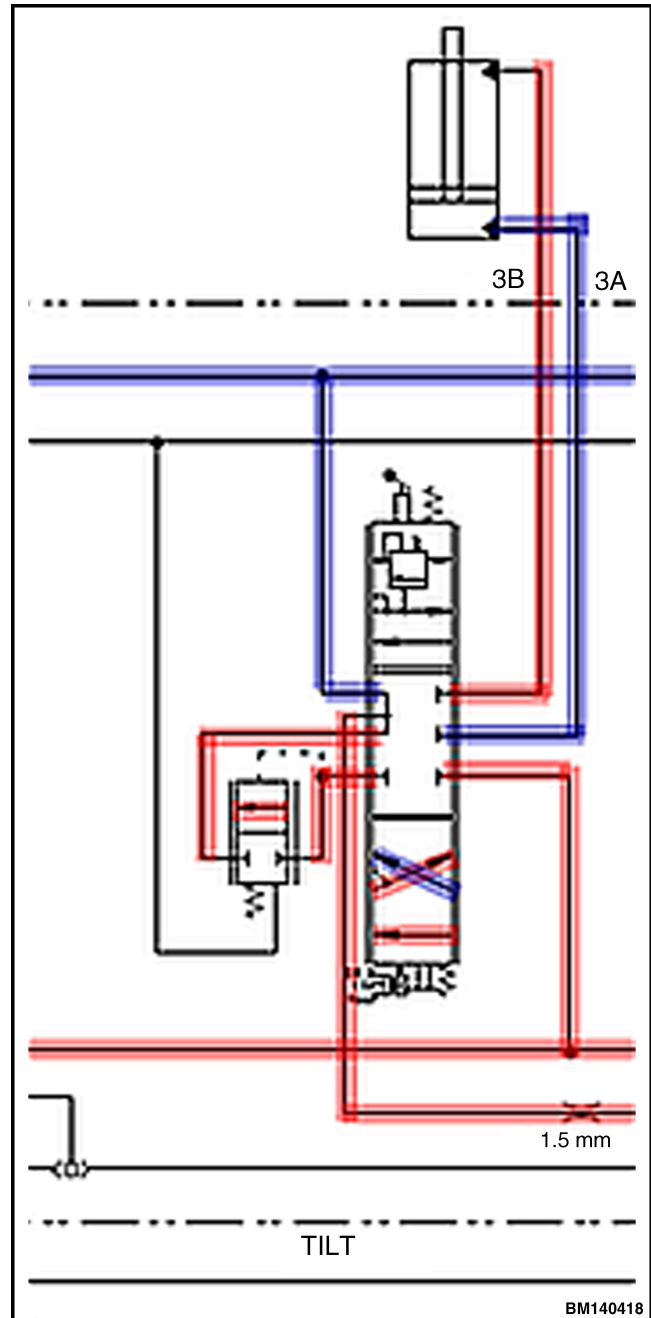


Figure 31. Tilt Section - Spool OUT

AUX 1 Section - Neutral

Work Port with trapped pressure.

Bridge drained to tank.

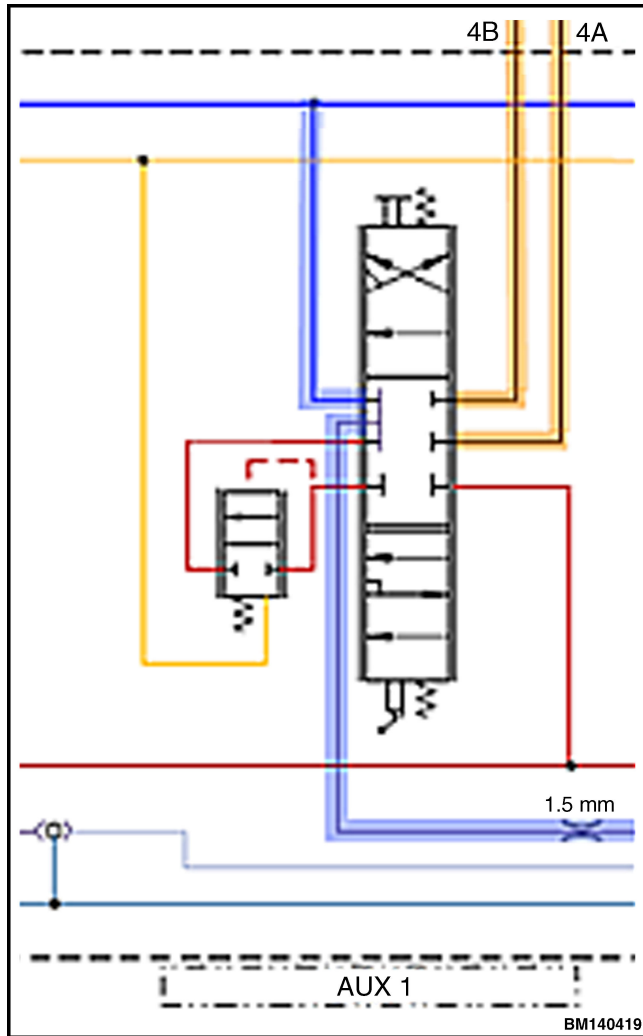


Figure 32. AUX 1 Section - Neutral

AUX 1 Section - Spool IN

Spool IN, EF connected to WP A (High Pressure) and WP B connected to tank. (Low Pressure).

Bridge is connected to LS and communicated to pump (unloader).

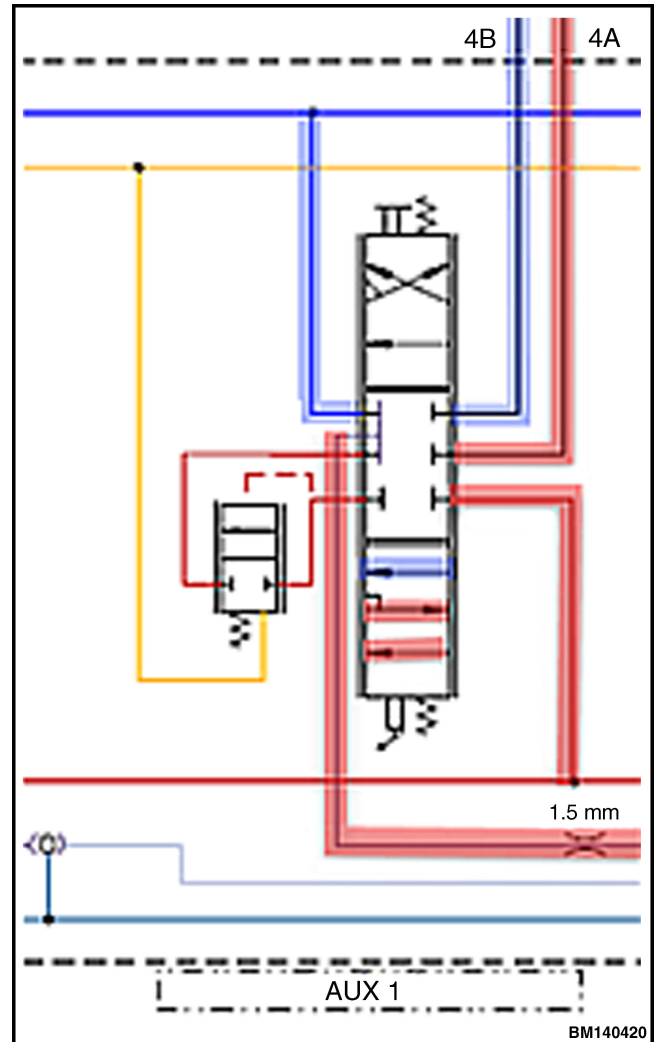


Figure 33. AUX 1 Section - Spool IN

AUX 1 Section - Spool OUT

Spool OUT, Pump connected to WP B (High Pressure) and WP A connected to tank. (Low Pressure).

Bridge is connected to LS and communicated to pump (unloader).

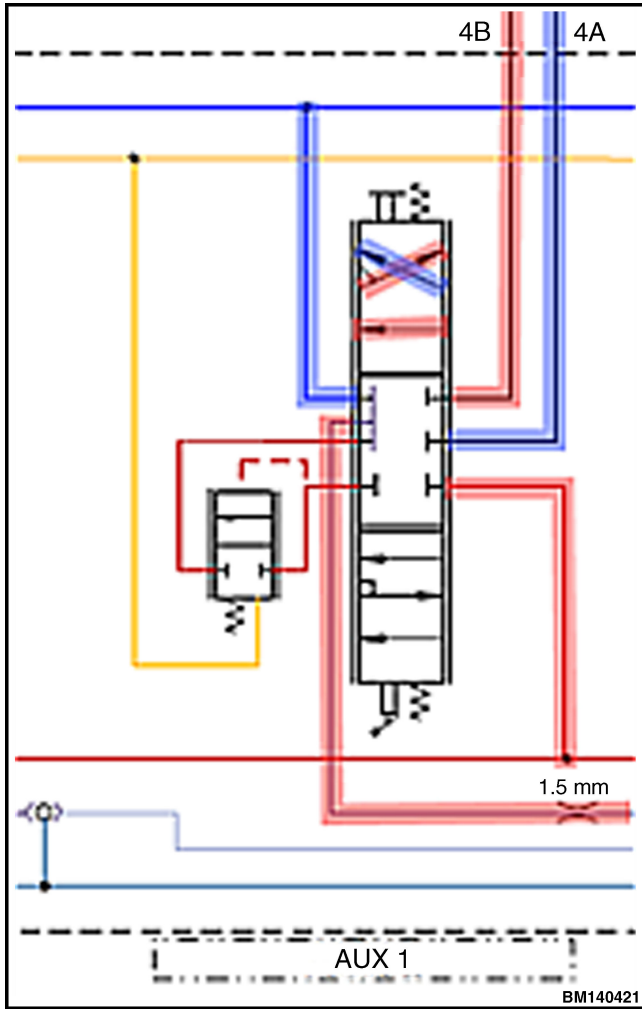


Figure 34. AUX 1 Section - Spool OUT

AUX 2 Section - Neutral

Work Port with trapped pressure.

Bridge drained to tank.

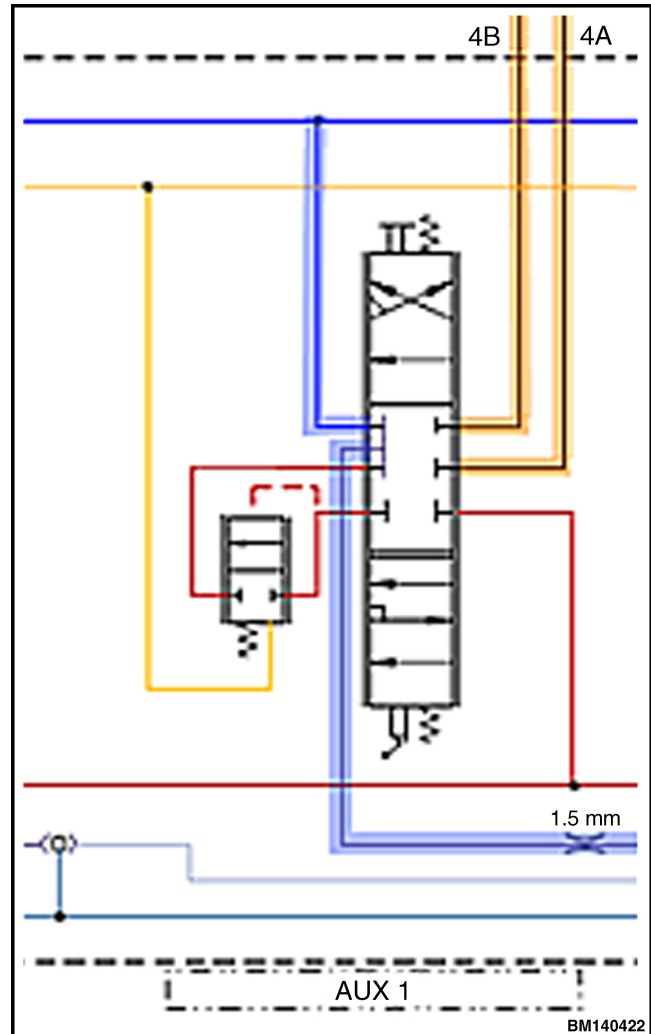


Figure 35. AUX 2 Section - Neutral

AUX 2 Section - Spool IN

Spool IN, EF connected to WP A (High Pressure) and WP B connected to tank. (Low Pressure).

Bridge is connected to LS and communicated to pump (unloader).

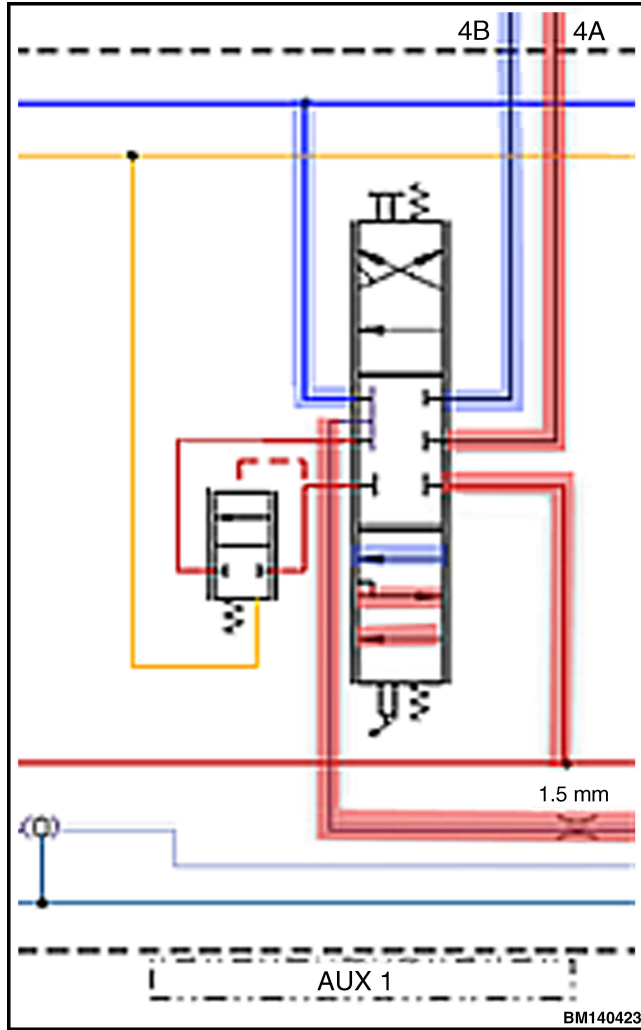


Figure 36. AUX 2 Section - Spool IN

AUX 2 Section - Spool OUT

Spool OUT, Pump connected to WP B (High Pressure) and WP A connected to tank. (Low Pressure).

Bridge is connected to LS and communicated to pump (unloader).

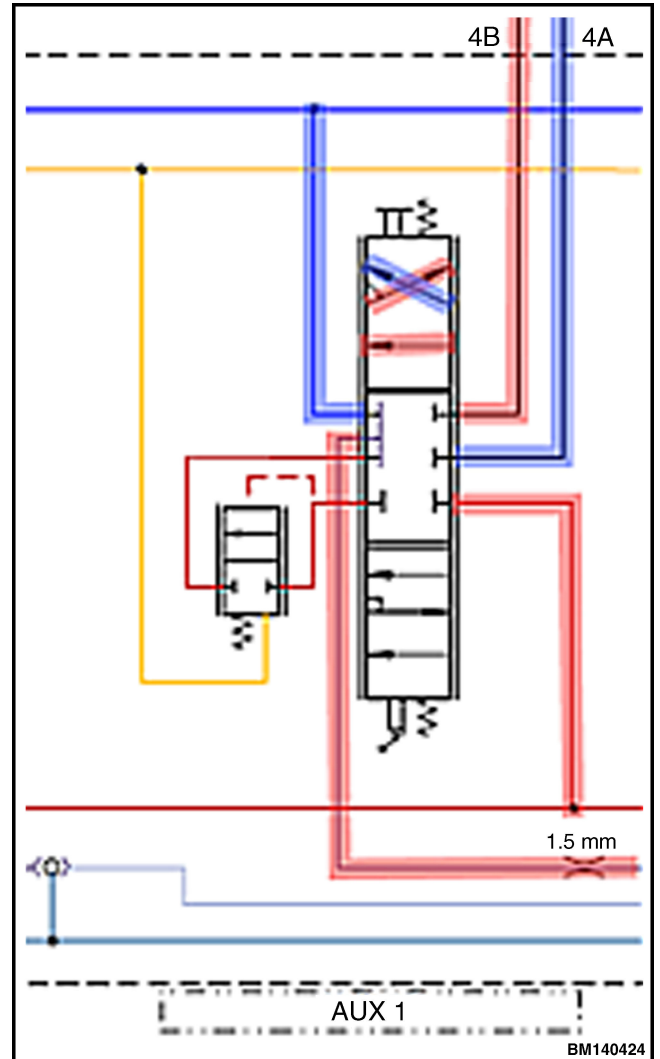


Figure 37. AUX 2 Section - Spool OUT

Unloader in Neutral - FDP

When all sections are in neutral condition.

Unloader set for 13 Bar.

When the margin pressure exceeds 13 Bar Unloader starts unloading flow.

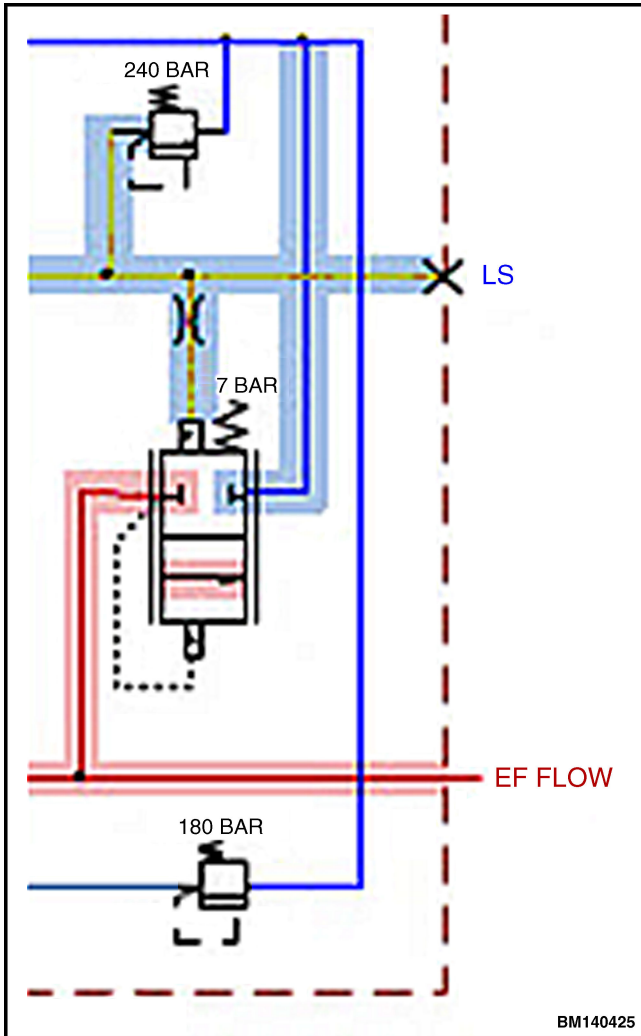


Figure 38. Unloader in Neutral - FDP

Unloader in Function - FDP

When sections starts working.

LS pressure will also act behind the Unloader to restrict unloader from dumping the flow to tank.

Unloader will fully shut once margin drops below 13 bar.

Due to the high LS pressure Unloader stays closed and holds the pressure at EF gallery until function demand is less than pump output.

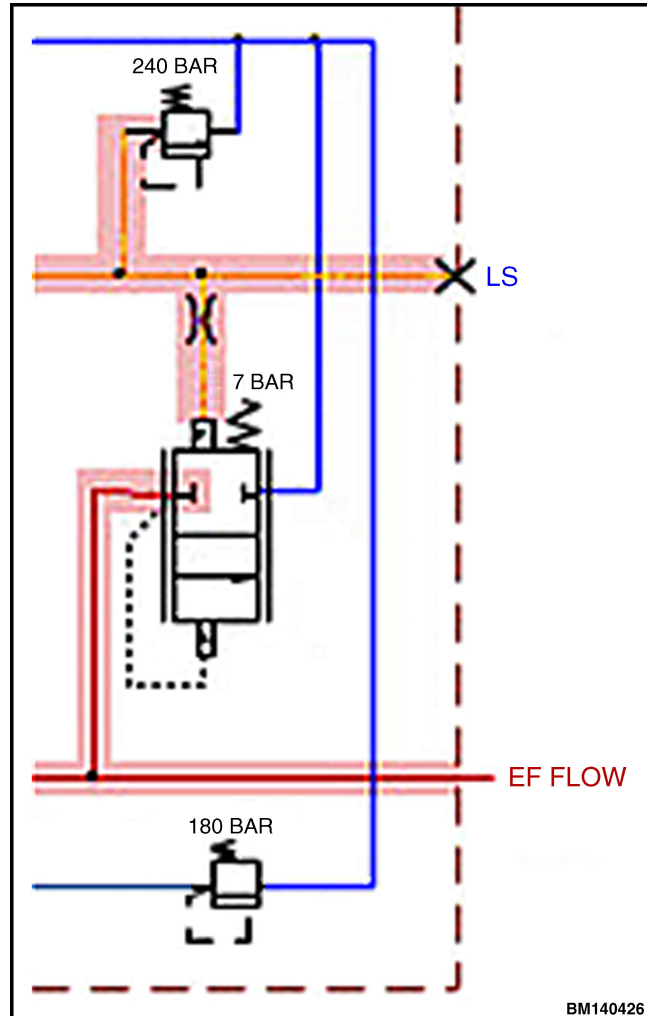


Figure 39. Unloader in Function - FDP

Anti-Stall Functionality

Command provided to anti-stall solenoid to prevent engine stall condition.

No command = EF connection to tank blocked

Command = EF connection to tank opened and allows EF pressure to vent to tank via orifice disk.

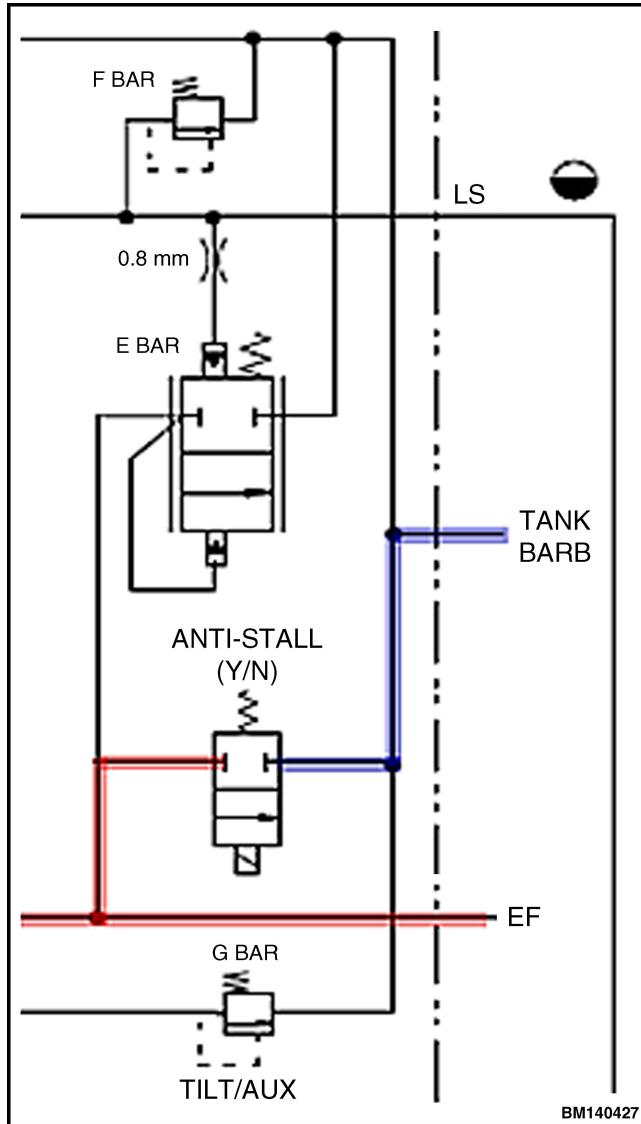


Figure 40. Anti-Stall, Solenoid OFF

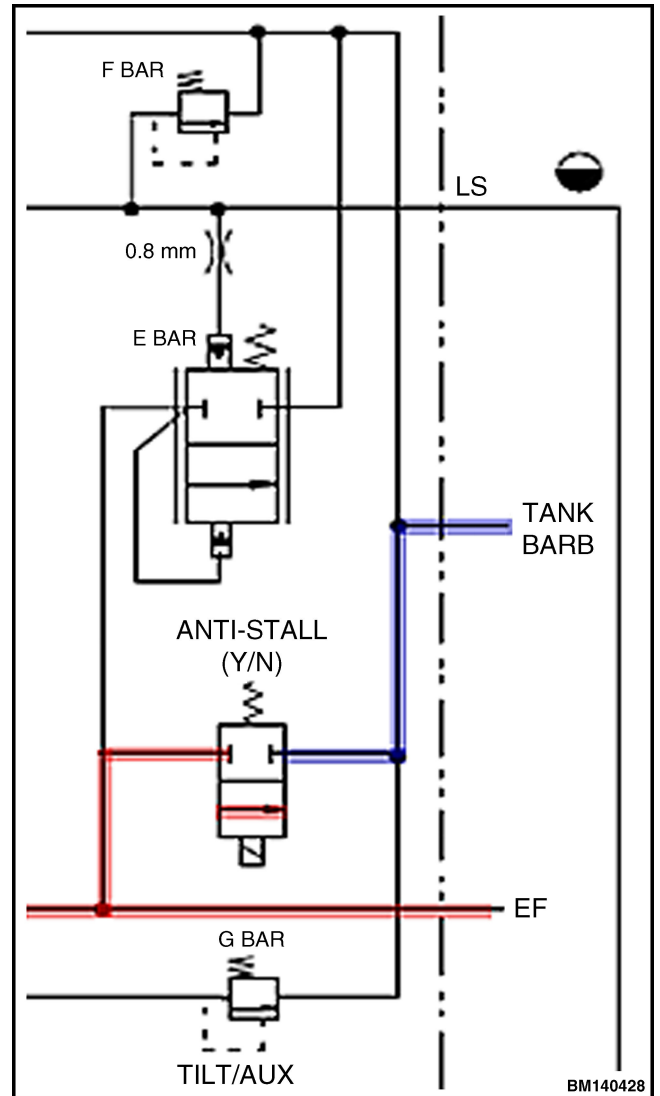


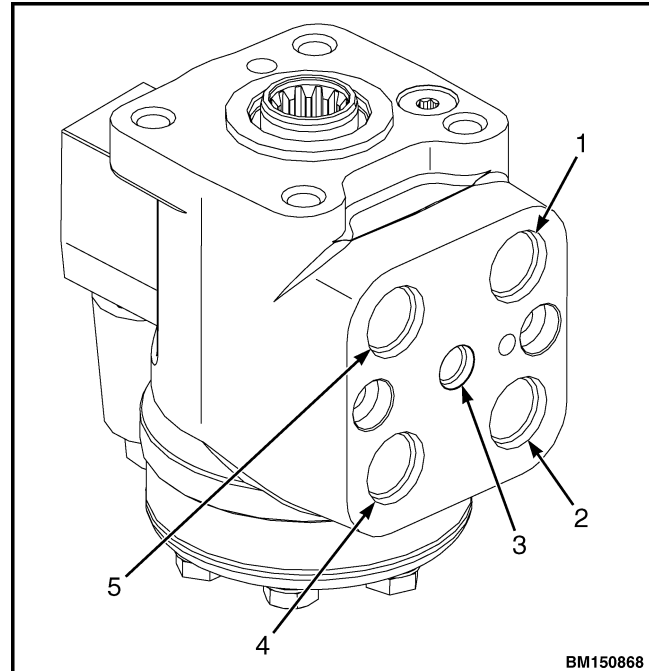
Figure 41. Anti-Stall, Solenoid ON

STEERING CONTROL UNIT DESCRIPTION 202001-142

STEERING CONTROL UNIT (SCU)

The Steering Control Unit (SCU) is a closed-center valve, hydrostatic unit that is controlled by the steering wheel. Turning the wheel directs hydraulic fluid flow to actuate the steer axle cylinder and turn the lift truck wheels. The SCU is mounted in the steering column as part of cowl subassembly. A hydraulic pump (either gear or variable displacement type) supplies oil directly to the SCU. Two hydraulic lines are connected to the SCU and directly to the steer axle assembly, which contains a two-way cylinder. Hydraulic pressure and flow to the steering cylinder control the steering axle wheel position.

The SCU is a load-sensing device and receives priority flow upon steer demand. The demand for steering is sensed at the Load Sensing (LS) port in the steering control unit. The pilot line from the LS port is connected to the priority valve in the main control valve. While steering, a spring and pilot pressure from the LS line hold the regulator spool open for steering. When there is no pressure in the LS line (no steering), pilot pressure from the hydraulic pump shifts the spool. In this position, most of the oil for steering system goes to the lift circuit. In addition, anti-steering kickback check valves are located in both P (Pump) port and LS (Load Sense) port.



1. L - LEFT PORT
2. R - RIGHT PORT
3. LS - LOAD SENSE PORT
4. P - PUMP PORT
5. T - TANK PORT

Figure 42. Steering Control Unit

OPERATION

NOTE: The following information pertains to a system equipped with a Variable Displacement Pump (VDP).

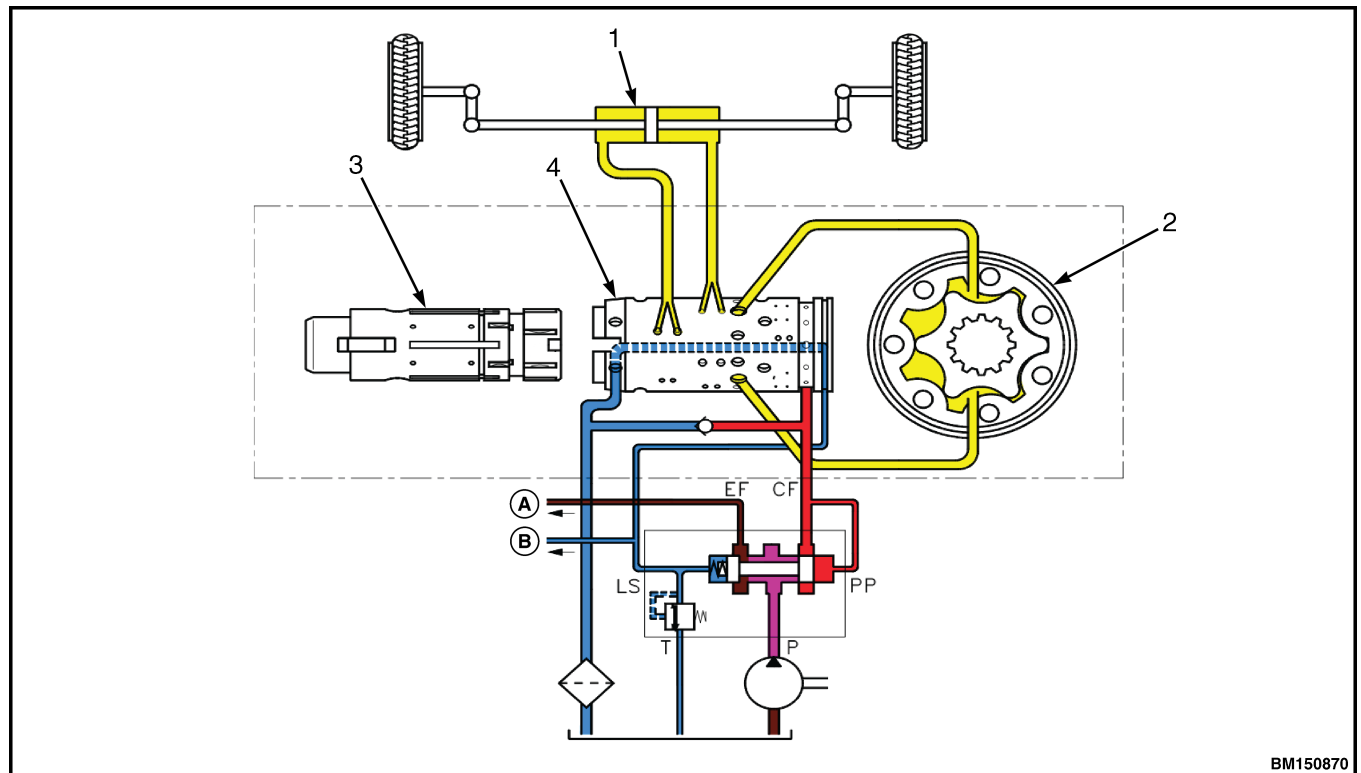
When the engine is running and the steering wheel is not being turned.

The steering valve spool and sleeve set are aligned in the neutral position. The LS circuit is connected to tank through the spool set. The oil flow is blocked from entering the left or right steering ports. Pressure at the pilot side of the priority flow divider valve spool builds forcing the spool to move against the spring on the opposite side.

The LS circuit is also connected to the variable displacement pump via the transition section of the valve. With no demand from the SCU the swash plate in the pump will be de-stroked, unless, there is another hydraulic function (such as lift, tilt or auxiliary) being operated. Any pump flow that may be created by demand from a hydraulic function will be routed to the control valve through the Excess Flow (EF) passage.

In this neutral position, a small amount of oil is constantly bled through the dynamic orifice. The oil then flows through the LS circuit and through the

spool and sleeve set, then back to hydraulic tank. This dynamic flow prevents initial hard spot when steering is turned rapidly or abruptly.



A. TO HYDRAULIC FUNCTIONS

B. TO LS CIRCUIT

- 1. STEERING CYLINDER
- 2. GEAR PUMP

- 3. SLEEVE
- 4. SPOOL

Figure 43. Steering Wheel not Being Turned

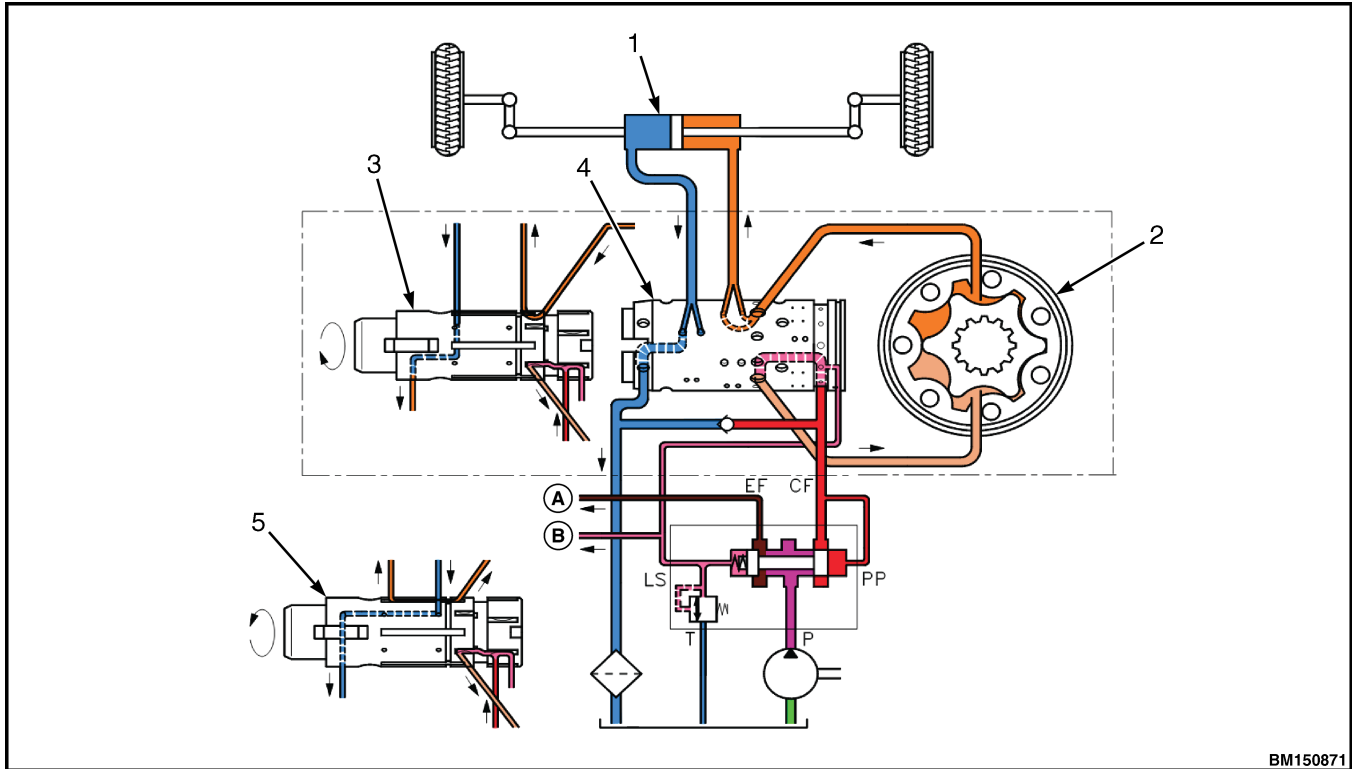
When the engine is running and the steering wheel is being turned.

The steering valve spool and sleeve set start to rotate when the operator starts turning the steering wheel. A passage opens for oil to flow to the internal gear pump on the SCU. The oil flow causes the gear pump to rotate. Oil flows back into the steering valve spool and sleeve set and out to the left or right steering ports depending on the direction of steering rotation.

At the same time, the LS circuit is blocked from returning to the hydraulic tank and is connected to the steering work port to sense pressure required to

turn the steering wheels. As the pressure required increases or decreases in the LS circuit, the priority flow divider valve spool shifts to meet the flow and pressure required to rotate the tires.

The priority flow divider maintains a pressure differential between the pump pressure and the load sense pressure. By maintaining this pressure differential, which is known as the margin pressure, the priority flow divider only delivers the amount of hydraulic fluid actually required by the steering function to the SCU. The priority flow divider spool shifts so the rest of the flow gets directed to the EF passage.



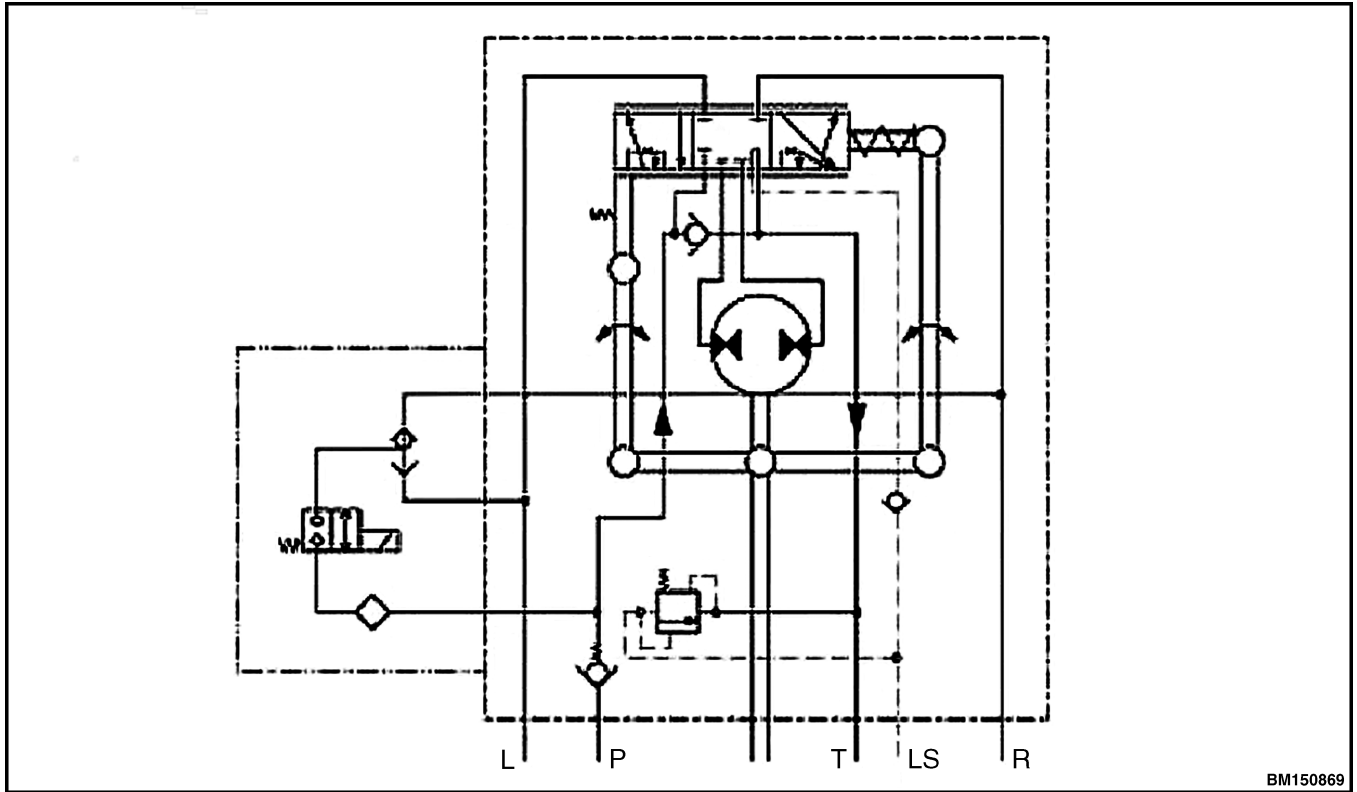
A. TO HYDRAULIC FUNCTIONS

B. TO LS CIRCUIT

- 1. STEERING CYLINDER
- 2. GEAR PUMP
- 3. SLEEVE (TURN RIGHT)

- 4. SPOOL
- 5. SLEEVE (TURN LEFT)

Figure 44. Steering Wheel is Being Turned



BM150869

- 1. L = TANK
- 2. P = PUMP
- 3. T = TANK

- 4. LS = LOAD SENSE
- 5. R = RIGHT

Figure 45. SCU Hydraulic Schematic

BRAKE SYSTEM DESCRIPTION
202001-143

BRAKE SYSTEM DESCRIPTION

The truck drive axle provides the components and sub-assemblies for the service braking and park braking of the truck. There are two major types of axle brake assemblies available, dry drum and wet brakes. Dry drum brake axles use traditional brake shoes and pads that clamp on a drum to provide braking energy. Wet brakes, or oil-cooled hydraulic disc brakes, are fully sealed in an oil bath. Both types of brakes are hydraulically activated using a brake pedal and master cylinder. In addition to the service brakes, a park brake mechanism is supplied to apply constant pressure to the service brakes. The park brake actuation is different depending on the style of brakes ordered with the truck.

Dry brake axles have a manual park brake that is foot-activated and hand-released. The operator applies the park brake with a foot pedal that is located to the left of the service brake. Releasing the manual park brake is carried out by pulling on the

handle on the left hand side of the dash. The large, wide lever is designed for easy use with or without gloves. The handle actuates a spring, over center mechanism, minimizing the force required to operate the handle. The manual park brake is cable-actuated. Cable tension can be adjusted using a socket-end wrench or ratchet, a small access cover in the dash above the park brake pedal gives service technicians access to the adjustment screw. This cover (reservoir moved to easy to see location under the dash flip up section for easier daily checks) also allows the operator to visually check the brake fluid level as part of the daily checks. Day to day operational checks have been made easier with the addition of a flip up cover in the dash to allow quick checking of the brake fluid level.

Dry Brakes

The brake system includes the following parts: master cylinder, brake shoes, wheel cylinders, and park brake system. A service brake assembly is installed on the mounts at each end of the drive axle.

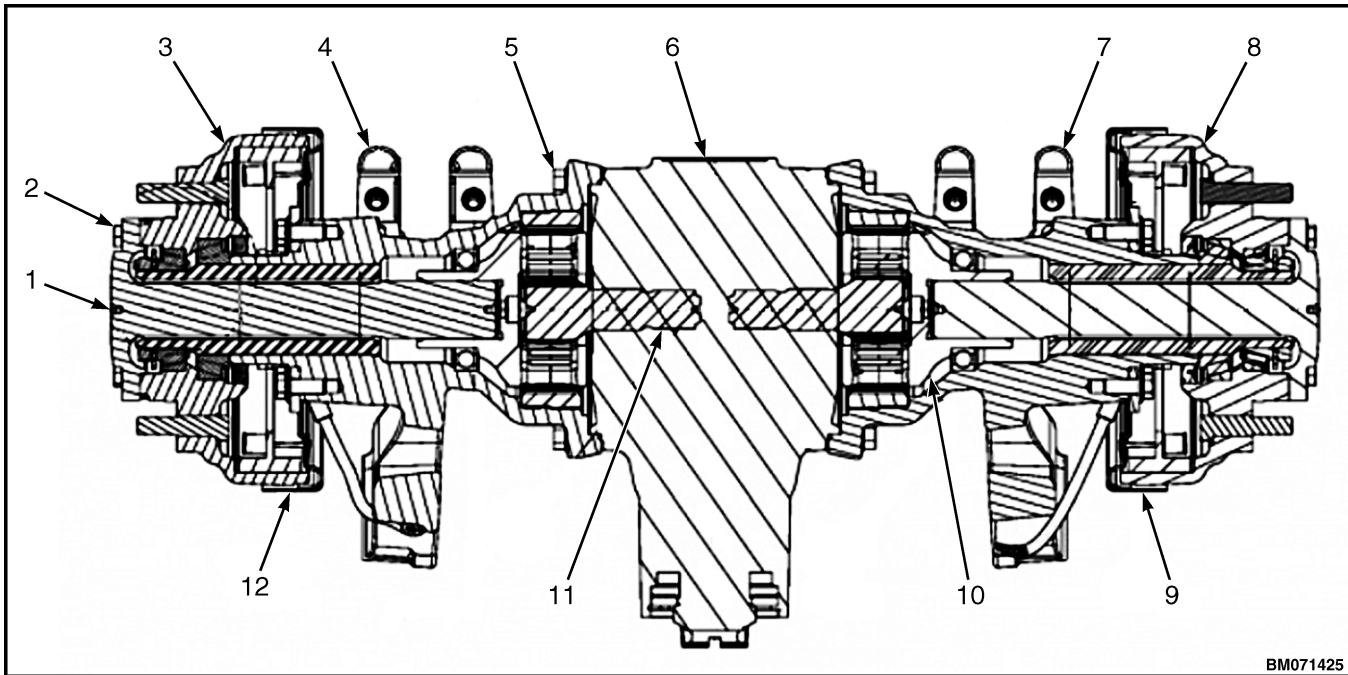
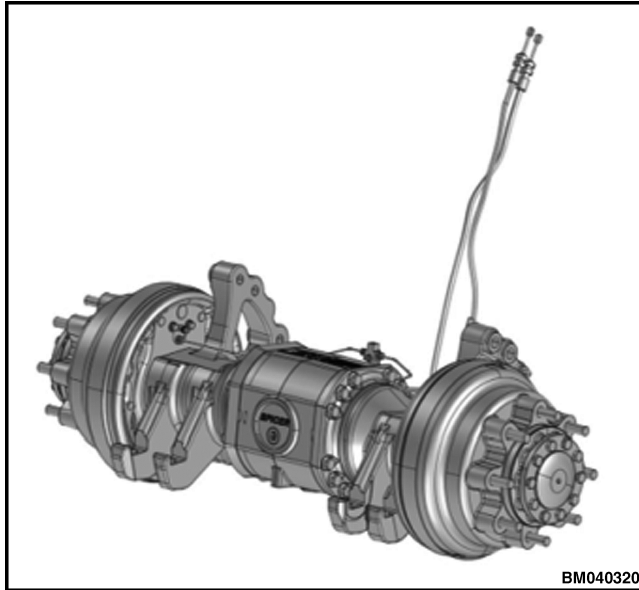


Figure 46. Drive Axle, Differential, and Brake Components

Legend for Figure 46.

- | | |
|------------------------------|----------------------------|
| 1. AXLE SHAFT | 7. HANGER, RH |
| 2. CAPSCREW | 8. DRIVE AXLE HUB (RH) |
| 3. DRIVE AXLE HUB (LH) | 9. BRAKE ASSEMBLY (RH) |
| 4. HANGER, LH | 10. PLANETARY GEAR BEARING |
| 5. CAPSCREW | 11. PLANETARY GEAR SHAFT |
| 6. DRIVE AXLE CENTER SECTION | 12. BRAKE ASSEMBLY (LH) |

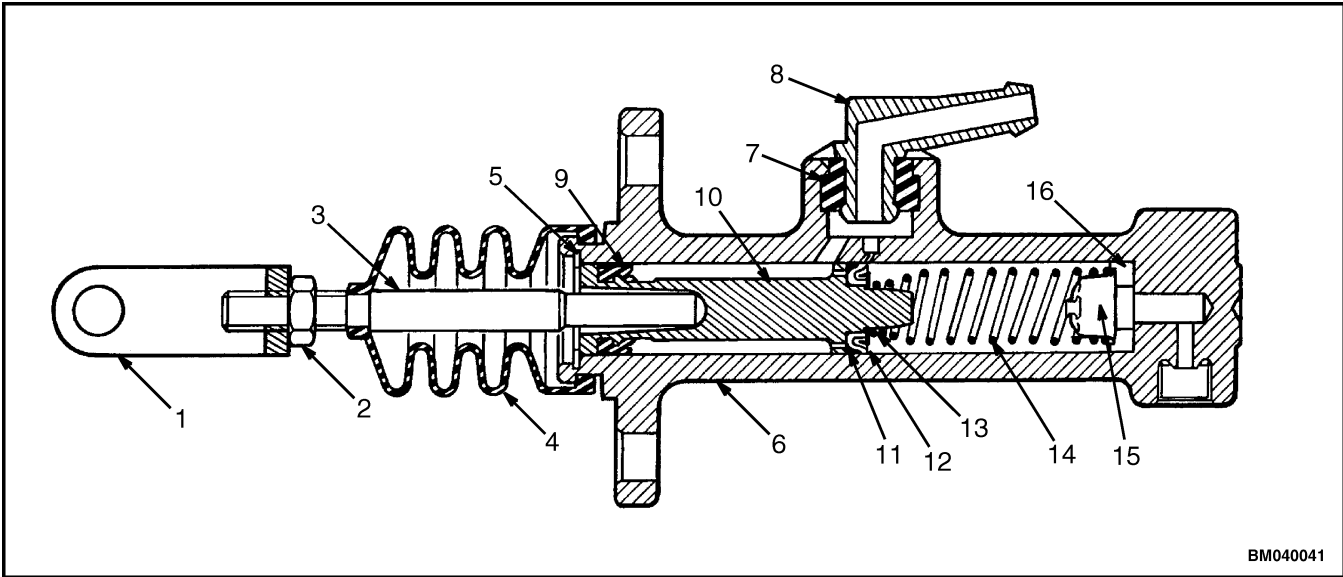
**Figure 47. Dry Brake Axle**

When the brake pedal is pushed, fluid pressure from the master cylinder causes the pistons in the wheel cylinder to extend. The pistons expand the brake shoes against the drums. The clearance between the brake shoes and the brake drum is adjusted automatically. An adjuster linkage turns the adjuster wheel to adjust the clearance. When the lift truck moves in the reverse direction and the brakes are applied, the rear brake shoe and the adjuster links move with the drum. This linkage moves the adjuster lever to rotate the adjuster wheel. The adjuster wheel can turn only when there is clearance between the lining of the brake shoe and the brake drum. The adjuster wheel can also be turned with a tool. A slot in the back plate gives access to the adjuster wheel.

Master Cylinder

The master cylinder is designed for a single-circuit system. The master cylinder has a piston that operates in the bore of the master cylinder. See Figure 48.

NOTE: The reservoir is located to the right of the park brake and is attached to the cowl. The reservoir is equipped with an indicator for low fluid level. A float in the reservoir moves up and down with the fluid level. When the fluid level is low, a magnet on the float activates a switch in the bottom of the reservoir. This switch signals the Vehicle System Manager (VSM) which illuminates a light on the user interface display.



BM040041

- | | |
|---------------------|-----------------|
| 1. ROD END | 9. PISTON SEAL |
| 2. NUT | 10. PISTON |
| 3. PUSH ROD | 11. SPACER |
| 4. BOOT | 12. PISTON CUP |
| 5. SNAP RING | 13. RETAINER |
| 6. CYLINDER HOUSING | 14. SPRING |
| 7. SEAL | 15. CHECK VALVE |
| 8. SEAL | 16. VALVE SEAT |

Figure 48. Master Cylinder

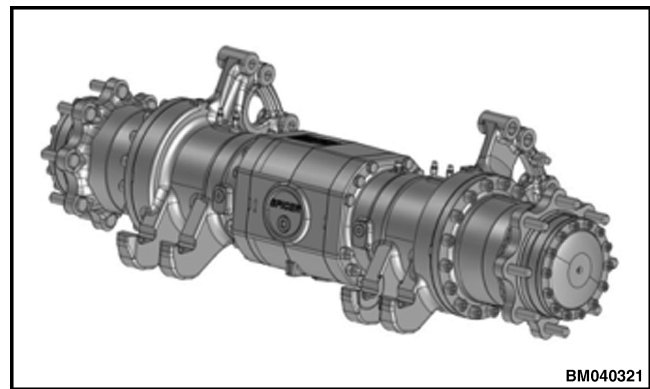
Brake Position Sensor

This sensor has two applications. It senses the inch/brake pedal position as well as the park brake hand lever position. The sensor is located to the left of the inch/brake pedal and left of the park brake handle.

dash. The automatic park brake is a spring-applied and hydraulically-released (SAHR) design. A benefit of the SAHR system is that the park brake engages whenever the truck is shut off or in any event of loss of truck power.

Wet Brakes

Wet brake axles have full circle disc brakes that feature a long service life. This brake system is actuated by a brake pedal and a master cylinder that pressurizes the brake chamber in the axle housing. Wet brake axles have an automatic park brake with push button. The operator can push a button on the dash to actuate the park brake as required, giving the driver control over the system in most circumstances. However the park brake will engage if the truck loses power, the operator turns off the truck, or if the operator presence system interlocks are not met. To release the park brake the operator will need to push the button on the



BM040321

Figure 49. Wet Brake Axle

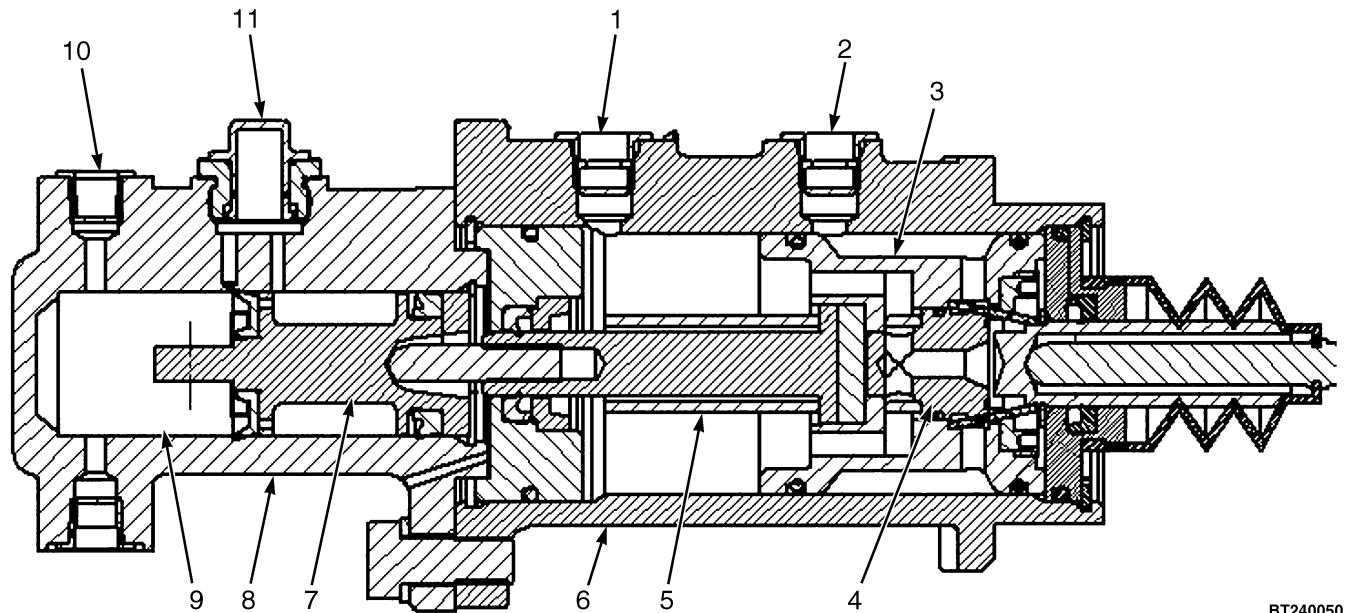
Wet brake axles are called as such because braking is done through packs of disc brakes submerged in oil, as opposed to the dry shoes and drums of a dry brake axle. The brake packs are actively cooled to withstand heavy-duty use and reduce wear and tear, even in the most abusive applications. Fully-sealed brake packs are protected from moisture, dirt, debris and corrosion from the environment. Trucks equipped with wet brake axles feature an automatic park brake system:

- Park brake engages automatically when the operator leaves the truck.
- Park brake engages automatically when the truck is shut off.
- Operator can manually turn on the park brake via a button on the dash.
- An override under the floor plate allows the park brake to be deactivated for service or towing of the truck.

similar to the transmission clutch packs. Rotating friction discs are interleaved with stationary separator discs within the axle housing. An annular piston forces the discs together when pressure is provided by the service brake system. An oil bath provides a shear film between the discs, greatly reducing wear of the friction material. Brake heat is removed by circulating the oil through the transmission sump and the transmission oil cooler. For park brake function, a cable-actuated cam assembly moves the piston instead of service brake oil pressure

2.0-7.0 ton wet brake systems use boosted master cylinders. A typical cross-section is shown in Figure 50. Service brake fluid is supplied from a reservoir equipped with a float switch that monitors fluid level. Boost pressure is provided by the transmission lube circuit.

The brake systems for all wet brake axles on 2.0-9.0 ton trucks operate on a common principal very



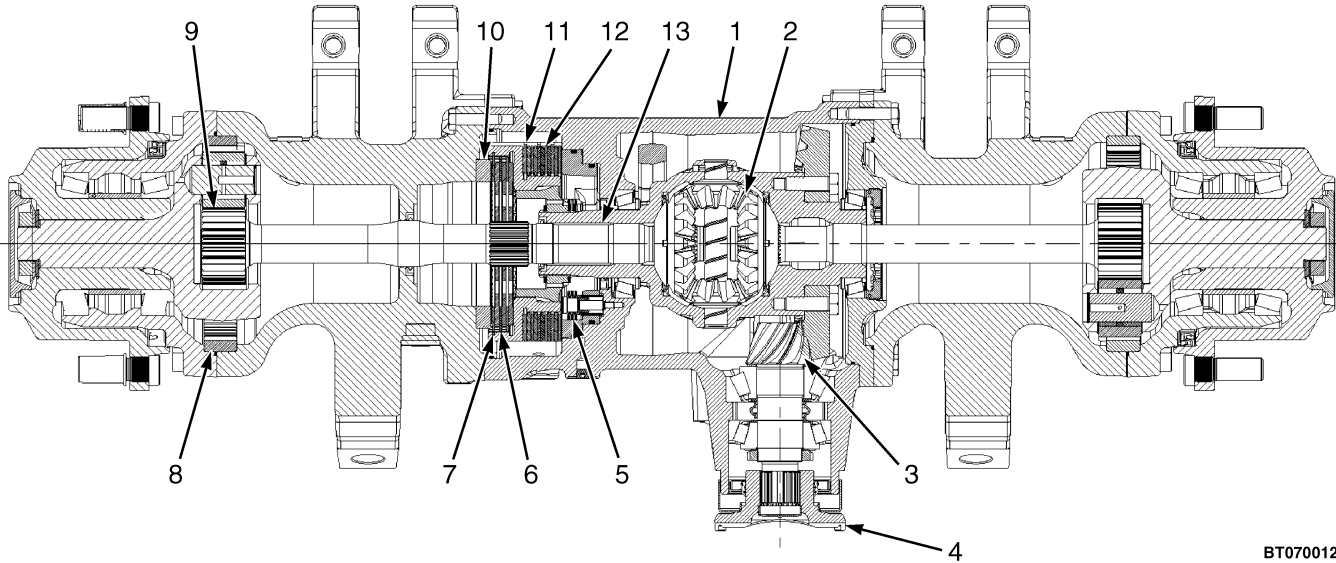
BT240050

- | | |
|-------------------------|------------------------------|
| 1. BOOST RETURN | 7. SERVICE BRAKE PISTON |
| 2. BOOST PRESSURE | 8. MASTER CYLINDER |
| 3. BOOSTER PISTON | 9. RETURN SPRING (NOT SHOWN) |
| 4. BOOST VALVE ASSEMBLY | 10. SERVICE BRAKE PRESSURE |
| 5. PUSH ROD | 11. SERVICE BRAKE RESERVOIR |
| 6. BOOSTER ASSEMBLY | |

Figure 50. Master Cylinder with Booster

The axle for 2.0-3.5 ton trucks has a single brake disc assembly, comprised of inner and outer disc assemblies. The brake piston clamp force is transferred to the inner service brake carrier, inner disc assembly, outer brake carrier, and then the outer disc assembly. The inner and outer disc assemblies are essentially locked at the same time.

The service brake assembly ultimately overcomes the differential assembly rotation and torque. The inboard disc assembly does the primary braking. The outboard disc assembly is used when the truck is on an incline or a split coefficient of friction ground condition. See Figure 51.



BT070012

- | | |
|---|--|
| <ol style="list-style-type: none"> 1. DIFFERENTIAL HOUSING ASSEMBLY 2. SPIDER ASSEMBLY 3. PINION SHAFT 4. INPUT YOKE 5. PISTON RETURN SPRING 6. DIFFERENTIAL LOCKER FRICTION DISC 7. DIFFERENTIAL LOCKER SEPARATOR PLATE | <ol style="list-style-type: none"> 8. PLANETARY GEAR ASSEMBLY 9. REDUCTION GEAR 10. DRIVE PLATE 11. SERVICE BRAKE SEPARATOR PLATE 12. SERVICE BRAKE FRICTION DISC 13. HALF SHAFT (LEFT HAND) |
|---|--|

Figure 51. Wet Disc Brake Drive Axle, Service Brake Assembly

Park Brake

Park brake is foot applied/hand released as standard. Option of push button or auto (for wet brake axles). Trucks equipped with wet brake axles feature an automatic park brake system:

- Park brake engages automatically when the operator leaves the truck.
- Park brake engages automatically when the truck is shut off.
- Operator can manually turn on the park brake via a button on the dash.
- An override under the floor plate (pushbutton bypass in the middle of the 2 pressure sensors on brake valve) allows the park brake to be deactivated for service or towing (disabled) of the truck.

A large visible park brake hand release (for the foot-operated style) provides an easy way for the operator to disengage the park brake without shuffling feet on the truck pedals.

NOTE: Dry brake axle cannot use the auto park brake option and wet brake axle cannot use the manual park brake option.

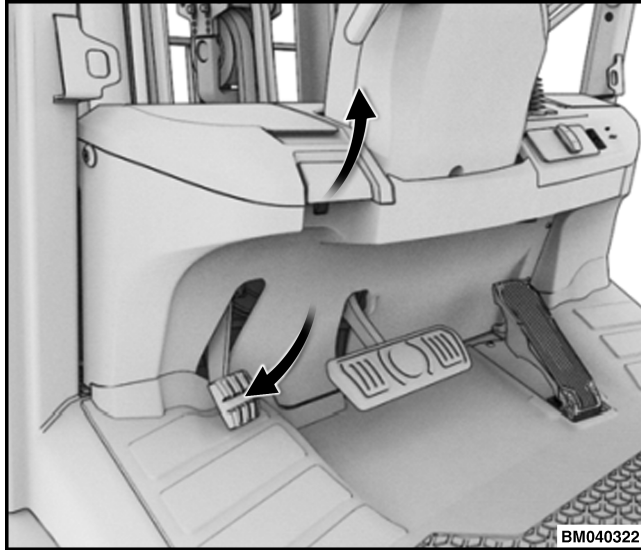


Figure 52. Park Brake

Dry Brake - Release the park brake with a light pull of a release in the dash. The park brake system uses the service brake shoes. Additional linkage activates the park brake system. When the pedal is moved (or dash button pressed) to apply the park brake, the cables and linkage expand the brake shoes against the drums. The design of the park brake linkage adjusts each cable so that the tension is the same when the lever is moved to apply the park brake.

Wet Brake - The park brake is applied automatically when the driver leaves the seat or the engine is switched off ensuring accidental uncontrolled truck movement is not possible. (Can also be engaged with push button on dash). The park brake system uses a single cable (or electrical circuit) to actuate the central brake. When the pedal (or dash button) is pressed to apply the park brake, the cables and linkage mechanically apply force to the brake piston(s) to compress the disk brake assembly. The design of the park brake linkage adjusts each cable so that the tension is the same when the lever is moved to apply the park brake. On all units with Forward Reverse Lever or MONOTROL® Pedal, the switch energizes the seat warning circuit when hand lever is released. This switch puts the transmission in Neutral by de-energizing the direction solenoid. There is also a switch on the left-hand side of bracket. This switch prevents engine from starting unless park brake is applied. If the operator leaves the seat with the park brake off, an audible alarm will sound for 10 seconds.

SAHR Park Brake: Spring-Applied, Hydraulic-Released - (Wet Brake Axles Only)

The park brake functions using springs within the brake packs that apply pressure. In order to release the park brake, the transmission sends pressure to a control valve, which then release the park brake by sending pressure to the axle.

Auto Park Brake with Push Button (wet brake axle) - same as above

Engages automatically when operator gets off truck; engages when truck is shut off; doesn't rely on operator. For trucks with the automatic park brake a push button override button replaces the manual release lever.

MONOTROL® Directional Control

The foot pedal direction control is configured with switches that input the direction command to the VSM. Pressing on the right side of the pedal selects the REV direction with corresponding backup lights and backup alarm activated. Pressing the left side of the pedal selects the FWD direction. The selection is latched in the VSM logic so it will remain in that direction until the opposite direction is commanded or the park brake is set. The foot pedal is also the accelerator pedal so pushing it further will increase the speed of the truck in the applied direction.

Inch Brake/Service Brake Pedal

NOTE: Dual brake pedal is only available on ICE (Internal Combustion Engine) trucks.

Lift trucks are available with single or dual brake pedals. Single brake pedals feature one brake pedal that actuates both the service brakes and inching function of the transmission. The dual pedal option has two brake pedals side-by-side. The brake pedal to the operator's left actuates both inching and service brakes, while the brake pedal to the operator's right actuates only the truck's service brakes.

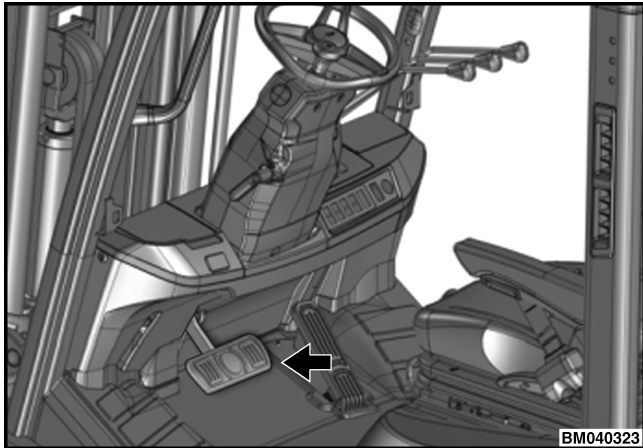


Figure 53. Single Pedal

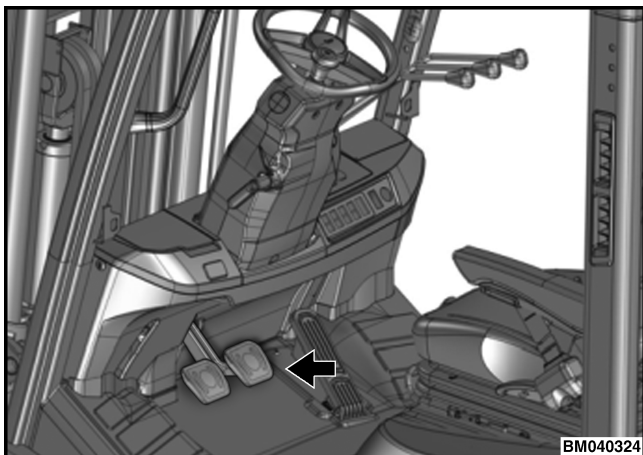


Figure 54. Dual Pedal

Depending upon inch brake/service brake pedal configuration, there may be one combined pedal or a two-pedal configuration. With the two-pedal configuration, the left pedal controls both the inch brake and service brake function (similar to the single-pedal configuration) while the right pedal controls service brake function only. The operation of the inch brake or service brake pedal will provide two levels of control. Full depression of the pedal will disengage the transmission and apply the wheel brakes to stop the truck. During lifting/loading operations, the inch brake function can be used to provide a slow travel speed while maintaining a high engine speed to maintain high hydraulic flow for faster control of the lift mechanism.

When the inch brake/service brake pedal is initially applied, the clutch in the transmission is partially disengaged and the movement of the truck is slow. Use the foot pedal/accelerator to maintain engine RPM while inching.

The standard braking function is applied when the inch brake/service brake pedal is pushed down further than the inching position. This will cause the transmission to disengage and permit normal braking operation to the wheels. Inch/brake overlap calibration is performed automatically.

Electrical system

CONTROLLER DESCRIPTION 202001-144

CONTROLLER DESCRIPTION

The Vehicle System Manager (VSM) is the primary or master controller of the electrical system communicating with all the other modules (or nodes) on the Controller Area Network (CAN). Expansion modules, known as the IBox (Input Box) and OBox (Output Box) also connect to the VSM. As

the electrical system options expand, the system allows for easy integration by adding the IBox and OBox accordingly. The IBox and OBox look similar, the key difference is the OBox is physically larger than the IBox. Other devices connected to the VSM are the Power Distribution Module (PDM), Engine Control Unit (ECU), user interface (display), smart antenna, Hydro Static Transmission (HST) controller, impact sensor, dash switch bank, cab switch bank, and Mini-Lever Module (MLM).

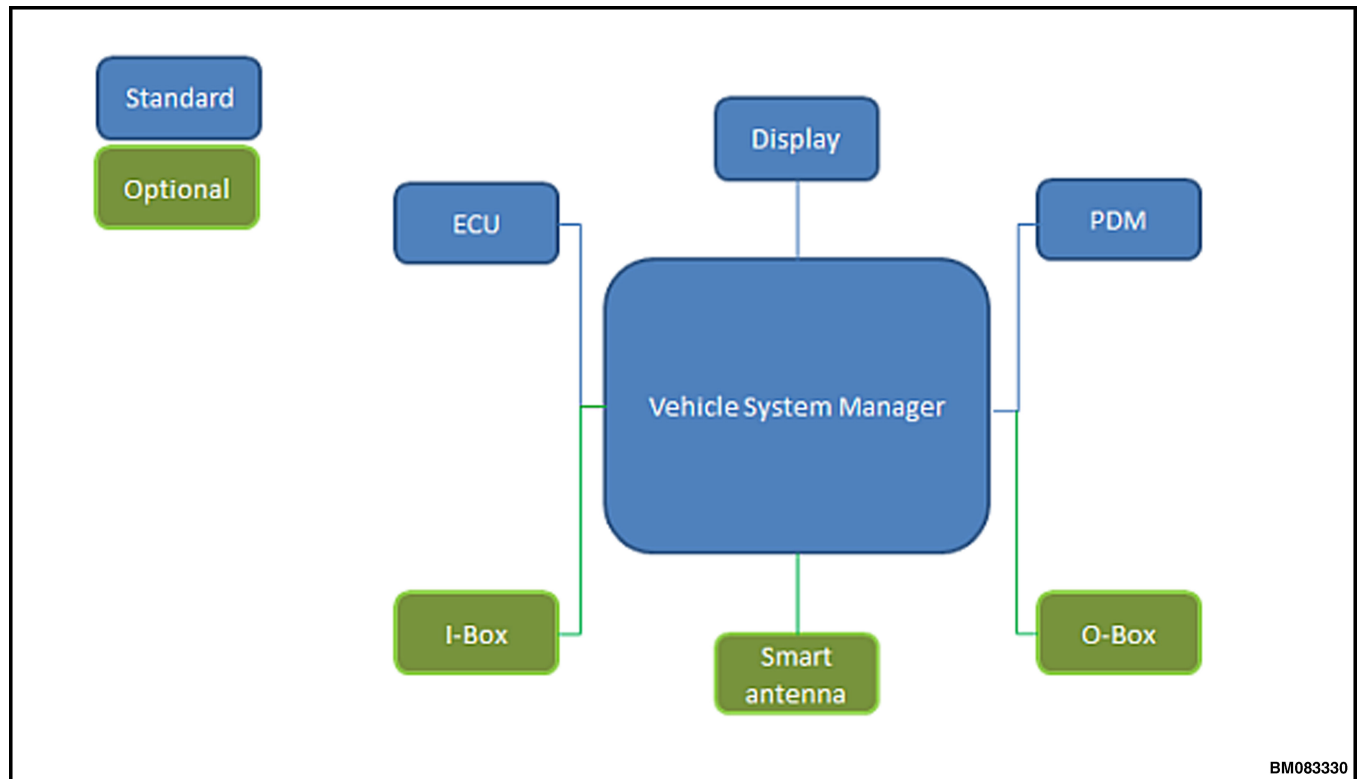


Figure 55. Controller and Devices Diagram

VSM

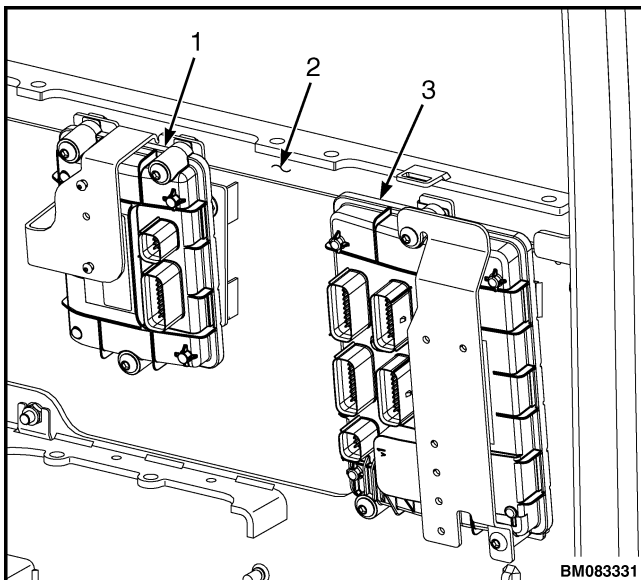
VSM is the primary, or master, module managing all communications on the vehicle CAN. Typically the VSM will be node 0 or 1 on the network. The VSM is the master controller handling feedback input from connected components and other CAN module inputs via CAN data packets. Much of the CAN communication the VSM receives is feedback in the form of parametric data from analog and digital components monitoring different phenomena. Some are as simple analog feedback like truck battery voltage. Other inputs are digital, feeding back the state of a circuit like operator presence in the form of a 1 or 0.

Some feedback to the VSM comes from other CAN modules with their own connected components (for example, oxygen sensor connected to engine controller). In addition to processing feedback input the VSM is a controller to drive the high or low side of connected outputs such as relay coils for hydraulic solenoids, contactors, etc. Some of the outputs are simply turned on by the VSM. Other outputs are controlled by a voltage of variable pulse width.

VSM relies on basic hardware components and a set of three micro-processors. The VSM runs on a core application, truck platform specific software, and a Configuration Data File (CDF) unique to the truck.

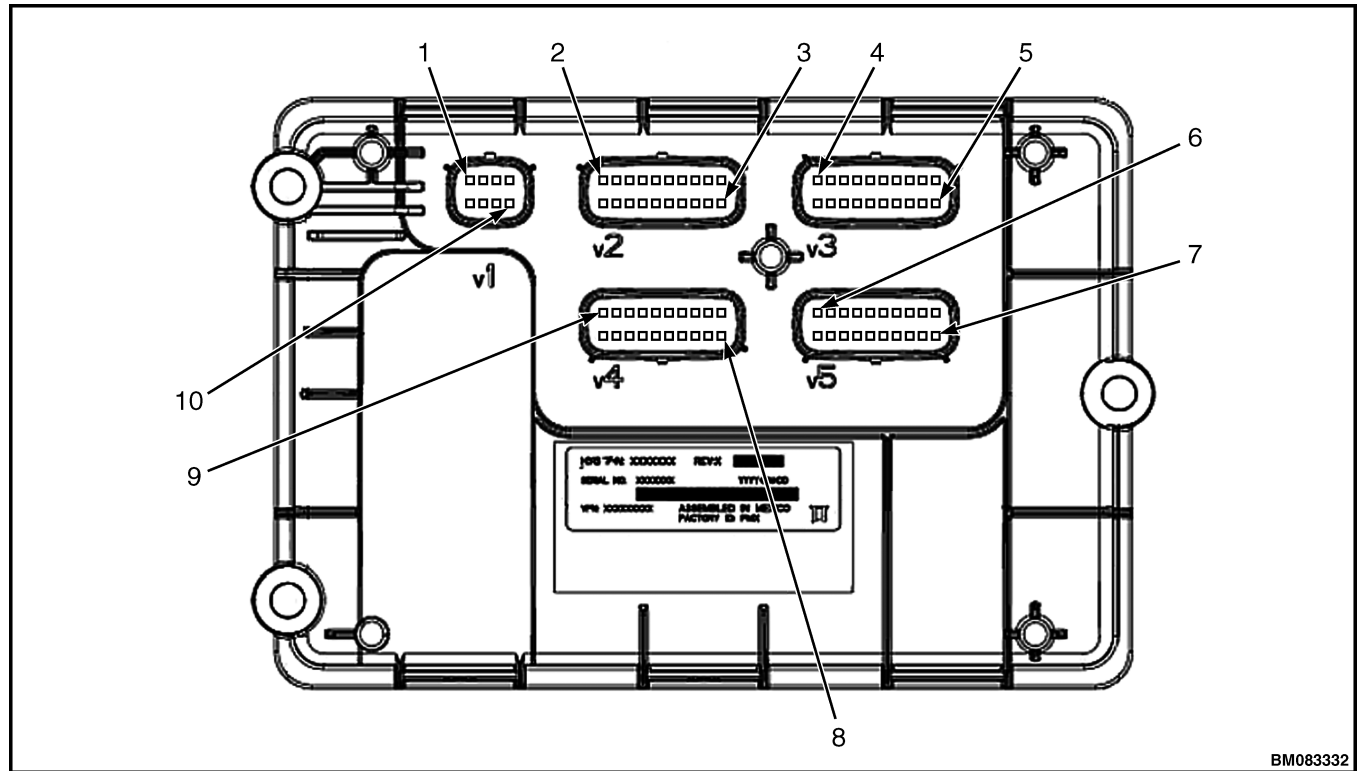
VSM module has 88 pins. Hardware Pin Features Available:

- 12V Electronic power supply (30 watts), (2) independently controlled outputs
- 5V, 500 mA Sensor supply
- 5V, 25 mA Seat or operator sensor supply for wake-up support
- (4) Wake inputs, 1 specifically for open collector wake-up from display
- (4) Low side, 2-amp drivers
- (3) High side, Pulse Width Modulation (PWM) capable 500 mA drivers
- (7) High side, 350 mA drivers (for relays), (20) Analog or Digital inputs capable of 12 volts, (2) pairs of quadrature frequency inputs
- (4) Analog or Digital inputs capable of 80 volts
- (2) Analog temperature inputs
- (1) Coolant level switch input
- (4) CAN-Buses within harness termination pins



1. OBOX
2. COWL
3. VSM

Figure 56. VSM and OBox



BM083332

- | | |
|----------------|----------------|
| 1. V1 - PIN 1 | 6. V5 - PIN 20 |
| 2. V2 - PIN 1 | 7. V5 - PIN 1 |
| 3. V2 - PIN 20 | 8. V4 - PIN 1 |
| 4. V3 - PIN 1 | 9. V4 - PIN 20 |
| 5. V3 - PIN 20 | 10. V1 - PIN 8 |

Figure 57. VSM Pin Locations

Table 1. V1 Pin Out

Pin	Type	Description	Connects to
1	GND	GROUND	----
2	Input Wake #4 (WKN)	WAKE INPUT 4	Seat Belt Switch
3	5V Out	5V-SEAT SENSOR SUPPLY	----
4	GND	GROUND POWER IN	----
5	12V in	VELEC IN	----
6	Input Wake #1 (WKN)	KEYSWITCH	Key Switch
7	Input Wake #3 (WKN)	SEAT SENSOR	OPS sensor
8	12V in VPwr (RVF)	VPOWER IN	----

Table 2. V2 Pin Out

Pin	Type	Description	Connects to
1	12V out	V POWER GND	Sync/rtst/clamp Sol
2	Lowside digital output	LS DRIVER 1 (2A)	RTST Coil
3	Lowside digital output	LS DRIVER 2 (2A)	Reserved for SPED
4	Lowside digital output	LS DRIVER 3 (2A)	Sync Steer Sol
5	Lowside digital output	LS DRIVER 4 (2A)	Clamp Coil
6	12V out	V POWER OUT	- - - -
7	Highside digital output	HS DRIVER 1 (350 mA)	Reserved for SPED
8	Highside digital output	HS DRIVER 2 (350 mA)	OPS Solenoid
9	Highside digital output	HS DRIVER 3 (350 mA)	Heater Contactor
10	Highside digital output	HS DRIVER 4 (350 mA)	Reserved for SPED
11	GND	V POWER GND	- - - -
12	Highside digital output	HS DRIVER 5 (350 mA)	Horn PWM
13	Highside digital output	HS DRIVER 6 (350 mA)	Rev Relay/rev lights
14	Highside digital output	HS DRIVER 7 (350 mA)	12V Acc relay RL3(PDM)
15	Highside digital output	HS DRIVER 8 (350 mA)	Brake Lights
16	Highside digital output	HS DRIVER 9 (350 mA)	Reserved for SPED
17	Highside digital output	HS DRIVER 10 (350 mA)	Key Power Relay RL5 (PDM)
18	12V in	V POWER IN	- - - -
19	GND	V POWER GND	- - - -
20	Not Available	- - - -	- - - -

Table 3. V3 Pin Out

Pin	Type	Description	Connects to
1	5V Out	5V2 Out	-----
2	5V Out	5V3 Out	Redun Pedal power
3	Input	ANA OR DIG INPUT 1	Accelerator Pedal Position A
4	Input	ANA OR DIG INPUT 2	Park Brake Pressure
5	Input	ANA OR DIG INPUT 3	Accelerator Pedal Position B
6	Input	ANA OR DIG INPUT 4	Service Brake Pedal Position A
7	Input	ANA OR DIG INPUT 5	Service Brake Pedal Position B
8	Input	ANA OR DIG INPUT 6	Service Brake Pressure
9	Input	ANA OR DIG INPUT 7 - FREQ INPUT 1	Brake Fluid Level
10	Input	ANA OR DIG INPUT 8 - FREQ INPUT 1	Automation Safety
11	5V GND	GND ^{5V} SENSOR	-----
12	5V GND	GND ^{5V} SENSOR	Redun Pedal Ground
13	Input	ANA OR DIG INPUT 9 - FREQ INPUT 3	Reserved for Sped
14	Input	ANA OR DIG INPUT 10 - FREQ INPUT 4	Reserved for Sped
15	Not Available	-----	-----
16	Input	ANALOG TEMP INPUT 1	Hydraulic Oil Temperature
17	Input	ANALOG TEMP INPUT 2	-----
18	Input	FLUID LEVEL INPUT	Very Special
19	Not Available	-----	-----
20	Not Available	-----	-----

Table 4. V4 Pin Out

Pin	Type	Description	Connects to
1	12V	$V_{ELEC}^{OUT} 1$ (CONTINUOUS)	O-box Power
2	12V	$V_{ELEC}^{OUT} 2$ (SWITCHED)	WL Relay coil (PDM)
3	CAN 1 Hi	CAN_{HI}^1 (VEHICLE BUS)	Vehicle BUS
4	CAN 1 Lo	CAN_{LO}^1 (VEHICLE BUS)	Vehicle BUS
5	CAN 2 Hi	CAN_{HI}^2 (DRIVETRAIN BUS)	Drivetrain BUS
6	CAN 2 Lo	CAN_{LO}^2 (DRIVETRAIN BUS)	Drivetrain BUS
7	CAN 3 Hi	CAN_{HI}^3 (FRONT- END BUS)	Front End BUS
8	CAN 3 Lo	CAN_{LO}^3 (FRONT- END BUS)	Front End BUS
9	CAN 4 Hi	CAN_{HI}^4 (SERVICE BUS)	Service BUS
10	CAN 4 Lo	CAN_{LO}^4 (SERVICE BUS)	Service BUS
11	O-box	LS OUT ENABLE (100 mA)	O-box Enable
12	Input Wake	WAKE INPUT 2 - DIGITAL	Display Wake
13	CAN 1	CAN_{TERM}^1 (VEHICLE BUS)	Vehicle BUS Term Resistor
14	CAN 1	- - - -	Vehicle BUS Term Resistor
15	CAN 2	CAN_{TERM}^2 (DRIVETRAIN BUS)	Drivetrain BUS Term Resistor
16	CAN 2	- - - -	Drivetrain BUS Term Resistor
17	CAN 3	CAN_{TERM}^3 (FRONT- END BUS)	Front End BUS Term Resistor
18	Not Available	- - - -	- - - -
19	CAN 4	CAN_{TERM}^4 (SERVICE BUS)	Service BUS Term Resistor
20	Not Available	- - - -	- - - -

Table 5. V5 Pin Out

Pin	Type	Description	Connects to
1	5V Out	V ^{SUPPLY} 5V	-----
2	5V Out	V ^{SUPPLY} 5V	-----
3	Input	ANA OR DIG INPUT 11	M-hyd Hoist SPS
4	Input	ANA OR DIG INPUT 12	M-hyd Tilt SPS
5	Input	ANA OR DIG INPUT 13	M-hyd Aux1 SPS
6	Input	ANA OR DIG INPUT 14	M-hyd Aux2 SPS
7	Input	ANA OR DIG INPUT 15	Fork Height Switch
8	Input	ANA OR DIG INPUT 16	Load Weight
9	Input	ANA OR DIG INPUT 17	Steer Wheel Position A
10	Input	ANA OR DIG INPUT 18	Battery Gate Switch/Quick Connect door switch
11	5V GND	G ND SENSOR ^{0V}	-----
12	5V GND	G ND SENSOR ^{0V}	-----
13	Input	ANA OR DIG INPUT 19	Dir Sel A
14	Input	ANA OR DIG INPUT 20	Dir Sel B
15	Not Available	-----	-----
16	Input	ANA OR DIG INPUT 21	Battery Voltage/E-stop detect
17	Input	ANA OR DIG INPUT 22	Park Brake Position
18	Input	ANA OR DIG INPUT 23	Steer Axle Position A
19	Input	ANA OR DIG INPUT 24	Steer Axle Position B
20	Not Available	-----	-----

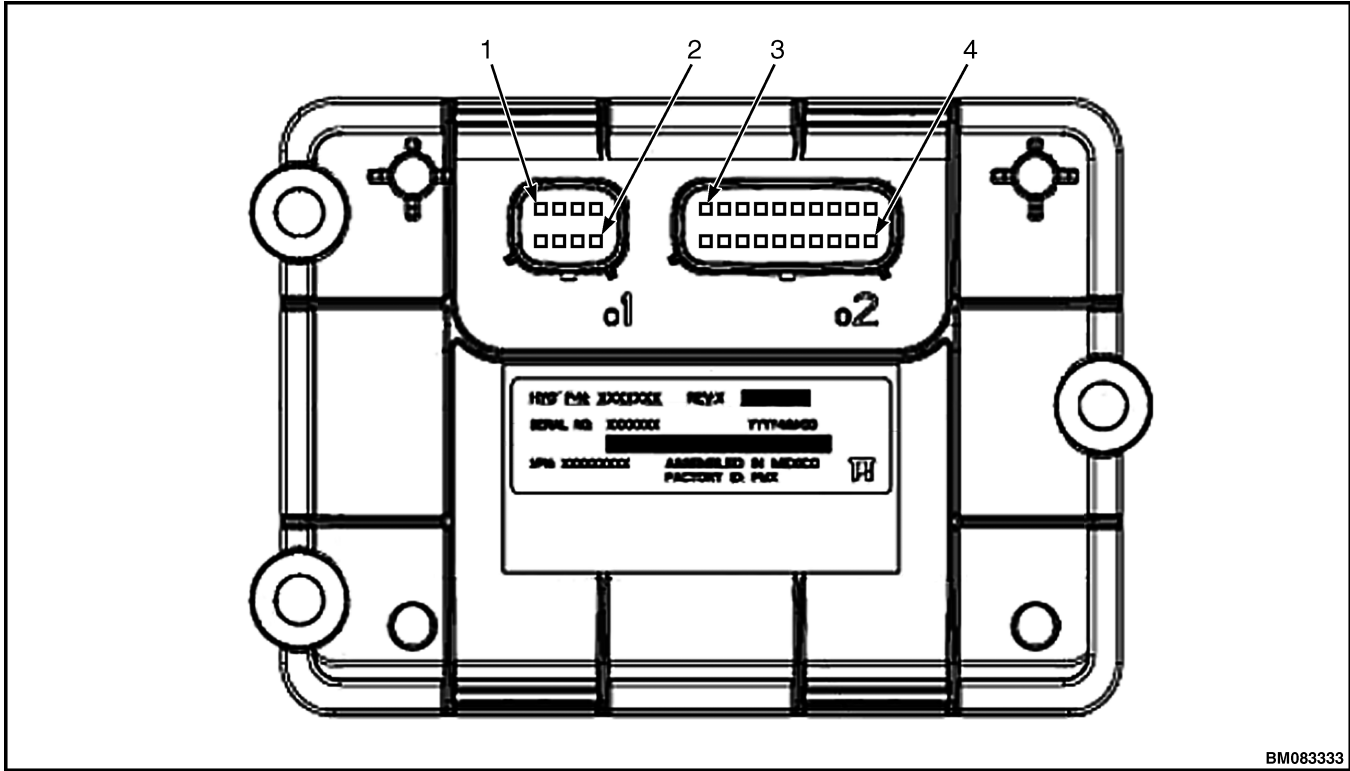
OBox (Output Box)

The OBox is a CAN controller and is an auxiliary device to the VSM. The OBox is used for driving high and low side outputs including higher current circuits (for example, hydraulic solenoids). The OBox is used on this truck for E-Hydraulics. For physical location see Figure 56.

OBox Pin Features Available:

- Powered by VSM 12V electronic only

- Single OE (Output Enable) input
- 5V, 100 mA sensor supply
- (3) General Purpose analog or digital inputs
- (3) Address Selection Pins (address 0-7)
- (10) High Power Sinking 2-amp PWM driver outputs, (4) Individual outputs, (3) Paired outputs
- CAN-Bus with integrated harness termination pins



BM083333

- 1. O1 - PIN 1
- 2. O1 - PIN 8
- 3. O2 - PIN 20
- 4. O2 - PIN 1

Figure 58. OBox Pin Locations

Table 6. o1 Pin Out

Pin	Type	Description	Connects to
1	GND	V ^{POWER} _{GND}	----
2	CAN 1 HI	CAN LO	----
3	CAN 1 Lo	CAN HI	----
4	GND	V ^{POWER} _{GND}	----
5	12V	V ^{POWER} _{IN}	----

Table 6. o1 Pin Out (Continued)

6	O-box	OUTPUT ENABLE	----
7	CAN 1	^{CAN} TERM	----
8	12V	^V POWER ^{IN}	----

Table 7. o2 Pin Out

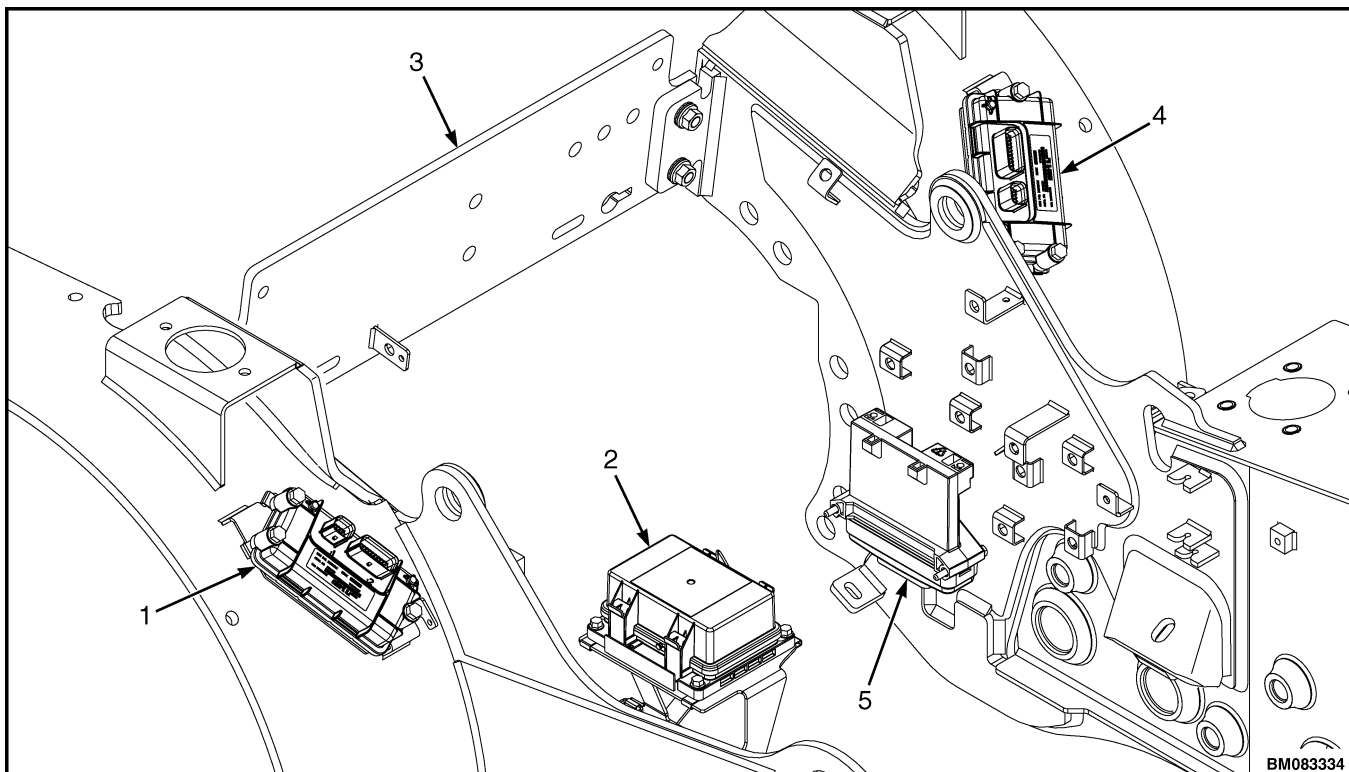
Pin	Type	Description	Connects to
1	5V	^V SUPPLY ^{5V}	----
2	12V	LOW SIDE FWD AND ^V POWER ^{OUT}	----
3	12V	LOW SIDE FWD AND ^V POWER ^{OUT}	----
4	Input	ANA OR DIG INPUT 1	----
5	Input	ANA OR DIG INPUT 2	----
6	Input	ANA OR DIG INPUT 3	----
7	Lowside digital output	LS DRIVER 1 (4A)	----
8	Lowside digital output	LS DRIVER 2 (4A)	----
9	Lowside digital output	LS DRIVER 3 (4A)	----
10	Lowside digital output	LS DRIVER 4 (4A)	----
11	GND	^{GND} SENSOR ^{0V}	Code GND
12	Code	CODE 1 INPUT	Code
13	Code	CODE 2 INPUT	----
14	Code	CODE 3 INPUT	----
15	Lowside digital output	LS DRIVER 5 (2A)	Tilt Back
16	Lowside digital output	LS DRIVER 6 (2A)	Tilt Forward
17	Lowside digital output	LS DRIVER 7 (2A)	E-hydraulic Aux 1A--PWM
18	Lowside digital output	LS DRIVER 8 (2A)	E-hydraulic Aux 1B--PWM
19	Lowside digital output	LS DRIVER 9 (2A)	E-hydraulic Aux 2A--PWM
20	Lowside digital output	LS DRIVER 10 (2A)	E-hydraulic Aux 2A--PWM

IBox (Input Box)

The IBox is a CAN auxiliary device to the VSM. The IBox primarily is used for processing input from components. This reduces the workload on the VSM and makes for a more distributed system of integrated components. Three IBoxes are available. IBox 1 is associated with mast work lights, ambient light sensor, Pedestrian Awareness Lights (PAL), red or blue front spot lights, and fork level laser. IBox 2 is associated with the hydraulic fan drive, Charge Air Cooler (CAC) sensor, and Mini-Lever Module (MLM). IBox 3 is for IDI diesel engines only.

IBox Pin Features Available:

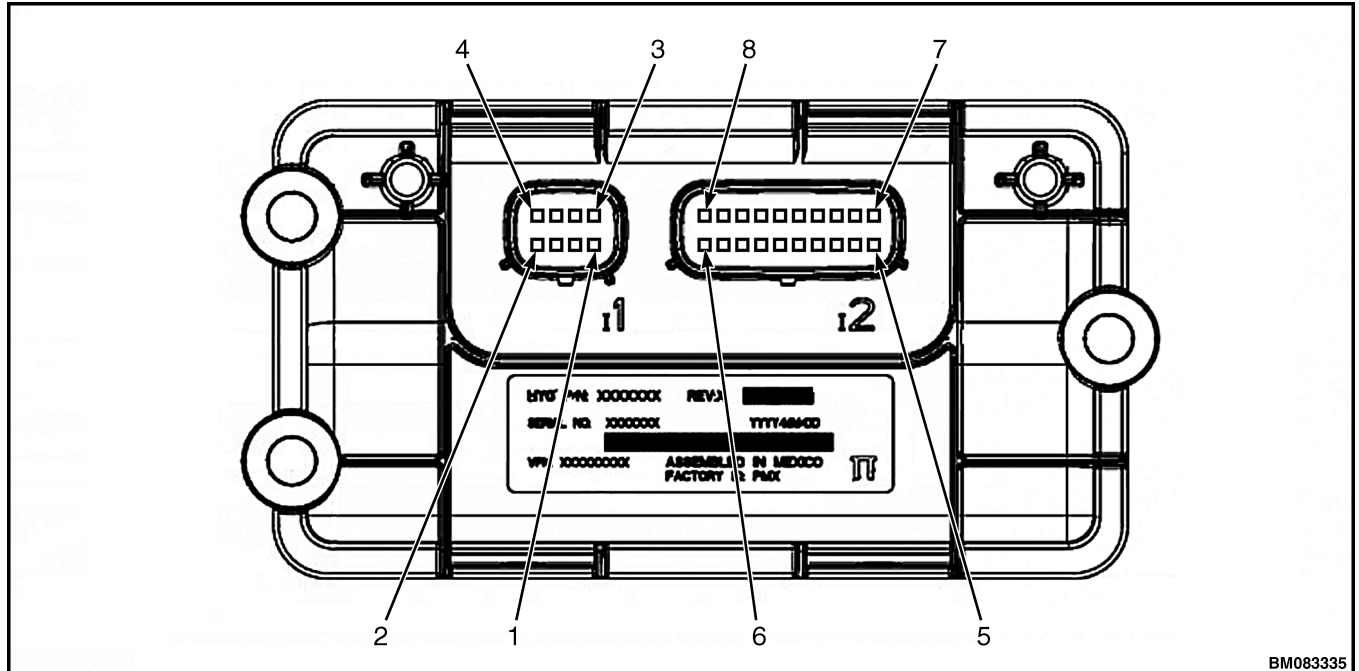
- Powered by VSM 12V electronic only
- Single OE (Output Enable) Input
- 5V, 100 mA sensor supply
- (8) General Purpose analog or digital inputs
- (1) Precision temperature sensor input
- (3) Address Selection Pins (address 0-7)
- (4) High Power Sinking 2-amp PWM driver outputs
- CAN-Bus with integrated harness termination pins



1. IBOX 1 (ACCESSORY 1)
2. MAIN PDM
3. FRONT COWL

4. IBOX 2 (ACCESSORY 2)
5. HST CONTROLLER

Figure 59. IBox 1 and 2 Locations



- 1. i1 - PIN 1
- 2. i1 - PIN 4
- 3. i1 - PIN 5
- 4. i1 - PIN 8

- 5. i2 - PIN 1
- 6. i2 - PIN 10
- 7. i2 - PIN 11
- 8. i2 - PIN 20

Figure 60. IBox Pin Out Locations

Table 8. i1 Pin Out

Pin	Type	Description	Connects to
1	GND	V_{ELEC}^{GND}	----
2	CAN 1 Lo	CAN LO	----
3	CAN 1 Hi	CAN HI	----
4	GND	V_{POWER}^{GND}	----
5	12V	V_{ELEC}^{IN}	----
6	O-box	OUTPUT ENABLE	----
7	CAN 1	CAN^{TERM}	----
8	12V	V_{POWER}^{IN}	----

Table 9. i2 Pin Out

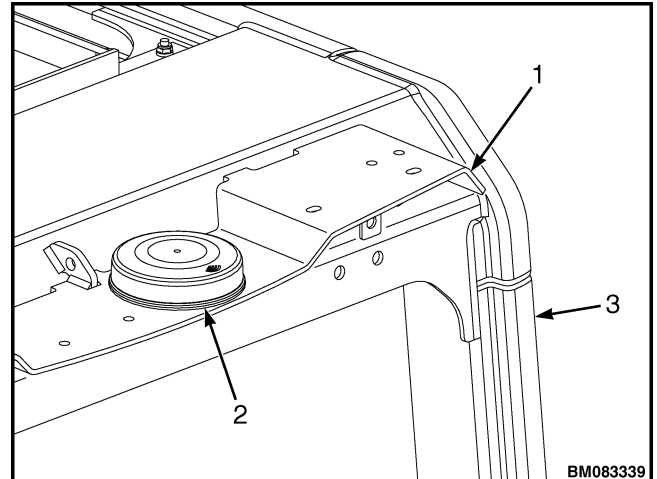
Pin	Type	Description	Connects to
1	5V Out	^{5V} SENSOR OUT	-----
2	Input	ANA OR DIG INPUT 8 - FREQ INPUT 4	-----
3	Input	ANA OR DIG INPUT 1	-----
4	Input	ANA OR DIG INPUT 2	-----
5	Power	V ^{POWER} _{OUT}	-----
6	Lowside Driver	LS DRIVER 4 (2A)	-----
7	Lowside Driver	LS DRIVER 3 (2A)	-----
8	Lowside Driver	LS DRIVER 2 (2A)	-----
9	Lowside Driver	LS DRIVER 1 (2A)	-----
10	Input	ANA OR DIG INPUT 3	-----
11	GND	GND ^{SENSOR} _{OUT}	-----
12	Input	CODE 1 INPUT	-----
13	Input	CODE 2 INPUT	-----
14	Input	CODE 3 INPUT	-----
15	Input	TEMPERATURE INPUT	-----
16	Input	ANA OR DIG INPUT 7 - FREQ INPUT 3	-----
17	Input	ANA OR DIG INPUT 6 - FREQ INPUT 2	-----
18	Input	ANA OR DIG INPUT 5 - FREQ INPUT 1	-----
19	Input	ANA OR DIG INPUT 4	-----
20	-----	-----	-----

Smart Antenna

The smart antenna is a device that allows communication between the telemetry systems and their cloud servers. Truck and performance data is transmitted to the telemetry portal and offered as data for the end user to create reports, monitor trucks, and drive fleet business opportunities. Telemetry devices including the smart antenna are CAN enabled so they can transmit messages over the network.

The smart antenna provides real-time telemetry data from equipped trucks. The system can be used to track product and operator data. Data examples include hour meters, fault codes, and impacts.

Events such as impacts can be configured to automatically send out an email alert, making it easier to track and review incidents. Alerts can also be received via the telemetry mobile application. The antenna communicates with the cloud based servers and is compatible with both Wi-Fi and GSM cellular signals. Telemetry monitoring enhances the process for periodic maintenance capture. An example includes the automatically loading of the known maintenance into the telemetry system when factory installed.



1. REAR LIGHT MOUNTING BRACKET
2. SMART ANTENNA
3. OVERHEAD GUARD SUPPORT POST, REAR, RH

Figure 61. Smart Antenna Location

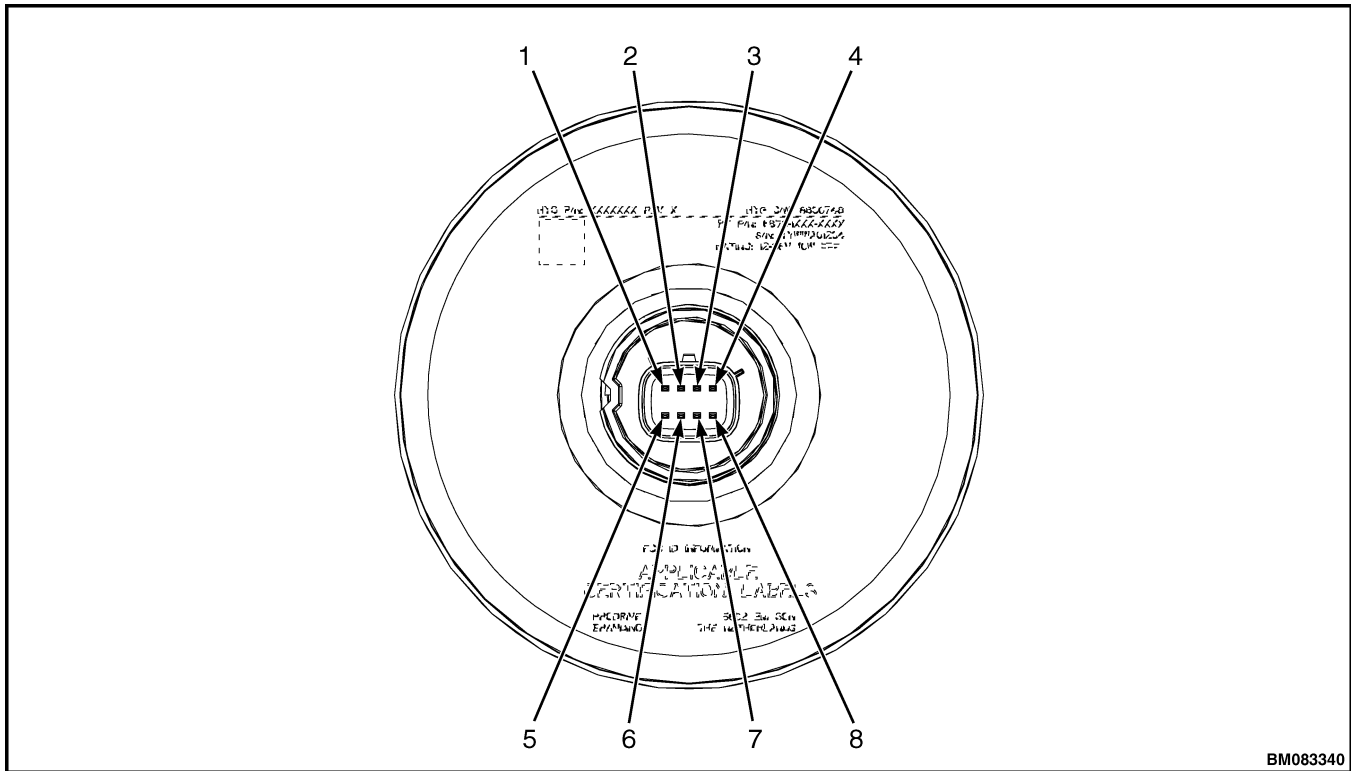


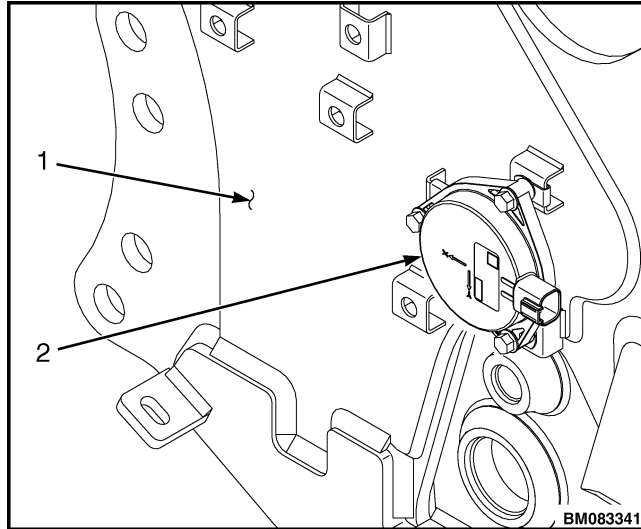
Figure 62. Smart Antenna Pin Out

Table 10. Smart Antenna Pin Out

Pin	Name	DIR	Type	Comments
1	CAN0_H	IO	CAN 2.0	PRIMARY CAN INTERFACE
2	CAN0_L	IO	CAN 2.0	PRIMARY CAN INTERFACE
3	CAN1_H	IO	CAN 2.0	SECONDARY CAN INTERFACE
4	CAN1_L	IO	CAN 2.0	SECONDARY CAN INTERFACE
5	RS232_RX	I	RS232	RS232 RECEIVE INPUT
6	WAKE	I	DIGITAL INPUT	CONFIGURABLE INPUT HI OR LO
7	PWR	-	PWR	POWER INPUT
8	GND	-	GND	GROUND

Impact Sensor

The impact sensor is capable of measuring acceleration along 3 axes. This impact sensor is CAN enabled 3 axis impact sensor capable of transmitting directly on the network.



- 1. RH FRAME
- 2. IMPACT SENSOR

Figure 63. Impact Sensor Location

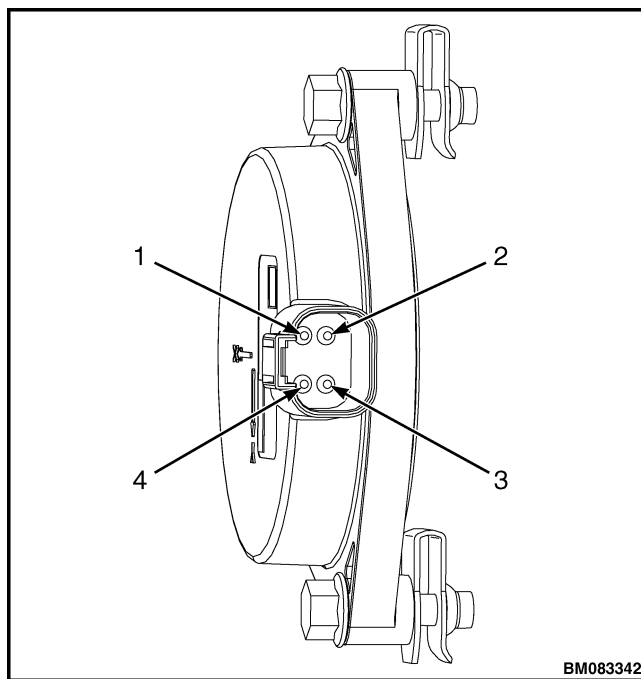


Figure 64. Impact Sensor Pin Out

Table 11. Impact Sensor Pin Out

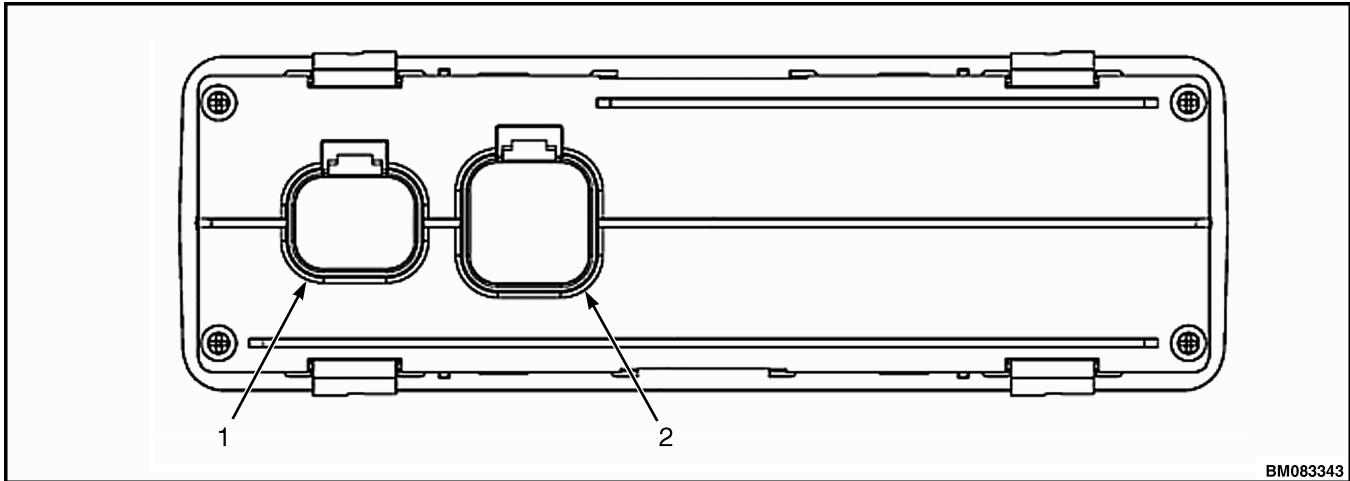
Pin	Type	Description
1	MODULE POWER	POWER INPUT
2	MODULE GND	GROUND
3	CAN LO	COMMUNICATION
4	CAN HI	COMMUNICATION

Dash and Cab Switch Bank (Control Module)

The control module is CAN enabled set of switches for requesting truck accessory response. These switches reduce wiring by transmitting each switch position in a CAN message. The truck may have two, 6-switch bank control modules. One is located on the dash and the other is located in the cab headliner. Dash switch bank available rocker switches are: front and rear work light, mast mounted work light, fork laser light, hazard lights, LPG or unleaded fuel, and fan reverse. Cab switch bank available rocker switches are: intermittent front wiper, front washer and single wipe, top wiper and washer, rear wiper and washer, heated front screen, and heated rear screen.

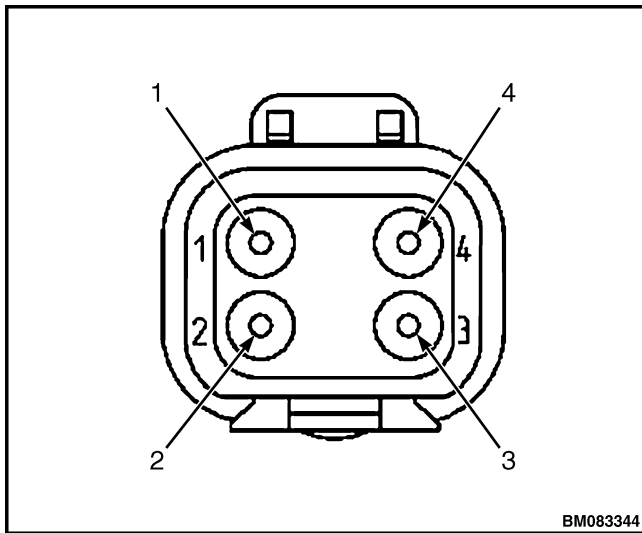
NOTE: Each truck may vary and not all rocker switches may be present. If a rocker switch is not used a blank cover will be present.

NOTE: Both control modules have the same connector configuration, however, the part numbers are different due to the different rocker switch configurations.



- 1. 4-PIN CONNECTOR
- 2. 6-PIN CONNECTOR

Figure 65. Control Module (Backside)

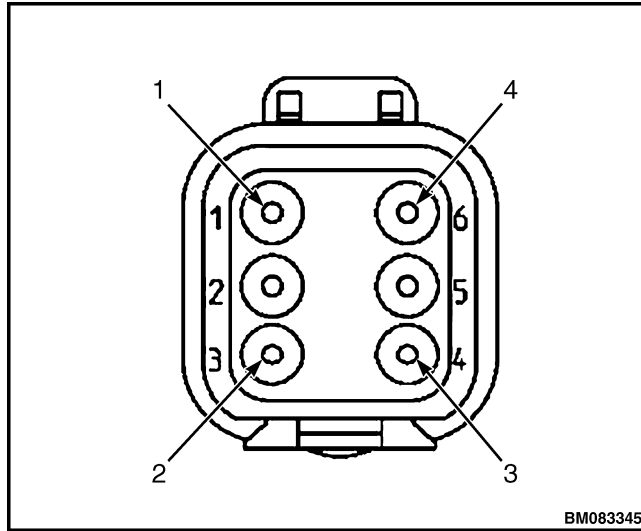


- 1. PIN 1
- 2. PIN 2
- 3. PIN 3
- 4. PIN 4

Figure 66. 4-Pin Connector Pin Locations

Table 12. 4-Pin Connector Pin Out

Pin	Type 1 Description	Type 2 Description
1	V+	OUTPUT 1
2	GND	OUTPUT 2
3	CAN HI	OUTPUT 3
4	CAN LO	OUTPUT 4



Legend for Figure 67.

- 1. PIN 1
- 2. PIN 3
- 3. PIN 4
- 4. PIN 6

Figure 67. 6-Pin Connector Pin Locations

Table 13. 6-Pin Connector Pin Out

Pin	Type	Description
1	CAN Lo	CAN LO
2	CAN Hi	CAN HI
3	----	----
4	----	----
5	GND	GROUND
6	5V	V+

Mini-Lever Module (MLM)

The Mini-Lever Module (MLM) is an integrated part of the armrest assembly and is a CAN enabled set of switches for requesting front end hydraulic response and may include an E-stop button. Fingertip control

of the levers and push buttons behind each of the levers provide shelf height selection, (4) hydraulic functions, clamping actions and return to set tilt, and other functions.

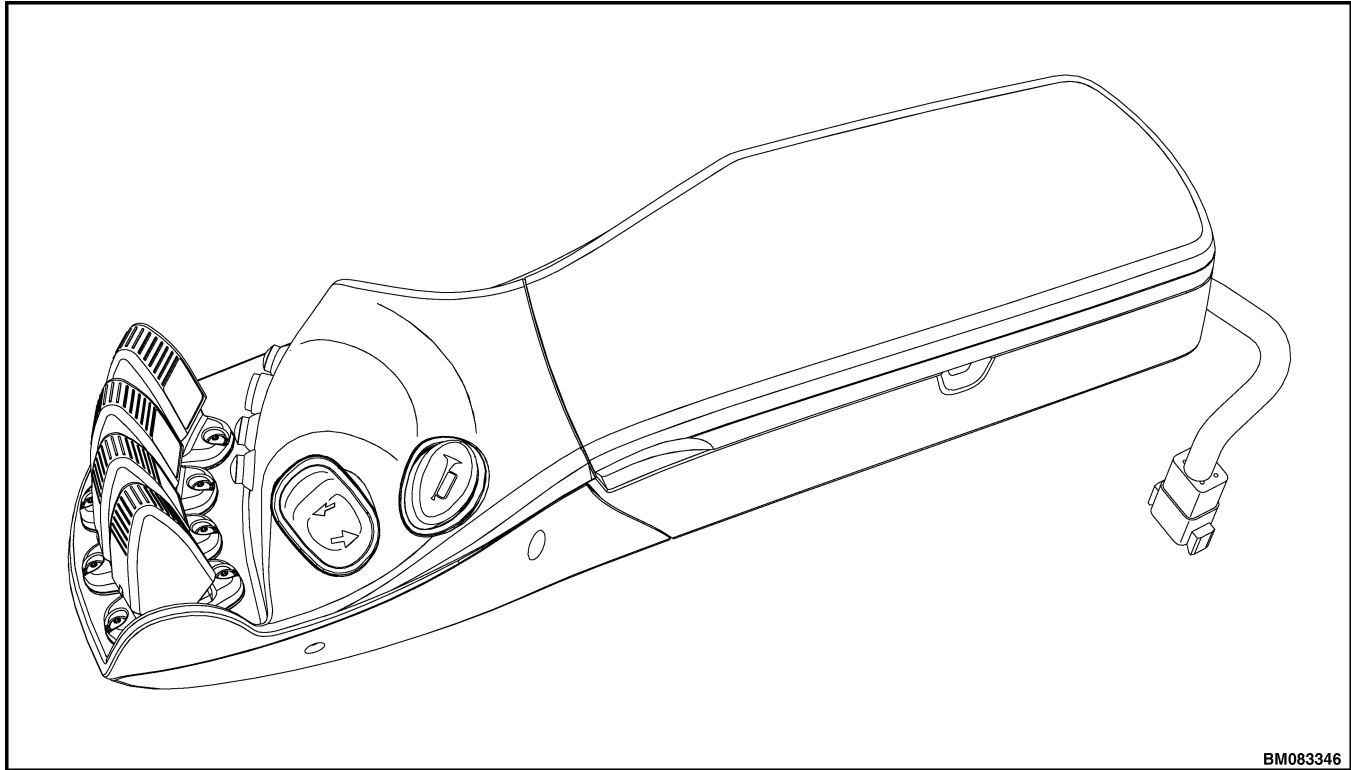
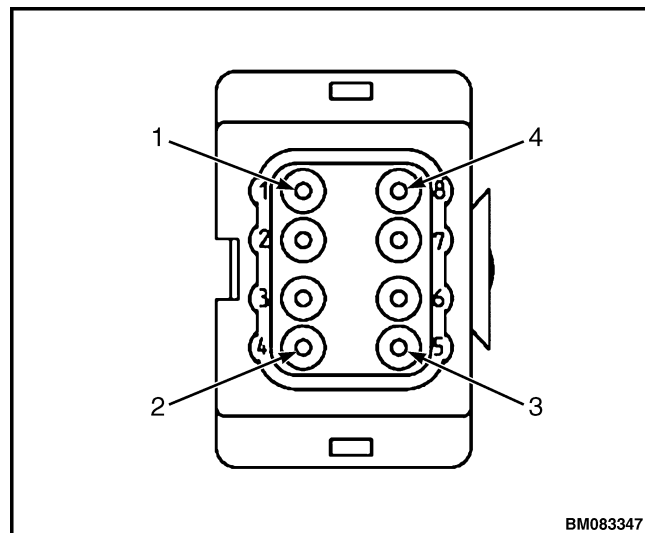


Figure 68. MLM and Armrest



Legend for Figure 69.

- 1. PIN 1
- 2. PIN 4
- 3. PIN 5
- 4. PIN 8

Figure 69. MLM Pin Locations

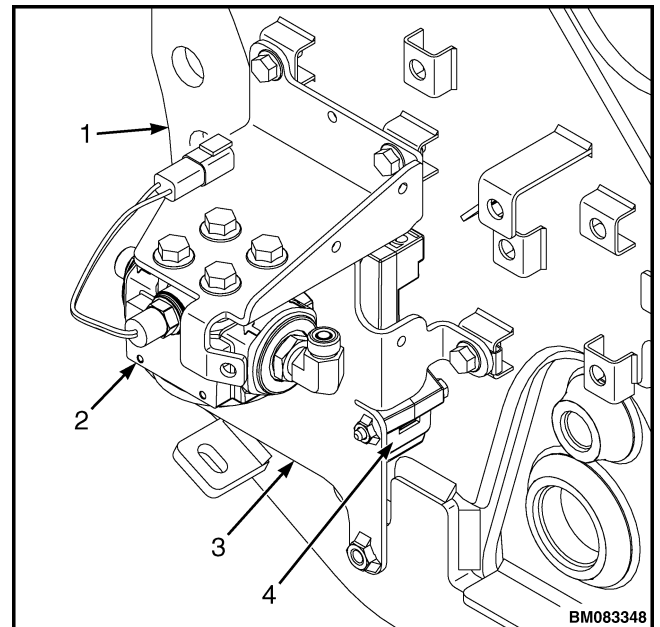
Table 14. MLM Pin Out

PIN NUMBER	SIGNAL RANGE	DESCRIPTION	TYPE
1	NA	HORN	DIGITAL
2	NA	BATTERY +VE	POWER
3	9V-16V	SUPPLY VOLTAGE	POWER
4	NA	CAN LOW	COMMUNICATION
5	NA	BATTERY +VE AFTER E-STOP	POWER
6	NA	CAN HIGH	COMMUNICATION
7	GND	SUPPLY GND	POWER
8	NA	PLUG	NA

Hydro Static Transmission (HST) Controller

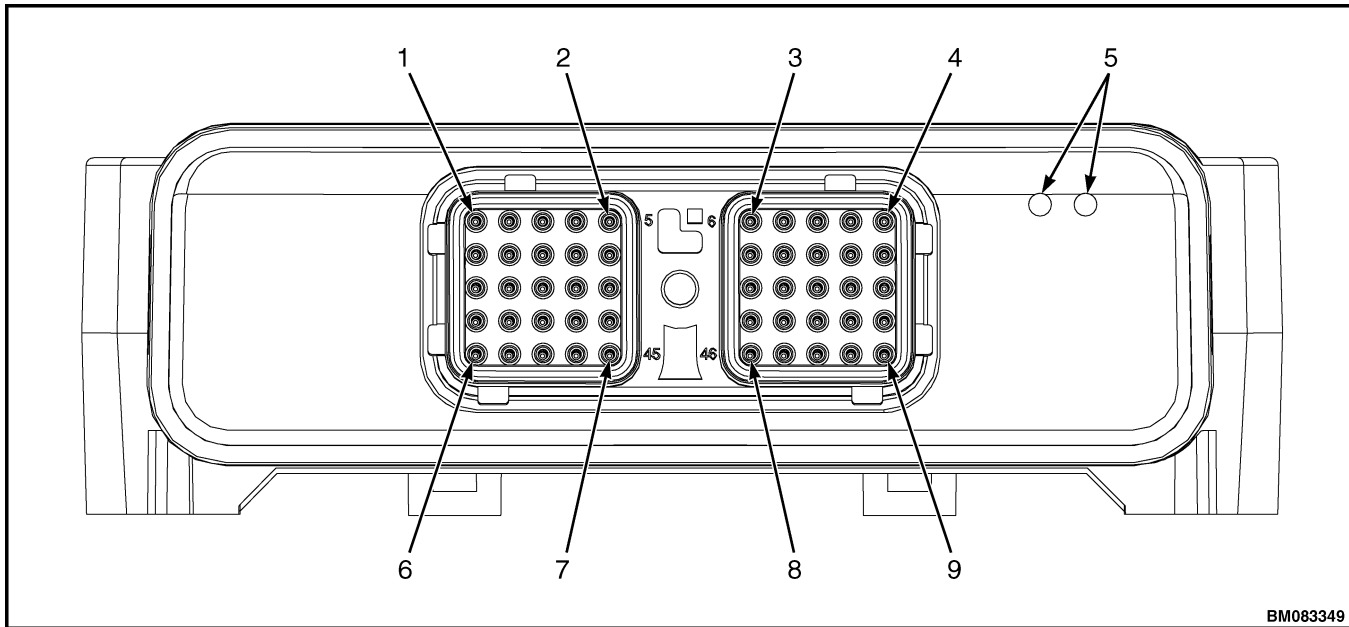
The primary responsibility of the controller and software is to execute operator commands by generating the appropriate output signals based on inputs provided by the truck VSM. These outputs will be broadcast over the CAN BUS and delivered directly to components via dedicated wires in order to control three primary aspects of the truck: engine speed, transmission ratio, and braking. All communication between the HST controller and VSM will take place over the CAN BUS following the J1939 protocol at a baud rate of 250k.

NOTE: Pin out table not available at this time.



- 1. RH FRAME
- 2. HST FILTER
- 3. HST FILTER BRACKET
- 4. HST CONTROLLER

Figure 70. HST Controller Location



BM083349

- | | |
|--------------------------|-----------|
| 1. PIN 1 | 6. PIN 41 |
| 2. PIN 5 | 7. PIN 45 |
| 3. PIN 6 | 8. PIN 46 |
| 4. PIN 10 | 9. PIN 50 |
| 5. *LED INDICATOR LIGHTS | |

NOTE: *THE TWO LEDS, ONE RED AND ONE GREEN, ARE BOTH ARE UNDER APPLICATION SOFTWARE CONTROL OF THE PRIMARY PROCESSOR. BEFORE THE PRIMARY PROCESSOR APPLICATION SOFTWARE STARTS RUNNING, THE GREEN LED WILL BE ON AND THE RED LED WILL BE OFF. EACH LED LIGHT PIPE WILL HAVE AN ALTERNATE YELLOW COLOR WHICH THE APPLICATION SOFTWARE WILL NOT HAVE ACCESS TO. THESE ALTERNATE YELLOW COLORS WILL BE USED TO INDICATE LOW-LEVEL SOFTWARE OR HARDWARE FAILURES. THE YELLOW LED SHARED WITH THE GREEN LED LIGHT PIPE WILL BE CONTROLLED BY THE **PRIMARY PROCESSOR**, AND THE YELLOW LED SHARED WITH THE RED LED LIGHT PIPE WILL BE CONTROLLED BY THE **SECONDARY CONTROLLER**. WHEN EITHER YELLOW LED IS ENABLED THE SIGNAL WILL OVERRIDE ITS SHARED GREEN OR RED LED.

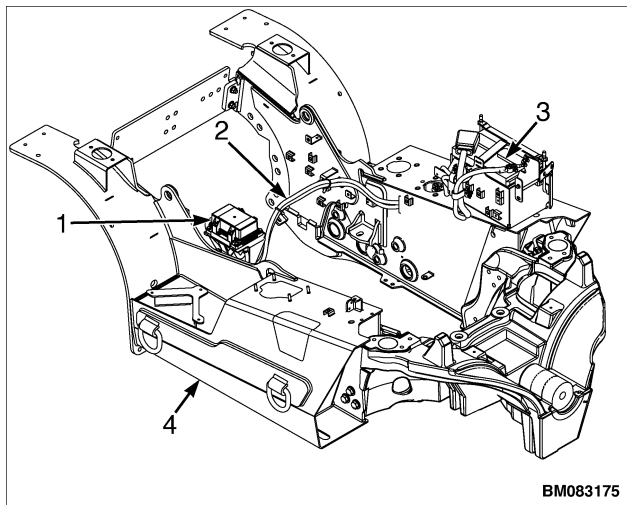
Figure 71. HST Controller Pin Locations

**POWER DISTRIBUTION MODULE (PDM)
DESCRIPTION
202001-145**

POWER DISTRIBUTION MODULE (PDM)

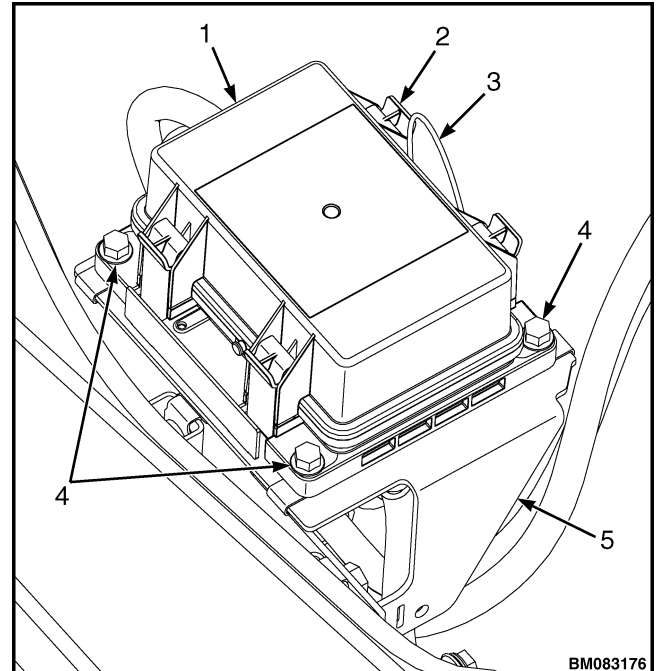
The main PDM (or fuse box) is used to provide electrical power from the battery to the vehicle peripherals. The PDM houses the fuses and relays and distributes all unswitched and switched power to the lift truck. Power and ground connections are supplied directly from the battery to the PDM and then distributed. All PDM distributed circuits are fused.

The PDM is located on the left side of the truck under the floor mat and rear floor plate and is attached to the frame with a mounting plate. The components in the PDM are plug-in socketed devices and automotive blade type fuses for ease of maintenance.



- 1. PDM
- 2. BATTERY CABLES (B+ AND B-)
- 3. BATTERY
- 4. FRAME

Figure 72. PDM Location



- 1. PDM COVER
- 2. PDM COVER SPRING TABS
- 3. PDM COVER TETHER
- 4. BOLTS
- 5. PDM BRACKET

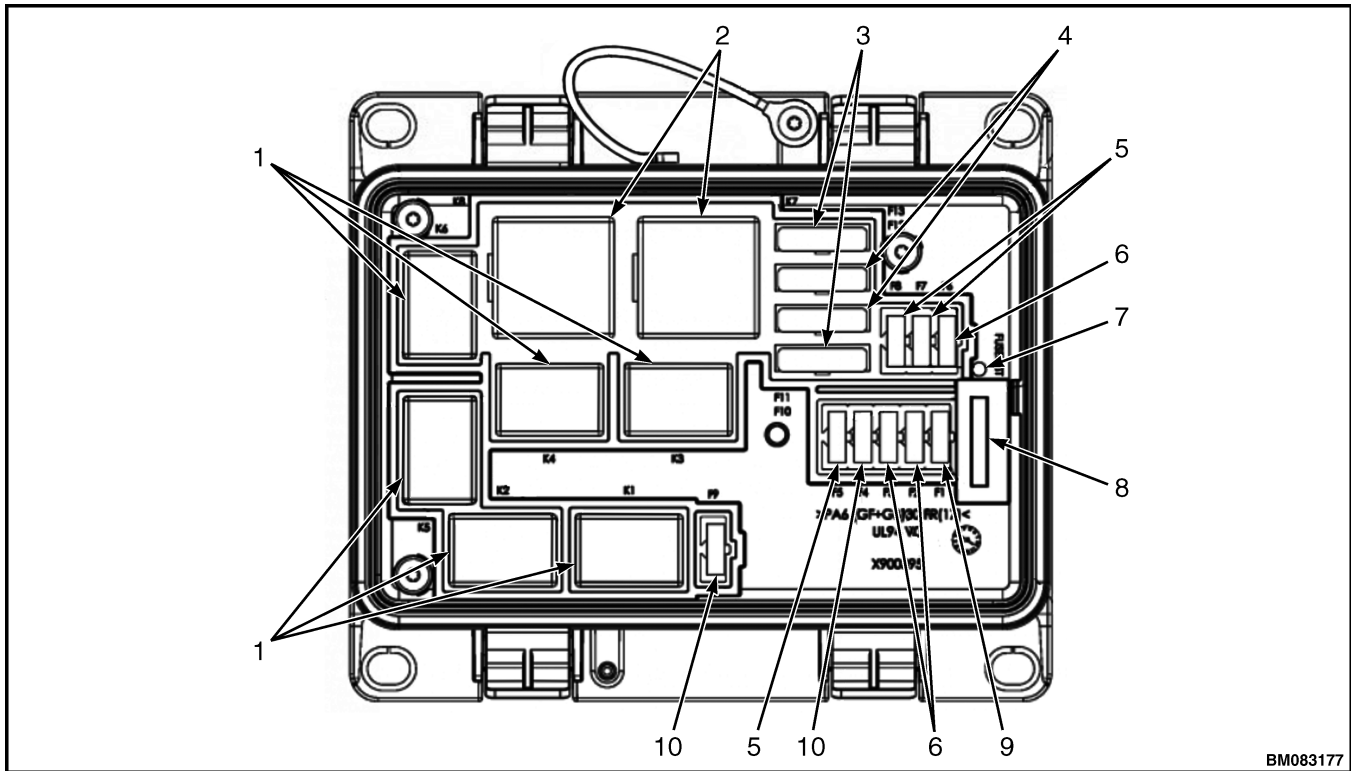
Figure 73. PDM and Cover



CAUTION

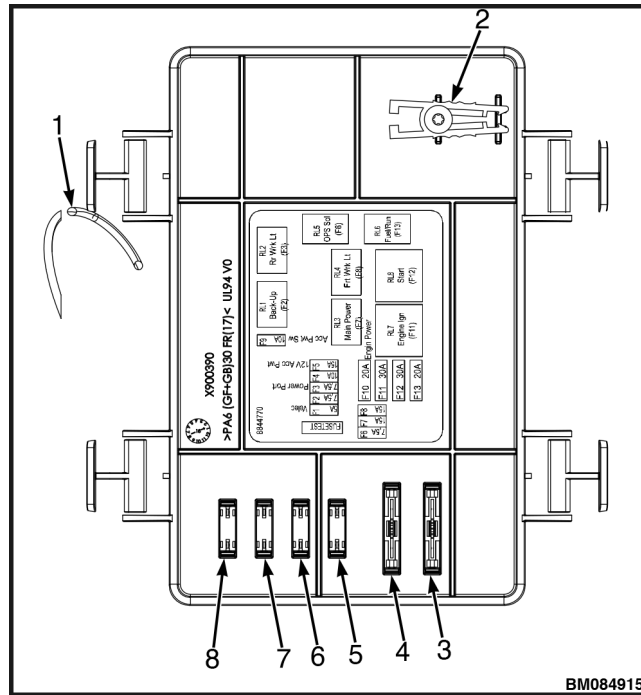
To reduce the risk of damaging the lift truck electrical system, only replace blown fuses with fuses of the same value, after the fuse-blowing fault has been detected and repaired.

NOTE: Located on the PDM is a fuse test socket (item 8, Figure 74) for checking suspected blown fuses. Extract the suspect fuse using the fuse puller and insert into the test socket. If the LED does not illuminate the fuse has failed and must be replaced. If the LED does illuminate the fuse is acceptable.



- | | |
|-------------------------------|--------------------------------|
| 1. MICRO RELAYS - 20A | 6. BLADE FUSE, ATM MINI - 7.5A |
| 2. MINI RELAYS - 30A | 7. FUSE TEST LED |
| 3. BLADE FUSE, ATO - 20A | 8. FUSE TEST SOCKET |
| 4. BLADE FUSE, ATO - 30A | 9. BLADE FUSE, ATM MINI - 5A |
| 5. BLADE FUSE, ATM MINI - 15A | 10. BLADE FUSE, ATM MINI - 10A |

Figure 74. PDM Fuse and Relay Locations (Cover Removed)



- | | |
|--------------------------------|--------------------------------------|
| 1. COVER TETHER | 5. SPARE BLADE FUSE, ATM MINI - 15A |
| 2. FUSE PULLER | 6. SPARE BLADE FUSE, ATM MINI - 10A |
| 3. SPARE BLADE FUSE, ATO - 30A | 7. SPARE BLADE FUSE, ATM MINI - 7.5A |
| 4. SPARE BLADE FUSE, ATO - 20A | 8. SPARE BLADE FUSE, ATM MINI - 5A |

Figure 75. PDM Cover (Underneath Side) and Spare Fuses

Fuse and Relay Descriptions

Table 15. Fuses

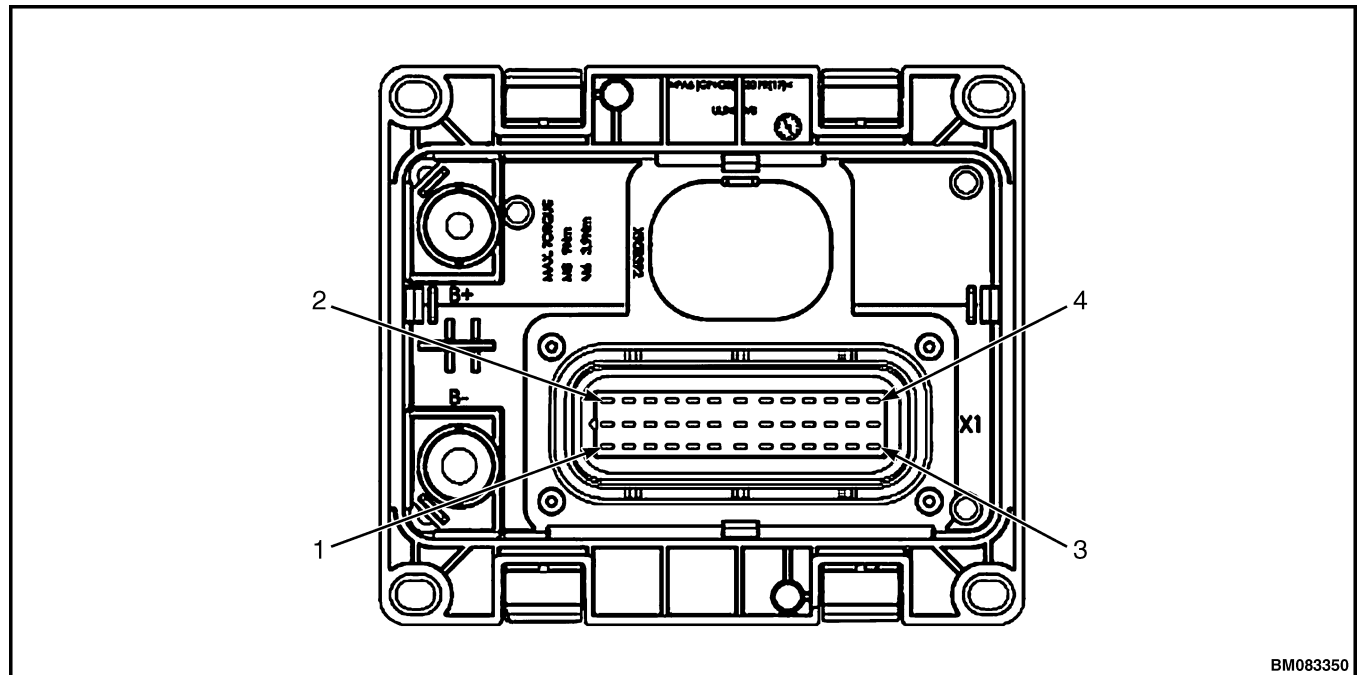
Fuse	Value	Description
F1	5A	12V Velectric
F2	7.5A	Back-up
F3	7.5A	Rear Worklight
F4	10A	Power Port
F5	15A	12V Acc Power
F6	7.5A	Manual Lever Valve
F7	15A	12V VPower
F8	15A	Front Worklight
F9	10A	Acc Conn
F10	20A	12V Engine
F11	30A	Engine Ignition
F12	30A	Start
F13	20A	Fuel Run/Latch

Table 16. Relays

Relay	Description
Micro Relay RL1 - (K1)	Back-up
Micro Relay RL2 - (K2)	Rear Worklight
Micro Relay RL3 - (K3)	Main Power
Micro Relay RL4 - (K4)	Front Worklight
Micro Relay RL5 - (K5)	OPS Solenoid
Micro Relay RL6 - (K6)	Fuel/Run
Mini Relay RL7 - (K7)	Engine Ignition
Mini Relay RL8 - (K8)	Start

PDM Pin Out

The PDM connector is located on the underneath side of the PDM.



- 1. PIN 1
- 2. PIN 3

- 3. PIN 37
- 4. PIN 39

Figure 76. PDM Pin Out Locations

Table 17. PDM Pin Out

Pin	Type	Description	Connects to
1	GND	Power Ground	LIGHTS GND 1
2	GND	Power Ground	#1 ACC GND
3	12V	Supply	12V ACC
4	GND	Power Ground	#2 ACC GND
5	GND	Power Ground	LIGHTS GND 2
6	12V	Supply	POWER PORT
7	GND	Power Ground	ENGINE POWER GND
8	----	----	----
9	12V	Supply	12V ENGINE PWR
10	GND	Power Ground	VPWR GND
11	----	----	----
12	12V	Supply	12V VELEC POS

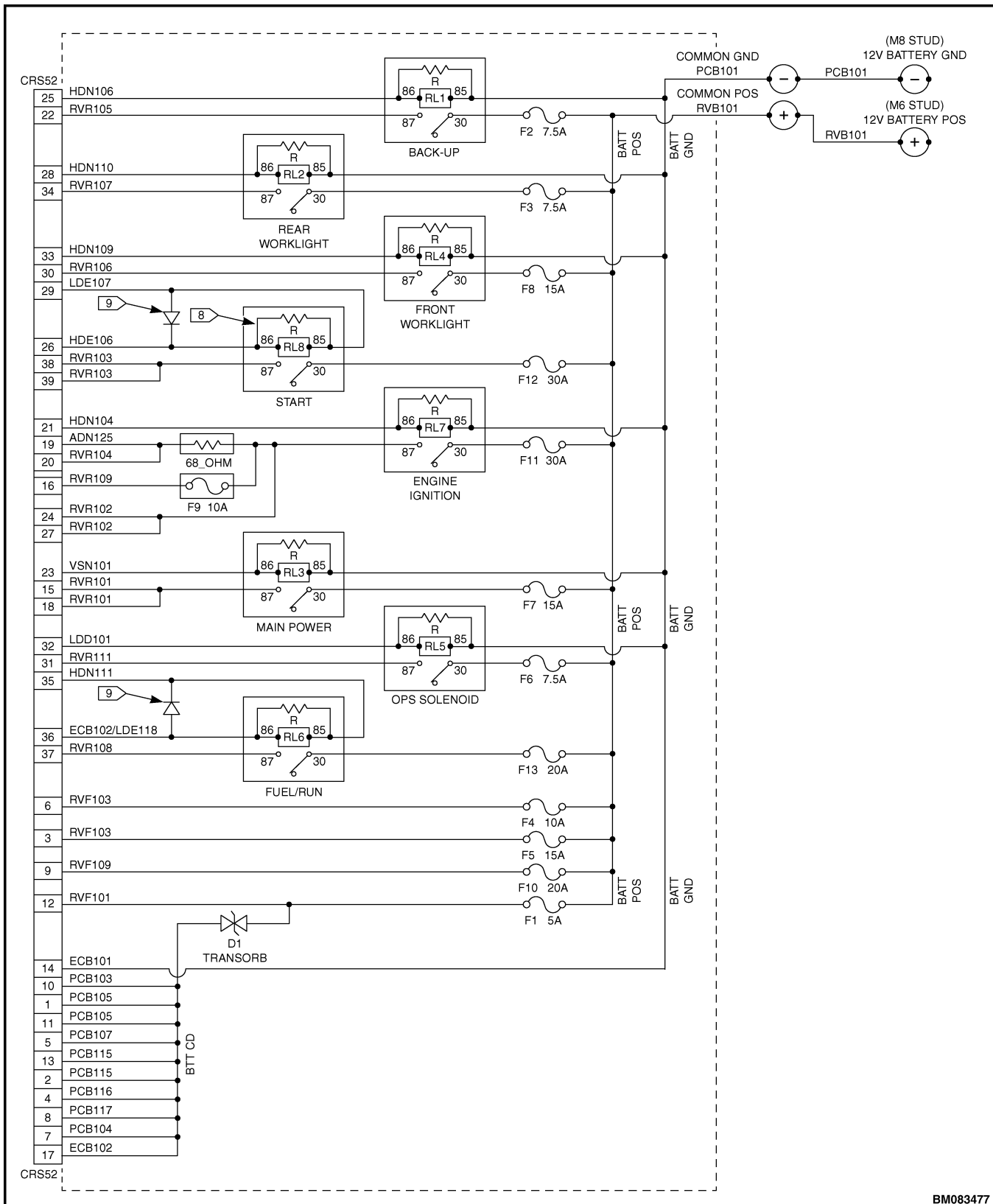
Table 17. PDM Pin Out (Continued)

13	GND	Power Ground	#1 ACC GND
14	GND	Electric Ground	VELEC GND
15	----	----	----
16	12V	Supply	ACC CONN
17	GND	Electric Ground	ENGINE LOGIC GND
18	12V	Supply	12V VPOWER
19	Analog/Digital Input	Input	VSM V_ALT
20	12V	Supply	ALT (E)
21	Highside Driver	Highside Driver	VSM HIGHSIDE SIGNAL (12V+)
22	12V	Supply	BACKUP OR BLUE LIGHT
23	VElect Out	VElect Out	SIG (FROM VSM)
24	12V	Supply	SWITCHED IGN
25	Highside Driver	Highside Driver	VSM HIGHSIDE SIGNAL (12V+)
26	Highside Driver	Highside Driver	VSM-ECM HIGHSIDE SIGNAL (12V+)
27	----	----	----
28	Highside Driver	Highside Driver	VSM HIGHSIDE SIGNAL (12V+)
29	Lowside Driver	Highside Driver	ECM LOWSIDE SIGNAL (12V-)
30	12V	Supply	FRONT WORK LIGHT
31	----	----	----
32	----	----	----
33	Highside Driver	Highside Driver	VSM HIGHSIDE SIGNAL (12V+)
34	12V	Supply	REAR WORK LIGHT
35	Highside Driver	Highside Driver	VSM HIGHSIDE SIGNAL (12V+)
36	GND	Electric Ground	ECM LOWSIDE SIGNAL (12V-)
37	12V	Supply	FUEL RUN OR LATCH PWR
38	12V	Supply	START SOL PWR

Table 17. PDM Pin Out (Continued)

39	-----	-----	-----
----	-------	-------	-------

PDM Electrical Schematic



BM083477

Figure 77. PDM Electrical Schematic

SENSORS AND OTHER COMPONENTS DESCRIPTION 202001-146

SENSORS

Various sensors are located on the truck and feed data to the Vehicle System Manager (VSM) in the form of parametric data from analog and digital components monitoring different phenomena. Some are as simple analog feedback like truck battery voltage. Other inputs are digital feeding back the state of a circuit like operator presence in the form of a 1 or 0, also known as a flag. Some feedback to the VSM comes from other CAN modules with their own connected components (for example, oxygen sensor connected to engine controller).

All sensors and switches used on these trucks are non-repairable parts. Replace with new sensors whenever a sensor malfunctions and is not operating correctly. See Parts Manual for replacement part numbers. Before installing new sensors, use a clean cloth and make sure the area around the sensor is clean and free of oils and contaminants. When removing and replacing sensors, be sure to tag connectors to aid in correct reconnecting.



CAUTION

Before removing and replacing any sensors or switches, **ALWAYS** disconnect the battery. Failure to disconnect the battery can cause damage to the sensor or switch and other electrical components. Always cover or protect the sensor or switch connector from contamination after disconnecting the harness mating part.

DO NOT use solvent-based cleaners to clean area around sensors or switches.

NOTE: The following are loosely categorized for a rough reference to a general location of the sensors on this truck.

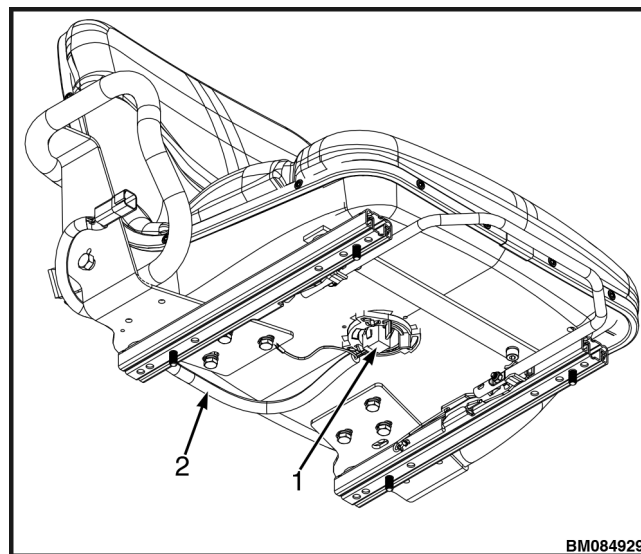
Operator Compartment

These sensors are either located in, on, or near the operator compartment and overhead guard.

Operator Presence Sensor (OPS)

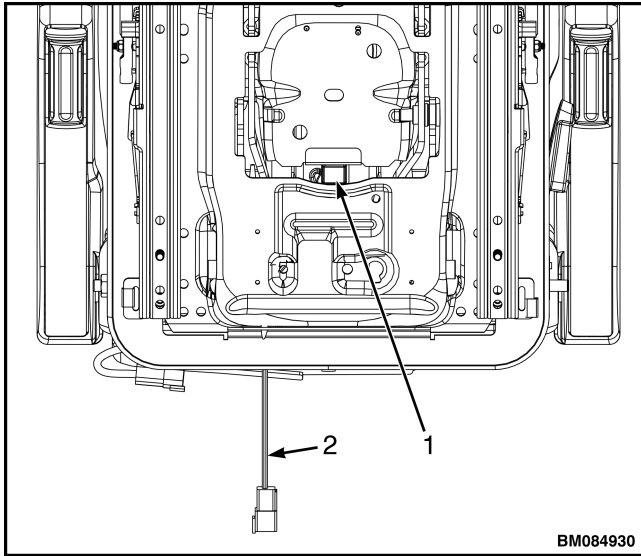
The OPS feature uses an electrical sensor in the seat which senses the presence of the operator. Interlocks are used to prevent use of hydraulic functions if the operator is not seated. This allows most hydraulic control functions to be engaged only when the operator is in the seat.

The OPS is designed with a delay in activating the interlock to allow the operator time to reposition without disabling hydraulic controls. The seat sensor will automatically disable hydraulics within 1-2 seconds when the operator leaves the seat. When the seat sensor disables hydraulic functions, the operator must sit in the seat and depress the service brake pedal to re-engage hydraulic functions. An optional engine shutdown feature is available that will shut down the engine if the operator is not in the seat.



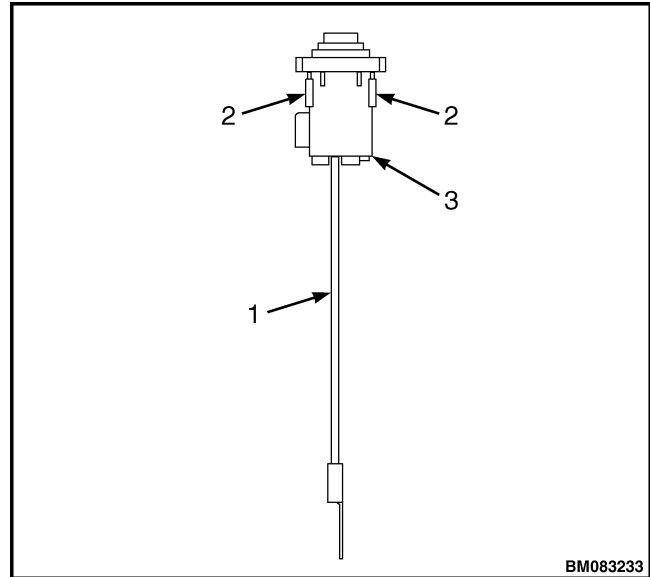
1. OPERATOR PRESENCE SENSOR
2. SENSOR HARNESS AND CONNECTOR

Figure 78. Seat (OPS) Sensor (Tiancheng Non-Suspension Seat)



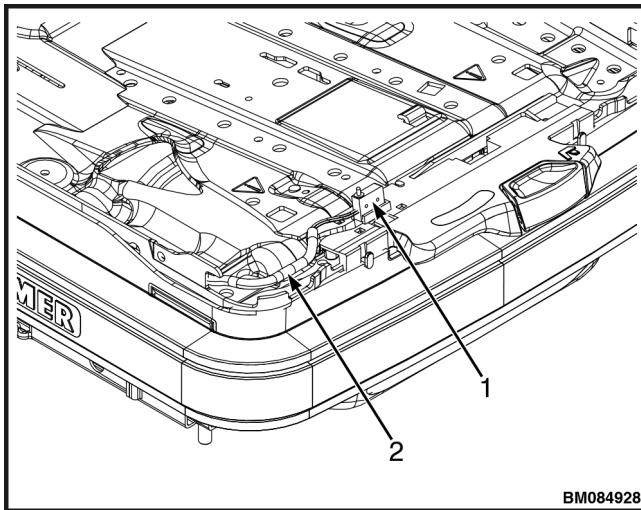
- 1. OPERATOR PRESENCE SENSOR
- 2. SENSOR HARNESS AND CONNECTOR

Figure 79. Seat (OPS) Sensor (Tiancheng Full-Suspension Seat)



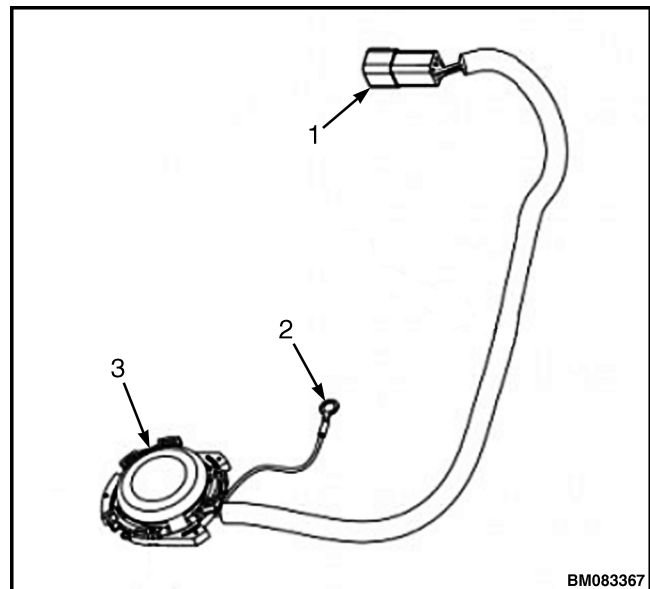
- 1. OPERATOR PRESENCE SENSOR HARNESS
- 2. SPRING TABS
- 3. OPERATOR PRESENCE SENSOR

Figure 81. Operator Presence Sensor and Harness (Tiancheng Seat)



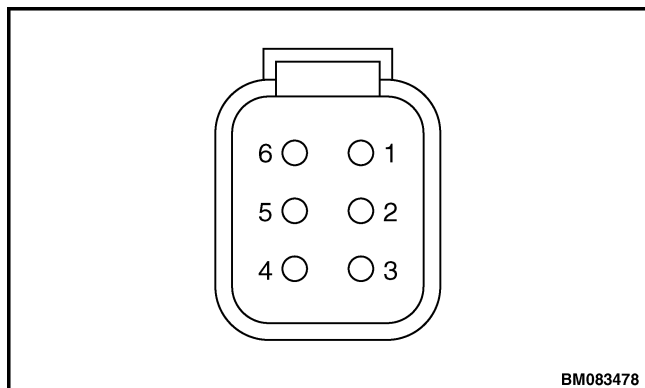
- 1. OPERATOR PRESENCE SENSOR
- 2. SENSOR HARNESS AND CONNECTOR

Figure 80. Seat (OPS) Sensor (Grammer Seat)



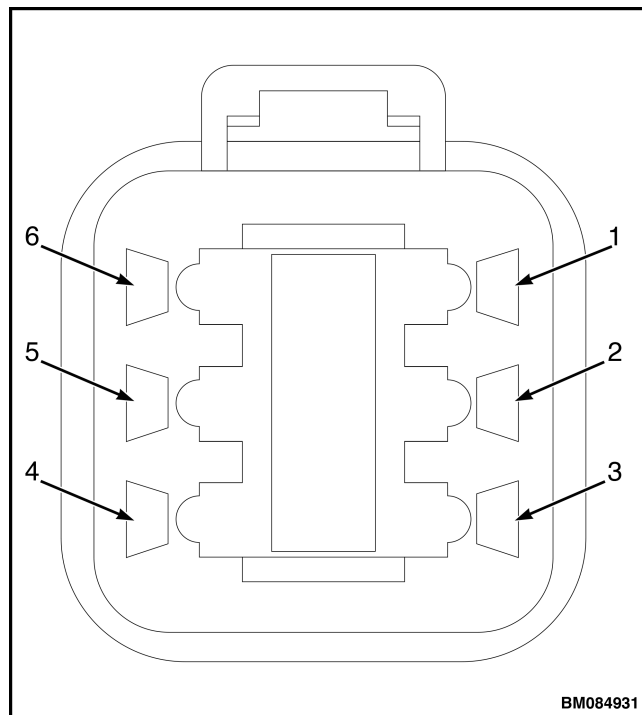
- 1. 6 PIN CONNECTOR
- 2. GROUND RING TERMINAL
- 3. SENSOR AND HOUSING

Figure 82. Operator Presence Sensor and Harness (Grammer Seat)



Pin	Type	Description
1	GND	SENSOR GROUND
2	5V	SENSOR SUPPLY
3	WKN	OUTPUT
4	12V	POWER TO AIR RIDE SEAT COMPRESSOR
5	GND	GROUND TO AIR RIDE SEAT COMPRESSOR
6	GND	STATIC GROUND

Figure 83. OPS Connector Pin Out (Tiancheng Seat)

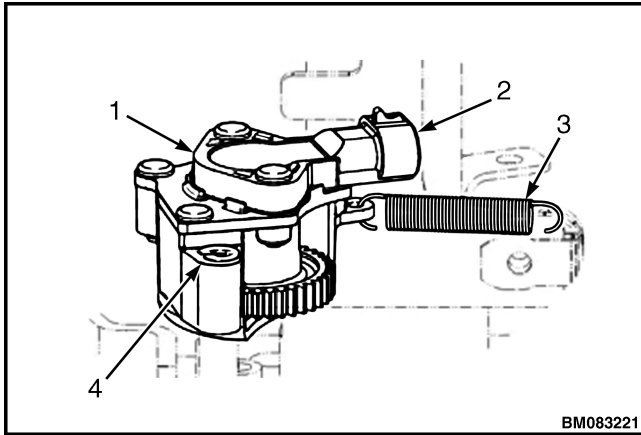


Pin	Type	Description
1	GND	SENSOR GROUND
2	5V	SENSOR SUPPLY
3	WKN	OUTPUT
4	12V	POWER TO AIR RIDE SEAT COMPRESSOR
5	GND	GROUND TO AIR RIDE SEAT COMPRESSOR
6	GND	STATIC GROUND

Figure 84. OPS Connector Pin Out (Grammer Seat)

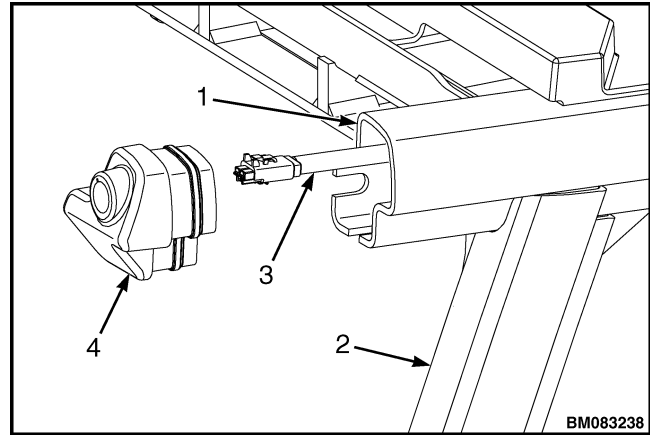
Steering Column Sensor

The steering wheel sensor (in conjunction with the steer axle position sensor) provides synchronous steering where the steering knob is synchronized with the steer axle. As a result the steering knob will come back to the same position while driving straight ahead. This system does so by utilizing the steering wheel sensor, an excess flow valve on the Steering Control Unit (SCU), and the steer axle position sensor. The straight ahead position of the steering wheel can set by the operator through the display in the calibrations menu.



1. STEERING COLUMN SENSOR
2. SENSOR ELECTRICAL CONNECTOR
3. SPRING
4. RETAINER RING (E-RING)

Figure 85. Steering Column Sensor



1. TOP LH OVERHEAD GUARD SUPPORT POST
2. FRONT LH OVERHEAD GUARD SUPPORT POST
3. JUMPER
4. PLUG WITH AMBIENT LIGHT SENSOR

Figure 87. Plug with Ambient Light Sensor

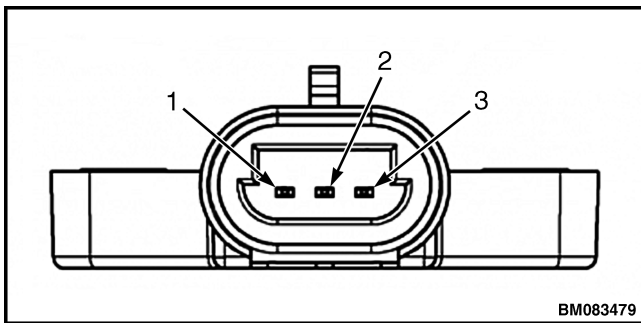
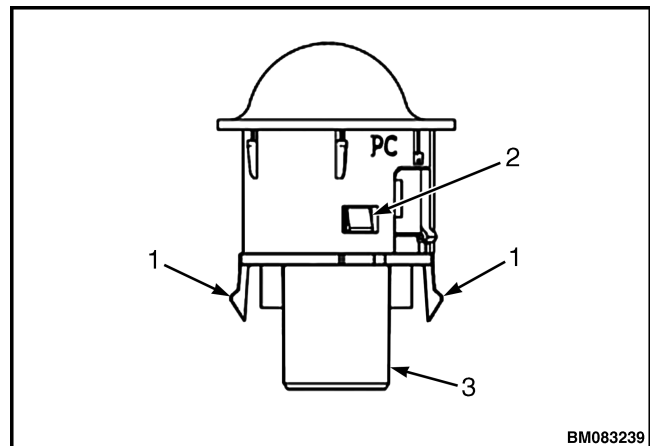


Figure 86. Steering Column Sensor Pin Out

Item	Pin	Type	Description
1	A	5V+	SUPPLY
2	B	OUTPUT	ANALOG/ DIGITAL
3	C	GROUND	SIGNAL GROUND

Ambient Light Sensor

Mounted on LH corner of Overhead Guard (OHG), the ambient light sensor automatically activates the work lights based on ambient light conditions.



1. SPRING TABS
2. ALIGNMENT NOTCH
3. CONNECTOR

Figure 88. Ambient Light Sensor

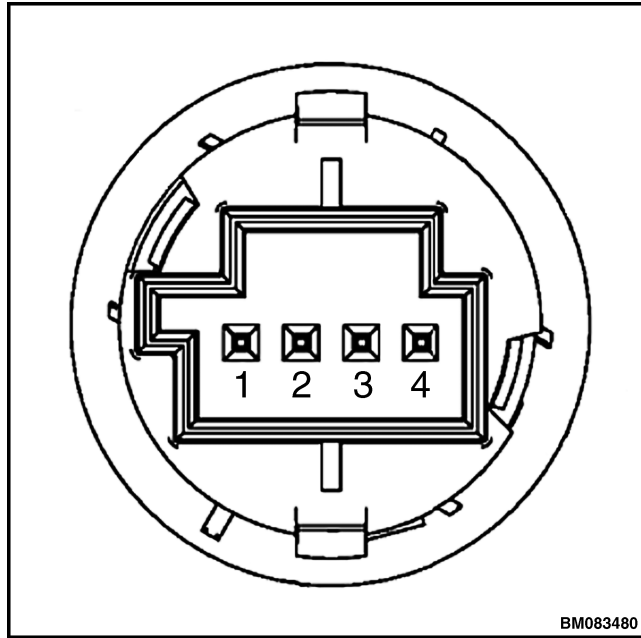


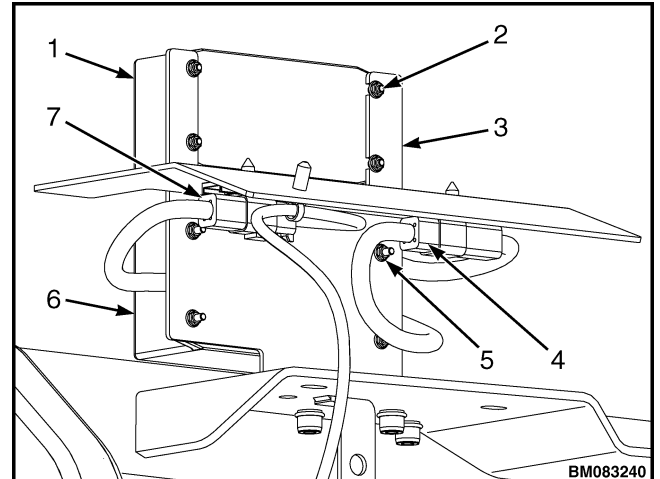
Figure 89. Ambient Light Sensor Pin Out

Pin	Type	Description
1	ANALOG/ DIGITAL OUTPUT	AMBIENT LIGHT OUTPUT
2	5V	5V SUPPLY
3	NOT USED	NOT USED
4	GND	GROUND

Proximity Sensor

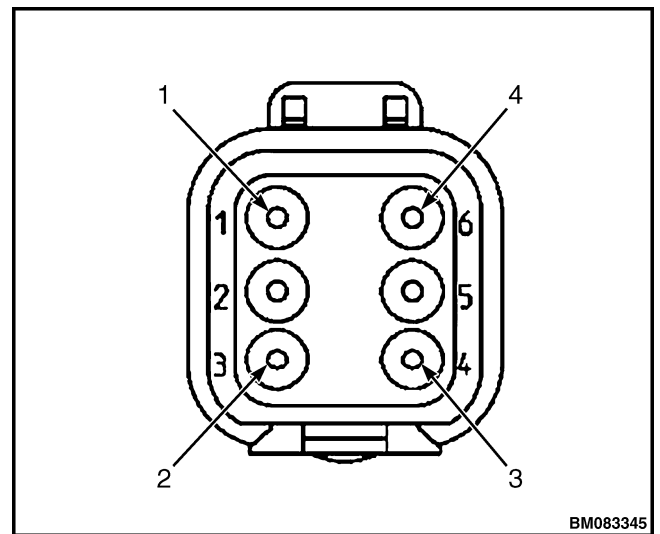
The proximity sensor is a part of the Operator Assist Systems (OAS). The sensor detects trucks, pedestrians, structures, and zones in real time for use of slowing the truck and informing the driver of potential risks. The sensor works in conjunction with the collision avoidance unit.

NOTE: The proximity sensor is mounted on the overhead guard, rear canopy tube.



1. COLLISION AVOIDANCE UNIT
2. CAPSCREW AND NUT
3. BRACKET
4. COLLISION AVOIDANCE UNIT CONNECTOR
5. CAPSCREW AND NUT
6. CAN BUS INTERFACE UNIT
7. CAN BUS INTERFACE UNIT CONNECTOR

Figure 90. Proximity Sensor



1. PIN 1
2. PIN 2
3. PIN 3
4. PIN 4

Figure 91. Collision Avoidance Unit Connector Pin Out

NOTE: This connector connects the Collision Avoidance Unit (item 1, Figure 90) to the CAN Bus Interface Unit (item 6, Figure 90).

Pin	Description
1	NA
2	NA
3	NA
4	NA
5	NA
6	NA

NOTE: Pin out descriptions currently not available at this time.

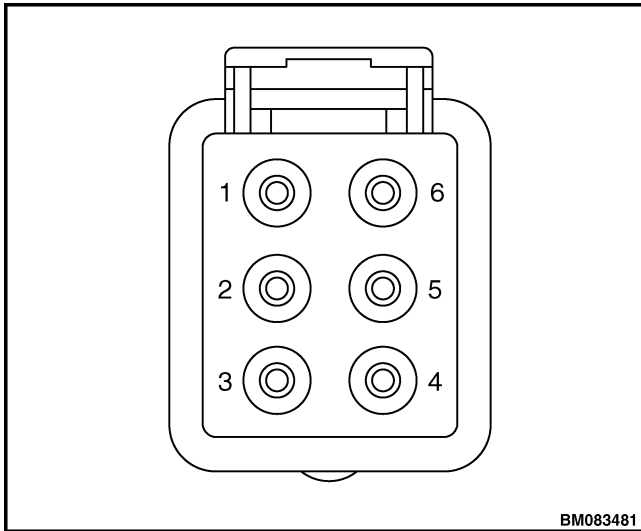


Figure 92. CAN Bus Interface Unit to Wire Harness Pin Out

NOTE: This connector connects the CAN Bus Interface (item 6, Figure 90) to the wire harness.

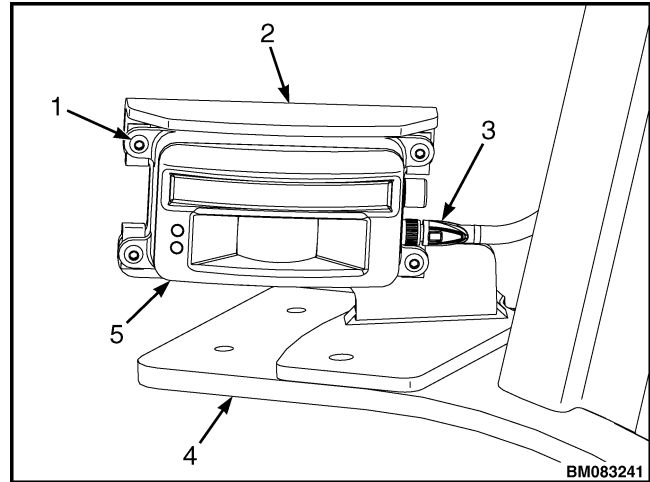
Pin	Description
1	NA
2	NA
3	NA
4	NA
5	NA
6	NA

NOTE: Pin out descriptions currently not available at this time.

Object Detection Sensors (Side)

The object detection sensors (side and rear) are a Light Detection and Ranging (LIDAR) based system. These are also a part of the Operator Assist Systems (OAS). The sensors provide input to the system to slow the truck down when operating in close proximity to objects or people and informs driver of potential objects or risks.

NOTE: One side sensor is mounted on each side of the truck. Only the left side is shown.

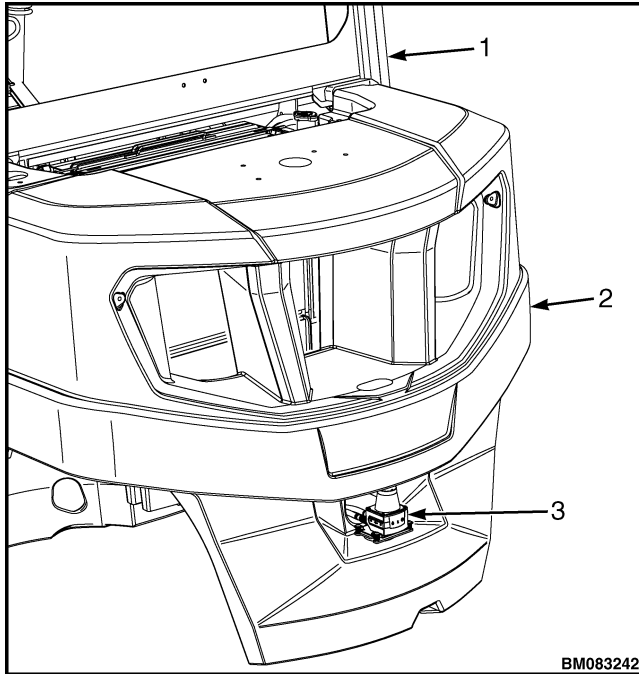


- 1. CAPSCREW
- 2. BRACKET
- 3. SENSOR CABLE
- 4. LH FENDER
- 5. SENSOR

Figure 93. Object Detection Side Sensor

Objection Detection Sensor (Rear)

NOTE: Rear object detection sensor is mounted in the counterweight.



1. RH, OVERHEAD GUARD SUPPORT POST
2. COUNTERWEIGHT
3. SENSOR

Figure 94. Object Detection Rear Sensor Location

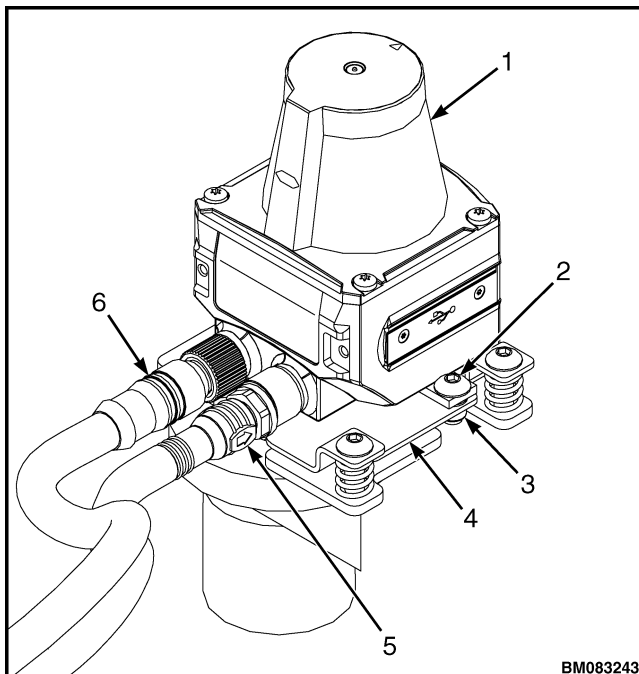


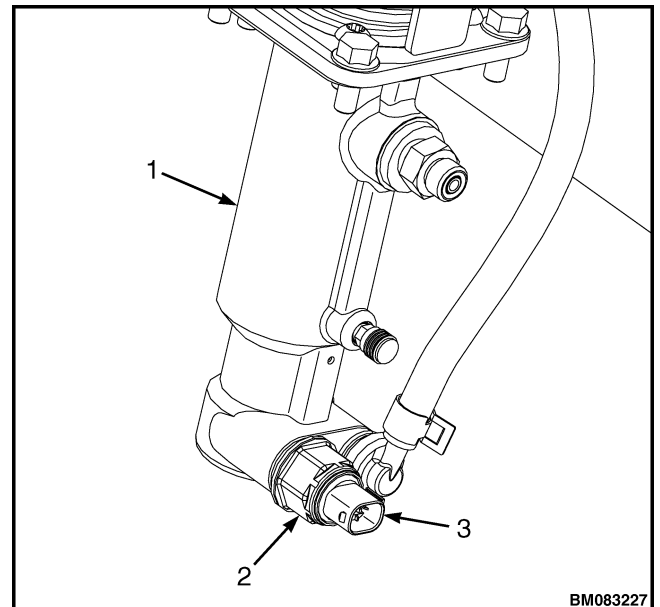
Figure 95. Object Detection Rear Sensor

Legend for Figure 95.

1. SENSOR
2. CAPSCREWS
3. THREADED INSERTS
4. ADJUSTMENT PLATE
5. ETHERNET CABLE
6. POWER CABLE

Brake Pressure Sensor

The brake pressure sensor measures the pressure of the service brake.



1. MASTER CYLINDER
2. SERVICE BRAKE PRESSURE TRANSDUCER
3. WIRE HARNESS CONNECTOR

Figure 96. Service Brake Pressure Transducer

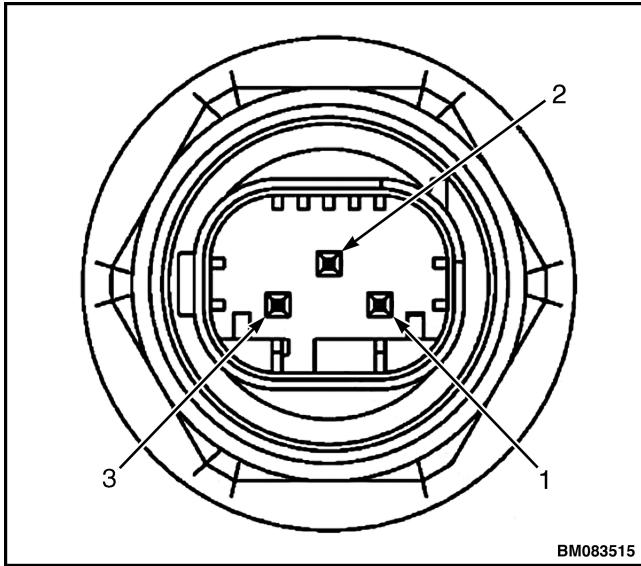
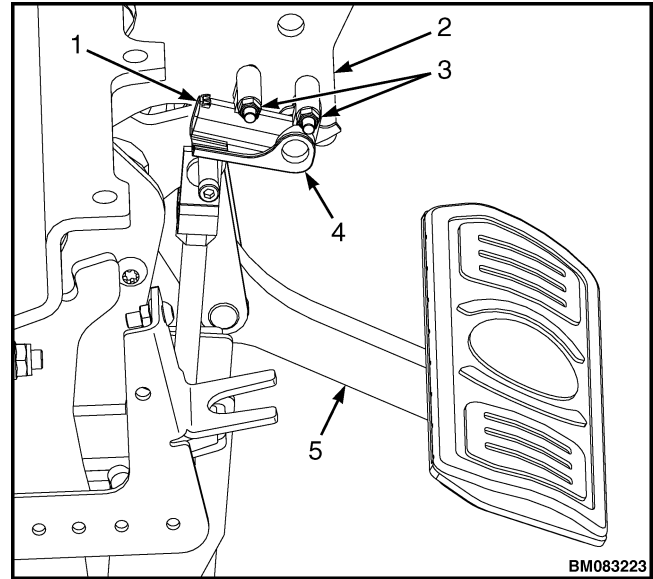


Figure 97. Brake Pressure Transducer Pin Out

Pin	Type	Description
1	GND	SIGNAL GROUND
2	ANALOG/ DIGITAL OUTPUT	OUT
3	5V	POWER

Service Brake Pedal Position Sensor

This Hall effect linear sensor uses a lever, rotating about a pivot. The system reads the sensor output at the pedal position of fully released and depressed pedal and anywhere in between. The sensor outputs are minimum when the pedal is fully pressed and maximum when fully released.



1. SENSOR ELECTRICAL CONNECTOR
2. LH STEERING COLUMN BRACKET
3. CAPSCREW AND NUT
4. BRAKE PEDAL POSITION SENSOR
5. BRAKE PEDAL ARM

Figure 98. Service Brake Pedal Position Sensor

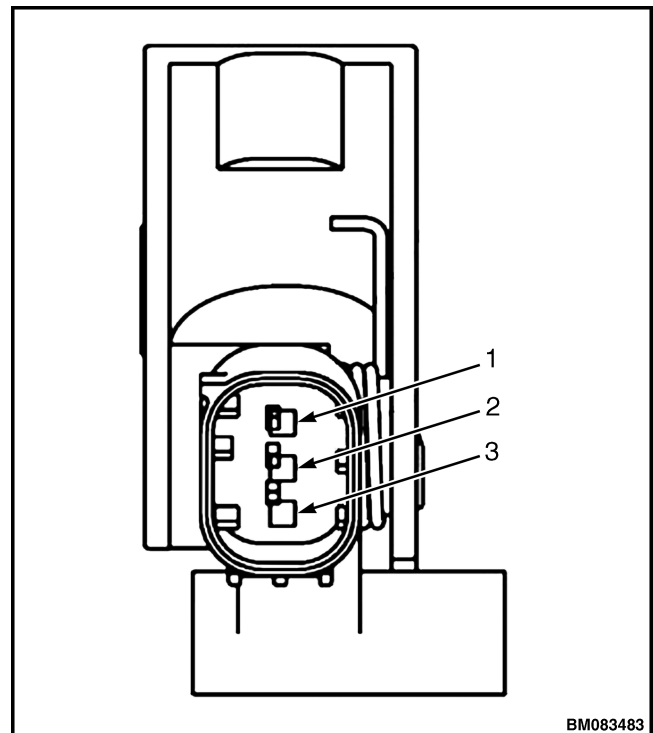
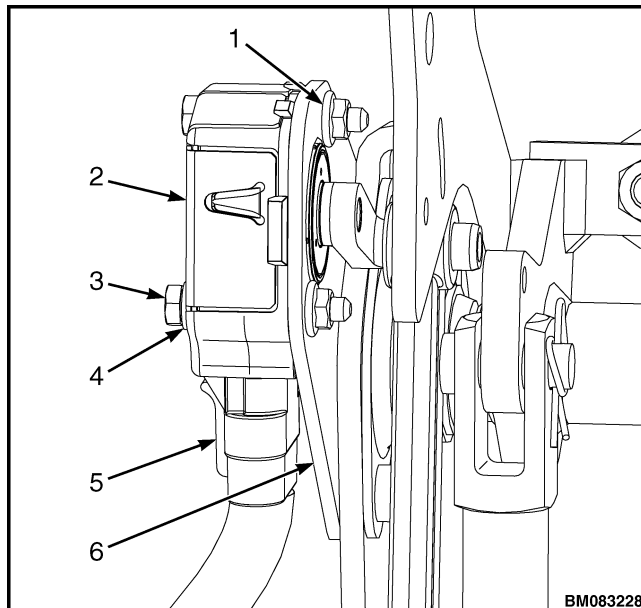


Figure 99. Service Brake Pedal Position Sensor Pin Out

Pin	Type	Description
1	5V	+5 DC
2	ANALOG/ DIGITAL	INPUT
3	GND	SIGNAL GROUND

E-Brake Position Sensor

This Hall effect linear sensor uses a lever, rotating about a pivot. The system reads the sensor output at the pedal position of fully released and depressed pedal and anywhere in between. The sensor outputs are minimum when the pedal is fully pressed and maximum when fully released.



1. NUT
2. E-BRAKE POSITION SENSOR
3. CAPSCREW
4. WASHER
5. E-BRAKE POSITION SENSOR CONNECTOR
6. E-PEDAL SENSOR PLATE

Figure 100. E-Brake Position Sensor

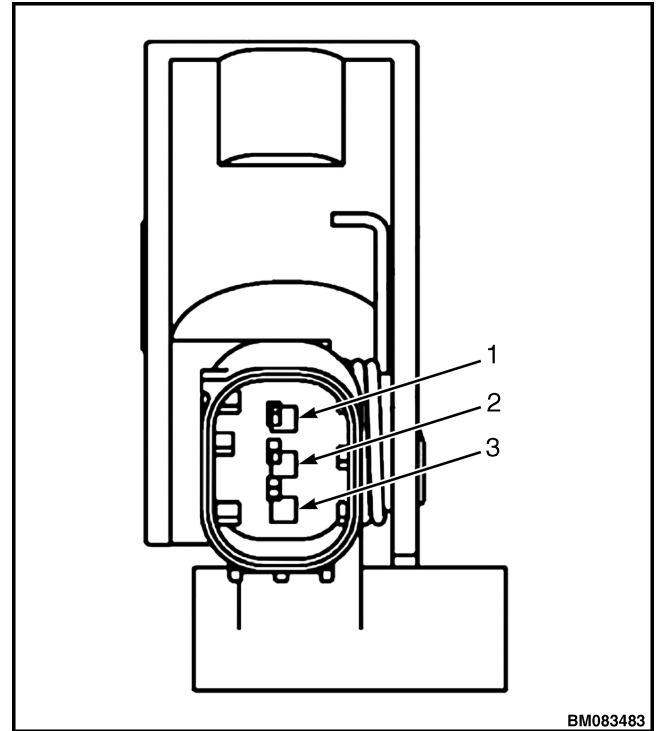
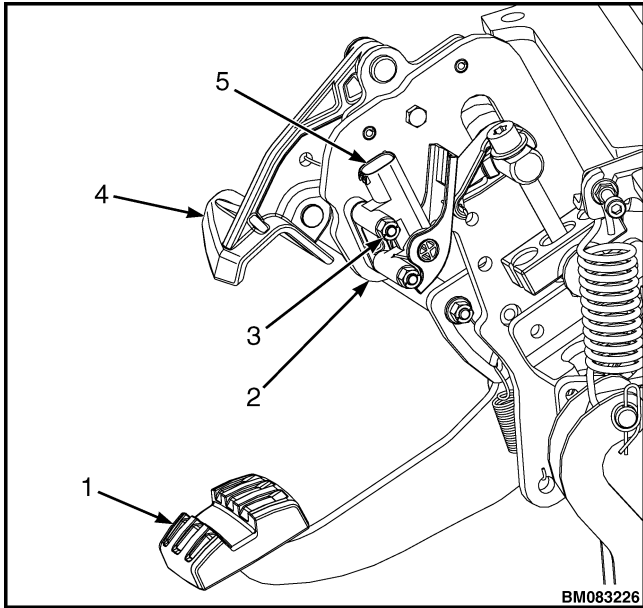


Figure 101. E-Brake Position Sensor Pin Out

Pin	Type	Description
1	GND	GROUND
2	GND	SIGNAL
3	5V	+5 DC

Park Brake Position Sensor

The park brake position sensor is also a Hall effect linear sensor uses a lever, rotating about a pivot. The system reads the sensor output at the pedal position of fully released and depressed.



- 1. PARK BRAKE PEDAL
- 2. PARK BRAKE POSITION SENSOR
- 3. PARK BRAKE POSITION SENSOR MOUNTING HARDWARE
- 4. PARK BRAKE RELEASE HANDLE
- 5. PARK BRAKE POSITION SENSOR ELECTRICAL CONNECTOR

Figure 102. Park Brake Position Sensor

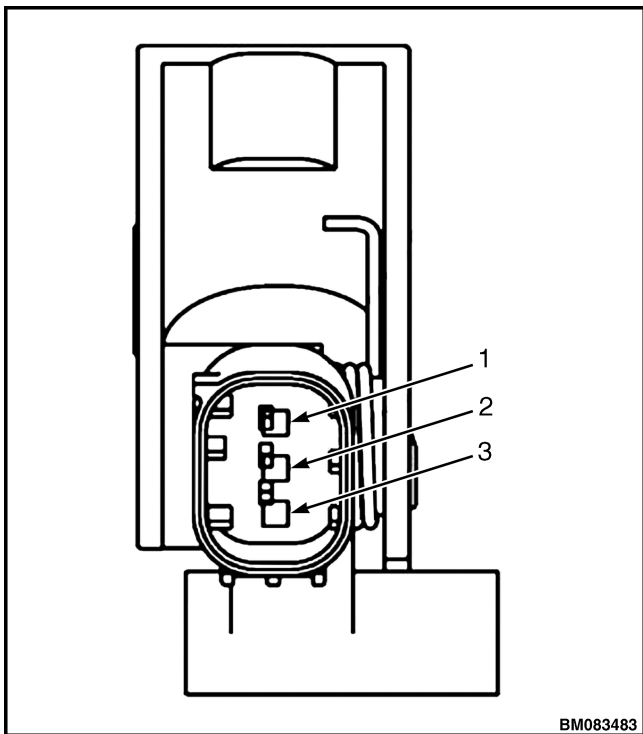
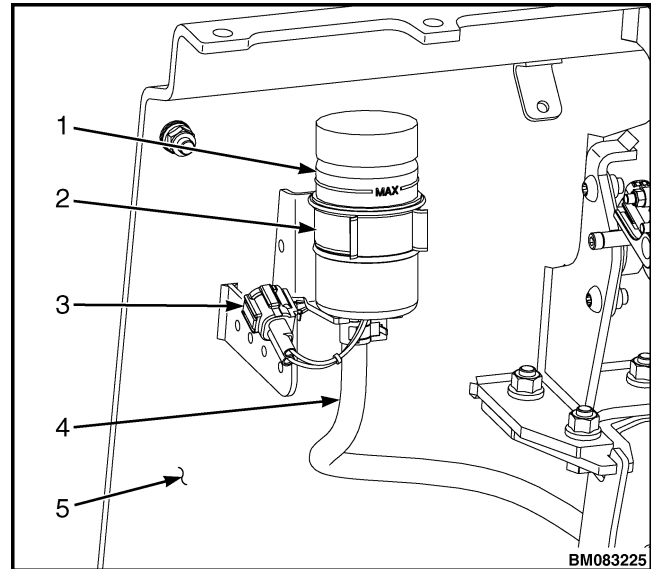


Figure 103. Park Brake Position Sensor Pin Out

Pin	Type	Description
1	5V	+5 DC
2	ANALOG/ DIGITAL INPUT	INPUT
3	GND	SIGNAL GROUND

Brake Fluid Level Sensor

The brake fluid level sensor is an integral part of the master brake cylinder reservoir and is located inside the reservoir. The sensor itself is not a serviceable part, the reservoir must be replaced as an assembly.

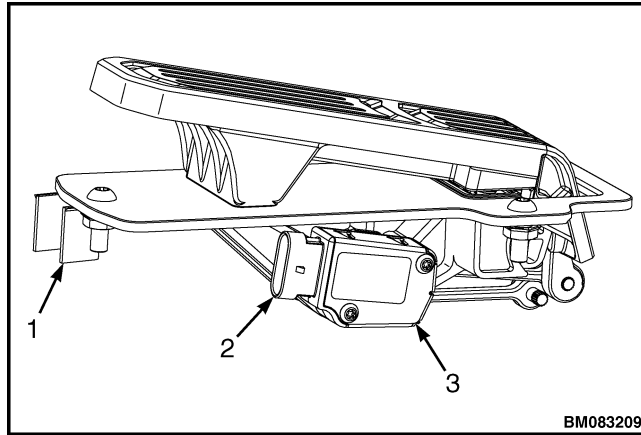


- 1. RESERVOIR
- 2. BRACKET
- 3. ELECTRICAL CONNECTOR
- 4. INLET BRAKE HOSE
- 5. COWL

Figure 104. Brake Fluid Level Sensor

Accelerator Pedal Position (APP) Sensor

The accelerator pedal position sensor is attached to the accelerator pedal in the operator station. The APP sensor physical position results in feedback voltage used by the engine ECU to set engine speed and truck acceleration.



1. FLOOR PLATE BRACKET
2. ELECTRICAL CONNECTOR
3. ACCELERATOR PEDAL POSITION SENSOR

Figure 105. Accelerator Pedal and Sensor

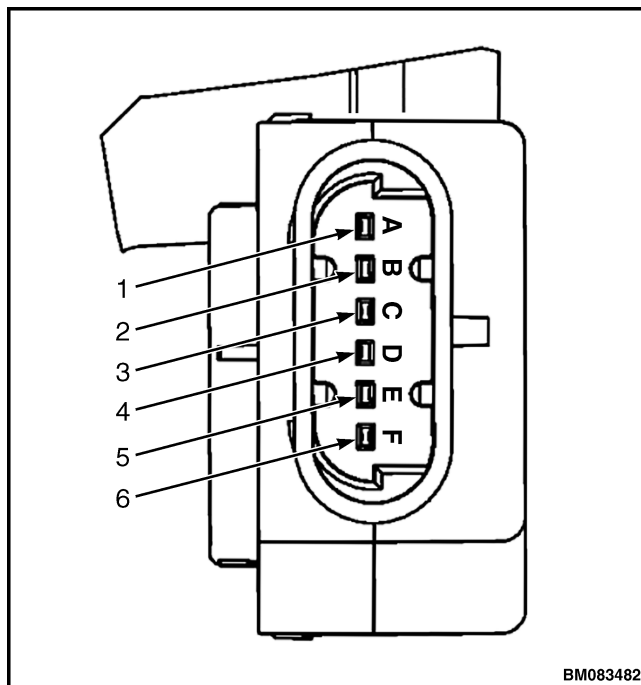


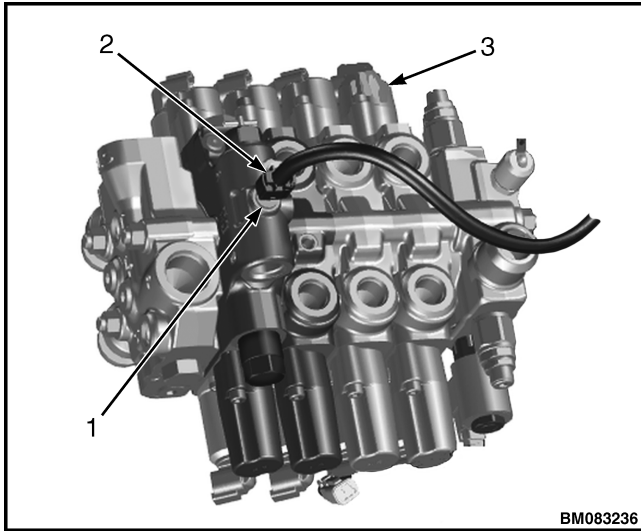
Figure 106. Accelerator Pedal Position Sensor Pin Out

Item	Pin	Type	Description
1	A	ANALOG/ DIGITAL	Primary (APS 1) SIGNAL
2	B	GND	Primary (APS 1) GROUND
3	C	5V	Primary (APS 1) SUPPLY (5V)
4	D	5V	Primary (APS 2) SUPPLY (5V)
5	E	GND	Primary (APS 2) GROUND
6	F	ANALOG/ DIGITAL	Primary (APS 2) SIGNAL

Load Weight Sensor

The load weight sensor is a component of the Dynamic Stability System (DSS). It is located on the main hydraulic valve and measures and displays the load on the forks to a tolerance of ± 25 kg (55 lb).

NOTE: The electronic hydraulic control valve is shown. Load weight sensor is in same position on manual control valve. Some components have been removed for clarity.



- 1. LOAD WEIGHT SENSOR
- 2. HARNESS CONNECTOR
- 3. CONTROL VALVE

Figure 107. Load Weight Sensor

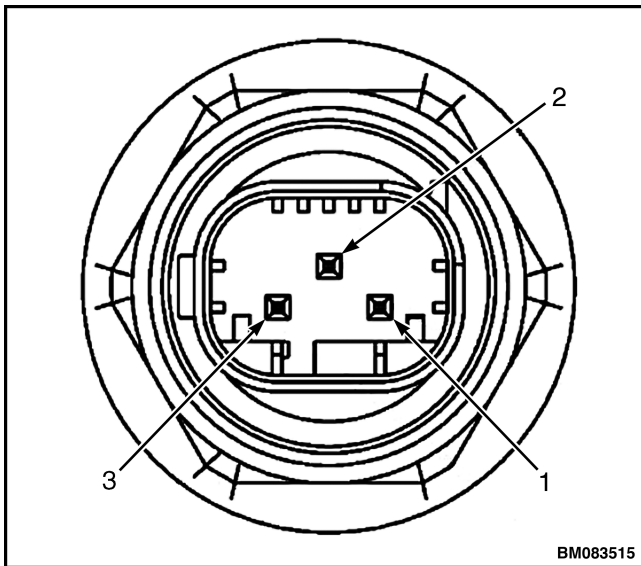


Figure 108. Load Weight Sensor Pin Out

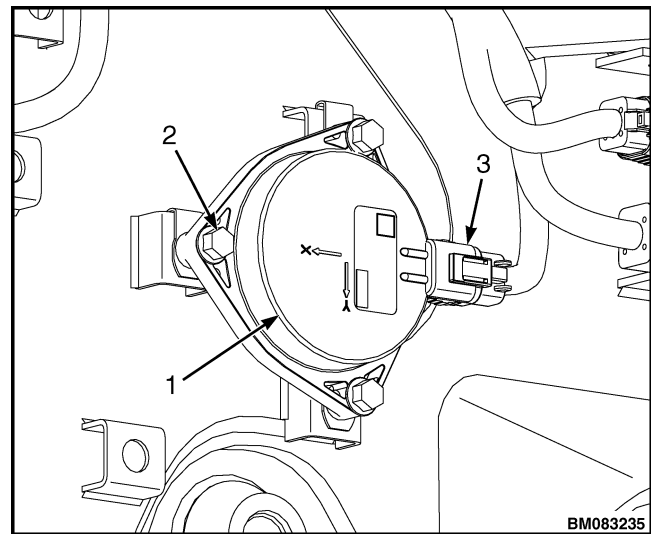
Pin	Type	Description
1	GND	SIGNAL GROUND
2	ANALOG /DIGITAL INPUT	INPUT
3	5V	V POWER

Frame

These sensors are located on or near the truck frame.

Impact Sensor

The frame-mounted impact sensor detects when the truck has hit an object and will cause lift truck to shutdown. Parameters are configurable for soft and hard impacts as well as time duration before truck shutdown. Once shutdown the truck cannot move until the impact sensor is reset by a supervisor or service technician.



- 1. IMPACT SENSOR
- 2. CAPSCREW
- 3. RIGHT CHASSIS HARNESS

Figure 109. Impact Sensor

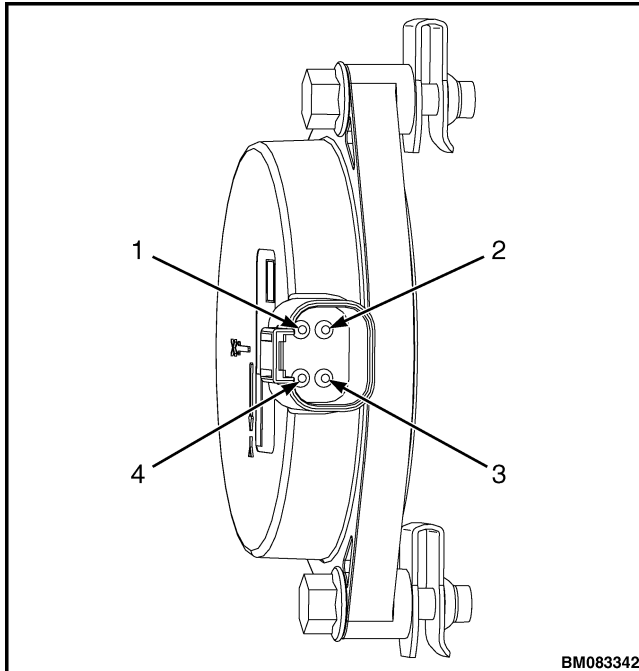


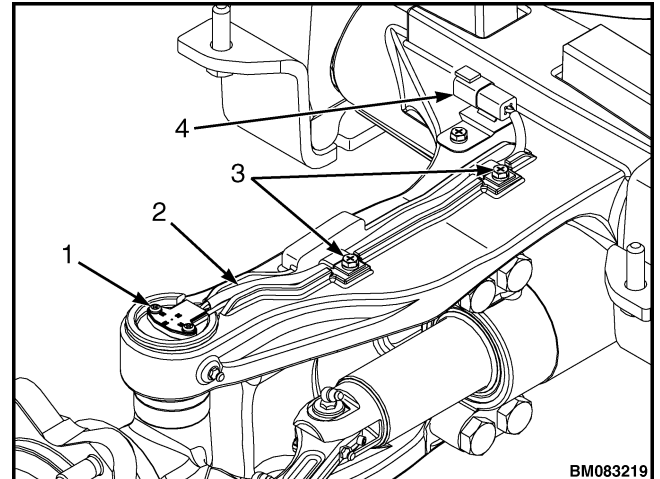
Figure 110. Impact Sensor Pin Out

Pin	Type	Description
1	ANALOG DIGITAL INPUT	MODULE POWER INPUT
2	GND	MODULE GROUND
3	CAN LO	COMMUNICAT ION
4	CAN HI	COMMUNICAT ION

Steer Axle Position Sensor

The steer axle position sensor is used in conjunction with the steering wheel position sensor. See Steering Column Sensor for additional information.

NOTE: The steer axle sensor and harness are replaced as a single component.



1. CAPSCREWS
2. STEER AXLE SENSOR ELECTRICAL HARNESS
3. INSULATED CLAMPS, CAPSCREWS, WASHERS
4. HARNESS CONNECTOR

Figure 111. Steer Axle Position Sensor and Harness

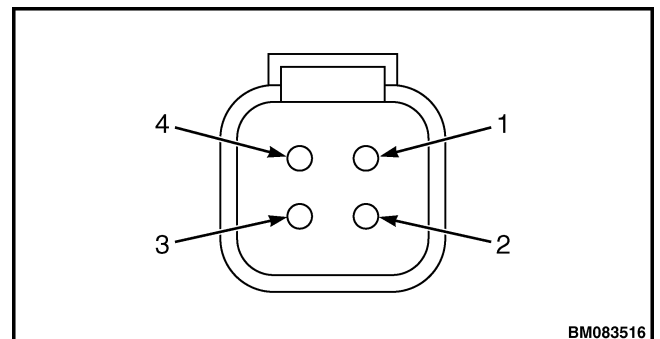


Figure 112. Steer Axle Sensor Pin Out

Pin	Description	Description
1	GND	SIGNAL GROUND
2	5V	VCC
3	ANALOG/ DIGITAL	SIGNAL 2
4	ANALOG/ DIGITAL	SIGNAL 1

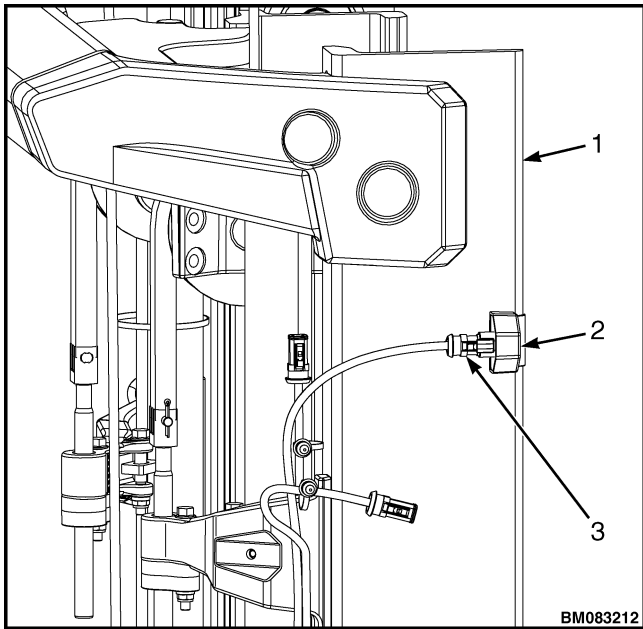
Mast

These sensors are located on or near the mast.

Mast Lift Height Sensor (Discrete)

This sensor is a component of the Dynamic Stability System (DSS). It is mounted directly to the right-hand outer mast channel and acts like a switch. A magnet mounted to the carriage activates the sensor when it passes by.

NOTE: Sensor is attached to mast with an adhesive, no mechanical fasteners are used.



- 1. RH OUTER MAST
- 2. SENSOR
- 3. ELECTRICAL CONNECTOR

Figure 113. Mast Height Sensor (Discrete)

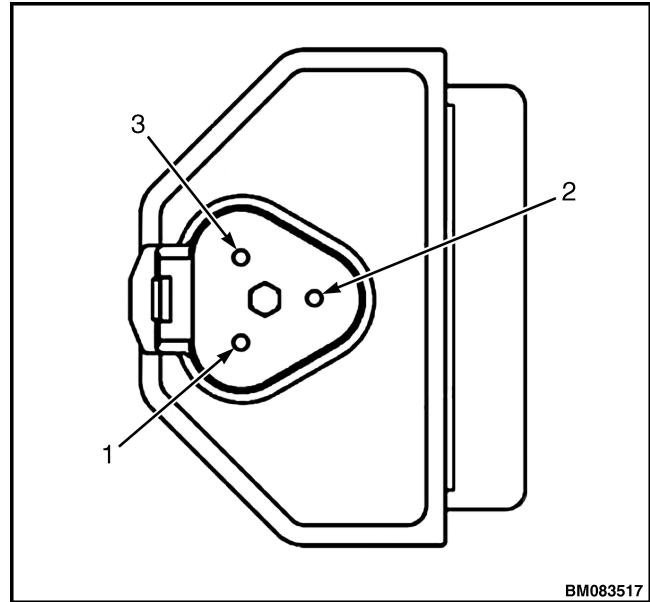
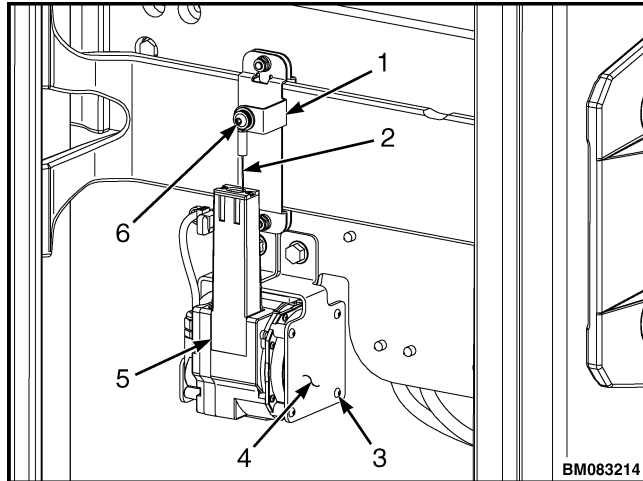


Figure 114. Mast Height Sensor (Discrete) Pin Out

Item	Pin	Type	Description
1	A	5V/12V	5 - 12 SUPPLY VOLTAGE
2	B	ANALOG/DIGITAL	SIGNAL VOLTAGE OUTPUT
3	C	GND	GROUND

Mast Height Sensor (Continuous)

The continuous mast height sensor is attached to the mast and allows fork position to be constantly monitored. This is used with the shelf height selector option and is a string pot type device with a stainless steel cable.



1. STRING POT BRACKET
2. STAINLESS STEEL CABLE
3. TORX SCREWS
4. SENSOR BRACKET (RH)
5. SENSOR
6. TORX SCREW, WASHER, LOCKNUT

Figure 115. Mast Height Sensor (Continuous), Rear View

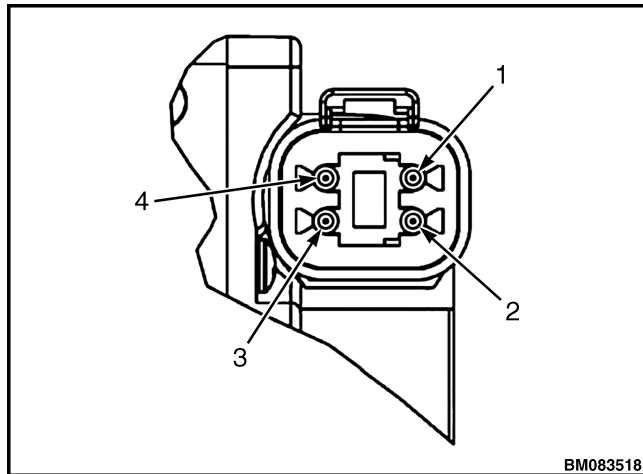
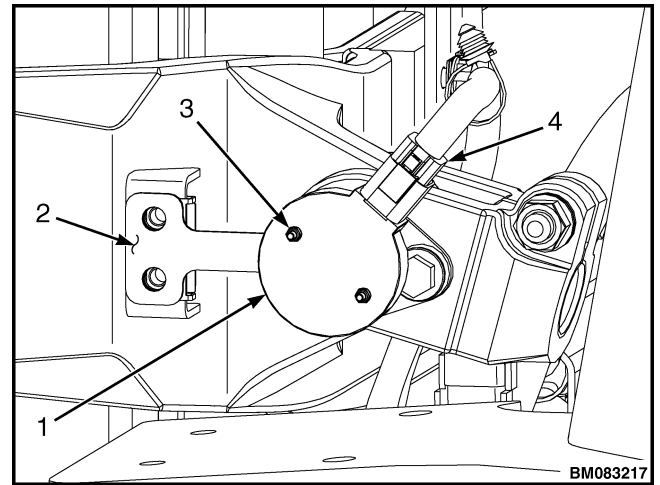


Figure 116. Mast Height Sensor (Continuous) Pin Out

Pin	Temp	Description
1		INPUT
2		COMMON
3	CAN Hi	CAN HIGH
4	CAN Lo	CAN LOW

Mast Tilt Sensor

The mast tilt sensor is mounted to the end of the tilt clevis and the angle sensor monitors the tilt angle of the mast. This sensor is also a key part of the Dynamic Stability System (DSS) and Return to Set Tilt (RTST) function that allows the operator to set a defined angle for the mast tilt to stop at between the tilt limits of the truck.



1. SENSOR
2. MAST SENSOR BRACKET
3. TORX SCREW AND NUT
4. WIRE HARNESS CONNECTOR

Figure 117. Mast Tilt Sensor (Guard Bracket Removed)

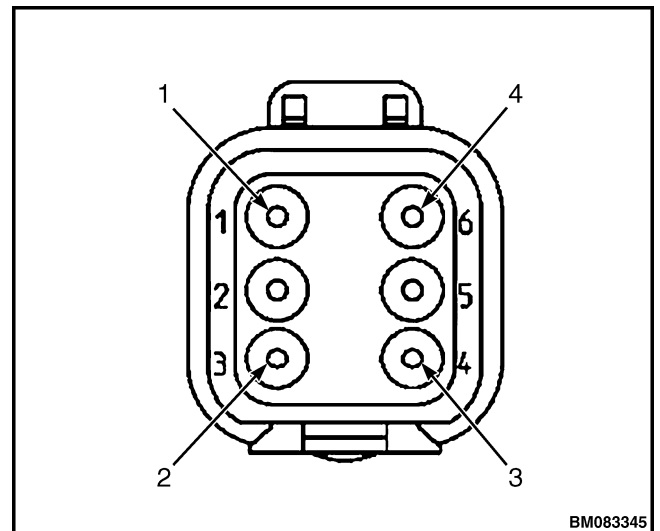


Figure 118. Mast Tilt Sensor Pin Out

Pin	Type	Description
1	GND	POWER GROUND
2	12V	SUPPLY POWER
3	NOT CONNECTED	NOT CONNECTE D
4	NOT CONNECTED	NOT CONNECTE D
5	CAN Lo	CAN - LO
6	CAN Hi	CAN - HI

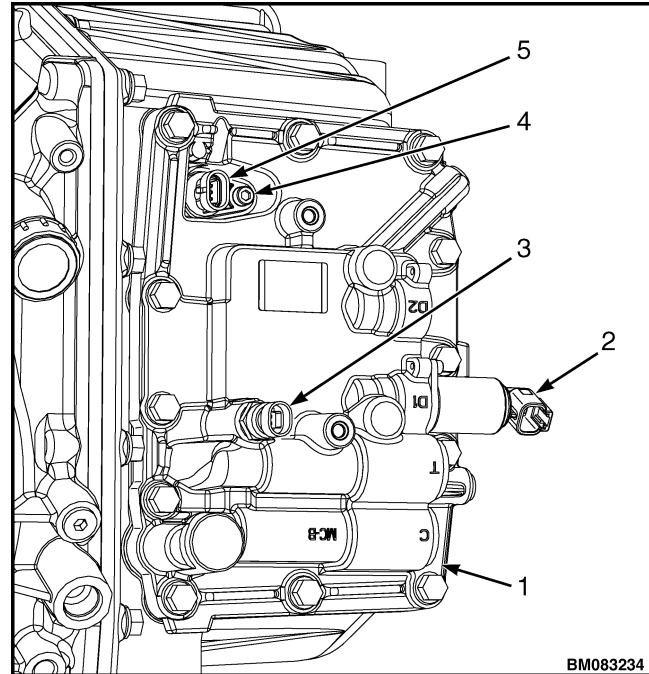
Transmission Sensors

These sensors are located on or near the transmission.

Transmission Output Shaft Sensor (TOSS)

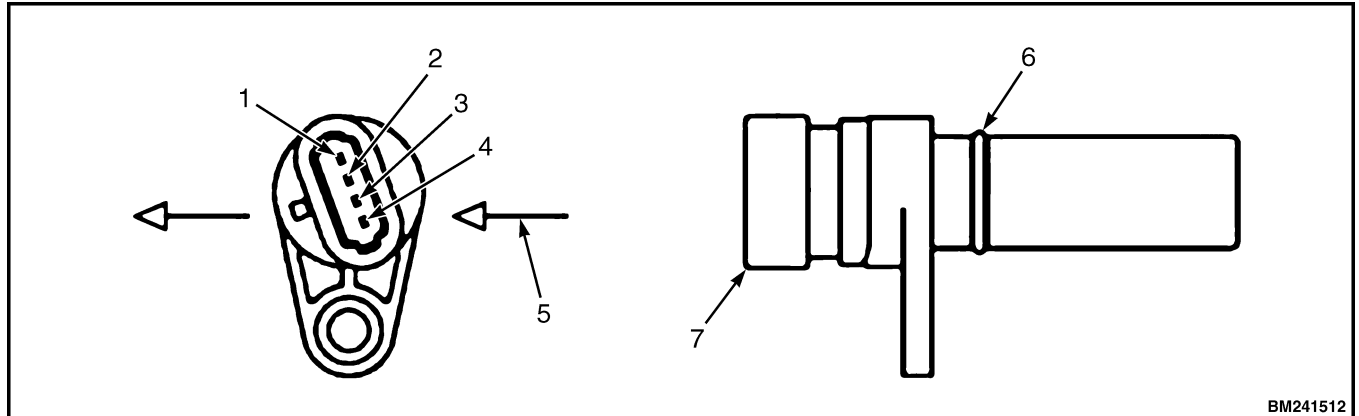
The transmission output shaft sensor is used to monitor truck speed. It is a component of the Dynamic Stability System (DSS).

For sensor location refer to item 5, Figure 119.



1. TRANSMISSION CONTROL VALVE
2. PRESSURE SENSOR
3. TEMPERATURE SENSOR
4. BOLT
5. SPEED SENSOR

Figure 119. Transmission Sensors



BM241512

1. PIN D
2. PIN C
3. PIN 2
4. PIN 1
5. GEAR TOOTH PASS DIRECTION WHEN CHANNEL A LEADS CHANNEL B
6. O-RING
7. TERMINAL HOUSING

Figure 120. TOSS Sensor Pin Out

Pin	Type	Description
A	INPUT	ELECTRIC CHANNEL B
B	INPUT	ELECTRIC CHANNEL A
C	5/12V	VCC SUPPLY
D	GND	GROUND

Pressure Sensor

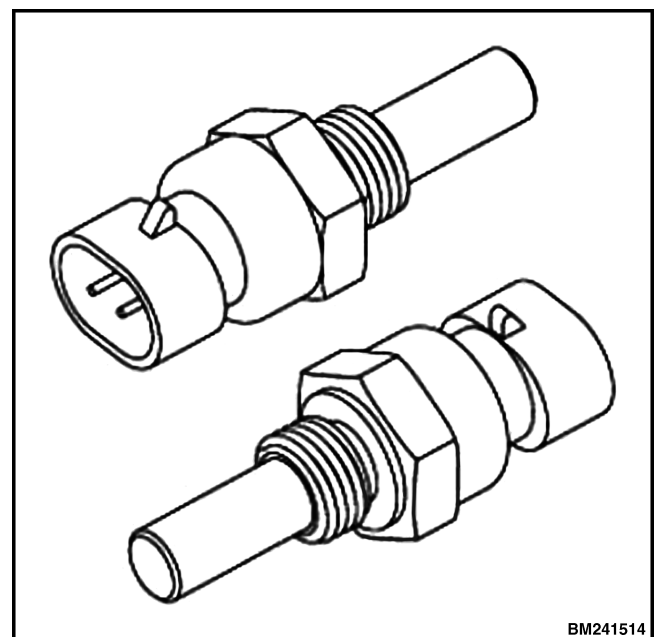
The transmission pressure sensor is used to monitor transmission hydraulic pressure.

For sensor location refer to item 2, Figure 119.

Temperature Sensor

The transmission temperature sensor is used to monitor the transmission hydraulic fluid temperature.

For sensor location refer to item 3, Figure 119.



BM241514

Figure 121. Temperature Sensor

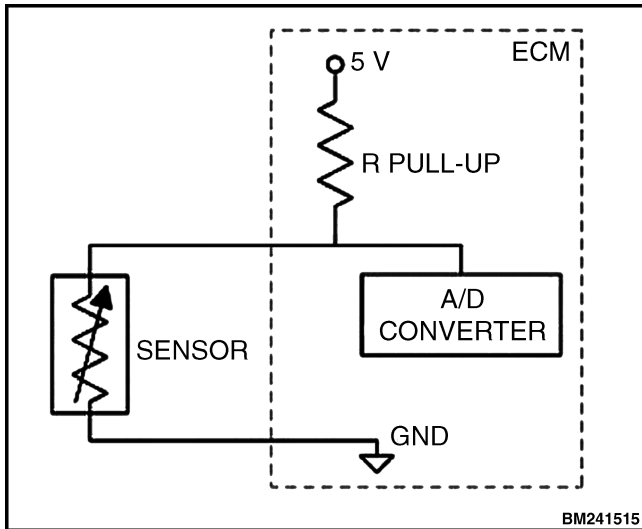


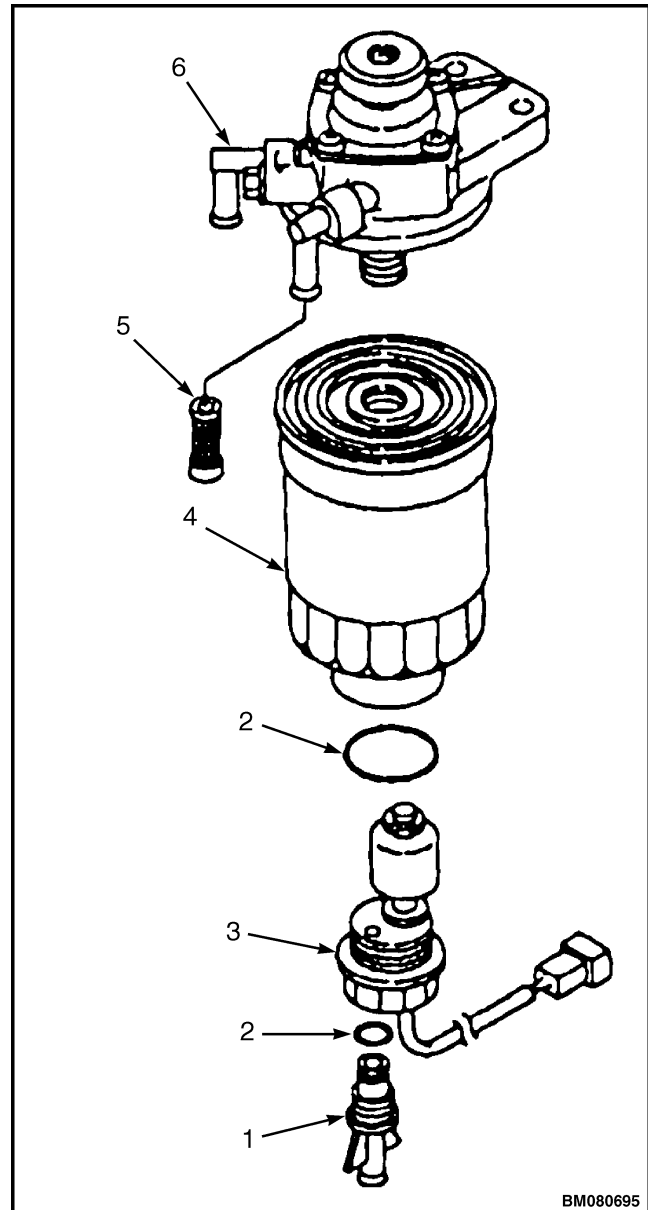
Figure 122. Temperature Sensor Electrical Schematic

Fuel

These sensors are located on or near the fuel system.

Fuel Water Separator Sensor

The fuel water separator sensor detects the amount of water in the unit. An indicator graphic will be displayed when a significant amount of water has been collected in the fuel filter-water separator.

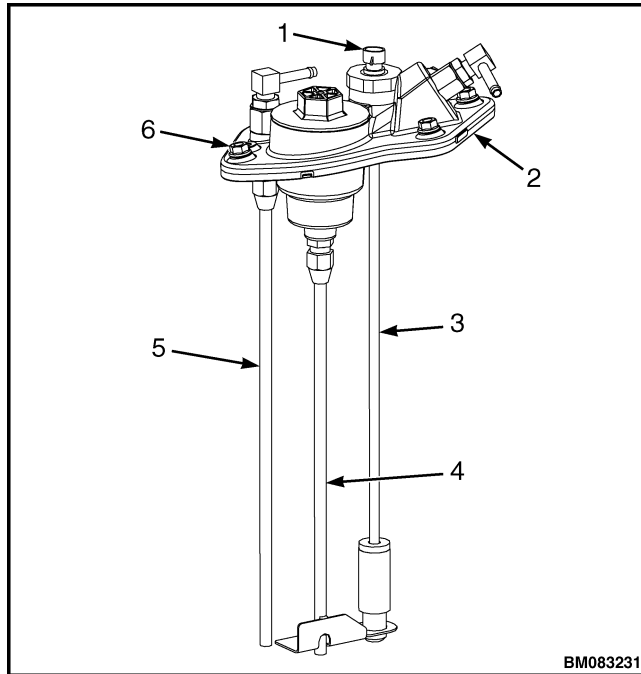


1. DRAIN PLUG
2. O-RING
3. FUEL/WATER SEPARATOR SENSOR
4. FUEL FILTER ELEMENT BODY
5. FUEL FILTER
6. FUEL FILTER COVER

Figure 123. Fuel Water Separator Sensor

Fuel Level Sensor (Gas and Diesel Engines)

The fuel level sensor detects the fuel level in the fuel tank.



1. FUEL LEVEL SENSOR ELECTRICAL CONNECTOR
2. FUEL LEVEL SENSOR MANIFOLD
3. FUEL LEVEL SENSOR
4. FUEL SUPPLY TUBE
5. FUEL RETURN TUBE
6. CAPSCREWS

Figure 124. Fuel Level Sensor

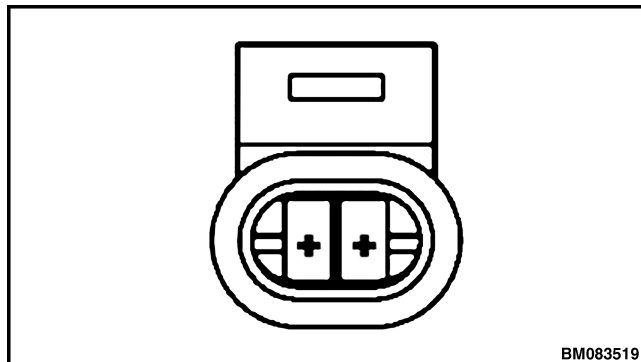
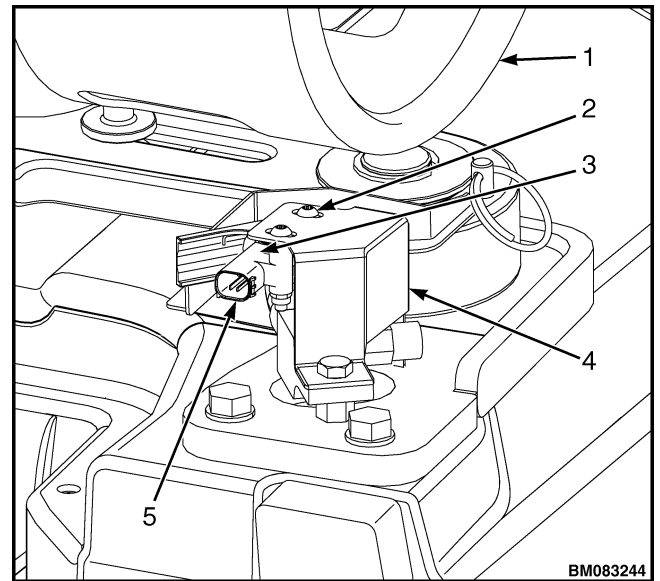


Figure 125. Fuel Level Sensor Connector

LPG Tank Bracket Sensor

The LPG tank bracket sensor is an interlock that tells the truck control system whether the LPG tank bracket is closed or open. If the LPG tank bracket is not fully closed and secured a visible warning on the main display will appear and the truck will not go into gear, it will remain in neutral regardless of operator input. This feature is for swing-out and swing-out drop-down tank brackets only.



1. LPG TANK
2. CAPSCREW AND NUT
3. POSITION SENSOR
4. BRACKET
5. SENSOR CONNECTOR

Figure 126. LPG Tank Bracket Sensor

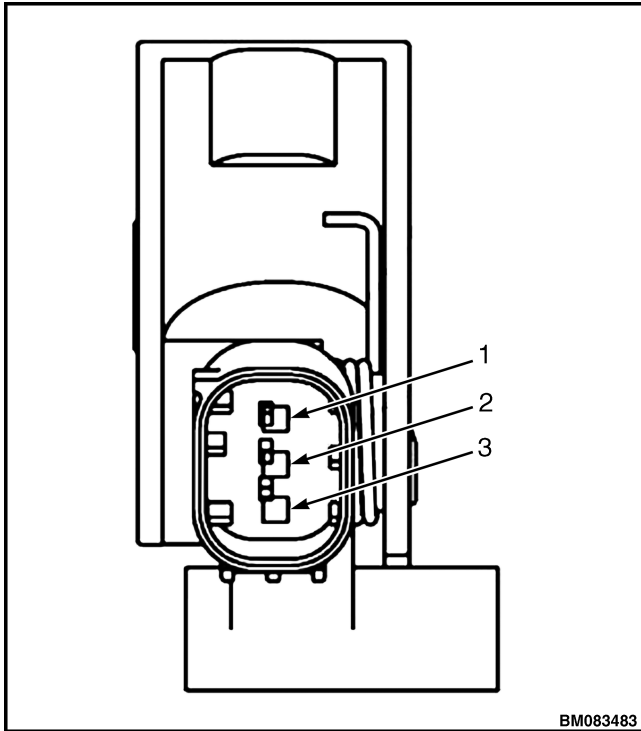
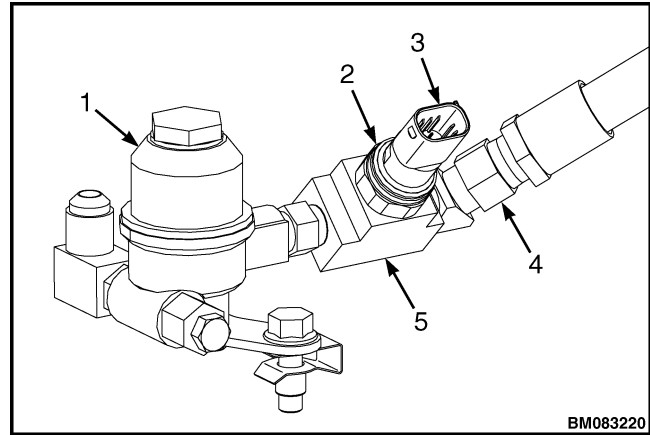


Figure 127. LPG Tank Bracket Sensor Pin Out

Item	Pin	Type	Description
1	3	GND	SIGNAL GROUND
2	2	ANALOG/ DIGITAL INPUT	SIGNAL
3	1	5V	(+5 DC)

Fuel Quality Sensor (FQS) - LPG and Dual Fuel Engines

The fuel quality sensor works by analyzing the fuel for propane and butane and adjusts the engine parameters automatically. The FQS also acts as a fuel warning sensor giving the operator a warning of about 10 minutes before the truck will run out of fuel. The fuel warning indicator is shown as required on the display of the truck.



- 1. LPG FILTER
- 2. FUEL QUALITY SENSOR
- 3. WIRE HARNESS CONNECTOR
- 4. FUEL SUPPLY SWIVEL CONNECTOR
- 5. FUEL QUALITY SENSOR VALVE BLOCK

Figure 128. Fuel Quality Sensor

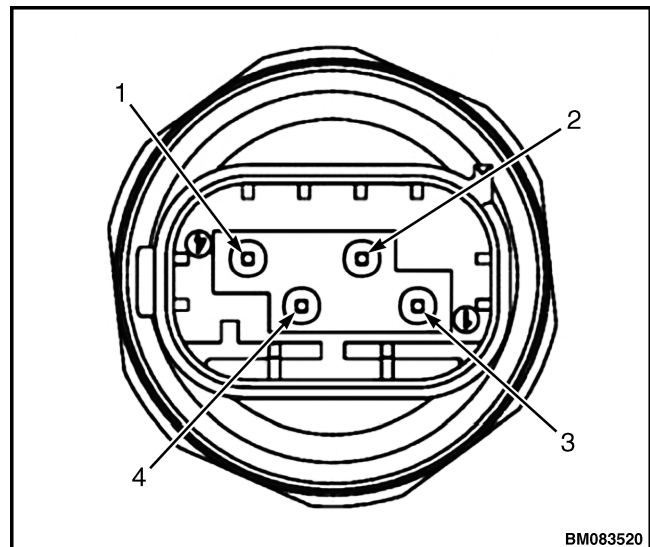


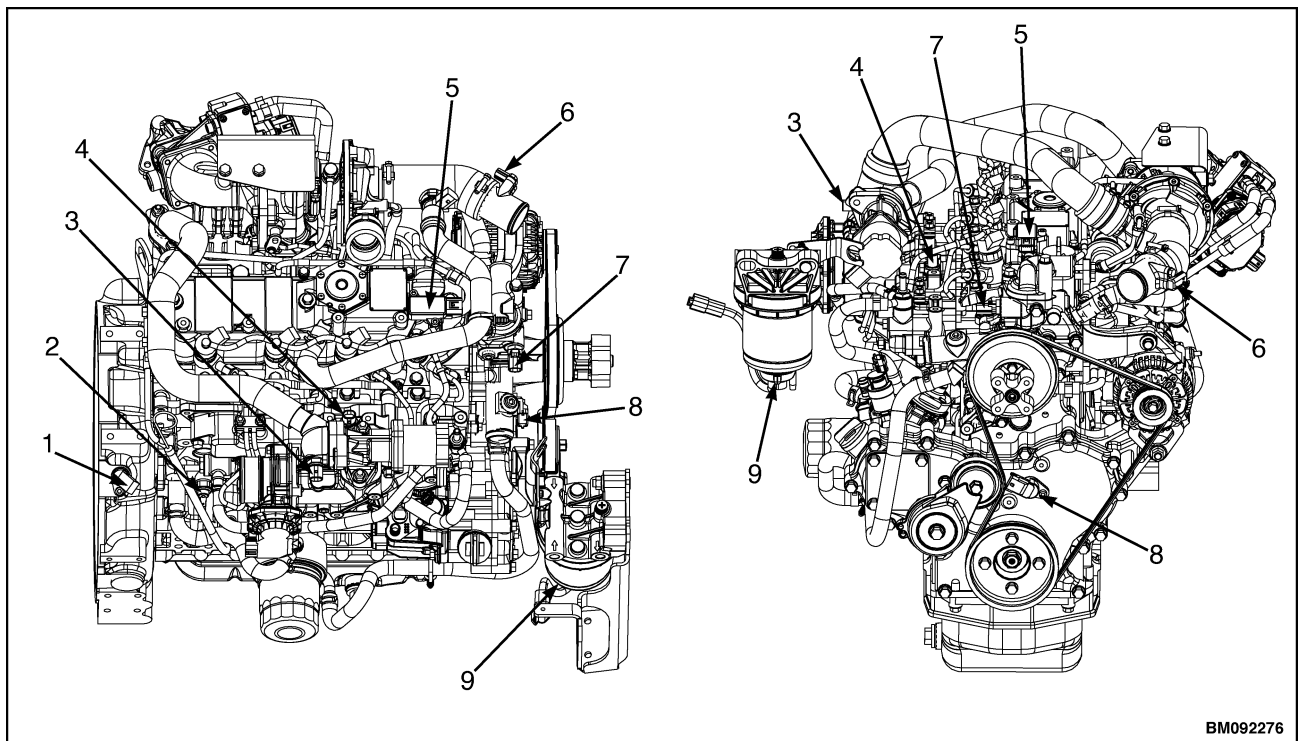
Figure 129. Fuel Quality Sensor Pin Out

Pin	Type	Description
1	V IN	POWER TERMINAL
2	V OUT	PRESSURE OUTPUT TERMINAL
3	GND	GROUND TERMINAL
4	V OUT	TEMPERATURE OUTPUT TERMINAL

Engine

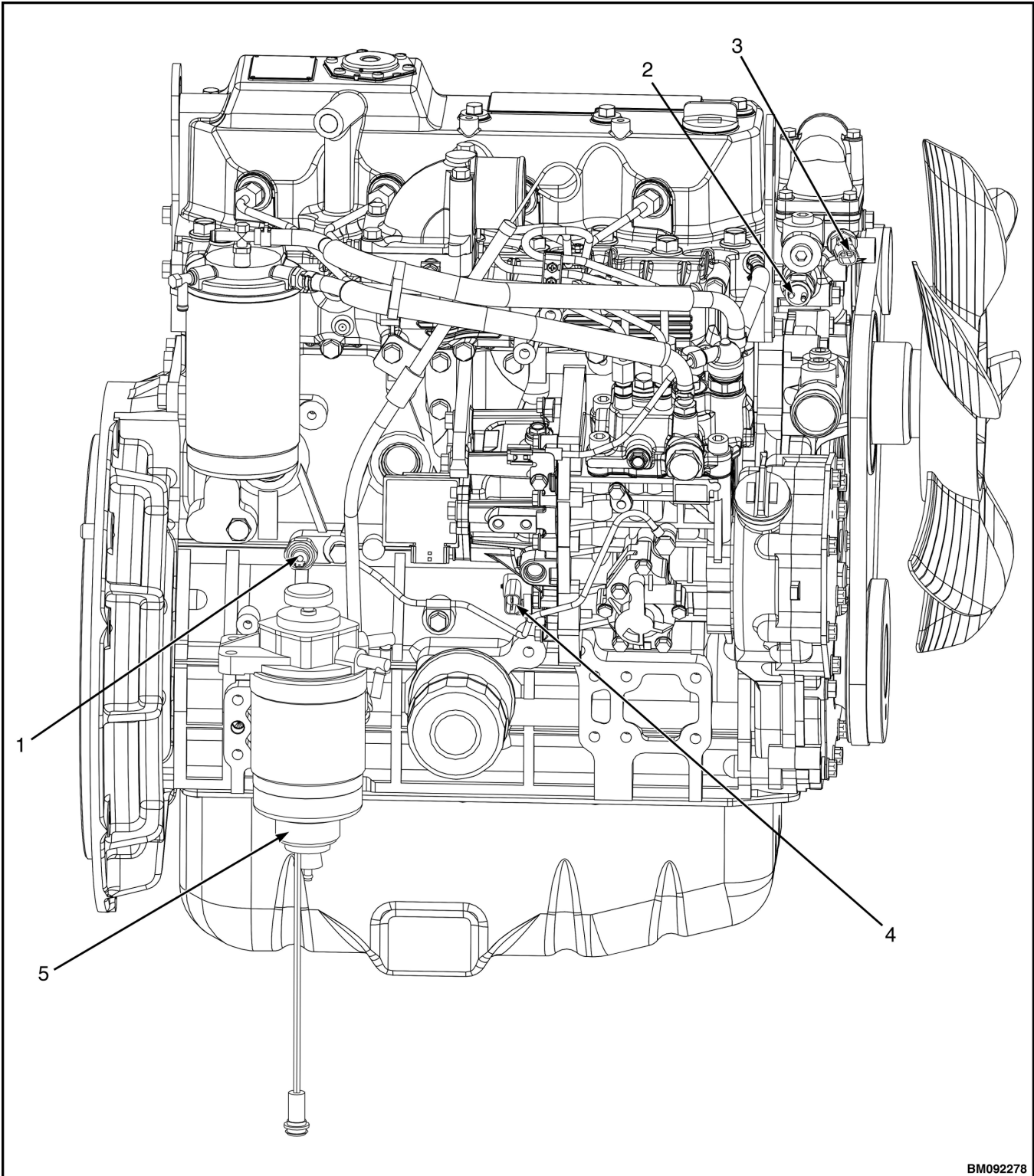
These sensors are located on or near the engine.

NOTE: For details and additional engine sensors refer to Diesel engine description.



- | | |
|-------------------------------|-----------------------------------|
| 1. CRANK ROTATION SENSOR | 6. TURBO INLET TEMPERATURE SENSOR |
| 2. OIL PRESSURE SWITCH | 7. COOLANT TEMPERATURE SENSOR |
| 3. EGR GAS TEMPERATURE SENSOR | 8. CAM SPEED SENSOR |
| 4. INTAKE TEMPERATURE SENSOR | 9. FUEL/WATER SEPARATOR SENSOR |
| 5. PRESSURE SENSOR | |

Figure 130. 2.1L Diesel Engine Sensors and Switches

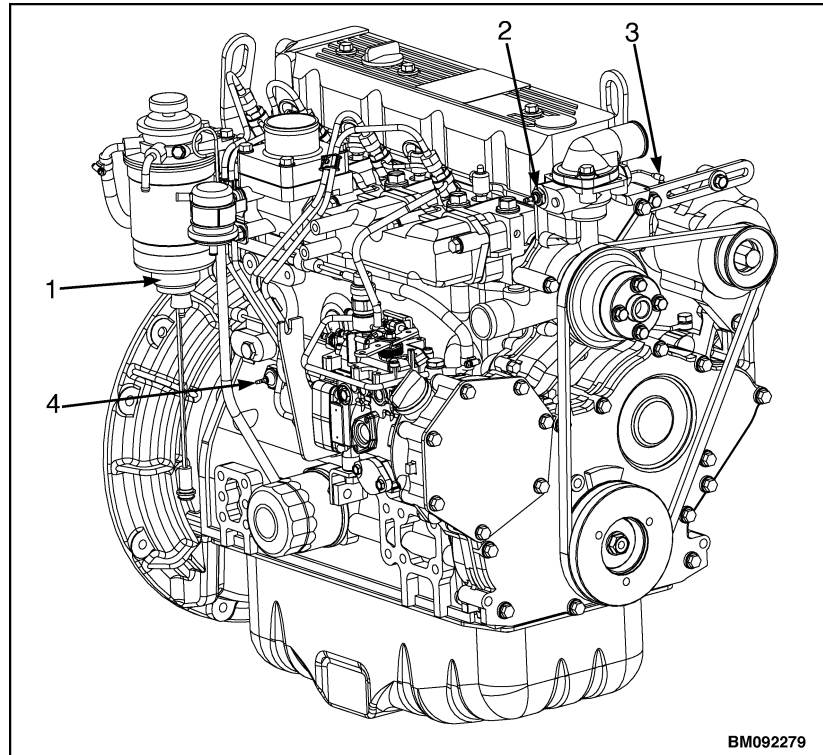


BM092278

Figure 131. 3.0L Diesel engine sensors and switches

Legend for Figure 131.

- | | |
|---|--------------------------------------|
| 1. OIL PRESSURE SWITCH | 4. ROTATION SENSOR (3.0L GB IV ONLY) |
| 2. COOLANT TEMPERATURE SWITCH (3.0L GB IV ONLY) | 5. FUEL/WATER SEPARATOR SENSOR |
| 3. COOLANT TEMPERATURE SENSOR | |



- | | |
|--------------------------------|-------------------------------|
| 1. FUEL/WATER SEPARATOR SENSOR | 3. COOLANT TEMPERATURE SENSOR |
| 2. COOLANT TEMPERATURE SWITCH | 4. OIL PRESSURE SWITCH |

Figure 132. 3.3L Diesel engine sensors and switches

Oil Pressure Sensor

The oil pressure sensor monitors the pressure created by the oil pump. If the oil pressure drops below a set level an engine shutdown sequence will be initiated.

For sensor location refer to Figure 130.

Engine Coolant Temperature (ECT) Sensor

The engine coolant temperature sensor behaves in the opposite manner of a resistor. As temperature rises the resistance of the sensor goes down. When the coolant temperature is low the feedback voltage will also be low as the sensor resistance is high. Once the coolant temperature increases, the resulting feedback voltage will also increase.

For sensor location refer to Figure 130.

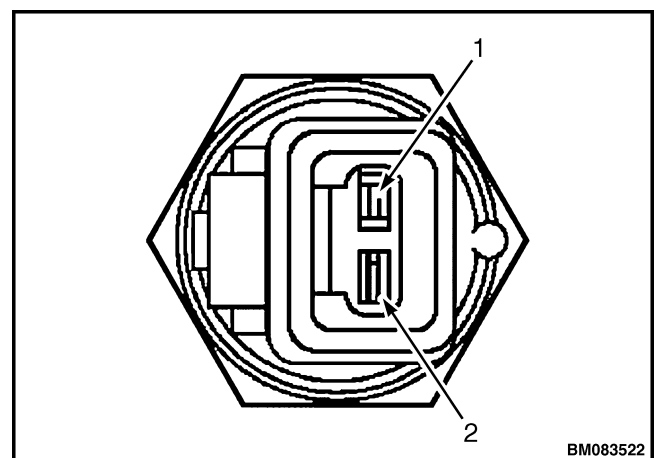


Figure 133. ECT Sensor Pin Out

Pin	Type	Description
1	5/12V	Vout
2	GND	GROUND

Engine Speed Sensor

The engine speed sensor is a differential Hall effect sensor that mates with an encoder made of magnetic material. The encoder wheel is mounted on the engine flywheel. This sensor effectively detects the encoder teeth and gaps indicating angular position of the crankshaft. The resulting feedback is a consistent square wave that corresponds with the pattern of the encoder wheel. The wave form is predictable and indicates to the engine ECU the rate the crankshaft is turning.

For sensor location refer to Figure 130.

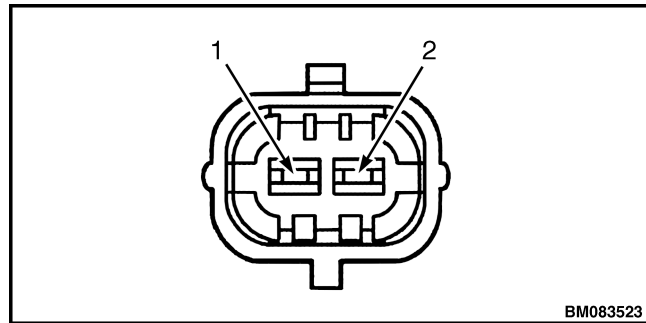


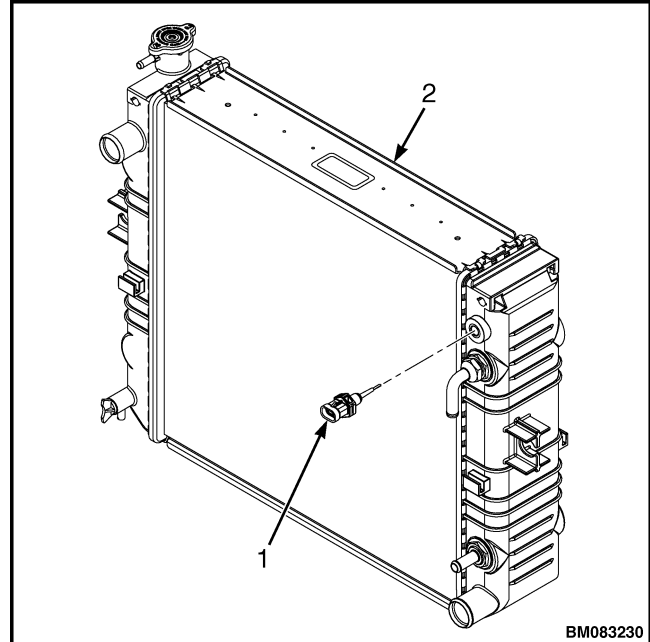
Figure 134. Engine Speed Sensor Pin Out

Pin	Type	Description
1	5/12V	Vout A
2	5/12V	Vout B

Low Coolant Level Sensor

The low coolant sensor detects the coolant level in the radiator and will illuminate an icon on the operator display when the coolant level is below a recommended level.

NOTE: If the truck does not have a low coolant sensor, a plug will be installed in place of the sensor.



- 1. LOW COOLANT LEVEL SENSOR
- 2. RADIATOR

Figure 135. Low Coolant Level Sensor

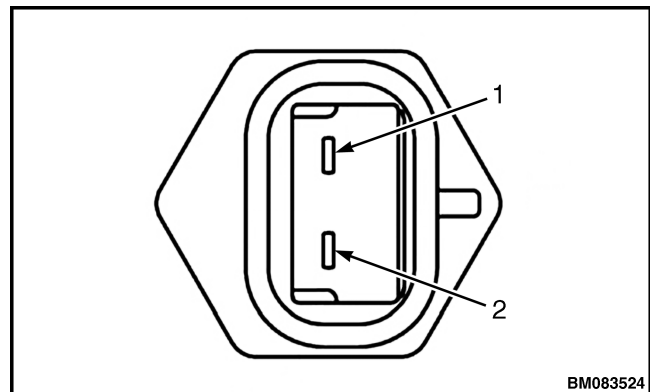


Figure 136. Low Coolant Level Sensor Pin Out

Pin	Description
1	POSITIVE (+)
2	NEGATIVE (-)

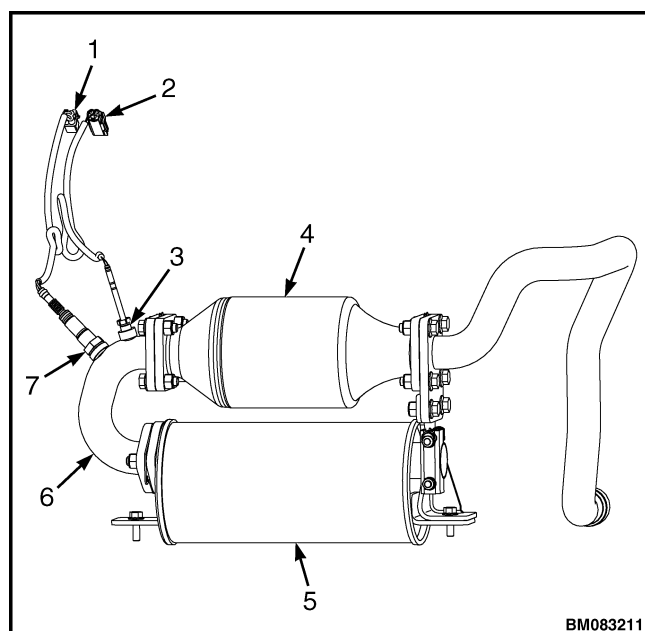
Exhaust System

These sensors are located on or near the exhaust system.

Heated Oxygen Sensor

This sensor constantly makes comparisons between the oxygen content inside the exhaust manifold and the air outside the engine. If a rich or lean air/fuel mixture is sensed in the exhaust, the sensor provides a signal to the Engine Control Unit (ECU). The ECU will then make an adjustment to the fuel-air mixture.

For sensor location refer to item 7, Figure 137.



1. HEATED OXYGEN SENSOR HARNESS
2. EXHAUST EGT SENSOR HARNESS
3. EXHAUST EGT SENSOR
4. CATALYTIC CONVERTER
5. MUFFLER
6. EXHAUST PIPE
7. HEATED OXYGEN SENSOR

Figure 137. Exhaust Gas Sensors

Exhaust Gas Temperature (EGT) Sensor

The EGT sensor detects the exhaust gas temperature and sends the data to the VSM.

For sensor location refer to item 3, Figure 137.

EGR Temperature Sensor

The EGR temperature sensor behaves in the opposite manner of a resistor. As temperature rises the resistance of the sensor goes down. So when exhaust gas temperature is low the feedback voltage will also be low as the sensor resistance is high. Once the coolant temperatures increase so will the resulting feedback voltage.

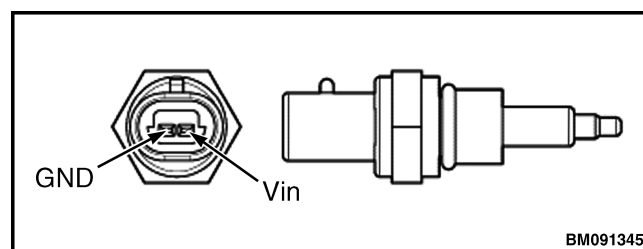
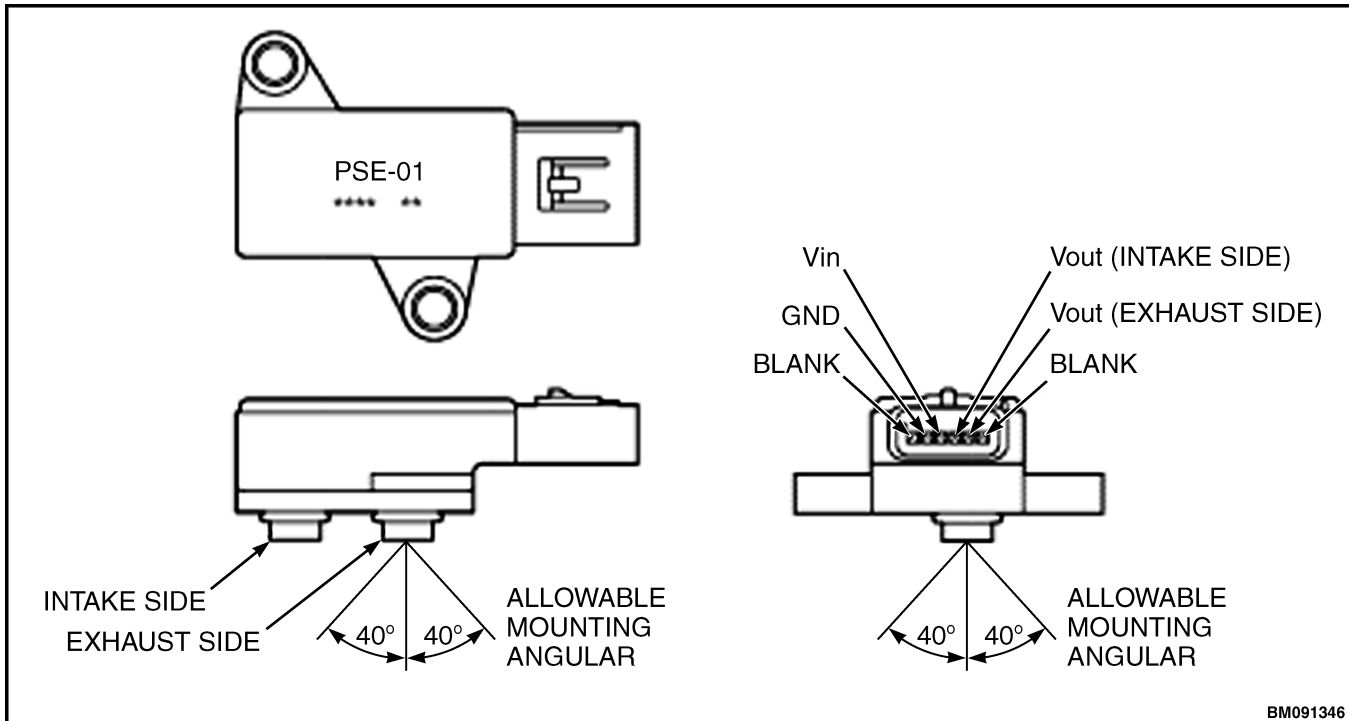


Figure 138. EGR Temperature Sensor

EGR Pressure Sensor

The EGR pressure sensor assembly contains two transducers. One side of the sensor is exposed to a port at intake pressure. The other is exposed to a port at exhaust manifold pressure. To regulate the valve position and control exhaust flow for recombustion feedback from this sensor is used by the engine controller to drive the valve to keep combustion temperatures as low as possible while not negatively impacting performance.



BM091346

Figure 139. EGR Pressure Sensor

OTHER COMPONENTS

Rear view camera

The truck features a rear view camera. The rear view camera is mounted on a bracket that attaches at the top of the overhead guard in the rear of the lift truck. A wire harness connects the rear view camera to the NCEA display or a separate display mounted behind the operator in the operator compartment. From the display the operator can view a screen that shows images captured by the rear view camera. The rear view screen on the display is activated after selecting a reverse travel direction.



HO191317

Figure 140. Rear view camera



BO193235

Figure 141. Rear view display, rear mounted option



BO193234

Figure 142. Rear view display, front mounted option

CONTROLLER AREA NETWORK (CAN) DESCRIPTION 202001-147

CONTROLLER AREA NETWORK (CAN)

The CAN is an International Standardization Organization (ISO) defined serial communications Binary Unit System (BUS) originally developed for the automotive industry to replace the complex wiring harness with a twisted, two-wire bus. The specification calls for high immunity to electrical interference and the ability to self-diagnose and repair data errors. The CAN communications protocol, ISO-11898-1: 2015, describes how information is passed between devices on a network and conforms to the Open Systems Interconnection (OSI) model that is defined in terms of layers. Actual communication between devices connected by the physical medium is defined by the physical layer of the model. Multiple pieces of information can be sent on this bus, an operation commonly referred to as multiplexing. The CAN conforms to the Society of Automotive Engineers (SAE) J1939 standards.

CAN communications allows the different modules to communicate with each other. This allows the sharing of information between modules, and eliminates the need for each module to be hard wired to each sensor. Using the CAN, information that may be received by only one module, can then be shared with all other modules. The information is sent out over the CAN in an encoded form and any other module that requires the information can pick it out from the data stream.

Fault confinement is also a major benefit of CAN. Faulty nodes are automatically dropped from the bus, which prevents any single node from bringing a network down, and ensures that bandwidth is always available for critical message transmission. This error containment also allows nodes to be added to a bus while the system is in operation, otherwise known as hot-plugging.

Operation

CAN bus uses two dedicated wires for communication. The wires are called CAN high and CAN low. The CAN controller is connected to all the components on the network via these two wires. Each network node has a unique identifier. All Electronic Control Units (ECUs) on the bus are effectively in parallel and all the nodes see all of the data, all of the time. A node only responds when it detects its own identifier. Individual nodes can be removed from the network without affecting the other nodes.

The nature of CAN bus communications allows all modules to transmit and receive data on the bus. Any module can transmit data, which all the rest of the modules receive. It is very important that the CAN bus bandwidth is allocated to the most safety-critical systems first. Nodes are usually assigned to one of a number of priority levels. For example, engine controls, and brakes are very important from a safety viewpoint, and commands to activate these systems are given highest priority. This means that they will be actioned before less critical ones. Other devices are medium priority, and lighting activation may be the lowest priority. A process known as arbitration decides the priority of any messages.

When the CAN bus is in idle mode, both lines carry 2.5V. When data bits are being transmitted, the

CAN high line goes to 3.75V and the CAN low drops to 1.25V, thereby generating a 2.5V differential between the lines: each of the CAN lines is referenced to the other one, not to vehicle ground. Since communication relies on a voltage differential between the two bus lines, the CAN bus is NOT sensitive to inductive spikes, electrical fields or other noise.

Standard CAN

The CAN communication protocol is a carrier-sense, multiple-access protocol with message collision detection and arbitration on message priority. Each node, or ECU, on a bus must wait for a prescribed period of inactivity before attempting to send a message and collisions are resolved through a bit-wise arbitration, based on a preprogrammed priority of each message in the identifier field of a message. The higher priority identifier always wins bus access. That is, the last logic high in the identifier keeps on transmitting because it is the highest priority. The ISO-11898 Standard, with the 11-bit identifier, provides for signaling rates from 125 kbps to 1 Mbps. The 11-bit identifier field provides for 211, or 2,048 different message identifiers. The standard was later amended with the extended 29-bit identifier. The extended 29-bit identifier provides for 229, or 537 million message identifiers.

Identifier Fields

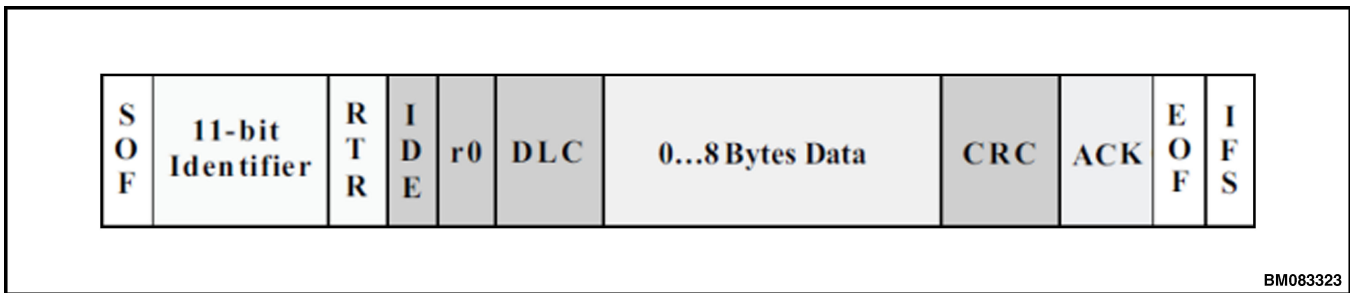


Figure 143. 11-Bit Identifier Fields

Table 18. Identifier Fields Defined

SOF (Start of Frame)	The single dominant SOF bit marks the start of a message, and is used to synchronize the nodes on a bus after being idle.
11-Bit Identifier	The Standard CAN 11-bit identifier establishes the priority of the message. The lower the binary value, the higher its priority.
RTR (Remote Transmission Request)	The single RTR bit is dominant when information is required from another node. All nodes receive the request, but the identifier determines the specified node. The responding data is also received by all nodes and used by any node interested. In this way, all data being used in a system is uniform.
IDE (Identifier Extension)	A dominant single IDE bit means that a standard CAN identifier with no extension is being transmitted.
r0 (Reserved bit)	For possible use by future standard amendment.
DLC (Data Length Code)	The 4-bit data length code contains the number of bytes of data being transmitted.
0...8 Bytes Data	Up to 64 bits of application data may be transmitted.
CRC (Cyclic Redundancy Check)	The 16-bit (15 bits plus delimiter) CRC contains the checksum (number of bits transmitted) of the preceding application data for error detection.
ACK (ACKnowledge)	Every node receiving an accurate message overwrites this recessive bit in the original message with a dominant bit, indicating an error-free message has been sent. Should a receiving node detect an error and leave this bit recessive, it discards the message and the sending node repeats the message after re arbitration. In this way, each node acknowledges (ACK) the integrity of its data. ACK is 2 bits, one is the acknowledgment bit and the second is a delimiter.
EOF (End Of Frame)	The EOF 7-bit field marks the end of a CAN frame (message) and disables bitstuffing, indicating a stuffing error when dominant. When 5 bits of the same logic level occur in succession during normal operation, a bit of the opposite logic level is stuffed into the data.
IFS (Inter Frame Space)	The 7-bit IFS contains the time required by the controller to move a correctly received frame to its proper position in a message buffer area.

Message Types

CAN allows for four different message types: 1) Data Frame, 2) Remote Frame, 3) Overload Frame, and 4) Error Frame.

1. Data Frame - A standard CAN data frame makes use of the identifier, the data, and data length code, the cyclic redundancy check, and the acknowledgment bits. Both the RTR and IDE bits are dominant in data frames. If the recessive acknowledge bit at the receiving end is overwritten by a dominant bit, both the transmitter and receiver recognize this as a successful transmission
2. Remote Frame - A CAN remote frame looks similar to a data frame except for the fact that it does not contain any data. It is sent with the RTR bit in a recessive state; this indicates that it is a remote frame. Remote frames are used to request data from a node.
3. Overload Frame - The overload frame works similarly but is used when a node is receiving frames faster than it can process them. This frame provides a time buffer so the node can catch up.

4. Error Frame - When a node detects an error in a message on the CAN bus, it transmits an error frame. This results in all other nodes sending an error frame. Following this, the node where the error occurred retransmits the message.

Multiple CANs

The system architecture on this truck includes four separate CANs: CAN1, CAN2, CAN3, and CAN4. The core modules are on the vehicle bus, CAN1.

CAN1 (Vehicle Bus)

Nodes on CAN1 are:

- OBox
- Object Detection Sensor
- Camera
- IBox2
- IBox1
- Impact Sensor
- MLM (Mini-Lever Module)

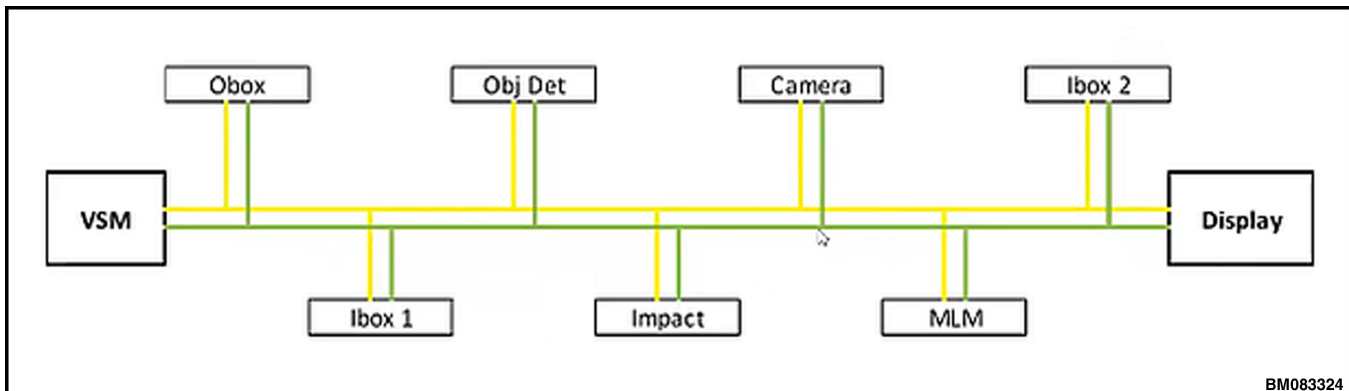


Figure 144. CAN1

CAN2 (DriveTrain Bus)

Nodes on CAN2 are:

- Dash Switch Bank
- Top Wiper Motor
- Front Wiper Motor
- Diagnostic Plug (Under Dash)
- Rear Wiper Motor
- Cab Switch Bank
- HST (Hydrostatic Transmission)
- SA-D (Yanmar Diagnostics)

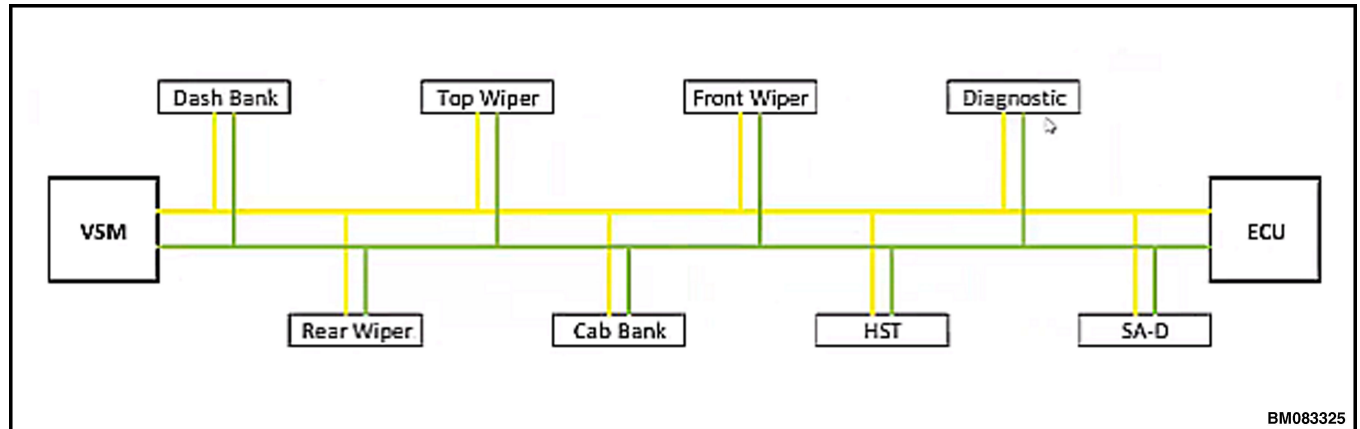


Figure 145. CAN2

CAN3 (Front End)

Nodes on CAN3 are:

- Mast Tilt Sensor
- Fork Height Sensor

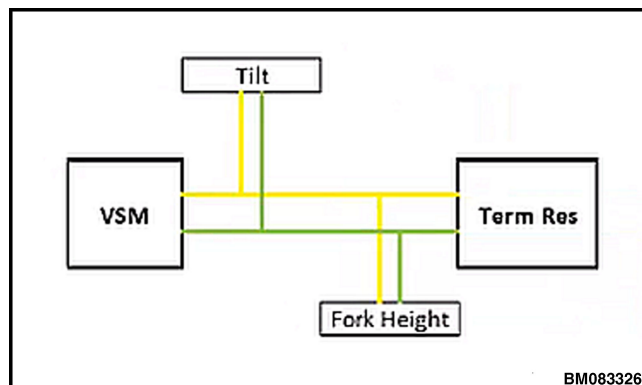


Figure 146. CAN3

CAN4 (Service)

Nodes on CAN4 are:

- Diagnostic
- Smart Antenna

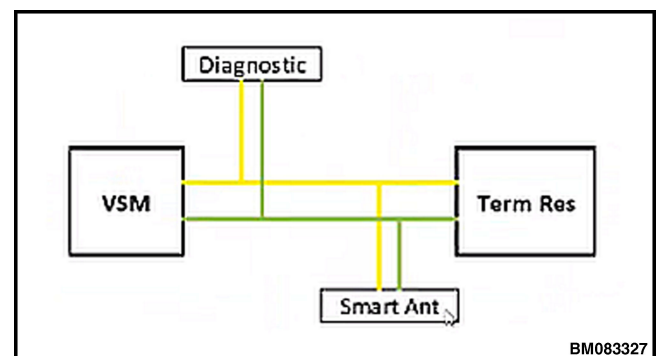


Figure 147. CAN4

CAN Failure

Possible reasons for failure in the CAN BUS network:

1. Peak to peak voltage levels is not correct.
2. Signal is not present on either CAN wire.

The ISO 11898 standard enumerates several failure modes of the CAN bus cable:

1. CAN_H interrupted
2. CAN_L interrupted
3. CAN_H shorted to battery voltage
4. CAN_L shorted to ground
5. CAN_H shorted to ground
6. CAN_L shorted to battery voltage
7. CAN_L shorted to CAN_H wire
8. CAN_H and CAN_L interrupted at the same location
9. Loss of connection to termination network

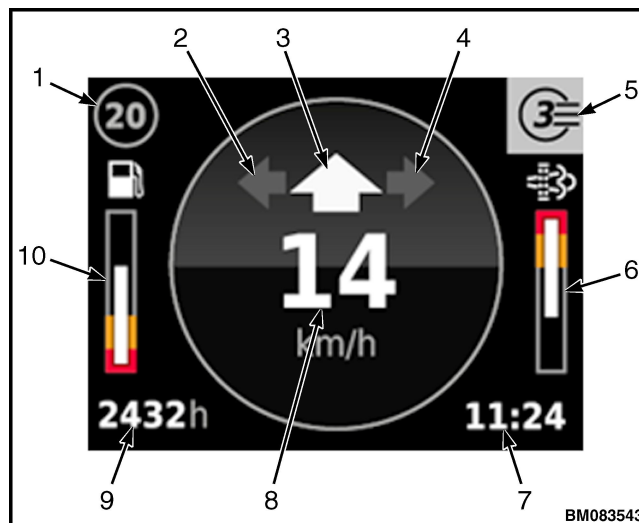
DISPLAY DESCRIPTION**202001-148****DISPLAY DESCRIPTION**

The LCD display is a Controller Area Network (CAN) device that facilitates operator input and reduces the need for conventional hardware switches. The display also replaces conventional gauges in the instrument cluster. Access to truck information, diagnostic alerts, system calibrations, parametric data, and system settings is available. The display is available in 3 sizes: 2.8-inch (71mm), 5-inch (127mm), 7-inch (178mm). All are full color

touch screens and are programmable. Standard display physical location is the upper, right corner of the front overhead guard leg (A-post).

Screen resolution for 2.8-inch display is 320 x 240 pixels, for both 5- and 7-inch displays it is 800 x 480 pixels. Applications designed for the 2.8-inch display will run only on that display. The 5- and 7-inch displays run the same software with the elements appearing larger on the 7-inch display.

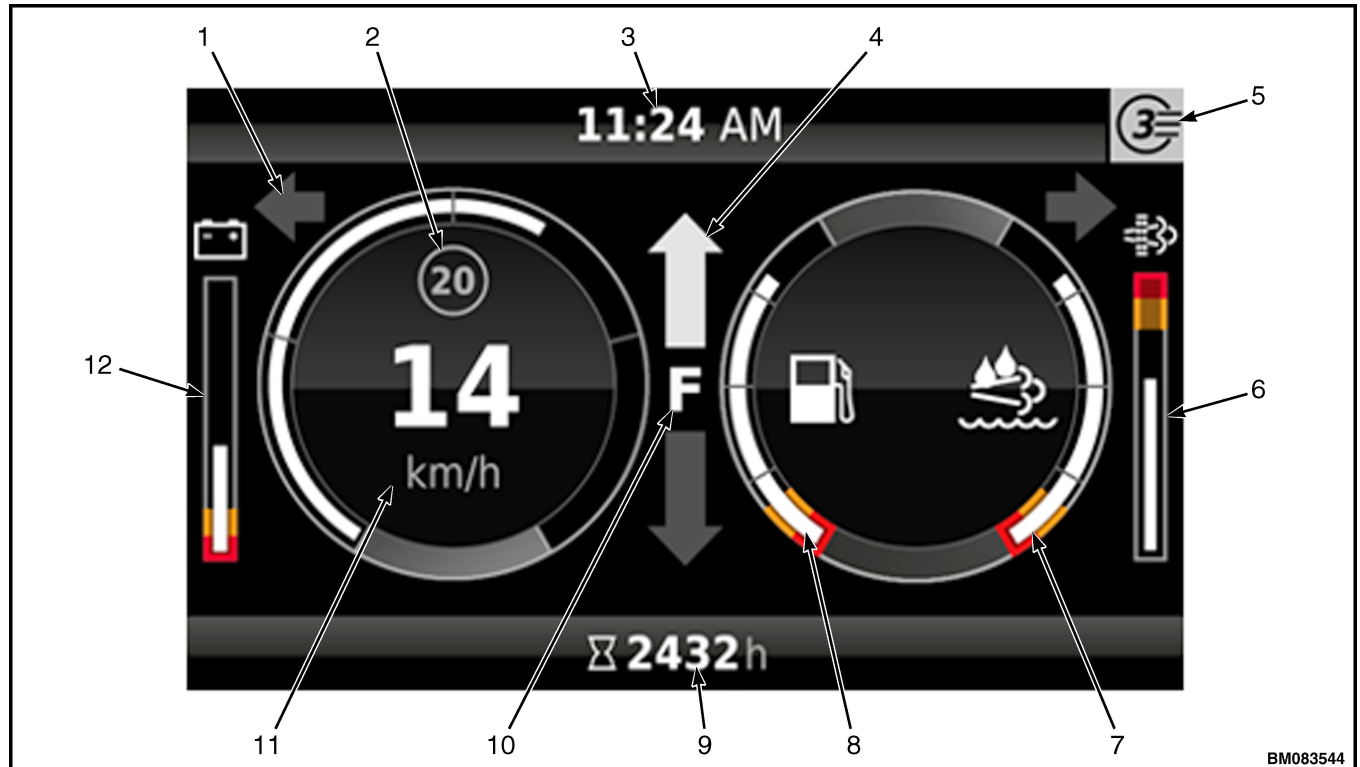
The display software is the main interface that operator, service technician, or supervisor uses to understand truck status, alter truck parameters, and communicate truck fault codes.

2.8-Inch Display

- | | |
|--|--|
| 1. ACTIVE SPEED LIMIT | 6. GAUGE (DIESEL PARTICULATE FILTER SHOWN) |
| 2. LEFT TURN SIGNAL | 7. CLOCK |
| 3. DRIVING DIRECTION INDICATOR (FORWARD SHOWN) | 8. CURRENT VEHICLE SPEED |
| 4. RIGHT TURN SIGNAL | 9. MACHINE OPERATING HOURS |
| 5. PERFORMANCE MODE INDICATOR | 10. GAUGE (FUEL GAUGE SHOWN) |

Figure 148. 2.8-Inch Display

5- or 7-Inch Display



- | | |
|--|--|
| 1. TURN SIGNAL INDICATOR | 7. DIESEL EXHAUST FLUID LEVEL |
| 2. ACTIVE SPEED LIMIT | 8. FUEL LEVEL |
| 3. CLOCK | 9. MACHINE OPERATING HOURS |
| 4. DRIVING DIRECTION INDICATOR (FORWARD SHOWN) | 10. DIRECTION INDICATOR LETTER (F, N, R) - WILL SHOW GEAR NUMBER IN PLACE OF LETTER IF GEAR LOCK IS ACTIVE |
| 5. PERFORMANCE MODE INDICATOR | 11. CURRENT VEHICLE SPEED |
| 6. DIESEL PARTICULATE FILTER | 12. BATTERY STATE OF CHARGE |

Figure 149. 5- or 7-Inch Display

Electrical Specifications

- Input Voltage: 6-36 V DC
- Input Current: 500 mA
- Sleep Current: < 10 mA
- Wake Time (After initial boot): 250ms
- Communications: USB host device, ISO-11898 CAN-Bus
- Power Conditioning: Reverse voltage and over voltage protection

- Video Input(s): Selectable NTSC or PAL

Wake Up

The display LCD wakes up on touch or a key press and is visible and functional 250ms after wake up. Wake up is achieved by power on, CAN communication present, button (if equipped), or touch (if equipped with a touch screen).

Wake Up Output

If a display is awake and no CAN-Bus is detected it will turn on the wake up output. The wake up output pin is intended to turn on the Vehicle System Manager (VSM) if it is in sleep mode. This is the indication that data is needed from the VSM by the display. The output is open collector so as to not interfere with other devices needing wake up on the same input line. The output will pull to sink to ground at 100mA to signal a wake up condition.

Memory Support

All displays support secure memory for back-up of truck serial number, Configuration Data File (CDF), and hour meter data.

Display Viewing

The 5- and 7-inch displays are designed to use either portrait or landscape orientation (not adjustable by operator). The 2.8-inch display can only be viewed in landscape orientation due to its smaller size.

5-BUTTON KEYPAD

NOTE: Your display may or may not have a keypad.

Ambient Light Sensor

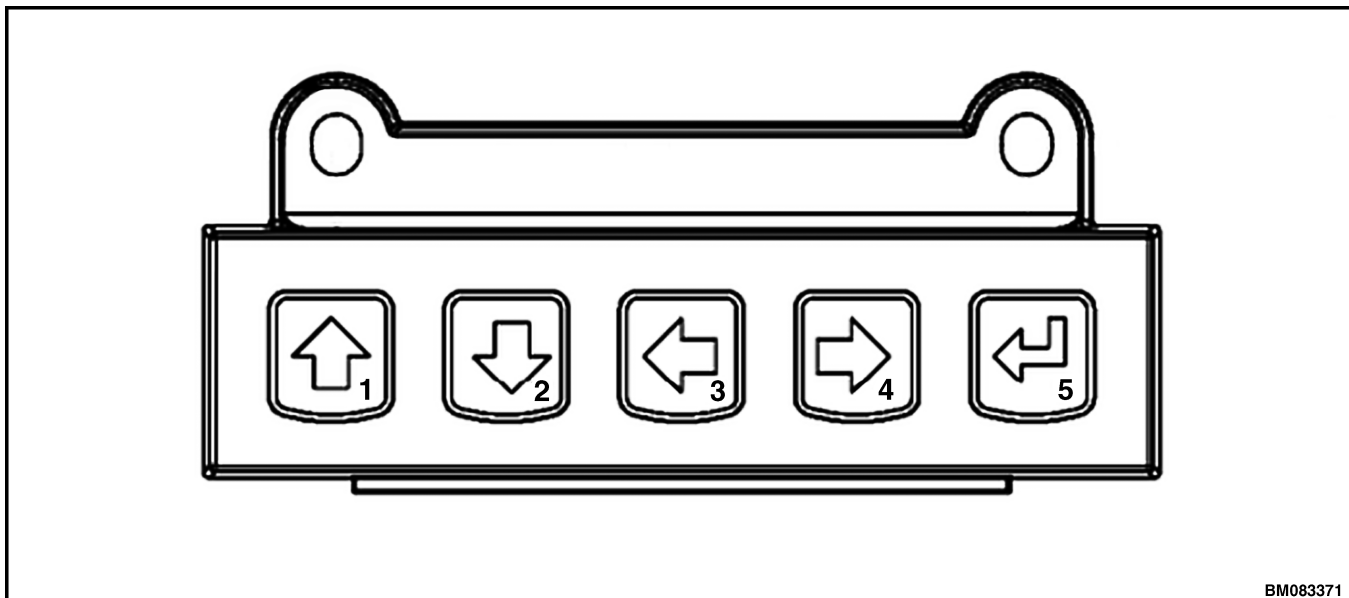
Each display has a built-in photoelectric ambient light sensor and the software automatically adjusts the screen brightness, contrast, and coloration based on the lighting level detected.

Video Inputs

The 5-inch display has a single video input and the 7-inch display has two video inputs. The 7-inch display has the capability to display both video feeds simultaneously. There is no video input available on the 2.8-inch display.

CONTROLLER CAN COMMUNICATIONS

The serial communications can be either 125, 250, or 500kbps using the CAN Open protocol. The display has a single-ended CAN termination resistor tied to CAN LO. The CAN termination is completed by a loop of wire in the harness connecting the other end of the resistor to CAN HI. The display may be shut down by a CAN initiated message.



BM083371

Figure 150. 5-Button Keypad

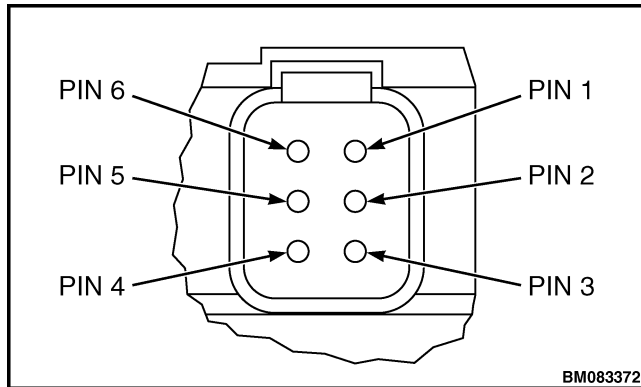


Figure 151. Key Pad Connector

Table 19. Connector Pin Out

Pin	Description	Type
1	GND	DIGITAL INPUT OR OUTPUT
2	GPIO-2	DIGITAL INPUT OR OUTPUT
3	GPIO-3	DIGITAL INPUT OR OUTPUT
4	GPIO-4	DIGITAL INPUT OR OUTPUT
5	GPIO-5	DIGITAL INPUT OR OUTPUT
6	GPIO-6	DIGITAL INPUT OR OUTPUT

MALE CONNECTOR POLARITIES

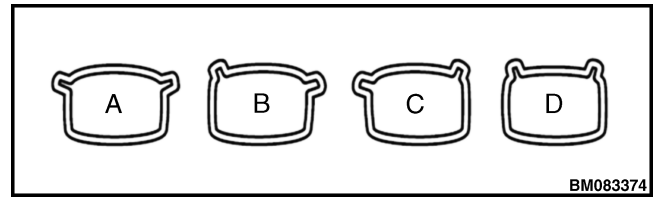


Figure 152. Male Connector Polarities

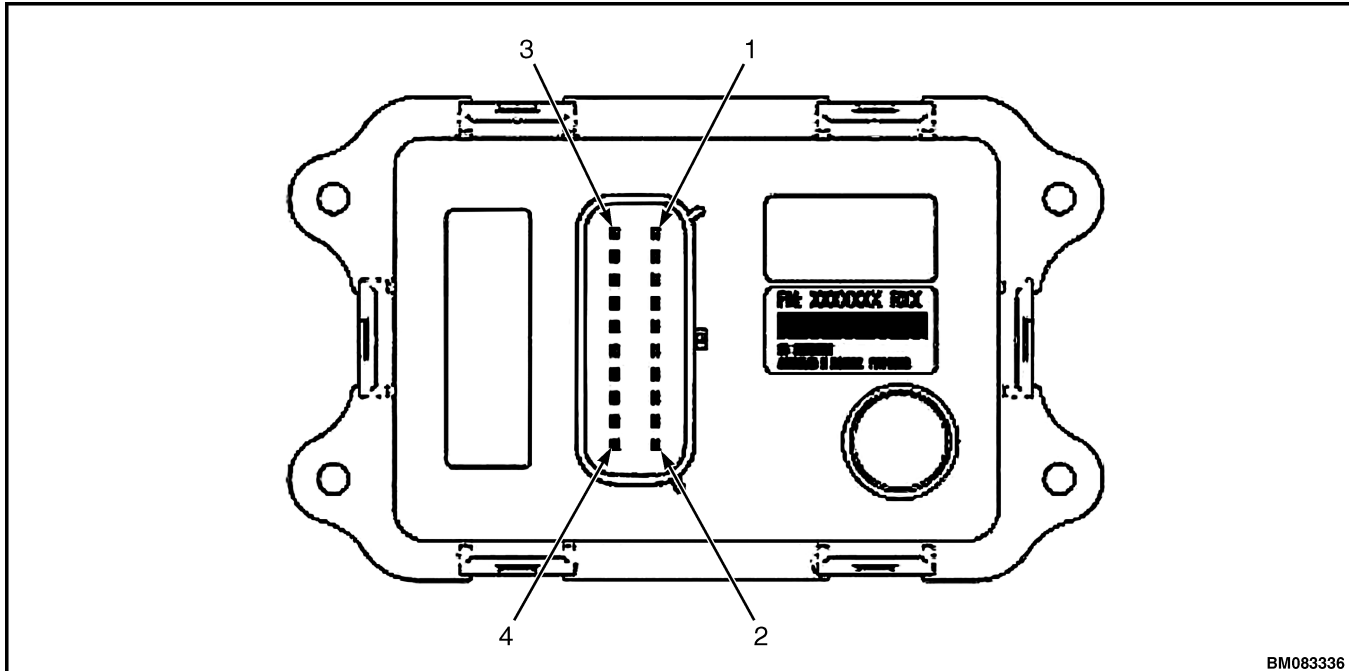
Connector Polarity	Connector Color
A	BLACK
B	GREY
C	BROWN
D	GREEN



Figure 153. 2 x 10 Connector Receptacle, Harness Side

2.8-INCH DISPLAY

The 2.8-inch display does not support a camera or landscape orientation and displays less items due to viewing screen size. Connector is polarity B.



BM083336

- | | |
|-----------|-----------|
| 1. PIN 1 | 3. PIN 11 |
| 2. PIN 10 | 4. PIN 20 |

Figure 154. 2.8-Inch Display Pin Locations

Table 20. 2.8-Inch Display Pin Out

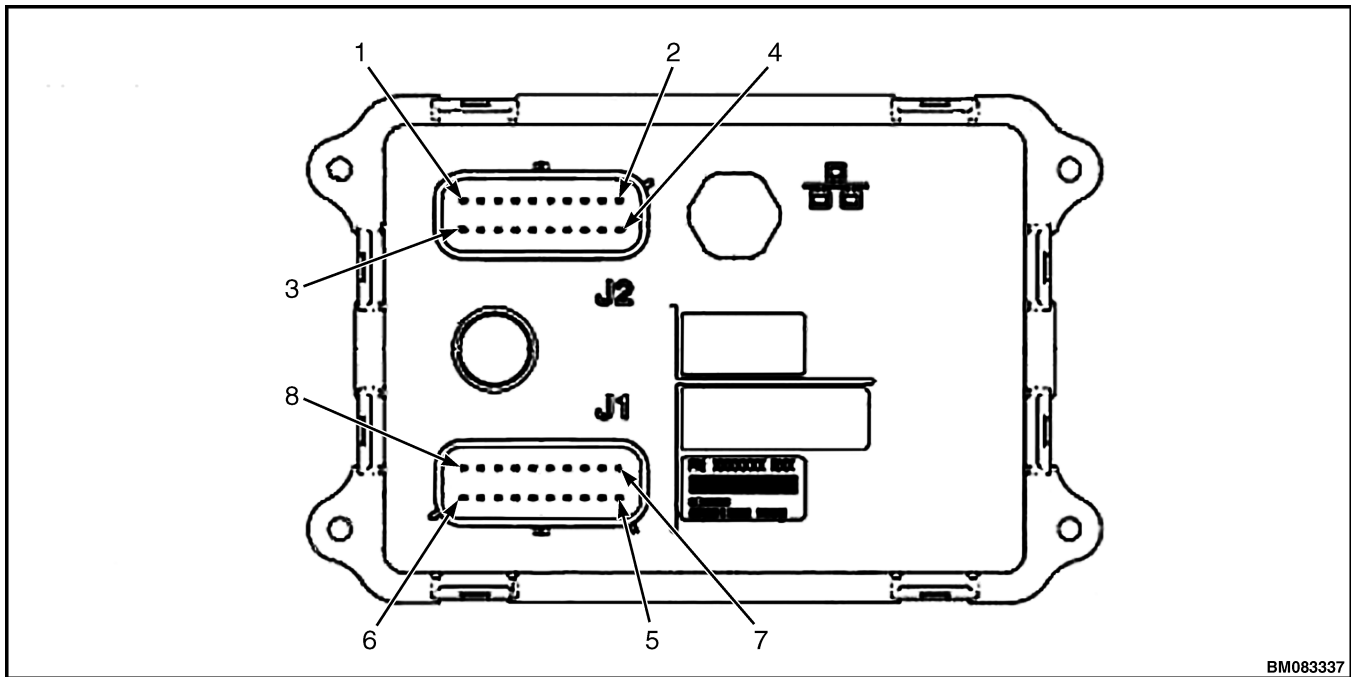
Pin	Type	Description
1	ANALOG OR DIGITAL INPUT	INPUT7_AD
2	ANALOG OR DIGITAL INPUT	INPUT1_AD
3	ANALOG OR DIGITAL INPUT	INPUT6_AD
4	LOWSIDE OUTPUT	OUTPUT 2_0A5_LS
5	CAN TERMINATOR	CAN1_TERM
6	CAN SHIELD	CAN1_SHLD
7	CAN1 LO	CAN LOW
8	CAN1 HI	CAN HIGH
9	GND	NEGATIVE BATTERY
10	POSITIVE BATTERY	+VBATT

Table 20. 2.8-Inch Display Pin Out (Continued)

11	ANALOG OR DIGITAL INPUT	INPUT5_AD (ANALOG OR DIGITAL INPUT)
12	ANALOG OR DIGITAL INPUT	INPUT4_AD (ANALOG OR DIGITAL INPUT)
13	ANALOG OR DIGITAL INPUT	INPUT3_AD (ANALOG OR DIGITAL INPUT)
14	ANALOG OR DIGITAL INPUT	INPUT2_AD (ANALOG OR DIGITAL INPUT)
15	USB_D -	USB_D -
16	USB_D +	USB_D +
17	GND	USB_GND
18	5V	VSENSOR1 OR USB_VBUS
19	12V BUZZER SUPPLY	VSENSOR2
20	LOWSIDE OUTPUT	OUTPUT1_0A5_LS

5-INCH DISPLAY

NOTE: Connector J1 is polarity B, connector J2 is polarity A.



BM083337

- | | |
|-------------------------|-------------------------|
| 1. CONNECTOR J2, PIN 1 | 5. CONNECTOR J1, PIN 1 |
| 2. CONNECTOR J2, PIN 10 | 6. CONNECTOR J1, PIN 10 |
| 3. CONNECTOR J2, PIN 11 | 7. CONNECTOR J1, PIN 11 |
| 4. CONNECTOR J2, PIN 20 | 8. CONNECTOR J1, PIN 20 |

Figure 155. 5-Inch Display Pin Locations

Table 21. 5-Inch Display, J2 Pin Out

Pin	Type	Description
1	Digital input	INPUT10_DF
2	Digital input	INPUT9_DF
3	----	----
4	----	----
5	----	----
6	GND	VIDEO1_GND
7	Power	VIDEO1
8	----	----
9	GND	GROUND
10	----	VSENSOR2 (SAME AS J1-19)
11	GND	GROUND

Table 21. 5-Inch Display, J2 Pin Out (Continued)

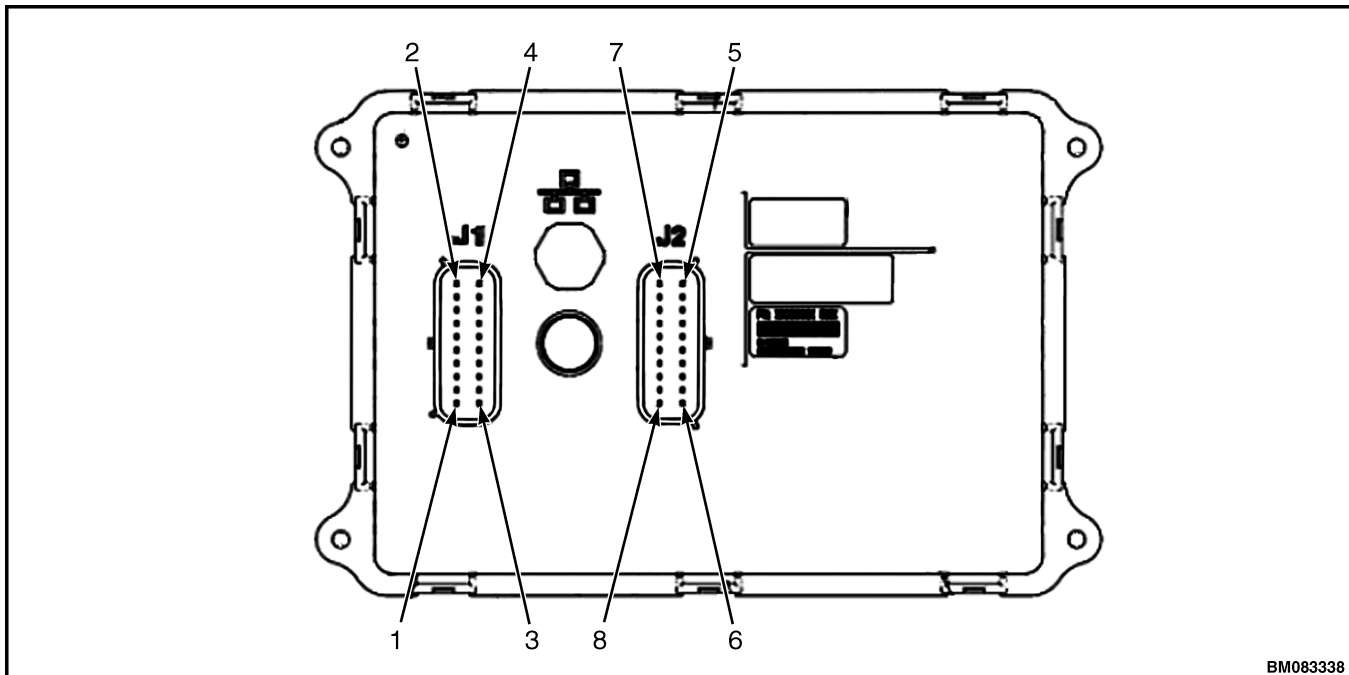
12	GND	GROUND
13	Analog or Digital Input	INPUT8_AD
14	5V	VSENSOR3
15	Reserved for Test	RESERVED FOR TEST
16	Reserved for Test	RESERVED FOR TEST
17	----	----
18	----	----
19	----	----
20	----	----

Table 22. 5-Inch Display, J1 Pin Out

Pin	Type	Description
1	Analog or Digital Input	INPUT7_AD
2	Analog or Digital Input	INPUT1_AD
3	Analog or Digital Input	INPUT6_AD
4	Lowside Output	OUTPUT2_0A5_LS
5	CAN Terminator	CAN1_TERM
6	CAN Shield	CAN1_SHLD
7	CAN Lo	CAN1_L
8	CAN Hi	CAN1_H
9	GND	GND
10	+VBATT	+VBATT
11	Analog or Digital Input	INPUT5_AD
12	Analog or Digital Input	INPUT4_AD
13	Analog or Digital Input	INPUT3_AD
14	Analog or Digital Input	INPUT2_AD
15	USB_D-	USB_D-
16	USB_D+	USB_D+
17	GND	USB_GND
18	VBUS	USB_VBUS
19	12V	VSENSOR2
20	Lowside Output	OUTPUT1_0A5_LS

7-INCH DISPLAY

NOTE: Connector J1 is polarity B, connector J2 is polarity A.



BM083338

- | | |
|-------------------------|-------------------------|
| 1. CONNECTOR J1, PIN 1 | 5. CONNECTOR J2, PIN 1 |
| 2. CONNECTOR J1, PIN 10 | 6. CONNECTOR J2, PIN 10 |
| 3. CONNECTOR J1, PIN 11 | 7. CONNECTOR J2, PIN 11 |
| 4. CONNECTOR J1, PIN 20 | 8. CONNECTOR J2, PIN 20 |

Figure 156. 7-Inch Display Pin Locations

Table 23. 7-Inch Display, J1 Pin Out

Pin	Type	Description
1	Digital Input	INPUT7_D
2	Digital Input	INPUT1_D
3	Digital Input	INPUT6_D
4	Lowside Output	OUTPUT2_0A5_LS
5	CAN Terminator	CAN1_TERM
6	CAN Shield	CAN1_SHLD
7	CAN 1 Lo	CAN1_L
8	CAN 1 Hi	CAN1_H
9	GND	GND
10	+VBATT	+VBATT
11	Digital Input	INPUT5_D

Table 23. 7-Inch Display, J1 Pin Out (Continued)

12	Digital Input	INPUT4_D
13	Digital Input	INPUT3_D
14	Digital Input	INPUT2_D
15	USB_D-	USB_D-
16	USB_D+	USB_D+
17	GND	USB_GND
18	USB_VBUS	USB_VBUS
19	12V	VSENSOR2
20	Lowside Output	OUTPUT1_0A5_LS

Table 24. 7-Inch Display, J2 Pin Out

Pin	Type	Description
1	Digital Input	INPUT10_DF
2	Digital Input	INPUT9_DF
3	CAN2 Shield	CAN2_SHLD
4	CAN2 Lo	CAN2_L
5	CAN2 Hi	CAN2_H
6	GND	VIDEO1_GND
7	Power	VIDEO1
8	Power	VIDEO2
9	GND	VIDEO2_GND
10	5V	VSENSOR2
11	GND	GROUND
12	GND	GROUND
13	Digital Input	INPUT8_D
14	5V	VSENSOR3
15	Reserved for Test	RESERVED FOR TEST
16	Reserved for Test	RESERVED FOR TEST
17	----	----
18	----	----
19	----	----
20	----	----

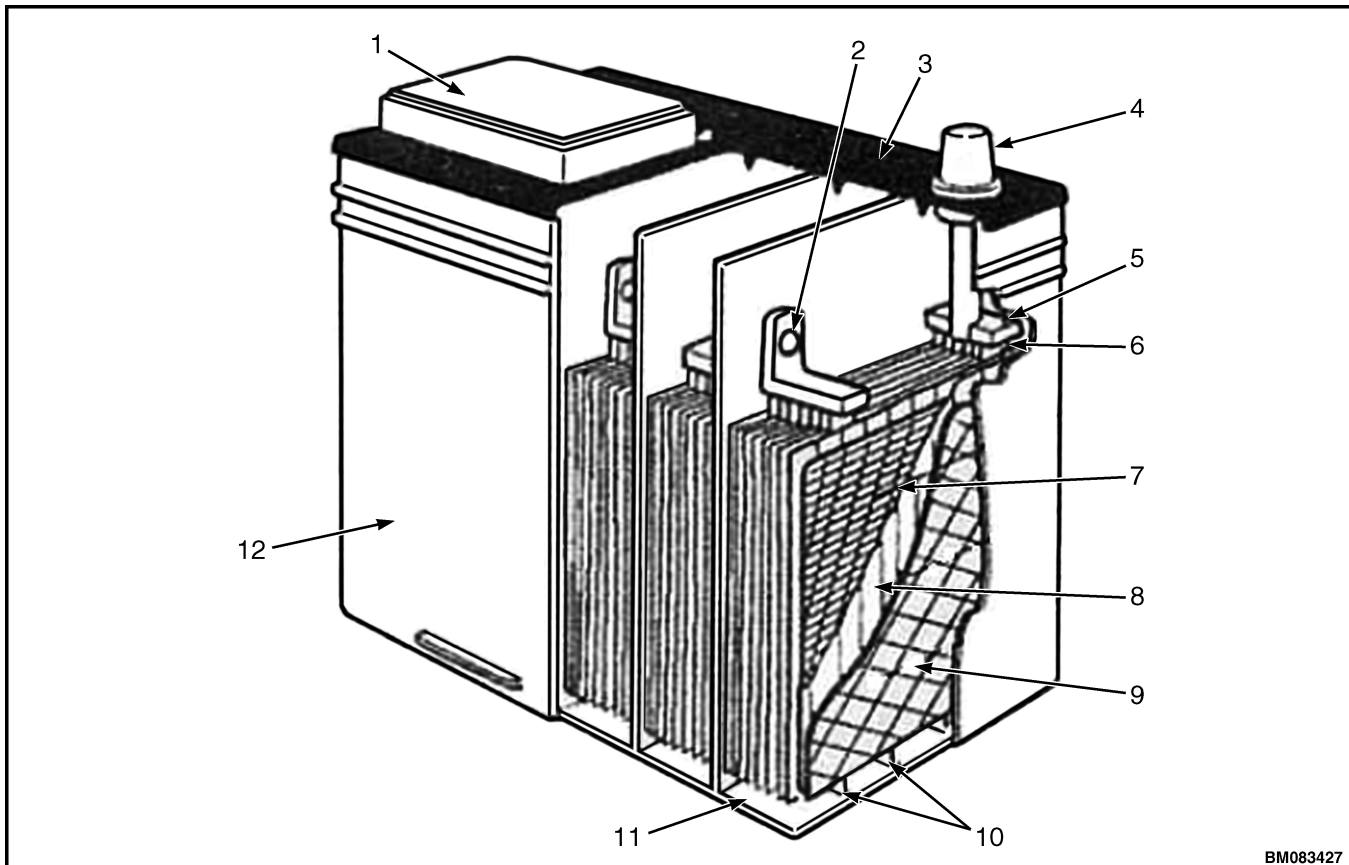
BATTERY DESCRIPTION

202001-149

BATTERY OVERVIEW

The battery stores energy for the complete truck electrical system. On demand, the battery produces

a flow of direct current for the devices connected to its terminals. After a period of use, the battery becomes discharged and no longer produces a flow of current. It can, however, be recharged by making an outside direct current flow through it in the opposite way from that which the current normally flows.



BM083427

- | | |
|-------------------------------------|------------------------|
| 1. VENT PLUGS | 7. POSITIVE PLATE |
| 2. THROUGH THE PARTITION CONNECTORS | 8. ENVELOPE SEPARATORS |
| 3. COVER | 9. NEGATIVE PLATE |
| 4. TAPERED TERMINAL POST | 10. ELEMENT RESTS |
| 5. POST STRAP | 11. SEDIMENT SPACE |
| 6. PLATE LUGS | 12. CONTAINER |

Figure 157. Typical Battery Anatomy

NOTE: Graphic is a generic representation and is for illustrative purposes only.

The battery is made up of a number of individual cells in a case. Each cell within the battery contains a group of positive and negative plates. There is always one more negative than positive plate within each cell group. Separators are between plates to prevent the plates from physically contacting each other and allow a free flow of electrolyte around

each plate. The plates hold the active materials in flat grids. Charged negative plates contain spongy lead (Pb). Charged positive plates contain lead peroxide (PbO₂). Plate groups of opposite polarity are interlaced so the negative and positive plates alternate. Negative plate groups normally have one more plate than positive groups. This keeps the negative plates exposed on both sides of the interlaced group.

The main battery terminals are the positive (+) and negative (-) posts. The positive (+) terminal is larger to prevent the danger of connecting the battery in reverse polarity. Reversing the polarity may damage some components and wiring in the system. A red cable is connected to the positive (+) battery terminal and a black cable is connected to the negative (-) terminal. The negative (-) cable is typically connected to the frame or engine block. The positive post cable is connected to the starter solenoid.



WARNING

Whenever disconnecting or reconnecting a battery, always disconnect the negative post cable first and connect it last. If you do not do this, dangerous sparking could occur. You should never connect the battery with the key switch in the ON position or the engine running. Never lay metal tools or any other objects across the battery which could potentially cause a short circuit.

BATTERY TYPES

Batteries are available in two types, either conventional or maintenance-free. A conventional battery has individual vent caps for each cell and requires periodic measurement and adjustment of the electrolyte levels. Most maintenance-free batteries do not have typical vent caps.

Conventional

A conventional battery has one vent cap for each cell. The caps serve two purposes: 1) close the opening in the cell cover through which the electrolyte level is checked and water added, 2) provide a vent for the escape of gases formed when the battery is charging. Each cell within the battery has a potential voltage of approximately 2 volts. A 12-volt battery will have six cells connected in series.

Maintenance-Free

Maintenance-free batteries come sealed for life from the factory, and do not require maintenance of the electrolyte levels. A maintenance-free battery operates similarly to a conventional standard battery. The use of lead-calcium plates instead of lead-antimony in their construction increases the ability of the battery to accept an overcharge, thus greatly reducing bubbling and gassing of the

electrolyte. Less fluid is lost, eliminating the need to add water, in fact there is no way of maintaining the water or acid level in the battery.

Venting of gases from a maintenance-free battery is done through a vent. Most maintenance-free batteries do not have typical vent caps. These batteries are ready for service when they leave the factory. They have a very low rate of discharge and have a longer shelf life than conventional batteries. The most significant benefit of the sealed design is that no service attention is required, other than ensuring the battery is kept clean and fully charged.

Battery Charging



WARNING

Safety is very important while charging batteries. Always wear safety goggles, protective clothing, and rubber gloves when charging a battery. Keep sparks and flames away from the battery. Make sure the work area is well-ventilated. When charging and discharging, a lead acid storage battery generates harmful fumes and gases. This gas is very explosive.

The amount of electrical current a battery can produce is limited by the amount of chemical reaction which can take place within it. When the chemical reaction in the battery has ended, either through defect or long use, it can no longer produce a flow of electrical current. In most instances, if the battery is not defective, it can be recharged.

The battery charge is maintained by the truck charging system. If a component in the charging system fails or if a truck system is drawing current while the truck is not running, the battery charge may be depleted. In these circumstances, external charging of the battery may be required. Batteries are charged by reversing their flow of current. Batteries can be recharged in two ways, either Fast Charging or Slow Charging.

A battery that is in satisfactory condition but requires recharging will accept a large amount of charging current without undesirable effects. This type of battery may be charged quickly at a high rate with a battery fast charger. The reaction of the battery itself to fast charging will indicate the amount of charging current it can accept without damage. NEVER allow the battery electrolyte to heat above 49°C (120°F).

A battery that becomes sulfated will not accept a high rate of charging current without possible damage. Its sulfated condition provides increased resistance to current flow within the battery. Flow of high current through this kind of resistance creates heat. Damage that may occur includes plate warping, boiling of the electrolyte, and possible damage of the separators. Also, the cell caps, covers, and battery case may be damaged or distorted. A battery that has become sulfated must be charged over a long period of time at a low rate of charge.

Fast Charging



WARNING

Safety is very important while charging batteries. Always wear safety goggles, protective clothing, and rubber gloves when charging a battery. Keep sparks and flames away from the battery. Make sure the work area is well-ventilated. When charging and discharging, a lead acid storage battery generates harmful fumes and gases. This gas is very explosive.

To fast charge the battery, perform the following steps:

1. Disconnect the truck negative (-) and then positive (+) lead. Check, and if necessary, fill the cells with distilled water to the level recommended.
2. Connect the battery to the charger following manufacturer's recommendations. Set the charger to 15-30 amps for a 12-volt battery.
3. Start the charger at a slow or low charging rate.
4. Increase the charging rate one selection at a time.
5. Observe the charger ammeter after one minute at each selection for a 10-amp charging rate. If necessary, select boost.
6. After the battery has charged for 3 minutes, monitor the electrolyte and look for signs of excessive gassing.
7. Reduce the charging rate until the electrolyte produces comparatively few bubbles, but gassing has not stopped entirely.

The maximum charging time at the boost selection is 10 minutes for a conventional battery and 20 minutes for a maintenance-free battery. Cold temperatures can increase the time required to charge the battery. Check the charger instructions for additional details. If the battery is not accepting the required 10-ampere charging rate by the specified time, replace the battery.

The charging rate for conventional batteries may require 2 to 4 hours. The charging rate for maintenance-free batteries may require 4 to 8 hours. Once the battery is charged, check the electrolyte specific gravity after the battery has cooled for 30 minutes. The specific gravity should be between 1.230 and 1.265.

Slow Charging



WARNING

Safety is very important while charging batteries. Always wear safety goggles, protective clothing, and rubber gloves when charging a battery. Keep sparks and flames away from the battery. Make sure the work area is well-ventilated. When charging and discharging, a lead acid storage battery generates harmful fumes and gases. This gas is very explosive.

To slow charge the battery, perform the following steps:

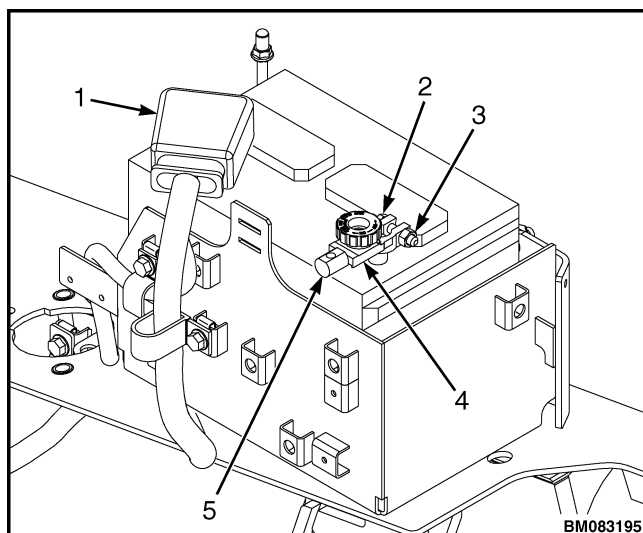
1. Disconnect the truck negative (-) and then positive (+) lead. Check, and if necessary, fill the cells with distilled water to the level recommended.
2. Charge the battery at a low rate (7% of the battery amp-hour rating or less) for an extended period of time until the battery is fully charged.
3. Take three consecutive hydrometer readings an hour apart, until it shows no rise in the specific gravity. The battery is now considered fully charged.

The normal slow charging period is from 12 to 24 hours. If the battery's specific gravity has not reached the normal full charge range (1.225 to 1.280) within 48 hours of slow charging, replace the battery. Badly sulfated batteries, however, could take between 60 to 100 hours to recharge completely.

Battery Disconnect Switch (Optional)

The battery disconnect switch is a component that breaks the 12V starting circuit in the truck. It is a special connection on the battery negative terminal and has a rotary knob that allows the battery to be disconnected quickly.

The disconnect switch has a green knob that when turned to the left will disconnect the battery from the circuit. Turning the knob all the way to the right will reconnect the circuit. This option can be useful when trucks need to be left un-used for long periods or isolated for safety reasons.



1. POSITIVE BATTERY CABLE BOOT
2. DISCONNECT SWITCH BOLT
3. DISCONNECT SWITCH NUT
4. DISCONNECT SWITCH
5. NEGATIVE BATTERY CABLE (NOT SHOWN)

Figure 158. Battery Disconnect

Battery Charge Dongle (Optional)

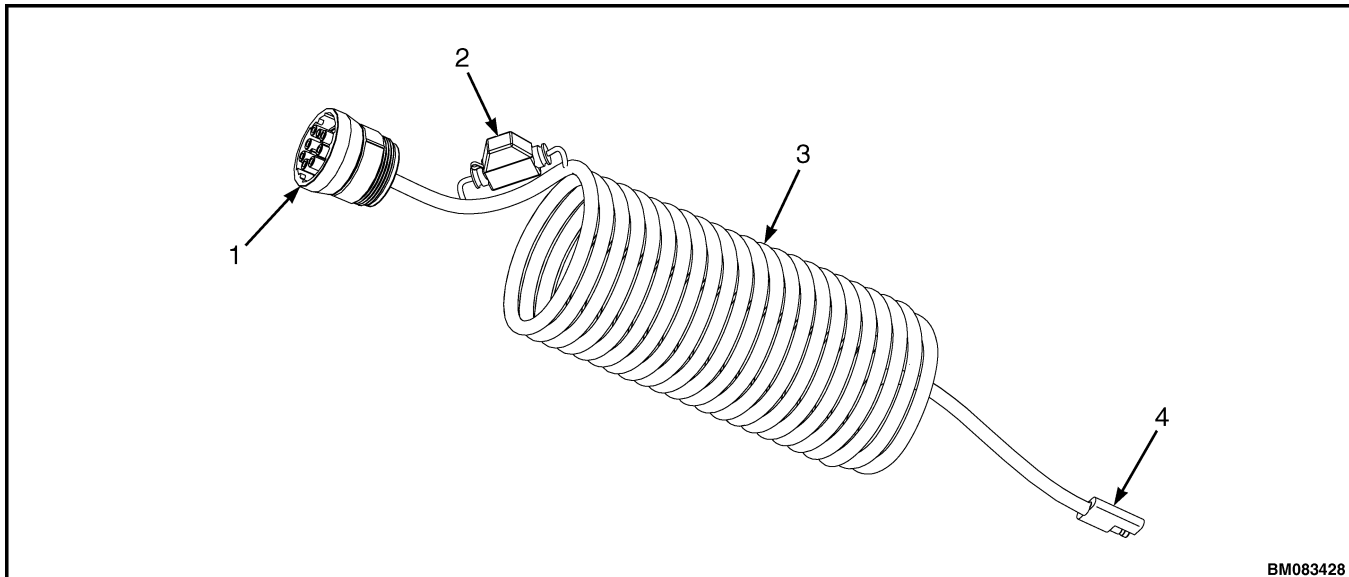
The battery charge dongle option is a separate harness that is provided for Internal Combustion Engine (ICE) trucks. It allows trickle charging or battery tending of the truck starter battery in the event that the truck battery is discharged, or for long-term storage. The dongle is provided with the truck from the factory and plugs into the 9-pin truck diagnostic port that is accessed through the kick panel. No removal of floor plates, mats or panels is required. The dongle cable is roughly 6m (19.7 ft) long and terminates in a common SAE bullet-style battery plug.



CAUTION

The battery dongle is only intended for battery maintenance, trickle charging, and long-term battery tending. It **CANNOT** be used to jump-start the truck in the event of a dead battery.

The dongle has an integrated 10-amp fuse to protect both the wires and the truck from misuse. If the 10-amp fuse is bypassed, the circuit is further protected in the truck by a 15-amp fuse in the Power Distribution Module (PDM). The battery charge dongle provides a no-tools-required way of trickle charging the starter battery of the truck.



1. 9-PIN DIAGNOSTIC CONNECTOR
2. FUSE HOLDER WITH MINI-COVER AND 10A FUSE
3. WIRE HARNESS
4. BATTERY TENDER CONNECTION

Figure 159. Battery Charge Dongle

LIGHTS DESCRIPTION

202001-150

LIGHTS

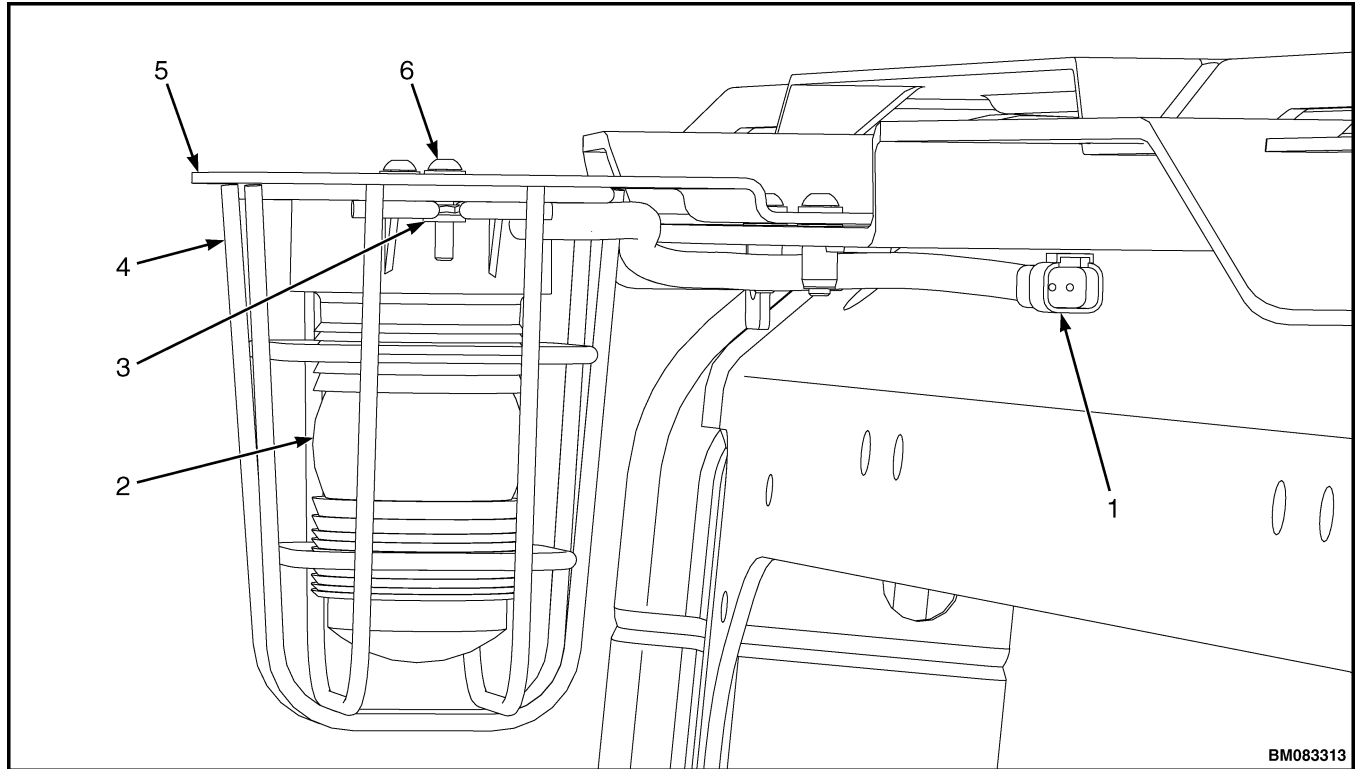
All lights on this truck are Light Emitting Diode (LED) with one exception being an option for halogen front work lights. The numerous lights provide ample bright, directed, and focused lighting to many essential key areas. In addition, some of the lights illuminate areas for truck presence and help provide awareness for pedestrians and other traffic.

Pedestrian Awareness Lights

Pedestrian awareness lights provide a means of alerting pedestrians and other traffic to the presence of the fork lift.

Orange Strobe Light

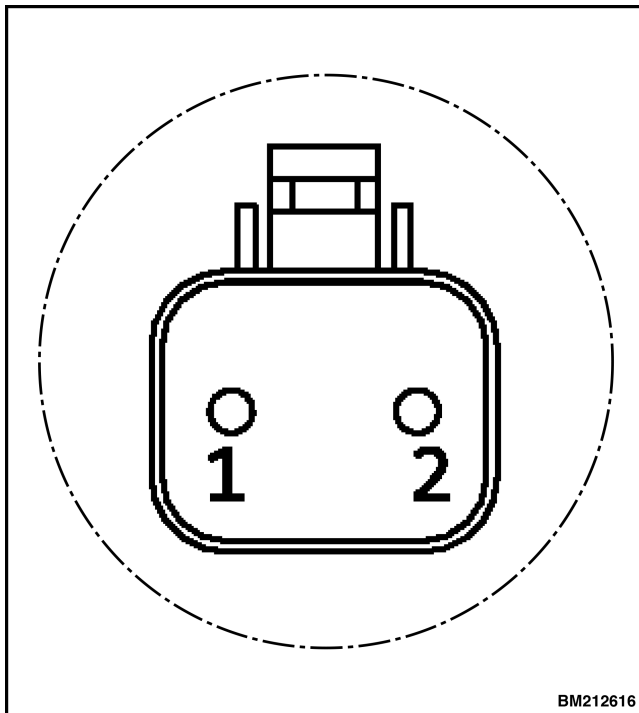
The industry standard orange LED strobe light flashes while the truck is on and is protected inside a metal cage. The strobe light provides a way to communicate truck position and status to other trucks and pedestrians.



- 1. ELECTRICAL HARNESS
- 2. STROBE LIGHT
- 3. NUT

- 4. GUARD
- 5. MOUNTING BRACKET
- 6. CAPSCREW

Figure 160. Strobe Light



Pin	Type	Description
1	GND	GROUND
2	5V	POWER

Figure 161. Strobe Light Pinout

Red or Blue Spot Lights

The red or blue spotlights work by shining a bright blue or red spot on the ground or floor that is clearly visible by pedestrians and other equipment operators. Lights are located on the front, rear, or both. These lights are ideal for applications where forklifts approach blind corners, cross aisles, load trailers, or where pedestrians are present in the workspace.

Two activation options are available:

1. Continuously on - spot lights are on whenever the truck is on.
2. Forward- and reverse-activated - the light(s) only activate based on truck's selected travel direction.

NOTE: For forward- and reverse-activated spot lights, rear spot light only activates when truck is in reverse, front spot light only activates when truck is in forward.

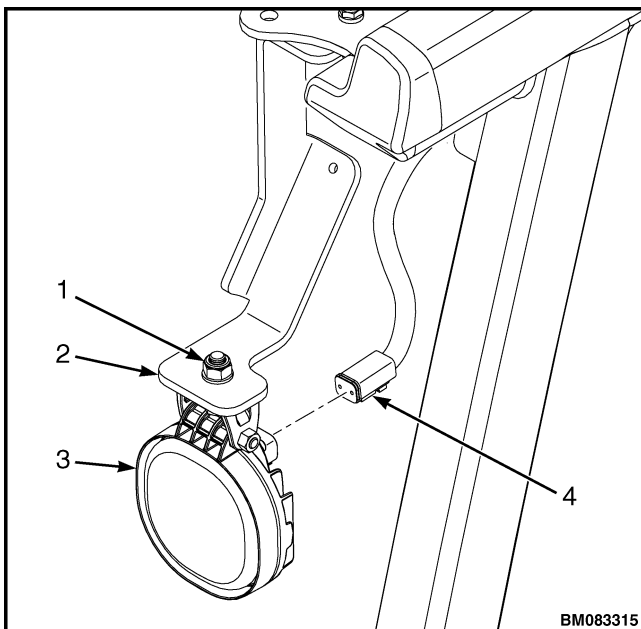
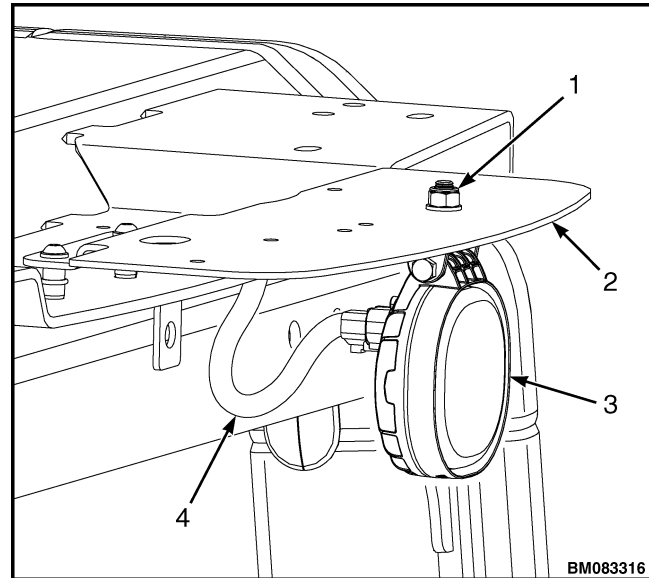


Figure 162. Front Spot Light

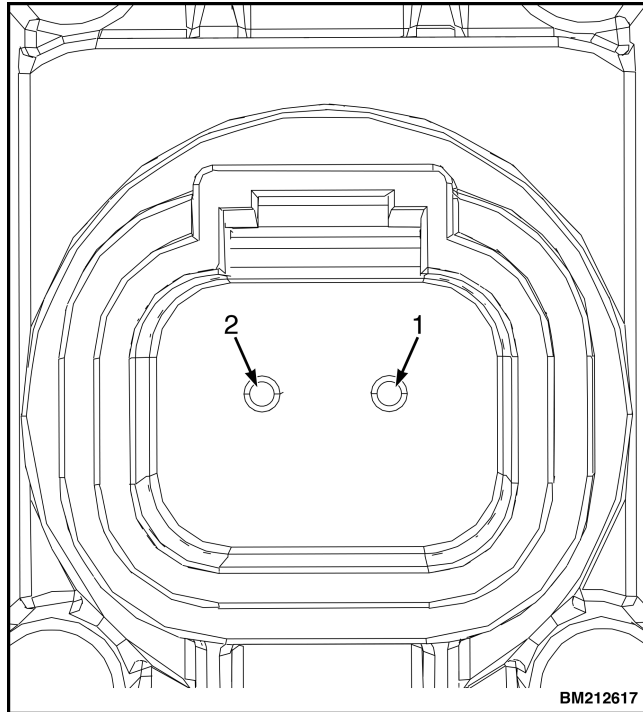
Legend for Figure 162.

1. WASHER AND NUT
2. BRACKET
3. SPOT LIGHT
4. ELECTRICAL HARNESS



1. WASHER AND NUT
2. BRACKET
3. SPOT LIGHT
4. ELECTRICAL HARNESS

Figure 163. Rear Spot Light



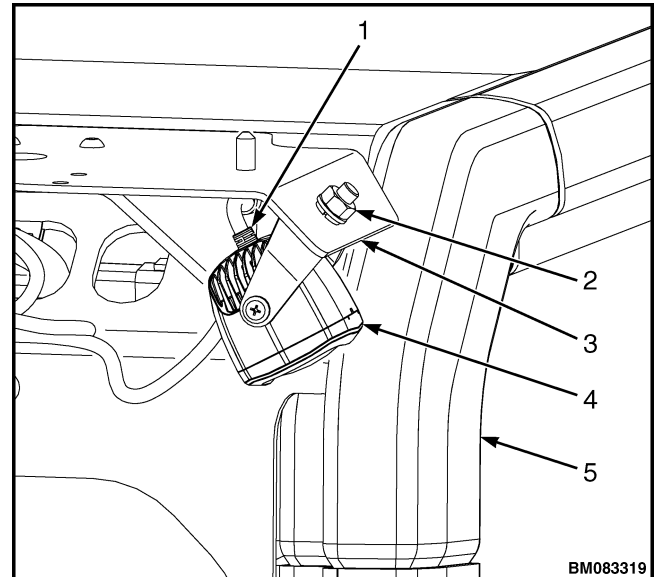
Pin	Type	Description
1	5V IN	POSITIVE
2	5V OUT	POSITIVE

Figure 164. Spot Light Pinout

Red LED Pedestrian Awareness Perimeter Lights

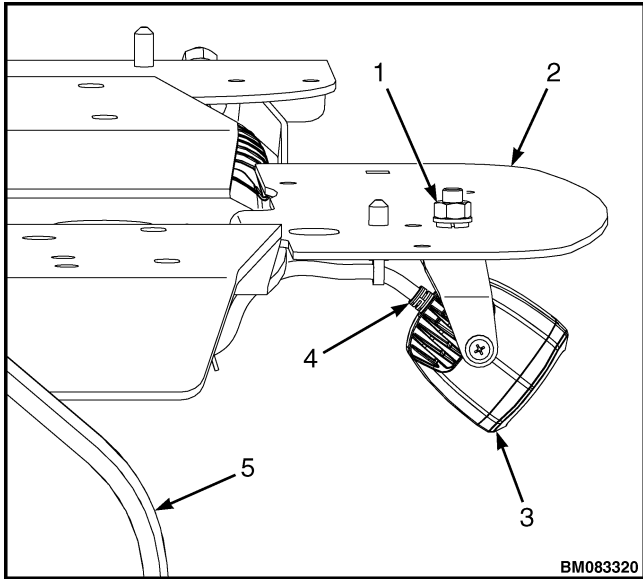
The perimeter pedestrian awareness lights shine a highly concentrated, bright red line on the ground at predetermined distance away from the truck

frame. These lights provide nearby pedestrians with a visual indication the amount of space needed to keep away from the vehicle to avoid truck tail swing. The lights create a visual box around the truck to notify pedestrians and other vehicles and only activate when the truck is at low speed. Available choices for lights are left and right, or left, right, and rear. Illustrations are shown for right side and rear lights. Left side light is similar to the right side.



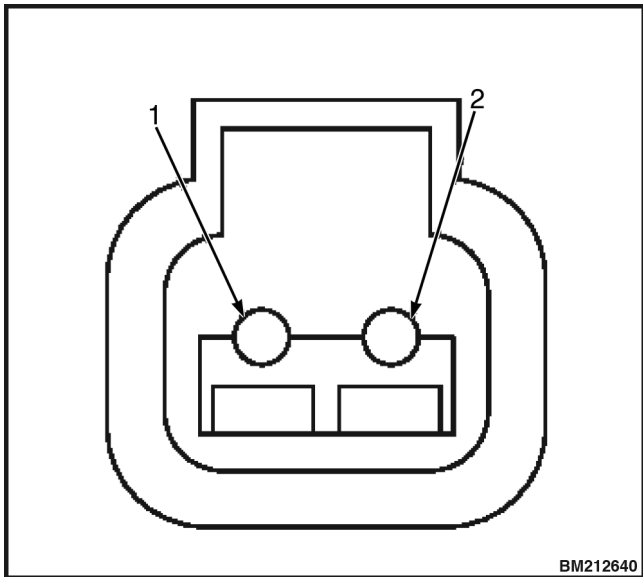
- 1. ELECTRICAL HARNESS
- 2. NUT
- 3. BRACKET
- 4. LIGHT
- 5. OVERHEAD GUARD SUPPORT POST, REAR, RH

Figure 165. Right Side Light



- 1. NUT
- 2. BRACKET
- 3. LIGHT
- 4. ELECTRICAL HARNESS
- 5. OVERHEAD GUARD SUPPORT POST, REAR, RH

Figure 166. Rear Light



Pin	Type	Description
1	12V IN	POSITIVE
2	GND	POWER GROUND

Figure 167. Pedestrian Awareness Perimeter Light Pinout

The factory set left and right side red awareness lines are projected 1m (3.3 ft) from the side of the forklift. The rear red awareness line is projected 2m (6.6 ft) from the rear counterweight profile to serve as a visual indicator for pedestrians to maintain distance from the rear of the truck to avoid the possible tail-swing of the forklift counterweight.

The lights can be adjusted in their mounts to move the light closer or further from the truck to suit customer expectations. The light pattern creates a visual box around the truck to notify pedestrian and other vehicles.

Work Lights

Work lights are available in three output levels: halogen at 600 lumen, LED at 750 lumen, or high output LED at 1,100 lumen. The halogen bulb is replaceable but the LED lights are not and must be replaced as a unit. Options for work light configurations are two lights in the front or two lights in the front and one light at the rear.

Activation of the work lights can be achieved in one of three different ways:

- 1. Manual - rocker switch on the dash.
- 2. Key - continuous with truck power on and remain on while the truck is active.
- 3. Automatic - ambient light sensor activates lights when the ambient light level drops below a threshold.

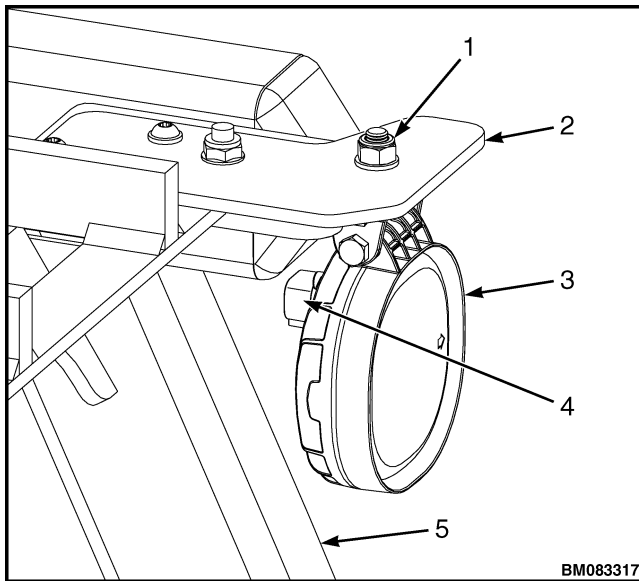
Front or Rear or Both

Front work lights are mounted on the front of the overhead guard. The rear work light is mounted on the rear of the overhead guard on a bracket.

Front work lights can be Halogen or LED. Halogen lights have replaceable bulbs, LED lights do not. Halogen light output is 600 lumen, LED light output can be either 750 lumen or 1,100 lumen. Halogen and LED both remove and install the same, only LED will be shown. Left and right lights have unique light output patterns and are not interchangeable.

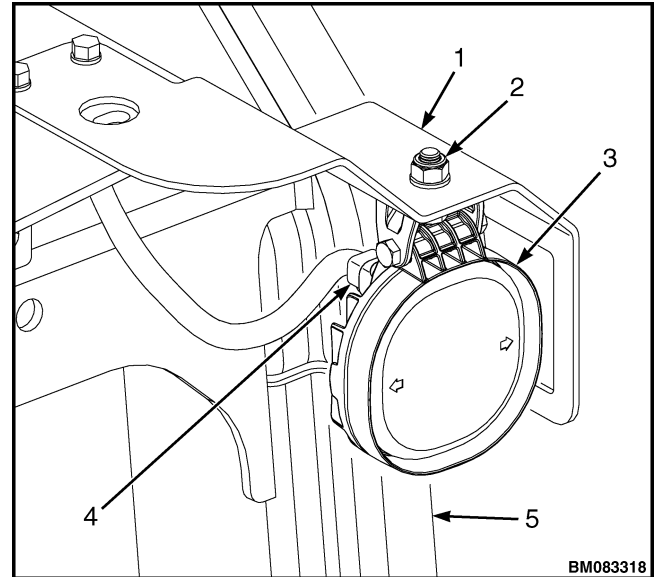
Work lights are used to light up the area around the truck for the purpose of seeing the working environment. At the front of the truck 2 work lights can be fitted to the top corners of the overhead guard. Mounting points for these lights are integrated into the overhead guard.

Optional Rear Work Light Control- The rear work light turns on when the truck is in reverse and turns off when the truck is not in reverse. The default activation of the rear work light is to be turned on and off with the front work lights.



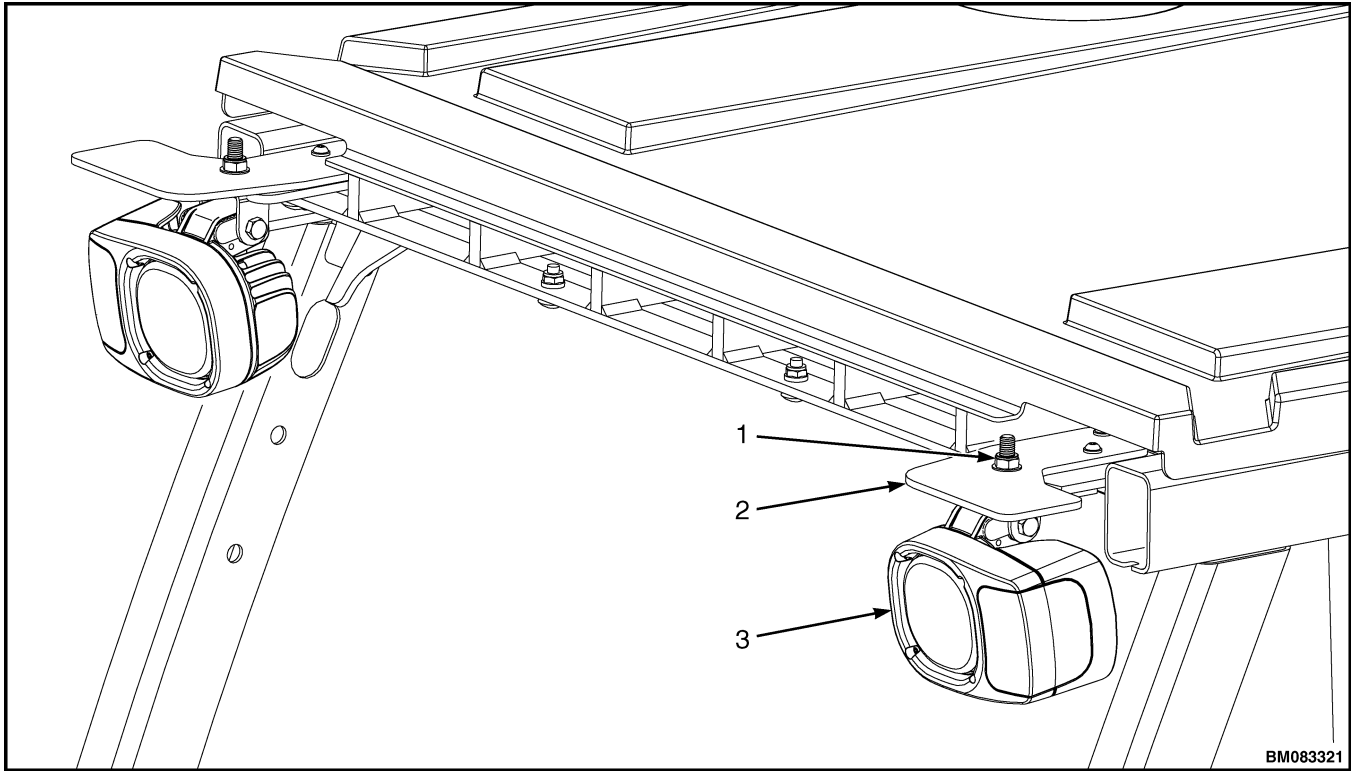
1. WASHER AND NUT
2. BRACKET
3. LIGHT
4. ELECTRICAL HARNESS
5. OVERHEAD GUARD SUPPORT POST, FRONT, LH

Figure 168. Front Work Light



1. BRACKET
2. WASHER AND NUT
3. LIGHT
4. ELECTRICAL HARNESS
5. OVERHEAD GUARD SUPPORT POST, REAR, RH

Figure 169. Rear Work Light

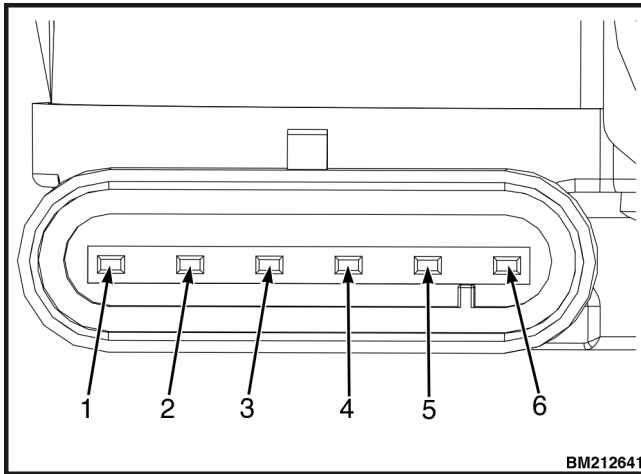


BM083321

- 1. LOCKNUT
- 2. BRACKET

- 3. LIGHT

Figure 170. Front Work Light with Marker Light



BM212641

Pin	Type	Description
1	12V	POSITIVE
2	GND	POWER GROUND

Figure 171. Work Light Pinout

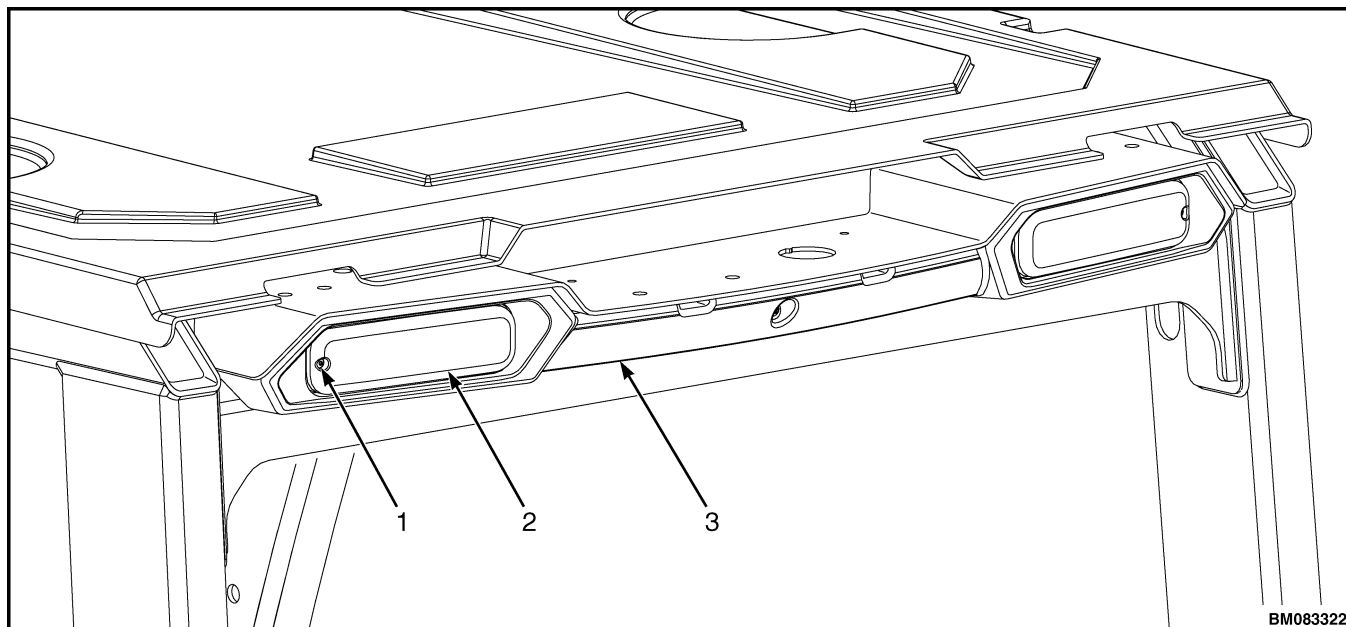
Brake, Tail, Reverse, Turn Signals, Hazard

NOTE: The hazard rocker switch (located on the dash) overrides any turn signal operation.

The tail light assembly is located on the rear part of the overhead guard and placed under a solid steel brow. This steel brow provides protection for the

lights and address the issue where lights can be easily damaged on outgoing trucks by hanging doors, racks and other obstacles.

A plastic housing covers the assembly and hides the wire harnesses for the lights and accessory options mounted on the back of the overhead guard.



1. SCREW
2. LIGHT ASSEMBLY

3. TAIL LIGHT COVER

Figure 172. Tail Light Assembly

Brake Lights (Red)

The brake lights illuminate when the service brake is applied. Each brake light houses 6 LEDs.

Tail Lights (Red)

The tail lights turn on whenever the front work lights are on. For trucks without work lights the tail lights will be on at all times. The plastic components of the tail light and surrounding cover are protected from damage by a metal structure (brow) that extended beyond the plastic parts. The resulting overhang is designed to protect the fragile components from plastic curtain screens which typically make contact with this area of the truck when the truck is backing through a doorway with curtains installed. Each tail light is comprised of 4 LEDs.

Turn Signals (Amber)

Each turn signal light has 4 LEDs and is activated based on movement of the turn signal lever. The turn signals flash whenever the turn signals or hazard lights are engaged. The hazard lights utilize the turn signal lights (both left and right are flashing at the same time and at the same rate).

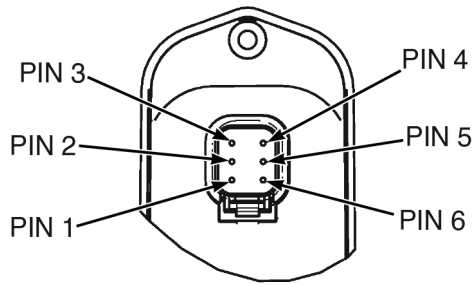
The factory set flash rate is measured in Hertz (Hz) or cycles per minute (cpm) and is 1.3 Hz (78 cpm) as default (measured as a complete on-off cycle). This rate can be changed through the Configuration Data File (CDF) with a valid range of 0.2-2.5 Hz (12-150 cpm) in 0.1 Hz (6 cpm) increments.

Hazard

The hazard lights are activated by pressing a rocker switch located in the operator compartment. The hazard lights override any turn signal command.

Reverse Lights (White)

The reverse lights (with 6 LEDs each) illuminate anytime the reverse direction is selected.



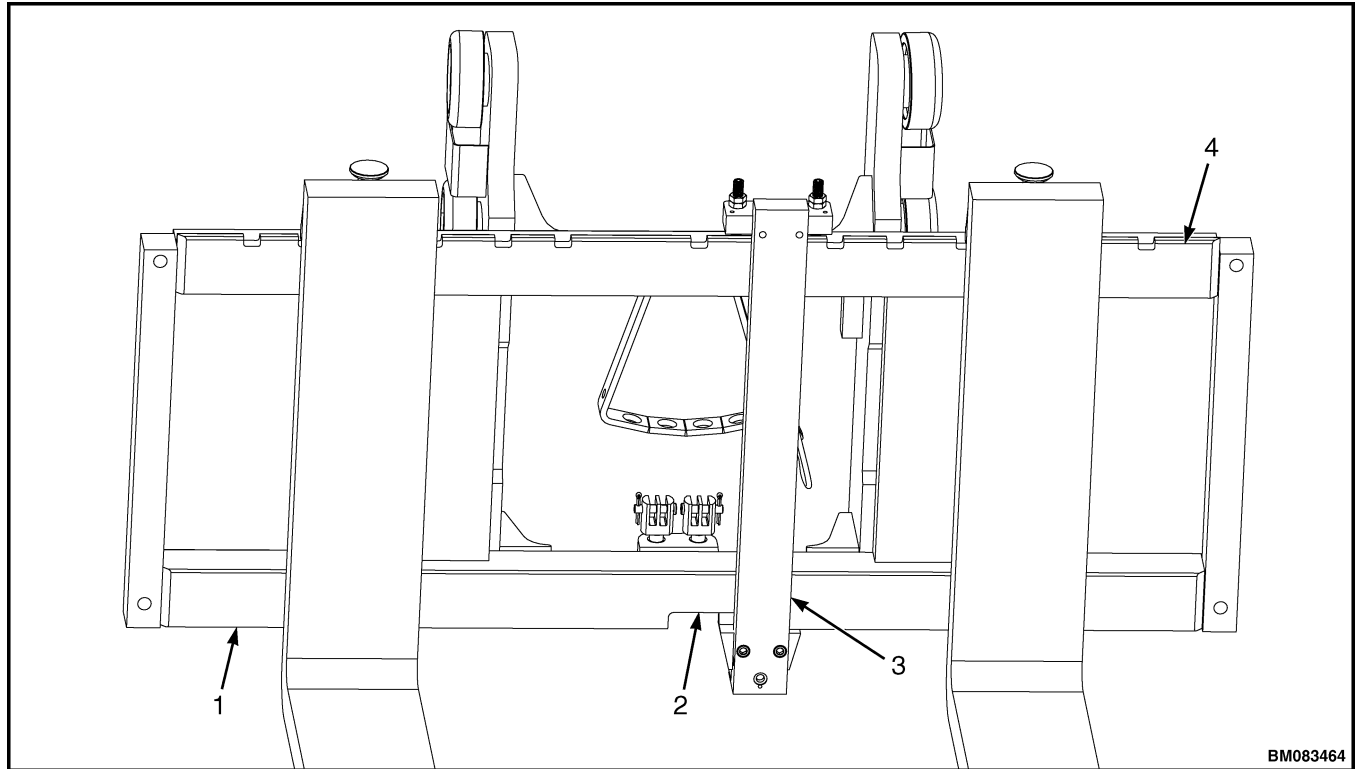
BM212623

Pin	Type	Description
1	GND	GROUND
2	N/A	NOT USED
3	12V IN	TAIL LIGHT (RED)
4	N/A	NOT USED
5	Highside Digital Output	BRAKE LIGHT (RED)
6	12V IN	BACK-UP LIGHT (WHITE)

Figure 173. Work Light Pinout

Fork Laser Level Light (Line)

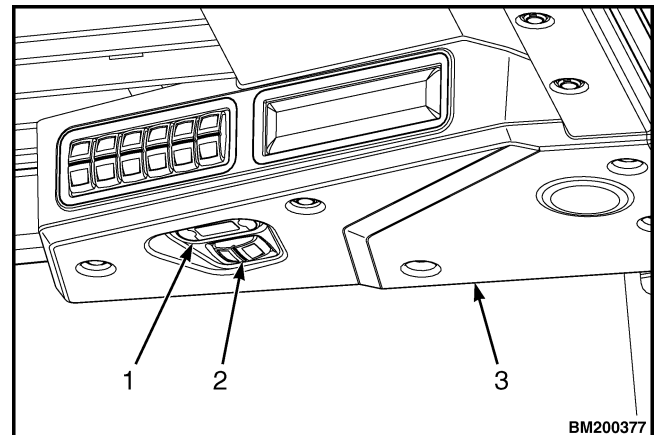
This option adds a laser to the fork carriage to help the operator quickly and easily see where the truck fork tips will enter a load. The line projected in front of the forks on the wall or racking provides the operator with an accurate and reliable indication of fork tip level from the ground. The laser line is especially useful for high lift applications or in situations where light levels are low or other lighting solutions may not be suitable.



- | | |
|------------------------|---------------------|
| 1. CARRIAGE BOTTOM BAR | 3. LASER ASSEMBLY |
| 2. FORK RELEASE NOTCH | 4. CARRIAGE TOP BAR |

Figure 174. Fork Laser Light

The laser assembly is carriage-mounted and can be moved to any position along the carriage except the center where the fork release notch (item 2, Figure 174) is located. The laser is powered by a permanent electrical connection which is routed above the sideshift hoses. For masts without sideshift the electrical cable follows the same path without the hoses. When this option is selected an additional switch is added to the dash to allow manual activation of the laser. The laser will only operate if the truck is below a set speed. This speed setting can be accessed using the full color display and a service level password and is adjustable from 0-20 Km/h (0-12.4 mph).



- | |
|------------------|
| 1. ROCKER SWITCH |
| 2. LIGHT |
| 3. HEADLINER |

Figure 175. Interior Reading Light

Interior Reading Light (Cab Only)

This option adds an interior reading light to any cab or cab ready operator compartment. The reading light produces a focused light onto the operators lap allowing documents to be read in low light conditions. The light is controlled by a rocker switch in the headliner.

SOFTWARE DESCRIPTION

202001-151

SOFTWARE DESCRIPTION

Software is computer logic described as a collection of individual programs (applications). A program itself is a list of coded instructions to control a certain component, function, or operation. An example of software is the truck Configuration Data File (CDF) and an example of a program would be Field Prog programming tool.

Several devices on the truck already contain programs (applications) from the factory such as:

- Vehicle System Manager (VSM)
- I-Box Controller
- O-Box Controller
- Hydro-Static Transmission (HST) Controller
- E-Hydraulic Controller
- Operator Display

Configuration Data File (CDF)

A Configuration Data File (CDF) is a factory-created file defining truck configuration details, dependent on truck model and option permutations (considered unique for a given truck). The CDF cannot be modified by service technicians, but a replacement file (with alternate options) may be factory-generated and loaded into the truck's VSM by a service technician.

The configuration files are generally read at startup by the operating system as well as by applications in order to customize the environment for the user.

Display Application (Program)

The touchscreen display with on-screen graphics provides virtual on-screen counterparts for several traditional interaction devices such as push buttons, switches and levers. An extensive menu system is used for setting up and reviewing machine parameters and other information.

The application for the display is the main interface the operator, service technician, or supervisor uses to understand truck status, alter truck settable parameters, and communicate truck fault codes.

A small example of parameters that can be modified are:

- Empty seat engine shutdown option - Time to shutdown can be programmed.
- Shelf Height Selector - Up to 10 different levels can be programmed and can quickly be selected.
- Return to Set Tilt (RTST) - Set a defined angle for the mast tilt to stop at between the tilt limits of the truck.

NOTE: All displays have an identification label located on the back surface of the unit. This label includes the part number, revision level, software part number, country of origin, and date of manufacture.

Vehicle System Manager (VSM) Application (Program)

The VSM is the master or main controller for the truck and has 3 internal processors that can be updated. It is mounted on the right side of the cab below the dash panel. The VSM controls every electrical device on the truck and receives inputs from the operator (user interface), sensors, controlled devices and the Engine Control Unit (ECU). The VSM program is factory-installed.

The VSM analyzes and determines the control of most of the truck's electrically controlled functions. The VSM is also programmed to detect truck malfunctions and provide feedback to the operator and service technician in the form of display messages, Diagnostic Troubleshooting Codes (DTCs), warning lights, and audible warnings.

NOTE: All of the controllers on the truck are connected by a communication link called a CANbus (Controlled Area Network bus). The CANbus conforms to the SAE (Society of Automotive Engineers) J1939 standards. Multiple pieces of information can be sent on this bus, an operation often referred to as multiplexing.

Service Tools

Several service tools are available to assist the technician in diagnosing, analyzing, monitoring, and programming multiple truck systems.

PC Service Tool (PCST)

NOTE: This is an overview only and not intended to be all inclusive. To obtain PC Service Tool visit HYPro .

PC Service Tool is a Windows based service application that is used to communicate with the truck’s internal control systems. It can be used to

monitor the status and condition of the various subsystems running within the truck. Other uses of the tool are to monitor component operation, determine if abnormal events have occurred in the truck, and assist with their diagnosis and correction. PC Service Tool accesses the truck’s internal communications network via various CAN adapters.

System Requirements

The following table lists the minimum configuration requirement for installing PC Service Tool.

Software Requirements	Hardware Requirements	Vehicle Adapter Requirements
<ul style="list-style-type: none"> • Microsoft Windows XP Professional (U.S. Version), Service Pack 2, with Internet Explorer v6.0 and above - or - • Microsoft Windows Vista (Professional equivalent), with Internet Explorer v7.0 and above - or - • Microsoft Windows 7,10 (Professional equivalent), with Internet Explorer v7.0 and above <p>NOTE: 64 bit operation has only been tested for Microsoft Windows 7</p> <ul style="list-style-type: none"> • Adobe Acrobat Reader version 8.0 or higher • Microsoft .net Framework version 4.0 	<ul style="list-style-type: none"> • Pentium class processor, 1.6 GHz or faster (notebook computer) • 512 MB of RAM • Hard disk of 20 GB • USB port • High Speed Internet strongly suggested for download 	<ul style="list-style-type: none"> • RP1210 compliant CAN communications adapters, such as iFak isCAN USB, or Vector CAN XL. <p>NOTE: Electric Warehouse products require an adapter that supports the RP1210B interface standard.</p>

Main Screen

The Main Screen has five tabs to choose from: **File**, **Diagnostics**, **Truck Configuration**, **Programming**, and **Help**.

The **File** tab has these choices: Connect, Application Configuration, Reports, Run, and Exit.

Connect - Connect your vehicle with this service application using an RP1210-compliant adapter.

Application Configuration - Has the following three tabs to choose from:

- **General:** Change the operating language of the application or the unit of measurement.
- **3rd Party Applications:** Add a 3rd party application in the File menu of PC Service tool. Also used to add and associate the truck programming applications with the tool.
- **Trouble Shooting Manuals:** Used to associate manuals with series codes including engine-specific manuals.

Reports - This allows generating a report to capture truck information and status such as: detailed truck information and truck setup parameters, a list of faults that may have occurred inside the truck, and diagnostic data that can be useful in correcting problems.

Run - If a 3rd Party (non-programming) application has been loaded via the Application Configuration window, you can launch the application from this menu.

Execute the following procedure: 1. Select File >> Run. 2. Select the application from the available list. This launches the selected application in the service application window.

Exit - To close the application, select File >> Exit.

The **Diagnostics** tab contains the following items: Fault, Monitor, Truck Information, Custom Data Monitor, Strip Chart, Diagnostic Tests, Activity Logs, Load Strip Chart, No Run Mode, and Databus Viewer.

The **Truck Configuration** tab contains information on Password Management, Operator Checklist, and Truck Setup.

The **Programming** tab will display any auxiliary programs that have been added to enable programming of various truck models. These programs are added via the Application Configuration menu and require a higher level password to access.

The **Help** tab has information on Help Topics (contains a summary of the tool's features), Troubleshooting Manual, Demo Mode (provides simulated data, rather than loading it from the truck) , and About (version, build and copyright information are displayed).

NOTE: The following Troubleshooting Guide is provided to address some of the most common problems when using the tool. For additional questions, please contact consult the Installation and Use Guide packaged with the setup file or your service and support organization.

Table 25. Troubleshooting Guide

Problem Seen	Potential Cause or Resolution
Truck not listed in File >> Connection >> Unit Code dialog box.	Check again carefully. Note that the truck unit code is the first 4 digits of the serial number.
PCST displays error dialog that it cannot find or connect to truck.	The CAN adapter may not be installed properly. Most of these adapters have complicated installation procedures, involving multiple steps, with the installation of multiple files. Installation is much more involved than a typical USB module on a PC. Follow the directions closely and contact the manufacturer for any model-specific directions.
PCST takes a long time (more than 20 seconds) to connect, open or close certain menus.	Depending on the amount of data moving on the truck's internal CAN bus, it can take the PCST quite some time to gather, or write out the data required for diagnosis. This time period can also vary. In some cases, a very extensive amount of data may need to be gathered for thorough diagnosis. A bad or "noisy" connection can extend this time significantly. Ensure a solid mechanical connection to the truck's CAN bus.
PCST stops responding, or seems locked up.	CAN connection interrupted. Ensure solid connection. Remove and re-insert CAN Adapter USB connector. Restart PCST.
Custom Data Monitor or Strip Chart responding very slowly. Strip Chart "jumps" between readings.	Too many items being monitored. Reduce the number of parameters to minimum necessary. Also, some parameters do not respond quickly. It is suggested that these be viewed in the Custom Data Monitor rather than the strip chart.
Links from fault code display to Troubleshooting Manual don't work, or loading Troubleshooting Manual from Help doesn't work.	TS manual not loaded on PC, or in wrong directory. See Installation and Use Guide for proper file location.

Field Prog Programming Tool

Field Prog is a Windows based application used to update software for various truck controllers. The tool is not backward compatible with previous platforms.

NOTE: To install Field Prog you need to obtain the file product zip file from HYPro . The tool operates on proprietary files with the extension 'hyz'.

After Field Prog is installed, files can be selected and a list of operations will appear. Operations

consist of any combination of CAN-based programming items, USB based display transfers, or messages and instructions to the user. As an example, a list of operations could consist of several CAN-based operations that will proceed automatically, followed by a message to the user to attach the USB cable used for displays, and then a display programming operation.

During each operation a progress bar will appear and a pass or fail is indicated for each operation.

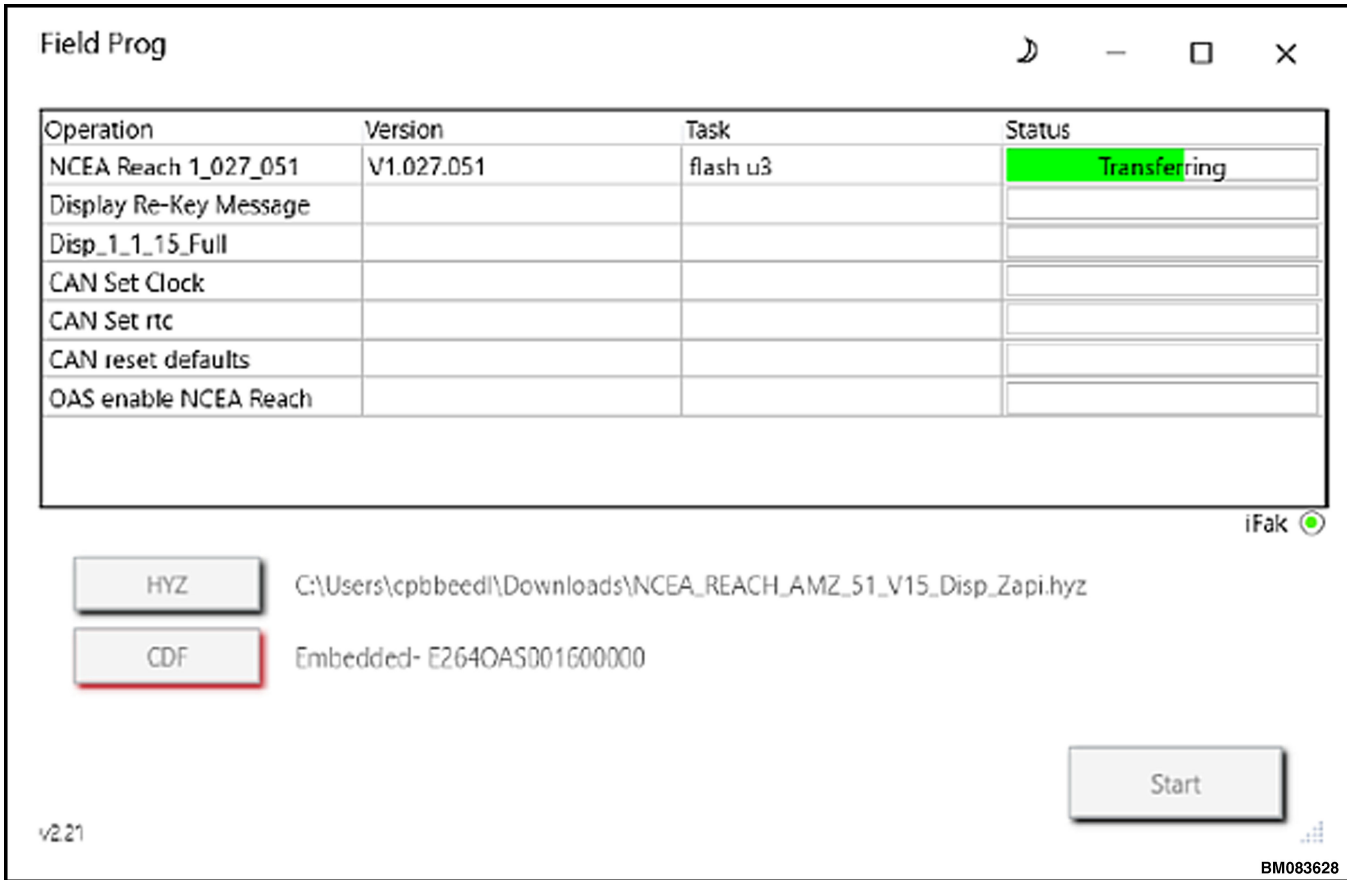


Figure 176. Progress Bar

Field Prog
☾ - □ ×

Operation	Version	Task	Status
NCEA Reach 1_027_051	V1.027.051		Completed
Display Re-Key Message			
Disp_1_1_15_Full			Failed
CAN Set Clock			Completed
CAN Set rtc		Pre-op Messages	Completed
CAN reset defaults		Pre-op Messages	Completed
OAS enable NCEA Reach			Completed

HYZ

C:\Users\cpbbeedI\Downloads\NCEA_REACH_AMZ_51_V15_Disp_Zapi.hyz

CDF

Embedded- E264OAS001600000

Start

v2.21
BM083629

Figure 177. Pass or Fail

NOTE: The J1 connector is common between all three available displays (2.8, 5 and 7 inch).

Display programming may also be performed on-truck by accessing the J1 connector on the back of the display.

Yanmar Smart Assist Direct (SAD) Tool (Engine)

NOTE: This is an overview only and not intended to be all inclusive. See Smart Assist Direct manual for full details.

The Smart Assist Direct tool provides the technician access to a wide array of tools for engine programming, data monitoring, data graphing, and other features.

System Requirements

The following table lists the minimum configuration requirement for installing Smart Assist Direct tool.

Software Requirements	Hardware Requirements	Vehicle Adapter Requirements (YANMAR Diagnosis Interface Box)
<ul style="list-style-type: none"> • Windows Vista - or - • Windows 7 32bit/64bit (recommended) - or - • Windows 8 (recommended) - or - • Windows 8.1 (recommended) - or - • Windows10 • Microsoft Excel 2000 or higher (for the display of operation data) 	<ul style="list-style-type: none"> • Intel Pentium 4, 2 GHz or more recommended • Hard disk of 200 MB or more recommended • USB port 1.1 or higher • High Speed Internet strongly suggested for download • Internet Explorer 8.0 or higher (for the manual link) • Display resolution: 1024 x 768 or higher 	<ul style="list-style-type: none"> • 1R1999-25000 (HITACHI interface box) • 1RF002-25000 (YANMAR interface box)

Features of Smart Assist Direct include:

- System Settings - This function allows you to change the settings necessary for replacing, repairing and adjusting the ECU, fuel injection pump, fuel injection valve (injector), and all sensors and switches after mounting and installation of the product. It has the submenus "Configuration", "Calibration", "Tuning", and "Initial Settings". You can create a report file after finishing the settings.
- Calibration - This function allows adjusting the standard position for sensors such as the accelerator position sensor.
- Tuning - You can adjust and set all performance parameters in accordance with industry standards and Yanmar Industrial Standards. Example: Adjusting the engine low idle speed, torque patterns, and speed performance within exhaust gas standards
- Injector Test - Fuel injection is turned on and off by each cylinder
- Intake Throttle Position Control - You can set the desired position of the intake throttle valve.
- Exhaust Throttle Position Control - You can set the desired position of the intake throttle valve.
- DPF Active Regeneration - Perform the DPF regeneration.
- Fuel Pump Learning - When replacing the supply pump using the DENSO CR System, it is necessary to perform fuel pump learning using forced operation after replacement.
- Calibration - This function allows adjusting the standard position for sensors such as the accelerator position sensor.
- ECU Replacement or Update - When replacing the ECU or updating (overwriting/correcting) of the ECU software is required, it is necessary to write the software to the new ECU (Service ECU) or ECU equipped machine. The software can be downloaded by accessing the center through the Smart Assist Direct, and a record of the download is uploaded to the center.

ECU Replacement or Update

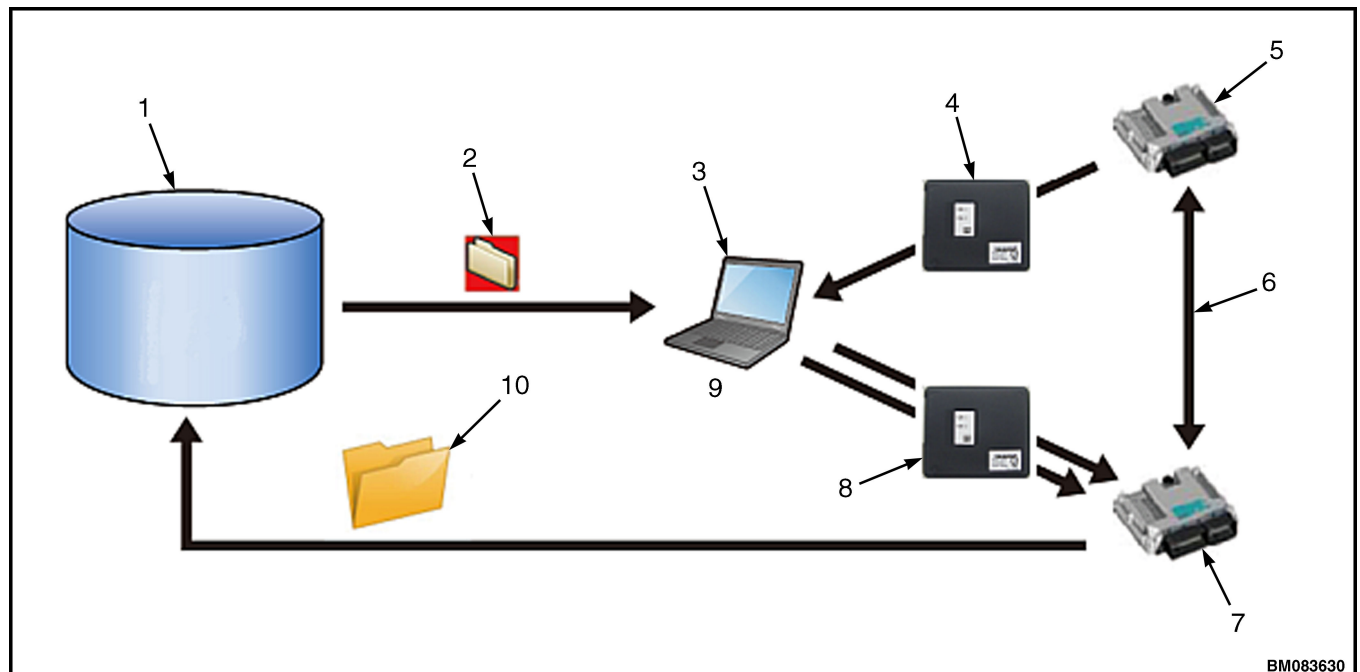
NOTE: Center refers to Smart Assist-Core.

Procedure for replacing or updating the ECU:

1. Download the ECU software.
2. Read and save the setting values (correction values) from old ECU.
3. Write to the software's ECU.

4. Copy settings (correction values) to the new ECU.
5. Upload the replacement and update data.

NOTE: There is no need to perform steps (2) to (4) when making a software update (overwriting/correction).



- | | |
|---|--|
| 1. CENTER | 6. REPLACEMENT |
| 2. ACCESS THE CENTER, DOWNLOAD THE ECU SOFTWARE | 7. NEW ECU (SERVICE ECU) |
| 3. PERSONAL COMPUTER (PC) | 8. COPY THE SETTING VALUES TO THE NEW ECU |
| 4. READ AND SAVE THE OLD ECU SETTING VALUES | 9. INTERFACE BOX (NOT SHOWN) - WRITE THE SOFTWARE |
| 5. OLD ECU | 10. ACCESS THE CENTER, UPLOAD THE REPLACEMENT DATA |

Figure 178. ECU Update or Replacement

TELEMETRY SYSTEM DESCRIPTION

202001-293

GENERAL



WARNING

Failure to follow the instructions in this section can cause the lift truck to become inoperable or damaged and result in personal injury, death, or property damage. Read and follow all **WARNINGS** and **CAUTIONS**.

The telemetry module module and related parts (harnesses, brackets, and subsystems) **MUST** be removed and installed by service technicians trained in the removal and installation of these systems and in accordance with the instructions outlined below.

DO NOT modify, tap into, splice, or solder existing factory harnesses, wiring, or connectors. Except for the wire harness clamps, replacement parts include all required wiring and hardware for proper installation of new parts without disturbing or modifying the factory installed wiring or accessories on the lift truck.

ALWAYS disconnect the battery prior to removing and installing parts of the telemetry system to prevent electrical shock or short circuits in the electrical system of the lift truck.

System reliability is dependent on correct wire harness routing. The wire harness must not interfere with other wires, hoses, brackets, or other components that might contact and rub the wire harness. The wire harness must be properly secured to lift truck frame to prevent rubbing with other components during normal vibration while lift truck is in operation. Clamps should be used to securely fasten harness in place without excessive crimping of the wire harness.

The lift trucks covered in this **Service Manual** may be equipped with an optional Telemetry Wireless Asset Management System. This system is designed to allow monitoring of key systems for which the lift truck is equipped with. There are three levels of the Telemetry Wireless Asset Management System that can be installed on your lift truck if this option is chosen.

- **Level 1 - Wireless Monitoring (WIFI Group)** - This level of service connects passively to the CANbus and does not

interlock the starting of lift truck. The main function of level 1 configuration is reporting hour meters and impacts through use of WIFI or GSM to the telemetry module.

- **Level 2 - Wireless Access** - This level of service connects passively to the CANbus and interlocks the lift truck. Only authorized users are allowed access through use of an RF-ID reader card. Performing maintenance will require use of a service card to disable all shut down timers.
- **Level 3 - Wireless Verification** - This level of service connects passively to the CANbus and interlocks the lift truck. Only authorized users are allowed access through use of an RF-ID reader card. Additionally, a checklist will be displayed and all items must pass inspection before lift truck can be started. Failing a checklist item can be configured to disable lift truck. A service card is required to start a lift truck that has failed a checklist item. Performing maintenance will require use of a service card to disable all shut down timers.

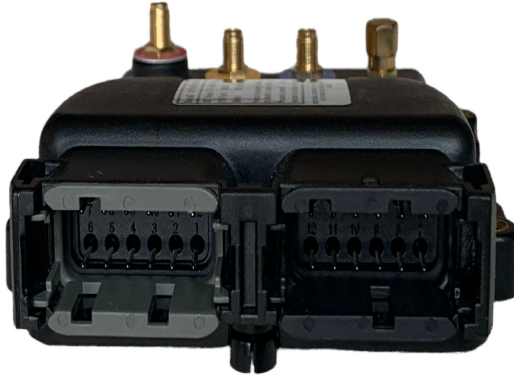
The information in this section describes components for each level of the Telemetry Wireless Asset Management System. For information on programming the Telemetry Wireless Asset Management System, for diagnostic and troubleshooting procedures, or for removing and installing components or connecting and routing the wire harnesses, see Telemetry Wireless Asset Management System in **Electrical, software, and controls** 2200SRM2304. Information on correctly routing and installing the power (wire) harness, interlock harness, and checklist display harness, can also be found in the **Diagrams and Schematics** 8000SRM2307 manual.

Telemetry Module

The telemetry module has two primary connectors. The GREY connector, and the BLACK connector are both 12 pin Deutsch connectors.

The GREY connector connects to the **chassis harness**. This connector carries the primary signals to the truck, the CAN communication lines to and from the truck's VSM, the wake up signals, and carries the positive and negative power rails to feed the telemetry module.

The BLACK connector connects to the RF-ID reader harness jumper. This connector carries relay contacts for interlocking the truck's systems, custom switched outputs for additional expansion, and the communication lines to the Checklist Display or ID Reader.



BM08387

Figure 179.

The checklist will appear on the main truck display. The checklist allows for the full capability of the telemetry system to be utilized.

The ID Reader has a simple 4 pin GREY connector. The ID Reader detects ID cards presented to it, and sends communication data to the communication module. The ID Reader allows the full capability of the telemetry system to be utilized.

The 4 Pin GREY connector connects to the checklist display harness (if a checklist display is installed) or the Interlock Harness (if no checklist display is installed).



BM120536

Figure 180.

Basic Operations

ID Card / ID Reader

ID reader interlock will prevent unauthorized operator access to equipment. A registered ID card must be swiped against the ID reader to allow equipment start up.

ID cards are registered to the equipment through the NTP website. Operator cards IDs are given standard access to equipment. Technician card IDs are used to clear equipment lockout and additionally do not require checklist interlock.

The ID reader will detect operator cards swiped within close range. After card swipe, the ID Reader sends card data to the telemetry module for processing. Telemetry module determines if access is granted or denied and whether a technician or operator card has been swiped.

Before ID card swipe, Display will prompt the following text: Please swipe card.

Swipe Valid Operator Card:

- Horn tone: Single long buzz.
- Display text: Access granted.

Swipe valid Technician Card:

- Horn tone: Single long buzz.
- Display text: Access granted.
- Checklist: Disabled.
- Lockout: Cleared.

NOTE: Swiping a Operator card during System Lockout will result in 2 short buzzes.

Swipe invalid Operator/Technician Card:

- Horn tone: Three short buzz.
- Display text: Access granted.

Wakeup

Telemetry module requires constant battery voltage.

A start-up signal is used to trigger wakeup of telemetry module.

Successful wakeup is observed through a horn and powering up of the Display Module.

Depending on equipment type, the start-up trigger will be one of the following:

- honk horn
- sit on seat
- toggle key switch

Depending on the start-up trigger, a 12v signal can be measured on pin3 or a ground signal on pin9 of the power harness.

The resulting wakeup is confirmed by hearing the buzz tone or confirming the 12V power to the Display Module. Measurable by any of the following:

- Observe Display screen LCD light up (if installed).
- 12V: Interlock Harness, 12pin Black connector pin5.
- 12V: Display harness, 12pin Green connector pin1.

Checklist

NOTE: Level 3 Only

Checklist interlock requires a Display module for operator interaction.

Pre and Post start questions are configured via the website.

The telemetry module module can be configured to prompt for checklist every set time period, or at particular shift times each day, or every key on.

Accessing the equipment by swiping technician ID card will cause the checklist to be skipped.

Pre-start questions will be completed before start/drive is enabled on the equipment.

Post-start questions will be completed after start/drive is enabled on the equipment.

To deter operators from blatantly using equipment during the post-start checklist phase, a question timer can be enabled. This timer will report operators to the website which do not complete their checklist.

Antenna

The antenna is a device that allows communication between the telemetry systems and their cloud servers. Truck and performance data is transmitted to the telemetry portal and offered as data for the end user to create reports, monitor trucks, and drive fleet business opportunities. The VAM module and the antenna are CAN enabled so they can transmit messages over the network.

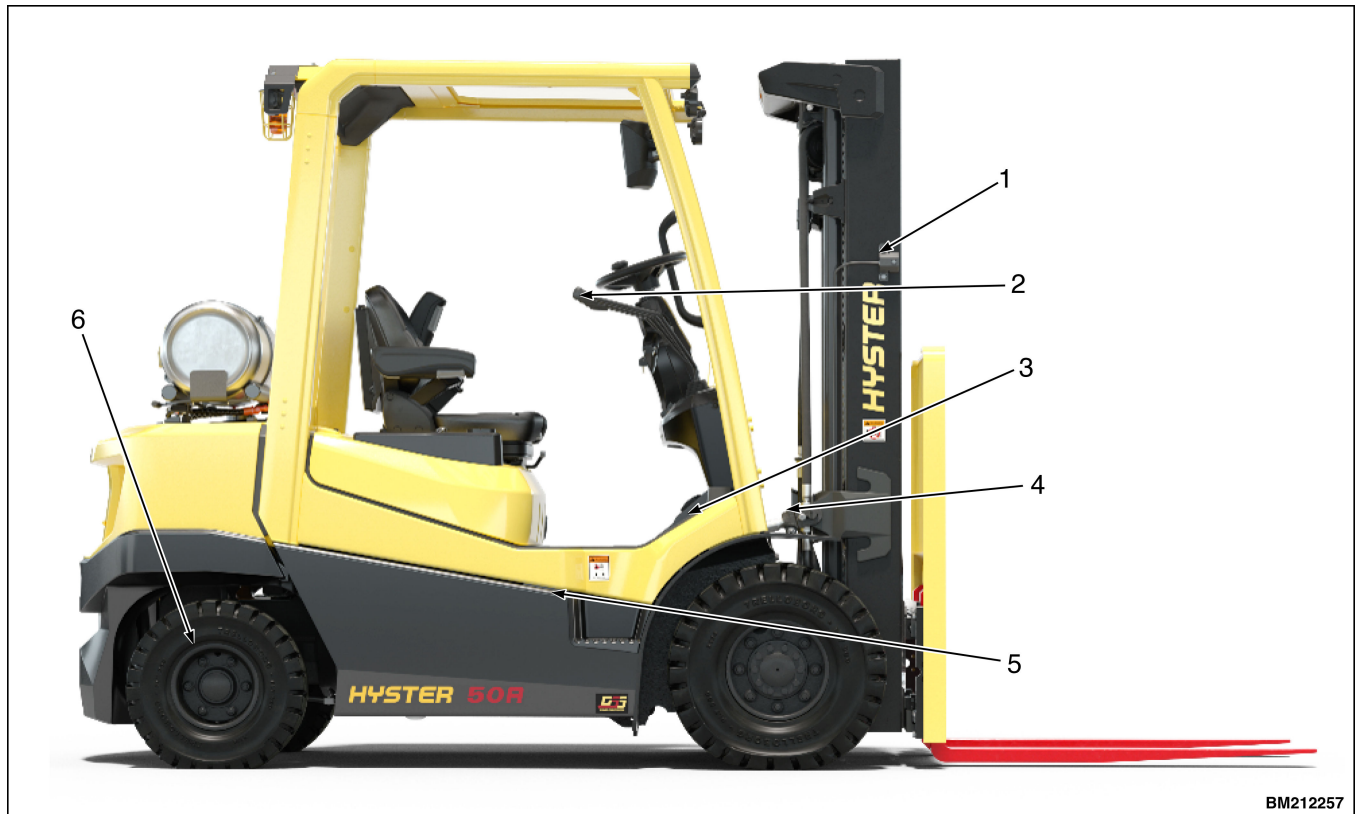
The antenna provides real-time telemetry data from equipped trucks. The system can be used to track product and operator data. Data examples include hour meters, fault codes, and impacts. Events such as impacts can be configured to automatically send out an email alert, making it easier to track and review incidents. Alerts can also be received via the telemetry mobile application. The antenna communicates with the cloud based servers and is compatible with both Wi-Fi and GSM cellular signals. Telemetry monitoring enhances the process for periodic maintenance capture. An example includes the automatically loading of the known maintenance into the telemetry system when factory installed.

DYNAMIC STABILITY SYSTEM (DSS) 202001-337

The Dynamic Stability System (DSS) is a training tool designed to provide feedback to the operator to promote and reinforce proper operating. The DSS features a series of sensors installed on the lift truck

to limit performance in the event the lift truck is being operated in a manner that is inconsistent with proper training.

COMPONENTS OF THE DSS



1. LIFT HEIGHT SENSOR
2. TILT OVERRIDE BUTTON
3. HYDRAULIC LOAD SENSOR

4. TILT ANGLE SENSOR
5. SPEED SENSOR
6. STEER ANGLE SENSOR

Figure 181. Components of the DSS

Vehicle System Manager (VSM)

The VSM controls the DSS system by taking information received from sensors and engaging DSS when the operator pushes the lift truck beyond determined thresholds. DSS provides audible and visual indicators to the operator when truck performance becomes limited.

Lift Height Sensor

The Lift Height Sensor is located on the outside of the right-hand post of the outer mast and is mounted at the height of the determined threshold. It works together with a magnet attached to the carriage. When the carriage is raised and the magnet passes by the Lift Height Sensor, the carriage has gone beyond the lift-height threshold and the sensor will send a signal to the VSM.

Hydraulic Load Sensor

The Hydraulic Load Sensor is a pressure sensor located in the hydraulic control valve. The Hydraulic Load Sensor measures the weight of the load to determine if the weight is above or below the threshold.

Tilt Angle Sensor

The Tilt Angle Sensor is located on the mast tilt clevis and continuously measures the angle of the mast.

Tilt Override Button

The Tilt Override Button is located near the tilt control and allows the operator to override the forward tilt limit.

Speed Sensor

The Speed Sensor is mounted on the transmission output and continuously measures the lift truck speed.

Steer Angle Sensor

The Steer Angle Sensor is mounted to the kingpin on the steer axle and continuously measures the steering angle.

DSS SUBSYSTEMS

The DSS is comprised of the following four subsystems:

- Lateral Stability System

- High-Lift Traction Control
- High-Lift Tilt Control
- Corner Control

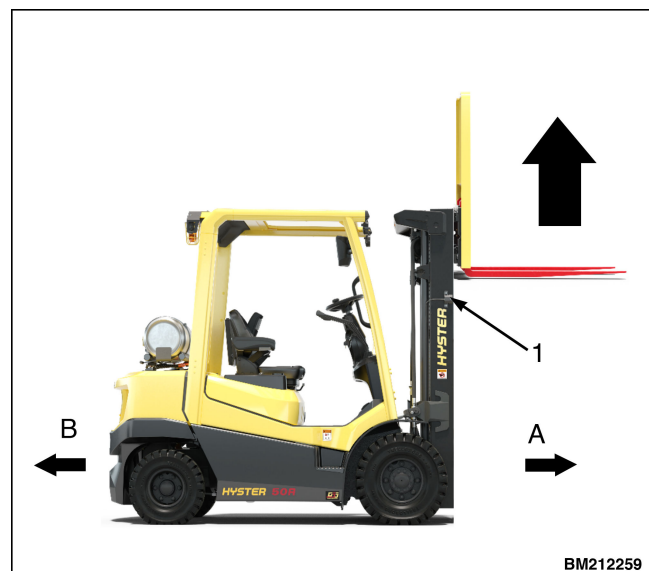
Lateral Stability System

The Lateral Stability System is designed to reduce leaning during turning. Rubber mounts on the steer axle improve travel over uneven surfaces.

High-Lift Traction Control

High Lift Traction Control feature is designed to reinforce careful operating practices by limiting truck speed in the event those practices are overlooked. When the truck is travelling in either forward/reverse direction with the carriage raised above the height threshold as determined by the Lift Height Sensor, the speed immediately becomes reduced and visual and audible indicators will alert the operator.

The reduced speed will remain in effect until the load is lowered below the threshold and the accelerator pedal has been fully released and re-applied.

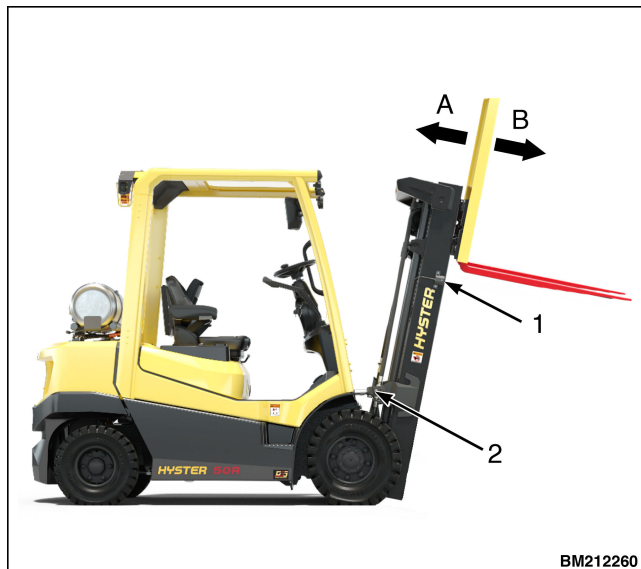


- A. FORWARD TRAVEL
B. REVERSE TRAVEL
1. LIFT HEIGHT SENSOR

Figure 182. High-lift traction control

High-Lift Tilt Control

High Lift Tilt Control feature is designed to reinforce careful operating practices by limiting mast speed and forward tilt range in the event those practices are overlooked. When there is a load on the forks that has met load weight conditions AND the carriage is raised above the determined height threshold, the Tilt Angle Sensor will measure the angle of the tilt. If the carriage tilt exceeds the determined threshold, the mast tilt speed (forward and back) and tilt range (forward only) immediately become reduced and visual and audible indicators will alert the operator. When the forward tilt becomes limited, the operator has the option to override by using the tilt override button located near the tilt control.



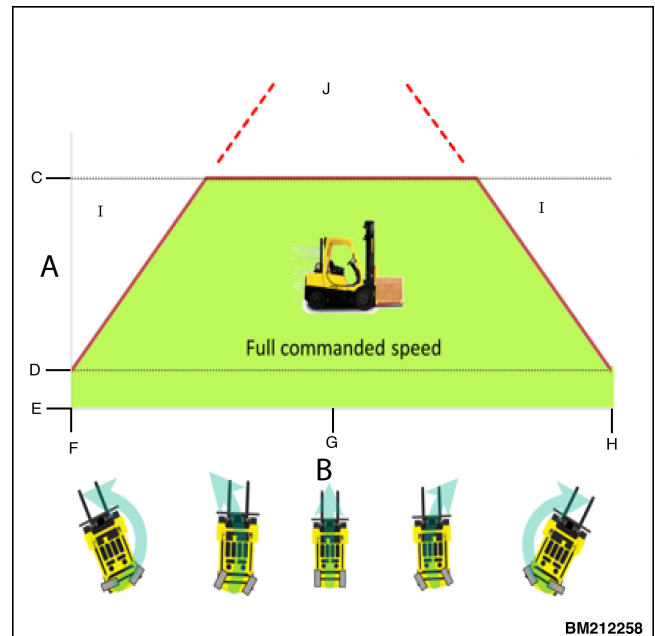
- A. REVERSE TILT
- B. FORWARD TILT

- 1. LIFT HEIGHT SENSOR
- 2. TILT ANGLE SENSOR

Figure 183. High-lift tilt control

Corner Control

Corner Control feature is designed to reinforce careful operating practices by limiting truck speed during cornering maneuvers. Truck speed becomes limited as the steer angle threshold increases as measured by the steer angle sensor mounted on the kingpin of the steer axle. Visual and audible indicators will alert the operator. There are three adjustable level settings which can be selected using a supervisor-level password.



- | | |
|----------------------------|--------------------------|
| A. TRUCK SPEED | F. STEERING = 100% LEFT |
| B. OPERATOR STEERING INPUT | G. STEERING = STRAIGHT |
| C. SPEED = MAX | H. STEERING = 100% RIGHT |
| D. SPEED = FULL COMMANDED | I. SPEED REDUCTION ZONE |
| E. SPEED = 0 MPH/KPH | J. STEER ANGLE THRESHOLD |

Figure 184. Corner control

DSS INDICATORS AND EVENTS

High-Lift Traction Control, High-Lift Tilt Control and Corner Control present visual and audible indicators to the operator when the operator approaches or exceeds the limits that cause DSS to engage. When the DSS engages, the event is logged and reported via telemetry.

Event	Indicators
DSS limit is being approached	<ul style="list-style-type: none"> • Visual indicators only
DSS limit has been exceeded	<ul style="list-style-type: none"> • Visual indicator • Audible indicator • DSS engages • Telemetry recorded

NOTE: Audible indicators may be turned on or off by a dealer service technician. Visual indicators may not be turned off.

Recording of DSS over telemetry may not be turned off.

Visual indicators

A visual DSS indicator will illuminate on the truck display when the operator places the truck in a condition that approaches or exceeds the limits of the DSS system.

The visual indicators will appear in the form of one of the following display icons:



Figure 185. Forward tilt icon



Figure 186. Backward tilt icon



Figure 187. Longitudinal icon



Figure 188. Lateral icon



Figure 189. Lift height sensor verification icon

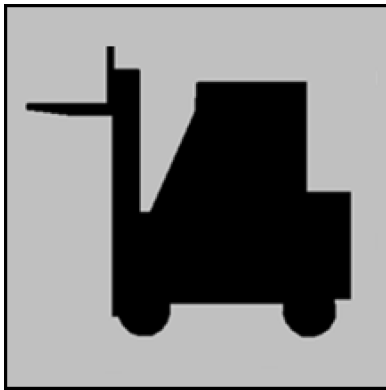


Figure 190. Lift height sensor status icon

Audible indicator

An audible DSS indicator will sound when the operator places the truck in a condition that exceeds the limits of the DSS system.

The audible indicator tone is unique to DSS and will sound the same for both longitudinal stability events and lateral stability events.

Telemetry

For trucks featuring Telemetry options, DSS events are recorded and reported over telemetry. While audible DSS indicators can be turned off, it is not possible to stop events from being recorded within the Hyster Tracker system. All DSS events recorded in the system shall be stamped with date, time and hour meter of the event.

Operator's cab

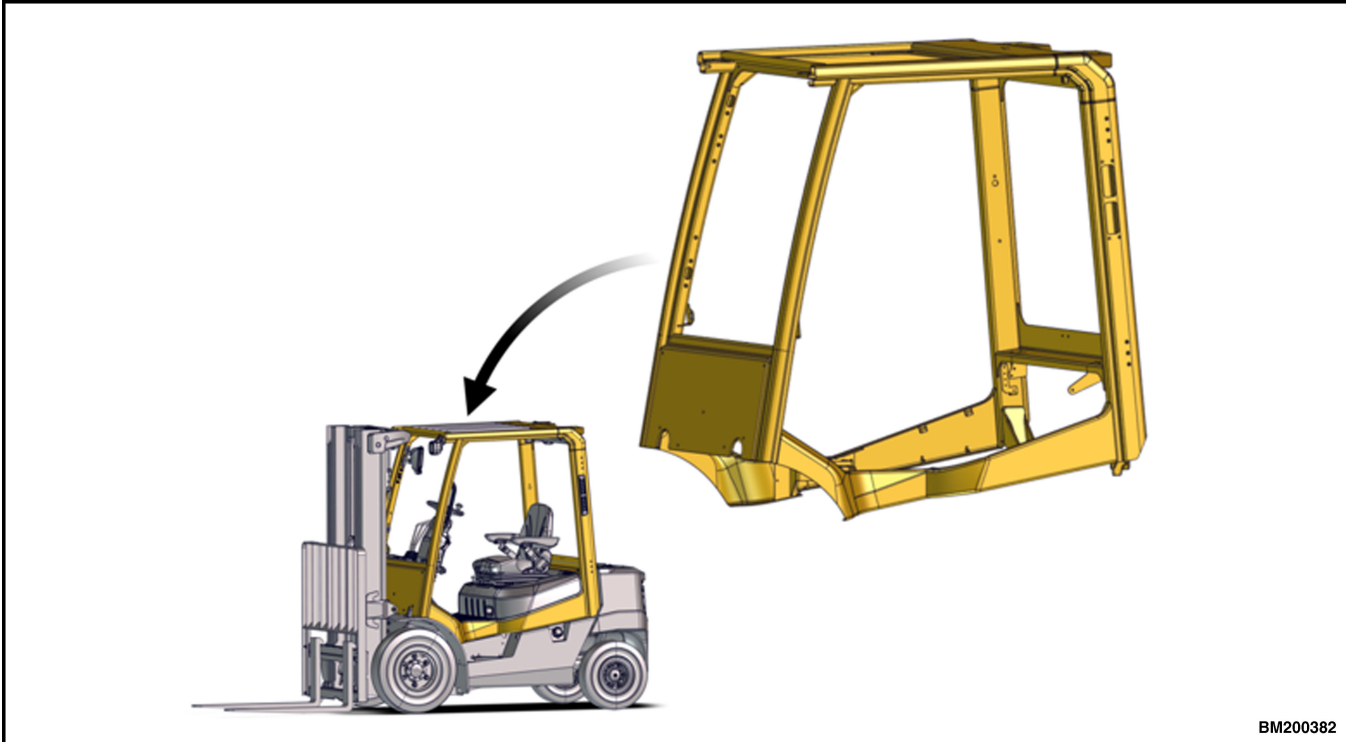
OVERHEAD GUARD DESCRIPTION 202001-152

OVERHEAD GUARD

The operator module encompasses the overhead guard, side panels, and cowl into a welded unitized frame. All major operator compartment components

(hood and seat, floor plate and floor mat, steering column, pedals, and dash) then assemble to this module.

The operator module allows the entire operator compartment to be isolated. Side panels are no longer removable due to the fully-welded construction of the operator module.



BM200382

Figure 191. Operator Module

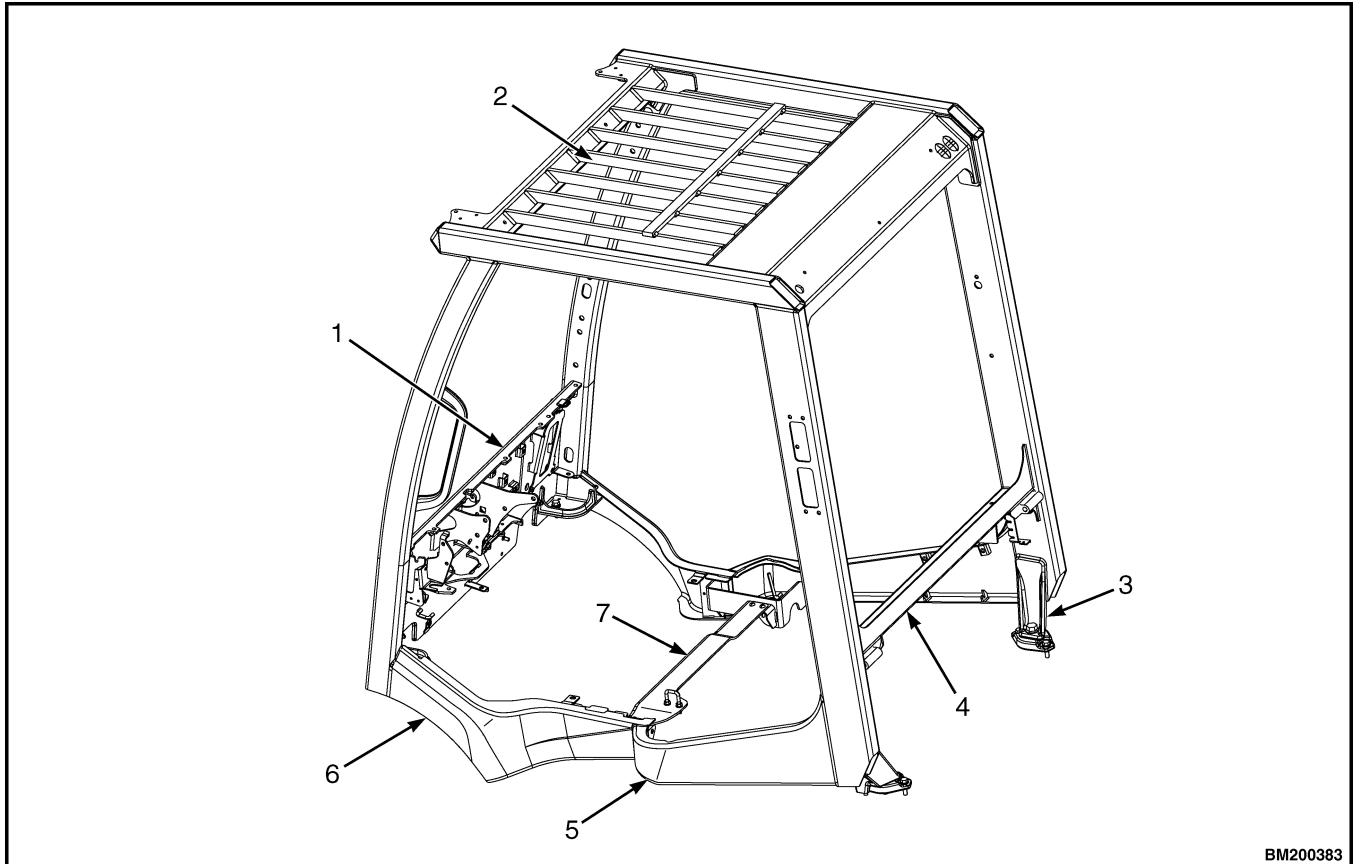
The overhead guard is installed regardless of truck configuration options and is designed to protect the operator. The overhead guard is available in either a standard version (rectangular tubing) or a premium (figure eight tubing) version. In either case the primary structural frame members are steel tubing welded into an assembly and bolted to the frame.

NOTE: The overhead guard is intended to offer reasonable protection to the operator from falling objects, but cannot protect against every possible impact. Therefore, it must not be considered a substitute for good judgment and care when handling loads.



WARNING

Do not operate the lift truck without the overhead guard correctly fastened to the lift truck.



BM200383

NOTE: STANDARD RECTANGULAR TUBING IS SHOWN, FIGURE EIGHT TUBING IS SIMILAR.

- | | |
|---|------------------------------|
| 1. COWL (BOLTED) AND FRONT COWL
CROSSMEMBER (WELDED) | 5. REAR SIDE PANEL (WELDED) |
| 2. CANOPY (WELDED) | 6. FRONT SIDE PANEL (WELDED) |
| 3. MACHINED CASTING SUPPORT (WELDED) | 7. HOOD CROSSMEMBER (BOLTED) |
| 4. REAR CROSSMEMBER (WELDED) | |

Figure 192. Overhead Guard, Standard Rectangular Tubing

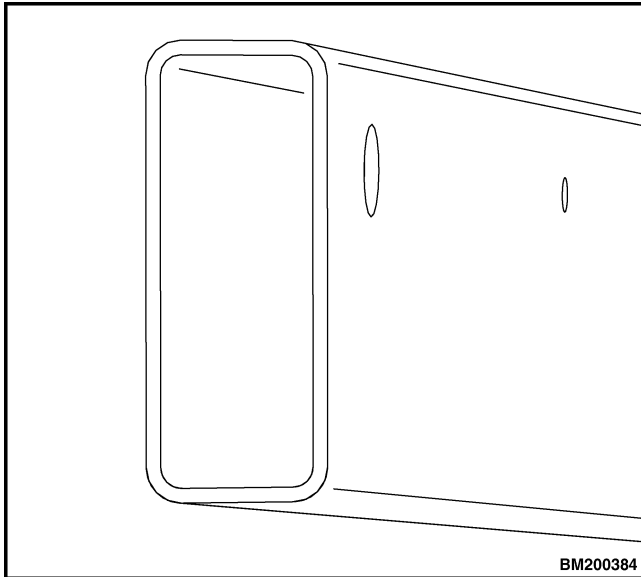


Figure 193. Rectangular Tubing Example

The rectangular tubing (standard) overhead guard can be a high or low version and is best suited for indoor applications (no cab option). It is designed to accommodate 10° of mast back tilt and has an open grid-style canopy providing excellent upward visibility. The rectangular tubing overhead guard option is not compatible with any cab options except the polycarbonate top option. Cab options and accessories are NOT available with the rectangular style overhead guard configurations.

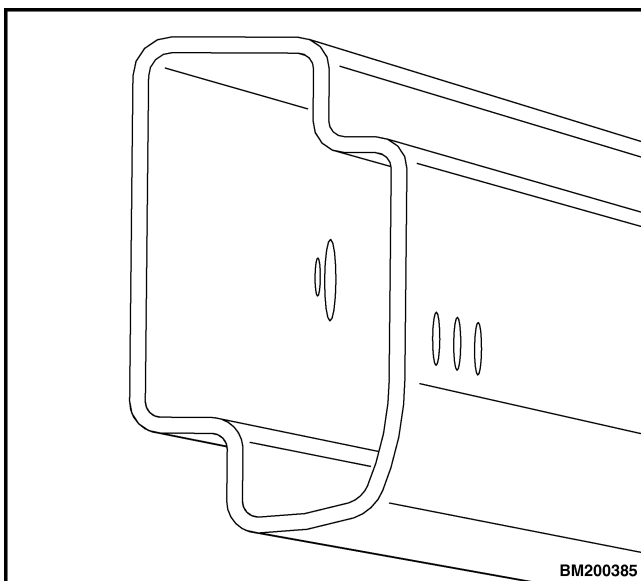


Figure 194. Figure Eight Tubing Example

The figure eight tubing overhead guard is required for trucks with cab option. This design cross section leaves a recess that allows fitment of flush-mounted cab panels and doors. Trucks equipped with rectangular tube overhead guards cannot be fitted with a cab.

An option for the figure eight overhead guard is the maintenance-free hydraulic isolators (dampers). They are completely sealed and provide more effective isolation than standard, solid rubber isolators mounting or hard mounting.

Cab Kit Options

Numerous options are available for attaching to the overhead guard and cab. Some of those options are listed below.

- Glass top, front, and rear screens
- Flexible PVC or rigid steel doors
- Front, top, rear wipers and washers
- Polycarbonate rain top (attached with straps)
- Heated front and rear screens
- Air conditioning (only available on full cabins with steel doors)
- Cab heater

CAB COMPONENTS DESCRIPTION 202001-153

CAB COMPONENTS

The optional fully-enclosed operator cab is a separate unit and can be installed or removed as a complete unit from the frame of the truck. The cab may come equipped with doors, screens, front and rear window wipers, heater system, front and rear work lights, strobe light, and an optional operator fan. The overhead guard is integrated into the operator cab. The operator cab may be hard mounted directly onto the truck frame or mounted on hydraulically damped isolators.

Other cab components may include grab handle, rear drive handle with horn button, 12 volt power supply with 2 USB charging ports, and a reading light.

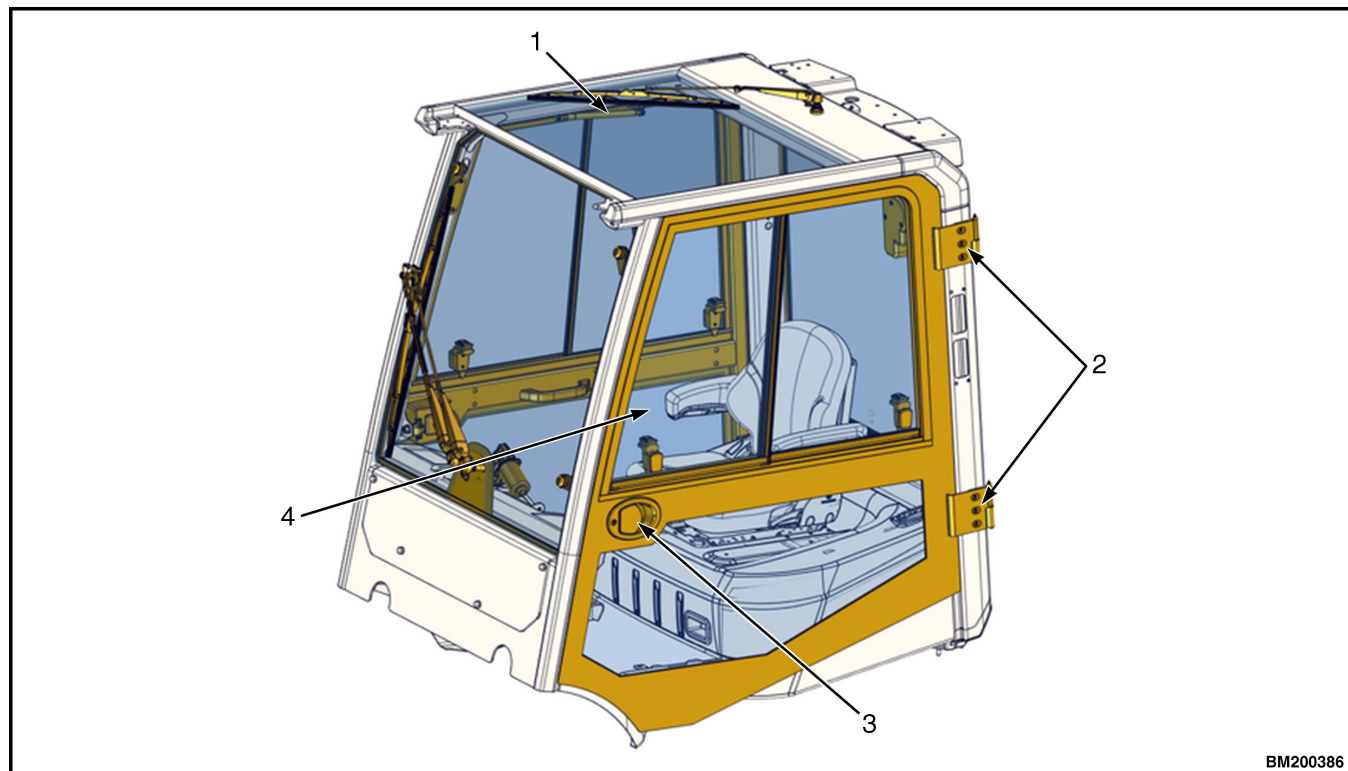
Doors

Doors may be either PolyVinyl Chloride (PVC) or steel. Cab doors can be removed without having to disassemble the Heating, Ventilation, and Air Conditioning (HVAC) system.

Steel Doors

The steel doors have AS2 tempered glass windows and a sliding window in the top half allowing drivers to communicate and allow air to come in and out of the cab. Gas springs are fitted to each door to

control the opening action and stop over travel of the assembly. The Left Hand (LH) steel cab door is fitted with an air overpressure vent (enclosed in a plastic cover) to stop pressure build up when a door is closed helping to ensure latching of the door.



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NOTE: GRAPHIC SHOWN WITH OPTIONAL SCREENS AND WIPERS.

1. GAS SPRING
2. HINGES

3. DOOR HANDLE
4. SLIDING WINDOW

Figure 195. Steel Doors

Hinges are welded to the door assemblies and then bolted to the overhead guard allowing removal and storage if required. During use the doors are protected by sitting within the width of the lower frame and counterweight. A full perimeter bulb seal weatherproofs the doors from the elements.

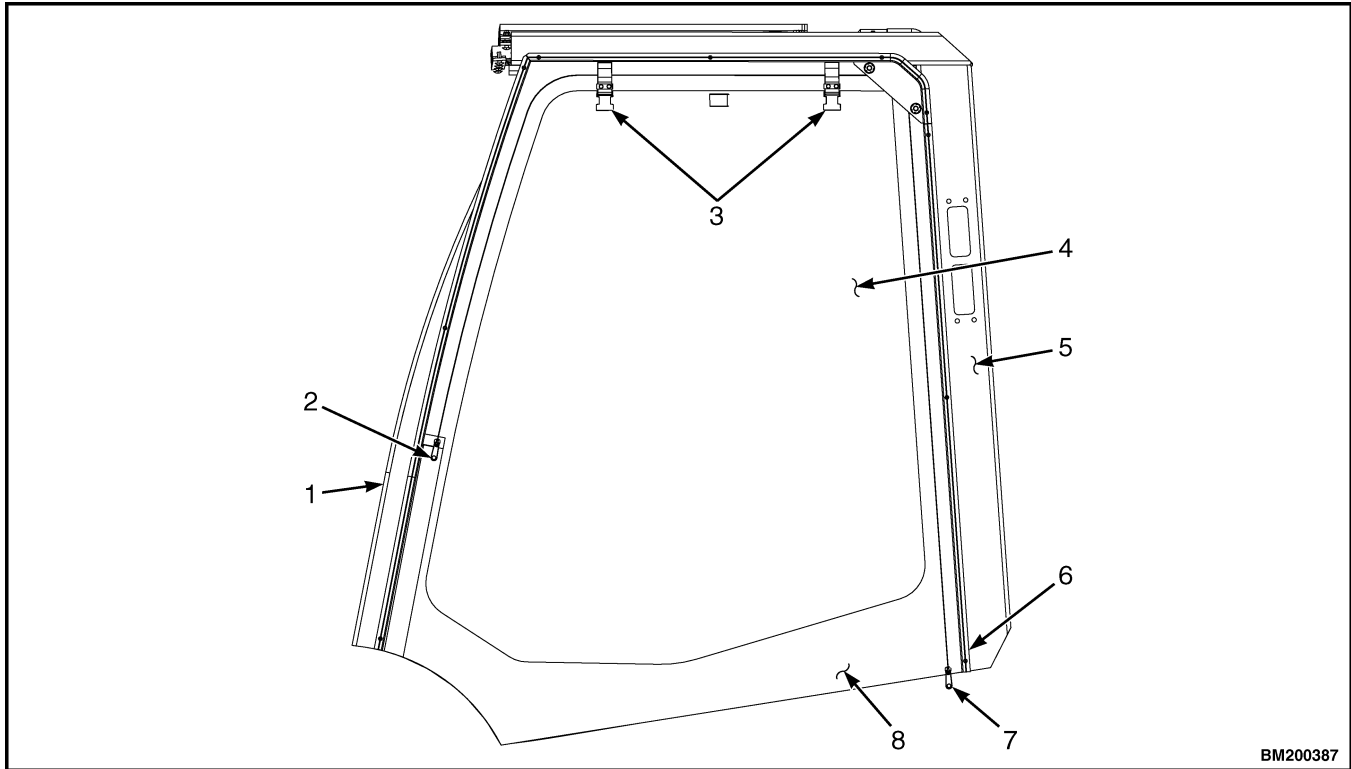
Both keyed doors have internal and external lockable handles. Doors are removable and include steel tubes ready to mount optional equipment.

PVC Doors

Flexible PVC doors with transparent panel windows can be rolled up and secured out of the way. The doors are fixed to the cab structure by an edge bead

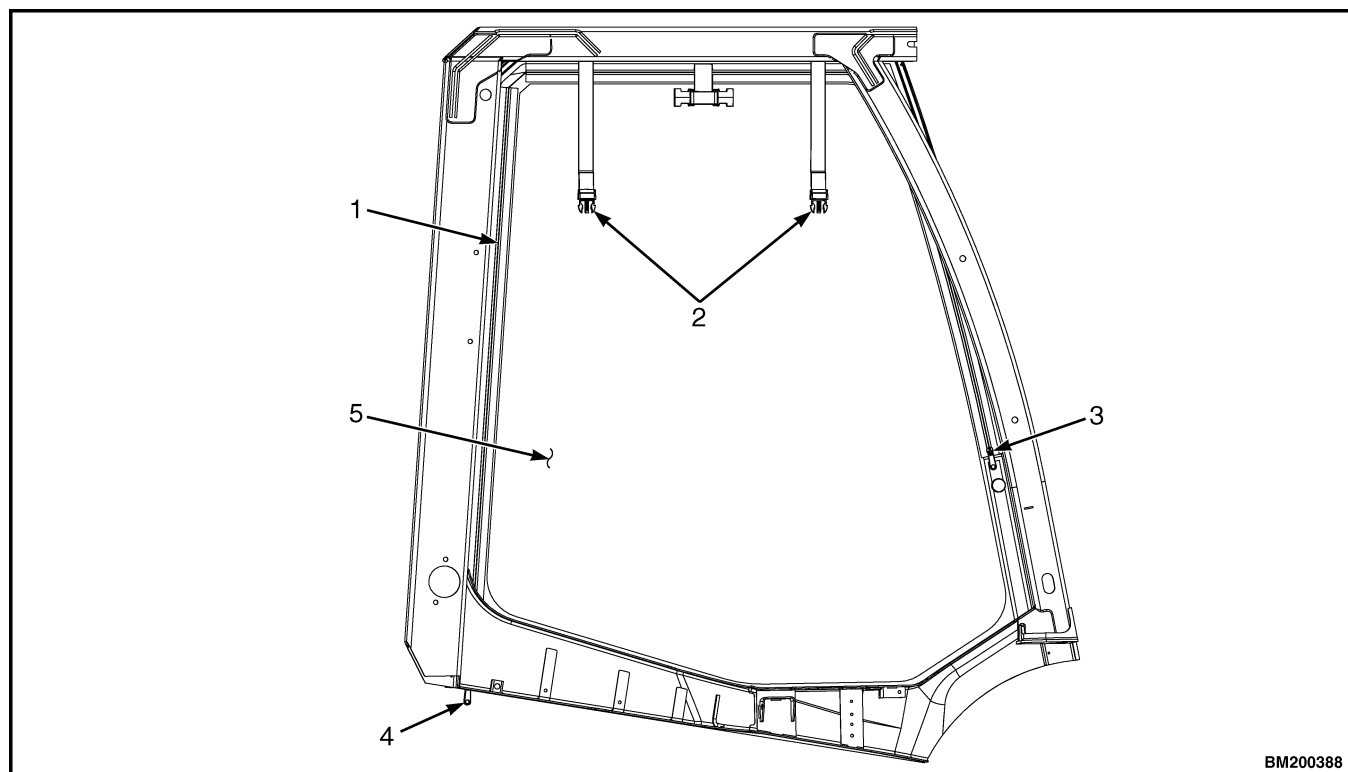
contained within an aluminum extruded section. The extruded section is held in place by 3M self-adhesive foam tape and self-tapping screws around the existing cab leg section.

Door support cloth is bonded to the transparent panels using high frequency welding and the zippers are attached by sewing. Steel insert pads embedded in the cab side material are designed to mate with the six door magnet positions. The neodymium magnets are bonded to the inside surface of the door seam to help keep the door in place. Two zippers, door ties, and quick release buckles allow the door to be rolled up and secured out of the way.



- | | |
|---|--|
| 1. OVERHEAD GUARD SUPPORT POST, FRONT, LH | 5. OVERHEAD GUARD SUPPORT POST, REAR, LH |
| 2. ZIPPER 1 START POINT | 6. SELF-TAPPING SCREW |
| 3. QUICK RELEASE FEMALE BUCKLE | 7. ZIPPER 2 START POINT |
| 4. TRANSPARENT PANEL | 8. DOOR SUPPORT CLOTH |

Figure 196. PVC Door, LH, Outside



BM200388

- | | |
|---|-------------------------|
| 1. DOOR SUPPORT CLOTH | 4. ZIPPER 2 START POINT |
| 2. STRAP WITH QUICK RELEASE MALE BUCKLE | 5. TRANSPARENT PANEL |
| 3. ZIPPER 1 START POINT | |

Figure 197. PVC Door, LH, Inside

Screens

Screens are available for the front, top (roof), and rear. Rear screens are electrically heated (optional for front screen), the top screen is glass only (no heating available). The heating elements are embedded micro-filaments that keep windows clear of condensation and help clear ice and frost while the engine is still warming. Front, rear, and top screens are all recessed to sit inside of the overhead guard section. Screens can be used with either steel or PVC doors.

Front Screen

When the operator turns the heated screen on, it runs for a short duration and automatically deactivates once the screen is demisted. This option allows the front screen to be demisted without relying on the HVAC system and also for loosening

ice accumulation on the screen. The heating elements are embedded micro-filaments.

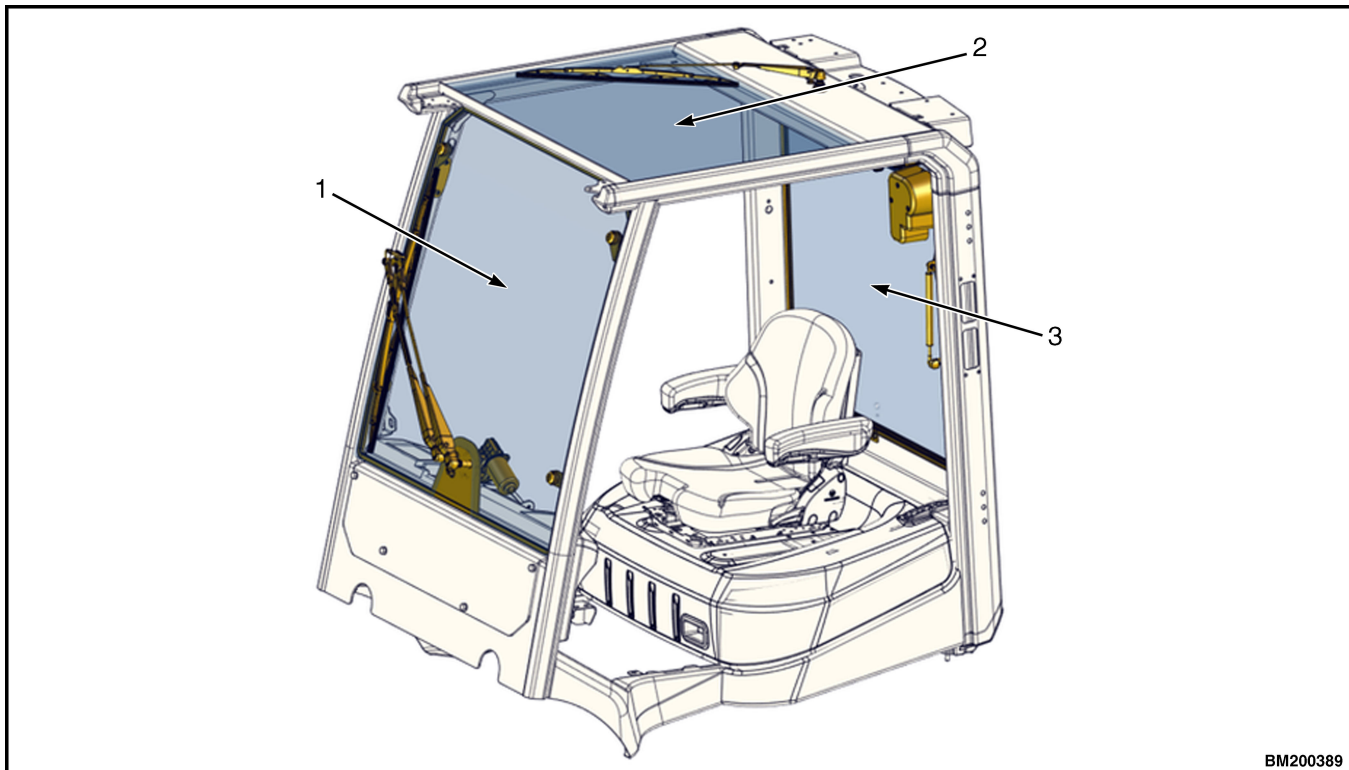
The heated front screen option is controlled by a button on the roof liner of the overhead guard. When the operator presses the button, the screen heats up and automatically shuts off after 5 minutes. The heated front screen is laminated rather than toughened glass, which means it will stick together if the glass breaks. The non-heated version will fall into small pieces if broken (just like a car side window).

Top (Roof) Screen

A 20mm (0.79 inch) thick solid pane of high strength laminated glass, helps operators view the load when loading or un-loading at height. The top screen is available with or without a wiper.

Rear Screen

The rear screen has been designed to have a steel panel on the left hand side allowing harness routing and air-conditioning pipe work to be secured while sitting behind the area normally occupied by the high level exhaust. The rear screen is hinged at the top allowing it to be opened for service access to the engine compartment or to allow more air to circulate in the cabin.



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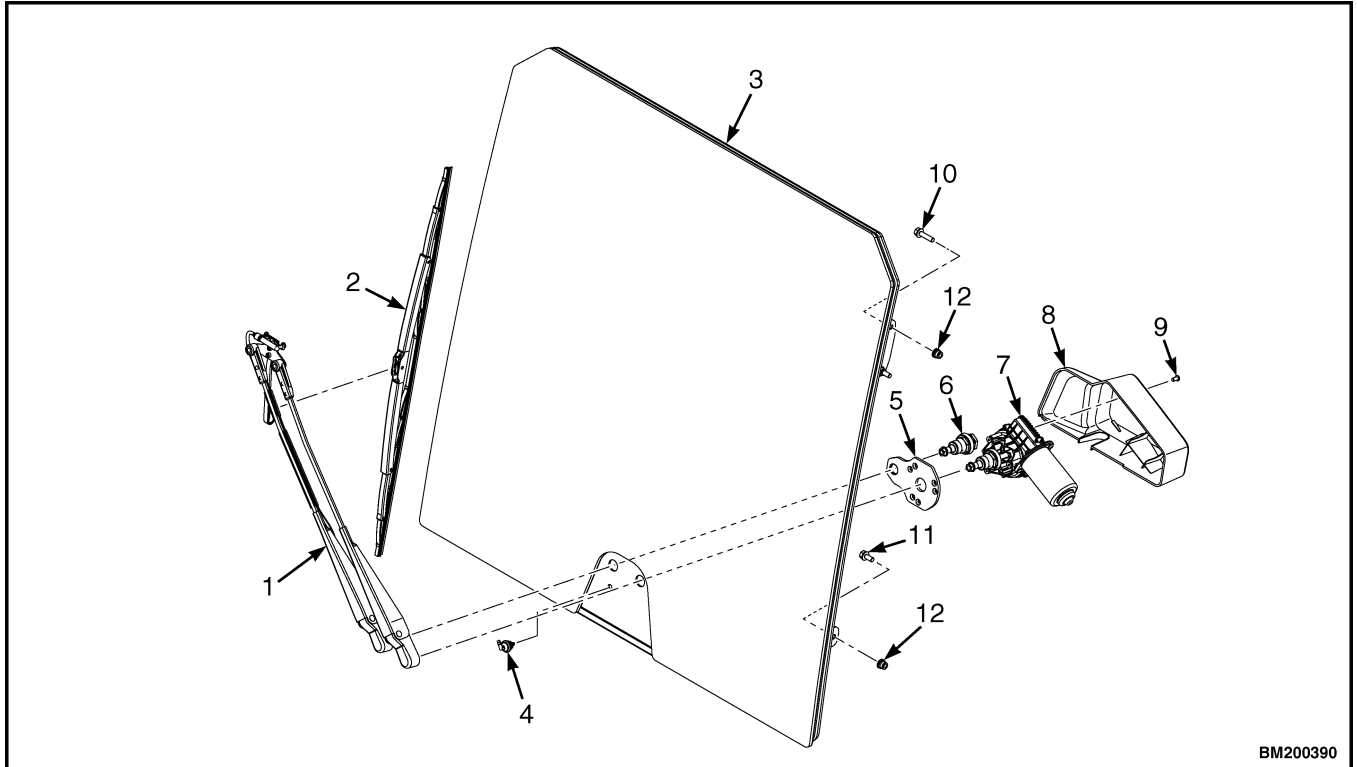
1. FRONT SCREEN WITH WIPER
2. TOP (ROOF) SCREEN (WITH OPTIONAL WIPER)
3. REAR SCREEN (WITH OPTIONAL WIPER)

Figure 198. Front, Top (Roof), and Rear Screens

Wipers

Wipers are standard with front and rear screens and optional for top screens.

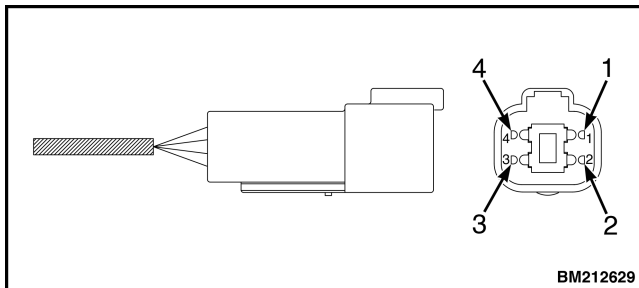
Front Screen and Wiper



BM200390

- | | |
|------------------------------|----------------------|
| 1. WIPER ARM | 7. WIPER MOTOR |
| 2. WIPER BLADE | 8. WIPER MOTOR COVER |
| 3. FRONT SCREEN | 9. SCREW |
| 4. ELBOW FITTING | 10. CAPSCREW |
| 5. WIPER MOTOR MOUNT BRACKET | 11. CAPSCREW |
| 6. DRIVEN SPINDLE WIPER | 12. INSERT |

Figure 199. Front Screen and Wiper

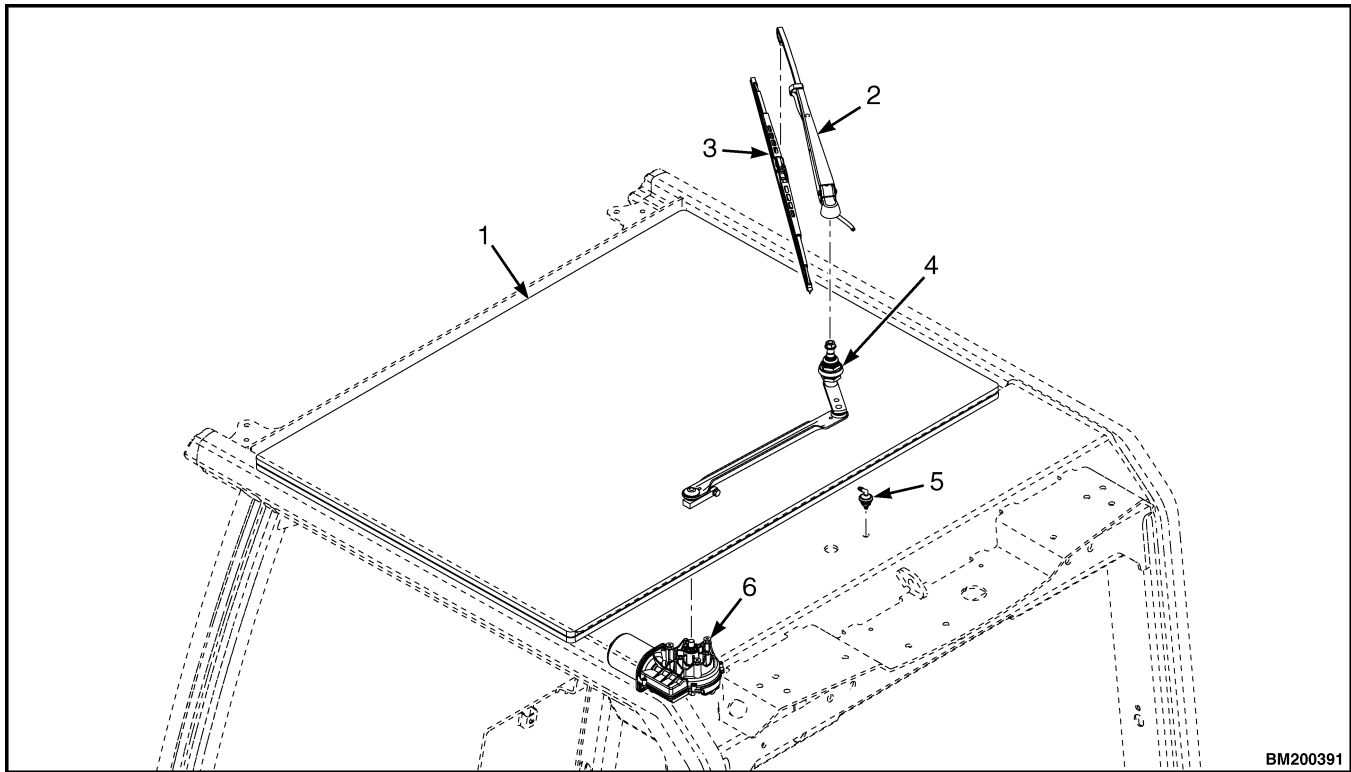


BM212629

Pin	Type	Description
1	GND	GROUND
2	12V	POSITIVE
3	CAN Lo	CAN Lo
4	CAN Hi	CAN Hi

Figure 200. Front Wiper Motor Connector Pinout

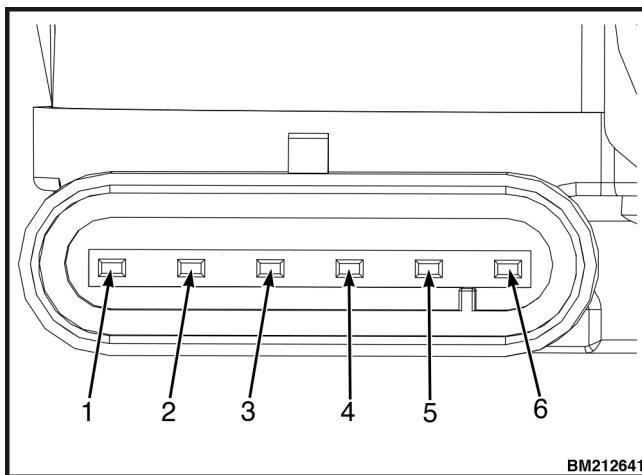
Top Screen and Wiper



BM200391

- 1. TOP SCREEN
- 2. WIPER ARM
- 3. WIPER BLADE
- 4. MOTOR LINKAGE
- 5. ELBOW FITTING
- 6. WIPER MOTOR

Figure 201. Top Screen and Wiper

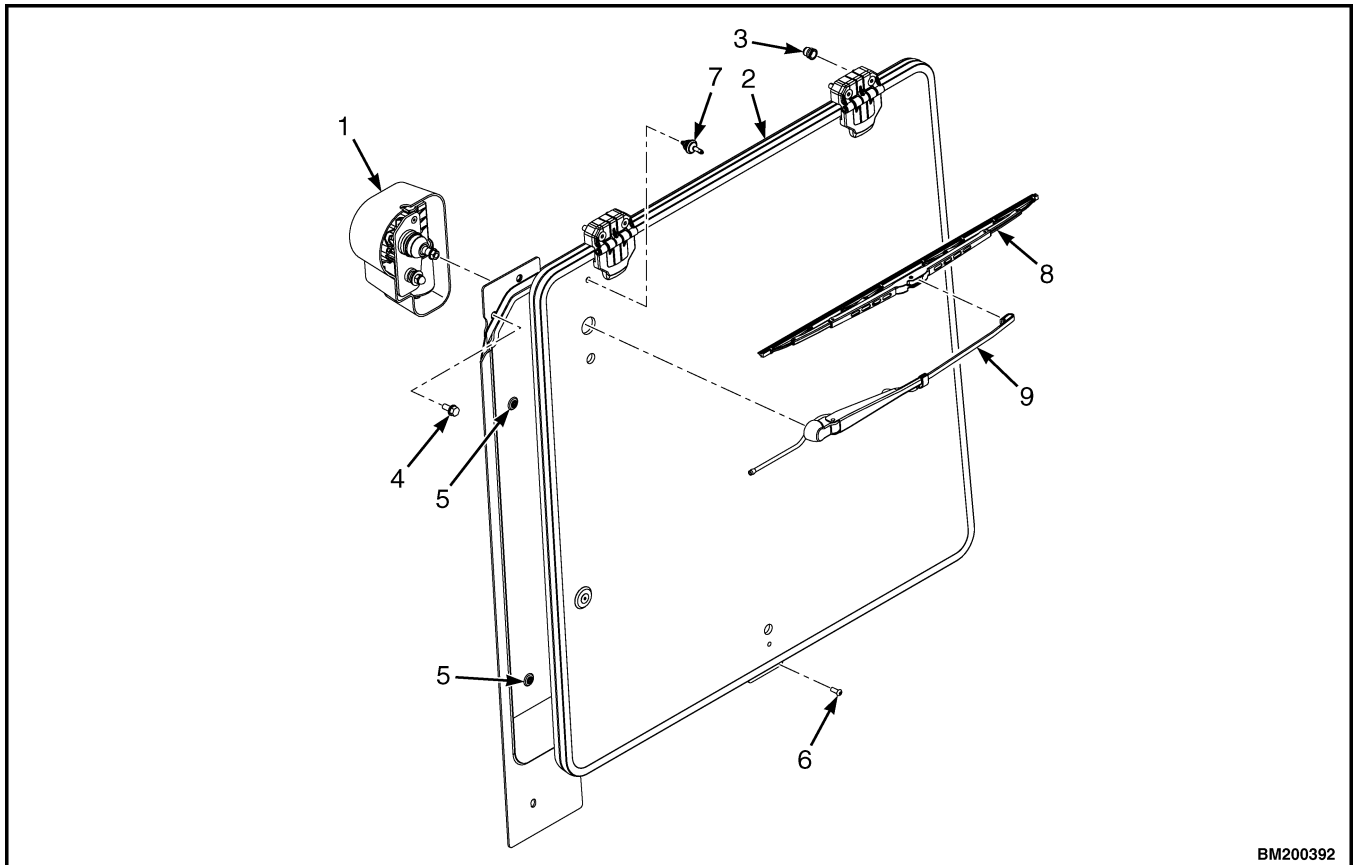


BM212641

Pin	Type	Description
1	12V	V. BAT
2	GND	GROUND
3	CAN Lo	CAN Lo
4	CAN Hi	CAN Hi
5	Not Used	Not Used
6	Not Used	Not Used

Figure 202. Top Wiper Motor Connector Pinout

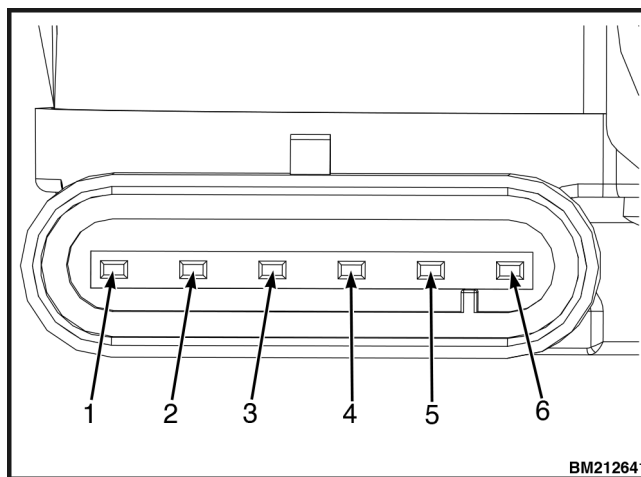
Rear Screen and Wiper



- 1. WIPER MOTOR
- 2. REAR SCREEN
- 3. INSERT
- 4. CAPSCREW
- 5. PLUG

- 6. SCREW
- 7. ELBOW
- 8. WIPER BLADE
- 9. WIPER ARM

Figure 203. Rear Screen and Wiper

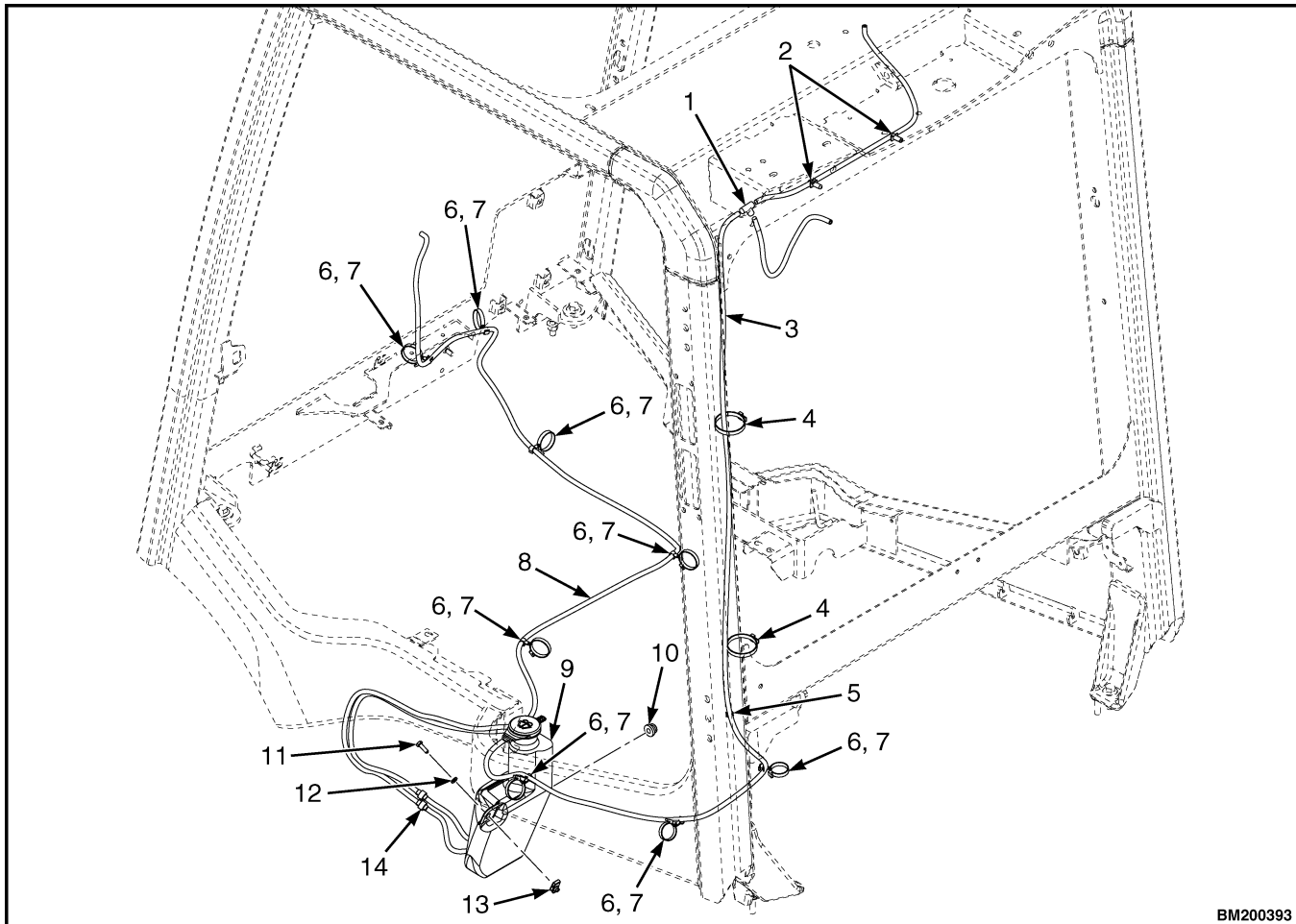


Pin	Type	Description
1	12V	V. BAT
2	GND	GROUND
3	CAN Lo	CAN Lo
4	CAN Hi	CAN Hi
5	Not Used	Not Used
6	Not Used	Not Used

Figure 204. Rear Wiper Motor Connector Pinout

Washer Fluid Tank and Supply Lines

The 1.5L (1.5 quart) washer fluid tank contains two pumps and can supply washer fluid to the front, top, and rear wipers. One pump supplies the front wiper and the other pump supplies both the top and rear wipers.



BM200393

- | | |
|-----------------------------|----------------------|
| 1. T-FITTING | 8. FRONT WASHER LINE |
| 2. CABLE CLIP | 9. WASHER FLUID TANK |
| 3. REAR AND TOP WASHER LINE | 10. GROMMET |
| 4. STRAP CLAMP | 11. CAPSCREW |
| 5. GROMMET | 12. WASHER |
| 6. SWIVEL CLAMP | 13. FOLDOVER NUT |
| 7. SWIVEL CLAMP | 14. CAP |

NOTE: LINE ITEM 14 (CAP) IS ONLY USED IF THE TOP AND REAR WASHER ARE NOT USED.

Figure 205. Washer Fluid Tank and Supply Lines

Heating and Cooling

The cab features a heating and cooling system to maintain climate control in the operator station. For more information, see Heating, Ventilation and Air Conditioning (HVAC) system in this manual.

Front and Rear Work Lights

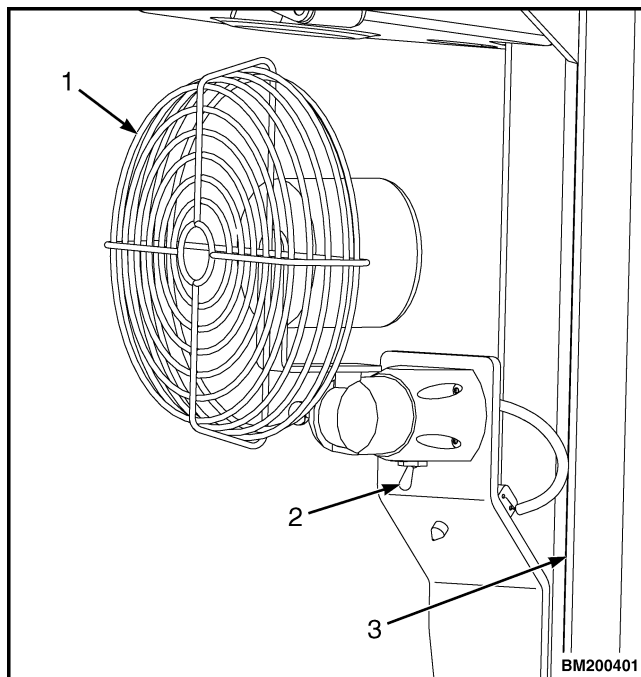
For details on lights refer to Lights description.

Strobe Light

For details on lights refer to Lights description.

Operator Fan

This option adds a 196.9mm (7.75 inch) diameter fan to the left rear overhead guard leg. The fan is designed to circulate air around the cabin and provide a breeze for trucks used in hot environments.

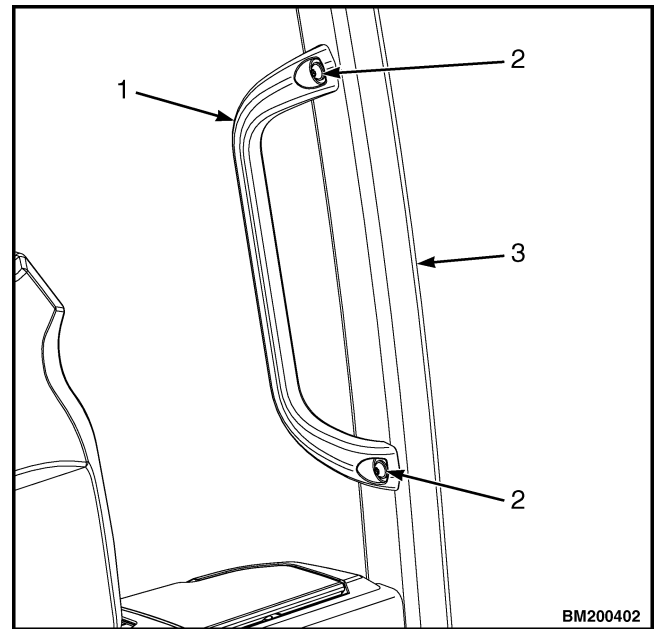


1. FAN
2. SWITCH
3. OVERHEAD GUARD SUPPORT POST, REAR, LH

Figure 206. Operator Fan

Front Grab Handle

The front grab handle provides operators a solid anchor point for getting on and off the truck.

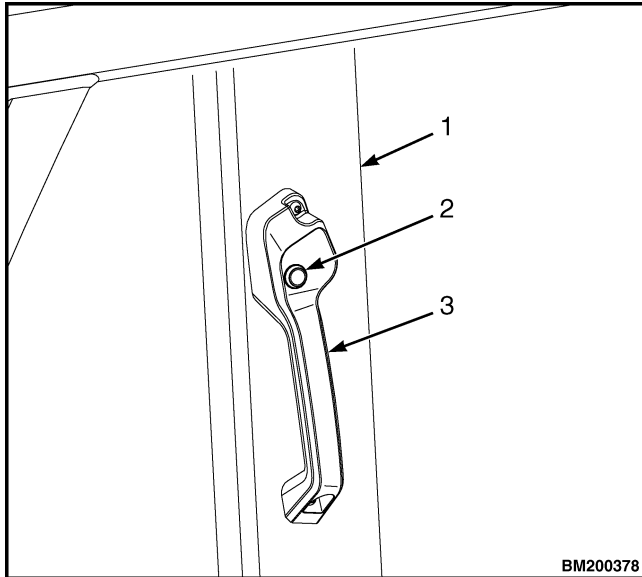


1. FRONT GRAB HANDLE
2. TORX SCREW
3. OVERHEAD GUARD SUPPORT POST, FRONT, LH

Figure 207. Front Grab Handle

Rear Drive Handle with Horn Button

The handle assembly is textured, and is common for both overhead guard and cab installations. This option provides a handle for the operator to hold while driving in reverse. The handle is located on the right, rear overhead guard leg. The addition of the horn button allows an operator to use the horn while reverse driving without having to remove their hands from the steering wheel.

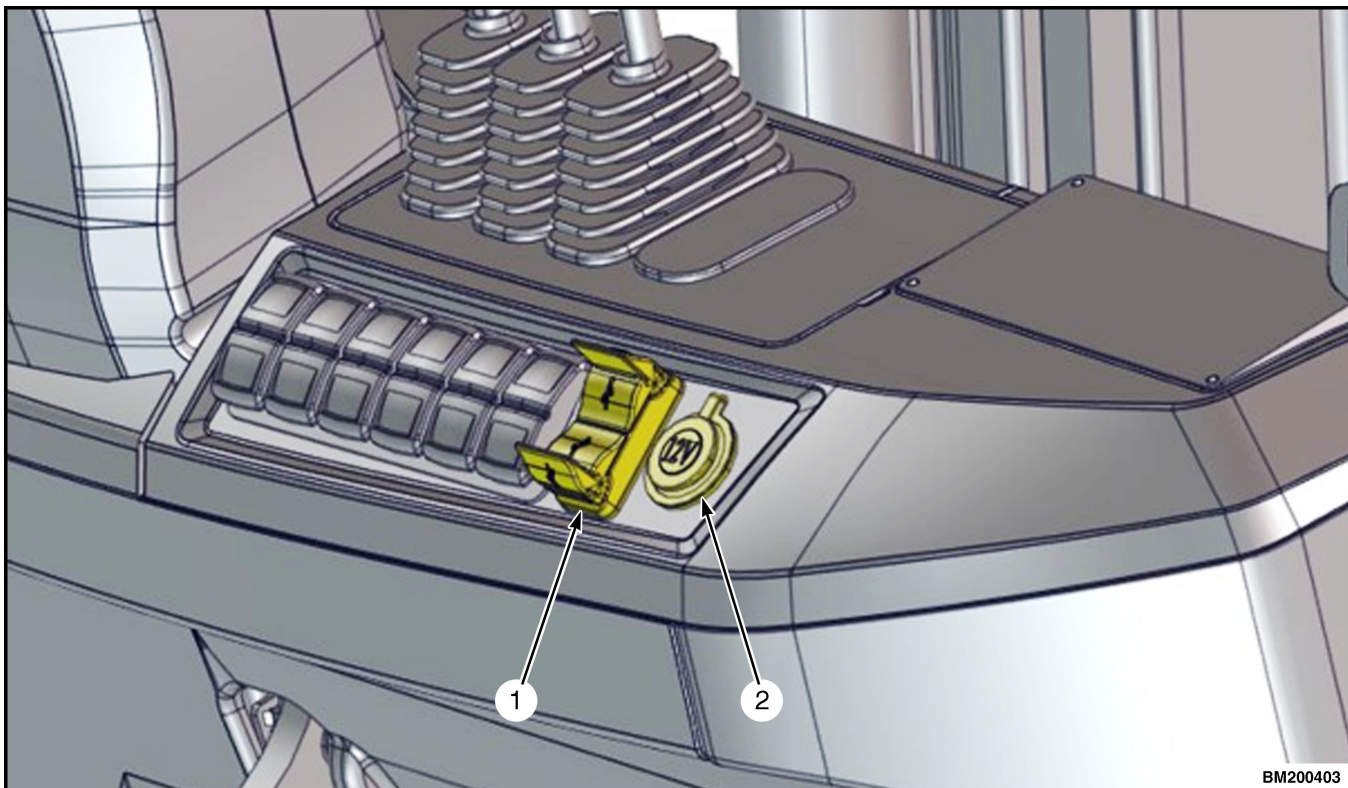
**Legend for Figure 208.**

1. OVERHEAD GUARD SUPPORT POST, REAR, RH
2. HORN BUTTON
3. REAR DRIVE HANDLE

12 Volt Power Supply with 2 USB Charging Ports

This option adds a twin USB charging port and a 12V DC power socket (cigarette lighter-style) to the dash of the truck. The USB charging port circuit is rated to 3.15A and the 12V DC power socket to 10A. This will charge a typical smart phone in 1-2 hours depending on model. Charging is indicated by a LED next to the socket.

Figure 208. Rear Drive Handle with Horn Button



1. USB CHARGING PORTS

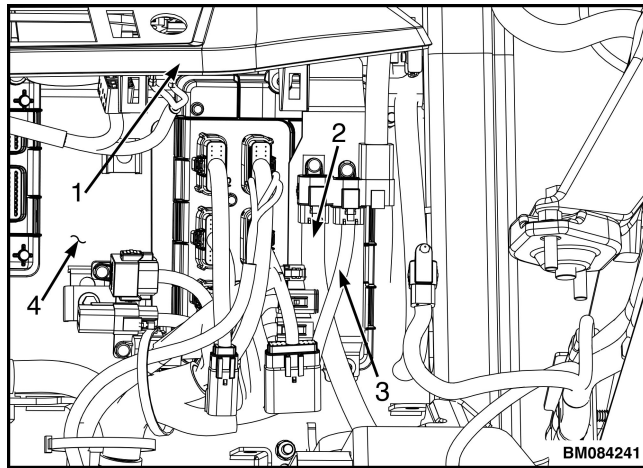
2. 12V DC POWER SOCKET

Figure 209. Power Supply and Charging Ports

The USB ports are protected with integrated over-current and thermal overload protection circuits, as well as optional load dump circuitry. These ports will operate in all truck temperature ranges detailed in the environmental construction options of -20°C to +50°C (-4°F to 122°F). The ports have 2 spring-loaded access doors that automatically close and provide IP65 sealing protection with silicone rubber seals.

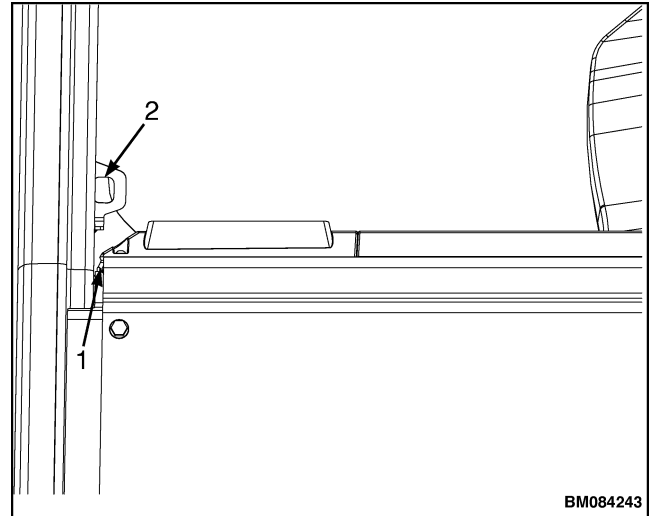
12 Volt Auxiliary Wire Harness

This option provides an auxiliary 12V wire harness that is attached to the cowl behind the kickplate (see Figure 210) and may be routed up through the opening between the dash and the cowl and secured to the overhead guard for later use (see Figure 211). To access the aux 12V wire harness, remove the kickplate.



1. DASH
2. 12V AUX. WIRE HARNESS
3. MAIN CHASSIS HARNESS
4. COWL

Figure 210. 12V Aux. Wire Harness

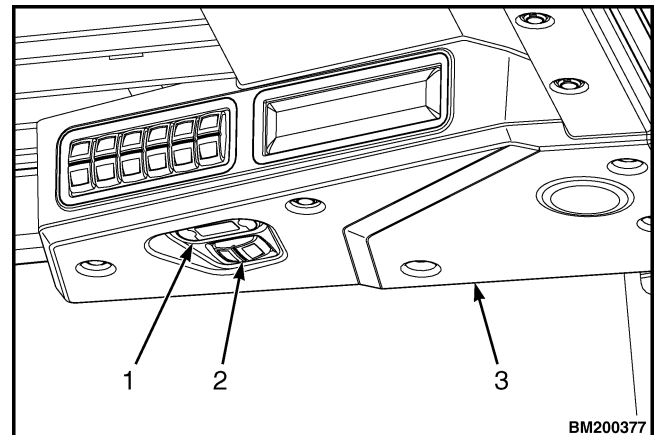


1. OPENING
2. OVERHEAD GUARD MOUNT

Figure 211. 12V Aux. Wire Harness Routing

Reading (Dome) Light

This option adds an LED interior reading light to any cab or cab ready operator compartments. The reading (dome) light produces a focused light onto the operators lap allowing documents to be read in low light conditions. The light is mounted in the headliner and controlled by a rocker switch.



1. DOME LIGHT
2. ROCKER SWITCH
3. HEADLINER

Figure 212. Reading Light

SEAT DESCRIPTION

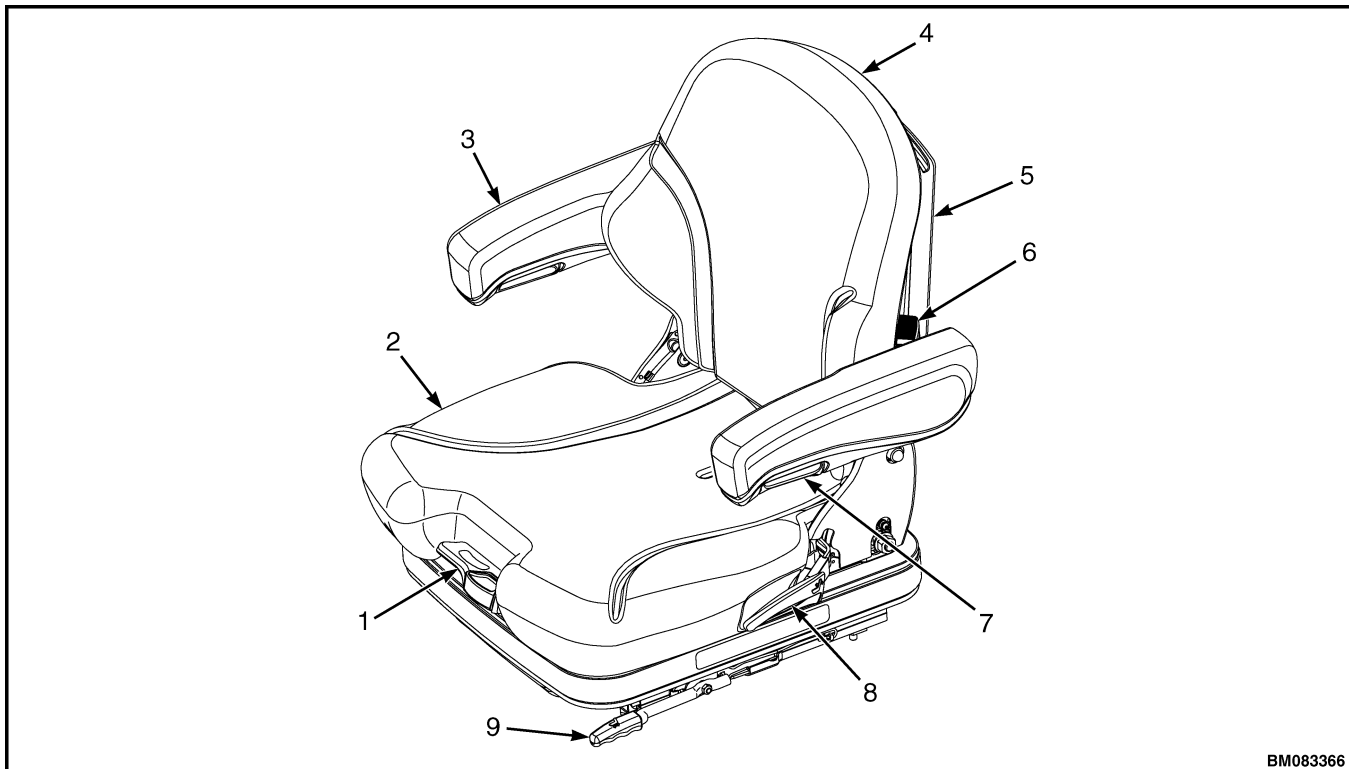
202001-154

There are four main tiers of operator seat to choose from:

- Non-Suspension are for basic comfort with low Seat Index Point (SIP) and fixed armrests.
- Semi-Suspension have limited mechanical suspension (for low SIP) with weight adjustment, flip-up armrests with tilt level adjustment for additional operator comfort.

- Full-Suspension include added mechanical suspension with weight adjustment, flip-up armrests with tilt level adjustment for additional operator comfort.
- Air Ride Full Suspension have added lumbar support adjustment, air bladder suspension with air compressor weight adjustment, and highest level of ride quality comfort.

For more information on each type of seat, or to remove and replace a seat, see **Operator's Cab** 0100SRM2298 service manual.



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- | | |
|-----------------------------|--------------------------------------|
| 1. WEIGHT ADJUSTMENT HANDLE | 6. LUMBAR ADJUSTMENT KNOB (OPTIONAL) |
| 2. SEAT CUSHION | 7. ARMREST ANGLE HANDLE |
| 3. ARMREST | 8. BACKREST ADJUSTMENT HANDLE |
| 4. BACKREST | 9. FORE AND AFT ADJUSTMENT HANDLE |
| 5. DOCUMENT HOLDER | |

Figure 213. Seat Components

NOTE: Full suspension seat is shown, not all seats may have the same features.

All truck seats come complete with fore and aft adjustment, a rear cushion tilt, and arm rests or hip restraint system. Seat cushions also have built in water drainage for all models.

Vinyl and cloth options are available for most types of seat. Vinyl seats are waterproof and are recommended for trucks that do not have a cab and maybe used outdoors. They are also the most suitable for indoor use if the environment is dirty or dusty. Cloth seats are recommended for use in cabins and trucks in clean environments. The cloth seat is harder wearing than a vinyl seat.

Non-Suspension

Non-suspension seats can be either cloth or vinyl, are equipped with fixed armrests, and are not compatible with flip-up armrests. They do not meet CE regulations for operator Whole Body Vibration (WBV) and are not offered in CE countries. Operator weight range of the seat is 40 to 150 Kg (88 to 331 lb). The seat fore and aft travel is 150 mm (5.9 in) in 10mm (0.39 in) increments.

Low Suspension

This seat has 40mm (1.6 inch) vertical travel rather than the 80mm (3.1 inch) of the full-suspension seats and is only available with vinyl upholstery. There is an additional 25mm (1 inch) of headroom for the operator. The shock-absorption and comfortable cushion of a full-suspension seat is retained.

This seat is CE compliant and has a operator weight range of 40 to 170 Kg (88 to 375 lb). Seat fore and aft travel is 210mm (8.3 inch) in 10mm (0.39 inch) increments and the backrest angle is adjustable between +5° and -30° in 2.5° increments. The waterproof vinyl seat has drainage grooves and is recommended for trucks that do not have a cab and may be used outdoors. They are also the most suitable for indoor use if the environment is dirty or dusty.

Full Suspension

Vinyl and Cloth Premium Seats - These seats have 80mm (3.1 inch) of vertical travel with a robust mechanical mechanism and easy adjustment via a handle on the front of the seat. Suitable for operators weighing between 40 to 170 Kg (88 to 375 lb). Seat fore and aft travel is 210mm (8.3 inch) in 10mm (0.39 inch) increments and the backrest angle is adjustable between +5° and -30° in 2.5° increments.

Vinyl Value-The full suspension value seat with vinyl upholstery is a light-duty suspension seat. It has 80mm (3.1 inch) of vertical suspension travel.

The operator weight adjustment is via a knob on the front of the seat and is suitable for operators weighing between 50 to 125 Kg (110 to 276 lb). The seat fore and aft travel is 210mm (8.3 inch) in 10mm (0.39 inch) increments and the backrest angle is adjustable between 0° and -22° in 2.5°.

Air Ride Full Suspension

Vinyl and Cloth - These air ride seats replace the mechanical suspension unit with a compressed air bladder that provides improved damping of shock and vibration. They are easily adjusted via a push button and operators do not have to crank or turn any mechanical levers to get the proper weight setting. A compressor within the air ride seat acts like a pump, drawing in outside air, pressurizing it and storing it in a small tank. This compressed air is then used to adjust the height and firmness of the seat, to the operators comfort. Air ride seats feature the same cushions used on full suspension seats.

Cloth provides superior durability but should be limited to use indoors or for trucks equipped with full cabs. It is suitable for operators weighing between 40 and 170 kg (88 and 375 lb). Seat fore and aft travel is 210 mm (8.3 in.) in 10 mm (0.39 in.) increments. The backrest angle is adjustable between +5° and -30° in 2.5° increments. Lumbar adjustment is also included offering additional comfort for operators who spend prolonged periods in the seat or have extra comfort demands. This seat type is suggested for trucks operating on rough or bumpy ground.

SERVICEABLE PARTS

The operator seat has serviceable components and they are listed below.

- Seat cushion
- Seat back cushion
- Operator Presence Sensor (OPS)
- Document box
- Electrical harness
- Armrests
- Seat rails
- Seat belt covers
- Compressor (air ride seats)

NOTE: The following operator seat items are replaceable without removing the seat from the truck:

- Seat cushion
- Seat back cushion
- Document box
- Seat belt covers

SEAT BELTS

NOTE: All seat belt options use the same latch with the interlocked option using a different buckle.

Standard: Standard seat belts are either black or hi-visibility red with Emergency Locking Retractor (ELR). All seat belts are 1.6m (63 inch) long to accommodate all operators without the need for belt extenders.

Interlocked: The interlocking feature requires the seat belt to be in use and the operator present for the truck to operate. This ensures the operator uses the seat belt correctly by restricting truck operation if it is not used. The seat belt utilizes a tongue-actuated IP67 switch. The switch is normally open with closure upon tongue insertion.

1. **Pin 1** is **Common** and the wire color is black.

2. **Pin 2** is **Normally Open** and the wire color is blue.

Sequential Interlock: Currently all trucks going to Australia require a sequential seat belt for truck start. The interlocking option is automatically sequential. The operator must be in the seat and buckle the seat belt before starting and operating the truck is even possible. This prevents an operator from buckling the seat belt and sitting on it.

Sensor Electrical Information:

The sensor has an electrical response for a 4.75 to 5.25 VDC input of

- un-occupied seat: $0.6 \leq v < 0.8$ (VDC)
- occupied seat: $2.0 \leq v \leq 4.0$ (VDC)

Sensor maximum supply current is 12 mA.

An occupied seat is defined as a 23 kg (50.6 lb) load vertically applied via a 50mm (2 inch) disc anywhere within the seat sensor boundary. The seat sensor boundary provides a test region to validate that an operator's presence will be detected. The digital OPS circuitry shall include the following circuit to be compatible with the truck electrical controls architecture.

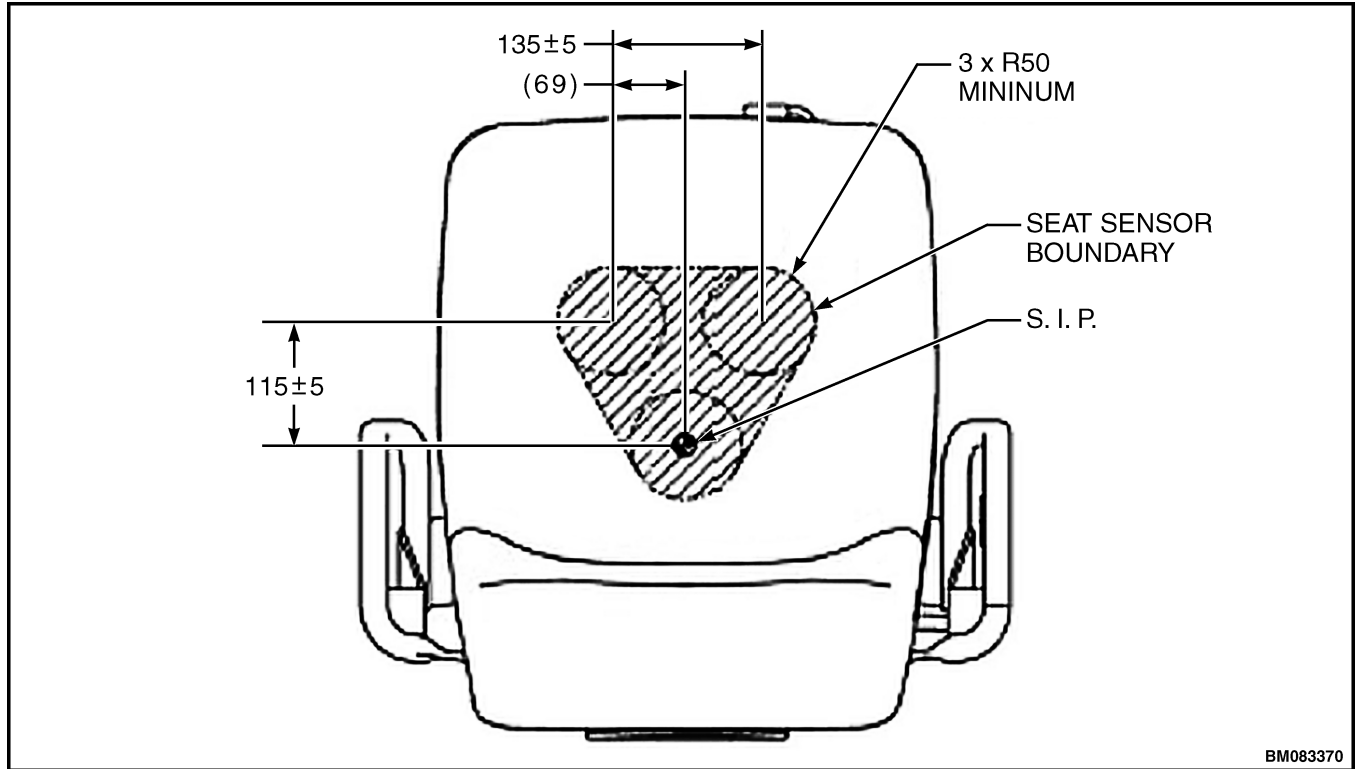


Figure 214. Seat Sensor Boundary

**OPERATOR CONTROLS DESCRIPTION
202001-155**

OPERATOR CONTROLS DESCRIPTION

The operator controls consist of buttons, levers, switches, touch screens, and pedals providing complete control of the truck. Electrical, mechanical, pneumatic, and hydraulic controls are all within reach of the operator.

LCD Display (User Interface)

The LCD display is a Controller Area Network (CAN) device that facilitates operator input and reduces the need for conventional hardware switches. The display also replaces conventional gauges in the instrument cluster. Access to truck information, diagnostic alerts, system calibrations, parametric data, and system settings is available. The display is available in 3 sizes: 2.8-inch (71mm), 5-inch (127mm), 7-inch (178mm). All are full color touch screens and are programmable. Standard display physical location is the upper, right corner of the front overhead guard leg (A-post). For detailed information see Display description.

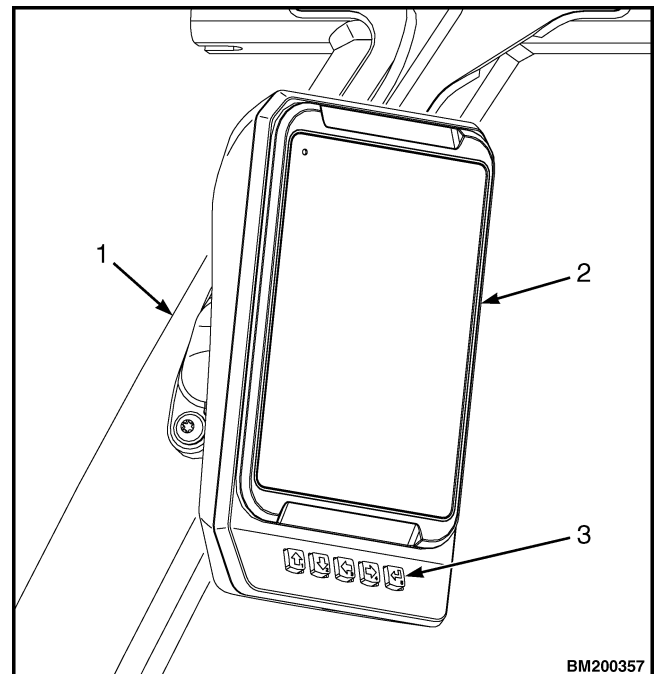


Figure 215. LCD Display

Legend for Figure 215.

NOTE: THE 7-INCH DISPLAY IS SHOWN, 2.8- AND 5-INCH ARE SIMILAR.

1. OVERHEAD GUARD SUPPORT POST, FRONT, RH
2. LCD DISPLAY
3. 5-BUTTON KEYPAD (OPTIONAL)

Radio Frequency IDentification (RFID) Card Reader

The card reader is an optional component of the truck telemetry system. It controls who has the ability to drive the truck, helping to ensure only those trained to use certain trucks have access. The system requires the operator to swipe their card before operating the truck. The card reader records who is operating the truck, how they are operating it, and also records any impact events. If an unapproved card is used, the truck will not turn on until an approved card is swiped.

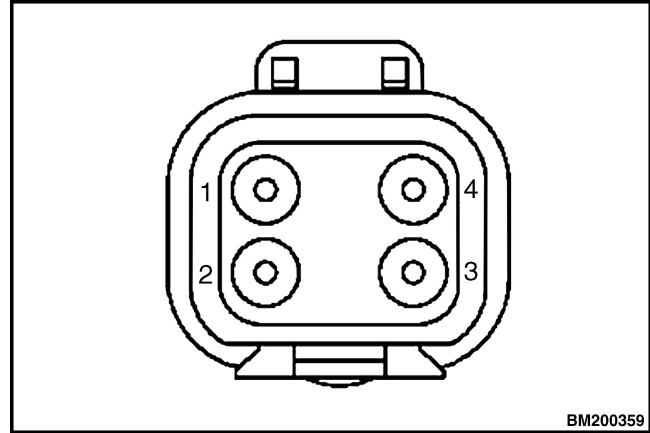
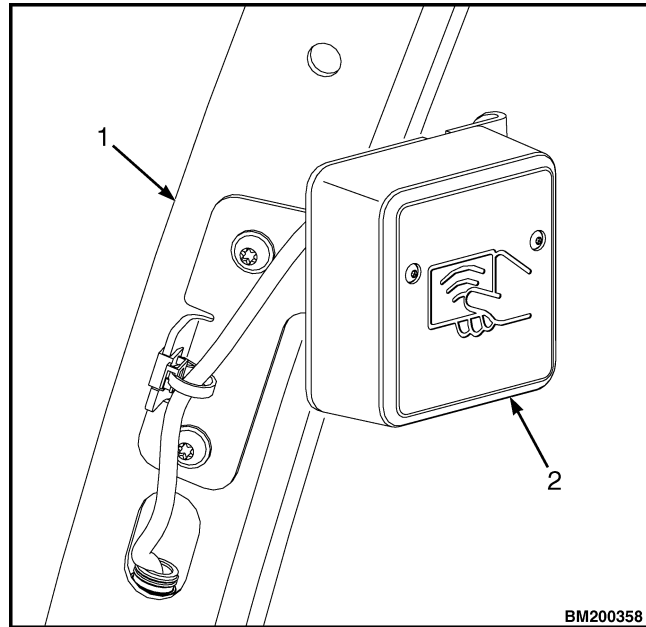


Figure 217. RFID Connector

Table 26. Card Reader Pin Out

Pin	Type	Description
1	HD	HIGH SIDE DRIVER
2	GND	GROUND POWER
3	AD	ANALOG/DIGITAL
4	AD	ANALOG/DIGITAL

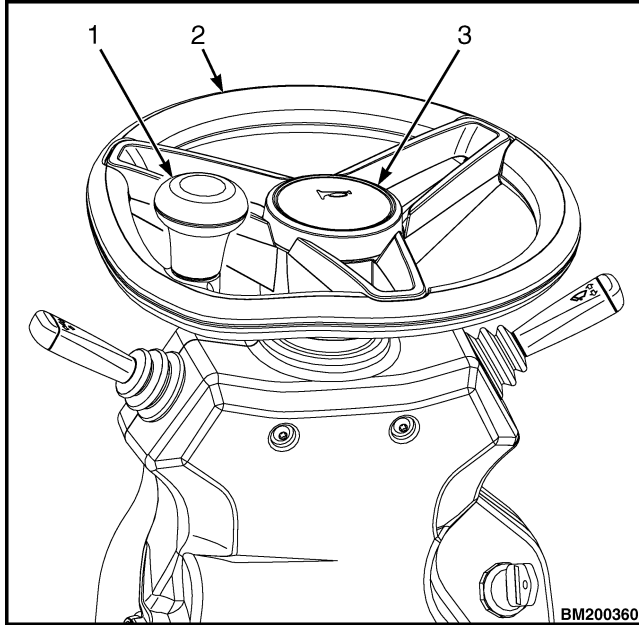


1. OVERHEAD GUARD SUPPORT POST, FRONT, RH
2. RFID CARD READER

Figure 216. RFID Card Reader

Steering Wheel and Horn

The steering wheel controls the position of the steer tires. An optional spinner knob is available. Press the horn button on the steering wheel to actuate the horn.

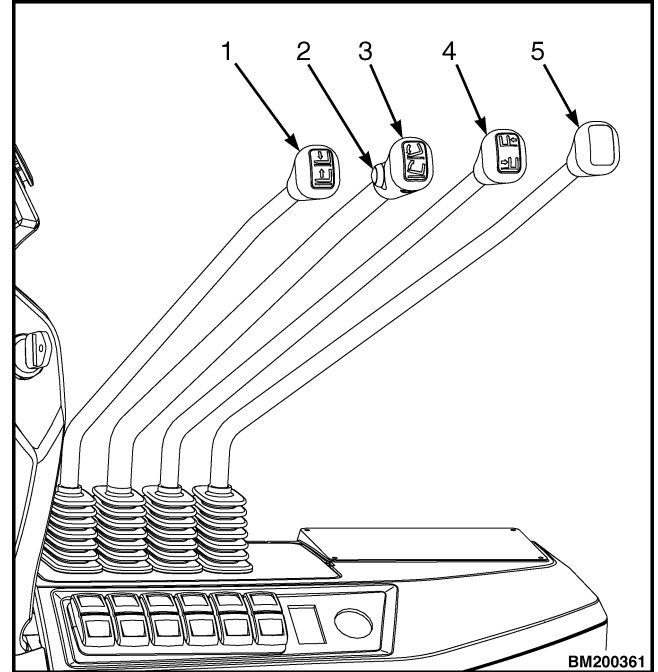


1. SPINNER KNOB
2. STEERING WHEEL
3. HORN BUTTON

Figure 218. Steering Wheel and Horn

Manual Hydraulic Levers

The manual hydraulic levers are linked directly to the spools on the control valve that open and close flow to the hydraulic circuits. Circuits do not open or close unless operator input is given directly. These levers allow the operator to lift and lower, tilt the mast forward and backward, side shift the carriage (if equipped), clamp (if equipped), and return the mast to set tilt for consistent operation.



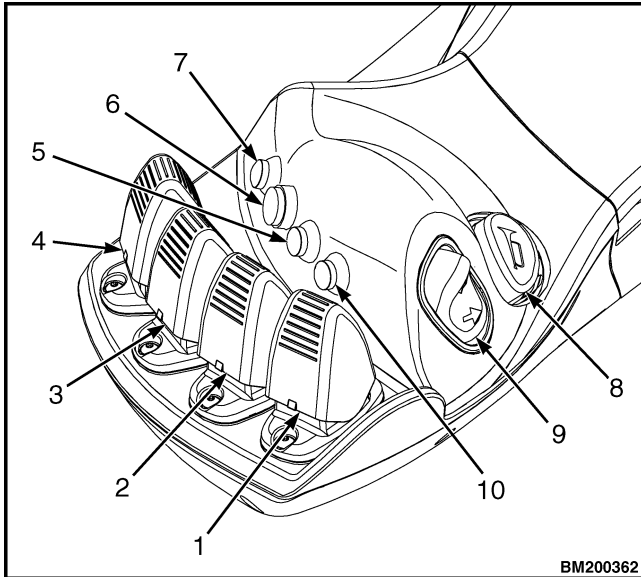
- | | |
|---|-------------------------------------|
| 1. LIFT LEVER | 4. SIDE SHIFT OR
AUXILIARY LEVER |
| 2. RETURN TO SET
TILT (RTST)
BUTTON | 5. AUXILIARY LEVER
(CLAMPING) |
| 3. TILT LEVER | |

Figure 219. Manual Hydraulic Levers

Mini-Lever Module (MLM) Hydraulic Levers

The mini-levers work by electrically opening the spools and are controlled via a proportional solenoid that is controlled by the truck Vehicle System Manager (VSM). Signal for the movement comes from the operator moving a finger control, but functions can be locked out or adjusted via the control system. The mini-levers perform the same functions as the manual hydraulic levers and offer additional options such as a horn button, Directional Control Switch (DCS), and a shelf height button. The mini-levers are located on the operator armrest.

NOTE: Mini-levers and joystick controls are only compatible with E-Hydraulics.



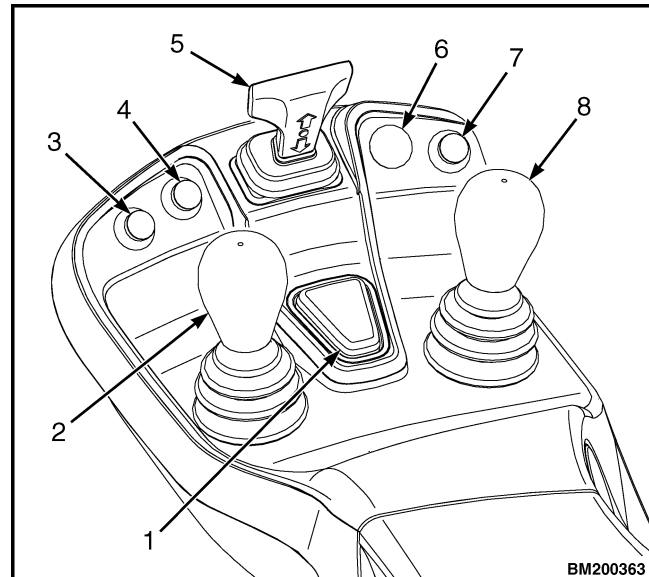
NOTE: SOME ITEMS ARE OPTIONAL AND YOUR TRUCK MAY NOT HAVE ALL THOSE SHOWN.

1. LIFT LEVER
2. TILT LEVER
3. AUXILIARY #1 LEVER (SIDE SHIFT)
4. AUXILIARY #2 LEVER (CLAMP)
5. RETURN TO SET TILT (RTST) PUSH BUTTON
6. PUSH BUTTON (5TH FUNCTION SELECT)
7. UNCLAMP PUSH BUTTON
8. HORN BUTTON
9. DIRECTION CONTROL SWITCH (DCS)
10. SHELF HEIGHT SELECT OVERRIDE PUSH BUTTON

Figure 220. Mini-Lever Module (MLM)

Joystick Hydraulic Controls

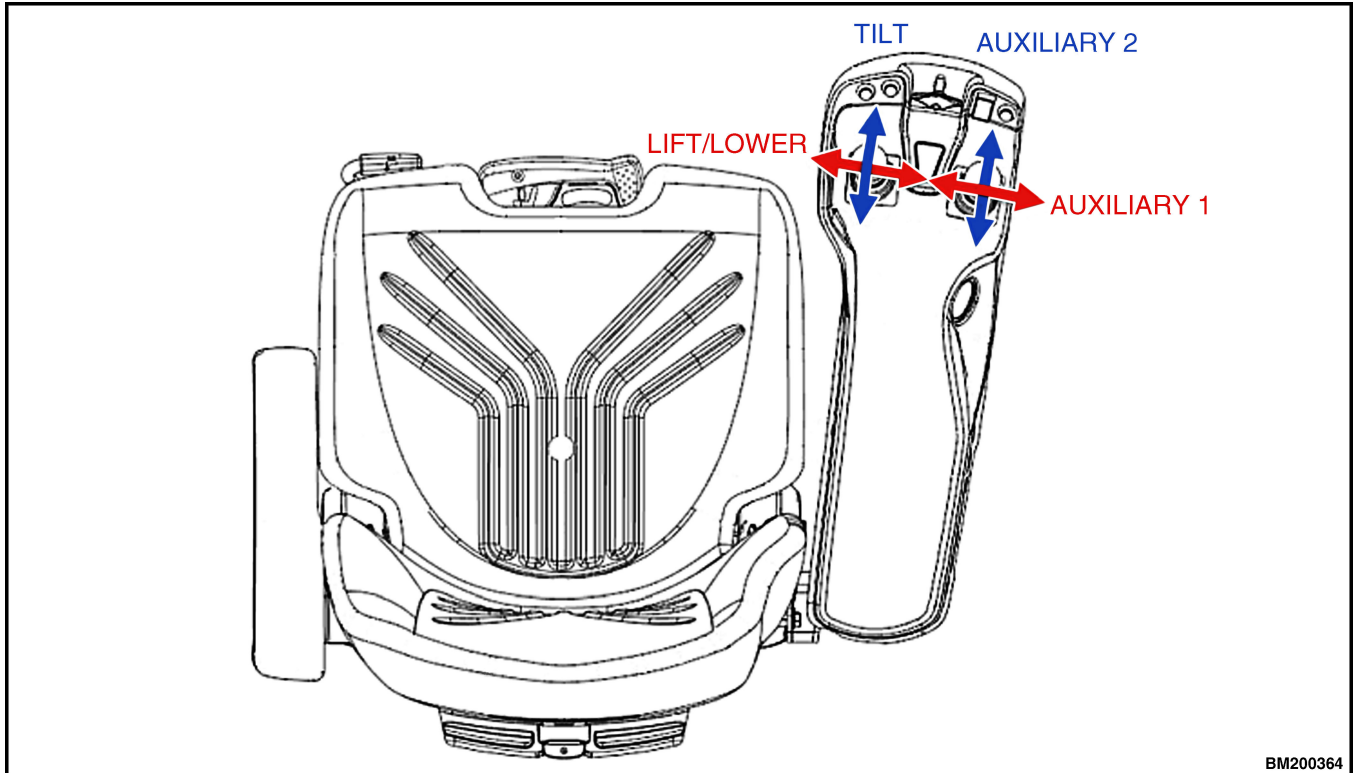
The joystick hydraulic controls perform all the functions of the mini-lever system although the appearance is quite different. Once a joystick is released from moving forward or backward, up or down, it will automatically return to the neutral position.



NOTE: SOME ITEMS ARE OPTIONAL AND YOUR TRUCK MAY NOT HAVE ALL THOSE SHOWN.

1. HORN BUTTON
2. LIFT AND TILT JOYSTICK CONTROL
3. RETURN TO SET TILT (RTST) PUSH BUTTON
4. SHELF HEIGHT SELECT PUSH BUTTON
5. DIRECTION CONTROL SWITCH (DCS)
6. PUSH BUTTON (5TH FUNCTION SELECT)
7. UNCLAMP PUSH BUTTON
8. AUXILIARY #1 AND AUXILIARY #2 JOYSTICK CONTROL (CLAMP OR SIDE SHIFT)

Figure 221. Joystick Hydraulic Controls



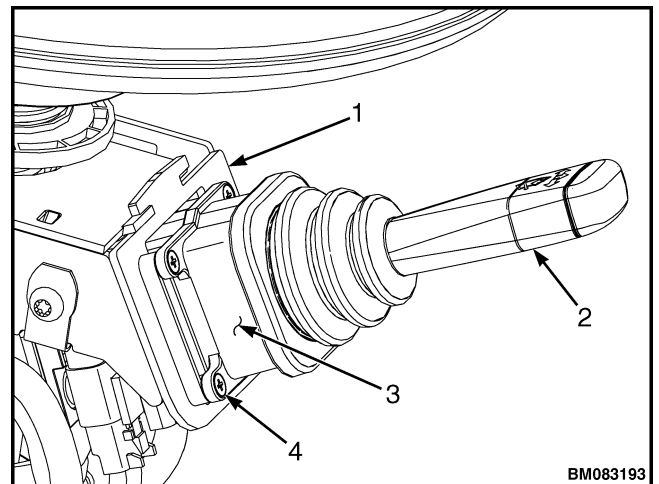
BM200364

Figure 222. Joystick Operation

Wiper Lever

The wiper lever controls operation of the wipers.

NOTE: The wiper control lever is located on the right side of the steering column.



BM083193

- 1. LEVER BRACKET
- 2. WIPER CONTROL LEVER ASSEMBLY
- 3. ADAPTER
- 4. SCREWS

Figure 223. Wiper Lever

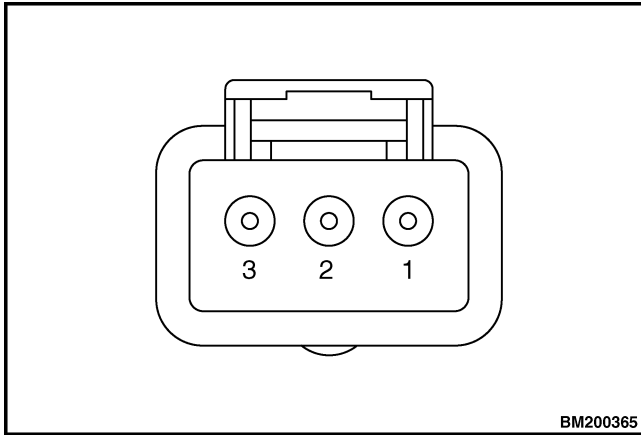


Figure 224. Wiper Lever Connector

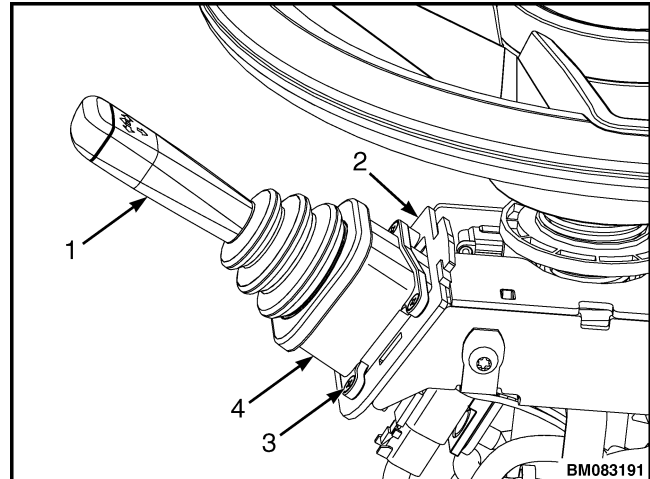
Table 27. Wiper Lever Pin Out

PIN	DESCRIPTION		
1	5V+		
2	SIG GND		
3	OUTPUT 1		
OUTPUT			
OUTPUT	-20° (DOWN POSITION)	0°	+20° (UP POSITION)
1	0.5V	2.5V	4.5V

Turn Signal Lever

The turn signal lever controls operation of the turn signals.

NOTE: The turn signal lever may be located on either the left or right side of the steering column.



1. TURN SIGNAL LEVER ASSEMBLY
2. LEVER BRACKET
3. SCREWS
4. ADAPTER

Figure 225. Turn Signal Lever

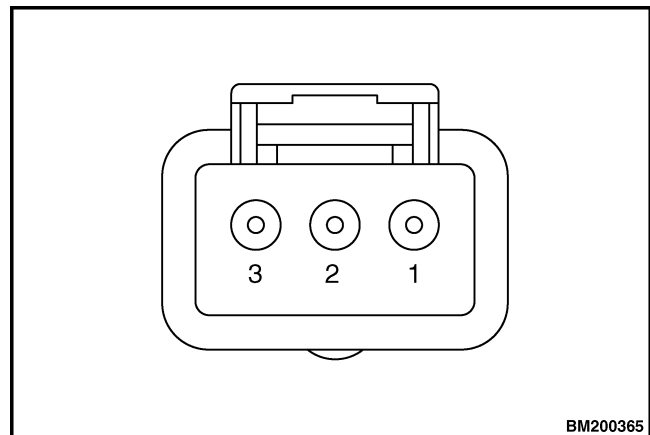


Figure 226. Turn Signal Lever Connector

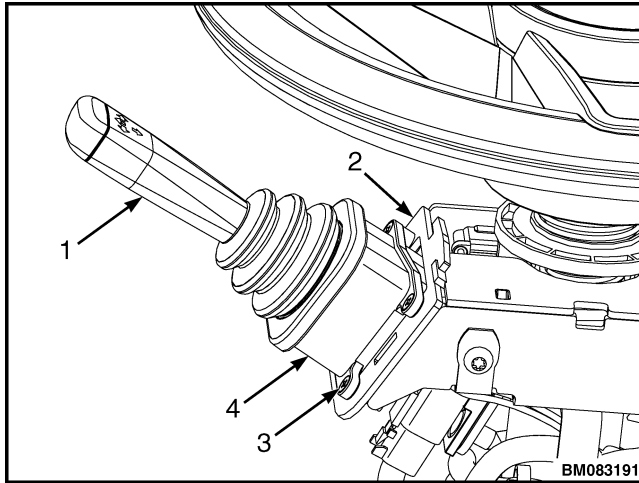
Table 28. Turn Signal Pin Out

PIN	DESCRIPTION		
1	5V+		
2	SIG GND		
3	OUTPUT 1		
OUTPUT			
OUTPUT	-20° (DOWN POSITION)	0°	+20° (UP POSITION)
1	0.5V	2.5V	4.5V

Direction (FNR) Lever

The direction control lever controls forward, neutral, and reverse operation of the transmission.

NOTE: The direction control lever (FNR) is located on the left side of the steering column.



1. LEVER ASSEMBLY
2. LEVER BRACKET
3. SCREWS
4. ADAPTER

Figure 227. Direction (FNR) Lever

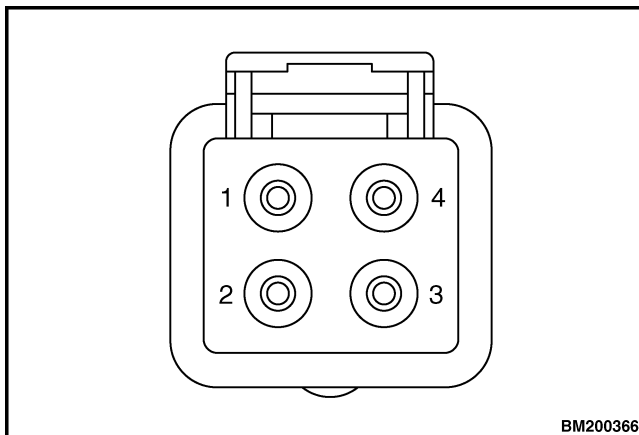


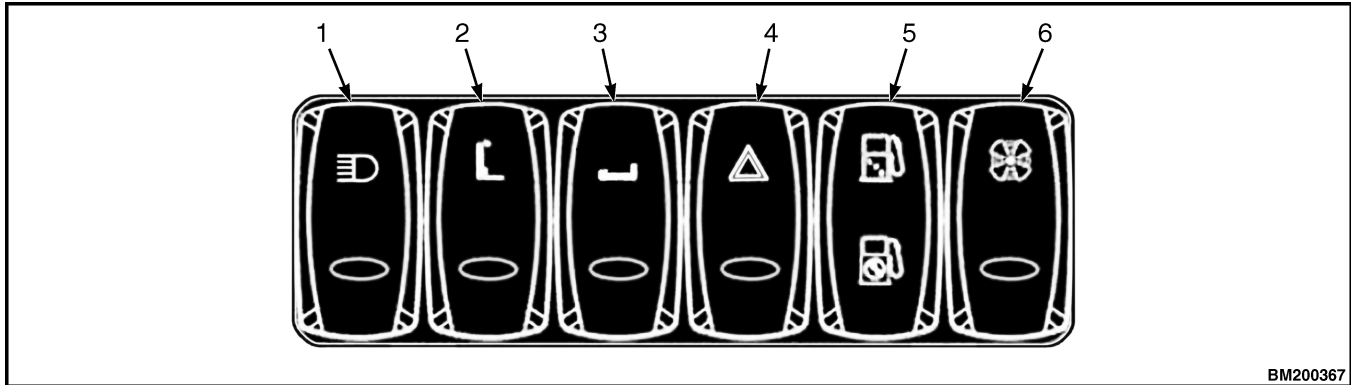
Figure 228. Direction (FNR) Lever Connector

Table 29. Directional Lever Pin Out

PIN		DESCRIPTION	
1		5V+	
2		SIG GND	
3		OUTPUT 1	
4		OUTPUT 2	
OUTPUT			
OUTPUT	-20° (REVERSE POSITION)	0° (NEUTRAL)	+20° (FORWARD POSITION)
1	0.5V	2.5V	4.5V
2	4.5V	2.5V	0.5V

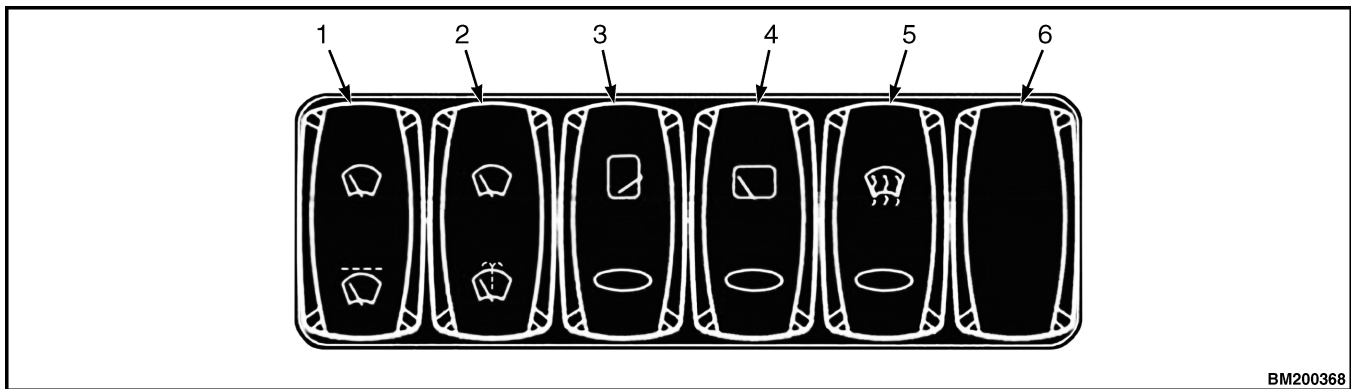
Dash and Cab Control Modules

The control modules are CAN enabled sets of switches for requesting truck accessory response. These switches reduce wiring by transmitting each switch position in a CAN message. The truck may have two, 6-switch bank control modules; one is located on the dash and the other is located in the cab headliner. For more details see Controller description.



- 1. WORK LIGHTS
- 2. MAST LIGHTS
- 3. FORK LASER
- 4. HAZARD
- 5. BI-FUEL
- 6. FAN REVERSE TIMER

Figure 229. Dash Control Module



- 1. WIPERS ON OR INT
- 2. WIPE OR WASH
- 3. TOP WIPER
- 4. REAR WIPER
- 5. HEATED SCREEN
- 6. BLANK

Figure 230. Cab Control Module

Manual Park Brake and Release

The manual park brake is located to the left of the service brake pedal and the hand release is located directly above the park brake.

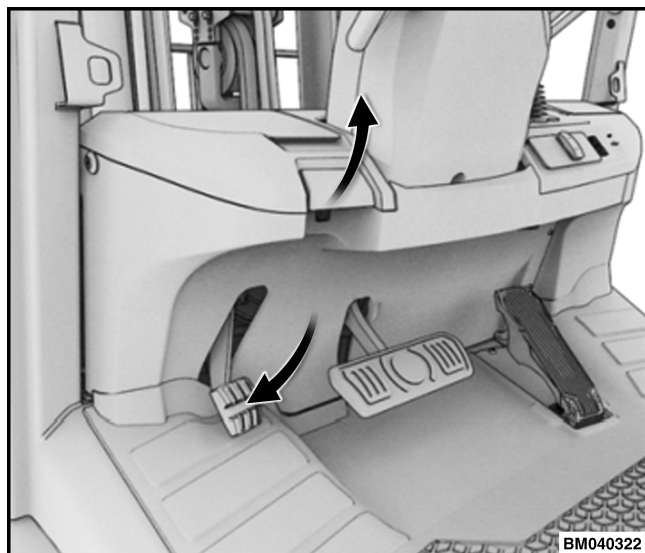
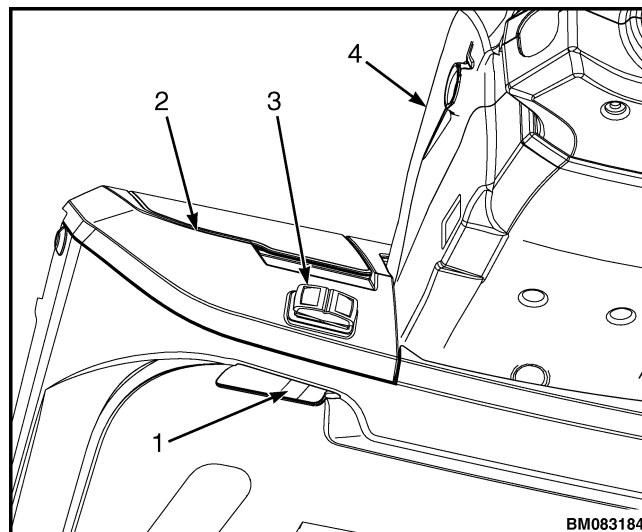


Figure 231. Manual Park Brake

Park Brake Rocker Switch (Optional)

The operator can push a rocker switch on the dash to actuate the park brake. This feature is only available on wet brake axles. The brake will also automatically apply when the engine is shut down. The park brake rocker switch is located on the left side of the dash.

NOTE: Some parts are not shown for illustrative clarity.

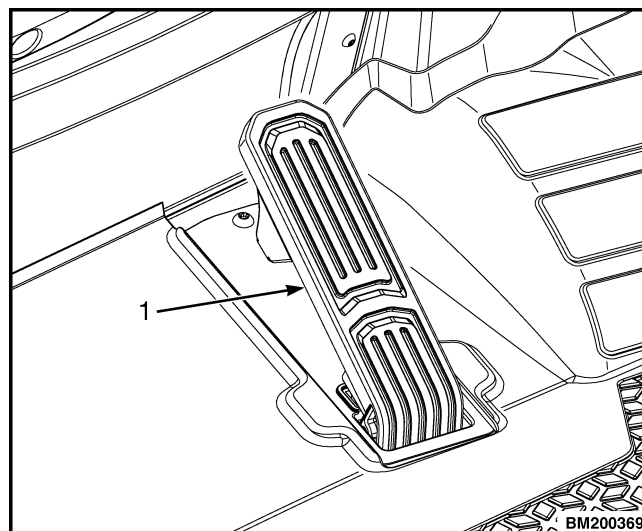


1. WIRE HARNESS
2. LEFT HAND DASH
3. PARK BRAKE ROCKER SWITCH
4. STEERING COLUMN COVER

Figure 232. Park Brake Rocker Switch

Accelerator Pedal

The accelerator pedal allows operator control of engine speed and forward (or reverse) directional speed when in gear. The accelerator may be mechanically controlled or electrically actuated.



1. ACCELERATOR PEDAL

Figure 233. Accelerator Pedal

Foot Direction Control (FDC)

The Foot Directional Control (FDC) replaces the normal accelerator pedal and steering column mounted direction lever with an accelerator pedal equipped with direction switches on the pedal itself. This allows the operator to both accelerate and control direction using a single pedal. The pedal itself has two separate switches internally and the truck ensures command of both switches cannot happen at once. Release of the pedal will cause the truck to decelerate to a stop.

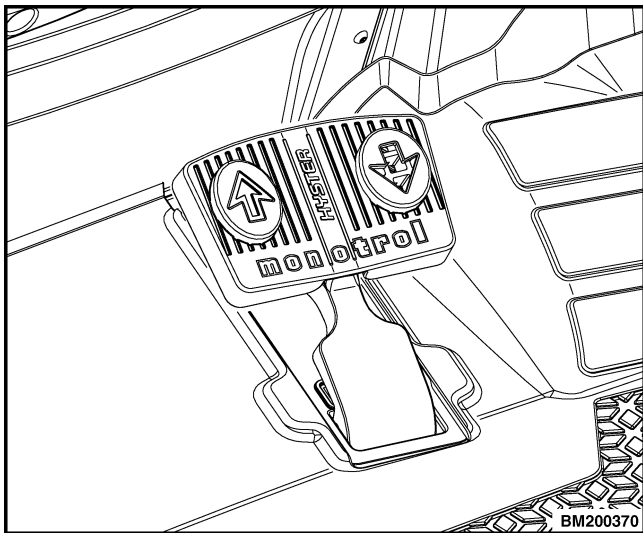
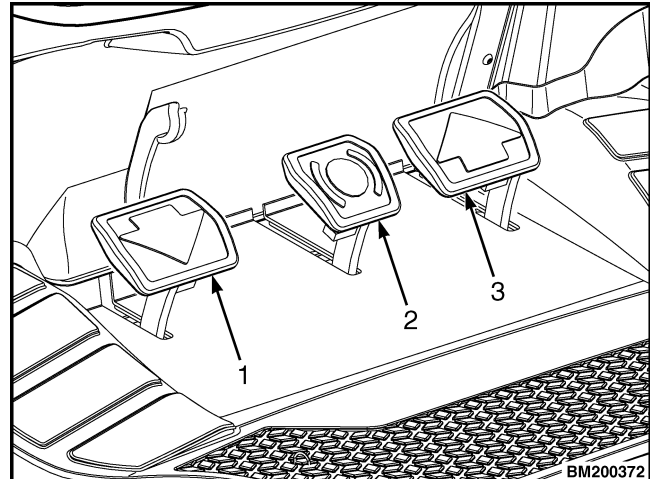


Figure 234. Foot Direction Control

Dual Pedal Direction Control

The dual pedal direction control has 3 pedals. From the left to right, the pedals are reverse accelerator, stop, and forward accelerator. This option helps to provide seamless direction changes by allowing the driver to simultaneously control direction and acceleration using different feet. The pedals are controlled by a linkage under the floor plate.

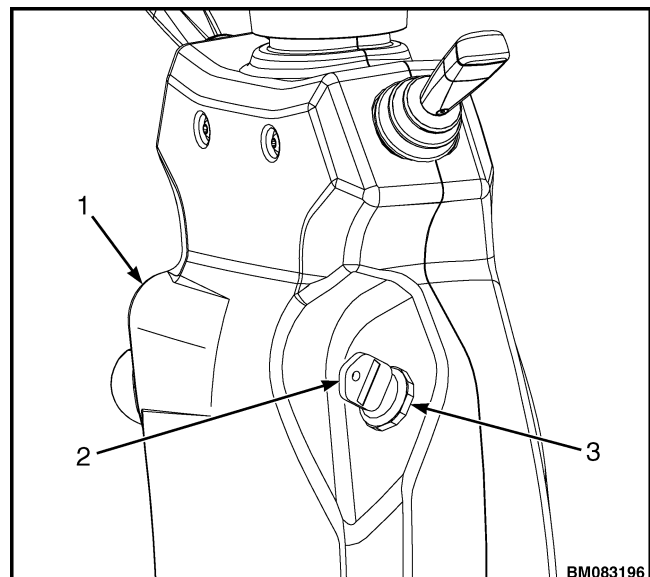


1. REVERSE ACCELERATOR PEDAL
2. STOP PEDAL
3. FORWARD ACCELERATOR PEDAL

Figure 235. Dual Pedal Direction Control

Keyed Ignition Switch

The standard option requires a stand-alone key to start the truck. The key switch is located on the right hand side of the steering column. The key switch is a three position switch: position 1 (OFF), position 2 (Accessory Power Mode), and position 3 (Start Mode).



1. STEERING COLUMN COVER
2. KEY
3. FACENUT

Figure 236. Keyed Ignition Switch

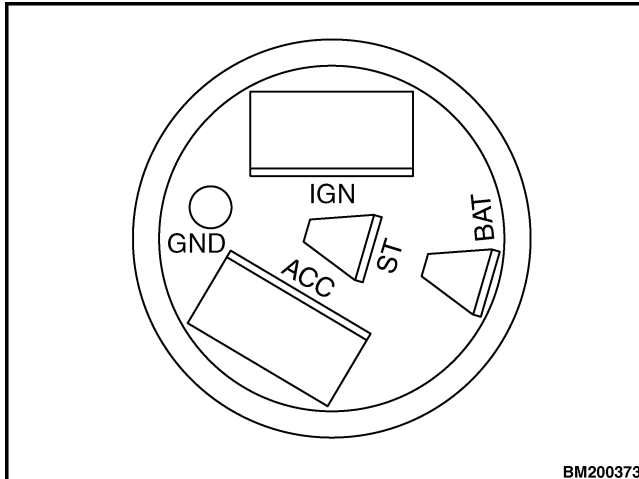
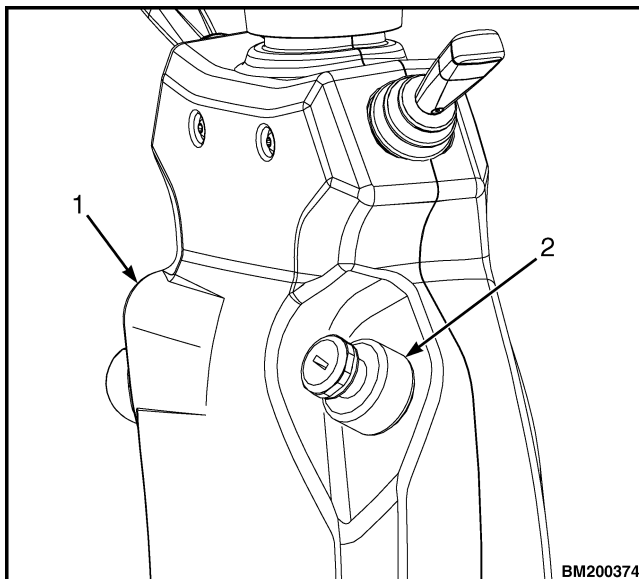


Figure 237. Keyed Ignition Switch Terminals

NOTE: Keyed and keyless ignition switch terminals are the same.

Keyless Ignition Switch

The keyless ignition switch option provides open access to the truck without the risk of losing keys. A keyless switch with operator password option is also available.



1. STEERING COLUMN COVER
2. KEYLESS IGNITION SWITCH

Figure 238. Keyless Ignition Switch

Pushbutton Ignition Switch

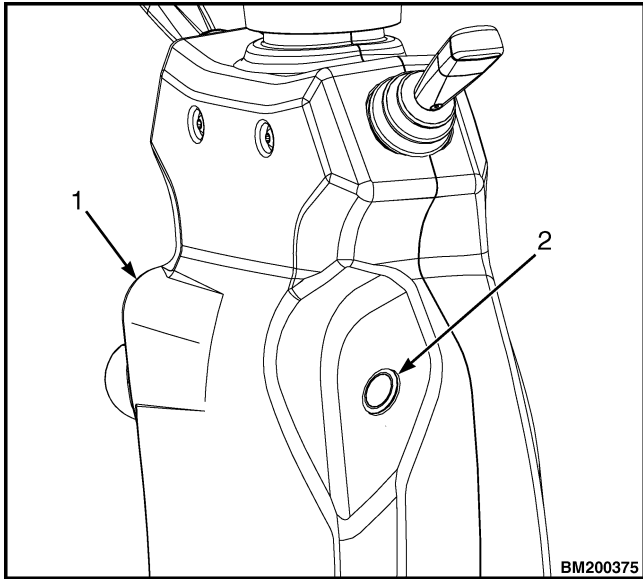
The pushbutton switch is also on the right hand side of the steering column and has a momentary button used for turning on and off the system power, as well as for cranking. The same operating modes exist as with the key switch option.

Accessory Power Mode:

- Pressing the start-stop button turns on accessory power.
- Initiates system checks.
- Turns on glow plugs for diesel engines if applicable.
- Times out after 5 minutes if engine is not running. This timer is configurable via software.
- If truck is equipped with telemetry access or password, these system requirements must be met before entering start mode.

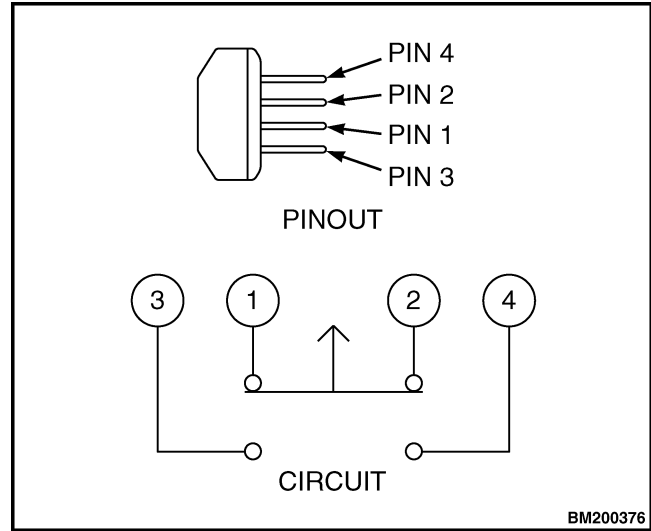
Start Mode:

- Pressing the start-stop button with service brake pedal applied initiates the automatic cranking sequence (applies to truck OFF condition, as well as accessory power ON condition). This assumes all other start requirements are satisfied (telemetry, interlocks).
- System will crank engine automatically until engine is running (engine above a minimum RPM threshold). Crank time duration limits may apply.



- 1. STEERING COLUMN COVER
- 2. PUSHBUTTON SWITCH

Figure 239. Pushbutton Ignition Switch

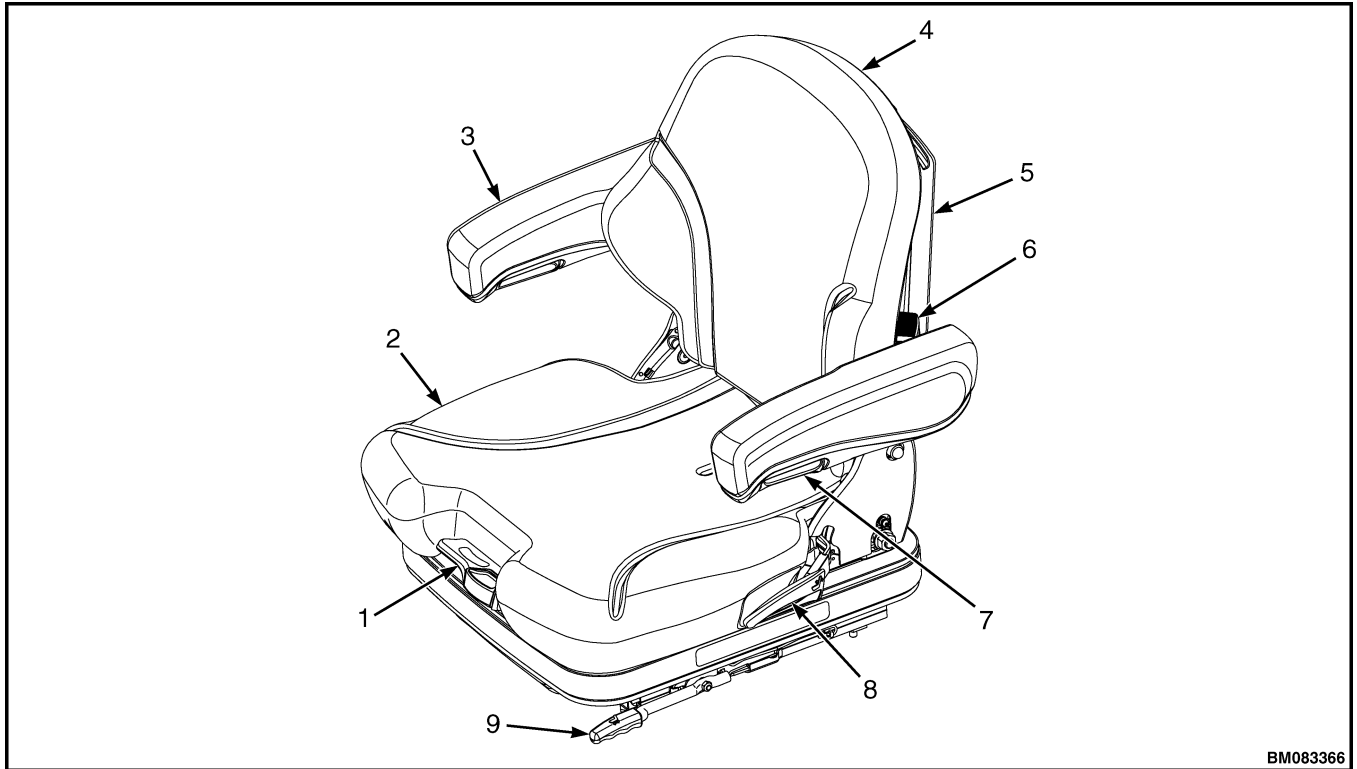


BM200376

Figure 240. Pushbutton Ignition Switch Pinout

Operator Seat

The operator seat provides comfort and security for the operator and may include optional Operator Presence Sensor (OPS) and seat belt interlocks for added security.



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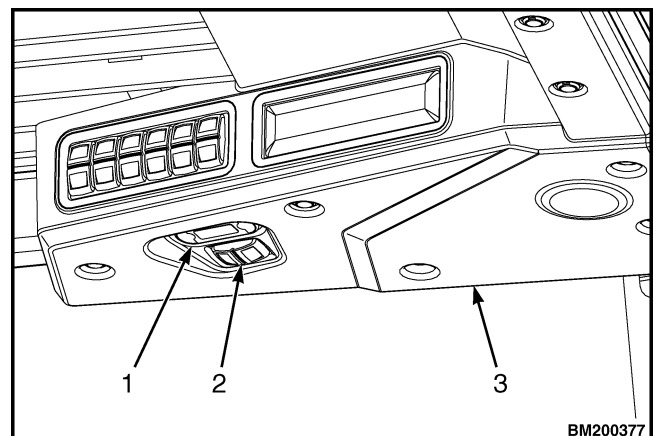
NOTE: FULL SUSPENSION AIR RIDE SEAT IS SHOWN, NOT ALL SEATS MAY HAVE THE SAME FEATURES.

- | | |
|-----------------------------|-----------------------------------|
| 1. WEIGHT ADJUSTMENT HANDLE | 6. LUMBAR ADJUSTMENT KNOB |
| 2. SEAT CUSHION | 7. ARMREST ANGLE HANDLE |
| 3. ARMREST | 8. BACKREST ADJUSTMENT HANDLE |
| 4. BACKREST | 9. FORE AND AFT ADJUSTMENT HANDLE |
| 5. DOCUMENT HOLDER | |

Figure 241. Operator Seat

Dome Light and Rocker Switch

The LED dome light provides illumination for the operator's work area and is mounted in the headliner. (Only available on trucks with the premium cab installed).

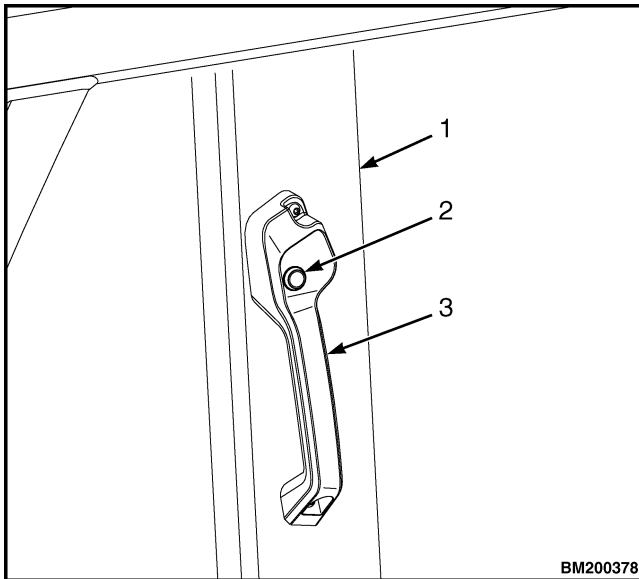


BM200377

- | |
|------------------|
| 1. DOME LIGHT |
| 2. ROCKER SWITCH |
| 3. HEADLINER |

Figure 242. Dome Light and Rocker Switch

Rear Drive Handle with Horn Button



1. OVERHEAD GUARD SUPPORT POST, REAR, RH
2. HORN BUTTON
3. REAR DRIVE HANDLE

Figure 243. Rear Drive Handle with Horn Button

Driver's Fan and Fire Extinguisher



1. DRIVER'S FAN
2. FIRE EXTINGUISHER

Figure 244. Driver's Fan and Fire Extinguisher

HEATING, VENTILATION AND AIR CONDITIONING (HVAC) SYSTEM 202001-424

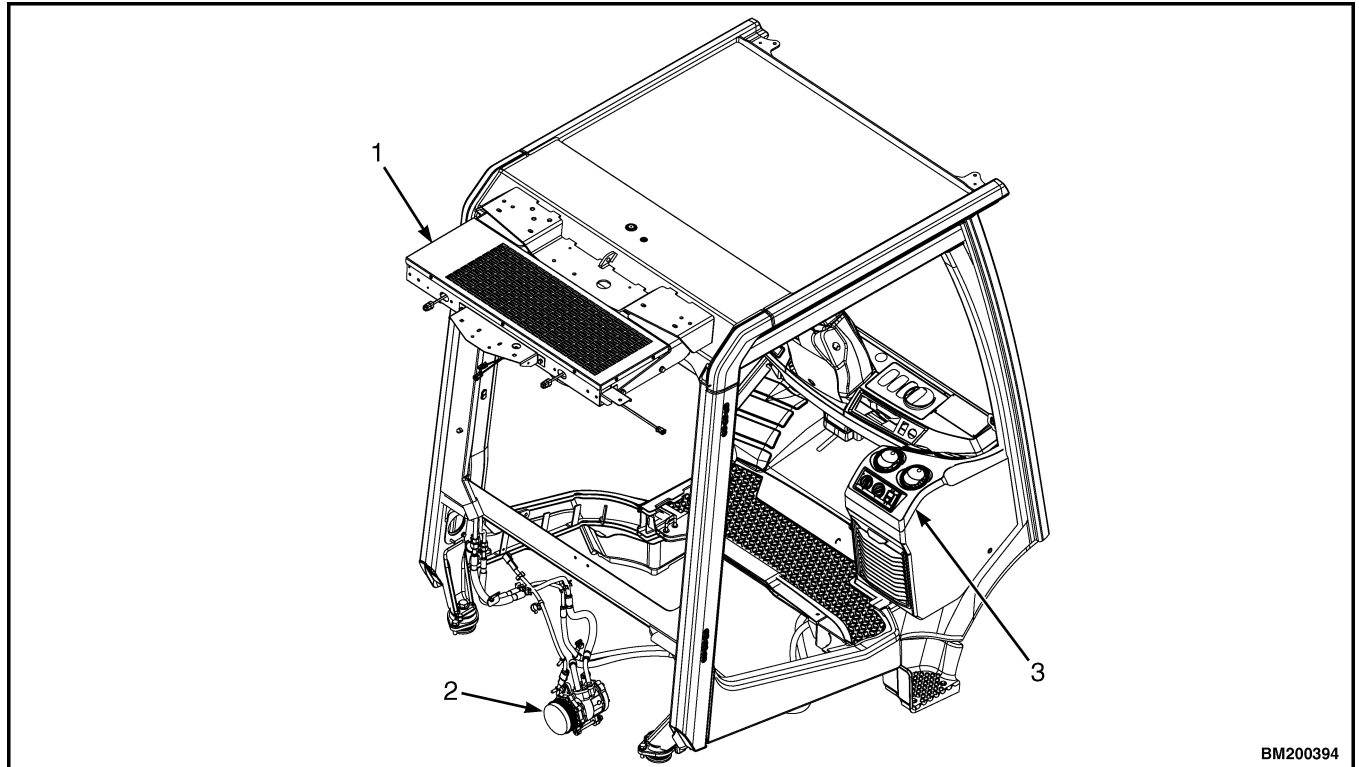
HVAC SYSTEM

NOTE: This section gives a brief overview of the HVAC system and its components. For a full description of how the HVAC system functions, see section Air conditioning principles of operation.

Lift trucks with a full operator station cabin feature a Heating, Ventilation, and Air Conditioning (HVAC) system, with standard and optional components. The HVAC system is designed to provide a comfortable environment for the operator, giving the operator full climate control capabilities within the cabin by utilizing one or all of the following system components:

- Heating
- Ventilation
- Air Conditioning

The HVAC unit (fan, control unit, vents) is integrated with the Right Hand (RH) side of the dash and floor plate.



BM200394

1. CONDENSER
2. AC COMPRESSOR

3. HVAC UNIT AND CONTROLS

Figure 245. HVAC system

Heating

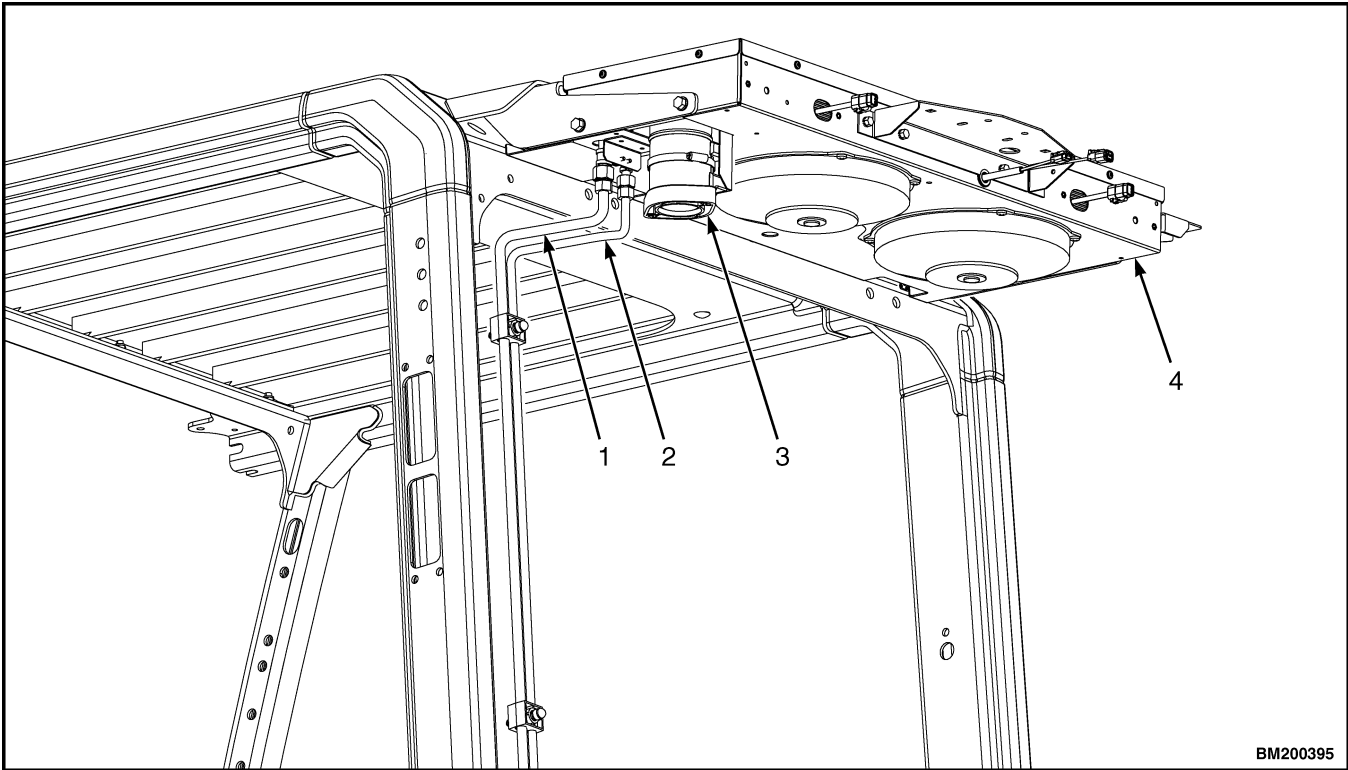
A cabin heater is standard on all lift trucks. The heater is part of the HVAC unit and is located on the floor of the operator station and is integrated with the Right Hand (RH) side of the dash and floor plate. Warm air is generated by the heater and flows through the adjustable vents that can be opened and closed manually to control the flow of warm air into the operator station.

Air conditioning system

The air conditioning system consists of the HVAC unit (fan, control unit, vents) and condenser. The air

conditioning system uses a refrigerant and circulates it through the condenser and evaporator by using the Air Conditioning (AC) compressor. The heater uses engine coolant circulated through the system by the engine water pump. The air conditioner condenser is located behind the overhead guard (see Figure 246). The condenser pipework is routed down the LH side of the rear screen frame to the compressor (see, Figure 247). The compressor is mounted on the engine and is driven by an accessory belt. The evaporator is located near the HVAC unit (see, Figure 248).

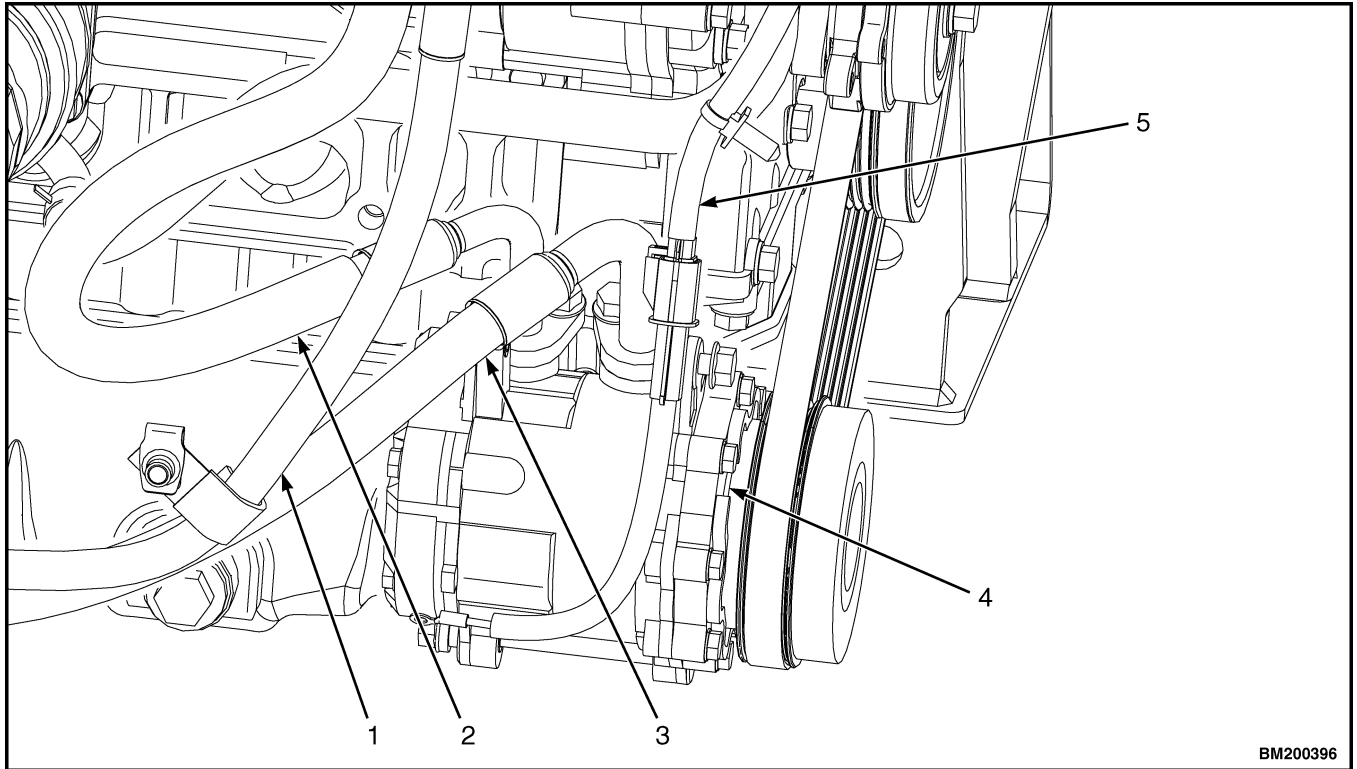
Components



NOTE: HEAT SHIELD ON REAR LH OVERHEAD GUARD SUPPORT POST NOT SHOWN FOR CLARITY.

- | | |
|---------------------------------|-----------------------|
| 1. CONDENSER TO COMPRESSOR LINE | 3. FILTER |
| 2. CONDENSER TO EVAPORATOR LINE | 4. CONDENSER ASSEMBLY |

Figure 246. Condenser and Lines

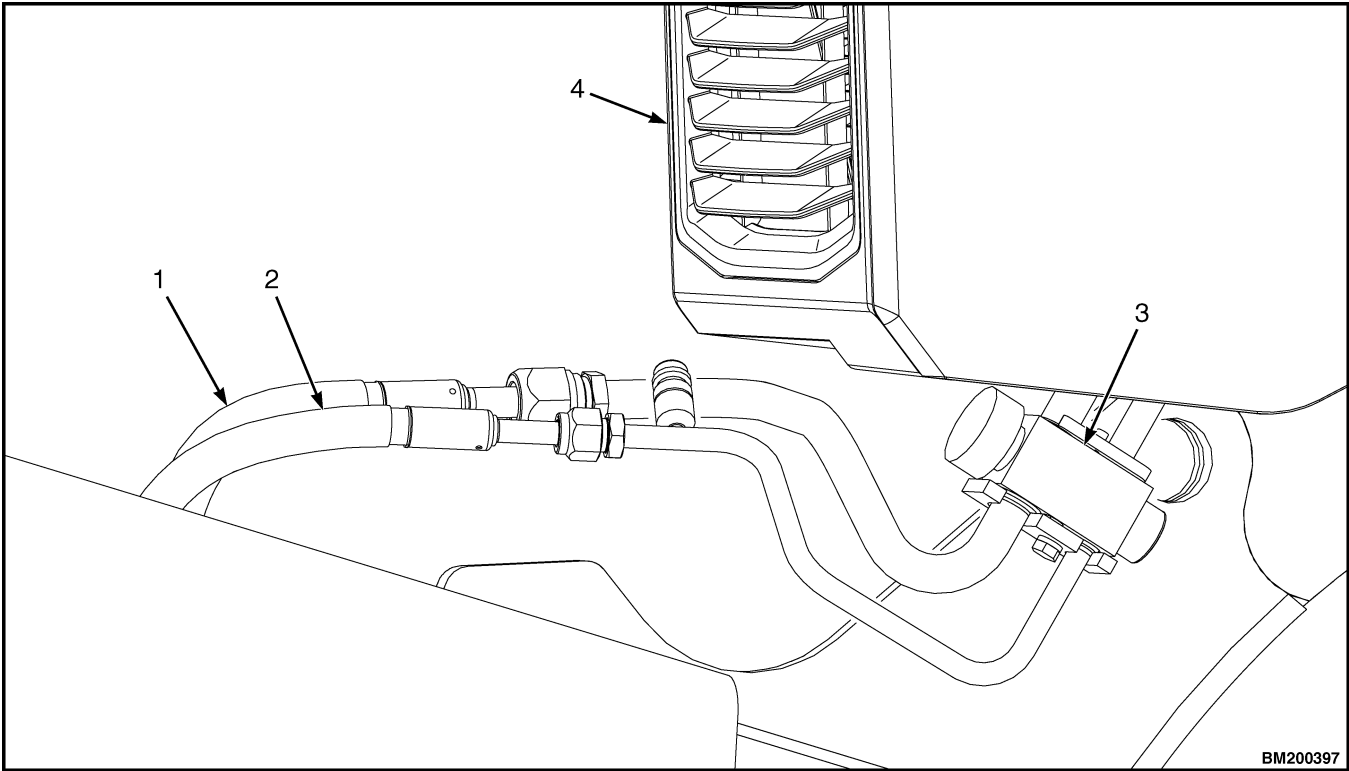


BM200396

NOTE: SOME COMPONENTS NOT SHOWN FOR CLARITY.

- | | |
|----------------------------------|-----------------------|
| 1. CONDENSER TO EVAPORATOR LINE | 4. AC COMPRESSOR |
| 2. CONDENSER TO COMPRESSOR LINE | 5. COMPRESSOR HARNESS |
| 3. COMPRESSOR TO EVAPORATOR LINE | |

Figure 247. AC Compressor Lines

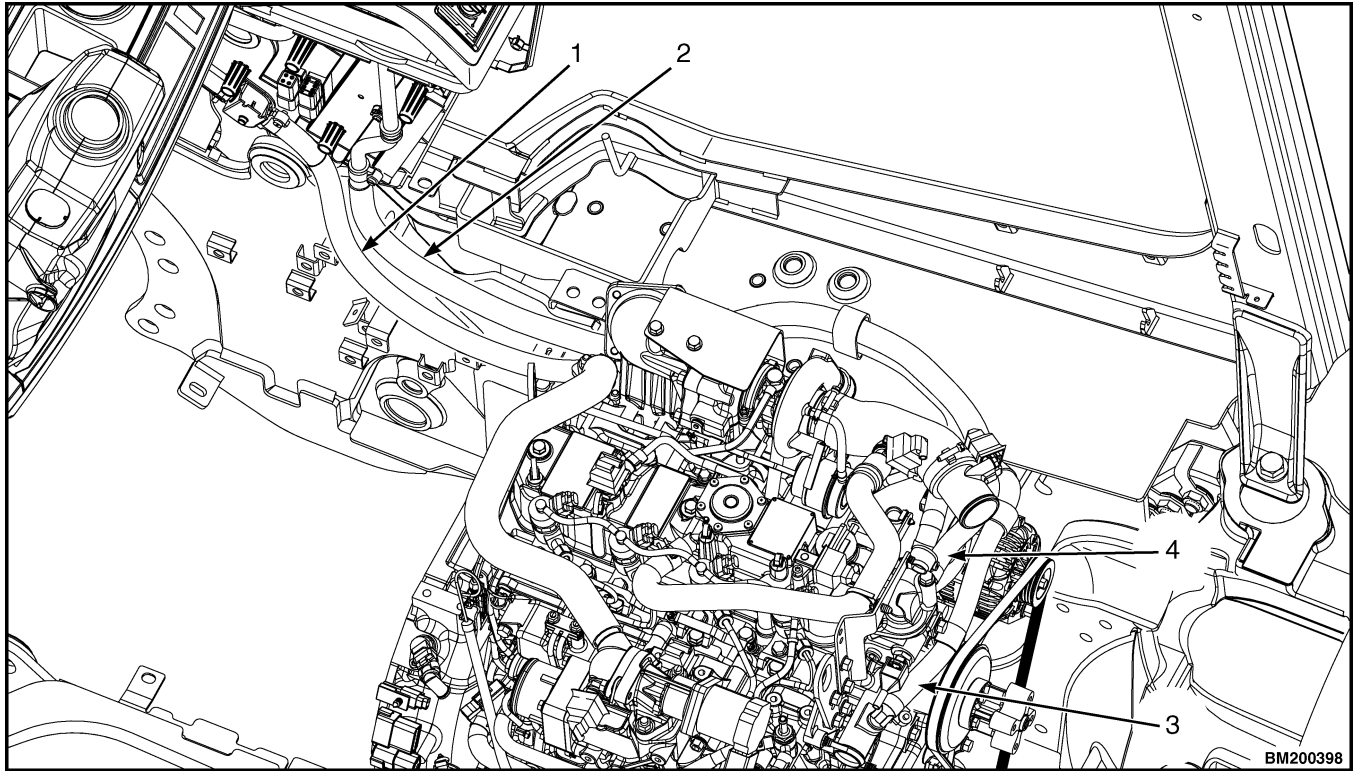


BM200397

NOTE: SOME COMPONENTS NOT SHOWN FOR CLARITY.

- | | |
|----------------------------------|--------------------------|
| 1. EVAPORATOR TO CONDENSER LINE | 3. EXPANSION BLOCK VALVE |
| 2. EVAPORATOR TO COMPRESSOR LINE | 4. HVAC ASSEMBLY |

Figure 248. Lines to Evaporator



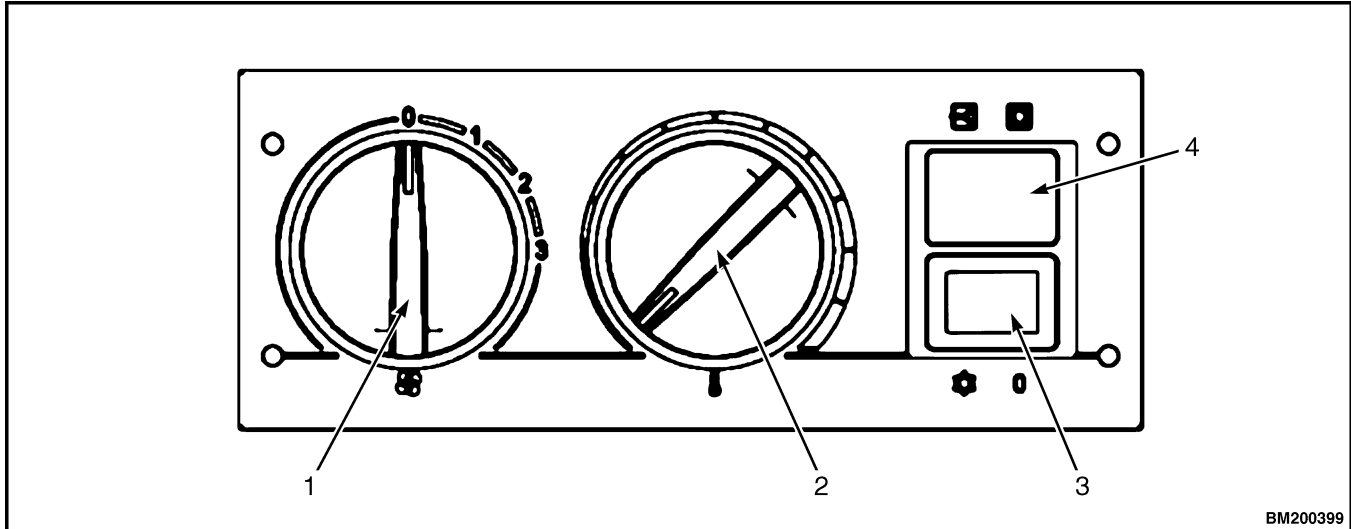
NOTE: HVAC LH AND GRILL COVERS NOT SHOWN FOR COMPONENT CLARITY.

- | | |
|---------------------------------|--------------------------------|
| 1. HEATER HOSE SUPPLY (HEATER) | 3. HEATER HOSE RETURN (ENGINE) |
| 2. HEATER HOSE RETURN (HEATER) | 4. HEATER HOSE SUPPLY (ENGINE) |

Figure 249. Heater Hoses

HVAC Controls

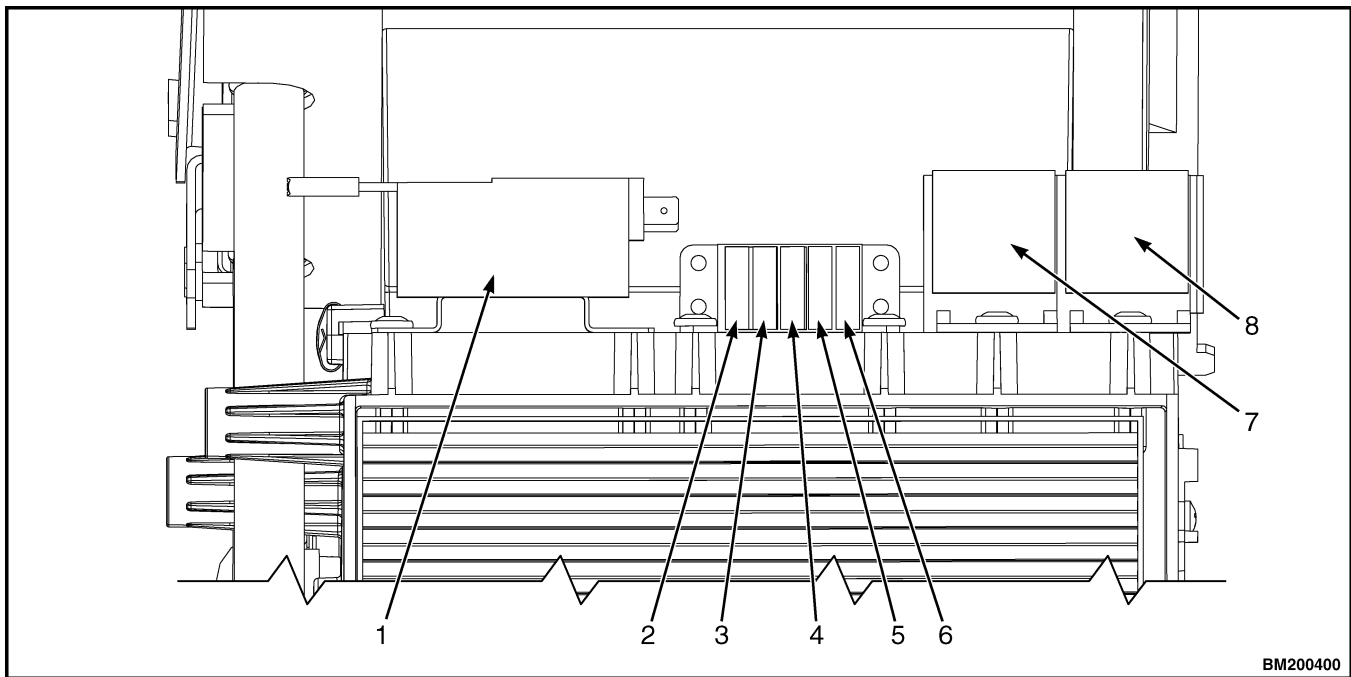
At the top of the HVAC unit is a manual control panel. Heat or air conditioning can be selected and activated. Temperature and cabin fan speed can be set.



BM200399

- 1. FAN SPEED (1-3)
- 2. TEMPERATURE
- 3. AIR CIRCULATION (INTERNAL-EXTERNAL)
- 4. AIR CONDITIONING (ON-OFF)

Figure 250. HVAC Controls



BM200400

Figure 251. HVAC Electrical Components

Table 30. HVAC Electrical Components

Item	Designation	Description	Rating
1	–	Temperature Sensor	–
2	Fuse 5	Control Panel Illumination	1A
3	Fuse 4	Water Valve	2A
4	Fuse 3	AC Clutch	5A
5	Fuse 2	Blower	25A
6	Fuse 1	Condenser Blowers	20A
7	R2	Relay - AC Clutch	–
8	R1	Relay - Condenser Blower	–

AIR CONDITIONING PRINCIPLES OF OPERATION

Refrigeration cycle

The air conditioning system uses refrigerant. Refrigerant will take on two forms:

- Liquid: absorbs heat when changed to gas.
- Gas: emits heat when changed to liquid.

The closed system of an air conditioner cycles the refrigerant through four phases including compression, condensation, expansion, and evaporation. As heat from outside the system is absorbed, the air-conditioned space is cooled. The refrigerant gradually changes state, and the system effectively moves the transferred heat and finally rejects the heat outside the air-conditioned space.

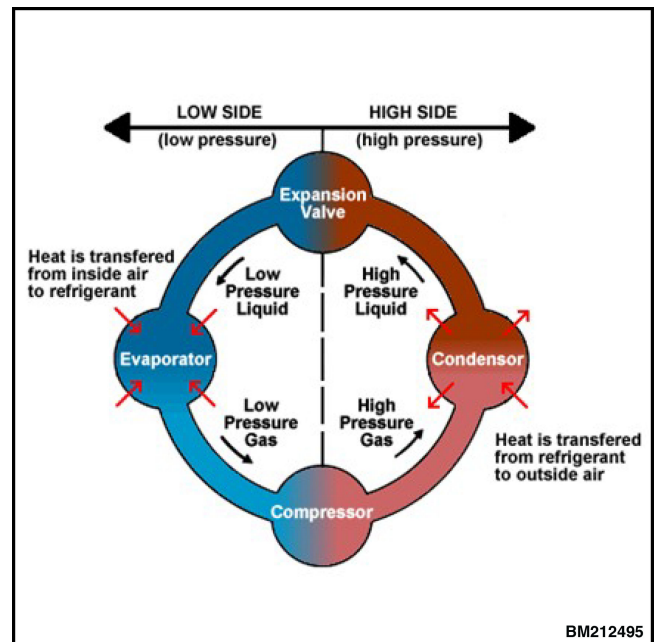


Figure 252. Refrigerant cycle

Let's begin the refrigeration cycle at the compressor. As heat is transferred to the system, high energy, low-pressure refrigerant in gaseous state, is drawn into the suction port of the compressor. In the compressor, refrigerant pressure is increased and pumped out. Then the refrigerant flows into the condenser inlet where the gas loses heat energy as it flows through the coil. By the outlet the refrigerant has rejected heat energy away from the system causing it to slow and condense to a liquid. Next, the now liquid refrigerant then moves to the expansion valve under high pressure. This valve restricts the flow and lowers its pressure as it leaves the expansion valve. The low-pressure liquid then moves to the evaporator, where heat from the inside air is absorbed and changes it from a liquid to a gas. As a hot low-pressure gas, the refrigerant moves to the compressor where the entire cycle is repeated.

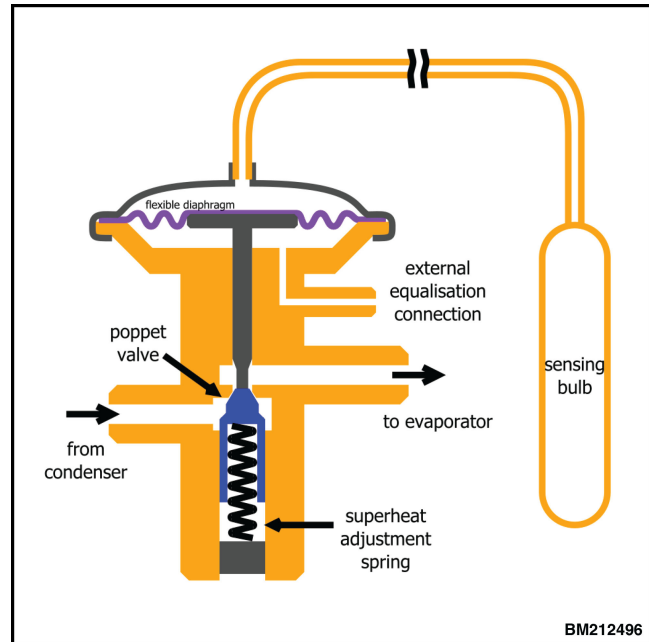


Figure 253. Thermal expansion valve

Drivetrain

DIESEL ENGINE DESCRIPTION 202001-156

NOTE: The content in this section is limited to the diesel engine and diesel fuel common in lift trucks for materials handling. This section was not written for a specific engine model, displacement, or range of output. The information here applies to all diesel Internal Combustion Engines used across the Hyster product family. The following content may be generally applicable to your lift truck configuration.

GENERAL ENGINE INFORMATION

The requirements for combustion in an internal diesel combustion engine are fuel, air, compression, and a method of ignition (compression for diesel engine). The combustible mixture for diesel engines consists of oil processed for use as fuel, atmospheric oxygen, and nitrogen.

Fuel entering the combustion chamber of a diesel engine is atomized into large droplets. Typically diesel fuel is injected into the combustion chamber at high pressure. The resulting cloud of atomized fuel in the combustion chamber is not very homogenous because the larger fuel droplets do not mix as thoroughly with the intake air. Also the fuel to air ratio is not typically measured and combustion takes place within the upper region of an engine cylinder.

The four-stroke cycle engine is a reciprocating engine design comprised of multiple cylinders in which pistons move up and down. The pistons are attached to a crankshaft by connecting rods and act as a lever against each piston. The reciprocating motion of the piston is converted into the rotary motion of the crankshaft by means of the connecting rod and crankshaft. Two valves are located near the top of the cylinder. The intake valve opens to admit the combustible mixture into the cylinder and the exhaust valve opens to expel the exhaust gases out. The valves are spring-loaded closed and they are opened by the action of the camshaft. The camshaft is driven by a timing gear (or in some cases by a belt or a chain) attached to the crankshaft. The camshaft gear is twice the diameter of the crankshaft gear, causing the camshaft to rotate at exactly half the speed of the crankshaft. The camshaft lobes (or cams) are arranged to open the valves at the correct

time during the engine's operational sequence. The physical arrangement of the valves and camshaft depends on the design of the engine. The valves of an overhead valve engine are located above the combustion chamber. The stem of each valve extends upward and rides against a rocker arm. Each travel the piston takes from one end of the cylinder to the other is called a stroke. Four complete strokes of the piston completes one cycle and the cylinder is then ready to begin another cycle. As previously stated, the crankshaft completes two revolutions during one cycle. Each stroke of the piston is given a name according to what happens within the cylinder during that interval. They are intake, compression, power, and exhaust.

COMBUSTION THEORY

The engine type most commonly used in any industrial vehicle is the four-stroke cycle engine. The four-stroke cycle engine design is sometime still today referred to as the Otto cycle engine named after the German physicist Nikolaus August Otto who developed the four-stroke engine in the 19th century. A complete rotation or cycle of the engine consists of four stroke intervals (intake, compression, power, and exhaust).

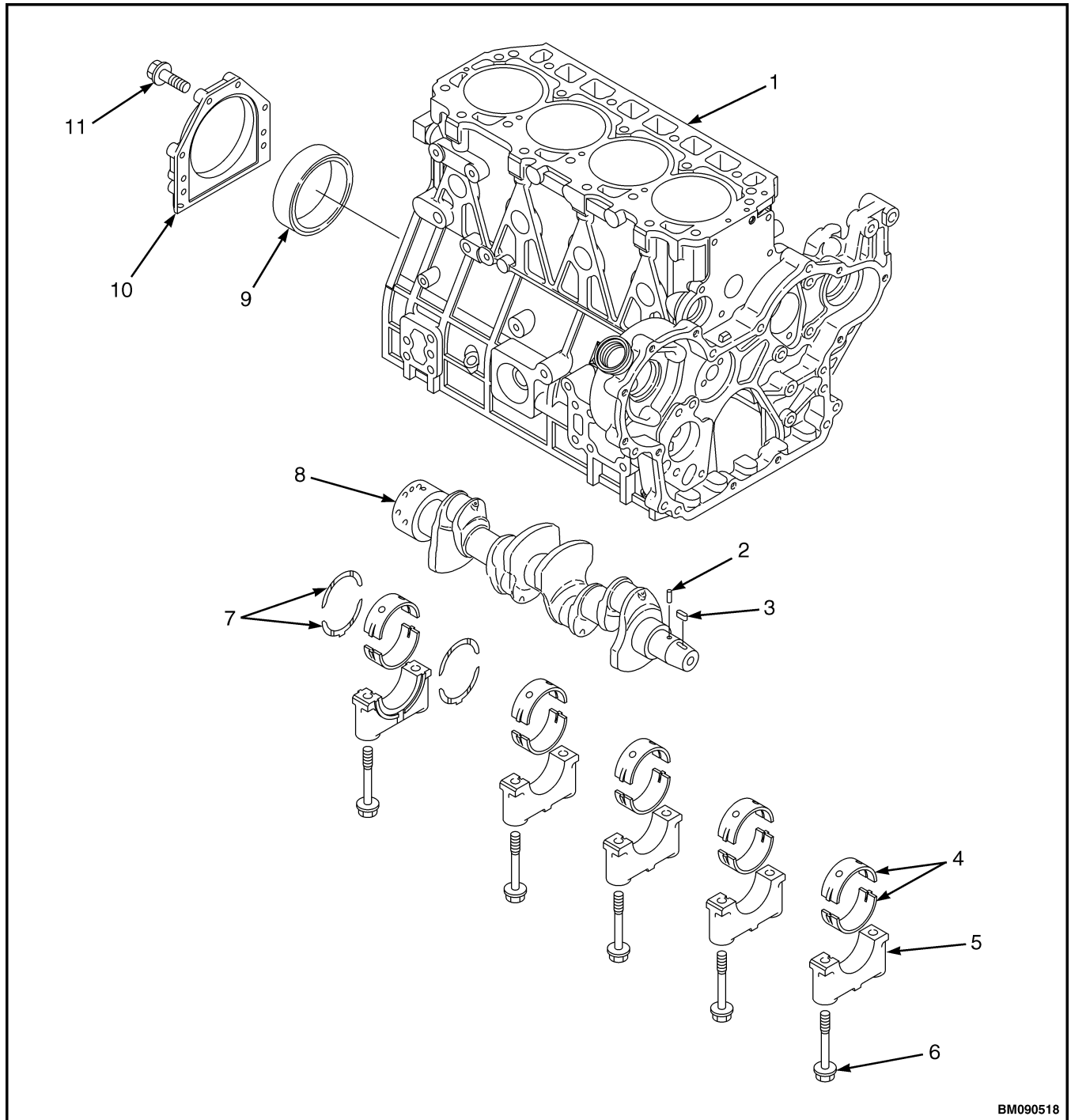
- 1. Intake** – The intake stroke is the interval during which fuel and air enters the combustion chamber of an engine cylinder. The stroke begins with the piston at the top of the cylinder. At this point the intake valve begins to open; and fuel is added to the cylinder. The exhaust valve is closed for the duration of the intake stroke. As the piston moves downward, a partial vacuum is produced and air is drawn past the intake valve filling the cylinder volume. As the piston approaches the bottom of the cylinder, the intake valve closes, now containing the fuel and air mixture within the cylinder.

- 2. Compression** – The compression stroke is the interval during which the fuel and air mixture is compressed for combustion. During this interval both valves are closed and the piston begins to travel back to the top of the cylinder. The piston compresses the fuel and air mixture into a small space above the cylinder in the cylinder head called the combustion chamber. Because the volume of fuel and air mixture is significantly reduced this causes a rise in pressure and temperature according to Boyle's gas law.
- 3. Power** – The power stroke begins with ignition when the piston is at the top of the cylinder and the fuel and air compressed. Under normal conditions the act of compressing the air and fuel ignites the fuel. The resulting combustion causes rapid expansion of gas in the cylinder. The expanding gases exert equally against the walls of the cylinder and the top of the piston. Since the piston is the only moveable element it is forced down. The descending piston drives the crankshaft another half-turn as it travels to the bottom of the cylinder. The power stroke is the only stroke that performs work.
- 4. Exhaust** – As the piston approaches the bottom of the cylinder at the end of the power stroke, the exhaust valve opens. As the piston travels upward, it acts like a pump to force the exhaust gases past the open exhaust valve to the exhaust system and into the atmosphere. When the piston is near the top of the cylinder, the exhaust valve closes and the intake valve opens so the four strokes can be repeated over and over again.

ENGINE BLOCK

The engine block is usually cast as one piece and contains the bearings that support the crankshaft and the cylinders within which each piston moves. It is typically liquid cooled through a water jacket. Components of the block include the crankshaft, piston and rod assemblies, bearings and seals, and the timing set. The camshaft is in the block unless it is an overhead cam engine.

The crankshaft converts the reciprocating motion of the pistons and rods into rotating motion. The crankshaft is located near the bottom of the block assembly. Because it is mounted in bearings, the crankshaft can rotate freely within the block.



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- | | |
|---------------------|---------------------------|
| 1. CYLINDER BLOCK | 7. THRUST BEARINGS |
| 2. PARALLEL PIN | 8. CRANKSHAFT |
| 3. KEY | 9. REAR OIL SEAL |
| 4. BEARING HALVES | 10. REAR OIL SEAL HOUSING |
| 5. MAIN BEARING CAP | 11. BOLT |
| 6. BOLT | |

Figure 254. Engine Block and Crankshaft

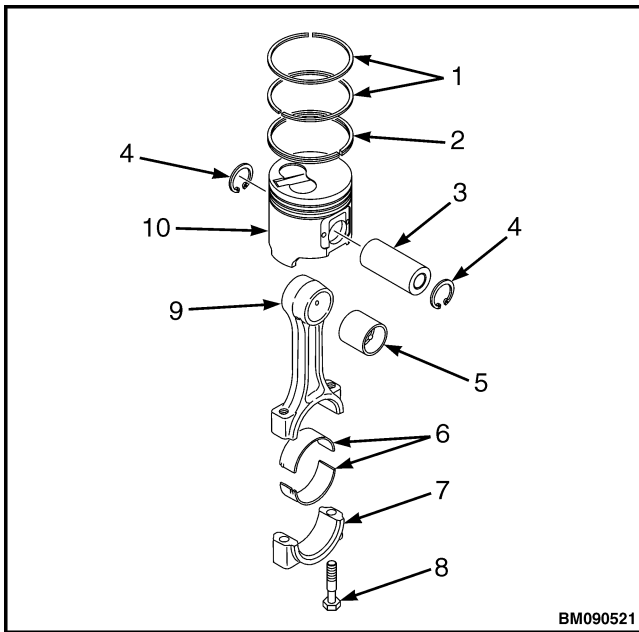
The piston and rod assembly absorbs the power released when the fuel-air mixture is ignited. The piston is machined so that it fits the cylinder properly when it reaches operating temperature.

A piston usually contains three piston rings. The bottom ring controls oil flow to the cylinder wall, the other two rings seal the combustion chamber during engine operation. The connecting rod assembly, usually made from forged steel, connects the piston to the crankshaft and transmits the energy created by the burning of the fuel/air mixture, to the crankshaft. The smaller end of the connecting rod is connected to the piston by a piston pin or wrist pin. The lower end, or large end, of the connecting rod contains the connecting rod bearing. This bearing allows the rod to be fastened to the crankshaft while still allowing it to rotate.

CAMSHAFT AND TIMING SET

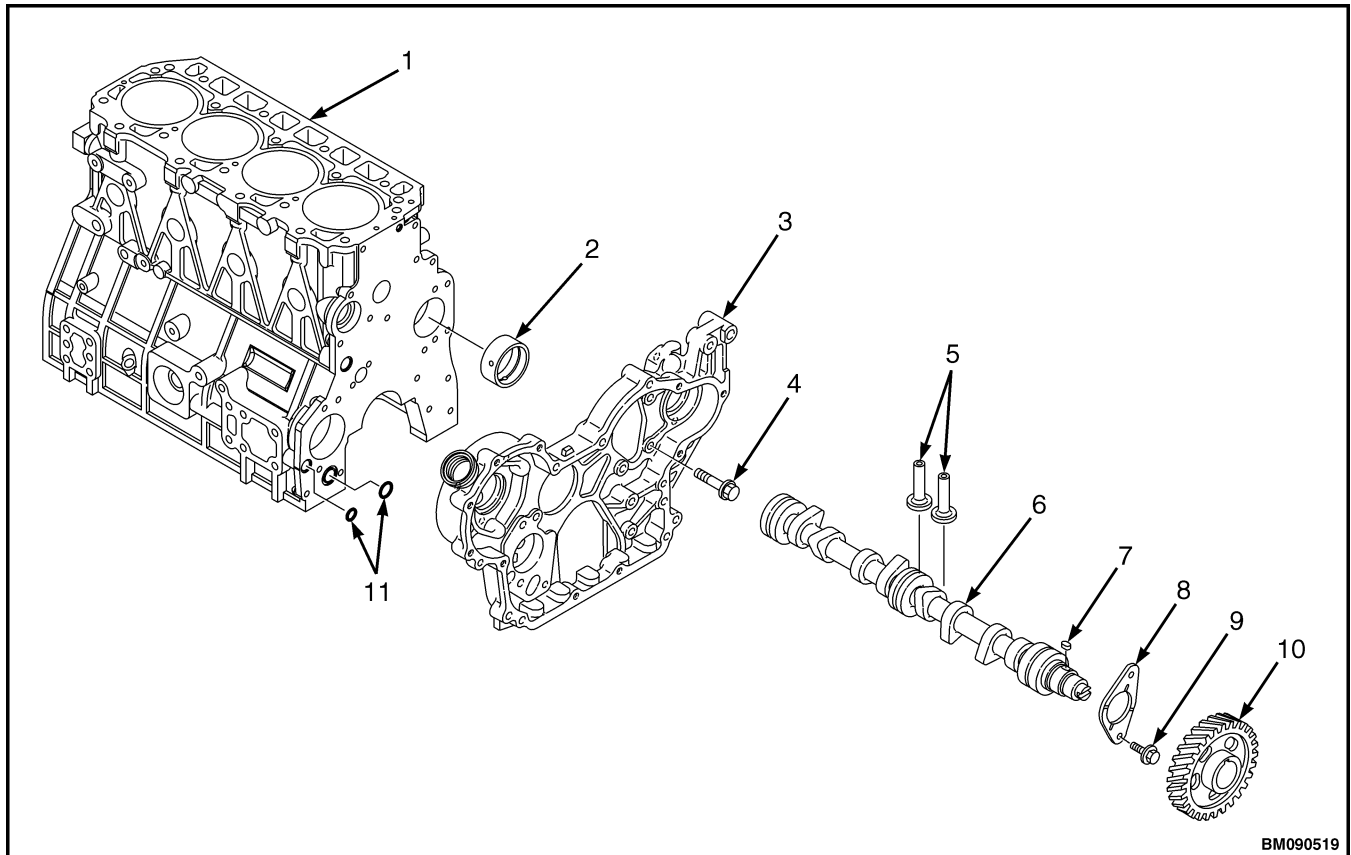
The camshaft operates the engine intake and exhaust valves. These valves channel the fuel-air mixture into the cylinders and remove the exhaust products from the cylinder. The camshaft is often responsible for other functions such as operating the fuel, oil, and vacuum pumps.

Either a chain, belt, or gears drive the camshaft at one-half the speed of the crankshaft. The chain and its sprockets; the belt and its sprockets; or the gears, are referred to as the timing set. A timing set includes all the components used to drive the camshaft.



- | | |
|----------------------|-----------------------|
| 1. COMPRESSION RINGS | 6. BEARING HALVES |
| 2. OIL SEAL RING | 7. CONNECTING ROD CAP |
| 3. WRIST PIN | 8. BOLT |
| 4. SNAP RING | 9. CONNECTING ROD |
| 5. WRIST PIN BUSHING | 10. PISTON |

Figure 255. Piston, Rings, and Connecting Rod



1. CYLINDER BLOCK
2. CAMSHAFT BUSHING
3. TIMING GEAR CASE
4. BOLT
5. TAPPETS
6. CAMSHAFT

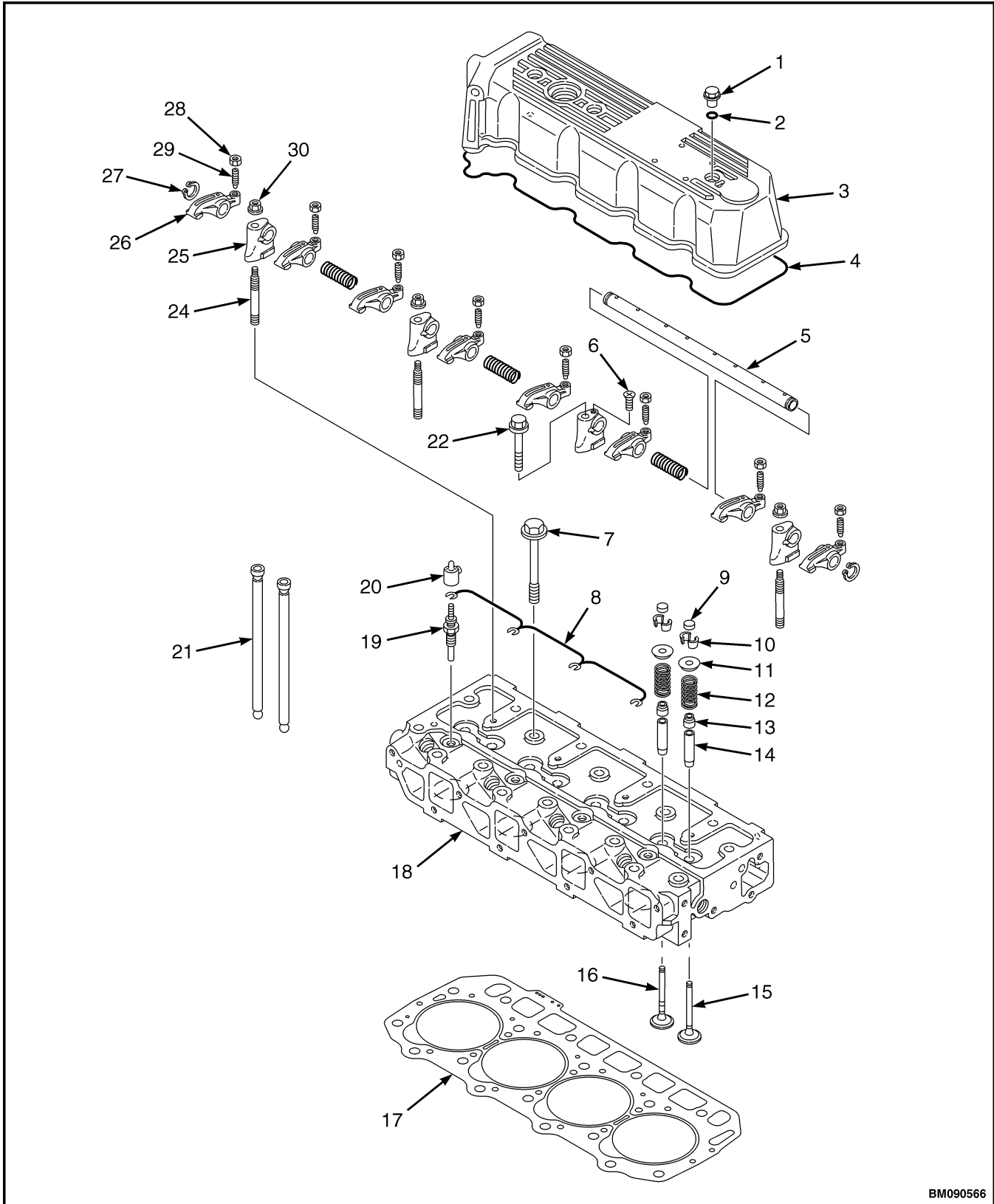
7. KEY
8. THRUST PLATE
9. BOLT
10. CAMSHAFT GEAR
11. O-RINGS

Figure 256. Camshaft and Components

CYLINDER HEAD

An engine has one or two cylinder heads, depending on the engine configuration. The cylinder heads are located on top of the cylinder block. The cylinder heads have one intake valve and one exhaust valve

for each cylinder. In many engines, a large portion of the valve train is located in the cylinder head. Many of the cooling system components may also be located in and around the cylinder head, such as the outlet housing, thermostat, and water jacket.



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Figure 257. Cylinder Head Components

Legend for Figure 257.

- | | |
|-------------------------------------|-------------------------------------|
| 1. VALVE COVER NUT | 16. EXHAUST VALVE |
| 2. O-RING | 17. CYLINDER HEAD GASKET |
| 3. VALVE COVER | 18. CYLINDER HEAD |
| 4. VALVE COVER GASKET | 19. GLOW PLUG |
| 5. ROCKER ARM SHAFT | 20. GLOW PLUG COVER |
| 6. ROCKER ARM SHAFT RETAINING SCREW | 21. PUSH ROD |
| 7. CYLINDER HEAD BOLT | 22. SUPPORT BRACKET BOLT |
| 8. GLOW PLUG HARNESS | 23. ROCKER ARM SHAFT SPRING |
| 9. VALVE CAP | 24. SUPPORT BRACKET STUD |
| 10. VALVE KEEPERS | 25. SUPPORT BRACKET |
| 11. SPRING RETAINER | 26. ROCKER ARM |
| 12. VALVE SPRING | 27. ROCKER ARM SHAFT RETAINING RING |
| 13. VALVE STEM SEAL | 28. VALVE ADJUSTING SCREW LOCK NUT |
| 14. VALVE GUIDE | 29. VALVE ADJUSTING SCREW |
| 15. INTAKE VALVE | 30. SUPPORT BRACKET NUT |

VALVE TRAIN

The valve train assembly transmits the valve signals from the camshaft to the engine valves. In some engine designs, the entire valve train is located in the block assembly. In other designs, the entire valve train is located in the cylinder head. Some of the components included in the valve train are: valve lifters (tappets), push rods, rocker arms, rocker shafts or stud valves and valve keepers, valve seats, valve springs, and other attachment parts.

MANIFOLDS

There are two types of manifolds connected to an engine: an intake manifold (to take air into the cylinders) and an exhaust manifold (to discharge the exhaust gas).

Intake

The purpose of the intake manifold is to distribute the air or fuel-air mixture uniformly to each of the engine cylinders.

To maximize volumetric efficiency, some engines have tuned intake manifolds, in which the port cross-sectional area and length are adjusted to a size that fills the cylinders most efficiently. A leaking intake system may allow unfiltered air to reach the cylinders. A leak can cause detonation, misfire, and exhaust emission problems during engine operation and evaporative hydrocarbon emissions when the engine is not operating. Leakage of air into the fuel-air mixture unbalances the engine by producing lean mixtures and upsetting the calibration of the fuel metering system.

Exhaust

The exhaust manifold is a casting or assembly of passages through which the products of combustion leave the exhaust-valve ports in the cylinder head or cylinder block and enter the exhaust piping system. The purpose of the exhaust manifold is to collect and carry the exhaust gases away from the cylinders with a minimum of back pressure. Exhaust manifolds operate at high temperatures and may be subject to erosive or corrosive attack.

Exhaust manifolds contain an exhaust port for each exhaust port in the cylinder head. A flat machined surface on the manifold fits against a matching surface on the exhaust port area of the cylinder head. Some manifolds have a gasket between the manifold and the cylinder head.

The entire exhaust system, including the exhaust manifold, catalytic converter, muffler, and piping affects the efficiency of combustive gas evacuation from the engine cylinders. Exhaust back pressure, when present, represents a direct loss of engine power.

The exhaust pipe is connected from the exhaust manifold to the DPF (Diesel Particulate Filter), DOC (Diesel Oxidation Catalyst) or muffler. On V-type engines, the exhaust pipe is connected to each manifold flange and these two pipes are connected into a single pipe under the rear of the engine. This single pipe is then attached to a DPF or DOC. Most exhaust pipes are made from stainless steel or aluminized steel, some are double walled.

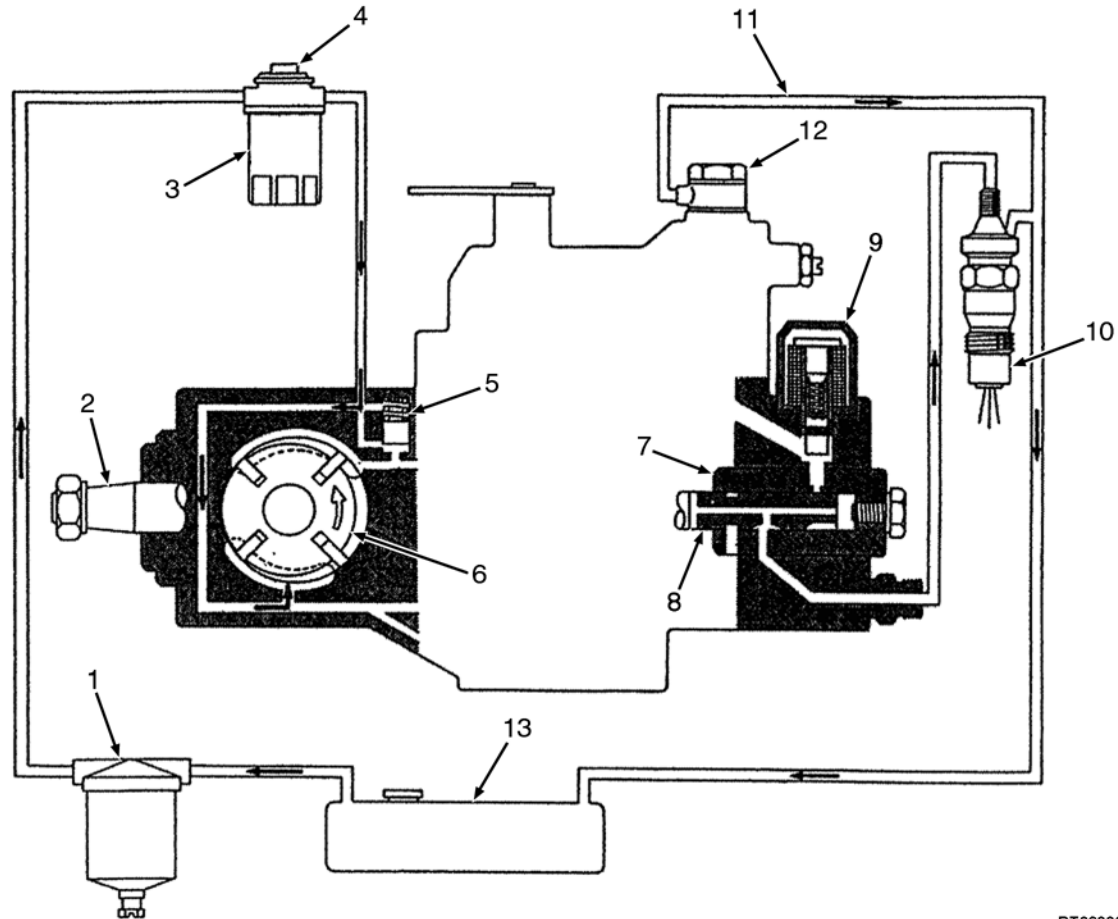
The muffler directs exhaust gases through a series of tubes, baffles, and chambers to reduce noise. The tail pipe dispenses water vapor and exhaust gases into the atmosphere. Another common component in the exhaust system is the oxygen (O₂) sensor. The sensor constantly makes comparisons between the oxygen content inside the exhaust manifold and the air outside the engine. If a rich or lean air/fuel mixture is sensed in the exhaust, the sensor provides a signal to the Engine Control Unit (ECU). The ECU will then make an adjustment to the fuel-air mixture.

AIR CLEANER/FILTER

The air cleaner/filter is common to all engine systems. The air cleaner utilizes a cyclone-type dust separator, forcing dust to circulate around the blades. Dust, separated from the fresh air by the centrifugal force, accumulates in the dust pan. A special paper filter element is used to trap dust not separated by the cyclone action.

DIESEL FUEL SYSTEM

Fuel is fed from the fuel tank through an external fuel filter to the fuel filter/water separator and strainer and then to the inlet port of the injection pump. This flow is accomplished by the feed pump, which is an internal component of the fuel injection pump. The fuel filter/water separator and strainer functions to remove contaminants, sediments and water from the diesel fuel. The fuel pressure created by the feed pump in the pump chamber is proportional to the pump RPM. Excess fuel is returned to the suction side by the regulating valve. Fuel is directed to the plunger via a fuel path within the distributor head. The plunger increases the fuel pressure, allowing the fuel to be fed to the fuel injectors. An overflow tube at each injector allows excess fuel to flow back to the fuel tank.



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- | | |
|---------------------|--------------------------|
| 1. WATER SEPARATOR | 8. PLUNGER |
| 2. DRIVE SHAFT | 9. ENGINE STOP SOLENOID |
| 3. FUEL FILTER | 10. FUEL INJECTOR NOZZLE |
| 4. PRIMING PUMP | 11. OVERFLOW PIPE |
| 5. REGULATING VALVE | 12. OVERFLOW VALVE |
| 6. FEED PUMP | 13. FUEL TANK |
| 7. PLUNGER BARREL | |

Figure 258. Typical Diesel Fuel System Diagram

ELECTRONIC FUEL INJECTION (EFI)

The function of an EFI system is to deliver the correct amount of fuel to the engine under all operating conditions. Engine conditions including speed, manifold pressure, engine coolant temperature, and throttle position are used to determine the engine mode of operation and the required fuel metering.

Port fuel injection delivers metered fuel directly prior to the intake valve. There is one port injector for each cylinder of the engine.

Electronic adjustment of fuel delivery is based on engine temperature, engine load, and atmospheric pressure.

POSITIVE CRANKCASE VENTILATION (PCV)

The PCV system is designed to remove harmful vapors from the engine and prevent those vapors from being expelled into the atmosphere. The PCV system uses manifold vacuum to draw crankcase vapors into the intake manifold. This vapor is then carried with the fuel-air mixture into the combustion chambers where it is burned. The flow or circulation within this system is controlled by the PCV valve. The PCV valve is effective as both a crankcase ventilation system and as a pollution control device.

The closed PCV system draws fresh air from the air filter housing. The oil filler cap in this system is NOT vented. Consequently, excessive vapor will be carried to the intake manifold.

Blow-by gases and vapor should be removed at about the same rate they enter the crankcase. Since blow-by is minimal at idle and increases during high speed operation, the PCV valve controls the flow of vapor accordingly.

A neglected PCV system can fail to function and result in maintenance troubles. If the crankcase is not adequately ventilated, the engine oil can be contaminated and heavy sludge accumulations will begin to form. Water and acids can become trapped within the crankcase and cause rust or corrosion of internal engine parts.

BATTERY CONSTRUCTION

The battery stores energy for the complete lift truck electrical system. On demand, the battery produces a flow of direct current for the devices connected to its terminals. After a period of use, the battery becomes discharged and no longer produces a flow of current. It can, however, be recharged by making an outside direct current flow through it in the opposite way from that which the current normally flows.

The battery is made up of a number of individual cells in a case. Each cell within the battery contains a group of positive and negative plates. There is always one more negative than positive plate within each cell group. Separators are between plates to prevent the plates from physically contacting each other and allow a free flow of electrolyte around each plate. The plates hold the active materials in flat grids. Charged negative plates contain spongy lead (Pb). Charged positive plates contain lead peroxide (PbO₂). Plate groups of opposite polarity

are interlaced so the negative and positive plates alternate. Negative plate groups normally have one more plate than positive groups. This keeps negative plates exposed on both sides of the interlaced group.

The main battery terminals are the positive (+) and negative (-) posts. The positive (+) terminal is larger to prevent the danger of connecting the battery in reverse polarity. Reversing the polarity may damage some components and wiring in the system. A red cable is connected to the positive (+) battery terminal and a black cable is connected to the negative (-) terminal. The negative (-) cable is typically connected to the frame or engine block. The positive post cable is connected to the starter solenoid.



WARNING

Whenever disconnecting or reconnecting a battery, always disconnect the negative post cable first and connect it last. If you don't do this, dangerous sparking could occur. You should never connect the battery with the key switch in the ON position or the engine running. Never place metal tools or any other objects across the battery which could potentially cause a short circuit.

A standard battery has one vent cap for each cell. The caps serve two purposes: First, they close the opening in the cell cover through which the electrolyte level is checked and water added, and second, they provide a vent for the escape of gases formed when the battery is charging. Each cell within the battery has a potential voltage of approximately 2 volts. A 12-volt battery will have six cells connected in series.

Conventional Standard Battery

A conventional, new standard battery contains fully-charged elements and is factory filled with electrolyte. It will not maintain its charged condition during storage and must be recharged periodically. A standard battery requires periodic measurement and electrolyte level adjustments. Access to the electrolyte within each cell is through the battery vent caps. The electrolyte level should be checked daily. The electrolyte should be 6.35 to 12.7 mm (1/4 to 1/2 in.) above the plate separators, so that the tops of the battery plates are covered. The battery should be filled with distilled water and never overfilled. Do not add electrolyte to the battery unless it has been lost by spillage.

Always wait until after checking battery specific gravity before adding distilled water to the battery. This will ensure a true reading. If the electrolyte level is too low to check specific gravity, add distilled water, operate in circuit for a few minutes to mix the distilled water and electrolyte, then check the specific gravity. Specific gravity testing procedures are covered later.

Standard batteries stored for long periods of time without recharging form lead sulfate crystals on the wires of the positive plates and could cause permanent damage. In some instances, if the sulfation is not too severe, a slow charge rate for a longer than normal period could restore the battery to normal operating condition.

Maintenance-Free Battery

A maintenance-free battery operates similarly to a conventional standard battery. The use of lead-calcium plates instead of lead-antimony in construction increases the ability of the battery to accept an overcharge, thus greatly reducing bubbling and gassing of the electrolyte. Less fluid is lost, eliminating the need to add water. Venting of gases from a maintenance-free battery is done through a vent. Most maintenance-free batteries do not have typical vent caps. These batteries are ready for service when they leave the factory. They have a very low rate of discharge and thus, have a longer shelf life than a conventional standard battery.

Battery Charging



WARNING

Safety is very important while charging batteries. Always wear safety goggles, protective clothing, and rubber gloves when charging a battery. Keep sparks and flames away from the battery. Make sure the work area is well-ventilated. When charging and discharging, a lead acid storage battery generates harmful fumes and gases. This gas is very explosive.

The amount of electrical current a battery can produce is limited by the amount of chemical reaction which can take place within it. When the chemical reaction in the battery has ended, either through defect or long use, it can no longer produce a flow of electrical current. In most instances, if the battery is not defective, it can be recharged.

The battery charge is maintained by the lift truck charging system. If a component in the charging system fails or if a lift truck system is drawing current while the lift truck is not running, the battery charge may be depleted. In these circumstances, external charging of the battery may be required. Batteries are charged by reversing their flow of current. Batteries can be recharged in two ways, either fast charging or slow charging.

A battery that is in satisfactory condition but requires recharging will accept a large amount of charging current without undesirable effects. This type of battery may be charged quickly at a high rate with a battery fast charger. The reaction of the battery itself to fast charging will indicate the amount of charging current it can accept without damage. NEVER allow the battery electrolyte to heat above 49°C (120°F).

A battery that becomes sulfated will not accept a high rate of charging current without possible damage. Its sulfated condition provides increased resistance to current flow within the battery. Flow of high current through this kind of resistance creates heat. Damage that may occur includes plate warping, boiling of the electrolyte, and possible damage of the separators. Also, the cell caps, covers, and battery case may be damaged or distorted. A battery that has become sulfated must be charged over a long period of time at a low rate of charge.

Battery Fast Charging



WARNING

Safety is very important while charging batteries. Always wear safety goggles, protective clothing, and rubber gloves when charging a battery. Keep sparks and flames away from the battery. Make sure the work area is well-ventilated. When charging and discharging, a lead acid storage battery generates harmful fumes and gases. This gas is very explosive.

To fast charge the battery, perform the following steps:

1. Disconnect the lift truck negative (-) and then positive (+) lead. Check, and if necessary, fill the cells with distilled water to the level recommended.

2. Connect the battery to the charger following manufacturer's recommendations. Set the charger to 15-30 amps for a 12-volt battery.
3. Start the charger at a slow or low charging rate.
4. Increase the charging rate one selection at a time.
5. Observe the charger ammeter after one minute at each selection for a 10-amp charging rate. If necessary, select boost.
6. After the battery has charged for 3 minutes, monitor the electrolyte and look for signs of excessive gassing.
7. Reduce the charging rate until the electrolyte produces comparatively few bubbles, but basing has not stopped entirely.

The maximum charging time at the boost selection is 10 minutes for a conventional battery and 20 minutes for a maintenance-free battery. Cold temperatures can increase the time required to charge the battery. Check the charger instructions for additional details. If the battery is not accepting the required 10-ampere charging rate by the specified time, replace the battery.

The charging rate for conventional batteries may require 2 to 4 hours. The charging rate for maintenance-free batteries may require 4 to 8 hours. Once the battery is charged, check the electrolyte specific gravity after the battery has cooled for 30 minutes. The specific gravity should be between 1.230 and 1.265.

Battery Slow Charging



WARNING

Safety is very important while charging batteries. Always wear safety goggles, protective clothing, and rubber gloves when charging a battery. Keep sparks and flames away from the battery. Make sure the work area is well-ventilated. When charging and discharging, a lead acid storage battery generates harmful fumes and gases. This gas is very explosive.

To slow charge the battery, perform the following steps:

1. Disconnect the lift truck negative (-) and then positive (+) lead. Check, and if necessary, fill the cells with distilled water to the level recommended.
2. Charge the battery at a low rate (7% of the battery amp-hour rating or less) for an extended period of time until the battery is fully charged.
3. Take three consecutive hydrometer readings an hour apart, until it shows no rise in the specific gravity. The battery is now considered fully charged.

The normal slow-charging period is from 12 to 24 hours. If the battery specific gravity has not reached the normal full-charge range (1.225 to 1.280) within 48 hours of slow charging, replace the battery. Badly sulfated batteries, however, could take between 60 to 100 hours to recharge completely.

STARTING SYSTEM PRINCIPLES OF OPERATION

The starting circuit converts electrical energy from the battery into mechanical energy at the starter motor to crank the engine.

The basic components of a starting system are:

- **Battery** - supplies energy for the circuit.
- **Starter Switch** - activates the circuit.
- **Solenoid-Operated Motor Switch** - engages the starter motor drive.
- **Starter Motor** - drives the flywheel to crank the engine.

When the starter switch is activated by the operator, a small amount of electrical energy flows from the battery to the starter solenoid and back to the battery through the ground circuit. As the starter solenoid gets this power from the battery, it moves the solenoid plunger against spring pressure, and engages the pinion gear with the flywheel ring gear. The plunger also closes the switch inside the solenoid between the battery and the starting motor, completing the circuit, and allowing a large amount of electrical energy to flow into the starting motor. The starter takes the electrical energy from the battery and converts it into rotary mechanical energy to crank the engine.

Starting System Components - Ignition Switch

The ignition switch is activated by the vehicle operator. It typically has three positions: **OFF**, **START**, and **RUN**. In the **OFF** position all lift truck circuits are de-energized. In the **START** position, system circuitry is activated to allow the starter to rotate and ignition systems to be energized. In the **RUN** position, the starter system is de-energized but the lift truck auxiliary systems and ignition remain powered.

Starting System Components - Starter Solenoid

The primary purpose of the starter solenoid is to engage the starter pinion gear. The starter solenoid is a magnetic switch, but in addition to closing a circuit, the solenoid provides a mechanical means of shifting the starter motor pinion. The solenoid switch can be either contained within the starter motor unit or a separate component.

A typical solenoid switch has two coils of wire wound in the same direction. The pull-in winding is made up of heavy wire connected to the motor terminal of the solenoid and through the motor to ground. The hold-in winding has an equal number of turns of fine wire with one end connected to ground. These coils are energized directly from the battery through the start position of the ignition switch. They work together to pull-in and hold-in the pinion gear positioning plunger against spring pressure, engaging the pinion gear with the flywheel.

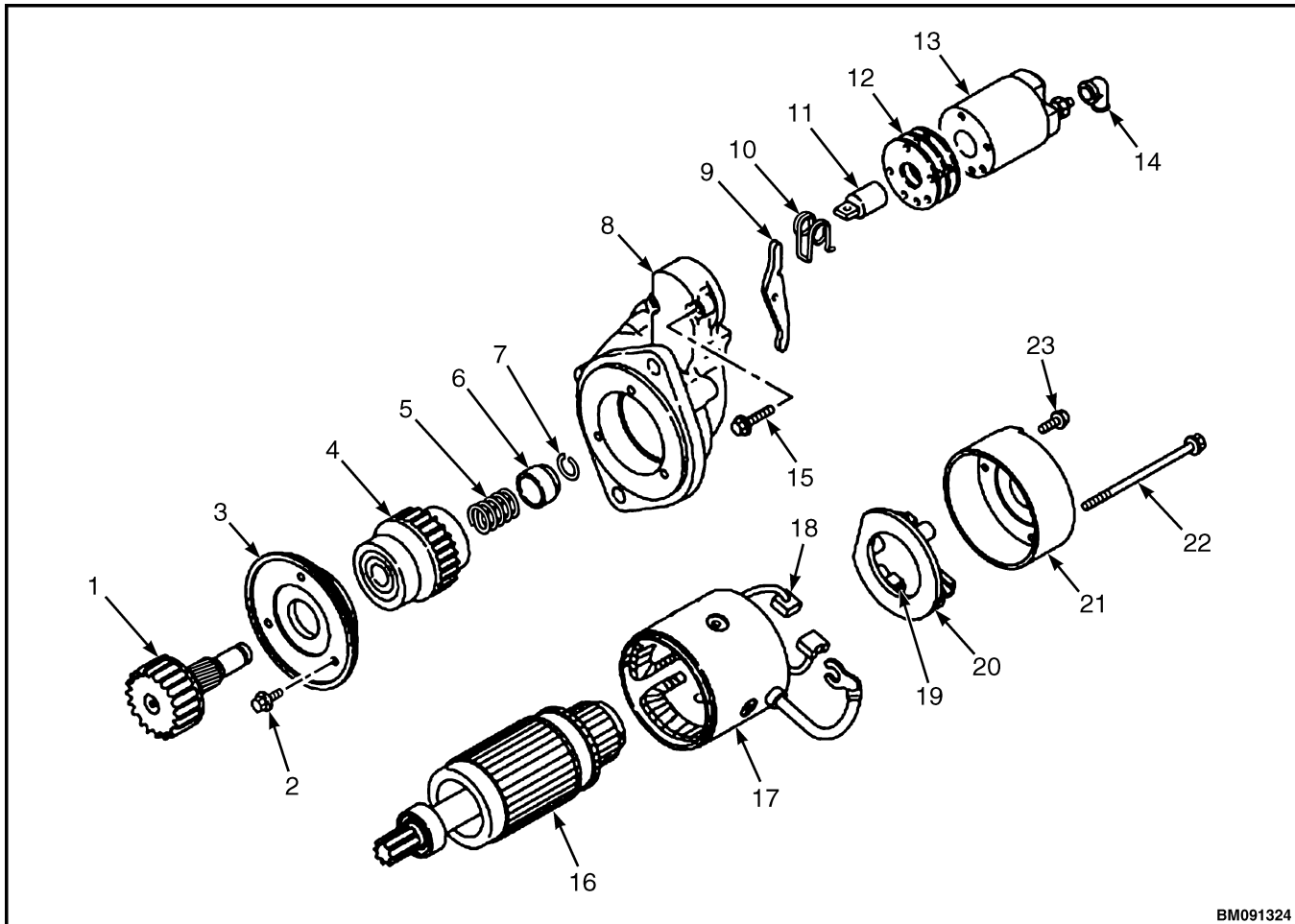
When the ignition switch is released to the run position, the pull-in and hold-in windings within the starter solenoid are energized in opposing directions. This causes the magnetic field controlling the plunger to collapse. Spring tension then acts on the plunger, moving it and disengaging the pinion gear from the flywheel.

Starting System Components - Flywheel and Ring Gear

The flywheel is connected to the engine crankshaft. During engine starting, the starter, through the starter pinion gear, rotates the flywheel and the crankshaft. A ring gear is installed around the outer edge of the flywheel. This ring gear is engaged by the starter pinion gear during the engine start cranking process.

Starting System Components - Starter and Motor Drive

The starter motor does the actual job of cranking the engine. It is a special electrical motor designed to operate for short intervals under great overload. It also produces very high horsepower for its size. The starter motor is a series-wound, direct-current electric motor designed to provide high power for a short time using current from a storage battery. Most starting motors have two, four, or six field poles with windings; a wound armature with a commutator; and two, four, or six brushes. The basic parts of a starter motor are the solenoid, a field frame assembly, an armature, and a drive mechanism.



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- | | |
|---------------------------|---|
| 1. PINION SHAFT | 13. MAGNETIC SWITCH ASSEMBLY (SOLENOID) |
| 2. M4 BOLTS (3 USED) | 14. COVER |
| 3. BEARING RETAINER | 15. M6 BOLTS (2 USED) |
| 4. PINION CLUTCH ASSEMBLY | 16. ARMATURE ASSEMBLY |
| 5. RETURN SPRING | 17. FIELD COIL ASSEMBLY |
| 6. PINION STOP | 18. POSITIVE (+) BRUSHES |
| 7. RETAINING RING | 19. NEGATIVE (-) BRUSHES |
| 8. GEAR HOUSING | 20. BRUSH HOLDER ASSEMBLY |
| 9. SHIFT LEVER | 21. REAR COVER |
| 10. TORSION SPRING | 22. M5 THROUGH BOLTS (2 USED) |
| 11. PLUNGER | 23. M4 BOLTS (2 USED) |
| 12. DUST COVERS (SHIMS) | |

Figure 259. Starter Motor

After electrical power is transmitted from the battery through a switch to the starting motor, some type of connection is needed to put this energy to work. The last link in the starting circuit is the starting motor drive. The drive makes it possible to use the mechanical energy produced by the starter motor. The starter motor armature revolves at a relatively high speed. Since the speed required to start the engine is comparatively slow, the starter motor is equipped with a small drive pinion which meshes with the teeth of the flywheel ring gear.

The gear ratio between the drive pinion and the flywheel are typically in the range of 20 to 1. This permits the starter motor to develop high armature speeds and considerable power while turning the engine over at a lower speed. After combustion has occurred and the engine speeds up to idle, the starter must be disengaged to prevent damage as the flywheel RPM increases. A starter drive on the end of the armature shaft meshes the drive pinion with the ring gear on the flywheel, and prevents the starter motor from over-speeding after the engine is started.

There are two basic ways in which starter drives are engaged. They are either Inertia Drives or Electromagnetic Drives. On an inertia drive, the pinion gear is weighted on one side to aid in its initial rotating motion. An inertia drive starter does not contain a starter solenoid. When not rotating, the inertia drive is out of mesh and separated from the flywheel ring gear. The drive relies upon inertia of a counterweight pinion and acceleration of the armature to move the pinion into mesh with the flywheel. As the starter armature shaft accelerates rapidly, the pinion gear, due to inertia created by the counterweight, runs forward on a revolving screw sleeve until it meets and meshes with the flywheel. When the engine starts, the flywheel rotates faster than the starter shaft, causing the pinion to turn in the opposite direction on the screw and it spins itself out of mesh.

Electromagnetic drives are shifted in or out of mesh by the magnetic field of a switch. The Overrunning Clutch, Dyer Drive, and Sprag Clutch Drive are all electromagnetic type drives.

- **Overrunning Clutch Type Drive** - uses a shift lever to actuate the drive pinion. The pinion, together with the overrunning clutch mechanism, is moved endwise along the armature shaft and into, or out of, mesh with the flywheel.

- **Dyer Drive** - is a special drive mechanism that provides positive meshing of the drive pinion with the flywheel, before the cranking of the starter motor armature begins. This action eliminates the clashing of pinion teeth with flywheel teeth, as well as, the possibility of broken or burred teeth on either gear.
- **Sprag Clutch Drive** - is constructed and operated similar to the overrunning clutch drive, except that a series of sprags replace the rollers between the shell and sleeve. The sprag clutch drive is used primarily on larger starting motors to carry the high torque required to turn over high-compression engines.

CHARGING SYSTEM - GENERAL

AC charging circuits have an alternator and a regulator. Most regulators are internal to the alternator. The alternator is really an AC generator. The generator produces AC current and then rectifies it to DC current through the use of diodes. Alternators are generally more compact than generators of equal output, and supply a higher current output at low engine speeds.

Charging System - Regulator

The regulator in an AC generation circuit limits the alternator voltage to a safe, preset value. Transistorized models are used in many charging circuits.

Charging System - Theory

All charging circuits operate in three stages:

- **Starting** - the battery supplies all load current.
- **Peak Operation** - the battery helps the generator supply current.
- **Normal Operation** - the generator supplies all current and recharges the battery.

In a typical charging circuit, the battery starts the circuit when it supplies the power to start the engine. The engine then drives the generator or alternator, which produces current to take over the operation of the ignition, lights, and lift truck accessory loads within the electrical system. It is important to remember that once the engine is started, the generator or alternator is the work horse which gives current to the ignition and accessory circuits.

Most lift trucks incorporate an AC charging circuit, comprised of an alternator and voltage regulator. The alternator is the heart of the charging circuit. Basically, like a generator, the alternator converts mechanical energy into electrical energy. The initial energy produced is alternating current. The AC current is electronically converted to direct current using diodes.

As the engine operates, the alternator is rotated by a belt. A voltage is produced within the alternator by moving a charged field across a stationary conductor, thereby inducing voltage. With each revolution alternating current is produced. The alternator is either ON or OFF. It generates maximum current when it is ON and no current when it is OFF. The regulator switches the alternator between ON and OFF to get the average current needed to charge the battery. Alternator output is directly changed by engine speed and rotor field current.

A diode is an electrical device that will allow current to flow through itself in only one direction. When a diode is connected to an alternating current, it only allows the alternating current to flow through it in one direction, thereby rectifying it to direct current. The diode provides what is termed half wave rectification of the alternating current. If the circuit only has one diode, the DC generation would be very limited. A diode bridge within the alternator is designed to extract maximum DC current from the produced alternating current.

Direct current from the diodes of the diode bridge flows to the alternator output terminal, sometimes called the BAT terminal. A capacitor between the BAT terminal and the electrical ground removes any remaining alternating current from the produced direct current. The capacitor also protects the diodes from high voltages.

The voltage regulator controls the alternator to charge the battery. The voltage is set by the manufacturer and is not adjustable. Battery voltage decreases as the starting circuit and other circuits use power from it. When the ignition switch is in the start position, the voltage regulator is energized. The regulator senses battery voltage and increases alternator output to charge the battery during various operating states of the electrical system.

EXHAUST AFTERTREATMENT

This section discusses Diesel Fuel Systems, Exhaust, and Emissions.

NOTE: Not all components described below will be on your particular lift truck. The information provided is intended to be generic but informative in nature. Please refer to your engine specific manual for details and descriptions.

Description and Operation

NOTE: Some of the components listed below may not be applicable to your particular lift truck.

Emission regulations allow only a very limited amount of NO_x and incompletely burned fuel to be present in the exhaust gases. NO_x is a collective name for nitrogen oxides, which are known to be harmful.

The flow of engine exhaust gases is through the Diesel Oxidation Catalyst (DOC), the Diesel Particulate Filter (DPF), and the exhaust end pipe. The exhaust tube between turbo and DOC has been insulated to maintain the high temperature of the exhaust gas and to reduce heat radiation into the engine compartment.

Incompletely burned fuel is neutralized in the DOC. The DOC oxidizes hydrocarbons and carbon monoxide into two natural substances: carbon dioxide and water. Oxidation generates heat, which is measured by temperature sensors at DOC entry and at DOC exit. The measured temperature difference is an input for the ECU to adjust the amount of injected fuel. For proper functioning, the DOC first needs to be heated up above 250°C (482°F) by the exhaust gases. This implies that the DOC does not function during the first minutes after a cold start.

Diesel Particulate Filter (DPF) - Yanmar



WARNING

It is extremely important to not bump, hit, or shock the DPF with any unnecessary force. DPF's that are dropped or kicked must be replaced even if there is no visual sign of damage. The ceramic filter inside the DPF is very delicate.

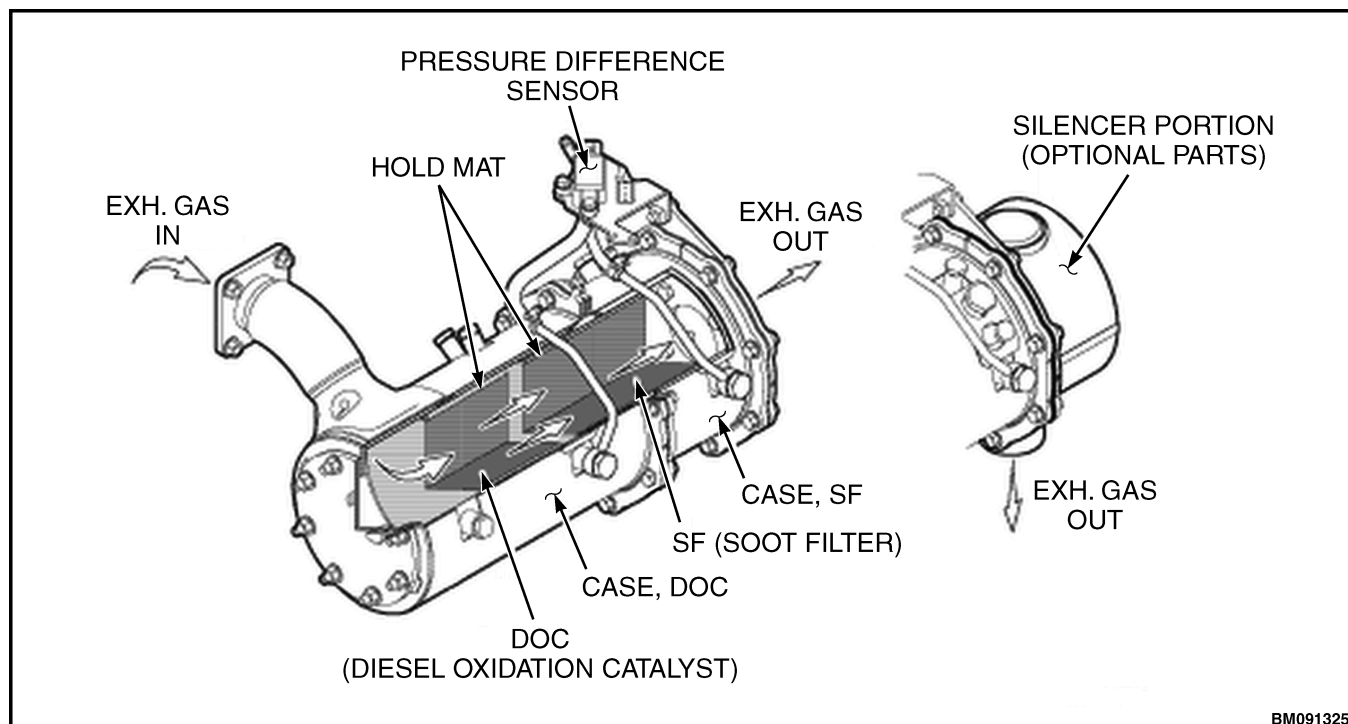


Figure 260. Diesel Particulate Filter

The DPF consists of the Diesel Oxidation Catalyst (DOC) and the Soot Filter (SF), mounted in a case that sends the exhaust gas to the DOC and the SF. Electrical components such as the DPF differential pressure sensor, inlet exhaust temperature sensor, and inside exhaust temperature sensor are mounted on the DPF. If the DPF cannot perform continuous regeneration due to low load operation, the ECU uses these electrical components to control assisted DPF regeneration (DPF regeneration control) automatically to prevent Particulate Matter (PM) from over-accumulating.

The DPF prevents the discharge of PM by breaking down hazardous constituents with the DOC and collecting the PM with the SF. The PM clogs the SF if left there and engine performance decreases, therefore a means of regeneration is required. Yanmar engines use a continuous regeneration method. While continuing the operation, the DPF collects the PM and is regenerated at the same time. To perform the regeneration, the PM collected in the SF is combusted with NO_2 generated in the DOC and O_2 in the exhaust gas. At the same time, the DOC purifies the exhaust gas elements such as HC and CO into H_2O and CO_2 .

Apart from the PM, ash also collects in the SF mostly from the metallic components in the lubricating oil additives. Part of the oil is burned in the high temperature combustion chamber and exhausted with the combustion gas. In that case, metallic components are collected together with the PM in the SF. However, because the amount of ash is very little compared to the PM, it does not clog the SF immediately.

Ash is a metallic component and cannot be combusted in the DPF for treatment like the PM. Therefore, ash is over-accumulated in the SF over a long period of time. This increases the pressure loss and has adverse effects on the engine. Periodic maintenance must be performed to remove the SF with the accumulated ash from the DPF.

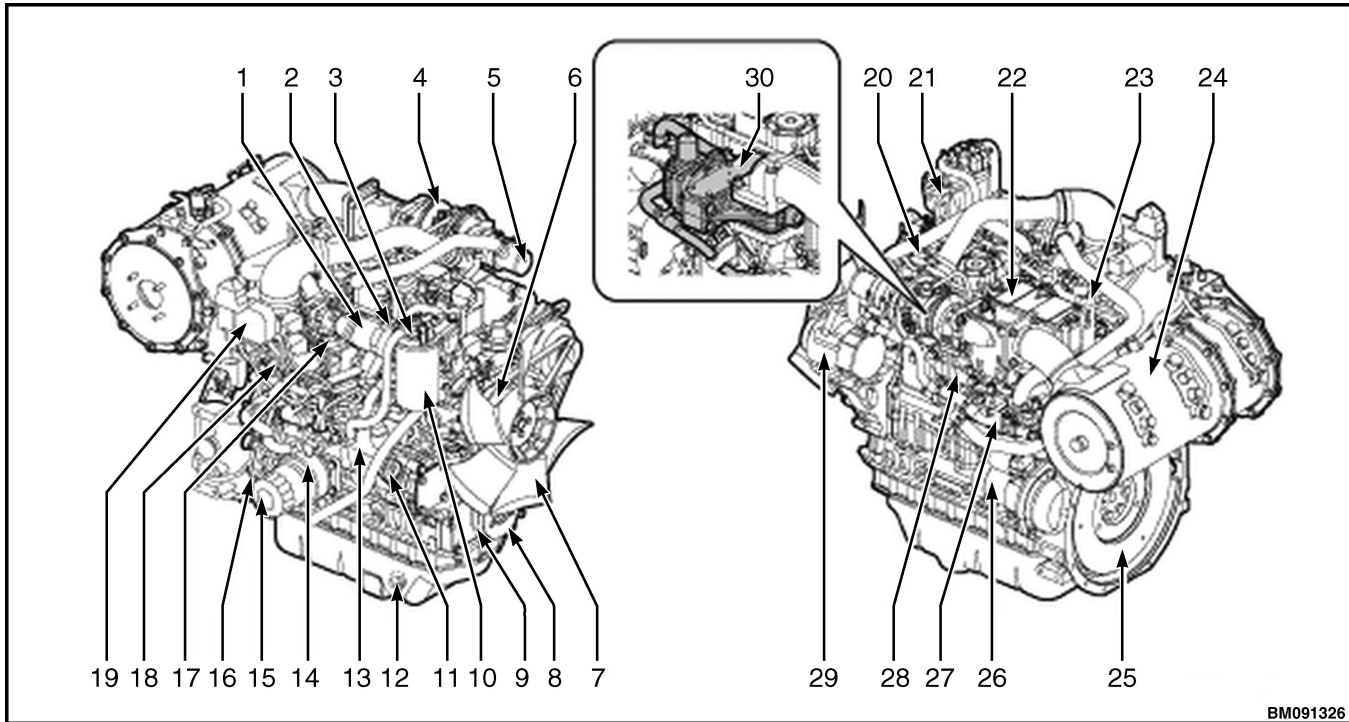
It is very important for DPF functionality to always use the specified fuel and lubricating oils. For fuel, use diesel fuel (ultra-low sulfur) with a sulfur mass of 15 ppm or lower. If fuel is used outside of this specification, performance of the catalyst contained in the DOC deteriorates rapidly due to sulfur. Because of this, the DPF cannot develop its regeneration capabilities and PM accumulates easier. This leads to increased fuel consumption, decreased engine performance, and frequent switching to the regeneration mode.

For lubricating oil, use low ash oil. If any oil other than the specified oil is used, a large amount of ash is vented through the exhaust and the DPF will clog within a short period of time. This will not only

cause the engine output to decrease and the fuel costs to increase, but also makes earlier maintenance of the SF necessary.

YANMAR DIESEL ENGINE

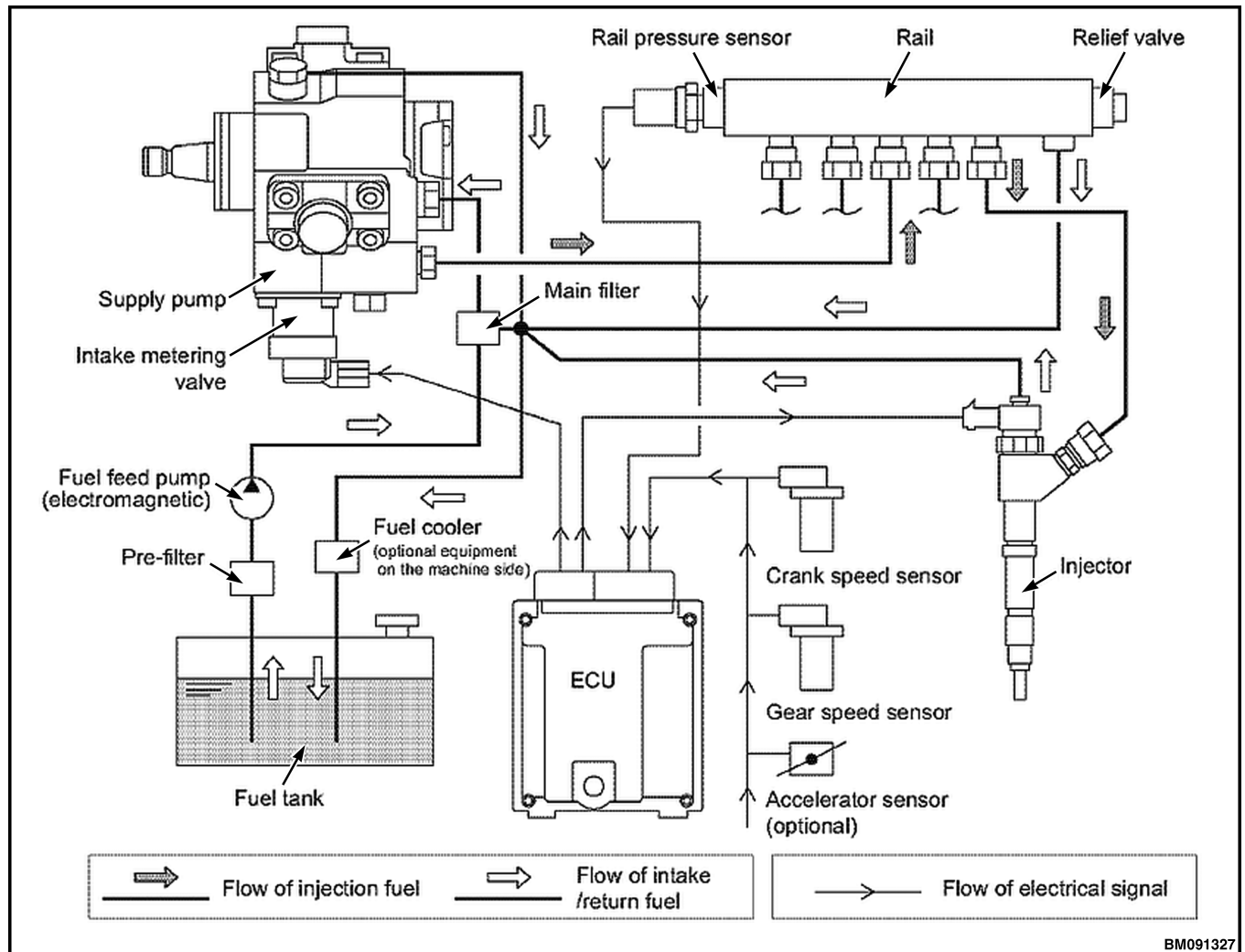
Major engine component locations are shown below.



- | | |
|---|--|
| 1. EGR VALVE | 16. DIPSTICK (ENGINE OIL) |
| 2. FUEL INLET | 17. INTAKE MANIFOLD |
| 3. FUEL RETURN TO FUEL TANK | 18. COMMON RAIL |
| 4. TURBOCHARGER (NOT ON ALL MODELS) | 19. INTAKE THROTTLE VALVE |
| 5. AIR INTAKE PORT (FROM AIR CLEANER) | 20. TOP FILLER PORT (ENGINE OIL) |
| 6. ENGINE COOLANT PUMP | 21. LIFTING EYE (ENGINE COOLING FAN END) |
| 7. ENGINE COOLING FAN | 22. CYLINDER HEAD COVER |
| 8. CRANKSHAFT V-PULLEY | 23. LIFTING EYE (FLYWHEEL END) |
| 9. V-BELT | 24. DIESEL PARTICULATE FILTER |
| 10. FUEL FILTER | 25. FLYWHEEL |
| 11. SIDE FILLER PORT (ENGINE OIL) | 26. STARTER MOTOR |
| 12. DRAIN PLUG (ENGINE OIL) - LOCATION MAY VARY | 27. EGR COOLER |
| 13. SUPPLY PUMP | 28. EXHAUST MANIFOLD |
| 14. ENGINE OIL COOLER (NOT ON ALL MODELS) | 29. ALTERNATOR |
| 15. ENGINE OIL FILTER | 30. EXHAUST THROTTLE (NOT ON ALL MODELS) |

Figure 261. Major Engine Component Locations

YANMAR DIESEL FUEL SYSTEM



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Figure 262. Fuel System Structure Diagram

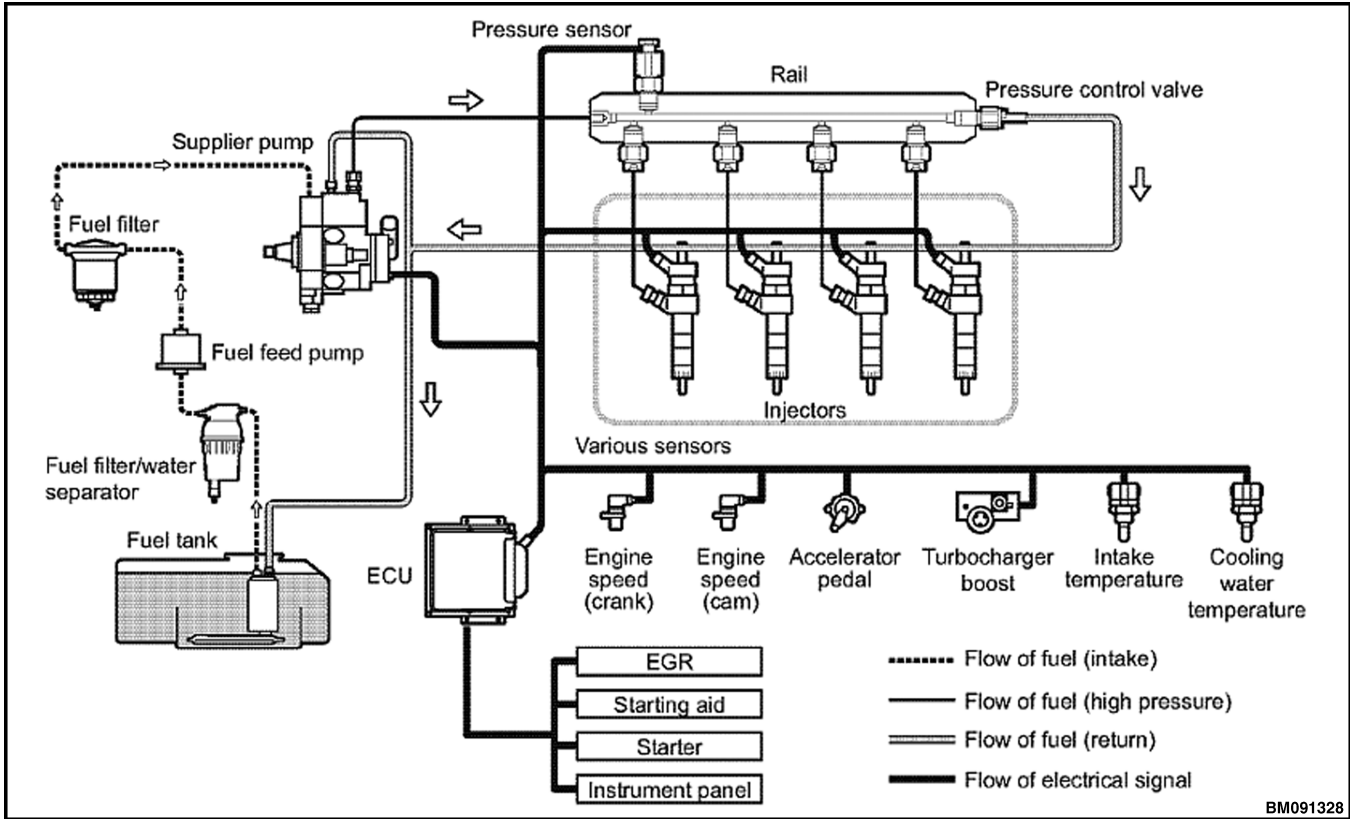
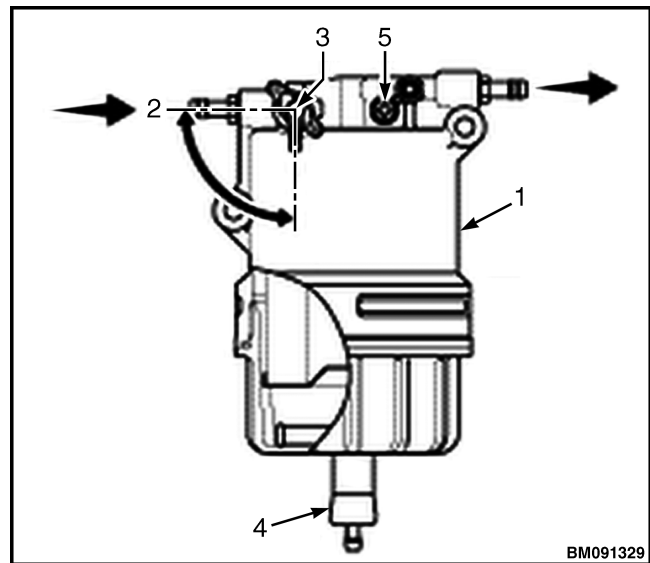


Figure 263. Fuel System Diagram

Fuel Water Separator

The purpose of the fuel/water separator is to trap any water that may have entered the fuel and supply a means of removing it. This is accomplished by a drain valve at the bottom of the unit. Periodically draining the water prevents fuel contamination and promotes engine performance. The cup of the separator is made from a semi-transparent material. In the cup is a red colored float ring. The float ring will rise to the surface of the water to show how much needs to be drained. Also, some optional water separators are equipped with a sensor to detect the amount of contaminants and send a signal to an operator alert indicator.



- 1. FUEL WATER SEPARATOR
- 2. FUEL VALVE (CLOSED POSITION)
- 3. FUEL VALVE (OPEN POSITION)
- 4. DRAIN VALVE
- 5. AIR VENT SCREW

Figure 264. Fuel Water Separator

Supply Pump

The supply pump receives fuel that has passed through the pre-filter, fuel feed pump and main filter, and pressurizes the fuel before sending it to the common rail. The supply pump features an intake Suction Control Valve (SCV), also known as a fuel metering valve, that is controlled by the ECU. The ECU will open and close the SCV as necessary to adjust the volume of the fuel intake and ensure the fuel pressure is at the target level before entering the rail. The supply pump also is equipped with a fuel temperature sensor that supplies data to the engine ECU.

Common Rail

The fuel pressure accumulates and is stored in the common rail at a maximum of 160 MPa (23,206 psi), and diverts the fuel pressure equally to each injector. The common rail features a rail pressure sensor that sends pressure readings to the ECU, and a pressure limiter valve that opens to release pressure when the reading reaches 205 MPa (29,733 psi). This prevents the fuel pressure from rising too high.

Injector

The injector takes the high-pressure fuel that accumulates in the rail and injects it into the cylinder. The injector is controlled by the ECU to maintain optimum injection volume and injection timing.



WARNING

Never touch the electrical wiring around the injector when the lift truck key switch is in the ON position. High-voltage current flows through the injector and can cause injury when contacted.

Each injector has its own unique correction data to optimize injection volume. This correction data is located on the top of the injector. The correction data is sent to the ECU and the ECU maintains the injection volume according to the correction data. It is necessary to write the correction data to the ECU when the injector or ECU are replaced. Connect to the PC service tool and use the SMARTASSIST-DIRECT (SA-D) feature.

Crankshaft Rotation Sensor and Gear Speed Sensor

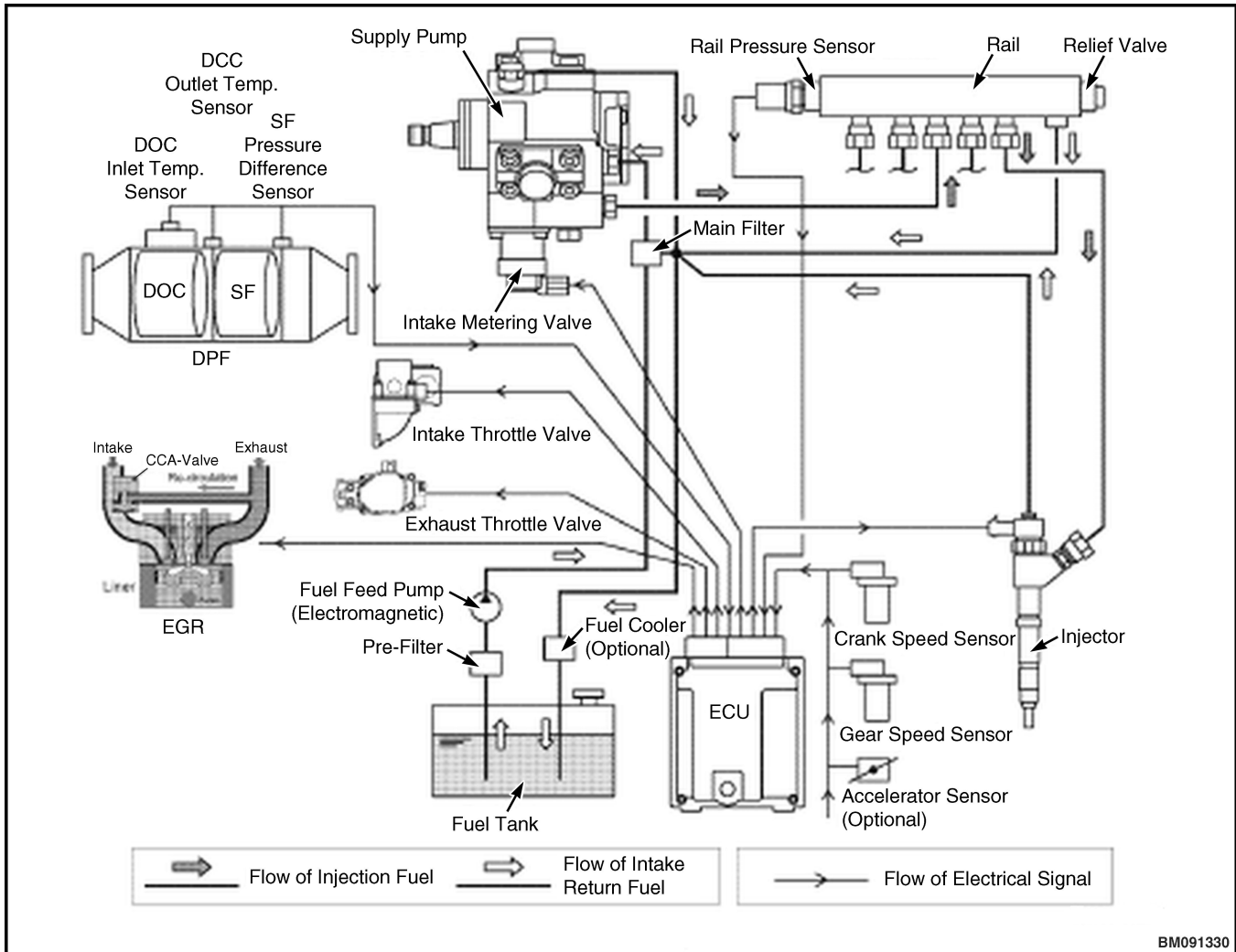
The crankshaft rotation sensor and the gear speed sensor each send outputs to the ECU, that allows the ECU to recognize both the engine speed and the position of each piston. The crankshaft rotation sensor is located on the flywheel side. The gear speed sensor is located on the gear side.

ECU

The ECU gathers information from each sensor to determine:

- Optimum injection volume
- Injection timing
- Rail pressure

The ECU controls the SCV of the supply pump and injector. It also monitors the occurrence of system abnormality at all times. If an abnormality is detected, the ECU notifies the operator to maintain the safe running condition of the system.



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Figure 265. Electronic Controls Diagram

ENGINE MECHANICAL

Engine Valves

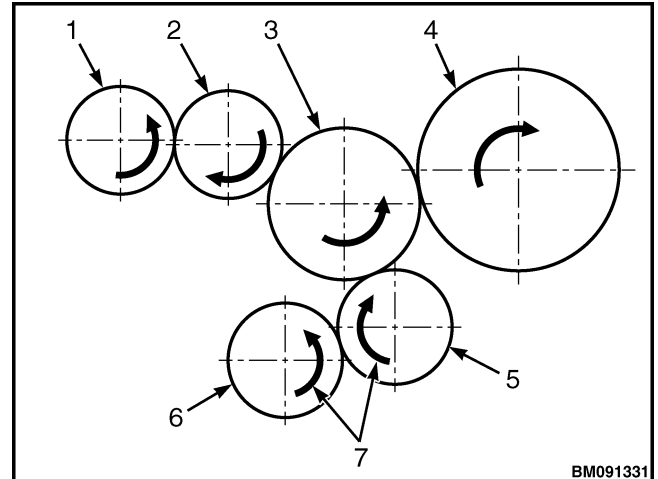
This engine incorporates an overhead valve design where the valves are actuated by rocker arms arranged on a fixed shaft mounted on the cylinder head. The engine valve camshaft is mounted in the engine block. Push rods rest on the lobes of the camshaft and mate with one end of the rocker arms. As with other engine valve system designs the valves are closed by the valve springs sitting on the top of the cylinder head at the end of the valve stem. The valves are opened by adjustable rocker arms arranged on the rocker shaft. An oil circuit in the cylinder head feeds engine oil to the mount.

Engine Pistons

The functional bottom end of the engine is the crankshaft and pistons. The pistons are actuated by connecting rods the same as any other internal combustion engine the crankshaft.

Engine Timing

Mechanically timing of the top and bottom functions of the engine is accomplished by a cluster of meshing bevel cut gears in the engine front cover. Among the gear cluster is a sprocket on the crankshaft driving the pistons and a gear sprocket on the camshaft driving the valves. By aligning timing marks during installation the engine remains in mechanical timing.



1. SUPPLY PUMP GEAR
2. IDLER GEAR (B)
3. IDLER GEAR (A)
4. CAMSHAFT GEAR
5. CRANKSHAFT GEAR
6. LUBRICATING OIL PUMP
7. DIRECTION OF ROTATION

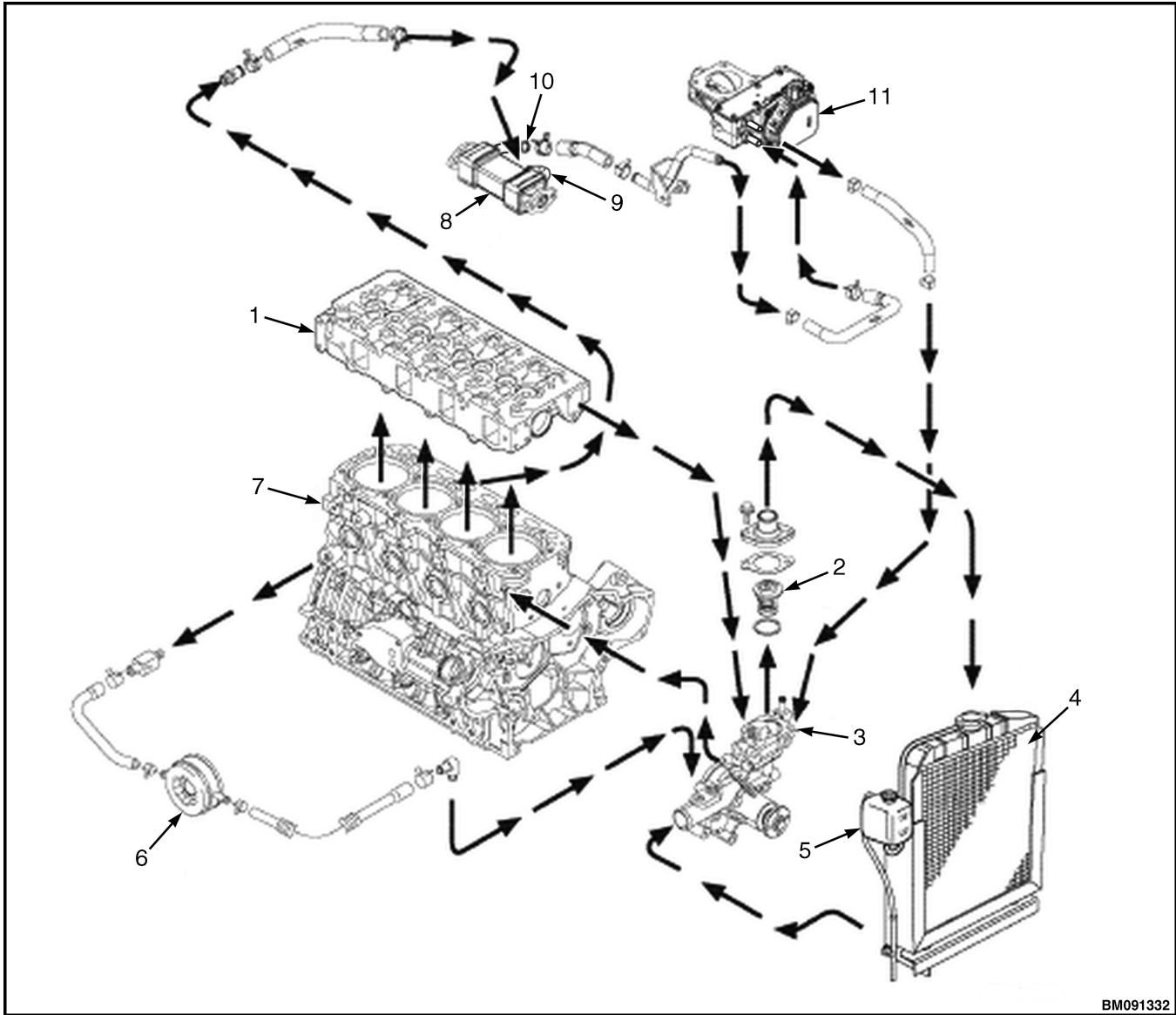
Figure 266. Timing Gears

ENGINE COOLING

Engine Coolant

One method of heat transfer for the engine is by conduction. Since engine temperatures are highest where combustion takes place a network of coolant passages are located around the combustion chambers in the cylinder head and around the

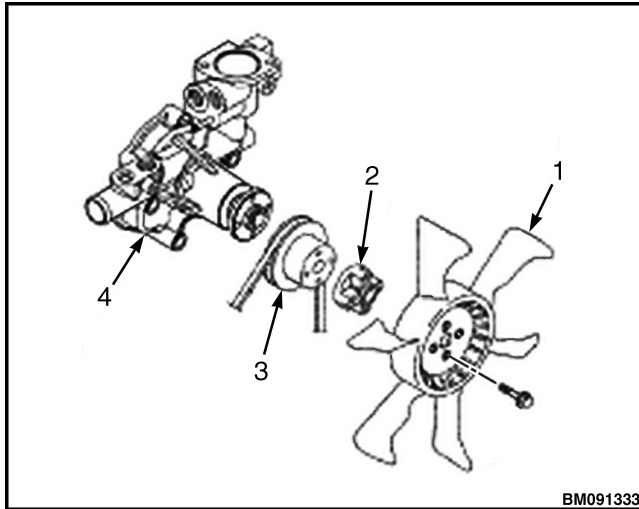
cylinder walls in the engine block. The engine coolant flows through these passages and extracts the heat. The coolant is formulated with a chemical composition where the boiling point is raised above that of water. The coolant is allowed to increase in pressure above atmosphere as it approaches its boiling point.



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- | | |
|---------------------------------|---------------------------------|
| 1. CYLINDER HEAD | 7. CYLINDER BLOCK |
| 2. THERMOSTAT | 8. EGR COOLER |
| 3. ENGINE COOLANT PUMP | 9. EGR COOLER INLET SIDE HOSE |
| 4. RADIATOR | 10. EGR COOLER OUTLET SIDE HOSE |
| 5. COOLANT RECOVERY TANK | 11. EXHAUST THROTTLE (OPTIONAL) |
| 6. ENGINE OIL COOLER (OPTIONAL) | |

Figure 267. Cooling System Diagram



1. FAN
2. SPACER
3. V-PULLEY
4. ENGINE COOLANT PUMP

Figure 268. Cooling System Components

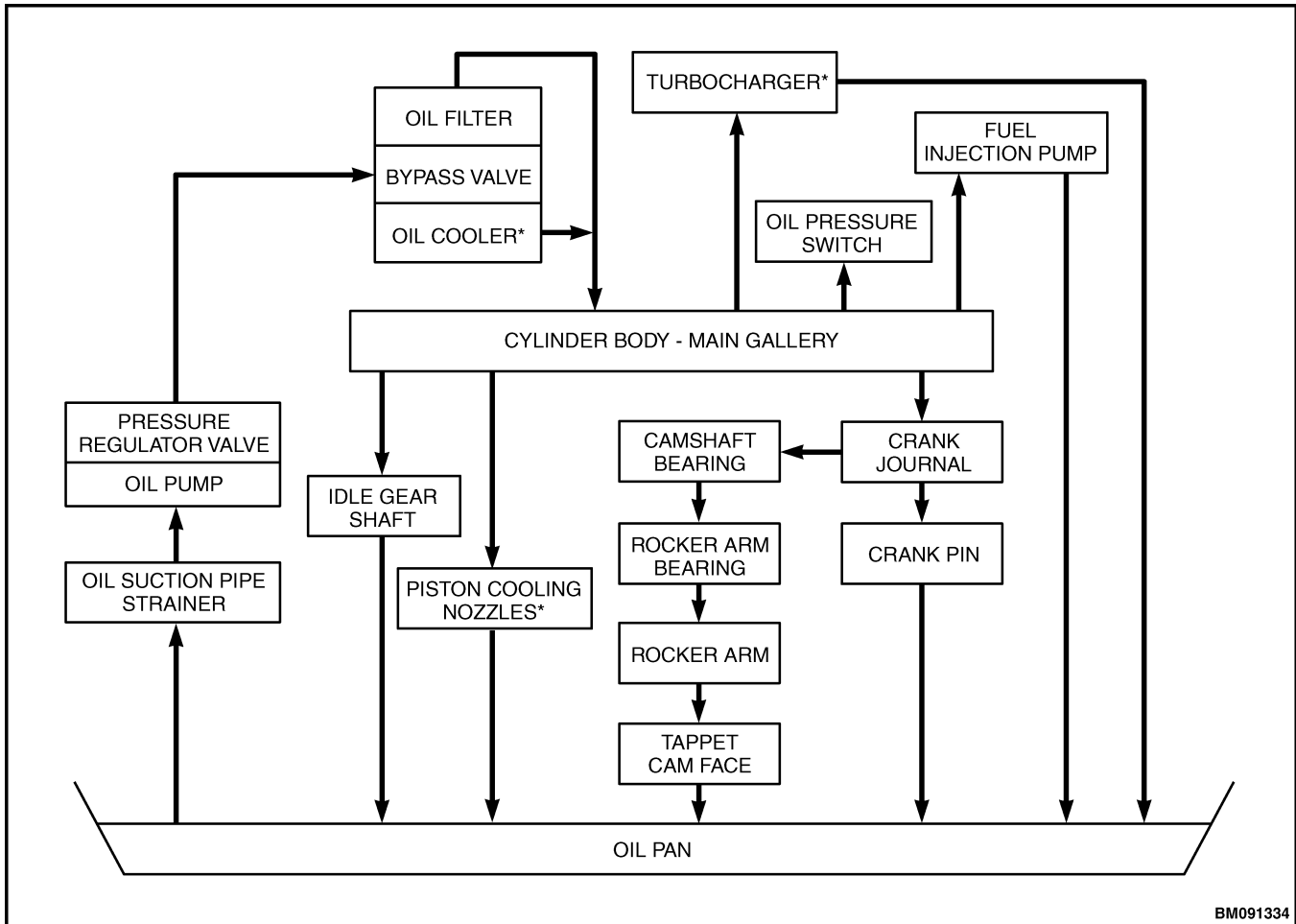
ENGINE OIL

The primary purpose of engine oil is to reduce friction between moving parts. Because liquid lubricants or oils can be circulated easily, they are used universally in internal combustion engines. In

theory, fluid lubrication is based on the actual separation of the surfaces so that no metal-to-metal contact occurs. As long as the oil film remains unbroken, metallic friction is replaced by the internal fluid friction of the lubricant. Under ideal conditions, friction and wear are held to a minimum. Oil is generally pumped throughout the engine to all areas that require lubrication.

In addition to reducing friction, the oil film acts as a cushion between metal parts. This is particularly important for such parts as engine crankshafts and connecting rods. The load-bearing qualities of the oil must prevent the oil film from being squeezed out, causing metal-to-metal contact in the bearing. Also, as oil circulates through the engine, it absorbs heat from the pistons and cylinder walls.

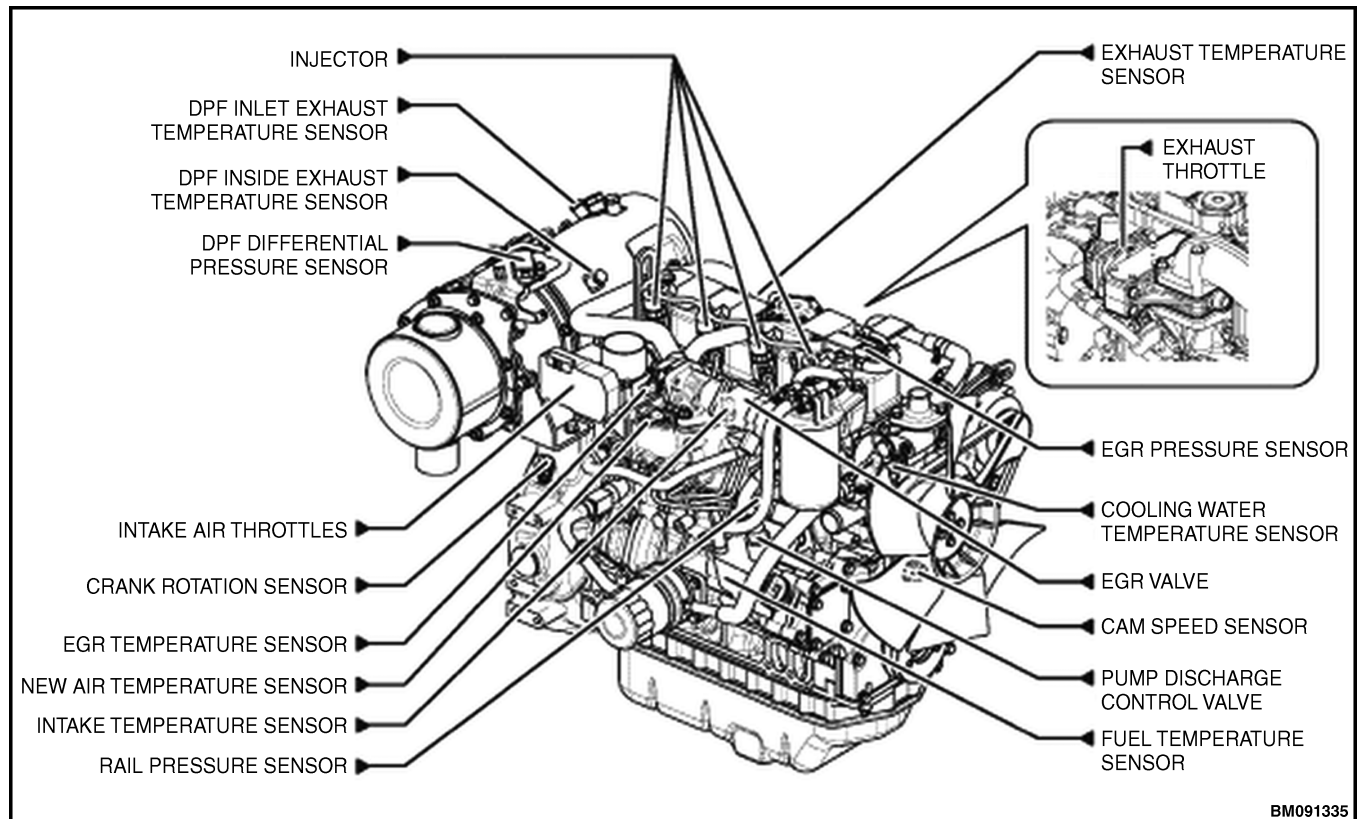
Engine oil also aids in forming a seal between piston and cylinder wall to prevent leakage of gases from the combustion chamber. Oils clean the engine by reducing abrasive wear by picking up contaminants which are passed through a filter where they are removed. The oil also prevents corrosion on the interior of the engine by leaving a coating on parts when the engine is shut down. However, it is important to avoid long engine shut down periods because this coating of oil will not last and eventually the parts will rust or corrode.



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Figure 269. Lubrication System Diagram

ENGINE MAIN ELECTRONIC CONTROL COMPONENTS



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Figure 270. Sensor Locations

Engine Control Unit (ECU)

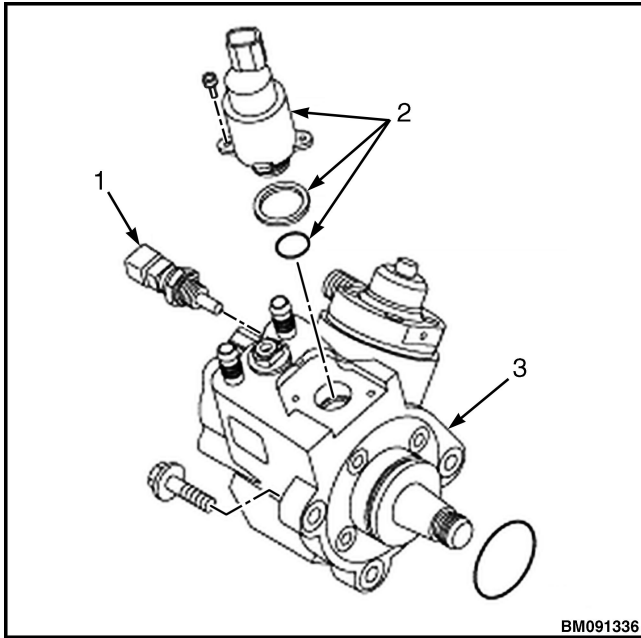
The ECU controls fuel injection timing, injection volume, injection pressure, and injection frequency. The engine ECU adjusts target speed and power output. The engine ECU also controls the Exhaust Gas Recirculation (EGR) valve.

Fuel Feed Pump

The fuel feed pump is an electric low pressure pump located between the fuel tank and high pressure pump. The fuel feed pump provides an initial lift to fuel pressure. A pre-filter strains the fuel before the low-side inlet of the pump. Located after the high-side outlet is the main fuel filter.

Fuel Pump (Supply Pump)

The fuel supply pump is a mechanical high pressure pump driven by the engine. This pump supplies the common fuel rail. Volume and pressure output to the fuel rail is regulated by a metering valve in the pump assembly. To reach target speed and load on the engine the ECU uses feedback from the fuel rail pressure sensor.

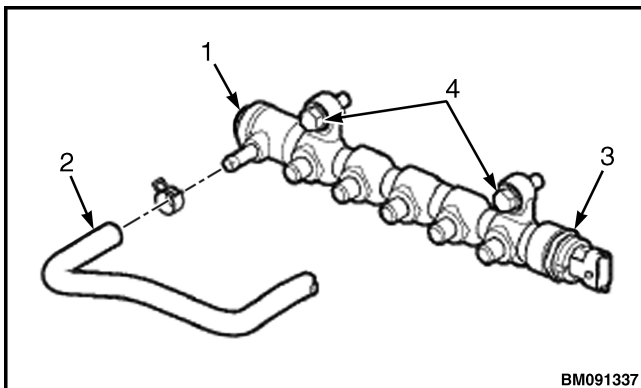


1. FUEL TEMPERATURE SENSOR
2. FUEL METERING VALVE (SUCTION CONTROL VALVE)
3. SUPPLY PUMP

Figure 271. Supply Pump

Common Rail

The common rail stores pressurized fuel from the fuel supply pump. The common rail is a distribution manifold supplying equal fuel pressure and volume to each fuel injector.

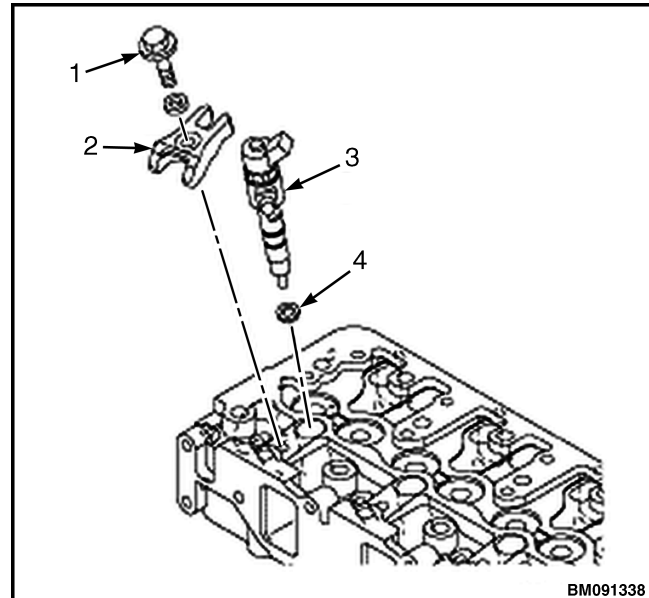


1. PRESSURE LIMITER VALVE
2. LEAK PIPING
3. PRESSURE SENSOR
4. BOLTS

Figure 272. Common Fuel Rail

Fuel Injector

The fuel injectors inject pressurized fuel from the common rail into the combustion chamber of each cylinder. The engine ECU determines injection timing, injection volume, injection pressure, and injection frequency.



1. INJECTOR RETAINING BOLT
2. INJECTOR RETAINER
3. INJECTOR
4. INJECTOR SEAT (GASKET)

Figure 273. Fuel Injector

Exhaust Gas Recirculation (EGR) valve

The EGR is a DC motor operated valve that controls flow of exhaust gas back into the intake. The primary purpose of the EGR is exhaust gas cooling. Mixing exhaust gas with unburned fuel produces lower combustion temperature. Since more Nitrogen Oxides are produced as combustion temperature rises the result of using an EGR is lower NO_x levels to improve exhaust emissions. The engine ECU determines open and close rate for the valve based on engine speed and load. This EGR valve is CAN enabled and so transmits feedback over the CAN network. Finally, a magnet and Hall effect sensor in the head of the EGR provides position feedback to the engine ECU.

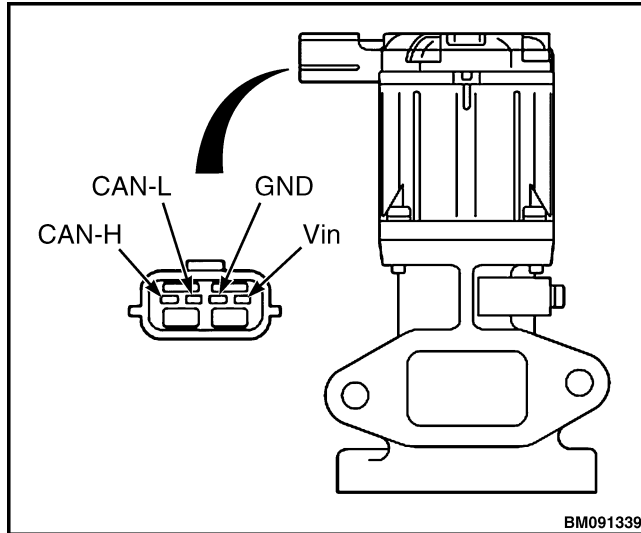


Figure 274. EGR Valve

Diesel Particulate Filter (DPF)

The DPF assembly consists of a Diesel Oxidation Catalyst (DOC) and a Soot Filter (SF). The DPF prevents discharge of exhaust gas by breaking down chemical constituents and collecting Particulate Matter (PM) in the combustion gas before exiting the DPF.

Intake Throttle

The intake throttle regulates intake air flow. The engine ECU determines the intake air flow rate, when to open and close the throttle plate based on engine speed and load. The engine ECU drives a DC motor in the assembly to move the throttle plate. The engine ECU controls the intake throttle to manage exhaust temperature for DPF regeneration. This throttle assembly is CAN enabled and so transmits feedback over the CAN network.

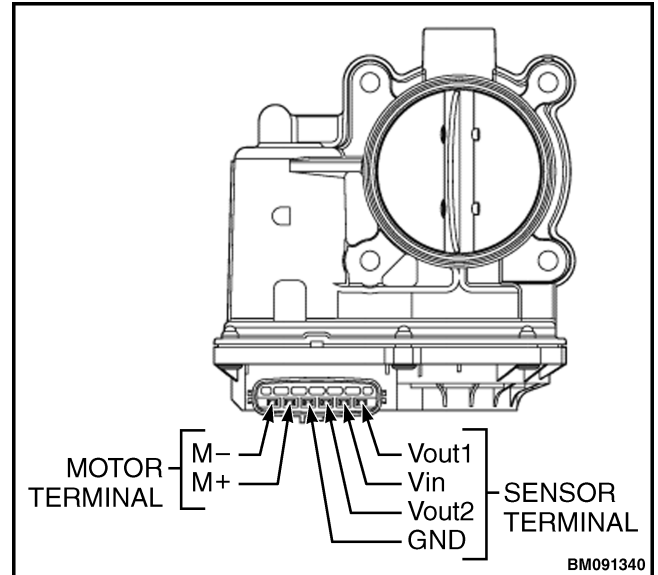


Figure 275. Intake Throttle

Exhaust Throttle (Optional)

The exhaust throttle is a DC motor operated valve to regulate exhaust flow from the exhaust manifold discharge port. The engine ECU controls the exhaust throttle valve to manage exhaust temperature for DPF regeneration. DC motors in the assembly operate the valve and a sensor provides valve position feedback. During normal engine operation the throttle plate is in the fully open position. This throttle assembly is CAN enabled and so transmits feedback over the CAN network.

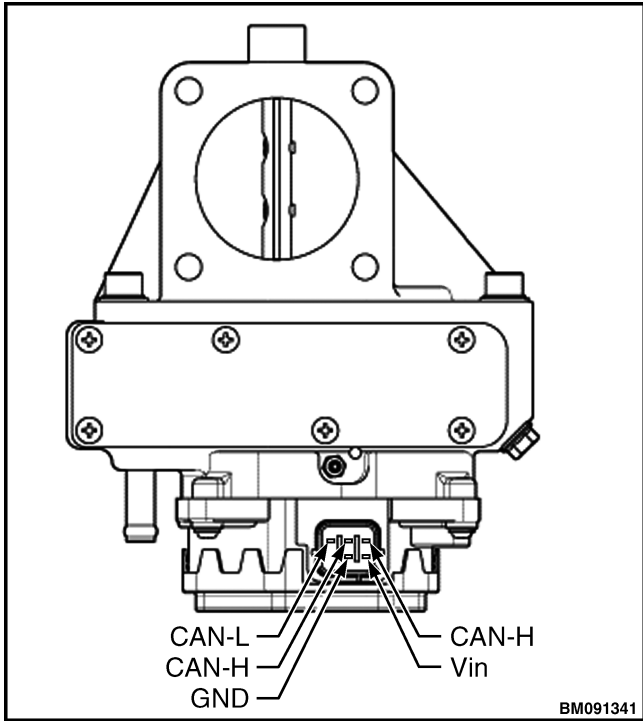


Figure 276. Exhaust Throttle (Optional)

Accelerator Pedal Position (APP) Sensor

The APP sensor is attached to the accelerator pedal in the operator station. The APP sensor physical position results in feedback voltage used by the engine ECU to set engine speed and truck acceleration.

Engine Coolant Temperature Sensor

The engine coolant temperature sensor behaves in the opposite manner of a resistor. As temperature rises the resistance of the sensor goes down. When the coolant temperature is low the feedback voltage will also be low as the sensor resistance is high. Once the coolant temperature increases, the resulting feedback voltage will also increase.

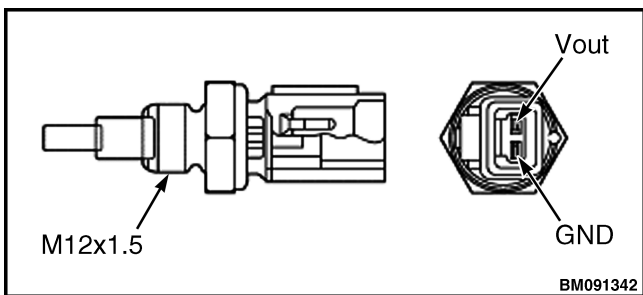
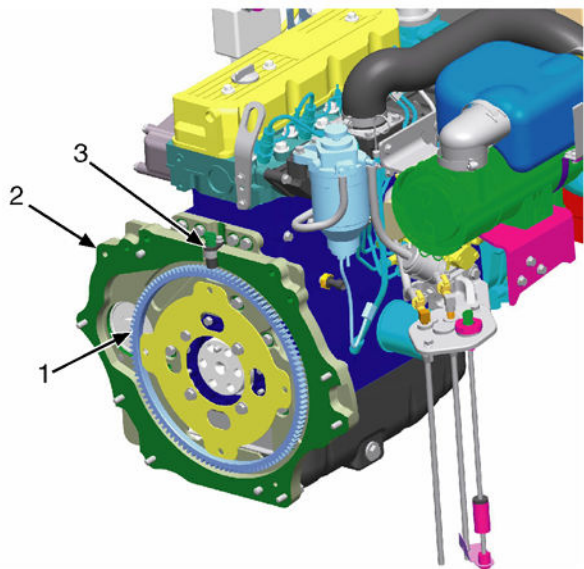


Figure 277. Coolant Temperature Sensor

Crankshaft Rotation Sensor

The crankshaft position sensor is a Hall effect switch that mates with an encoder made of magnetic material. The encoder wheel is mounted on the engine flywheel. This sensor effectively detects the encoder teeth and gaps as the magnetic field changes indicating angular position of the crankshaft. The resulting feedback is a periodic square wave that corresponds with the pattern of the encoder wheel. The wave form is predictable and indicates to the engine ECU when the position of the cylinder 1 piston is occurring and the rate the crankshaft is turning.



- 1. FLYWHEEL
- 2. FLYWHEEL HOUSING
- 3. CRANKSHAFT ROTATION SENSOR

Figure 278. Crankshaft Rotation Sensor

Gear Speed Sensor

The gear speed sensor is a Hall sensor that mates with an encoder made of magnetic material. The encoder wheel is mounted in the engine front cover about the camshaft. This sensor effectively detects the encoder teeth and gaps as the magnetic field changes indicating angular position of the crankshaft. The resulting feedback is a periodic square wave that corresponds with the pattern of the encoder wheel. The wave form is predictable and indicates to the engine ECU when the position of the cylinder 1 piston is occurring. The feedback is used to synchronize the fuel and ignition systems.

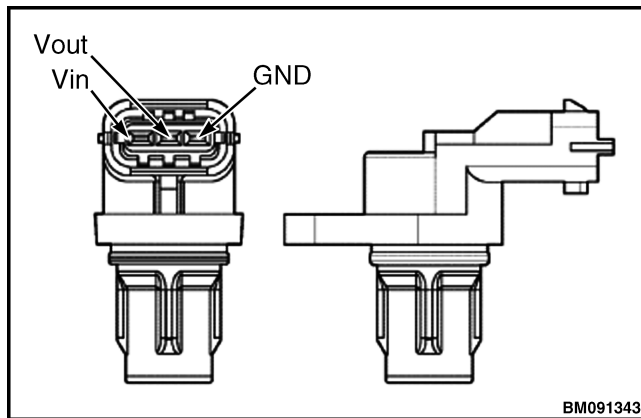


Figure 279. Gear Speed Sensor

New Air Temperature Sensor

The new air temperature sensor measure the temperature of the incoming air to the engine. This information is provided to the ECU to calculate air density and adjust the air/fuel mixture accordingly.

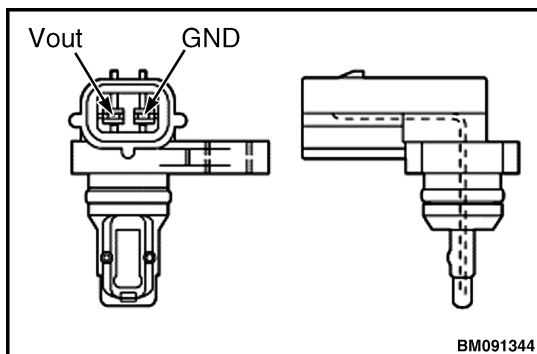


Figure 280. Air Temperature Sensor

Exhaust Gas Recirculation (EGR) Temperature Sensor

The EGR temperature sensor behaves in the opposite manner of a resistor. As temperature rises the resistance of the sensor goes down. So when exhaust gas temperature is low the feedback voltage will also be low as the sensor resistance is high. Once the coolant temperatures increase so will the resulting feedback voltage.

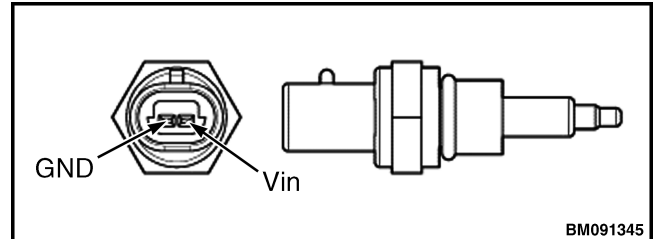


Figure 281. EGR Temperature Sensor

EGR (EGR) Pressure Sensor

The EGR pressure sensor assembly contains two transducers. One side of the sensor is exposed to a port at intake pressure. The other is exposed to a port at exhaust manifold pressure. To regulate the valve position and control exhaust flow for re-combustion feedback from this sensor is used by the engine controller to drive the valve to keep combustion temperatures as low as possible while not negatively impacting performance.

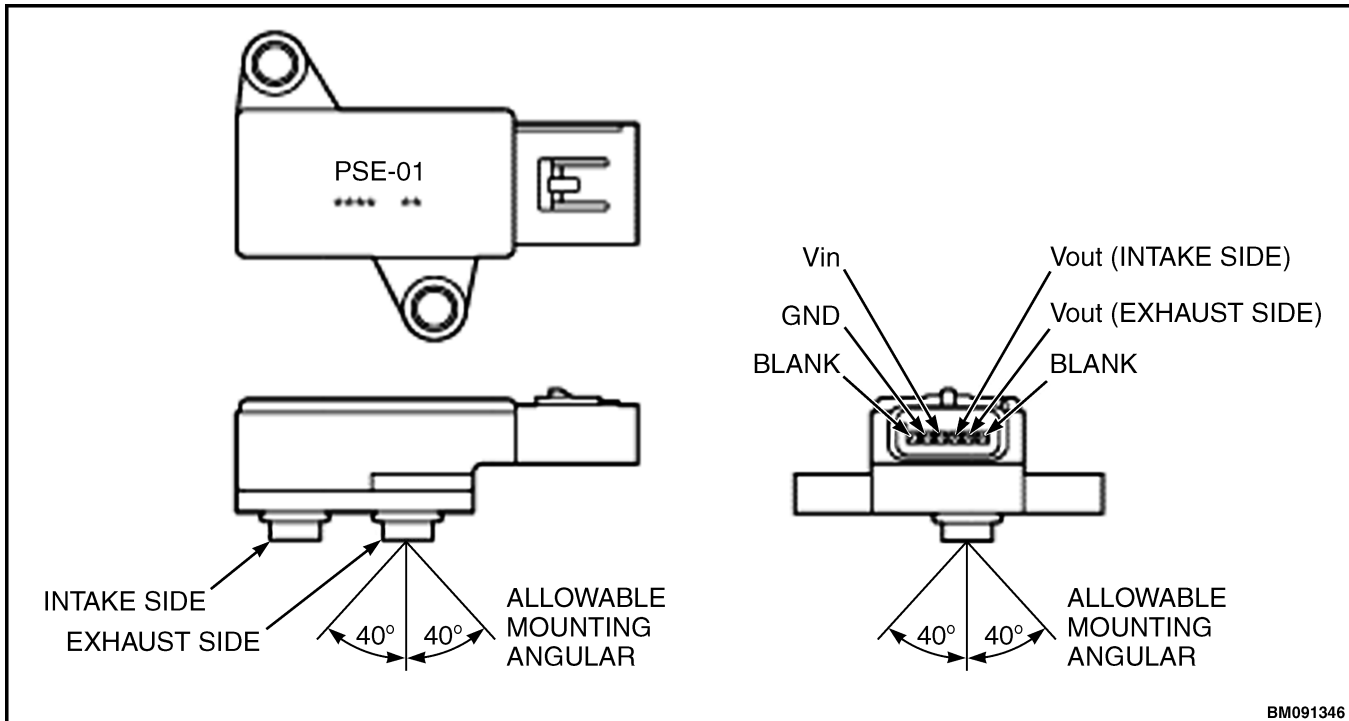


Figure 282. EGR Pressure Sensor

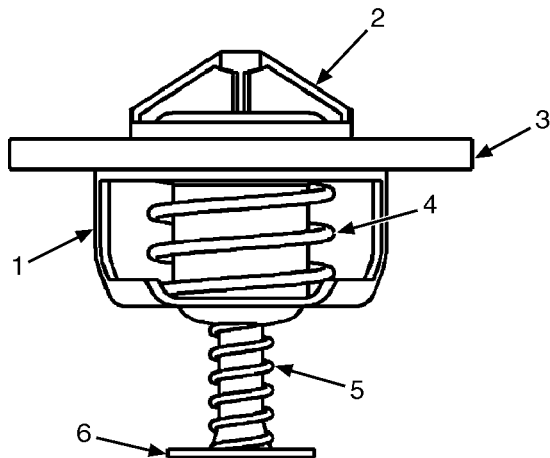
Intake Air Temperature Sensor

The Intake Air Temperature and/or Temperature Manifold Absolute Pressure (TMAP) sensor behaves in the opposite manner of a resistor. As temperature rises the resistance of the sensor goes down. So when the coolant temperature is low the feedback voltage will also be low as the sensor resistance is high. Once the coolant temperatures increase so will the resulting feedback voltage.

Engine Coolant Thermostat

The thermostat is a device that controls coolant flow by opening and closing to regulate coolant temperature. The thermostat uses a wax pellet to control its operation. The wax pellet expands when it is heated and contracts when it is cold. When heated, the wax pellet pushes on the piston, causing the valve in the thermostat to open. As the wax pellet cools, it contracts and lets a spring close the valve. When the engine is first started and the coolant is cold, the thermostat remains closed. During this time, the coolant circulates through the engine, letting it warm quickly. As the engine becomes warm, the thermostat opens, letting coolant circulate through the radiator. The opening and closing of the thermostat helps keep the coolant within the operating limits of the system. The same

thermostat is used for summer and winter seasons. Do not operate the engine without a thermostat, the engine will take longer to warm up and can run improperly.



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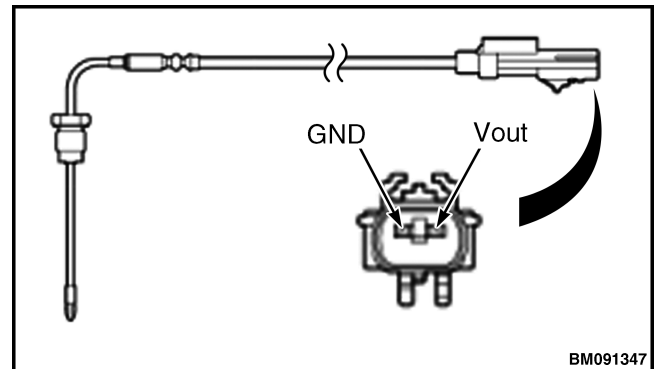
1. FRAME
2. FLANGE
3. RUBBER SEAL
4. SPRING
5. SPRING
6. SEAL

Figure 283. Typical Thermostat

DPF Inside/Inlet Temperature Sensors

The DPF exhaust gas temperature sensors behaves in the opposite manner of a resistor. As temperature rises the resistance of the sensor goes down. So when the exhaust gas temperature is low the feedback voltage will also be low as the sensor resistance is high. Once the coolant temperatures increase so will the resulting feedback voltage. The

DPF has three sensors: exhaust temperature sensor, DPF inside exhaust temperature sensor, and DPF inlet exhaust temperature sensor.



BM091347

Figure 284. DPF Temperature Sensor

DPF Differential Pressure Sensor

The DPF differential pressure sensor connects to two runs of tubing, basically one port is on the soot filter side and the other on the DOC (Diesel Oxidation Catalyst) side. To sense a pressure differential in the DPF one side of the sensor is connected to near the inlet and the other connected near the outlet of the DPF assembly. Normally the difference in pressure from the inlet to the outlet should be minimal. After a period of use the DOC and soot filter react and exhaust flow through the DPF assemble becomes restricted with catalyst material and particulate matter. The restriction will result in higher pressure at the inlet and eventually a pressure difference that will be evident in the feedback voltage from the differential pressure sensor.

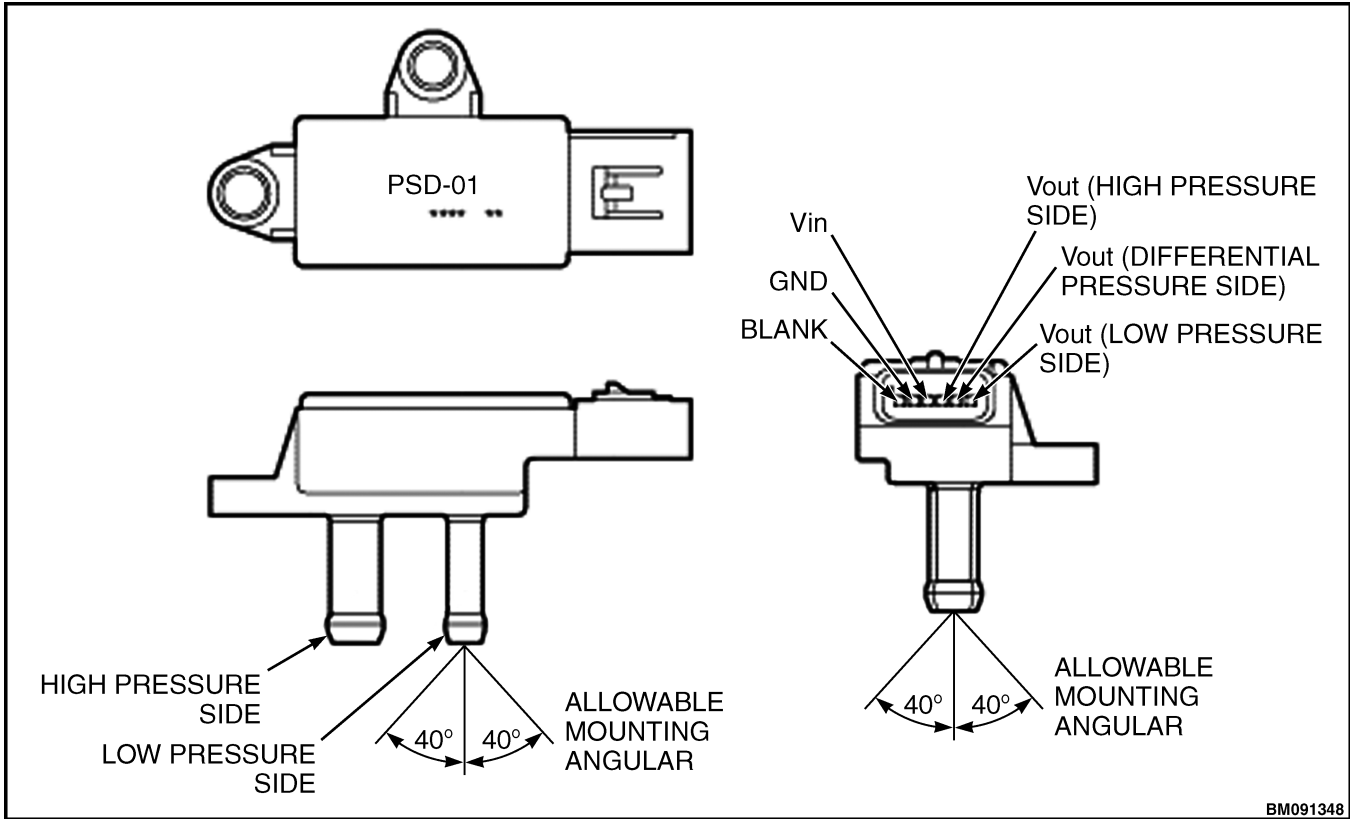


Figure 285. DPF Differential Pressure Sensor

Fuel Rail Pressure Sensor

The fuel rail pressure sensor is an electronic device that is designed to monitor the fuel pressure at the fuel rail. The sensor sends a signal to the ECU, which then uses it to make adjustments to the vehicle fuel and timing.

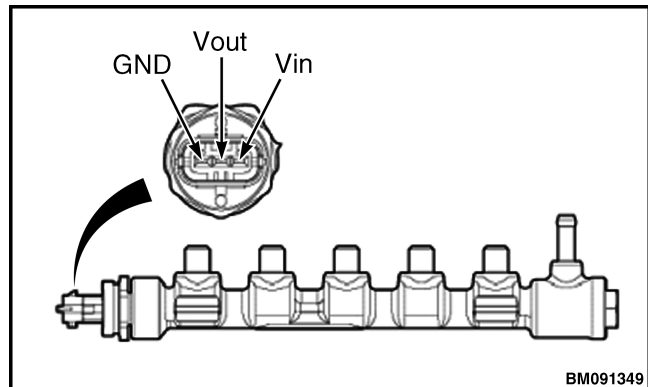


Figure 286. Fuel Rail Pressure Sensor

ENGINE ECU MANAGEMENT CONTROLS

Cold Start Assist

The glow plugs protrude into the combustion chamber of each cylinder. The glow plugs help with diesel fuel ignition by pre-heating the combustion chamber and air fuel mixture during start up. The relay is energized when engine the ECU determines the ambient temperature is low enough to reduce ignition performance.

Droop Control

This ECU function is to reduce engine speed by a certain percentage from no load to full load in steady state operation. The same percentage droop is maintained even when the load increases at any no load speed.

Isochronous Control

This ECU function is to produce constant engine speed from no load to full load. The engine speed does not decrease even when the load increases at any no load speed.

Low-Idle Speed Up

This ECU function is to raise engine idle speed when engine coolant temperature is 10° C (50° F) or less. The engine low idle speed is raised to 1000 rpm or higher to boost engine warm up and returns idle speed to normal once engine reaches normal temperatures.

Turbocharger Protection (at low temperature)

This ECU function is to limit high-idle speed during engine start up. The engine high-idle speed is limited to 1500 rpm. This function is enabled during startup when engine coolant temperature is -15° C (5° F) or less. Once engine is running this function will remain active for 10 seconds.

High-Idle Speed Reduction at Low Temperature (optional)

On an engine with a rated speed of 2300 rpm or higher, if the temperature is -30° C (-22° F) or lower, this function will lower the high-idling speed by about 150 rpm, and shorten the time for blue-white smoke to disappear. Operating the accelerator to a speed lower than the low-temperature high-idling speed limit when the engine coolant temperature 30° C (86° F) or higher will release the control.

Auto Idle Speed Reduction (optional)

This ECU function will reduce idle speed automatically when no APP input is received for a pre-determined period of time. Once the accelerator pedal is moved this function is deactivated.

DPF REGENERATION CONTROL

Self-Regeneration

This occurs naturally by design of the DOC and soot filter when the DPF is up to temperature. When up to temperature the DPF will process the exhaust gas constituents.

Assisted Regeneration

When the differential pressure sensors indicate build up in the DPF, the engine ECU will close the

EGR for maximum combustion temperature, adjust engine speed to high-idle, adjust the intake and exhaust throttle plates to heat up the DPF. All these controller actions will initiate and support DPF regeneration.

Reset Regeneration

This mode adds post-ignition fuel injection to the engine ECU actions of assisted DPF regeneration. Every 100 hours of engine operation this mode is activated. By injecting fuel post ignition the raw fuel will significantly increase the catalyst temperature to approximately 600° C (1112° F) resulting in accelerated DPF regeneration.

Manual (Stationary) Regeneration

The ECU determines that performing a stationary regeneration is required. A DPF regeneration request lamp (or icon) will illuminate to indicate a stationary regeneration is necessary. Pressing the DPF regeneration switch will initiate the regeneration process.

DIAGNOSTIC TOOL TESTS AND ADJUSTMENTS

NOTE: The service tool connects to the ECU and provides a variety of diagnostic, programming, and calibration information for electrical control devices found on this vehicle.

EGR Active Control

Using the diagnostic tool the EGR valve can be controlled. See service tool user manual for details.

Exhaust Gas Throttle Active Control

Using the diagnostic tool the exhaust throttle can be controlled. See service tool user manual for details.

Intake Air Throttle Active Control

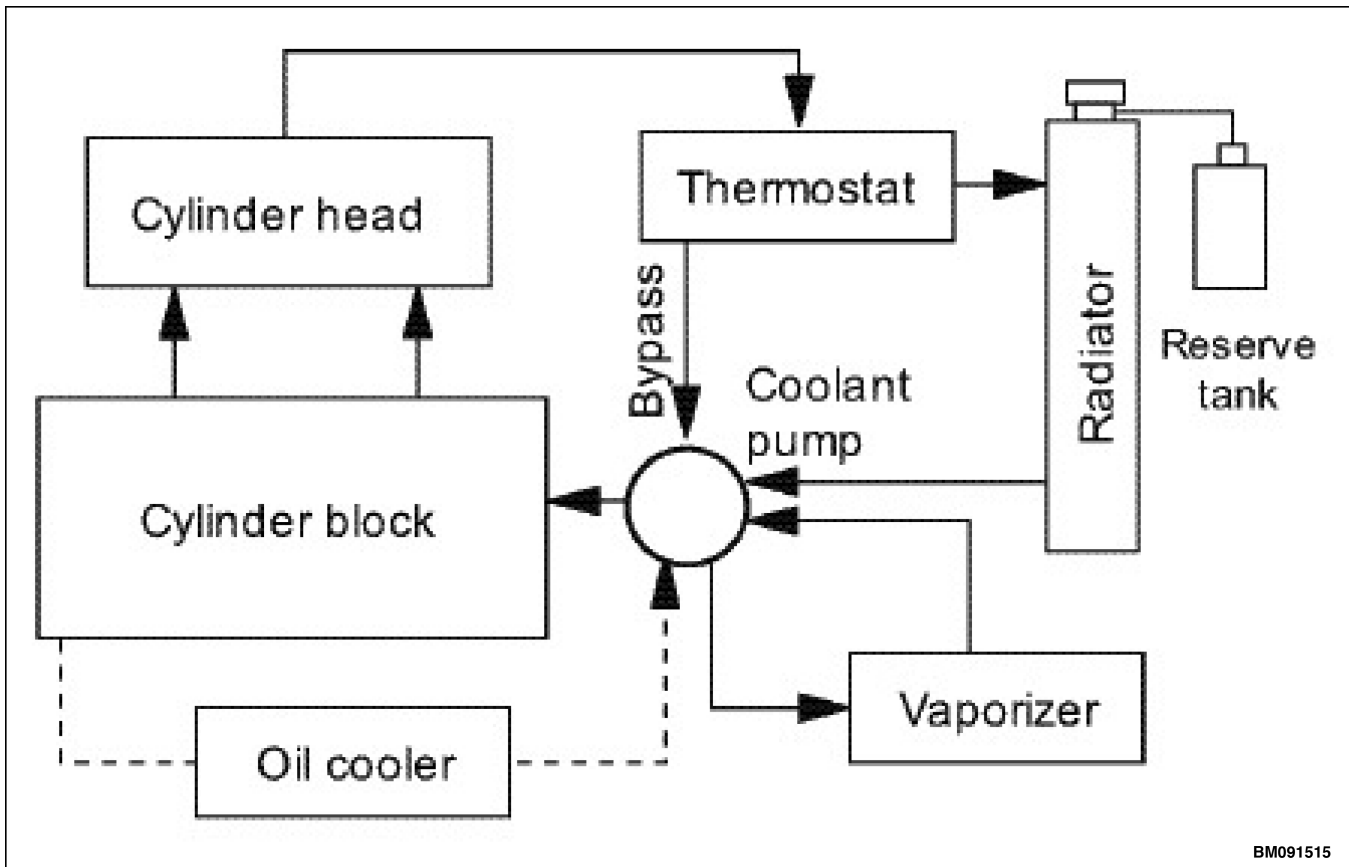
Using the diagnostic tool the intake throttle can be controlled. See service tool user manual for details.

LPG ENGINE DESCRIPTION 202001-157

ENGINE COOLANT SYSTEM

The engine coolant goes through the radiator and is fed by the engine coolant pump into the engine coolant jacket to cool the inside of the engine, the

cylinder outer walls and cylinder head. The coolant then returns to the radiator via the thermostat. When hot engine coolant comes through the radiator, the engine coolant fan circulates air through the radiator fin, then the heat is released into the air. In addition, it is required to circulate the engine coolant through the vaporizer to vaporize LPG in the fuel supply system.



BM091515

Figure 287. Engine coolant system

ENGINE OIL

The engine lubricating oil system, force-feeds engine lubricating oil to engine parts such as the crankshaft journal bearings, connecting rod crank pins, piston pin bearings, camshaft bearings, and valve train. The engine lubricating oil lubricates, cools and cleans each part. In addition, engine lubricating oil is supplied to the pistons, cylinders and gears by splash lubrication and the piston

cooling nozzles. If these functions are impaired, consumption of engine lubricating oil during operation will increase, causing damage to the engine. To maintain the performance of the lubricating system, it is necessary to use the specified engine lubricating oil, check the oil level, and change the oil and filter in accordance with the prescribed schedule.

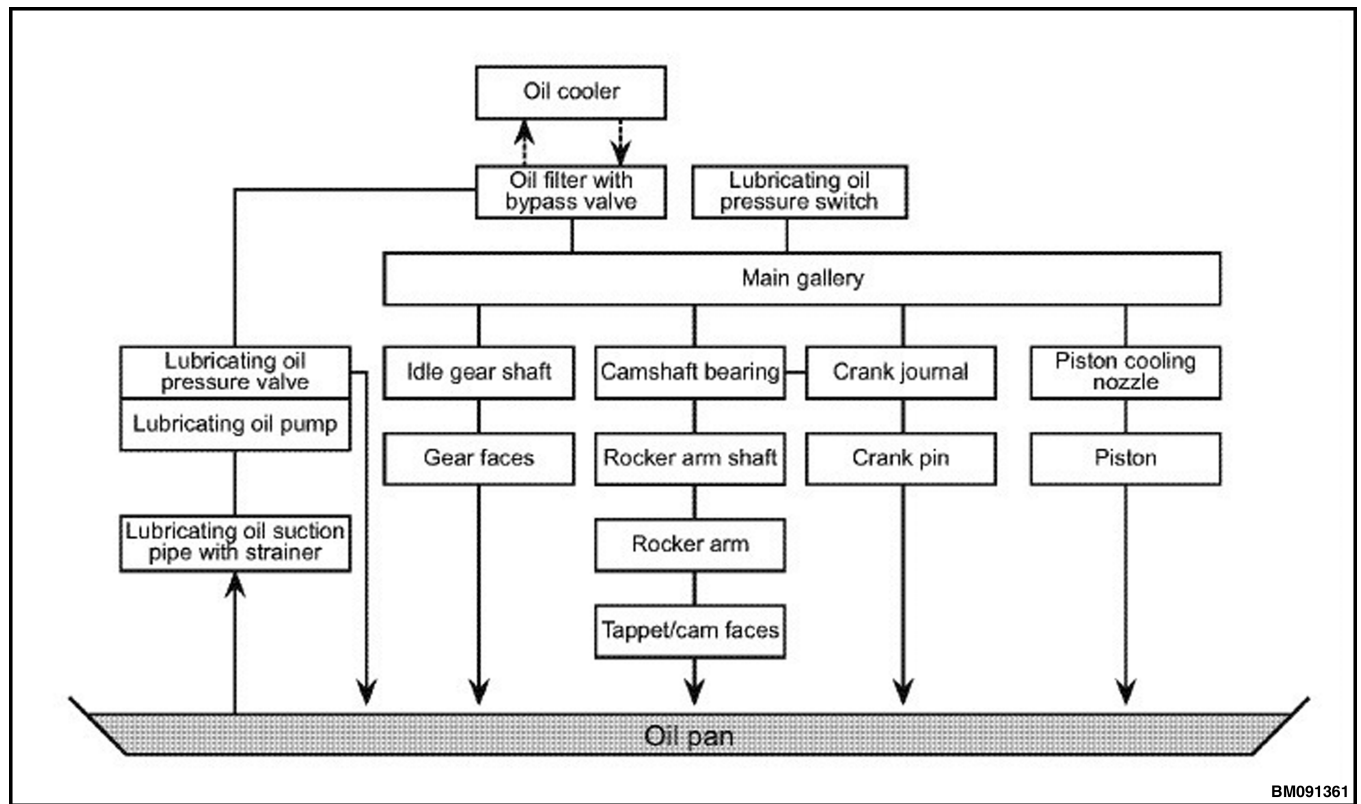


Figure 288. Engine lubrication oil system

FUEL SYSTEM

NOTE: On trucks equipped with LPG engines, an odor of sulphur may be detectable from time to time during operation with the engine running. This can be caused by variations in LPG fuel quality in your region, and is **not** an indication of malfunction of the engine. If the odor of sulphur is present when the engine is not running, **DO NOT** operate the truck and contact your service department.

The gas fuel injection system injects gas fuel immediately prior to combustion in each cylinder combustion chamber of the intake manifold. The amount of fuel being burned determines the engine output. Accurate control of the amount of fuel injected into the intake port is necessary to obtain the appropriate engine output.

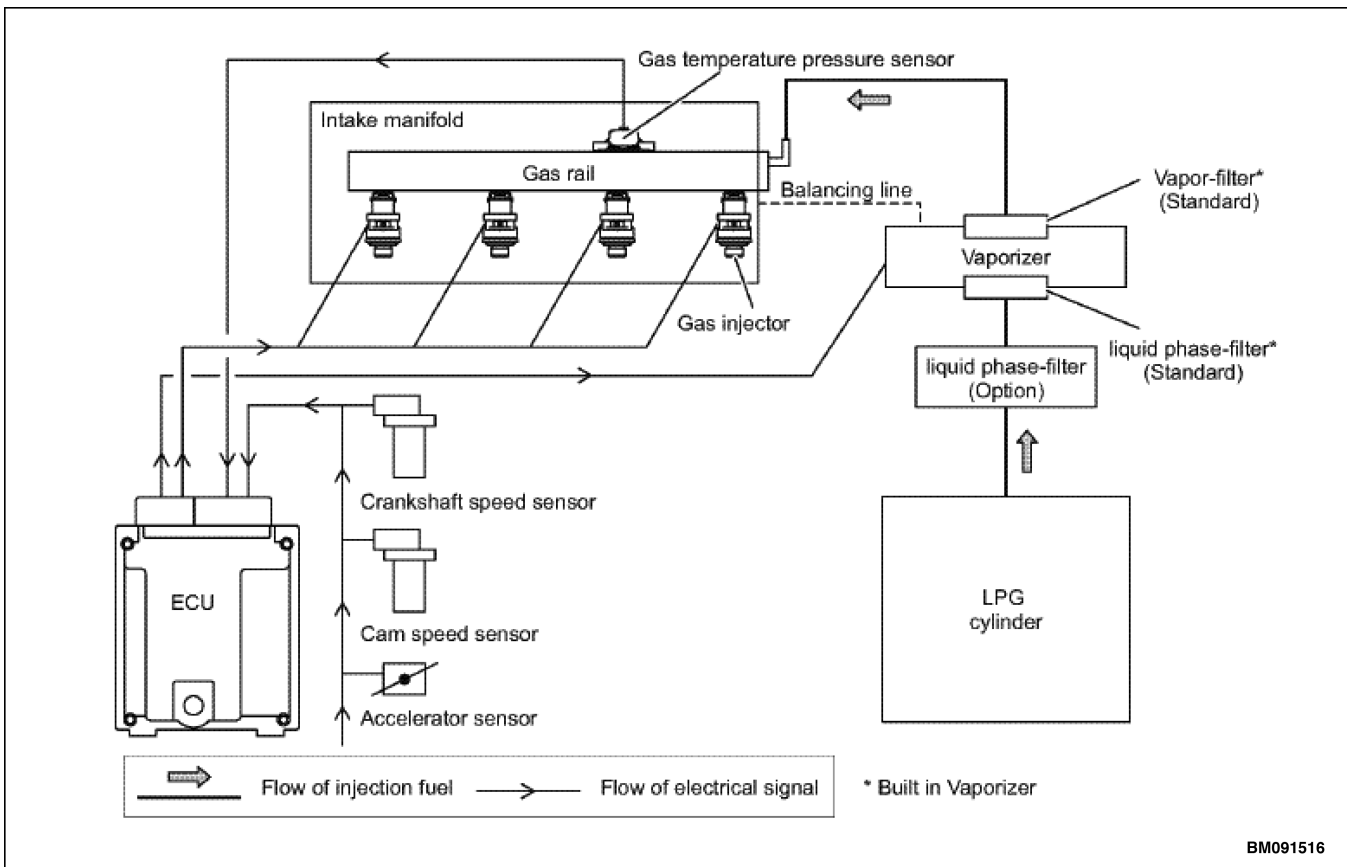
To maintain correct operation of the fuel system, it is important to note the following:

- The vaporizer and fuel hoses must be installed correctly.

- High quality fuel is used.
- All periodic maintenance is performed for the fuel filter as stated in the **Periodic Maintenance** 8000SRM2305 **Periodic Maintenance** 8000SRM2305 manual.

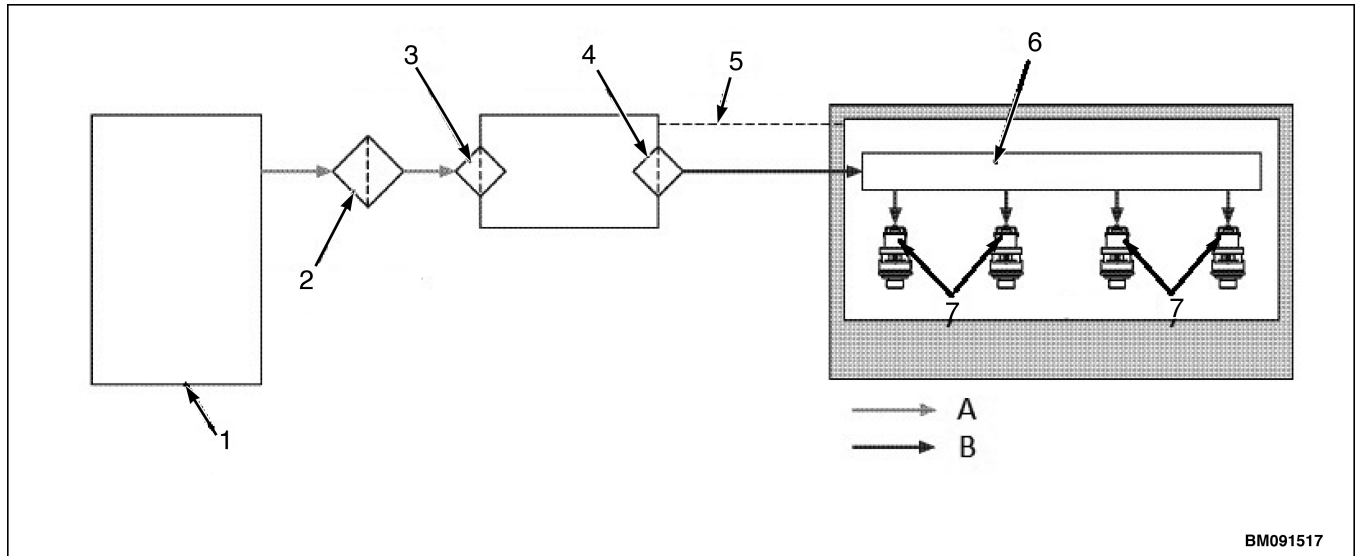
These engines features a multi-point injection system that detects the operational status (rpm, degree of accelerator opening, etc.) of the engine with various sensors. The ECU uses this information to control the intake air amount, fuel injection amount, and ignition timing to optimize engine performance.

These engines are also compatible with multiple fuel types, and achieve reliable performance, low consumption and cleaner emmissions. The ECU also performs diagnostics of the engine's major components. In the event of a malfunction, diagnostic and failsafe functions of the ECU notifies the operator and restricts engine operation to ensure safety.



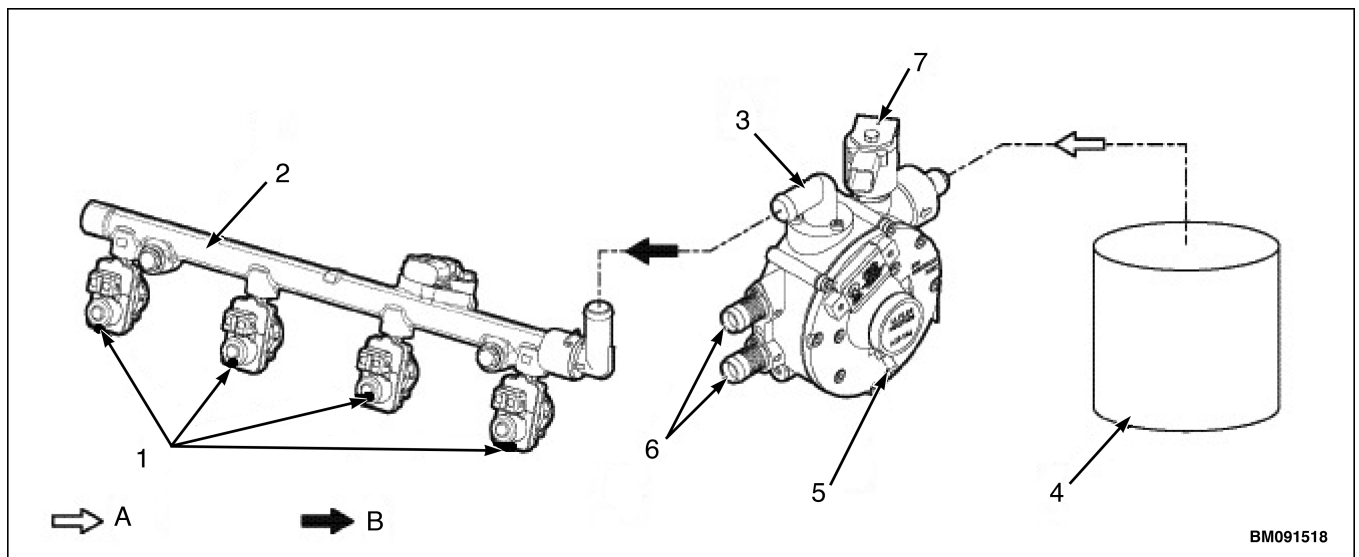
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Figure 289. Fuel system structure



- A. LIQUID FUEL PATH
- B. GAS FUEL PATH

- | | |
|-----------------------------------|-------------------|
| 1. LPG CYLINDER | 5. BALANCING LINE |
| 2. LIQUID PHASE-FILTER (OPTIONAL) | 6. GAS RAIL |
| 3. LIQUID PHASE-FILTER (STANDARD) | 7. GAS INJECTOR |
| 4. VAPOR-FILTER (STANDARD) | |



- A. LIQUID FUEL PATH
- B. GAS FUEL PATH

- | | |
|-----------------|-----------------------|
| 1. GAS INJECTOR | 5. BALANCING LINE |
| 2. GAS RAIL | 6. COOLANT FLOW PORT |
| 3. VAPORIZER | 7. FUEL SHUTOFF VALVE |
| 4. LPG CYLINDER | |

Figure 290. LPG fuel system

Vaporizer

Liquid fuel is pumped from the LPG cylinder to the vaporizer. A solenoid valve located in the vaporizer opens upon receiving a signal from the ECU, and uses engine coolant to activate the vaporization mechanism and turns the liquid into gas fuel. The gas fuel is regulated by the vaporizer and pumped to the fuel rail.

To prevent sludge accumulation, some installation conditions apply when installing the vaporizer. To prevent accumulation, the fuel-shutoff valve must be installed facing upward. Please contact YANMAR for further details.

Balancing line

To control the fuel injection amount, connect the pressure balancing port on the vaporizer to the intake manifold. With the vaporizer, regulate pressure inside the fuel rail so it is consistent with the pressure inside the intake manifold.

Fuel rail

The fuel rail is equipped with a rail pressure sensor that sends information to the ECU. In the case of an abnormal increase in the rail pressure, a diagnosis function will operate to automatically return to safe condition.

Injector

The ECU controls the injectors to maintain the optimum injection volume and injection timing, and injects the fuel accumulated in the rail into the intake port.

Crankshaft speed sensor and cam speed sensor

The crankshaft speed sensor is equipped on the flywheel side and the cam speed sensor is equipped on the gear side. Based on these sensor outputs, the ECU recognizes the engine speed and each piston position.

Gas temperature pressure sensor

A gas temperature pressure sensor is installed on the fuel rail and the ECU recognizes the temperature and pressure of the gas fuel based on this sensor output.

ECU

Based on information from sensors, the ECU determines the optimum injection volume and ignition timing, and controls the injectors and ignition coils. It also monitors the occurrence of system abnormality at all times. If an abnormality is detected, it notifies the operator and controls the running condition of the system.

Engine trouble caused by improper fuel

Quality and composition of fuel is very important. Poor fuel reduces engine performance and durability. Always use the fuel specified in LPG engine specifications.

- **Clogging or corrosion of the injection port of the fuel gas injector**

Contaminations or impurities in the fuel gas will clog the injection holes of the injectors, reducing the amount of gas that can be injected. This will cause improper air-fuel ratio.

- **Occurrence of knocking**

By using fuel with a low methane number, knocking occurs in the normal range of operation, which may cause damage to the pistons and cylinder liners.

- **Three-way catalyst deterioration**

If using a fuel which has a high sulfur content, the three-way catalyst will deteriorate due to sulfur poisoning, causing a reduction in the purification performance of the three-way catalyst. Silicon oil deteriorates the three-way catalyst, and reduces the purification performance. Therefore, do not use silicon oil for installing the fuel pipes.

Fuel properties and engine performance

Fuel properties related to engine performance are as follows:

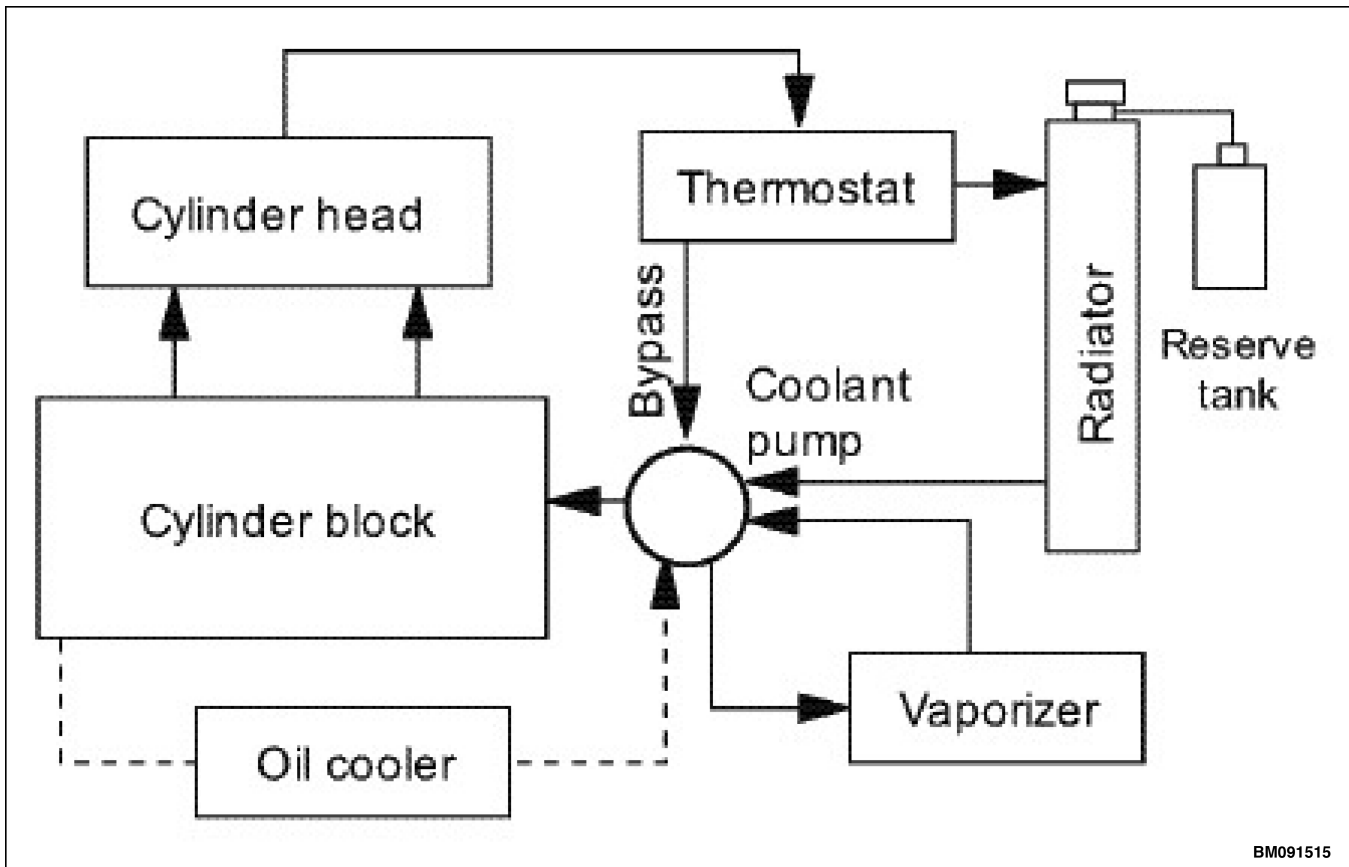
Fuel gas property	Starting performance	Durability	Output	Knocking occurrence
Heavy hydrocarbon content	The higher the content, the worse the starting performance	No direct relation	The higher the content, the better the output	The higher the content, the easier it is for knocking to occur
Sulfur	No relation	This can relate to catalyst deterioration	No relation	No relation

BI-FUEL ENGINE DESCRIPTION 202001-158

ENGINE COOLANT SYSTEM

The engine coolant goes through the radiator and is fed by the engine coolant pump into the engine coolant jacket to cool the inside of the engine, the

cylinder outer walls and cylinder heard. The coolant then returns to the radiator via the thermostat. When hot engine coolant comes through the radiator, the engine coolant fan circulates air through the radiator fin, then the heat is released into the air. In addition, it is required to circulate the engine coolant through the vaporizer to vaporize LPG in the fuel supply system.



BM091515

Figure 291. Engine coolant system

ENGINE OIL

The engine lubricating oil system, force-feeds engine lubricating oil to engine parts such as the crankshaft journal bearings, connecting rod crank pins, piston pin bearings, camshaft bearings, and valve train. The engine lubricating oil lubricates, cools, and cleans each part. In addition, the engine lubricating oil is supplied to the pistons, cylinders, and gears by splash lubrication and the piston

cooling nozzles. If these functions are impaired, consumption of engine lubricating oil during operating will increase, causing damage to the engine. To maintain the performance of the lubricating system, it is necessary to use the specified engine lubricating oil, check the oil level, and change the oil and filter in accordance with the prescribed schedule.

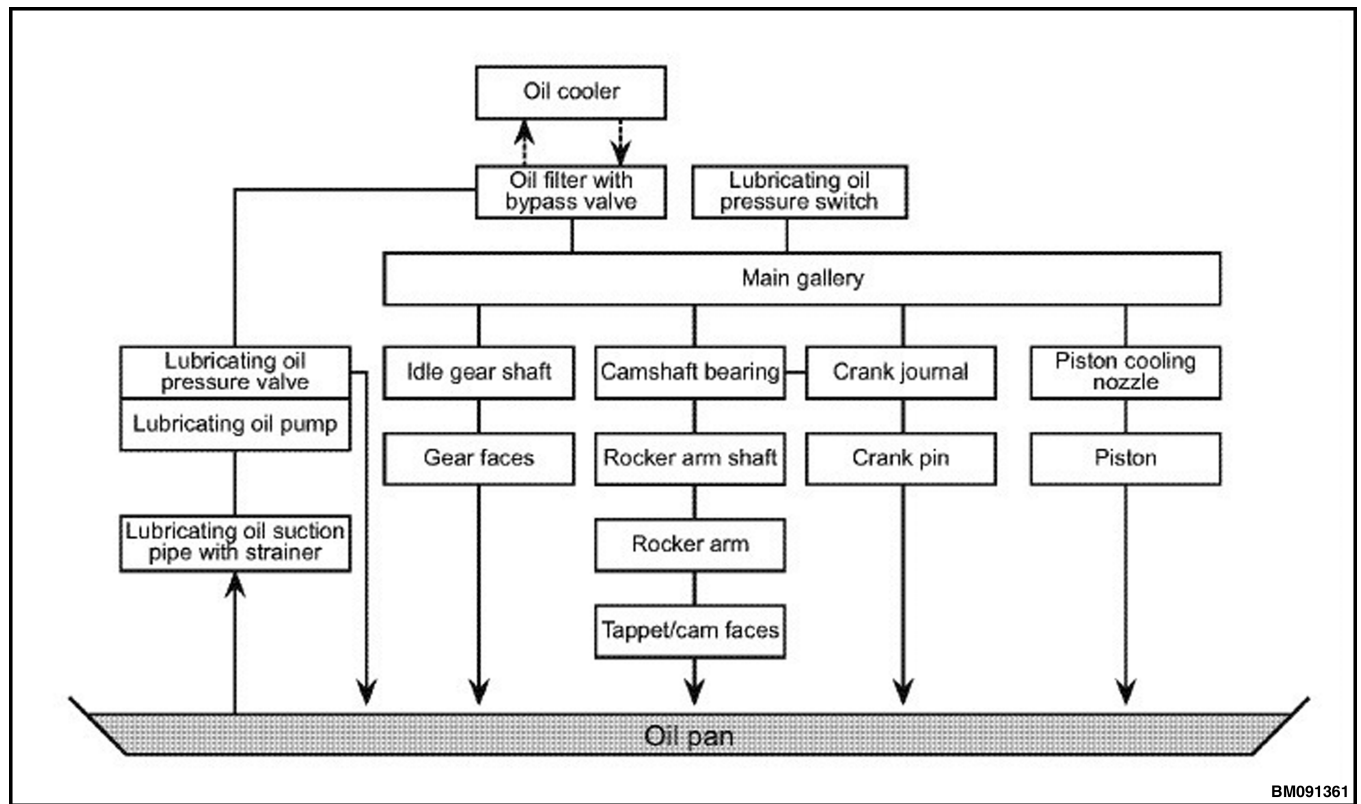


Figure 292. Engine lubrication oil system

LPG FUEL SYSTEM

NOTE: On trucks equipped with LPG engines, an odor of sulphur may be detectable from time to time during operation of the engine. This can be caused by variations in LPG fuel quality in your region, and is **not** an indication of malfunction of the engine. If the odor of sulphur is present then the engine is not running, **DO NOT** operate the truck and contact your service department.

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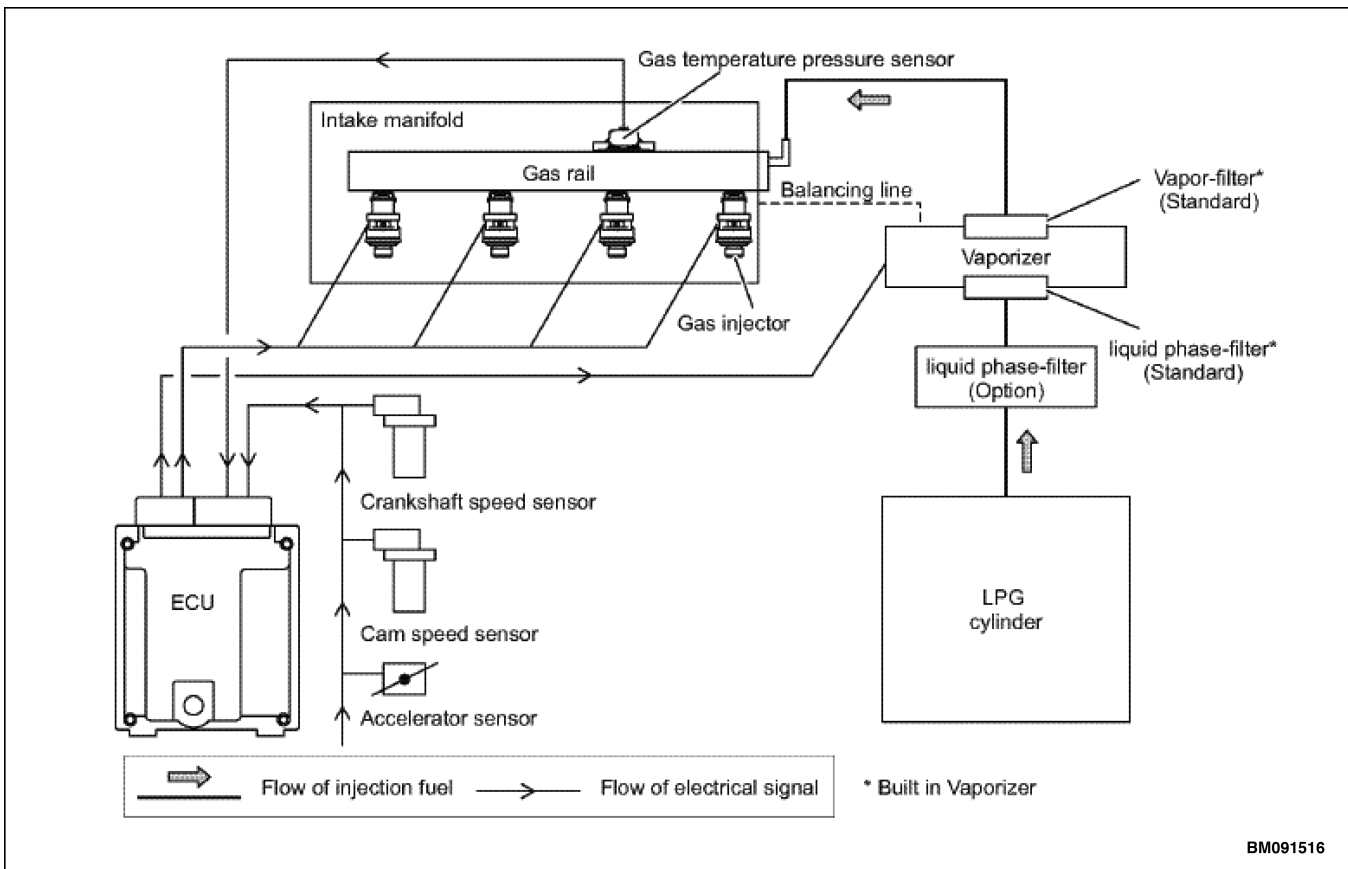
To maintain correct operation of the fuel system, it is important to note the following:

- The vaporizer and fuel hoses must be installed correctly.

- High quality fuel is used.
- All periodic maintenance is performed for the fuel filter as stated in the **Periodic Maintenance 8000SRM2305**.

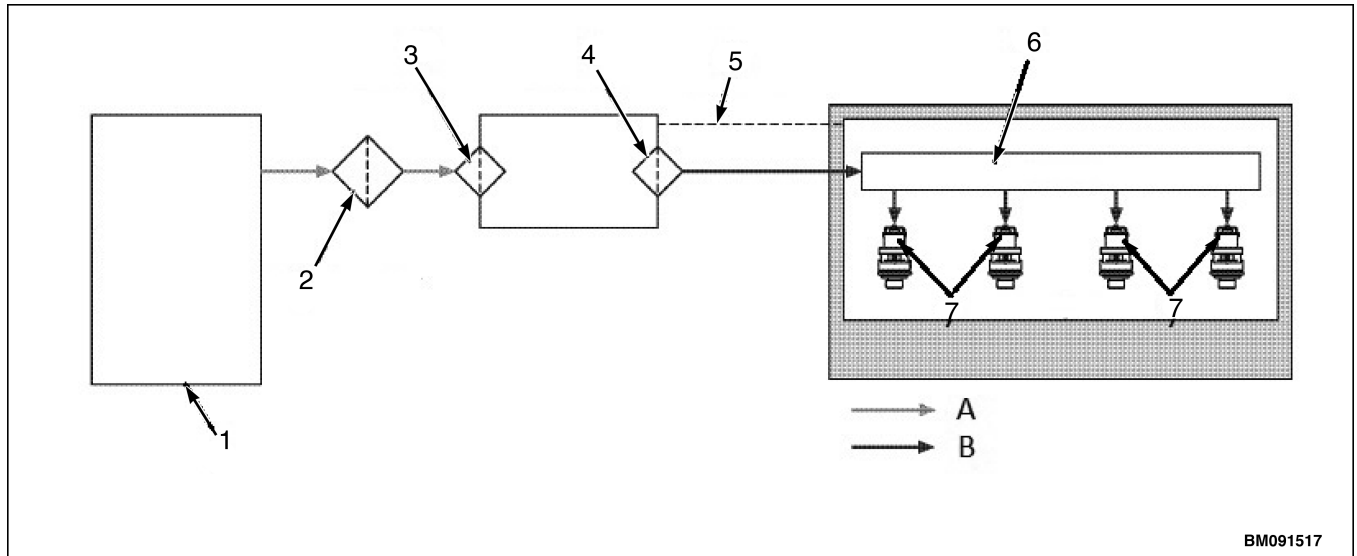
These engine feature a multi-point injection system that detects the operation status (rpm, degree of accelerator opening, etc.) of the engine with various sensors. The ECU uses this information to control the intake air amount, fuel injection amount, and ignition timing to optimize engine performance.

These engines are also compatible with multiple fuel types, and achieve reliable performance, low consumption, and cleaner emissions. The ECU also performs diagnostics fo the engine's major components. In the even of a malfunction, diagnostic and failsafe functions of the ECU notifies the operator and restricts engine operation to ensure safety.



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Figure 293. Fuel system structure



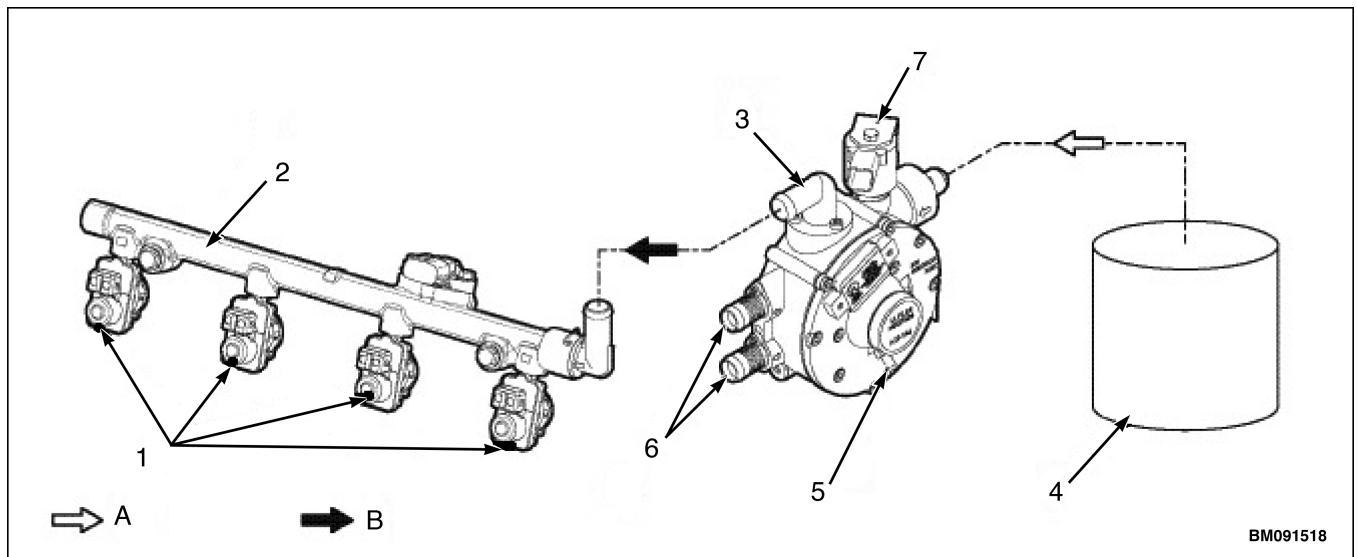
A. LIQUID FUEL PATH

B. GAS FUEL PATH

- 1. LPG CYLINDER
- 2. LIQUID PHASE-FILTER (OPTIONAL)
- 3. LIQUID PHASE-FILTER (STANDARD)
- 4. VAPOR-FILTER (STANDARD)

- 5. BALANCING LINE
- 6. GAS RAIL
- 7. GAS INJECTOR

Figure 294. Fuel system (Sheet 1 of 2)



A. LIQUID FUEL PATH

B. GAS FUEL PATH

- 1. GAS CYLINDER
- 2. GAS RAIL
- 3. VAPORIZER
- 4. LPG CYLINDER

- 5. BALANCING LINE
- 6. COOLANT FLOW PORT
- 7. FUEL SHUTOFF VALVE

Figure 294. Fuel system (Sheet 2 of 2)

Vaporizer

Liquid fuel is pumped from the LPG cylinder to the vaporizer. A solenoid valve located in the vaporizer opens upon receiving a signal from the ECU, and using engine coolant activates the vaporization mechanism and turns the liquid into gas fuel. The gas fuel is regulated by the vaporizer and pumped to the fuel rail.

To prevent sludge accumulation, some installation conditions apply when installing the vaporizer. To prevent accumulation, the fuel-shutoff valve must be installed facing upward. Please contact YANMAR for further details.

Balancing line

To control the fuel injection amount, connect the pressure balancing port on the vaporizer to the intake manifold. With the vaporizer, regulate pressure inside the fuel rail so it is consistent with the pressure inside the intake manifold.

Fuel Rail

The fuel rail is equipped with a rail pressure sensor that sends information to the ECU. In the case of an abnormal increase in the rail pressure, a diagnosis function will operator to automatically return to safe conditions.

Injector

The ECU controls the injectors to maintain the optimum injection volume and injection timing, and injects the fuel accumulated in the rail into the intake port.

Crankshaft speed sensor and cam speed sensor

The crankshaft speed sensor is equipped on the flywheel side and the cam speed sensor is equipped on the gear side. Based on these sensor outputs, the ECU recognizes the engine speed and each piston position.

Gas temperature pressure sensor

A gas temperature pressure sensor is installed on the fuel rail and the ECU recognizes the temperature and pressure of the gas fuel based on this sensor output.

ECU

Based on information from sensors, the ECU determines the optimum injection volume and ignition timing, and controls the injectors and ignition coils. It also monitors the occurrence of system abnormality at all times. If an abnormality is detected, it notifies the operator and controls the running condition of the system.

Engine trouble caused by improper fuel

Quality and composition of fuel is very important. Poor fuel reduces engine performance and durability. Always use the fuels specified in Bi-Fuel engine specifications.

- **Clogging or corrosion of the injection port of the fuel gas injector**
Contamination or impurities in the fuel gas will clog the injection holes of the injectors, reducing the amount of gas that can be injected. This will cause improper air-fuel ratio.
- **Occurrence of knocking**
By using fuel with a low methane number, knocking occurs in the normal range of operation, which may cause damage to the pistons and cylinder liners
- **Three-way catalyst deterioration**
If using a fuel which has a high sulfur content, the three-way catalyst will deteriorate due to sulfur poisoning, causing a reduction in the purification performance of the three-way catalyst, and reduces the purification performance. Therefore, do not use silicon oil for installing the fuel pipes.

Fuel properties and engine performance

Fuel properties related to engine performance are as follows:

Fuel gas property	Starting performance	Durability	Output	Knocking occurrence
Heavy hydrocarbon content	The higher the content, the worse the starting performance	No direct relation	The higher the content, the better the output	The higher the content, the easier it is for knocking to occur
Sulfur	No relation	This can relate to catalyst deterioration	No relation	No relation

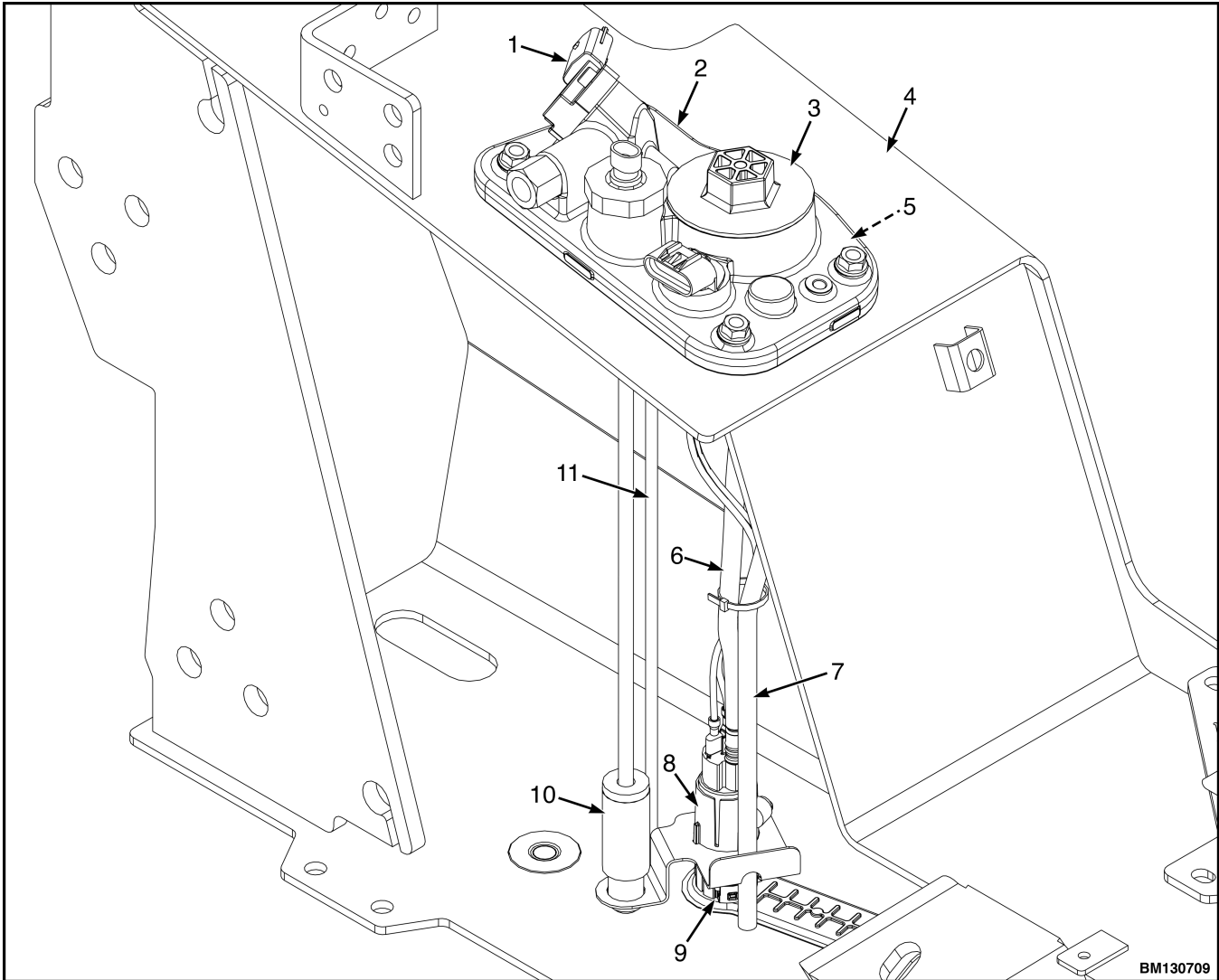
GASOLINE FUEL SYSTEM

Gasoline Fuel Tank Sending Unit

The gasoline fuel tank sending unit is an assembly of a few important components. A debris strainer is attached to the pump inlet at the end of the pickup tube. The fuel pump lifts and produces fuel system pressure to the fuel rail. A fuel level sender is another component of the assembly. At the top of

the unit is a serviceable fuel filter in line with fuel output.

The sending unit manifold of the fuel sending unit is the mounting plate for the sending unit assembly. Also, the manifold as you would expect includes the outlet to the fuel system, return inlet, a reservoir for the fuel filter, and mounting for the fuel level sensor. See Figure 295.



- | | |
|-------------------------|---------------------|
| 1. SENSOR | 7. SUPPORT ROD |
| 2. MANIFOLD | 8. FUEL PUMP |
| 3. GASOLINE FUEL FILTER | 9. FUEL STRAINER |
| 4. LH FRAME - FUEL TANK | 10. FUEL SENDER |
| 5. GASKET | 11. RCV RETURN LINE |
| 6. GASOLINE TUBE | |

Figure 295. Gasoline Fuel System

Gasoline Fuel Pump

The fuel pump lifts and produces fuel system pressure to the fuel rail. For gasoline fuel systems the in-tank pump is the only fuel pump required to produce enough pressure for distribution to the fuel rail. See Figure 295.

Gasoline Fuel Level Sensor

The fuel level sensor for the sending unit is part of the fuel sending unit assembly. The sensor is mounted on the top plate next to the filter cap. See Figure 295.

Gasoline Fuel Filter

The gasoline fuel filter is a serviceable component. The filter element can be accessed by removing the cap on the top plate of the fuel sending unit. See Figure 295.

CNG ENGINE DESCRIPTION 202001-207

This content is under development and will be released when available.

POWERSHIFT TRANSMISSION DESCRIPTION 202001-159

POWERSHIFT TRANSMISSION Mechanical Overview

The powershift transmission is one component of the drive train system. The drive train components make up a mechanical system that transfers power from the engine to the ground. The drive train system consists of the following components:

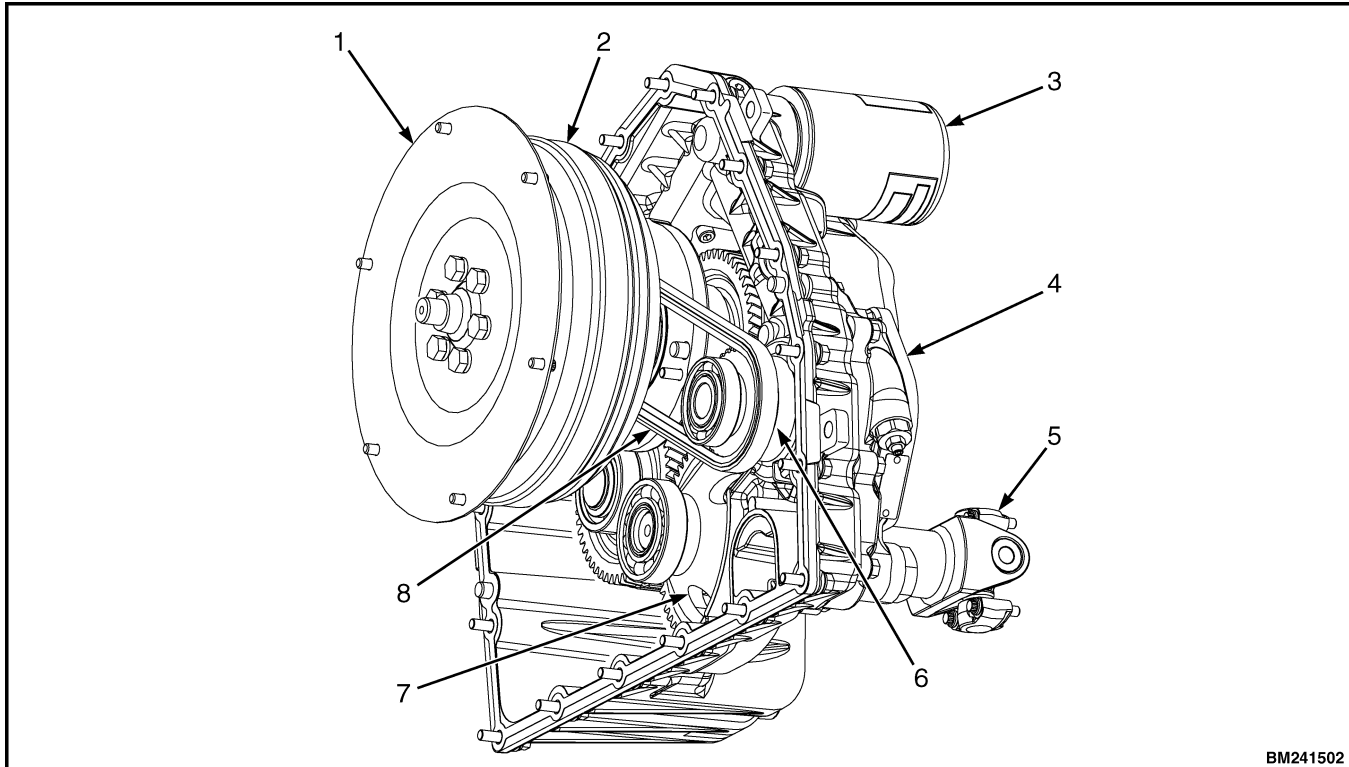
- a. Engine
- b. Torque converter
- c. Transmission
- d. Clutch assemblies
- e. Output gear and yoke
- f. Driveshaft, differential, drive axle
- g. Brakes

Engine

For engine details refer to Diesel engine description, LPG engine description, or Bi-fuel engine description.

Torque Converter

The torque converter is a fluid coupling that transfers power from the engine to the transmission smoothly and isolates engine torsional fluctuations to the transmission. It also reduces the torque transferred at low engine and vehicle speeds and is used with the transmission to supply power to hydraulic functions. There is no direct mechanical connection between the engine and the transmission. The torque converter has an impeller, a turbine, and a stator with a stator clutch. The impeller is fastened to the flywheel (flexplate) and has a set of curved blades. The turbine also has blades, and is connected to the input shaft (forward clutch housing) of the transmission by splines. The stator is between the turbine and the impeller. The stator clutch is a single-direction clutch that permits the stator to turn freely in the direction of engine rotation, but locks to prevent rotation in the opposite direction of engine rotation. When the turbine is rotating at the same speed as the impeller, the stator clutch permits the stator to rotate as a unit with the impeller and turbine.



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- | | |
|---------------------|--------------------------------|
| 1. FLEXPLATE | 5. DRIVESHAFT |
| 2. TORQUE CONVERTER | 6. CHARGE PUMP DRIVEN SPROCKET |
| 3. OIL FILTER | 7. TRANSMISSION OUTPUT GEAR |
| 4. TRANSMISSION | 8. PUMP DRIVE CHAIN |

Figure 296. Torque Converter

The torque converter has two main functions. It operates as a fluid clutch to smoothly transfer power from the engine to the transmission. The torque converter will also multiply the torque from the engine. When the engine works against a load, the torque converter can multiply the torque from the engine to the transmission. The maximum torque multiplication is available just before the torque converter stalls. If the need for torque multiplication is not required, the torque converter operates as a fluid coupling.

The impeller has a set of curved blades that accelerate the oil from the center of the impeller when the impeller turns. The volume of the impeller decreases toward the outer circumference. This decreasing volume increases the speed and energy of the oil as it leaves the impeller and flows into the outer circumference of the turbine. The force from the high-speed oil hitting the blades in the turbine transfers most of the energy to the turbine and causes it to move in the direction of engine rotation. The oil then flows from the outer circumference

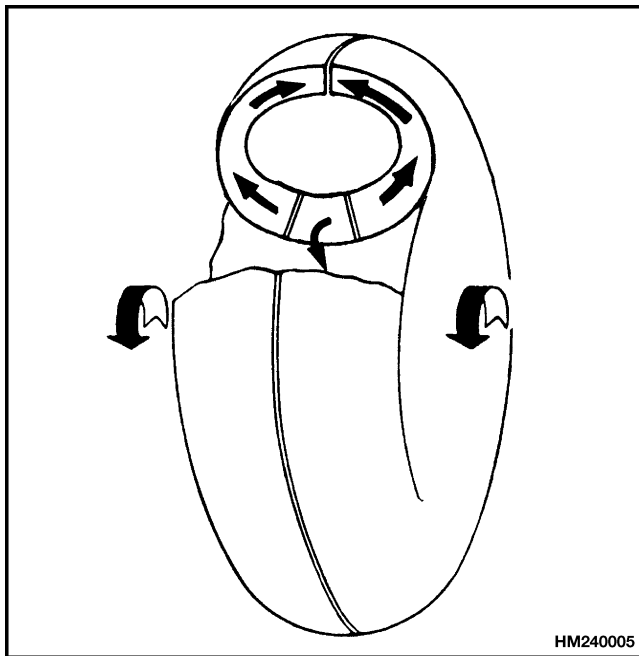
toward the center of the turbine. The turbine blades change the direction of the oil flow so that the oil leaving the center of the turbine is going in the direction opposite of engine rotation. This oil now has a lower velocity because it has given most of its energy to rotate the turbine.

Stator

The stator is between the turbine and impeller in the center of the torque converter. When the oil hits the stator blades, the stator clutch prevents the stator from turning in the direction opposite of engine rotation. The blades of the stator change the direction of the oil so that the oil enters the impeller in the direction of engine rotation. The energy that remains in the oil flow as it leaves the stator is added to the new energy being added to the impeller by the engine. This use of energy, controlled by the stator, permits the torque converter to multiply the torque of the engine.

Turbine

Resistance to the flow of oil in the turbine, because of centrifugal force, increases as the speed of the turbine increases. This resistance decreases the energy and amount of oil flow to the impeller from the stator. When the flow to the impeller decreases, the additional force added to the impeller decreases. Less torque is generated when less torque is needed. When the lift truck is traveling at a constant speed on level ground, the turbine and impeller rotate at approximately the same speed.

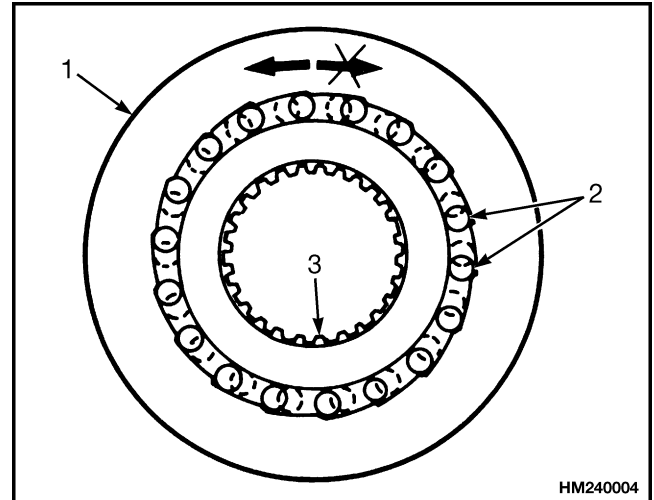


NOTE: LIFT TRUCK TURBINE AT CONSTANT SPEED, NO TORQUE MULTIPLICATION IN EFFECT.

Figure 297. Turbine

The centrifugal force of the oil is the same for both the impeller and turbine. The oil does not flow

through the stator, and torque is not multiplied. The rotating oil hits the back of the stator blades and turns the stator in the direction of engine rotation. The stator clutch permits the stator to turn with engine rotation. The impeller, turbine, stator, and oil rotate as a unit when torque multiplication is not required.



- 1. OUTER RACE
- 2. SPRAG
- 3. SPLINES ON INNER RACE

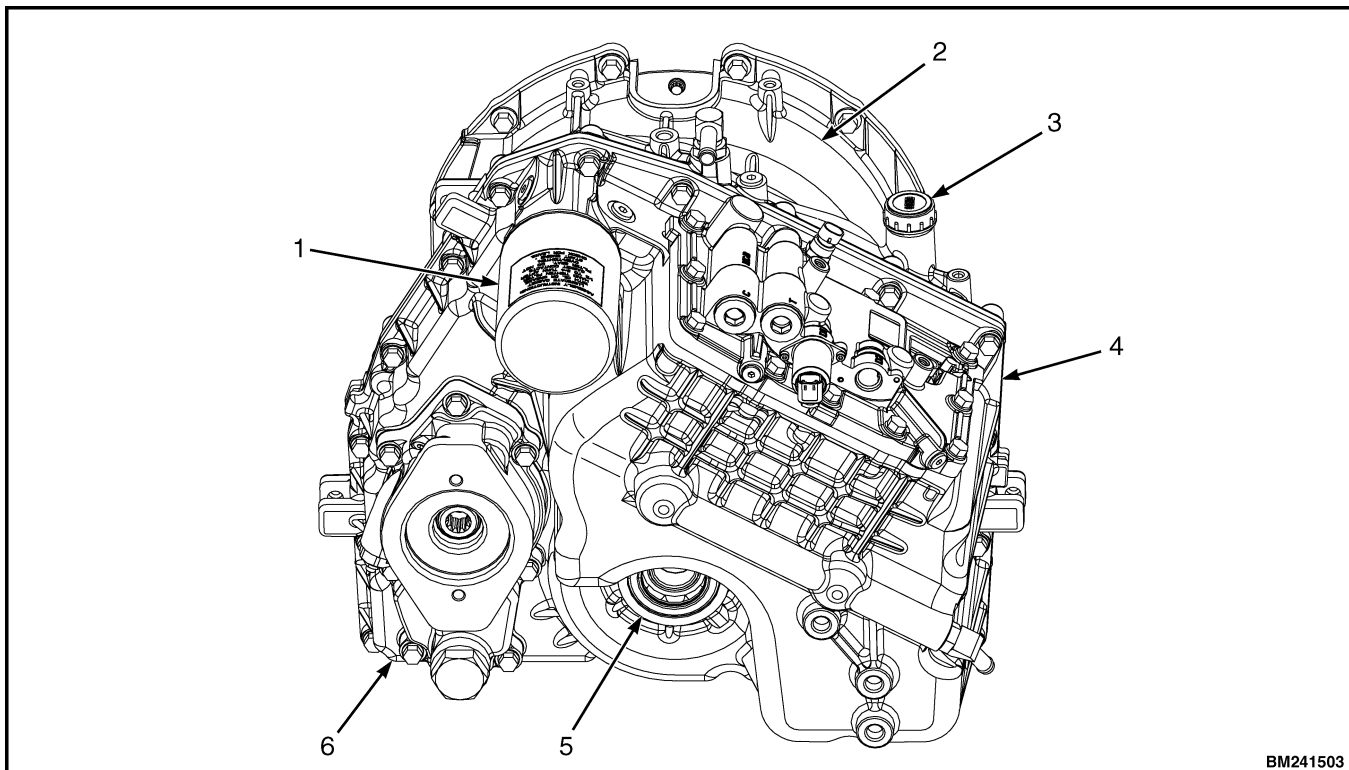
Figure 298. Stator Clutch

When the lift truck begins to travel up a ramp, the resistance to turning the turbine increases. The centrifugal force of the oil in the turbine decreases. When the speed of the turbine is less than the speed of the impeller, the stator locks in place. Torque is multiplied only when the stator is held by the stator clutch. The oil flows from the impeller, through the turbine and stator, and enters the impeller to multiply the torque. The torque converter again increases the torque when more torque is needed.

Powershift 1-speed and DuraMatch transmissions

The transmission is mounted directly to the engine block. Engine power is transmitted through a torque converter to the hydraulic clutch packs. Both the Powershift 1-speed and the DuraMatch transmissions, are controlled by the Vehicle System Manager (VSM). The VSM receives input from the operator through the use of the accelerator pedal, directional command, and brakes. Based on these inputs, the VSM sends signals to the transmission's

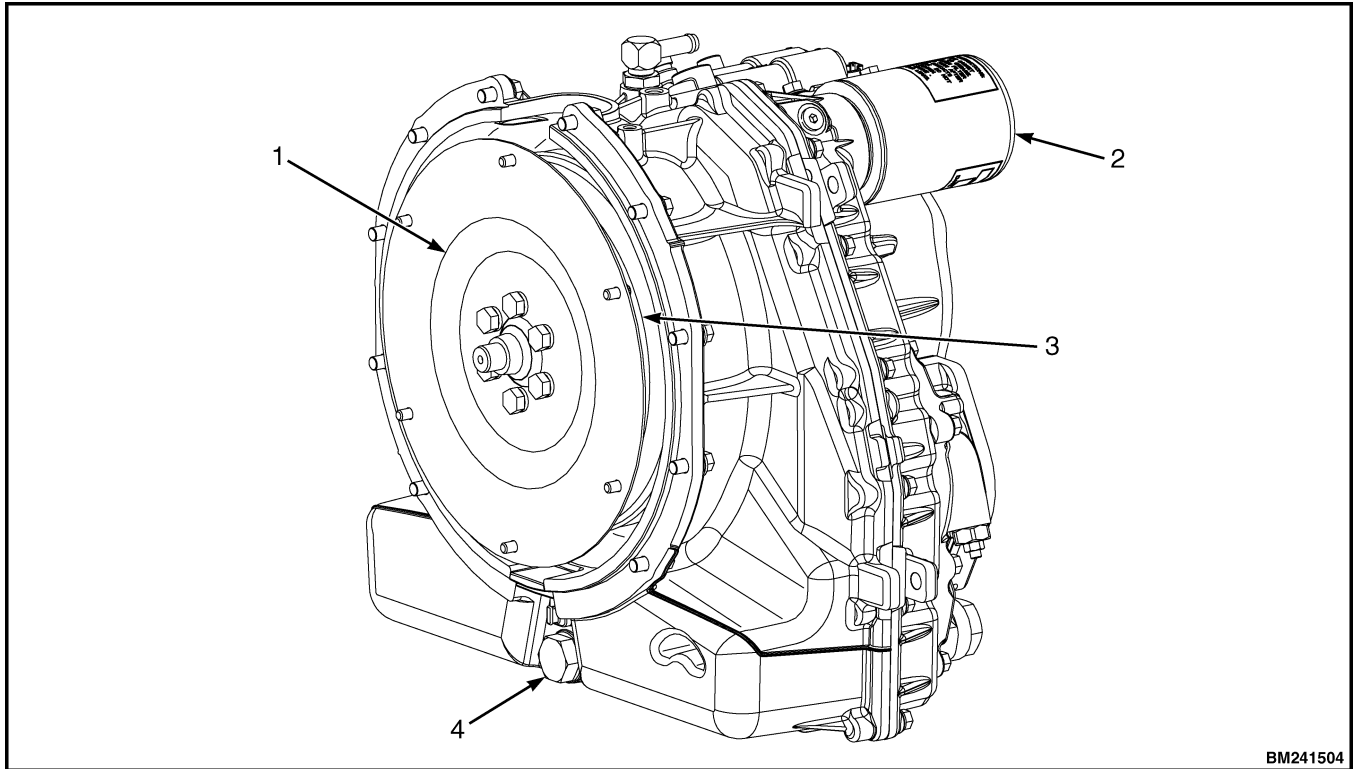
proportional solenoid valves to pressurize the clutch packs, providing travel or transmission braking as required. The DuraMatch transmission adds additional sensors (pressure and speed) and an additional proportional solenoid valve to allow for increased control of the transmission. The VSM software is factory installed with the appropriate settings for each transmission type. For more information of different options featured on Powershift 1-Speed and DuraMatch transmissions, see the **Operator Manual** for your lift truck.



NOTE: POWERSHIFT 1 TRANSMISSION OPTION IS SHOWN. DURAMATCH TRANSMISSION OPTION WILL BE SIMILAR.

- | | |
|---------------------------------|--|
| 1. TRANSMISSION FILTER | 4. BASIC CONTROL VALVE |
| 2. TORQUE CONVERTER AND HOUSING | 5. TRANSMISSION OUTPUT |
| 3. OIL FILL AND DIPSTICK | 6. CHARGE PUMP AND HYDRAULIC PUMP FLANGE |

Figure 299. Transmission Overview



BM241504

- 1. FLEXPLATE
- 2. OIL FILTER

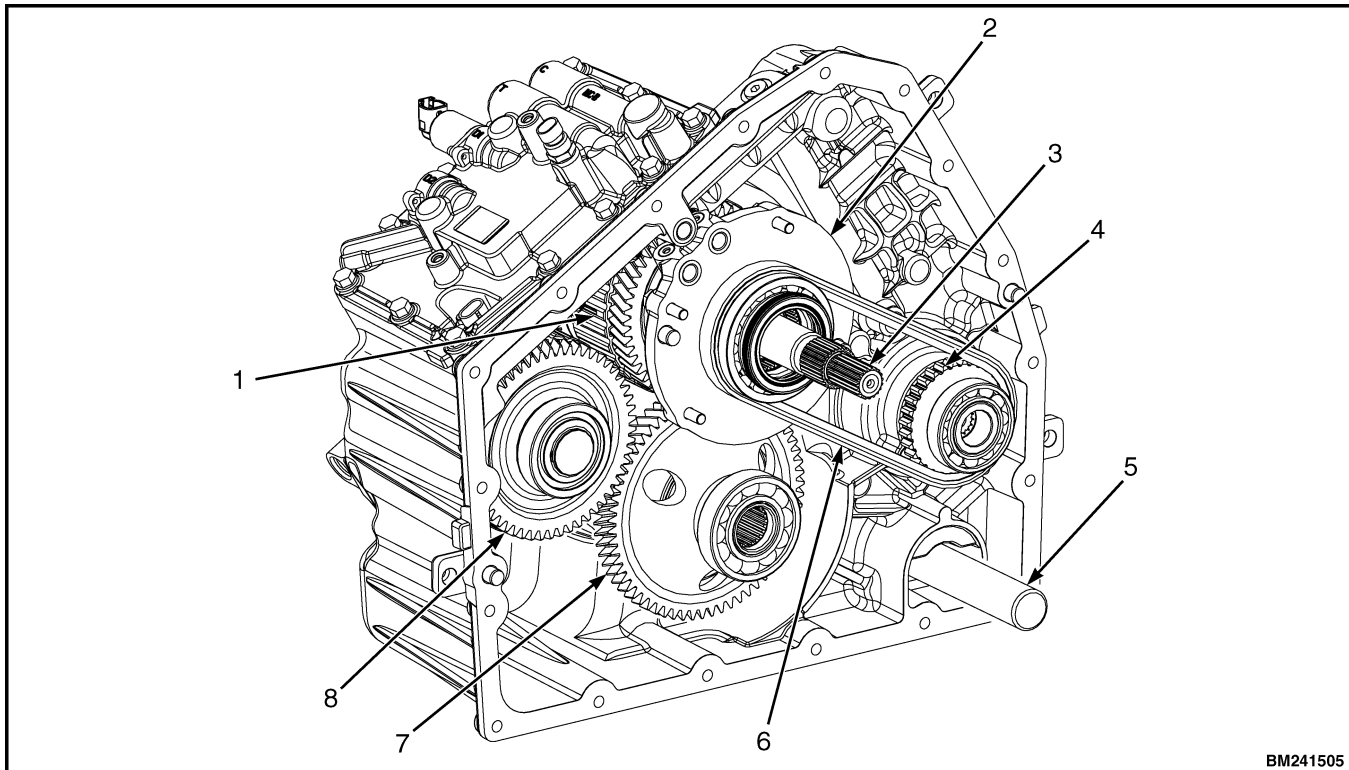
- 3. TORQUE CONVERTER
- 4. MAGNETIC DRAIN PLUG

Figure 300. Transmission Overview, View 2

Single-Speed

The single-speed transmission is a constant mesh counter shaft transmission that has one forward and one reverse speed. The transmission has two clutches, an Input (Forward 1) and Counter (Reverse 1) clutch, which are applied hydraulically and released by spring force. The transmission

valve controls clutch pack engagement using independent electronic proportional valves. The Vehicle System Manager (VSM) controls the clutch pack proportional valves according to installed software programming. This system permits control of clutch pack engagement, with the ability to apply the clutch packs in any required combination.



BM241505

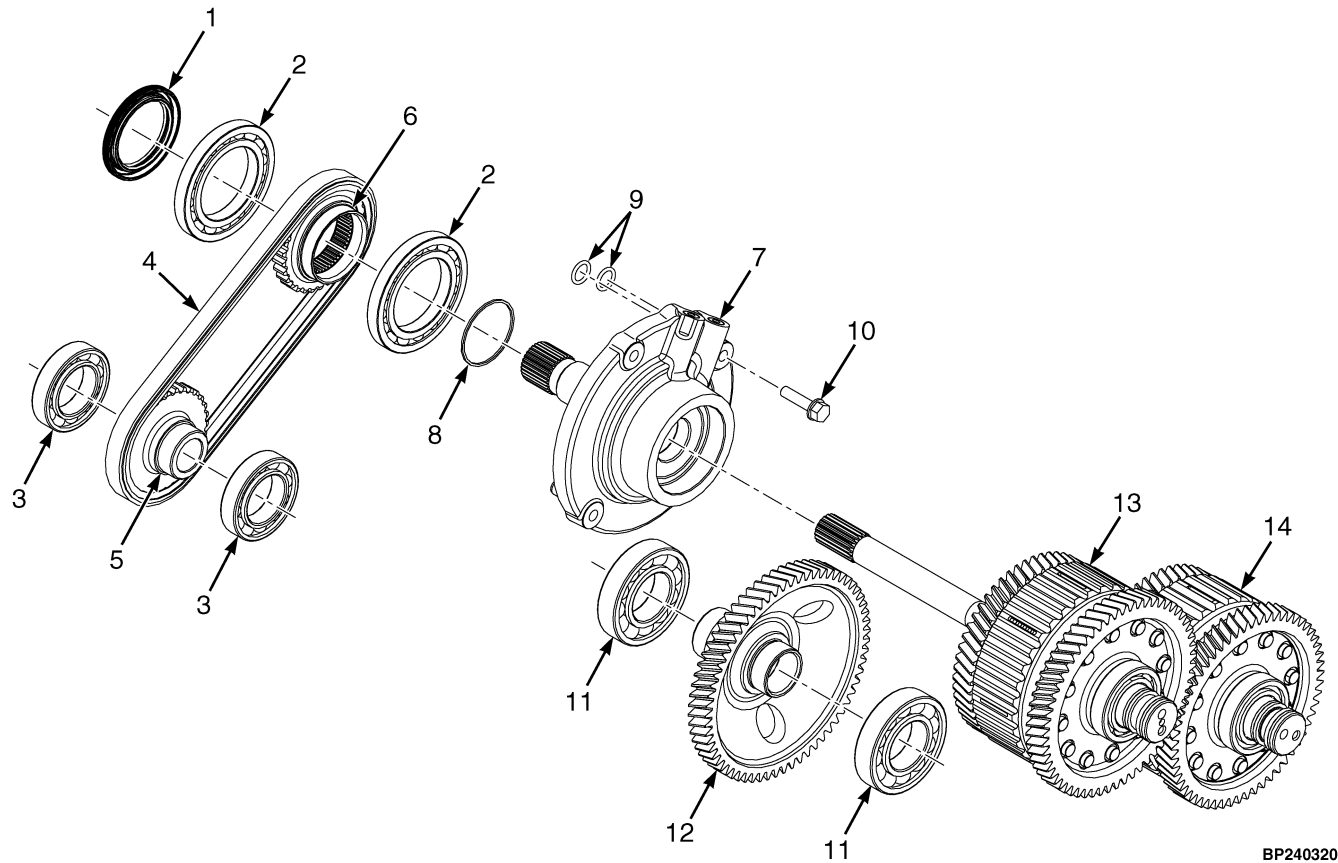
- | | |
|----------------------------|-----------------------------|
| 1. FORWARD CLUTCH PACK | 5. SUCTION SCREEN |
| 2. STATOR SUPPORT ASSEMBLY | 6. PUMP DRIVE CHAIN |
| 3. INPUT SHAFT | 7. TRANSMISSION OUTPUT GEAR |
| 4. CHARGE PUMP SPROCKET | 8. REVERSE CLUTCH PACK |

Figure 301. Transmission (Torque Converter Housing Removed)

Clutch Packs

Single-speed and two-speed transmissions use similar clutch assemblies. Each clutch assembly has a housing, a pressure plate, a piston, friction discs, separator plates, a conical plate, and return springs. The friction discs and separator plates are installed

in the clutch pack housing in sequence. Each friction disc is next to a separator plate. The separator plates have a smooth metal surface. The friction discs have a friction material on the contact faces.



BP240320

- | | |
|----------------------------|------------------------------|
| 1. SEAL | 8. STATOR SEAL |
| 2. BALL BEARING | 9. O-RING |
| 3. BALL BEARING | 10. CAPSCREW |
| 4. DRIVE CHAIN | 11. BALL BEARING |
| 5. SPROCKET | 12. TRANSMISSION OUTPUT GEAR |
| 6. SPROCKET | 13. FORWARD CLUTCH PACK |
| 7. STATOR SUPPORT ASSEMBLY | 14. REVERSE CLUTCH PACK |

Figure 302. Clutch Packs (Single Speed)

The clutch output gear shaft of each clutch assembly engages the inner splines of the friction discs. The clutch housing inner splines of each clutch assembly engage outer splines of the separator plates. A pressure plate holds the friction discs and separator plates in the housing. A hydraulic piston compresses the clutch plates together when pressurized. Two return springs retract the piston against the housing. When the piston is not pressurized, the clutch pack shaft and drum are free to rotate independently, due to clearance between the friction discs and separator plates.

All clutch shafts in the transmission have an oil passage that connects the clutch piston to the control valve. When hydraulic pressure is applied to the piston, the friction discs and separator plates are pressed together, and the clutch assembly rotates as a single unit. Power is then transmitted through the clutch pack.

There are also oil passages in the transmission housing and the clutch assemblies for the lubrication and cooling of the clutch assemblies. Seal rings on one end of each clutch shaft seal the oil passages so that oil can flow from the passages in the transmission housing to the passages in the clutch shafts. The clutch drum gears of all clutch packs are constantly in mesh with adjacent packs.

Forward Operation

When the Input (Forward 1) clutch is applied, the power from the engine is sent through the Input (Forward 1) clutch assembly to the output gear. The flow of power is from the input shaft (part of the Forward 1 clutch housing) through the applied clutch to the Forward 1 hub. The gear on the hub of

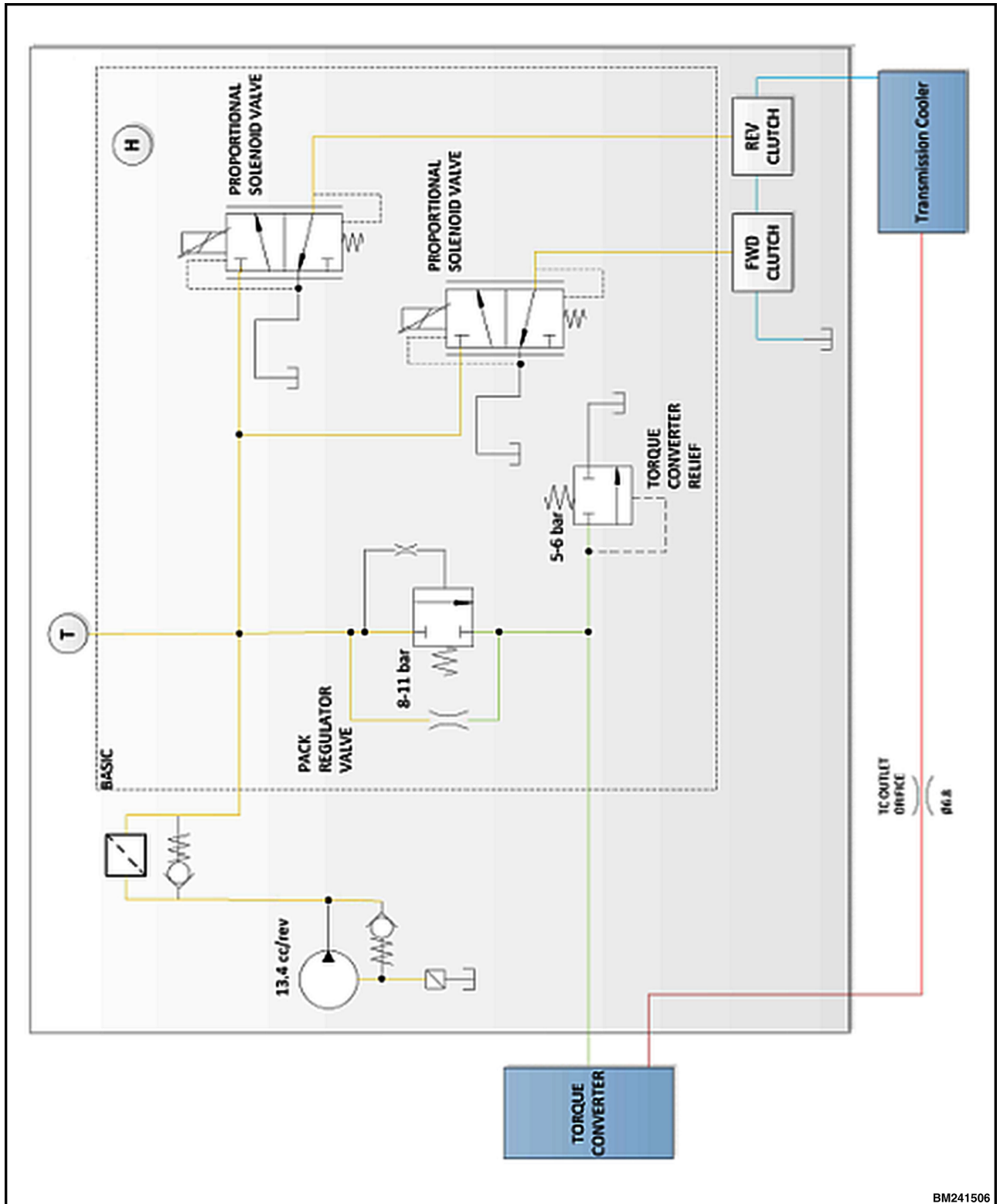
the Input (Forward 1) clutch is engaged with the output gear. The power flows from the applied clutch in the transmission through the drive shaft to the drive axle. The gear on the outside of the Input (Forward 1) clutch housing is engaged with the gear on the outside of the Counter (Reverse 1) clutch housing. The gear on the Counter (Reverse 1) clutch hub is engaged with the output gear on the pinion. These gears are always engaged so that they rotate, but when the Counter (Reverse 1) clutch is released, they do not transfer power.

Reverse Operation

When the Counter (Reverse 1) clutch is applied, the Input (Forward 1) clutch is released. The flow of power is from the input shaft (Forward 1 clutch housing) to the Counter (Reverse 1) clutch housing. The power is transferred through the applied Counter (Reverse 1) clutch to the hub. The hub gear transfers the power to the output gear. The output gear will rotate in the opposite direction as it did when the Input (Forward 1) clutch was applied.

Transmission Hydraulic Schematic

The hydraulic schematic shows the fluid pathway. Pressurized oil is supplied by the charge pump initially, and is either diverted to the brake valve or is applied directly to the transmission control valve. The pressurized oil then goes to both regulators. The pack regulator provides flow at a constant pressure to the valves and boosted service brake as needed. The torque converter relieves to case. Excess flow from both regulators is dumped back to case (back to sump). Additionally, both proportional valves as well as the enable valve shall have relief to case.

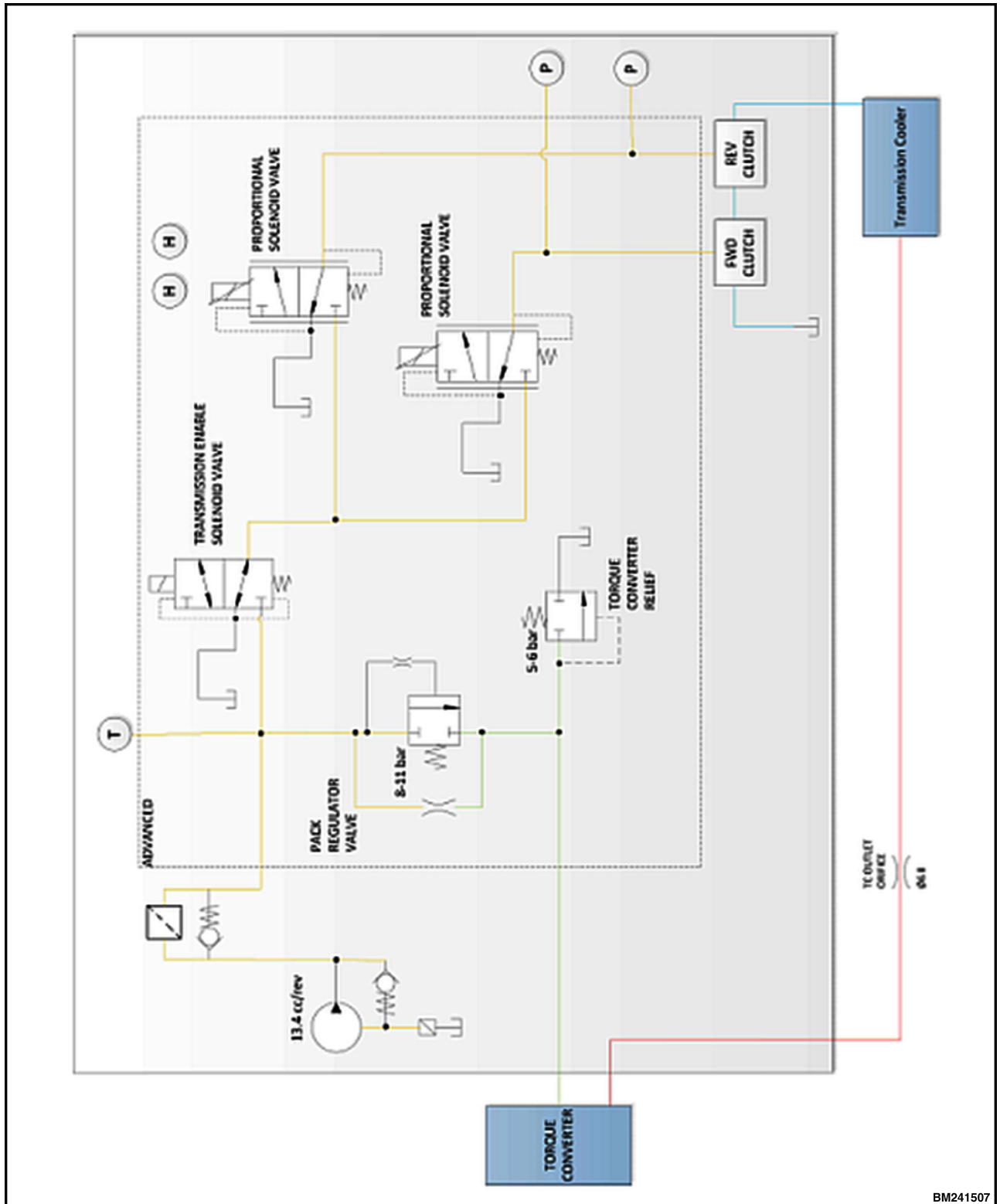


BM241506

Figure 303. Hydraulic Schematic (Powershift 1 Transmission Control Valve)

Legend for Figure 303.

H = HALL EFFECT SENSOR
T = TEMPERATURE SENSOR

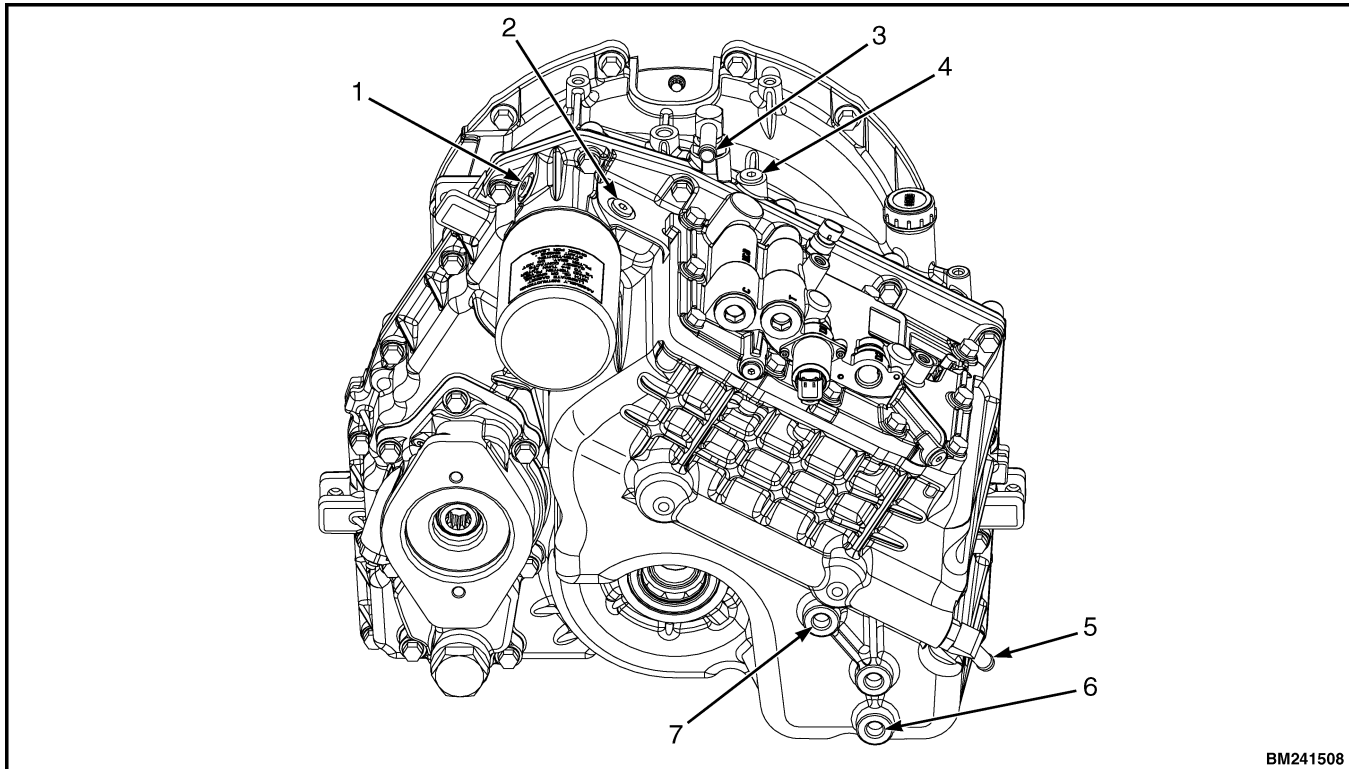


BM241507

Figure 304. Hydraulic Schematic (DuraMatch Transmission Control Valve)

Legend for Figure 304.

H = HALL EFFECT SENSOR
 P = PRESSURE TRANSDUCER
 T = TEMPERATURE SENSOR



NOTE: POWERSHIFT 1 TRANSMISSION OPTION IS SHOWN. DURAMATCH TRANSMISSION OPTION WILL BE SIMILAR.

- | | |
|---------------------------------------|-----------------------------|
| 1. PARK BRAKE SUPPLY (WET BRAKE ONLY) | 5. COOLER RETURN PORT |
| 2. CHARGE PUMP CHECK PORT | 6. PARK BRAKE RETURN PORT |
| 3. COOLER SUPPLY PORT | 7. AXLE COOLING RETURN PORT |
| 4. TORQUE CONVERTER CHECKPOINT | |

Figure 305. Transmission Ports

Transmission Oil Flow

The transmission sump is the main reservoir for the oil. Oil flows from the sump through the baffle, which removes turbulence and entrained air. From here, the oil passes through a particle screen, and is routed to the pump inlet. The pump forces the transmission oil past the pump pressure regulator. If the pressure is above the low pressure, the regulator opens and allows oil to vent into the sump. This protects the filter from pressure damage.

The oil then flows through the filter, where it is cleaned of contamination. If the pressure across the filter element is too high, a bypass valve in the filter will open. This can happen when the filter element has become clogged due to infrequent maintenance, or if the oil is thick from cold temperatures. From the filter, oil flows to the control valve through passages in the transmission case.

Control Valve Oil Flow

Entering the control valve, oil can either go to the clutch packs or through the pack regulator. If the oil goes to the clutch packs, it first must go through the transmission enable valve. This is a pilot operated valve that is controlled by the transmission enable solenoid. If the VSM commands a given pressure and that pressure is much greater or much less than what is seen in the clutch pack as being sensed by the pressure transducers, then the VSM will turn off all solenoids including the transmission enable solenoid.

When the transmission enable solenoid is shut off, it drops the pressure that keeps the transmission enable spool open. When this happens, the transmission enable spool closes and connects the clutch packs and proportional valves to tank. As long as no faults are registered by the VSM, flow is supplied to the proportional valves through the transmission enable spool. Proportional valves then vary the pressure sent to the clutch packs according to the command of the VSM.

If oil does not travel to the clutch packs, it will go through the orifice in the pack regulator. This

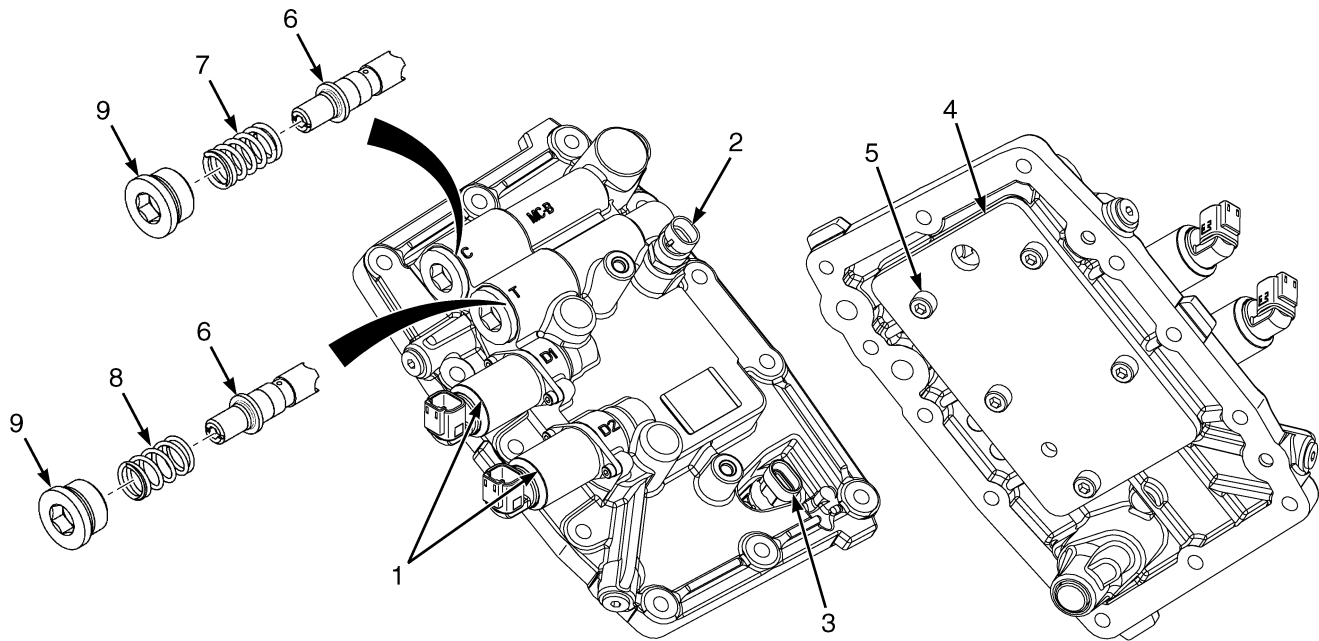
orifice allows oil to travel to torque converter at all times. As flow through the bypass orifice increases, pressure also increases, and eventually the pack regulator opens. As oil flows past the pack regulator, it can either go to the torque converter or to the torque converter regulator. As more and more flow goes toward the torque converter, back pressure begins to build. Once this back pressure increases to a high enough level, the torque converter regulator will open and allow oil to flow directly back to the sump.

If the oil travels through the torque converter, it will heat up as it is used to transfer energy. The oil then travels to the cooler. The oil returns from the cooler and then flows into the lube channels on the end of the clutch packs. The oil flows through the clutch packs and out between the friction disc and separator plates. As oil flows between the friction disc and separator plates it takes away heat generated in the pack due to engagement or disengagement. The oil then flows from the packs down into the sump.

Control Valve

The control valve is installed on the top of the transmission. The forward and reverse proportional valves, enable solenoid valve, supply spool, forward and reverse pressure sensors, supply regulator for clutch pressure, and regulator for the torque converter are part of the control valve. The Transmission Input Shaft Sensor (TISS), Transmission Output Shaft Sensor (TOSS), forward (High) proportional valve, pressure and temperature sensors are located on the transmission housing.

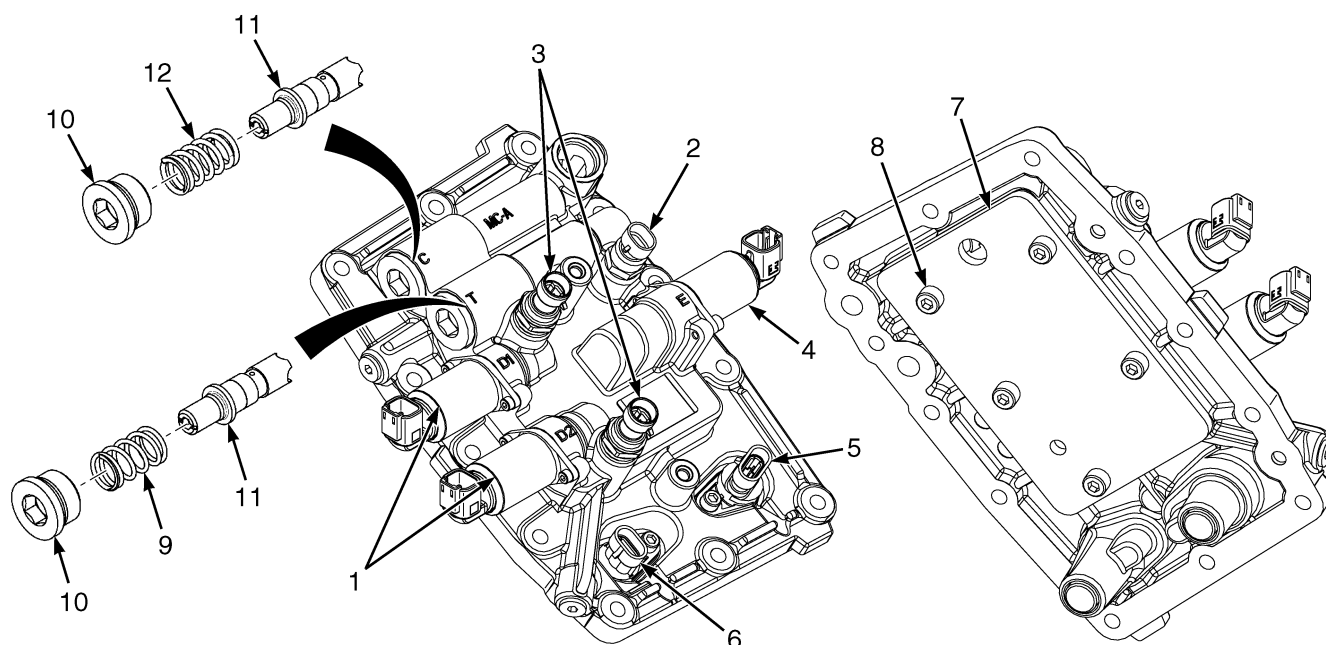
The transmission control valve controls clutch pack engagement using independent electronic proportional valves. The transmission control functions are embedded in the software programming. This permits precise control of clutch pack engagement, and the ability to apply the clutch packs in any required combination.



BP240328

- | | |
|--|---|
| 1. FWD PROP VALVE (D1) REV PROP VALVE (D2) | 6. SPOOL |
| 2. TEMPERATURE SENSOR | 7. SPRING (YELLOW), CLUTCH PACK REGULATOR |
| 3. SENSOR (OUTOUT SPEED, TOSS) | 8. SPRING (GREEN), TORQUE CONVERTER REGULATOR |
| 4. COVER PLATE GASKET | 9. PLUG |
| 5. CAPSCREW | |

Figure 306. Control Valve (Powershift 1)



BP240329

- | | |
|--|---|
| 1. FWD PROP VALVE (D1) REV PROP VALVE (D2) | 7. COVER PLATE GASKET |
| 2. TEMPERATURE SENSOR | 8. CAPSCREW |
| 3. PRESSURE SENSOR | 9. SPRING (GREEN), TORQUE CONVERTER REGULATOR |
| 4. ENABLE VALVE (E) | 10. PLUG |
| 5. SENSOR (OUTPUT SPEED, TOSS) | 11. SPOOL |
| 6. SENSOR (INPUT SPEED, TISS) | 12. SPRING (YELLOW), CUTCH PACK REGULATOR |

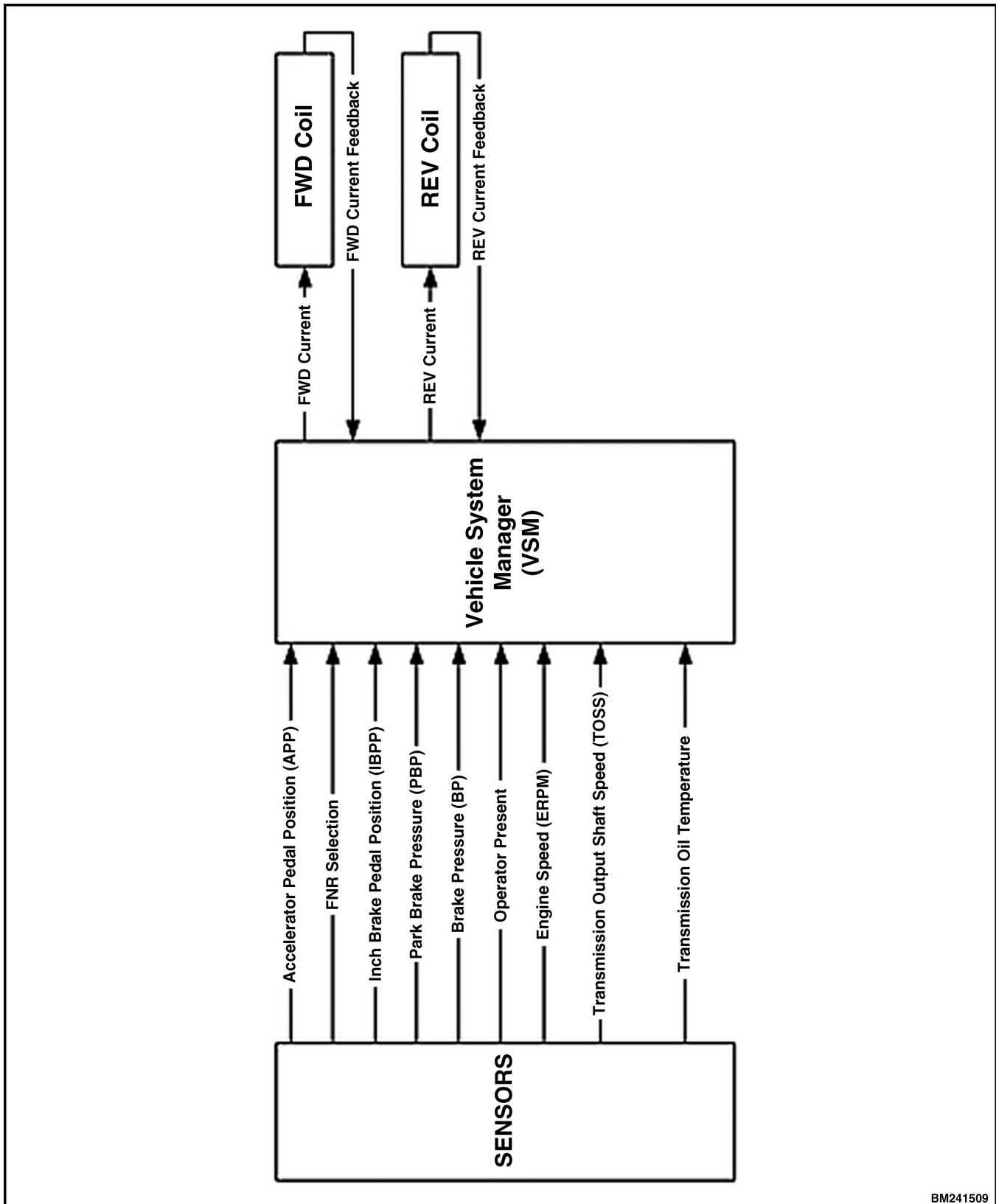
Figure 307. Control Valve (DuraMatch)

Torque Converter Regulator

The torque converter regulator receives oil flow through an orifice in the bore of the clutch pressure regulator. The torque converter pressure regulator stays closed until pressure to the torque converter increases to a set pressure range. When the

pressure regulator for the torque converter opens, the oil that is not directed to the torque converter flows directly to sump. The oil that flows to the torque converter goes through the oil cooler before entering the passage to cool and lubricate the clutches.

Electrical System Architecture



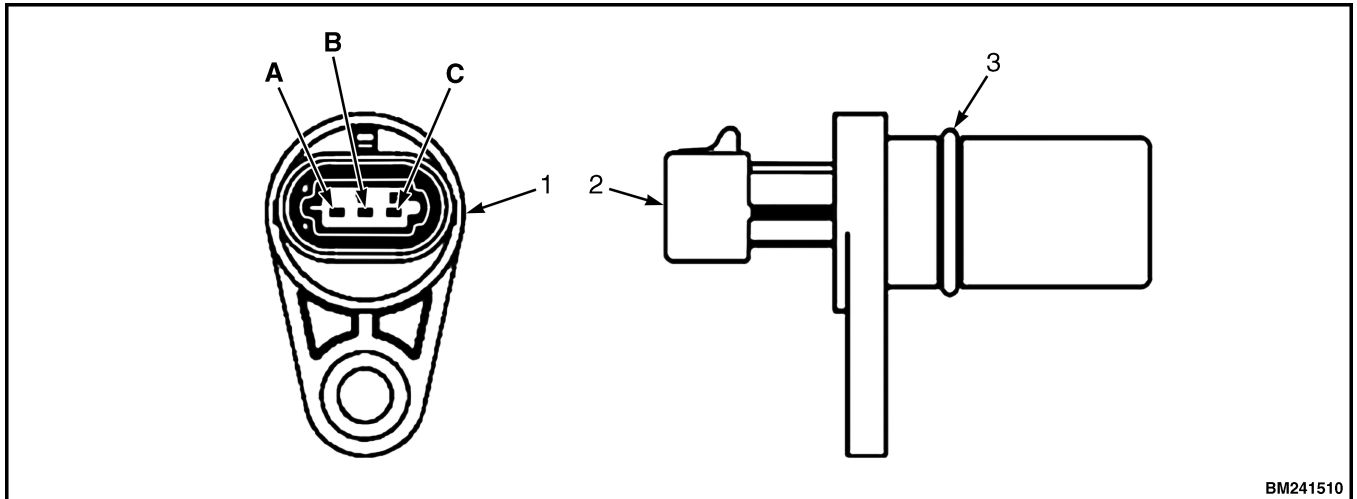
BM241509

Figure 308. Electrical System Architecture

**Transmission Input Shaft Speed (TISS)
(DuraMatch) transmission only**

The TISS senses the rotational speed of the input shaft of the transmission. The transmission is coupled to the engine through the torque converter. The transmission input shaft speed is equal to the output speed of the torque converter. The TISS sensor sends an electrical pulse to the VSM every time a gear tooth passes it. It does not sense direction of gear rotation.

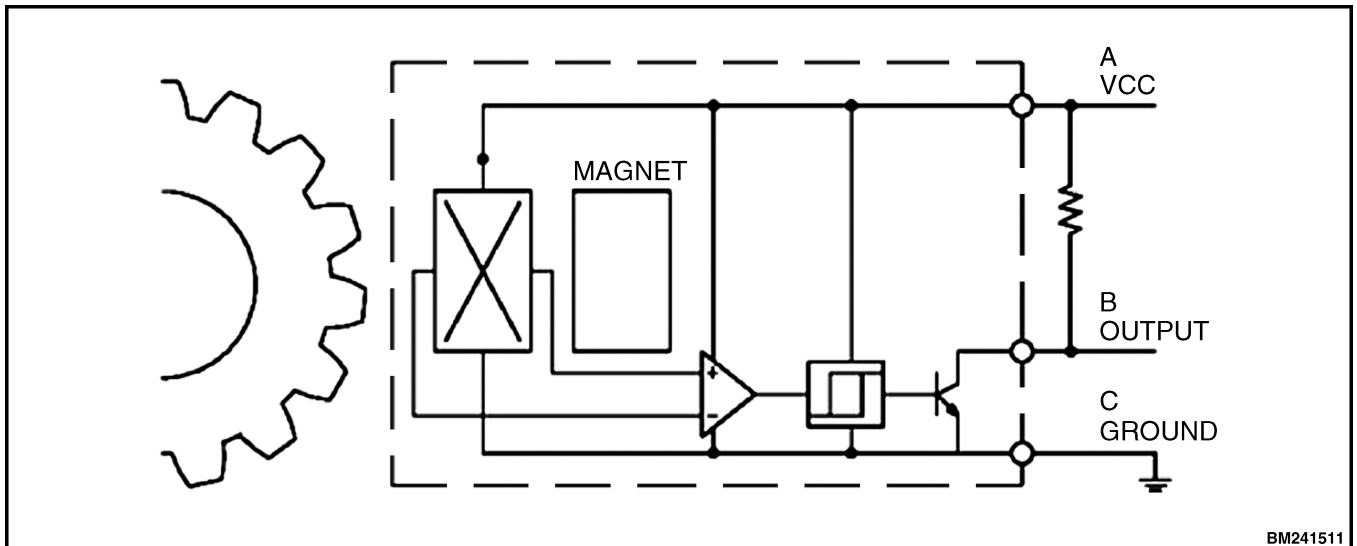
The transmission input shaft speed sensor is a Hall effect sensor that mates with an encoder made of magnetic material. The encoder wheel is mounted on the transmission input shaft. This sensor effectively detects the encoder teeth and gaps as the magnetic field changes. The resulting feedback is a square wave that corresponds with the pattern of the encoder wheel. The wave form is predictable and indicates to the VSM the rate the shaft is turning.



BM241510

- 1. CONNECTOR
- 2. TERMINAL HOUSING
- 3. O-RING

Figure 309. TISS Sensor



BM241511

Figure 310. TISS Sensor Electrical Schematic

Transmission Output Shaft Speed (TOSS)

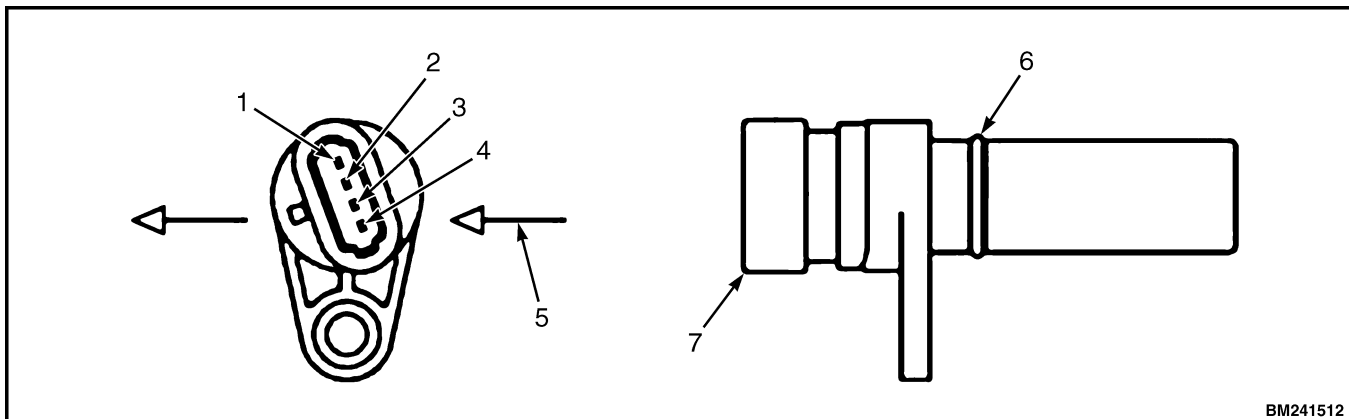
The TOSS senses the rotational speed of the transmission output shaft. The TOSS sensor sends electrical pulses to the VSM every time a gear tooth passes it. It sends two pulse signals, so direction and speed can be determined. TOSS is proportional to ground speed once tire diameters, axle and drop box ratios are considered.

The transmission output shaft speed sensor is a Hall effect sensor that mates with an encoder made of magnetic material. The encoder wheel is mounted

on the transmission input shaft. This sensor effectively detects the encoder teeth and gaps as the magnetic field changes. The resulting feedback is a square wave that corresponds with the pattern of the encoder wheel. The wave form is predictable and indicates to the VSM the rate and direction the shaft is turning.

The DuraMatch transmission features a four-wire TOSS. See Figure 311 and Figure 312.

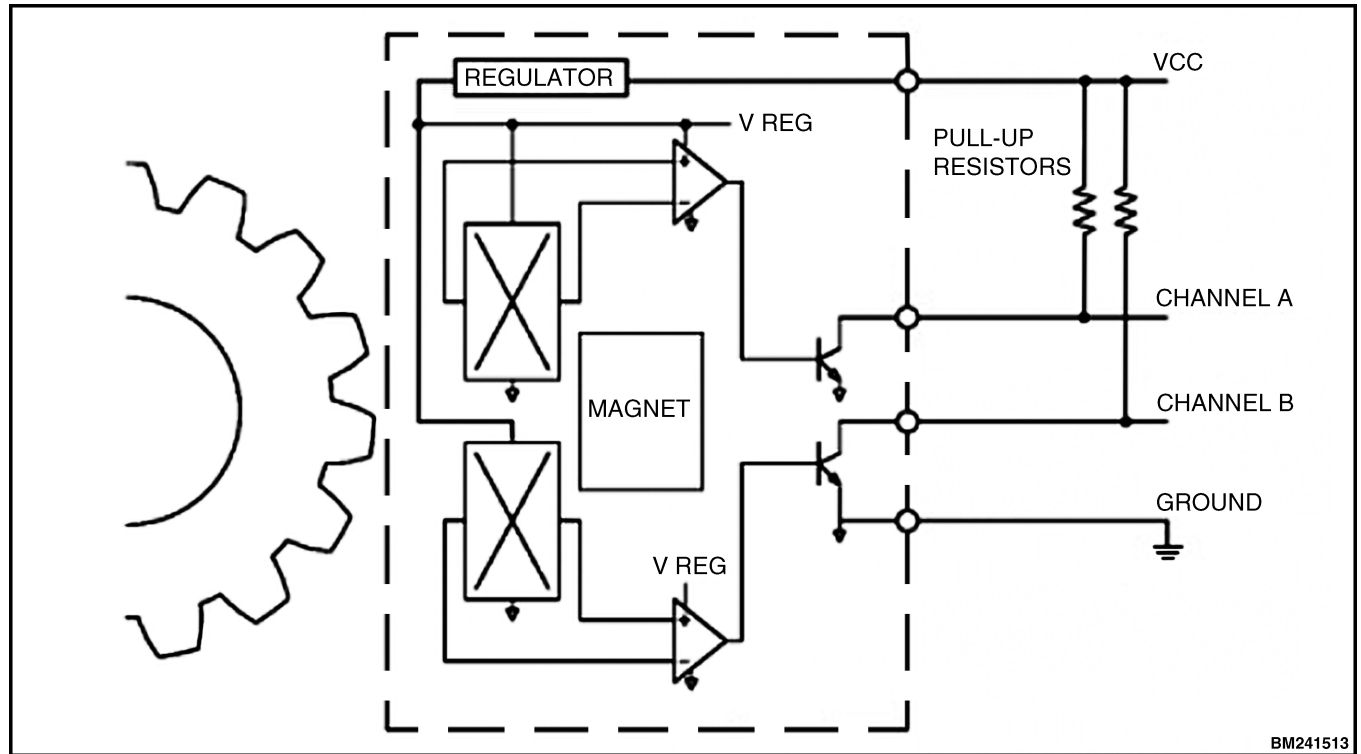
The Powershift 1-speed transmission features a three-wire TOSS. See Figure 313 and Figure 314.



1. GROUND
2. VCC. SUPPLY
3. CHANNEL A
4. CHANNEL B

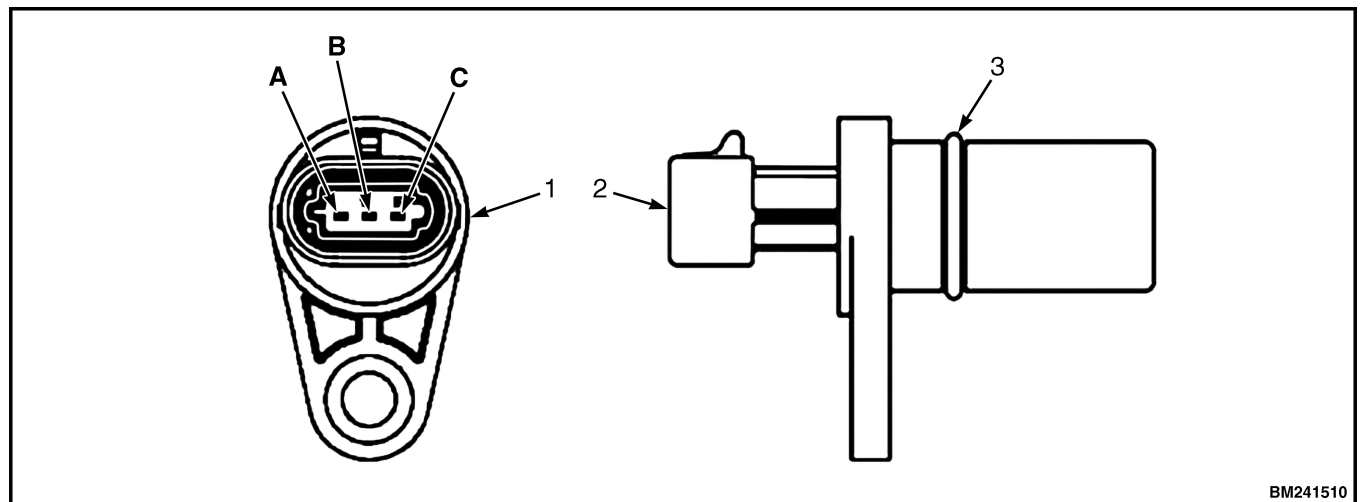
5. GEAR TOOTH PASS DIRECTION WHEN CHANNEL A LEADS CHANNEL B
6. O-RING
7. TERMINAL HOUSING

Figure 311. TOSS Sensor (DuraMatch) transmission



BM241513

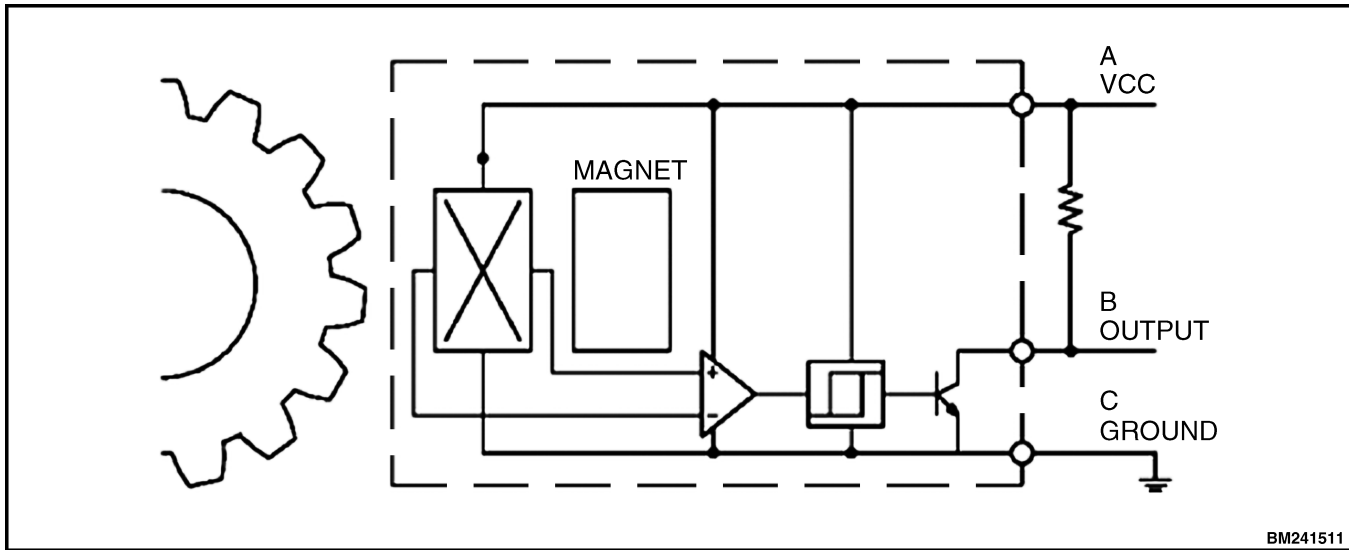
Figure 312. TOSS Sensor Electrical Schematic (DuraMatch transmission)



BM241510

1. CONNECTOR
2. TERMINAL HOUSING
3. O-RING

Figure 313. TOSS Sensor (Powershift 1-speed transmission)

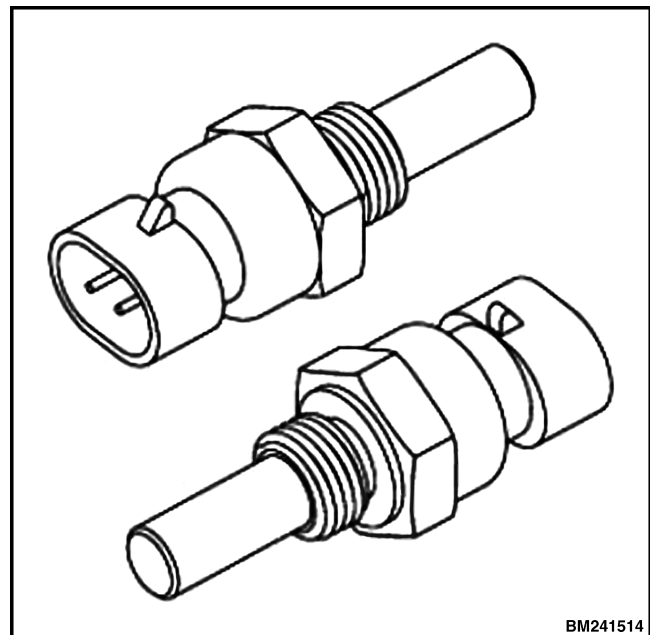


BM241511

Figure 314. TOSS Sensor Electrical Schematic (Powershift 1-speed transmission)

Transmission Oil Temperature Sensor

The transmission oil temperature sensor provides an analog signal to the VSM to determine the oil temperature. The sensor uses a thermistor to sense the temperature of the oil. The transmission oil temperature sensor behaves in the opposite manner of a resistor. As temperature rises the resistance of the sensor goes down. When the oil temperature is low, the feedback voltage will also be low as the sensor resistance is high. Once the oil temperatures increase so will the resulting feedback voltage.



BM241514

Figure 315. Temperature Sensor

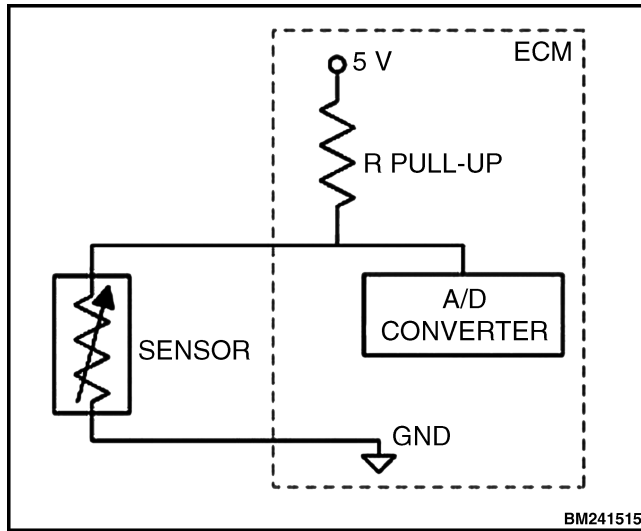


Figure 316. Temperature Sensor Electrical Schematic

Accelerator Pedal Position (APP) Sensor

The APP sensor is attached to the accelerator pedal in the operator station. The APP sensor physical position results in feedback voltage used by the VSM to command engine speed from the engine ECU and set truck acceleration, and help determine loading on engine and transmission.

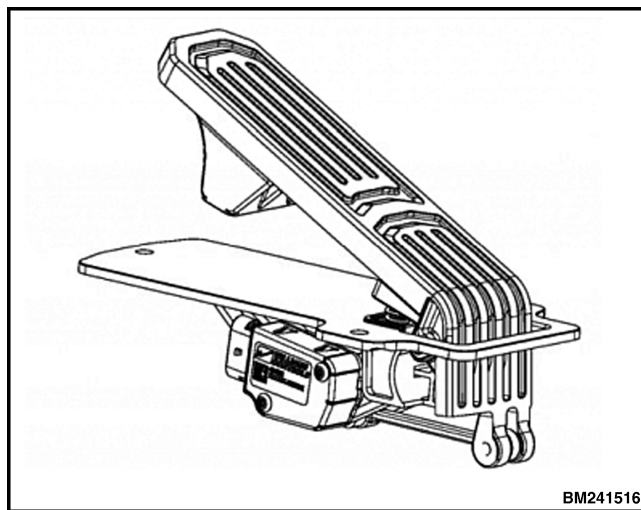
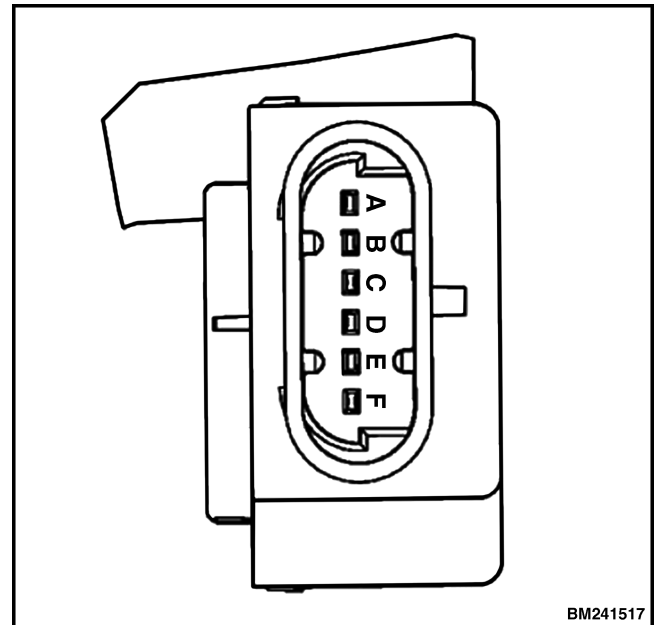


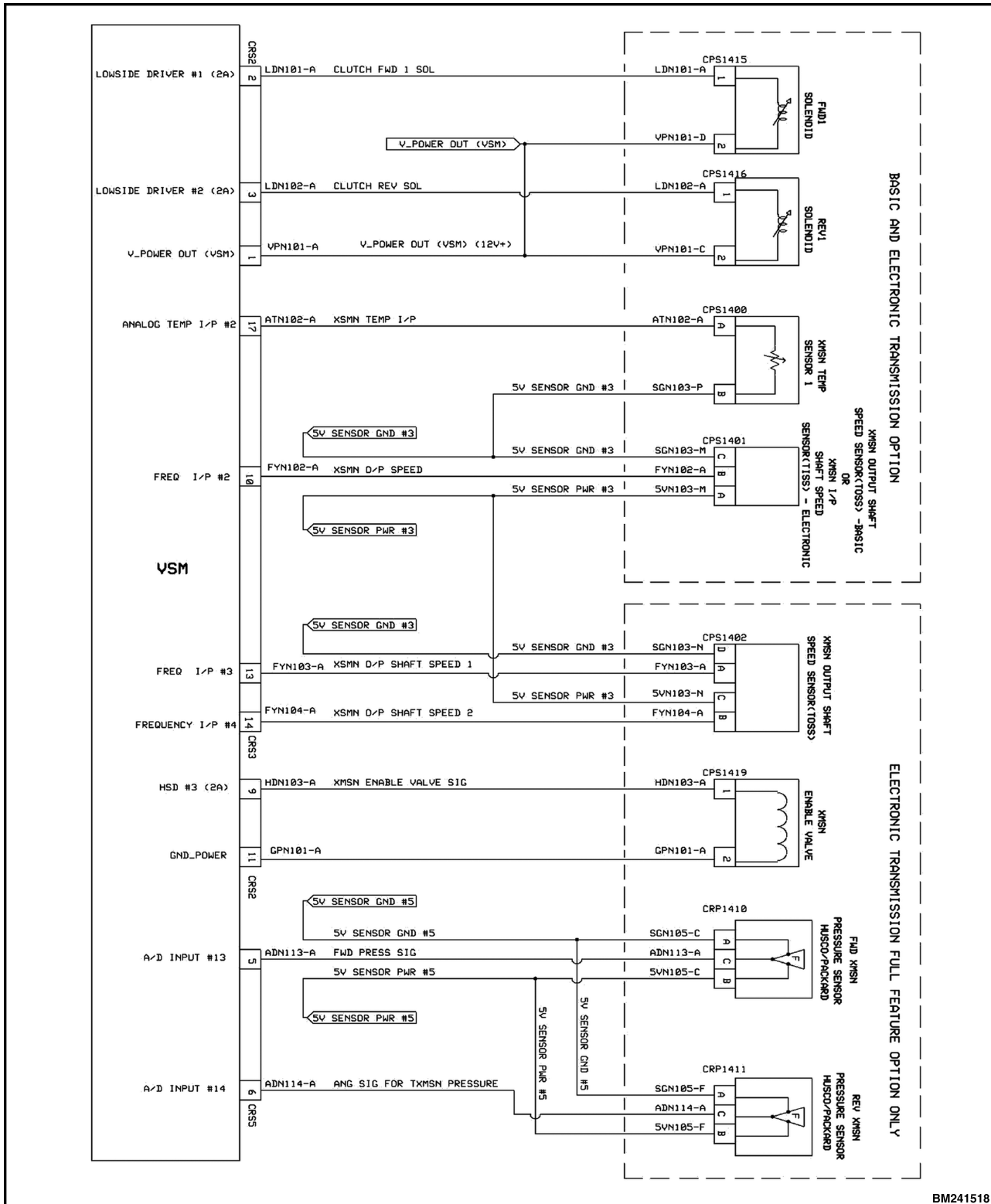
Figure 317. Accelerator Pedal and Sensor



- A APS 1 SIGNAL
- B APS 1 GROUND
- C APS 1 SUPPLY (5V)
- D APS 2 SUPPLY (5V)
- E APS 2 GROUND
- F APS 2 SIGNAL

Figure 318. APP Sensor Connector Pin Out

Electrical Control Schematic



BM241518

Figure 319. Electrical Control Schematic

NOTE: "BASIC AND ELECTRONIC TRANSMISSION OPTION" AS DEFINED ON THE ABOVE SCHEMATIC REFERS TO ITEMS COMMON TO BOTH TRANSMISSIONS. "FULL FEATURE OPTION" REFERS TO DURAMATCH TRANSMISSION.

Transmission Operational Modes

Powered Off Mode

Powered Off is considered an actual mode. This mode is when the truck is powered off, engine is not running, and the transmission is not performing any function.

Neutral Interlock Mode

Neutral Interlock mode is when the transmission is not enabled. This mode is activated when the truck is powered on, the engine is running, and the transmission is initialized, and an interlock is active (such as operator is not in the seat, the engine is not running, or the engine is in startup).

Normal Mode

Normal is where all conditions are met including interlock conditions. When the engine is running, the engine is not cranking, and the operator is present normal mode is active. Normal mode has five sub-states: Neutral, Normal (FWD or REV), Pack Braking, Inching, and Operator Interlock. The operator-present dependency of neutral interlock is required only when the system transitions from Neutral Interlock mode to Normal Operation mode.

Fault Mode

Fault mode is where critical faults affecting transmission performance have been detected. When these faults are detected the transmission is disabled and no transmission engagement is allowed.

Pack Braking Mode

Pack Braking is the process of partially engaging two or more clutch packs to create a braking effort on the transmission output shaft. The benefit of clutch pack braking is that all partially engaged packs share the braking load (heat), which otherwise is absorbed by only one clutch pack. Clutch pack braking is applied to accomplish torque controlled power reversals. Reversals on grade that exceed the power reversal torque will result in the operator using the service brake to complete the power reversal.

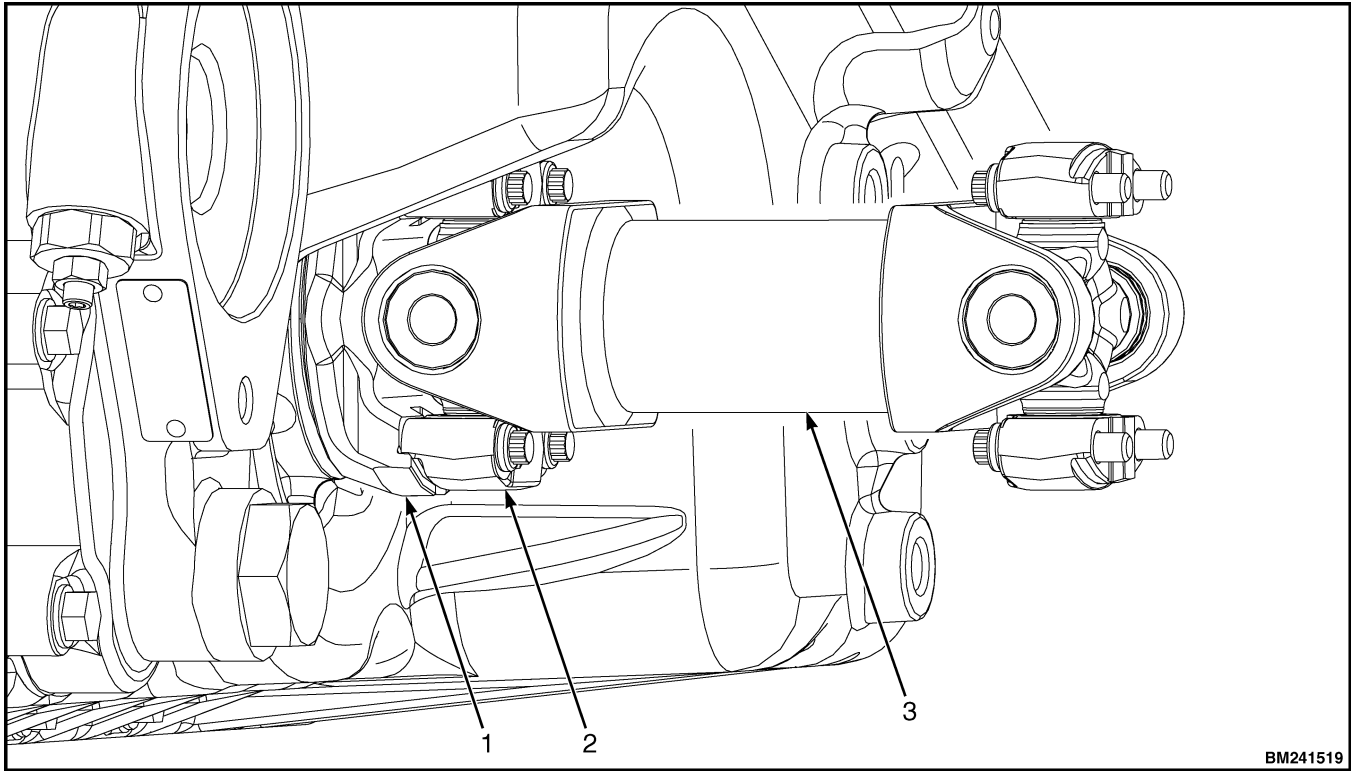
The transmission is engaged in both the Forward or Reverse direction at a pressure proportional to the accelerator pedal position until the truck speed is slow enough to engage the selected direction. Then the selected pack pressure is modulated.

Inching Mode

Inching control allows driving the truck at a low speed (or be stopped) by partially or fully engaging the driving clutch pack and the service brake simultaneously. The selected pack is partially engaged to allow the truck to move more slowly and allows the engine to run at high speed to support hydraulic operations.

Transmission Output Gear Yoke and Driveshaft

The transmission output gear and yoke are connected to the driveshaft with a universal joint. On the other end of the driveshaft is another universal joint that connects to the drive axle. The driveshaft transfers power between the transmission and the drive axle. The driveshaft also allows the transmission and engine to be isolated from the frame.

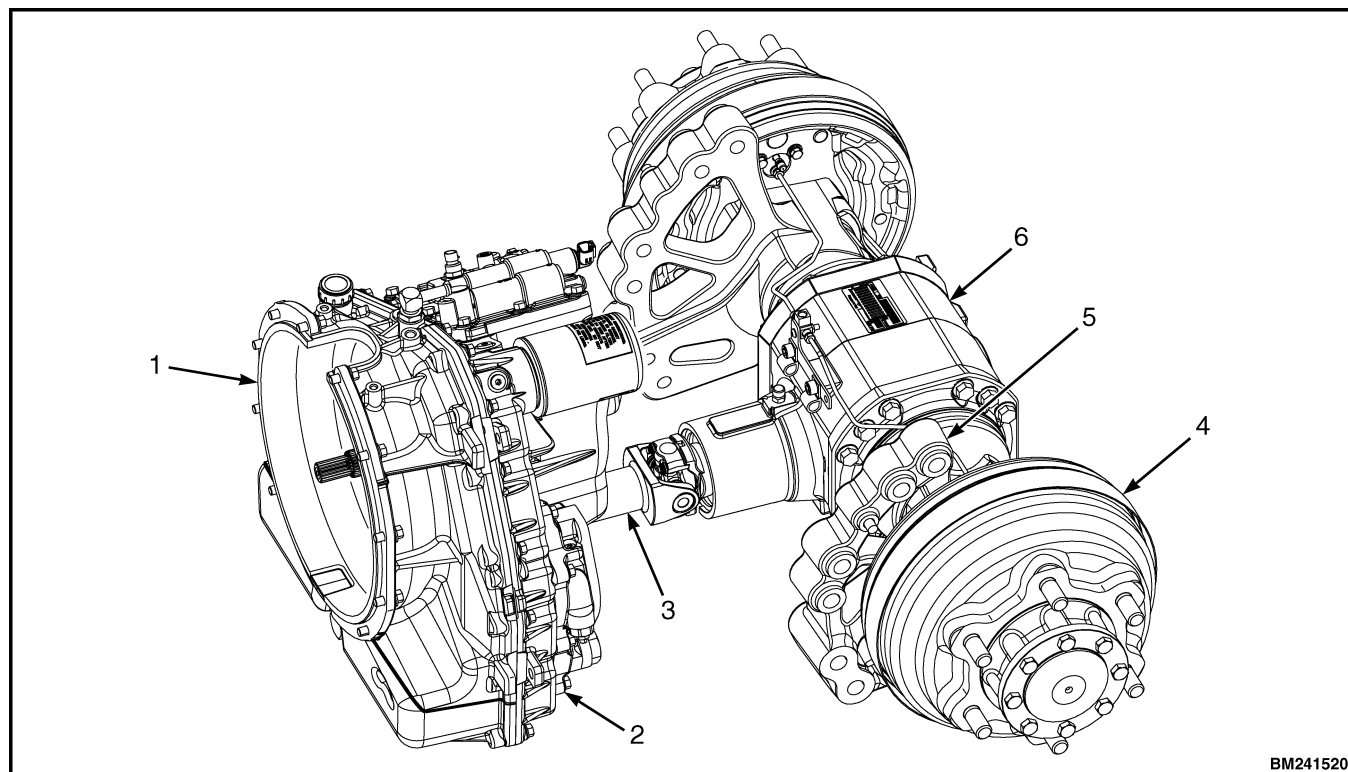


- 1. OUTPUT GEAR YOKE
- 2. UNIVERSAL JOINT

- 3. DRIVESHAFT

Figure 320. Yoke and Driveshaft

Transmission, Driveshaft, and Drive Axle



BM241520

- | | |
|---------------------------------|----------------------|
| 1. TORQUE CONVERTER AND HOUSING | 4. DRY BRAKE |
| 2. TRANSMISSION | 5. DRIVE AXLE HANGER |
| 3. DRIVESHAFT | 6. DRIVE AXLE |

Figure 321. Transmission, Driveshaft, and Drive Axle

HYDROSTATIC TRANSMISSION (HST) DESCRIPTION 202001-160

HYDROSTATIC TRANSMISSION Mechanical Overview

The hydrostatic transmission is a component of the drive train system. The drive train system transfers power from the engine to the ground. The drive train system consists of the following components:

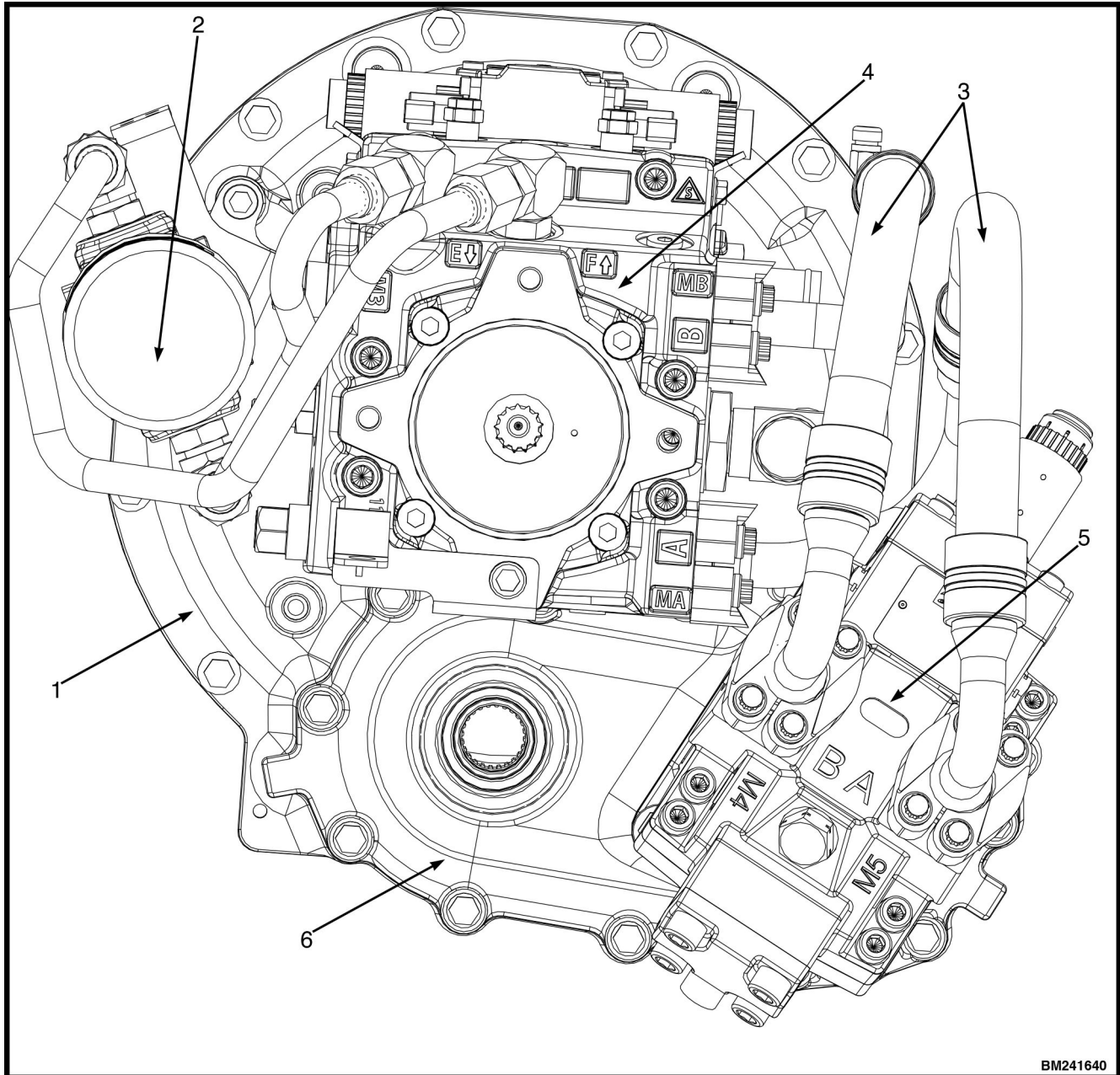
- a. Engine
- b. Transmission
- c. Driveshaft and drive axle
- d. Brakes

Engine

For engine details refer to Diesel engine description, LPG engine description, Bi-fuel engine description.

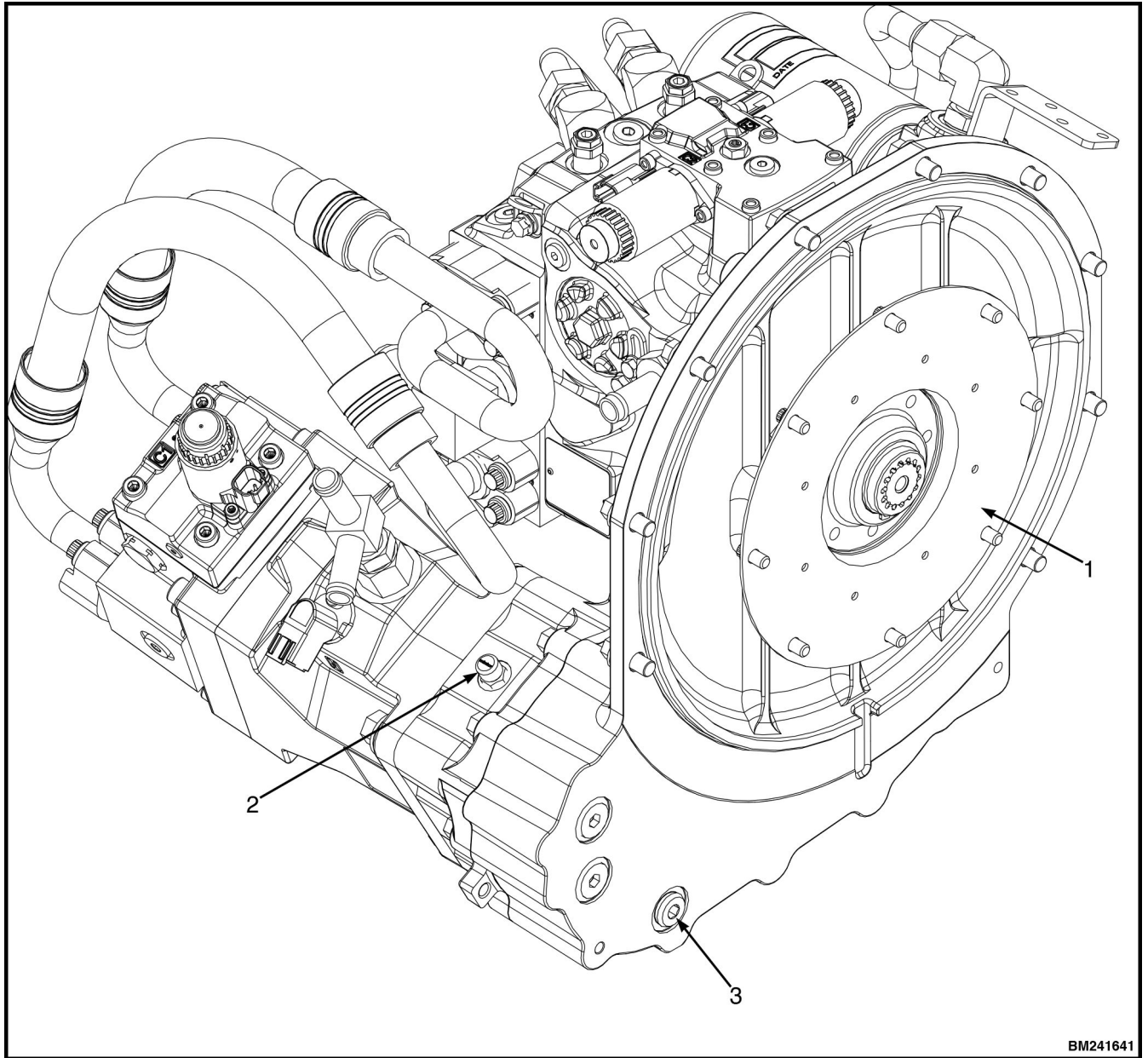
Transmission

The HST is mounted to the engine block. Engine power is transmitted via the flywheel on the engine engaging with the flexplate coupling on the flywheel. The VSM receives input from the operator through the directional control lever or directional pedal(s), accelerator pedal, and the brake pedal. Based on these inputs, the VSM sends signals to the transmission controller, providing travel or transmission braking as required. The software is factory installed with the appropriate settings for each truck configuration type.



- | | |
|-----------------------------|----------------------|
| 1. HST HOUSING | 4. HYDROSTATIC PUMP |
| 2. TRANSMISSION FILTER | 5. HYDROSTATIC MOTOR |
| 3. HIGH PRESSURE LOOP HOSES | 6. DRIVE CHAIN COVER |

Figure 322. Transmission overview, view 1



BM241641

- 1. FLEXPLATE
- 2. CHAIN CASE BREATHER

- 3. MAGNETIC DRAIN PLUG

Figure 323. Transmission overview, view 2

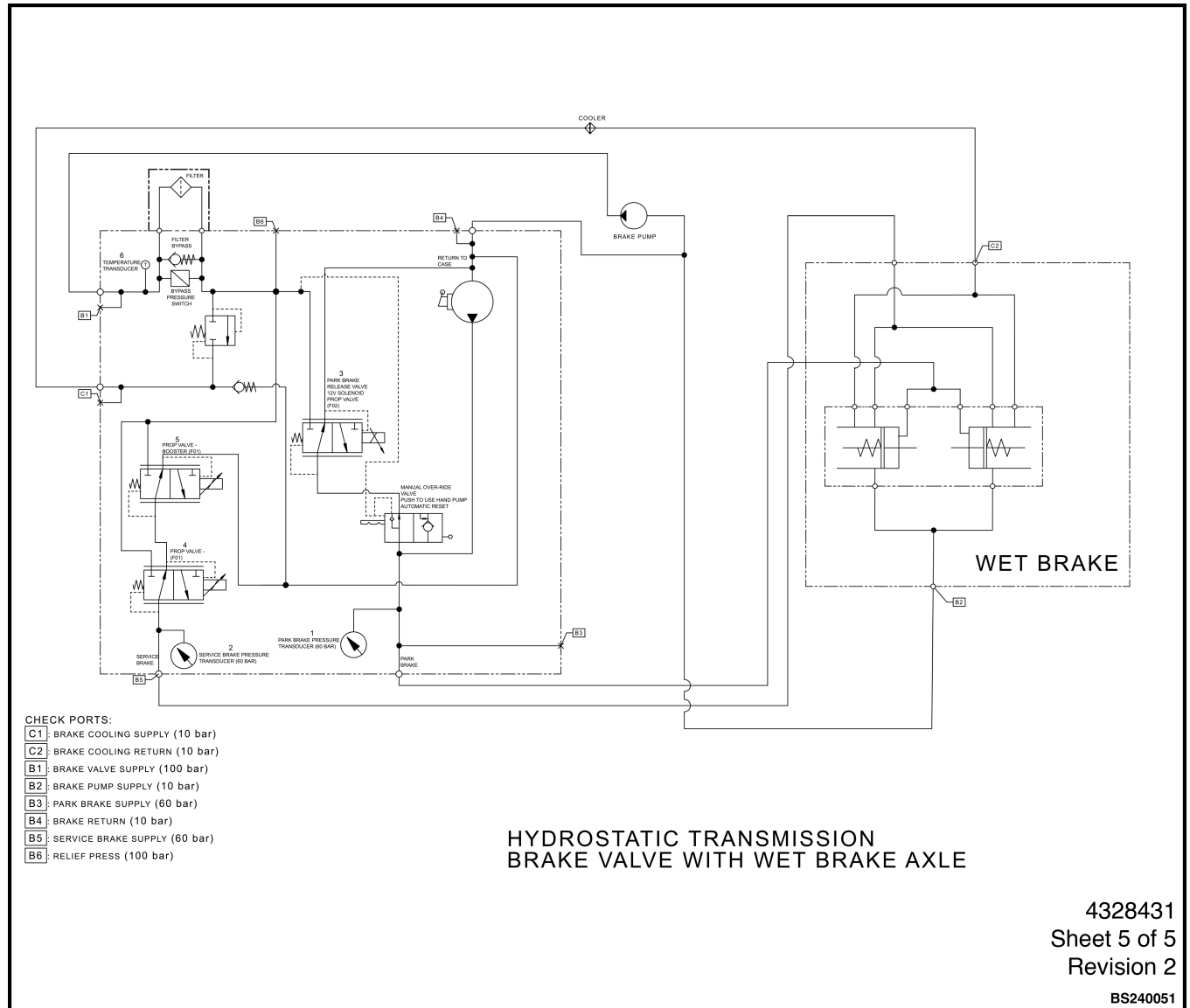


Figure 325. HST hydraulic schematic (sheet 2 of 2)

Control Valve

Transmission Output Shaft Speed (TOSS)

The TOSS senses the rotational speed of the hydrostatic motor output shaft. The TOSS sensor sends electrical pulses to the transmission control unit every time a gear tooth passes it. It sends two pulse signals, so direction and speed can be determined. TOSS is proportional to ground speed once tire diameters, chain drive, axle and drop box ratios are considered. The TOSS speed is sent to the VSM from the transmission control unit for further vehicle uses.

The transmission output shaft speed sensor is a Hall effect sensor that mates with an encoder made of magnetic material. The encoder wheel is mounted on the HST motor output shaft. This sensor effectively detects the encoder teeth and gaps as the magnetic field changes. The resulting feedback is a square wave that corresponds with the pattern of the encoder wheel. The wave form is predictable and indicates to the VSM and TCU the rate and direction the shaft is turning.

Transmission Oil Temperature Sensor

The transmission oil temperature sensor provides an analog signal to the VSM to determine the oil temperature. The sensor uses a thermistor to sense the temperature of the oil. The transmission oil temperature sensor behaves in the opposite manner of a resistor. As temperature rises the resistance of the sensor goes down. When the oil temperature is low, the feedback voltage will also be low as the sensor resistance is high. Once the oil temperatures increase so will the resulting feedback voltage.

The transmission oil temperature sensor is incorporated into the transmission TOSS sensor digital output.

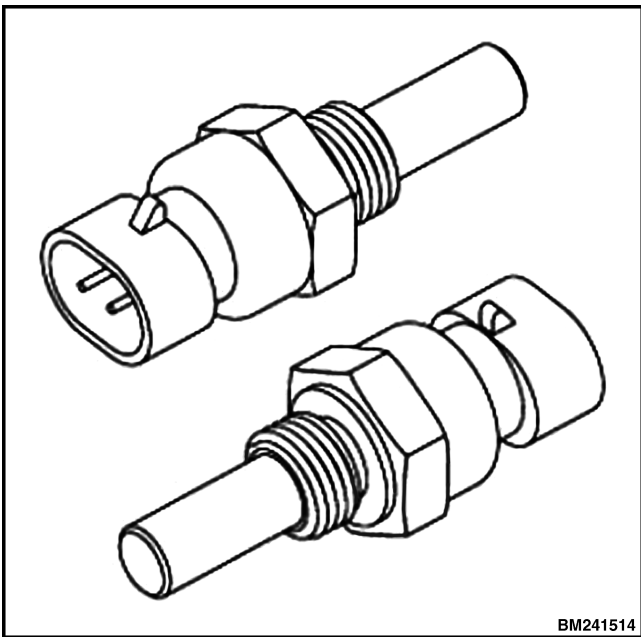


Figure 326. Temperature Sensor

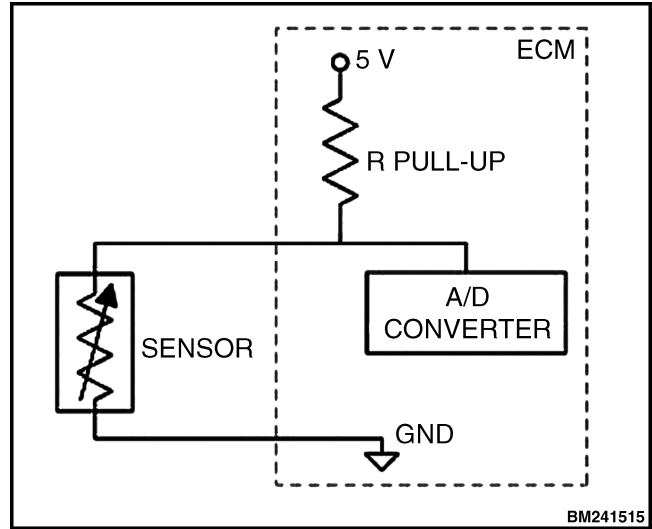


Figure 327. Temperature Sensor Electrical Schematic

Accelerator Pedal Position (APP) Sensor

The APP sensor is attached to the accelerator pedal in the operator station. The APP sensor physical position results in feedback voltage used by the VSM to command vehicle speed from the engine ECU and TCU. The transmission controller sets acceleration and deceleration rates.

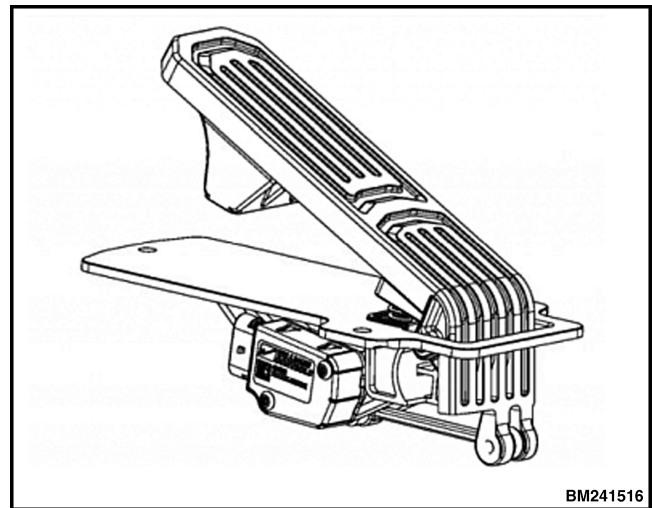
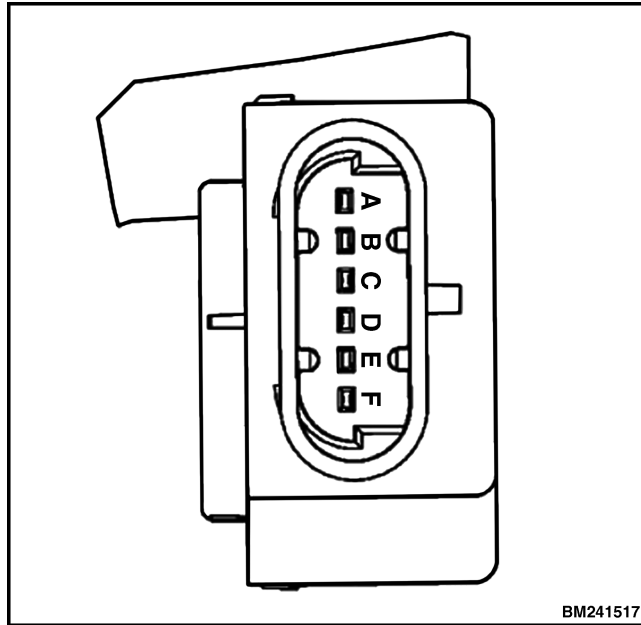


Figure 328. Accelerator Pedal and Sensor



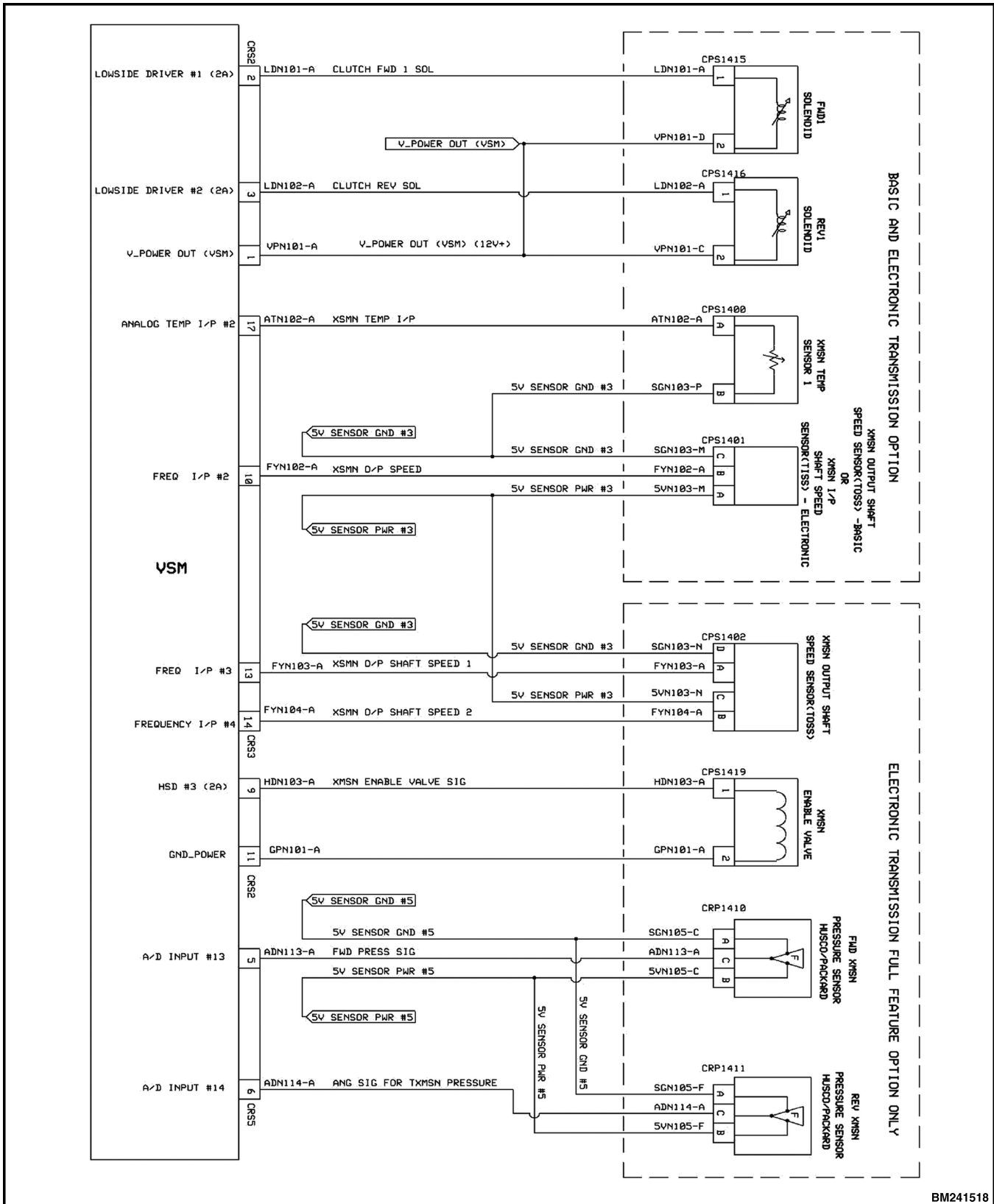
BM241517

Legend for Figure 329.

- A APS 1 SIGNAL
- B APS 1 GROUND
- C APS 1 SUPPLY (5V)
- D APS 2 SUPPLY (5V)
- E APS 2 GROUND
- F APS 2 SIGNAL

Figure 329. APP Sensor Connector Pin Out

Electrical Control Schematic



BM241518

Figure 330. Electrical Control Schematic

HST operational modes

Powered Off mode

Powered Off is considered an actual mode. This mode is when the truck is powered off, engine is not running, and the transmission is not performing any function.

Neutral Interlock mode

Neutral Interlock mode is when the transmission is not enabled. This mode is activated when the truck is powered on, the engine is running, and the transmission is initialized, and an interlock is active (such as operator is not in the seat, the engine is not running, or the engine is in startup).

Normal mode

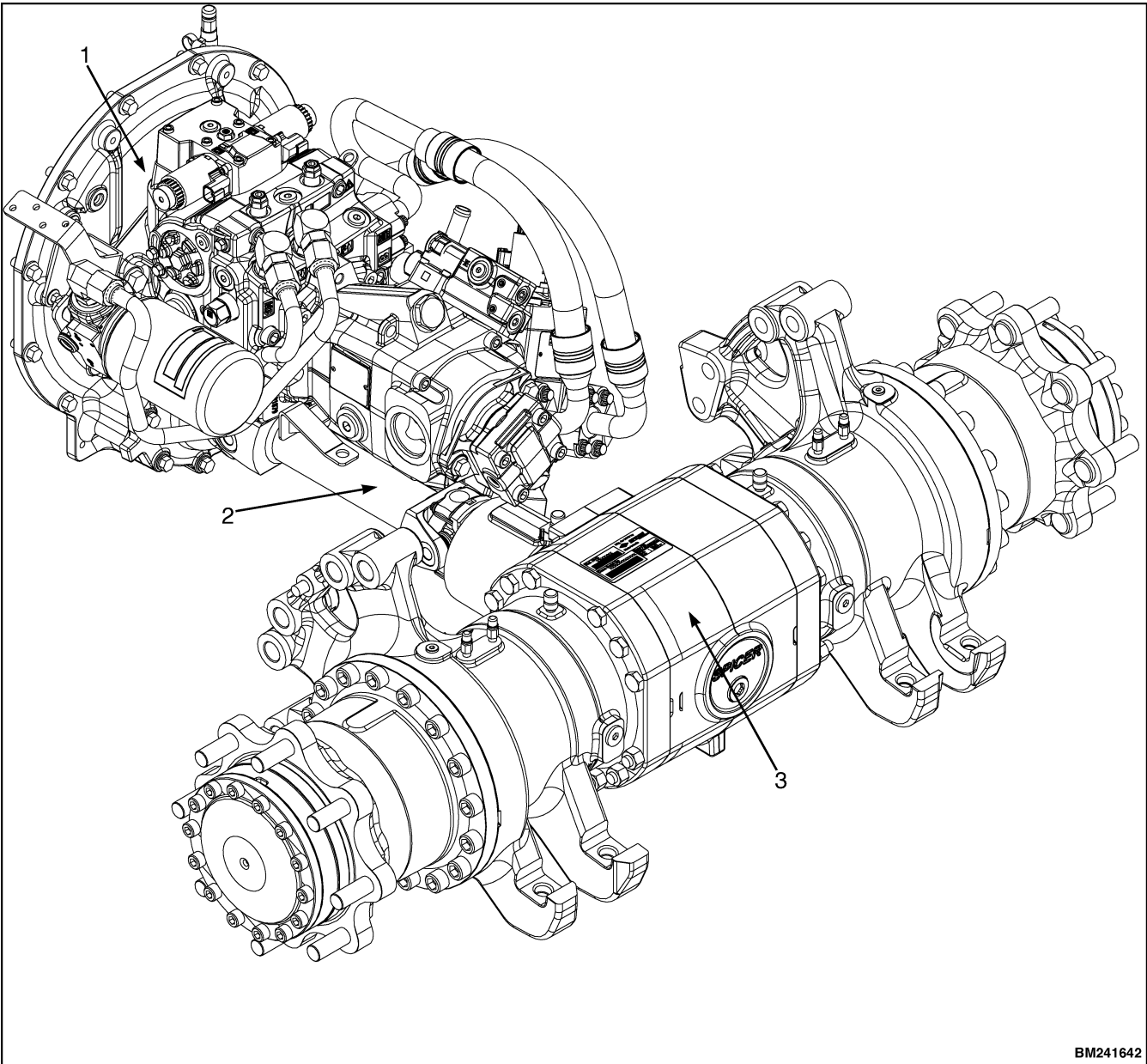
Normal is where all conditions are met including interlock conditions. When the engine is running,

the engine is not cranking, and the operator is present normal mode is active. Normal mode has five sub-states: Neutral, Normal (FWD or REV), Park Braking, Inching, and Operator Interlock. The operator-present dependency of neutral interlock is required only when the system transitions from Neutral Interlock mode to Normal Operation mode.

Fault mode

Fault mode is where critical faults affecting transmission performance have been detected. When these faults are detected the transmission is disabled and no transmission engagement is allowed.

Hydrostatic transmission, driveshaft, and drive Axle



BM241642

- 1. HYDROSTATIC TRANSMISSION
- 2. DRIVESHAFT

- 3. DRIVE AXLE

Figure 331. Hydrostatic transmission, driveshaft, and drive Axle

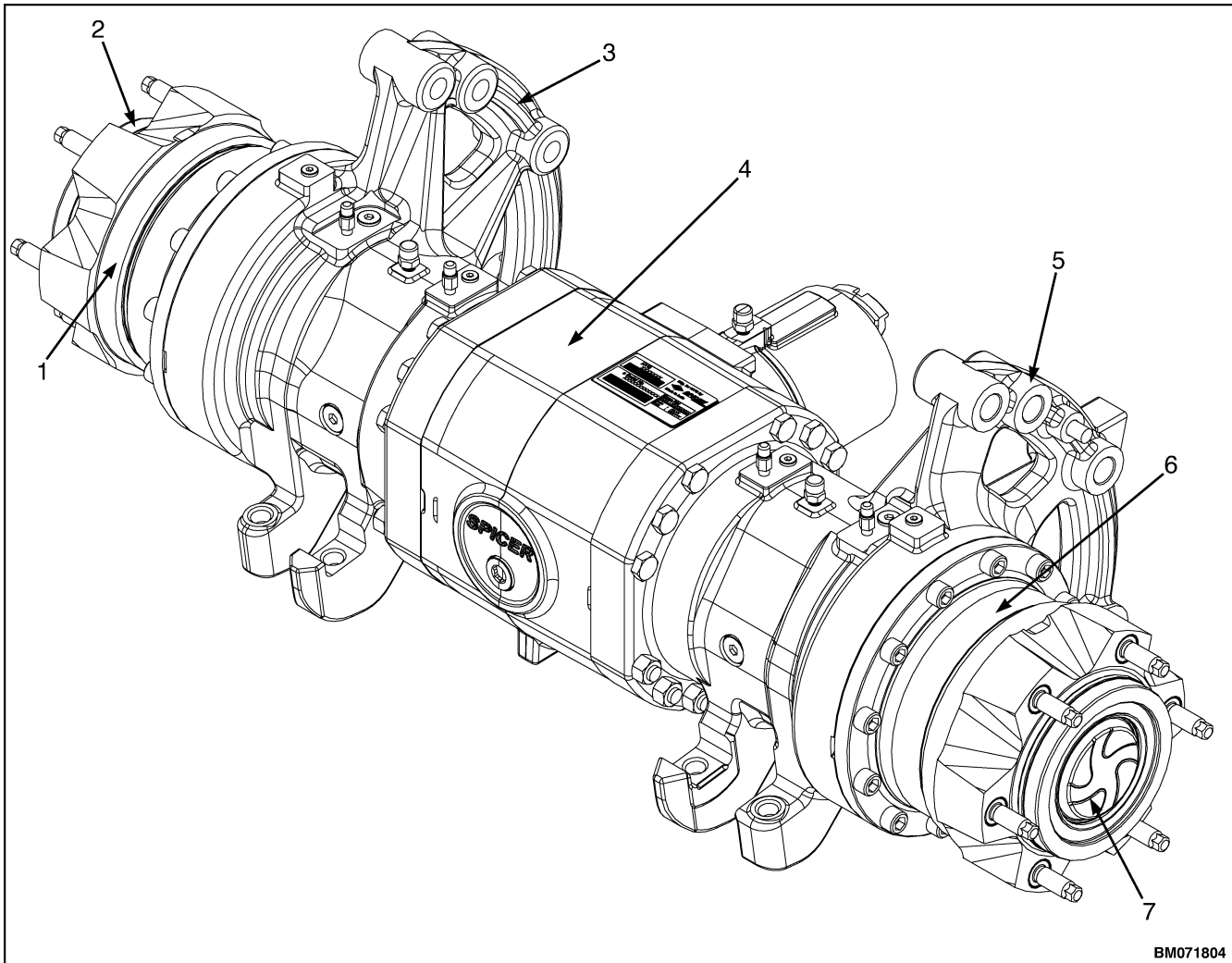
WET BRAKE AXLE DESCRIPTION 202001-161

WET BRAKE AXLE

The drive axle takes transmission output shaft rotation and translates that rotation through the differential and planetary gear set to turn the wheels. The drive axle also facilitates the mechanical braking for the truck. Two types of drive axle are available, dry brake and wet brake. This module will only discuss the wet brake axle. On wet brake axles, there are no immediately obvious

outboard brake components like a drum, rotor, or caliper. The wet-brake axle also has no exposed fasteners at the wheel hub center. Hardware configuration details are provided on the part identification plate mounted on the top face of the axle center section.

The driveshaft transfers power between the transmission and the drive axle. The driveshaft also allows the transmission and engine to be isolated from the frame. If the transmission and engine were mounted directly to the axle, their vibrations would be passed to the frame and the noise and vibration levels would be much higher.



- | | |
|-------------------------|-------------------------|
| 1. LH WHEEL END/HUB | 5. RH DRIVE AXLE HANGER |
| 2. LH AXLE SHAFT | 6. RH WHEEL END/HUB |
| 3. LH DRIVE AXLE HANGER | 7. RH AXLE SHAFT |
| 4. CENTER SECTION | |

Figure 332. Wet brake drive axle

There are three important sections to the wet-brake drive axle

- The center section of the axle houses the final drive gear set. The final drive includes the input pinion gear, the ring gear, and differential side gears.
- The next sections attach to the left and right of the center section. These sections house the axle shafts.
- The last sections are the axle hub assemblies. The hub assemblies house the brake assembly and wheel bearing.

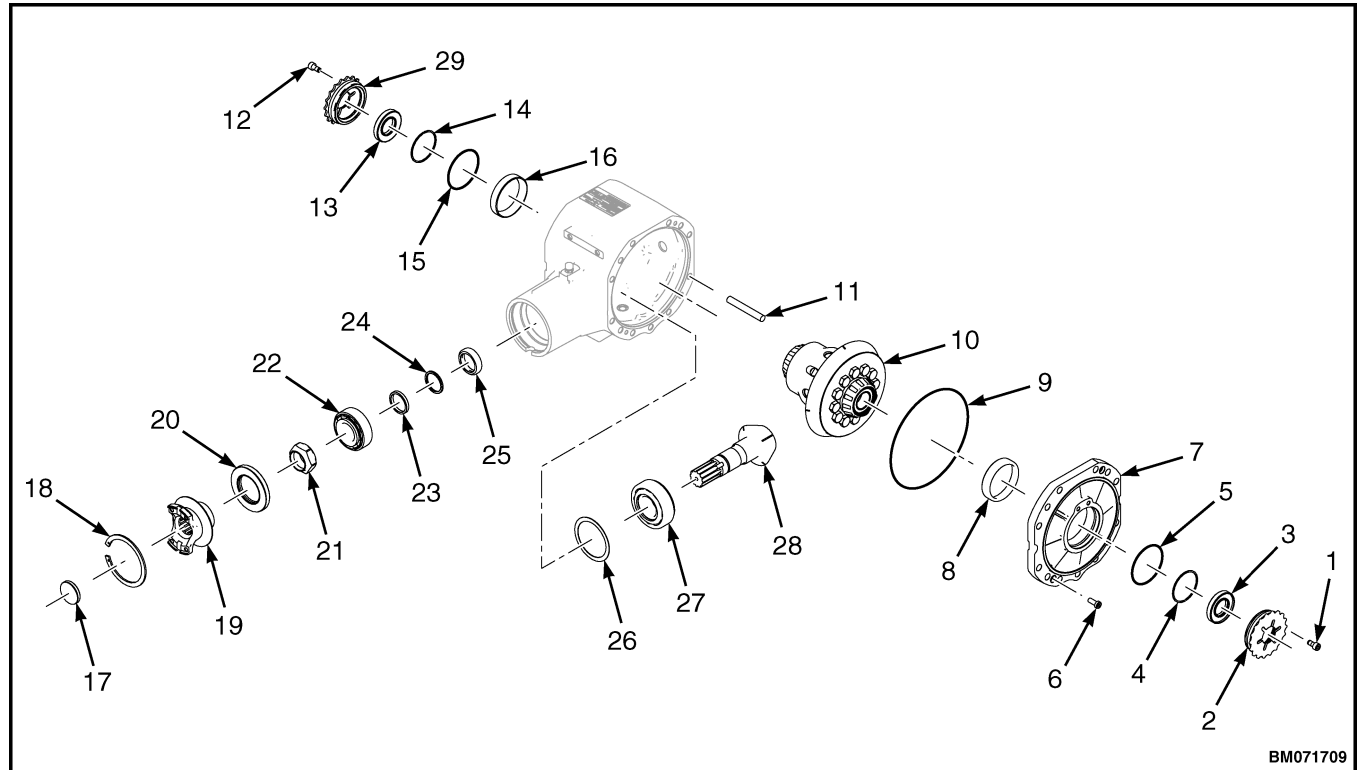
Mounting points are cast and machined to connect the axle to the truck frame, and front-end mast assembly.

The wet brake system components are internal to the wet brake axle. Also, the brake friction surfaces are bathed in oil. The wet-brake axle is quiet and can achieve greater stopping force.

The drive axle is vented at the top to allow air to escape and reduce foaming of the hydraulic oil. While the oil is shared by all sections of the drive axle the oil must past tightly tolerance mating components and seals. The oil lubricates, cools, and provides working pressure for the axle wet braking system. There is a fill port in the left and right axle section used for adding oil, to help ensure no section

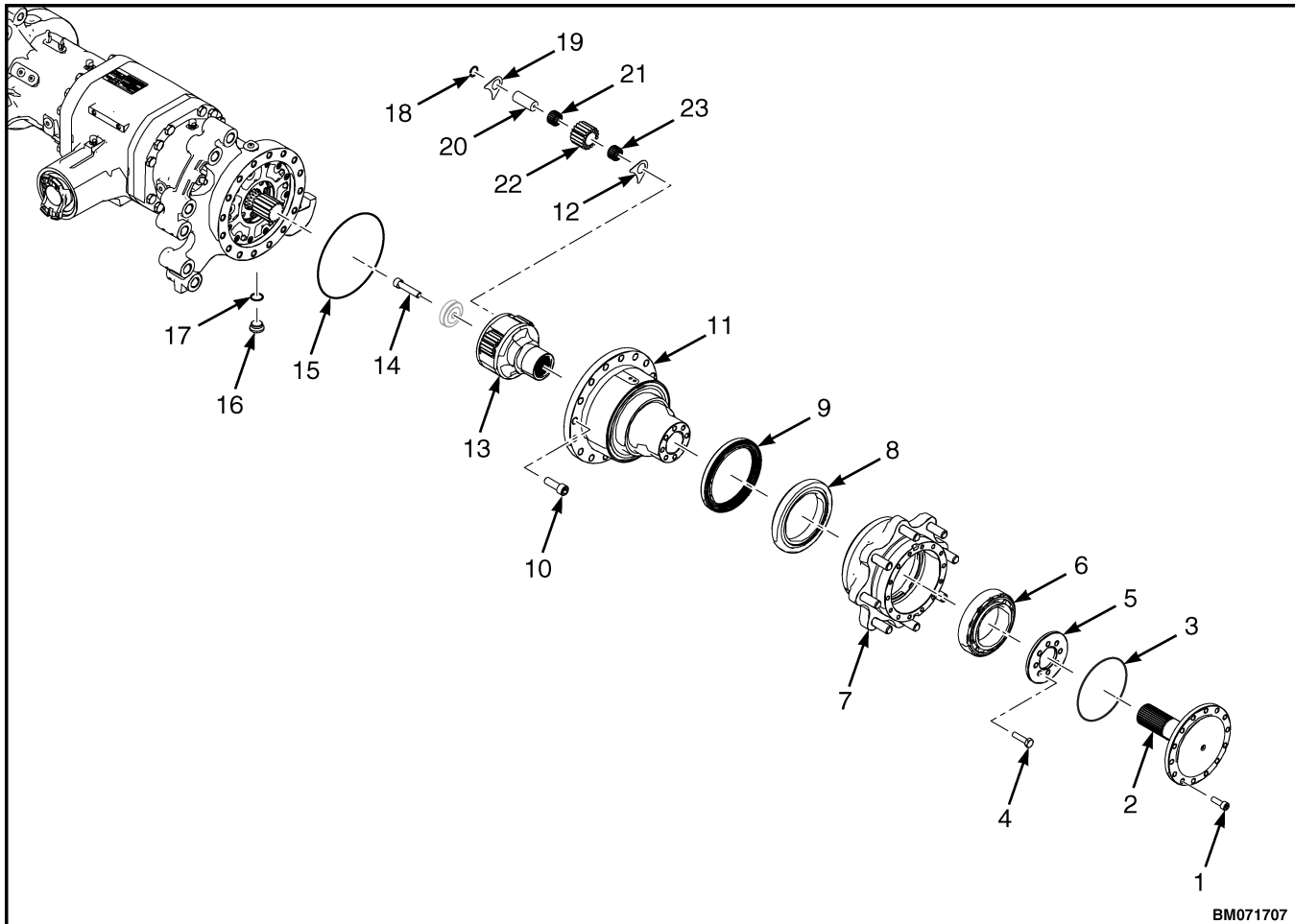
is lacking oil following a service. The force of the gears and brake effort can generate a lot of heat. The wet brake axle has strategically placed inlets and outlets for exchanging oil.

The center section houses the drive pinion, ring gear, and the differential assembly with gears and shims.



- | | | |
|-------------------|-----------------|-----------------------|
| 1. CAPSCREW | 11. STUD | 21. RING NUT |
| 2. ADJUSTMENT NUT | 12. CAPSCREW | 22. BEARING |
| 3. SEAL | 13. SEAL | 23. CALIBRATED SPACER |
| 4. SNAP RING | 14. SNAP RING | 24. CALIBRATED SPACER |
| 5. O-RING | 15. O-RING | 25. SPACER |
| 6. CAPSCREW | 16. BEARING CUP | 26. PINION SHIMS |
| 7. MIDDLE COVER | 17. CAP | 27. BEARING CUP |
| 8. BEARING CUP | 18. SNAP RING | 28. PINION |
| 9. O-RING | 19. FLANGE | 29. ADJUSTMENT NUT |
| 10. DIFFERENTIAL | 20. PINION SEAL | |

Figure 333. Center section components



- | | | |
|-------------------------|-----------------------|--------------------------|
| 1. CAPSCREW | 9. HUB SEAL | 17. O-RING |
| 2. HUB AXLE SHAFT | 10. CAPSCREW | 18. SNAP RING |
| 3. O-RING | 11. SPINDLE | 19. WASHER |
| 4. BOLT | 12. WASHER | 20. PIN |
| 5. SAFETY FLANGE | 13. PLANETARY CARRIER | 21. NEEDLE CAGE BEARINGS |
| 6. EXTERNAL BEARING CUP | 14. CAPSCREW | 22. GEAR |
| 7. HUB | 15. O-RING | 23. NEEDLE CAGE BEARINGS |
| 8. INTERNAL BEARING CUP | 16. OIL DRAIN PLUG | 24. WASHER |

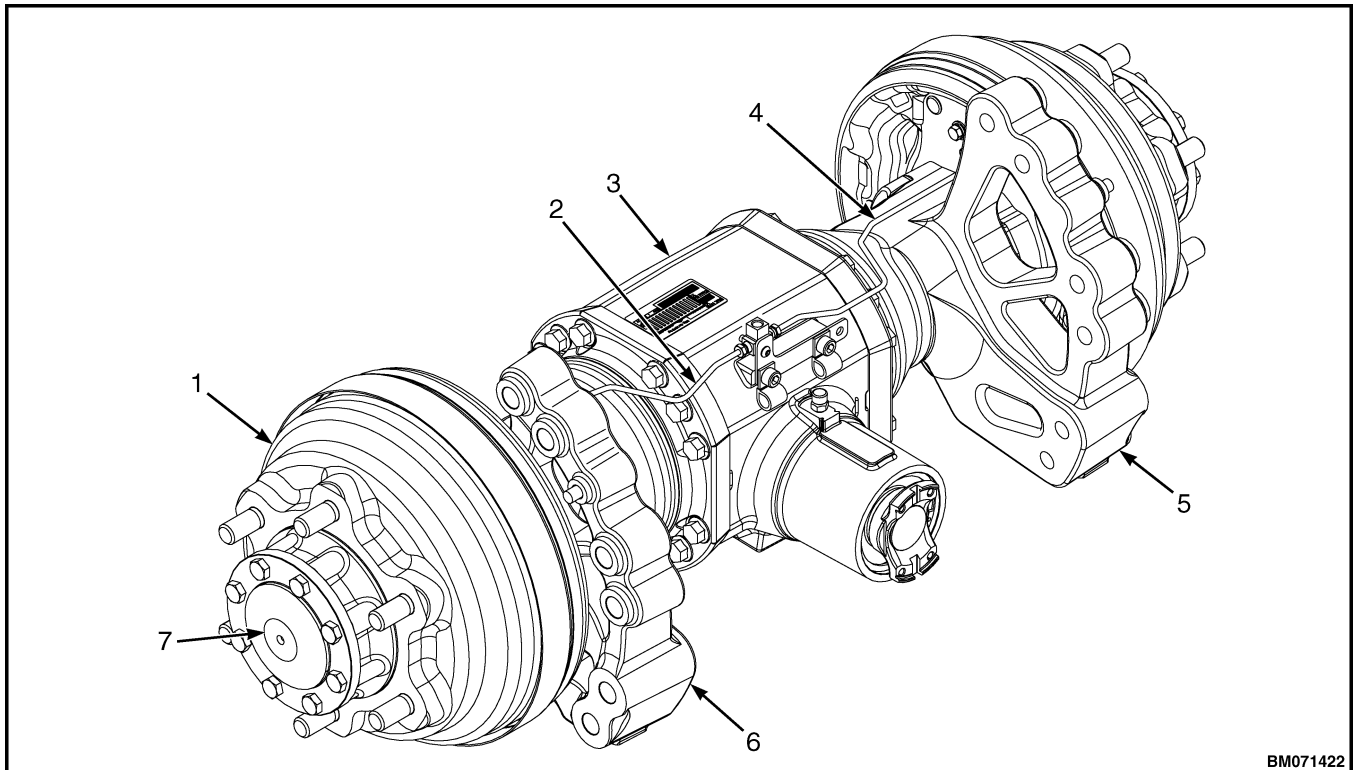
Figure 334. Wheel end components

DRY BRAKE AXLE DESCRIPTION 202001-162

DRY BRAKE AXLE

The drive axle takes transmission output shaft rotation and translates that rotation through the differential and planetary gear set to turn the wheels. The drive axle also facilitates the

mechanical braking for the truck. Two types of drive axle are available, dry brake and wet brake. This module will only discuss the dry brake axle. On dry brake axles the brake drums are located at the wheel ends. Dry drum brake axles use traditional brake shoes and pads that clamp on a drum to provide braking energy. Hardware configuration details are provided on the part identification plate mounted on the top face of the axle center section.



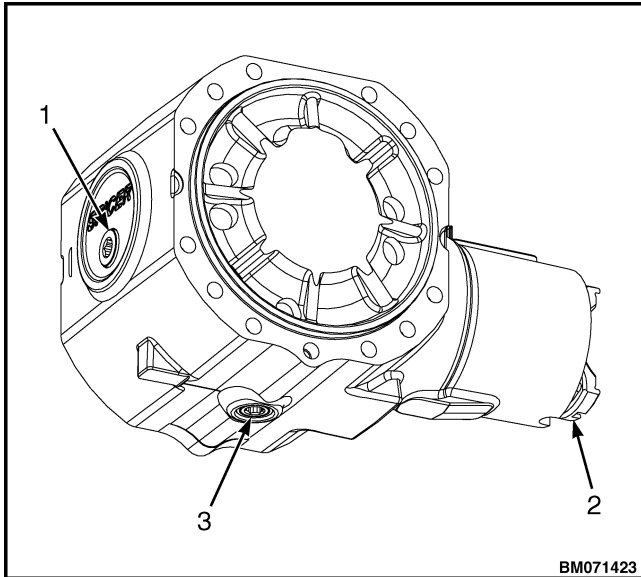
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NOTE: PARK BRAKE CABLES NOT SHOWN FOR CLARITY.

- | | |
|------------------------------|--------------------------|
| 1. DRIVE ASSEMBLY HUB, LH | 5. DRIVE AXLE HANGER, RH |
| 2. HYDRAULIC BRAKE LINE, LH | 6. DRIVE AXLE HANGER, LH |
| 3. DRIVE AXLE CENTER SECTION | 7. AXLE SHAFT, LH |
| 4. HYDRAULIC BRAKE LINE, RH | |

Figure 335. Dry Brake Axle with Drum Brakes

The driveshaft transfers power between the transmission and the drive axle. The driveshaft also allows the transmission and engine to be isolated from the frame. If the transmission and engine were mounted directly to the axle, their vibrations would be passed to the frame and the noise and vibration levels would be much higher.



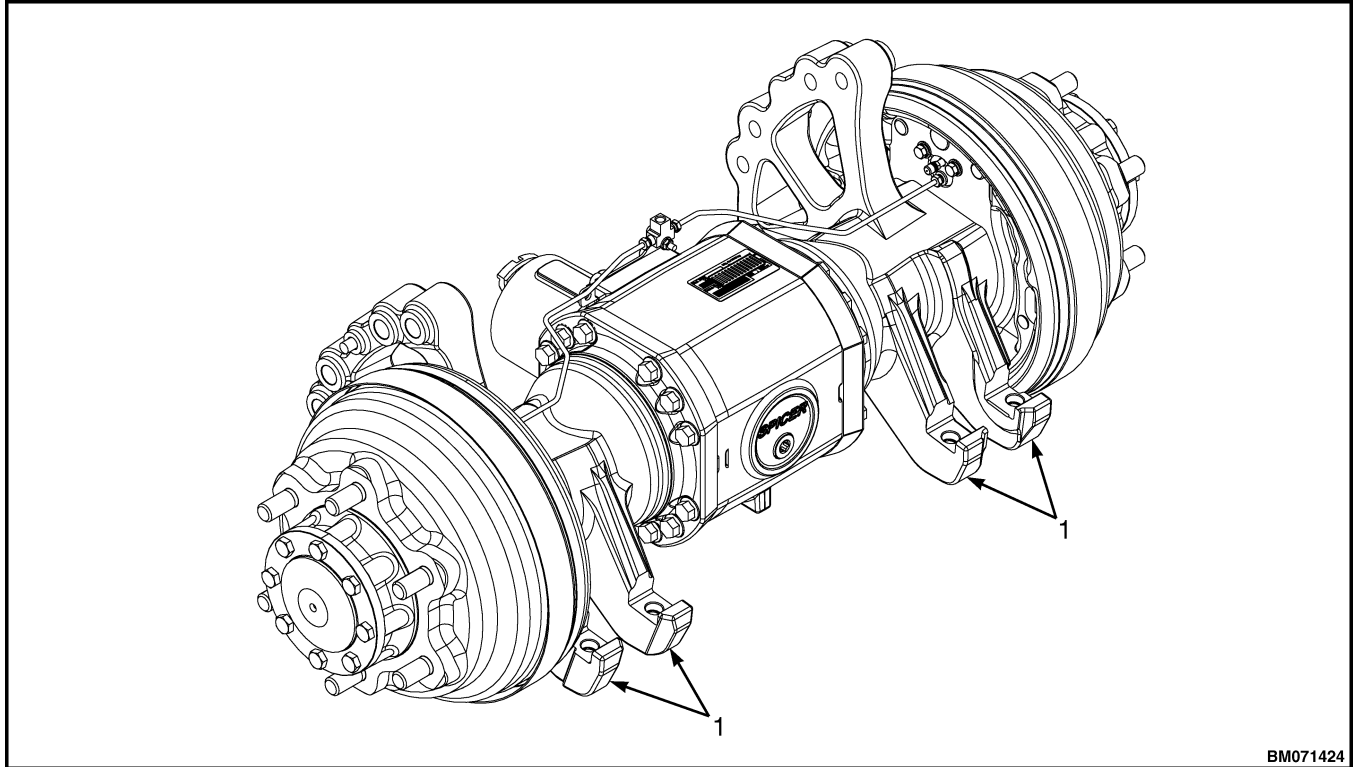
1. FILL PLUG
2. WING YOKE
3. DRAIN PLUG

Figure 336. Drive Axle Center Section

The differential receives power from the transmission via a short driveshaft connected to the input yoke. Power is sent through a drop box reduction gear to the pinion shaft. The ring and pinion is also a gear reduction which increases the torque to the drive wheels. The differential assembly permits the drive wheels to turn at different speeds when the truck is turning a corner. The ring and pinion gears are held in position in the differential housing. The axle shaft side gears are meshed to a spider gear assembly that is turned by the ring gear. The mounting points are cast and machined to connect the axle to the truck frame and front-end mast assembly.

There are three important sections to the dry brake drive axle:

- The center section of the axle houses the final drive gear set. The final drive includes the input pinion gear, the ring gear, and differential side gears
- The next sections attach to the left and right of the center section. These sections house the axle shafts.
- The last sections are the axle hub assemblies. The hub assemblies house the wheel bearings and provide a mounting surface for the drive wheels.



BM071424

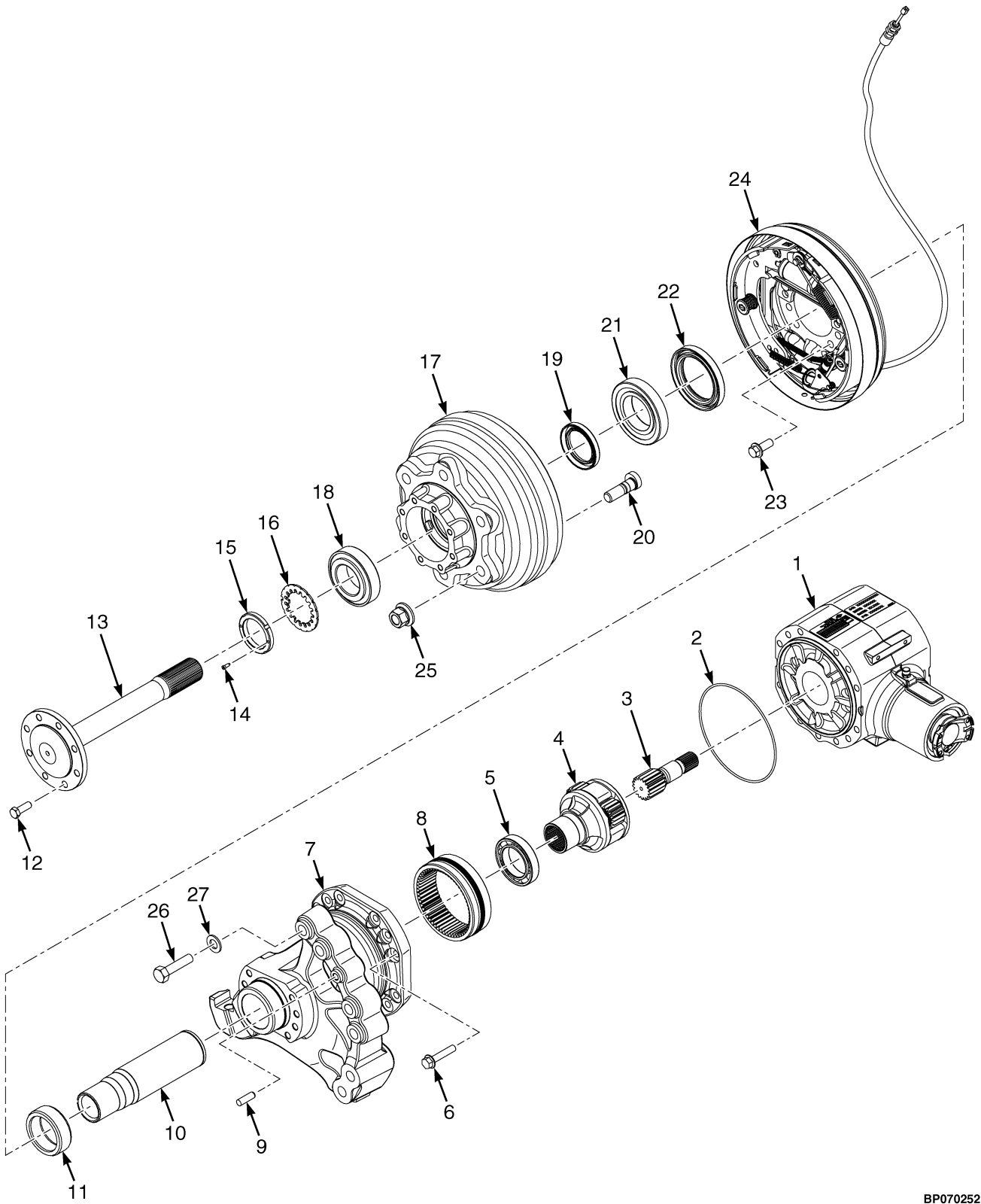
1. MAST J-HOOK HANGERS

Figure 337. Mast J-Hook Hangers

The drive axle is held to the truck by axle mounts fastened to the frame of the truck by six bolts. The drive axle is a structural element of the truck. When each hanger is bolted to the frame, it helps to provide rigidity to the truck frame. The outer ends of the spindles are the mounts for the wheel bearings. The wheel bearings are tapered roller bearings with the cups pressed into the hub and brake drum. The nut on the end of the spindle holds and adjusts the wheel bearings. The axle shafts are fastened to the hubs by capscrews. The back plate and brake assembly are fastened to the axle housing mounts. The axle housing provides the J-hook hangers for the mast. The outer wheel bearings are

lubricated with gear oil from the differential housing. The inner wheel bearings are lubricated with wheel bearing grease.

The dry brake system components include a set of brake shoes, a hydraulic wheel cylinder to move the brake shoes, and a brake drum to act against. Dry brake axles have a manual, foot activated and hand released park brake. The operator applies the park brake with a foot pedal located to the left of the service brake. To release the park brake the operator pulls the lever on the left hand side of the dash. Oil is shared through center section all the way out to the spindles.



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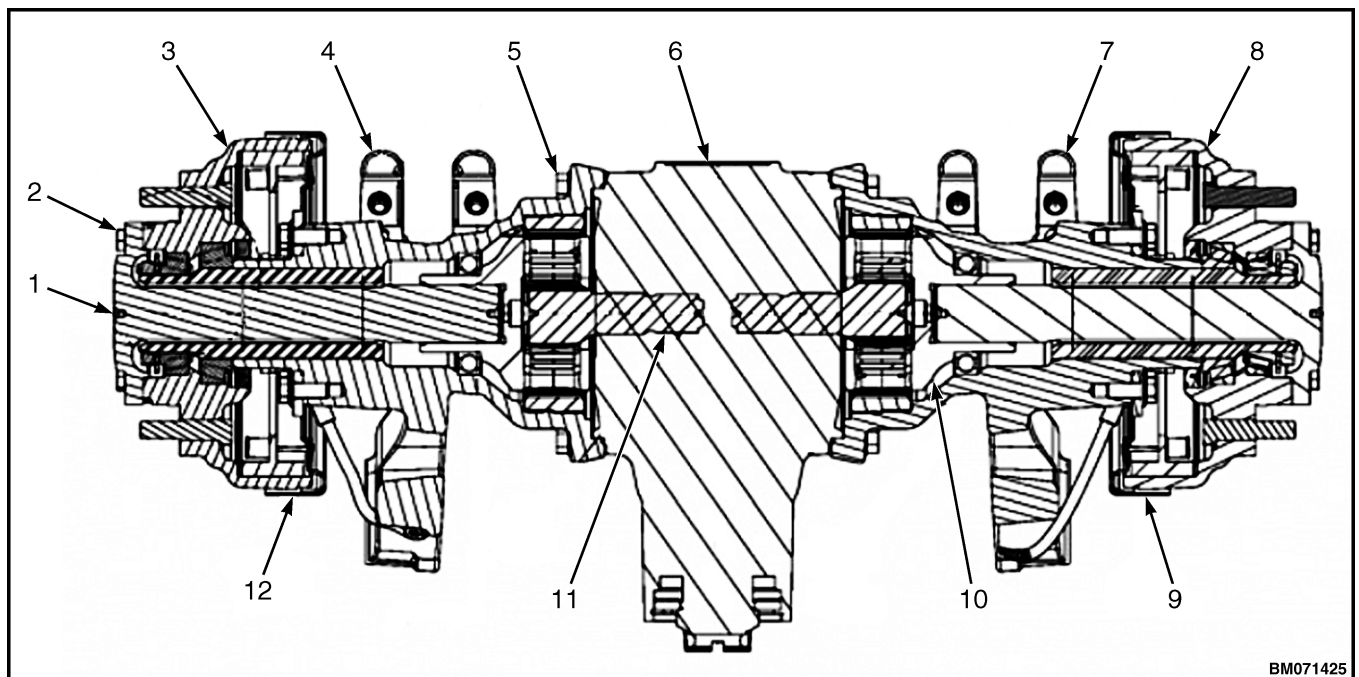
Figure 338. Dry Axle Assembly

Legend for Figure 338.

- | | | | |
|---------------------------------|----------------|-----------------------------|----------------|
| 1. DRIVE AXLE
CENTER SECTION | 8. RING GEAR | 15. NUT | 22. OIL SEAL |
| 2. O-RING | 9. DOWEL | 16. WASHER | 23. BOLT |
| 3. SHAFT | 10. SPINDLE | 17. DRIVE ASSEMBLY
HUB | 24. BRAKE ASSY |
| 4. PLANETARY GEAR | 11. SPACER | 18. BEARING SET,
TAPERED | 25. WHEEL NUT |
| 5. BALL BEARING | 12. CAPSCREW | 19. OIL SEAL | 26. CAPSCREW |
| 6. CAPSCREW | 13. AXLE SHAFT | 20. WHEEL STUD | 27. WASHER |
| 7. HANGER, LH | 14. SETSCREW | 21. BEARING SET,
TAPERED | |

The brake assemblies, hubs, wheel bearings, and seals are all serviceable in the truck. The hangers, ring gear, planetary, and stub shaft sun gear are

not serviceable in the truck. The drive axle center section must be replaced as a unit or rebuilt with the manufacturer's service procedures.



BM071425

- | | |
|------------------------------|----------------------------|
| 1. AXLE SHAFT | 7. HANGER, RH |
| 2. CAPSCREW | 8. DRIVE ASSEMBLY HUB |
| 3. DRIVE ASSEMBLY HUB | 9. BRAKE ASSEMBLY, RH |
| 4. HANGER, LH | 10. PLANETARY GEAR BEARING |
| 5. CAPSCREW | 11. PLANETARY GEAR SHAFT |
| 6. DRIVE AXLE CENTER SECTION | 12. BRAKE ASSEMBLY, LH |

Figure 339. Dry Brake Axle Cutaway

SYNCHRONOUS STEER AXLE

DESCRIPTION

202001-163

SYNCHRONOUS STEERING

Synchronous steering is a drive-by-wire function and there is no mechanical link connecting the steering wheel to the steer axle. Synchronous steering is enabled by a position sensor in the steering column, a position sensor on the steer axle, and the Vehicle System Manager (VSM) to translate the position feedback. Synchronous steering operates by knowing and utilizing both the steering wheel and steer axle positions. The steering wheel returns to the same position after completing a turn and the turning point of the wheel remains constant. This system maintains a consistent steering wheel position for improved hand placement during operation.

OPERATION

Without a mechanical connection between the steering wheel angle and the steer axle position, the relationship between the two may not be completely known or defined. The steering wheel angle for the straight-ahead driving condition changes over time. Typical drive-by-wire systems are programmed to constantly monitor steering wheel and steer axle position and adjust the position the steering wheel or steer axle to maintain a defined relationship between the two.

The steer axle position sensor provides feedback to the VSM. By knowing the wheel position the VSM and other control modules can respond, for example derate systems to reduce travel speed and improve stability without requiring the operator to make changes.

Synchronous steering may be used to bring the steering to a predetermined position for the straight ahead driving condition. The desired straight ahead driving position can be programmed via a user display and may be set by the operator to a comfortable straight ahead driving position.

Synchronous steering is part of the optional Dynamic Stability System (DSS). DSS is a system that enhances driver best practices and dynamically takes action to help maintain truck stability. DSS is composed of three key subsystems to help the operator: Lateral Stability, High-Lift Traction Control, and Corner Control. The Corner Control

system controls speed, acceleration, and deceleration during cornering maneuvers which helps reinforce proper operating practices. The steer axle position sensor provides feedback to the VSM to perform these actions and reduce travel speed and improve stability without requiring the operator to make changes.

COMPONENTS

The components of the synchronous steering system are: steering wheel sensor, steer axle position sensor, and VSM.

Steering Wheel Sensor

The steering wheel sensor (in conjunction with the steer axle position sensor) provides synchronous steering where the steering knob is synchronized with the steer axle. As a result the steering knob will come back to the same position while driving straight ahead. This system does so by utilizing the steering wheel sensor, an excess flow valve on the Steering Control Unit (SCU), and the steer axle position sensor. The straight ahead position of the steering wheel can set by the operator through the display in the Calibrations menu.

For more information, see Sensors and other components description.

Steer Axle Position Sensor

The steer axle position sensor is an integrated sensor mounted directly above the knuckle on the steer axle and directly measures steer wheel angle. This sensor is also used to activate cornering control of the DSS to reduce speed when turning for stability. The steer axle position sensor is used in conjunction with the steering wheel position sensor.

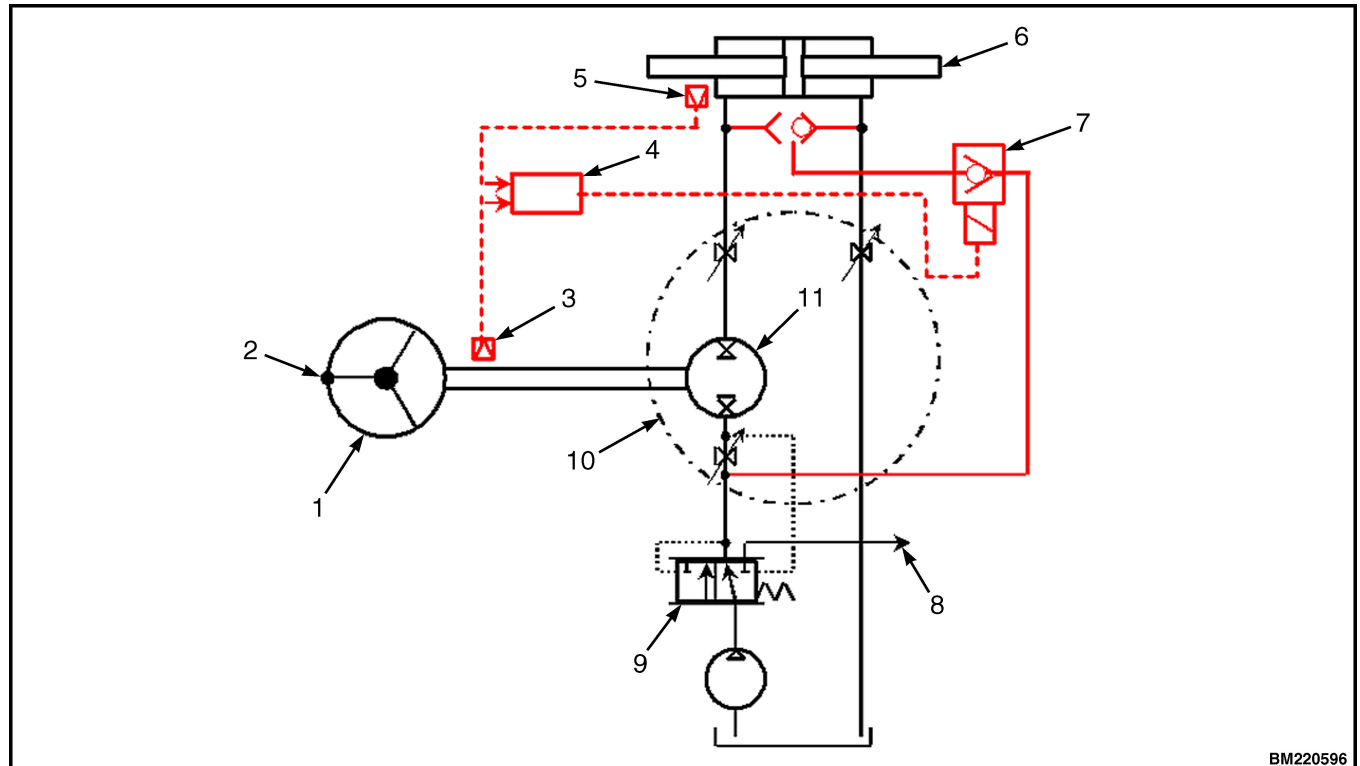
For more information, see Sensors and other components description.

NOTE: The steer axle sensor and harness are replaced as a single component.

CALIBRATION

The straight ahead position of the steering wheel can be set by the operator through the display in the calibrations menu.

SYNCHRONOUS STEERING HYDRAULIC SCHEMATIC



BM220596

- | | |
|-------------------------------|--------------------------------|
| 1. STEERING WHEEL | 7. SOLENOID VALVE |
| 2. SPINNER KNOB | 8. EXCESS FLOW |
| 3. STEERING WHEEL SENSOR | 9. PRIORITY VALVE |
| 4. CONTROLLER | 10. LOAD SENSING STEERING UNIT |
| 5. STEER AXLE POSITION SENSOR | 11. ROTARY VALVE |
| 6. STEER AXLE ASSEMBLY | |

Figure 340. Hydraulic Schematic

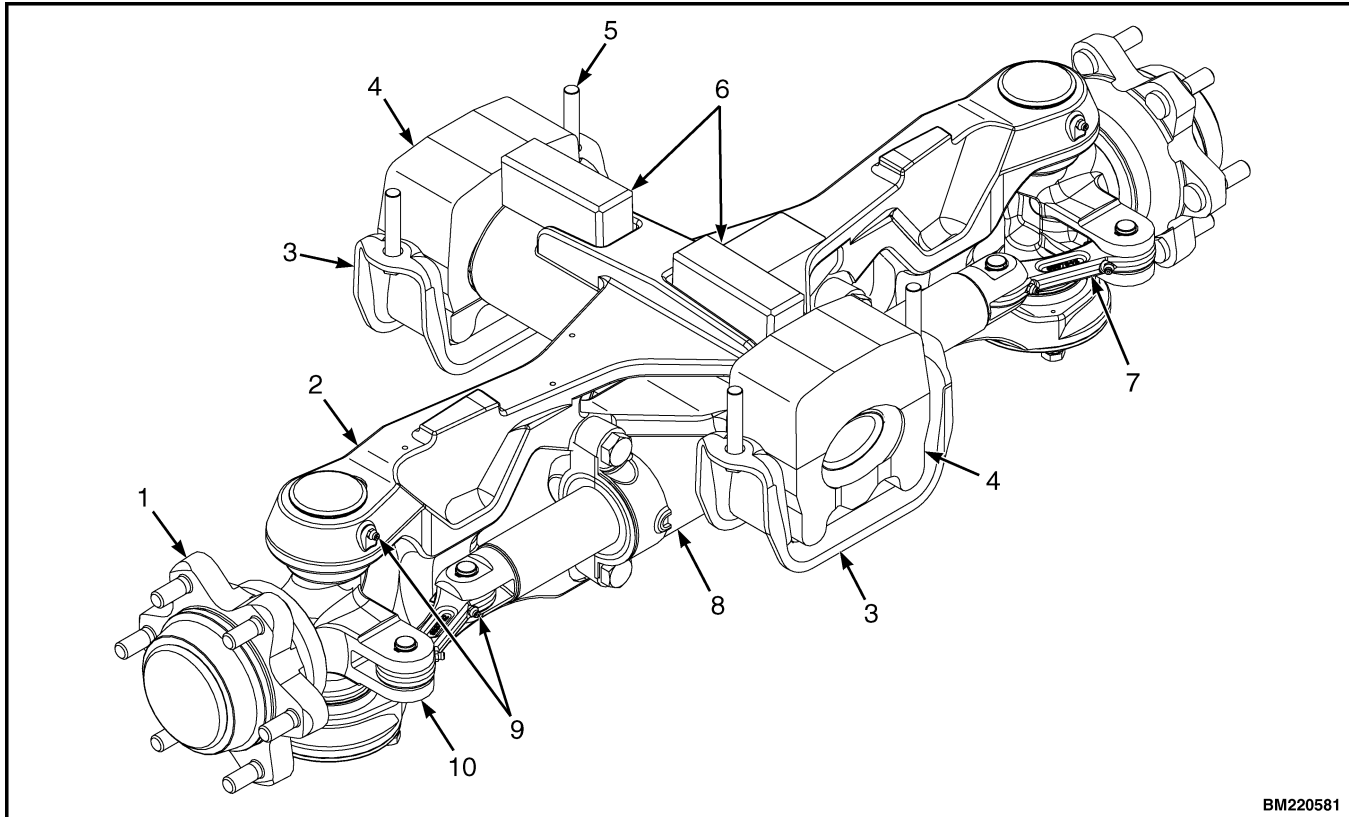
NON-SYNCHRONOUS STEER AXLE DESCRIPTION 202001-164

NON-SYNCHRONOUS STEER AXLE

The steer axle assembly consists of an axle frame, steering cylinder, spindle and hub assemblies, attaching brackets, top bushing blocks, and center

pivot mount bushings. The two center pivot mounts isolate the axle from the frame and permit the steering axle to articulate as the lift truck travels over rough surfaces.

The steer axle assembly controls the position of the wheels. All hydraulic circuits use a common hydraulic tank, hydraulic pump, return filter assembly, and breather.



BM220581

- | | |
|--------------------------------|----------------------|
| 1. WHEEL HUB | 6. TOP BUSHING BLOCK |
| 2. STEER AXLE | 7. TIE ROD |
| 3. STEER AXLE MOUNTING BRACKET | 8. STEERING CYLINDER |
| 4. CENTER PIVOT MOUNT BUSHING | 9. GREASE FITTING |
| 5. CAPSCREW | 10. SPINDLE |

Figure 341. Non-Synchronous Steer Axle

The steer axle assembly is comprised of an axle frame, steering cylinder, tie rods, and spindle and hub assemblies. The steer axle is articulated and is connected to the counterweight by mounting brackets and center pivot mount bushings. The center pivot mount bushings permit the steer axle to move in the frame mount when the lift truck travels over rough surfaces.

The end caps of the steering cylinder are also the mounts for the cylinder and are held to the shell by the mount cap screws. There are O-rings, seals, and wipers in the end caps to seal the caps to the shell and rod. The ends of the piston rod extend from both ends of the cylinder. A single piston and the seal are at the center of the rod. Oil pressure on one side of the piston moves the piston in the bore. The piston pushes an equal amount of oil from the opposite side of the cylinder.

When the piston reaches the end of the stroke, a relief valve in the steering circuit controls the oil pressure. The tie rods connecting the spindle arms to the cylinder are not adjustable.

Each spindle turns on two tapered roller bearings in mounts in the axle frame. The preload on the bearings is controlled by shims at the lower bearing cap.

The wheels rotate on two tapered roller bearings and are held on the spindles by a castle nut. The bearing preload of the wheels is adjusted by the castle nut. The grease seals protect the bearings from dirt and water. Wear sleeves protect the hub from wear by the seals.

Steer Axle Components

The steer axle is a beam as opposed to a tube assembly. The steering cylinder is attached to the center channel of the axle beam. The cylinder piston rod connects to the tie rod and the tie rod connects to the spindle assembly. The spindle mates with the wheel hub assemblies.

There are two mounting points where the center of the steer axle mounts to the counterweight. The center pivot mount bushings allow the assembly to pivot as the wheel end reacts to surface irregularities.

Top Bushing Blocks

Two rubber bushing blocks (item 6, Figure 341) are fitted on the top of the steer axle. These rubber bushing blocks help provide cushion to reduce harsh vibration transferred to the truck frame.

Center Pivot Mount Bushings

Two rubber center pivot mount bushings (item 4, Figure 341) are held in place by the steer axle mounting brackets. One pivot mount bushing is located at the front of the steer axle and the other is located at the rear. The rubber pivot mount bushings have a hole in the center. The hole allows

the steer axle to pivot at the mount and articulate up and down at the wheel ends.

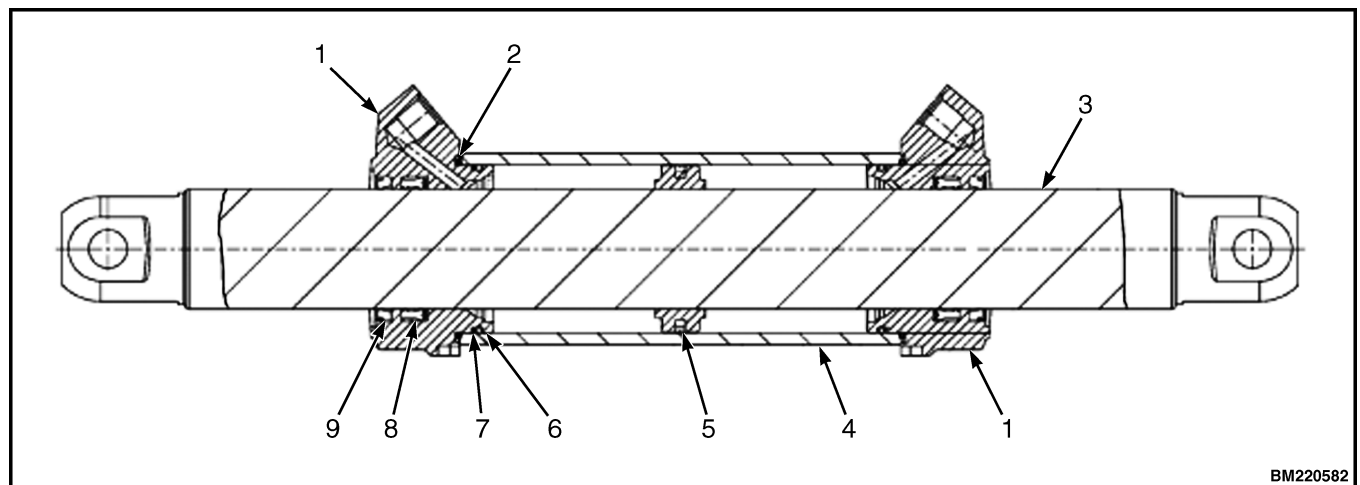
Steer Axle Mounting Brackets

The steer axle mounting brackets (item 3, Figure 341) hold the center pivot mount bushings and bolt the steer axle to the counterweight. One bracket with pivot mount bushing is located at the front of the steer axle and the other is located at the rear.

Steering Cylinder

The steering cylinder moves the steer wheels in the control direction. The steering cylinder has two parts; a single piston, and a single piston rod. The direction the piston rod moves is determined by which port is the acting supply and which is the acting exhaust port. Hydraulic oil acts on either side of the single piston, to move the piston rod in the control direction. Each end of the piston rod connects to a tie rod and the tie rod connects to spindle.

NOTE: The steering cylinder needs to be inspected for leaks at the wiper seals, hydraulic hoses, and fittings during periodic maintenance.



1. CYLINDER END CAP
2. O-RING
3. PISTON ROD
4. CYLINDER TUBE
5. CYLINDER PISTON SEAL

6. O-RING
7. BACK-UP RING
8. PISTON ROD SEAL
9. PISTON ROD WIPER

Figure 342. Steering Cylinder

Tie Rods

The tie rods (item 7, Figure 341) connect the steering cylinder to the spindle assemblies. One end of the tie rod is connected to the piston rod end of the steering cylinder. The other end of the tie rod connects to spindle assembly.

NOTE: The tie rods have grease fittings and need to be greased according to the periodic maintenance schedule.

Spindle Assembly

The spindle assembly (item 10, Figure 341) consists of the machined spindle, wheel hub, and wheel

bearings. The spindle assembly has grease fittings at the upper and lower pivot points.

The steering knuckle has a machined boss on the top and bottom that mate with a bearing cap. The knuckle is pressed into the steer axle ends.

Wheel Hub

Two sets of bearings are pressed into the wheel hub (item 1, Figure 341) and mate with the spindle on the steering knuckle. The hub is secured to the spindle with a washer, castle nut, and cotter pin.

POWERTRAIN PROTECTION SYSTEM

The Powertrain Protection System is designed to prevent damage to the engine and transmission from overheating. The Powertrain Protection System features sensors that monitor the transmission oil temperature, engine coolant temperature, engine oil pressure and optionally, engine coolant level, to ensure that correct specification levels are maintained.

There are two options for Powertrain Protection Systems:


- Powertrain Protection System (Standard on all trucks)
- Advanced Powertrain Protection System (Optional)

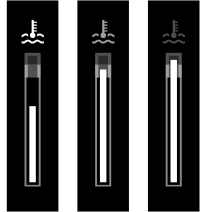
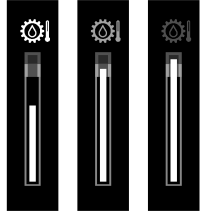
All trucks are shipped with these standard Powertrain Protection System features:


- Engine oil pressure sensor
- Engine coolant temperature sensor
- Transmission oil temperature sensor

Optional Advanced Powertrain Protection System offers these features:

- Engine oil pressure sensor
- Engine coolant temperature sensor
- Transmission oil temperature sensor
- Low coolant level sensor

Sensor	Function	Display Icon	Description/Procedure
Engine oil pressure sensor	Monitors engine oil pressure. Engine will shutdown when the engine oil pressure is below the minimum operating threshold. The truck electrical system will initiate a 30 second countdown prior to shutdown of engine. Illuminates an icon on the display when the engine oil pressure is below the minimum operating threshold.	 BO210764	For further description, see Oil Pressure Sensor in this manual. For service procedure, see Oil Pressure Sensor in Electrical, software, and controls 2200SRM2304.

Sensor	Function	Display Icon	Description/Procedure
<p>Engine coolant temperature sensor</p>	<p>Monitors engine coolant temperature. Engine will shutdown when the engine coolant temperature rises above operating threshold of 116°C (241°F). Illuminates an icon on the display when the engine coolant temperature rises above operating threshold.</p>	 <p>HO191592</p>	<p>For further description, see Engine Coolant Temperature (ECT) Sensor in this manual. For service procedure, see Engine Coolant Temperature (ECT) Sensor in Electrical, software, and controls 2200SRM2304.</p>
<p>Transmission oil temperature sensor</p>	<p>Monitors transmission oil temperature. Transmission will shift into NEUTRAL when the transmission oil temperature rises above operating threshold of 115°C (239°F). Illuminates an icon on the display when the engine coolant temperature rises above operating threshold.</p>	 <p>HO191593</p>	<p>For further description, see Pressure Sensor in this manual. For service procedure, see Temperature Sensor in Electrical, software, and controls 2200SRM2304.</p>

Sensor	Function	Display Icon	Description/Procedure
Low coolant level sensor (Optional)	Monitors engine coolant level. Engine will shutdown when the coolant level drops below the operating threshold. Illuminates an icon on the display when the engine coolant temperature drops below the operating threshold.	 <p>BO210778</p>	For further description, see Low Coolant Level Sensor. For service procedure, see Low Coolant Level Sensor in Electrical, software, and controls 2200SRM2304.

Cooling

FAN DESCRIPTION

202001-165

FAN (RADIATOR COOLING)

High cooling efficiency is achieved by a composite material pusher type fan (6- or 7- blade) and a shroud design that directs cooling fan air to the radiator. The cooling fan may be either a conventional crankshaft belt driven version or an optional hydraulic belt driven version.

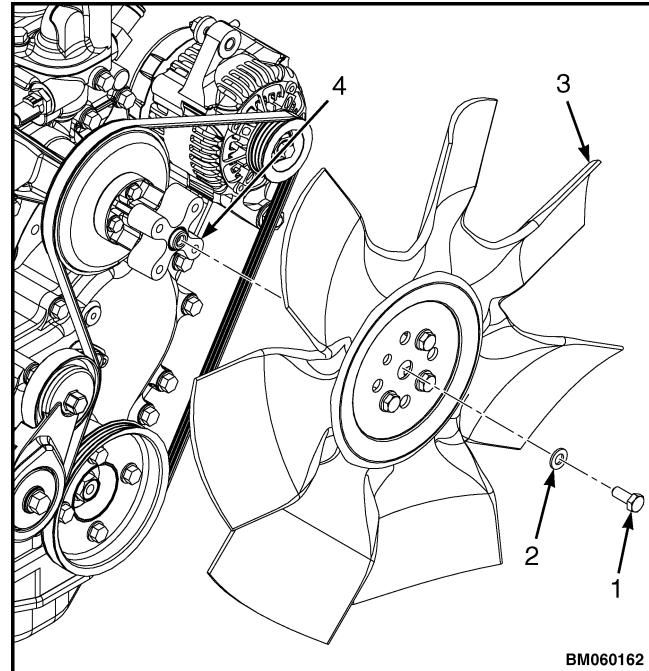


WARNING

DO NOT try to repair a damaged fan. If a fan has a bent blade or is cracked, install a new fan. A damaged fan can break during use and cause damage or serious injury.

Crankshaft Belt Drive Fan

The fan attaches to the engine and is driven by the rotation of the engine crankshaft via a pulley and belt drive system. The fan causes air to flow through the radiator and reduces the temperature of the coolant. The fan is used to provide airflow through the radiator at all engine speeds. The cooling fan is driven by a ribbed stretch belt.



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1. FAN MOUNTING CAPSCREW
2. WASHER
3. FAN
4. FAN PULLEY SPACER

Figure 343. Crankshaft Belt Drive Fan

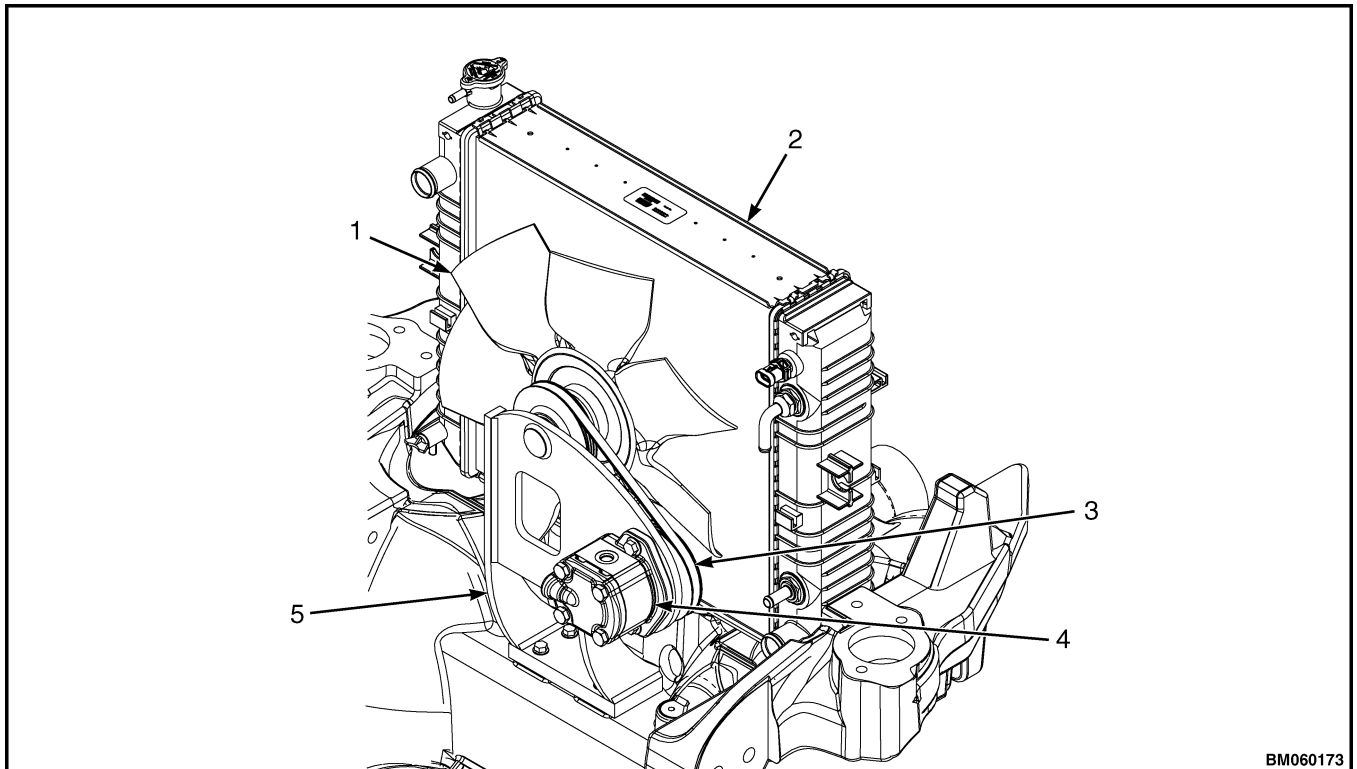
Hydraulic Belt Drive Fan

The optional hydraulic fan drive system requires the truck be equipped with the E-hydraulics option and a variable displacement pump. The fan and hydraulic motor are attached to the fan mount which is bolted to the frame. The fan motor sheave drives the fan belt and fan. A dedicated controller and wire harness are associated with the hydraulic fan drive system. The fan is driven by a bi-directional hydraulic motor mounted to the frame and operates at speeds between 500-3,500 RPM.

The system interfaces with the truck CANbus to read engine RPM, engine coolant temperature, and transmission oil temperature. The software controls the fan speed to maintain coolant temperatures at a desired level. Based on the temperature targets the software can speed up or slow down the fan speed as needed. Every 20 minutes the fan goes through an automatic reversal cycle. The fan is run in reverse for 20 seconds at full speed to clear the radiator and engine compartment of debris. The fan reversal cycle can be initiated manually by a rocker switch located on the dash.

The hydraulic fan drive system consists of the following components:

- Electro-hydraulic control valve with Load Sense port
- Hydraulic fan drive manifold and hoses
- Fan assembly with hydraulic motor
- Controller and wire harness
- Software



1. FAN
2. RADIATOR
3. BELT

4. HYDRAULIC MOTOR
5. FAN ASSEMBLY MOUNT

Figure 344. Hydraulic Belt Drive Fan

COOLING SYSTEM DESCRIPTION 202001-166

COOLING SYSTEM

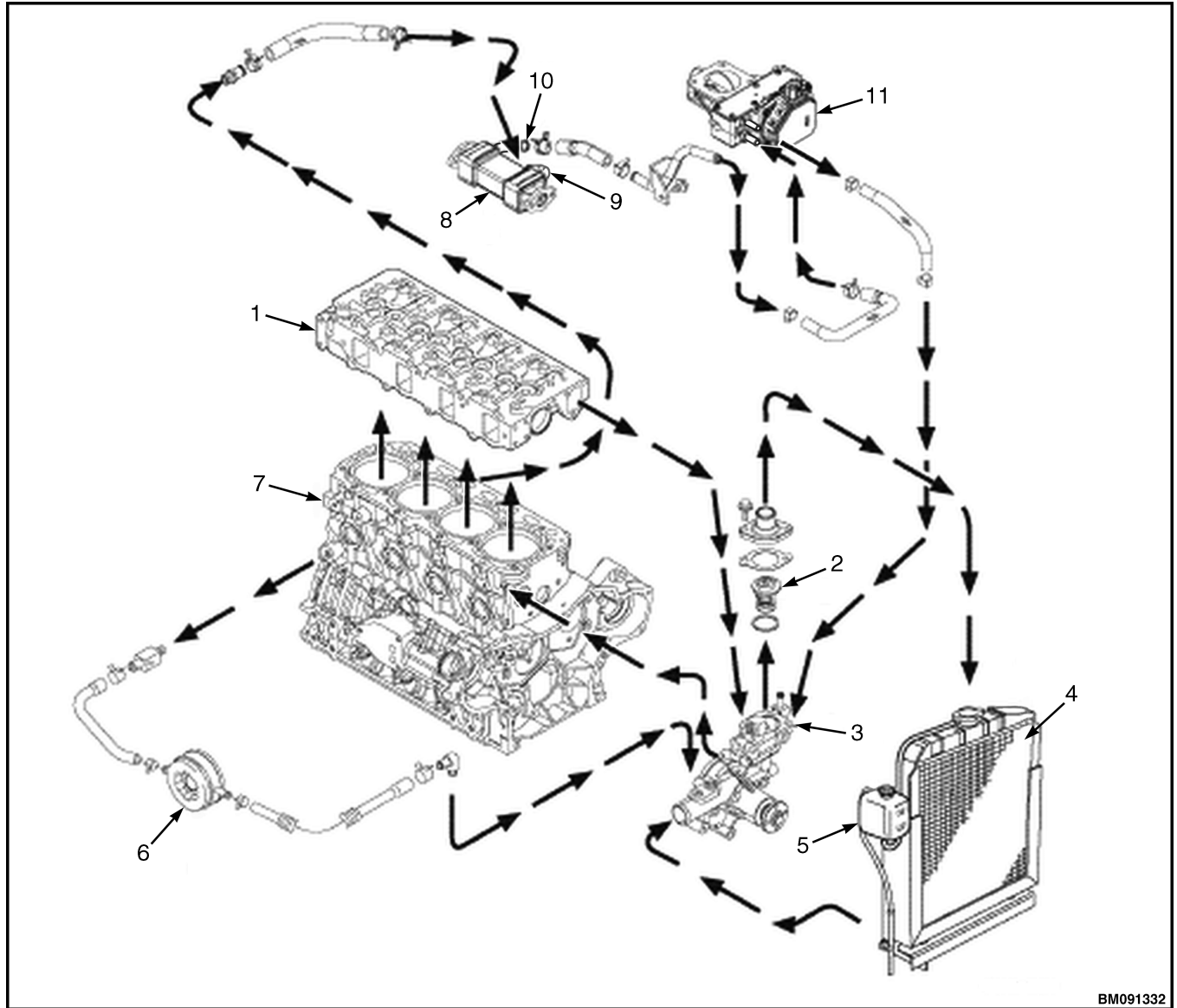
The engine cooling system is comprised of the radiator, radiator cap, engine cooling fan, thermostat, engine coolant pump, coolant recovery reservoir, and coolant. The standard cooling system configuration uses an engine driven fan (6 blade pusher type) to provide the necessary air flow across the radiator to dissipate heat from the system. An optional hydraulic motor driven fan is available (see Fan description for details).

The purpose of the cooling system is to control the operating temperature of the engine and

transmission. A centrifugal engine coolant pump circulates coolant through passages in the engine block and radiator. A coolant temperature sensor is installed in the coolant outlet fitting on the engine. As the coolant flows through the radiator, the fan moves air through the radiator to cool the system.

The Diesel Oxidation Catalyst (DOC) engine also requires a Charge Air Cooler (CAC) system. The CAC is part of the radiator. Incoming air goes through a filter, through the turbo and into the radiator to be cooled before it enters the engine intake manifold (see Radiator).

The basic cooling systems are available with an optional radiator screen located between the fan and the radiator core that will collect debris from the air stream prior to the radiator (see Radiator).



BM091332

- | | |
|---------------------------------|---------------------------------|
| 1. CYLINDER HEAD | 7. CYLINDER BLOCK |
| 2. THERMOSTAT | 8. EGR COOLER |
| 3. COOLANT PUMP | 9. EGR COOLER INLET SIDE HOSE |
| 4. RADIATOR | 10. EGR COOLER OUTLET SIDE HOSE |
| 5. COOLANT RECOVERY RESERVOIR | 11. EXHAUST THROTTLE (OPTIONAL) |
| 6. ENGINE OIL COOLER (OPTIONAL) | |

Figure 345. Cooling System Diagram

Radiator

The radiator (item 4, Figure 345) acts as a heat exchanger. As the engine coolant circulates through the cylinder block it absorbs heat. The heat in the engine coolant is dissipated in the radiator. As the engine cooling fan circulates air through the radiator, the heat is transferred to the air. The aluminum radiator is also an oil cooler. Oil from the transmission flows through a second set of coils in the radiator tank to help reduce transmission oil temperature.

Radiator Cap

The radiator cap controls the cooling system pressure. The cooling system is pressurized to raise the boiling point of the engine coolant. As the engine coolant temperature rises, the system pressure and the coolant volume increases. When the pressure reaches a preset value, the release valve in the radiator cap opens and the excess engine coolant flows into the coolant recovery reservoir. As the engine coolant temperature is reduced, the system pressure and volume is reduced. The vacuum valve in the radiator cap opens allowing the engine coolant to flow from the coolant recovery reservoir tank back into the radiator.

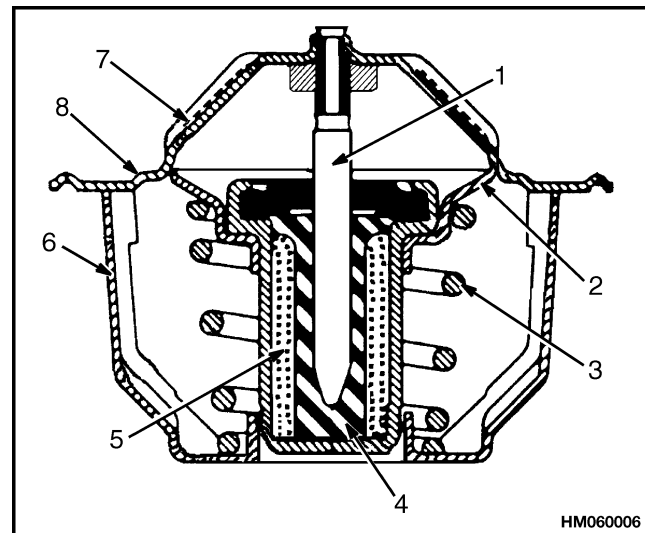
The radiator cap has a pressure valve and a vacuum valve. The pressure valve is held against its seat by a spring. The pressure valve opens when the pressure in the cooling system exceeds 103 kPa (15 psi). The vacuum valve is held against its seat by another spring. The vacuum valve opens to relieve the vacuum created when the coolant temperature decreases.

Cooling Fan

The fan is used to provide airflow through the radiator at all engine speeds. The fan is a pusher type and is installed on a separate hub. The engine cooling fan is driven by a V-belt which is powered by the crankshaft V-pulley. An optional hydraulic motor is also available to drive the cooling fan (see Fan description).

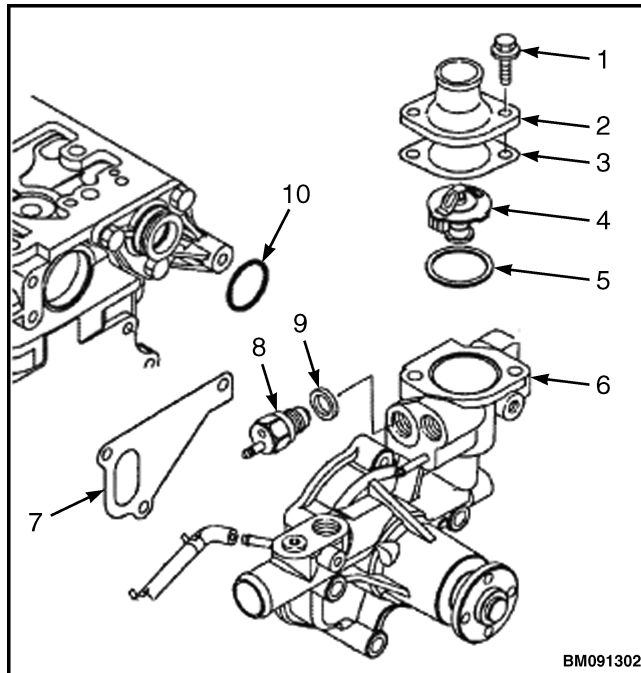
Thermostat

The thermostat (item 2, Figure 345) is a device that controls coolant flow by opening and closing to regulate coolant temperature. The thermostat uses a wax pellet to control its operation. The wax pellet expands when it is heated and contracts when it is cold. When heated, the wax pellet pushes on the piston, causing the valve in the thermostat to open. As the wax pellet cools, it contracts and lets a spring close the valve. When the engine is cold, no engine coolant flows through the radiator, the coolant circulates only through the engine. Once the engine reaches its operating temperature, the thermostat opens and allows the engine coolant to circulate through the radiator. The opening and closing of the thermostat helps keep the coolant within the operating limits of the system.



- | | |
|---------------|----------------|
| 1. PISTON | 5. WAX PELLETT |
| 2. VALVE SEAT | 6. FRAME |
| 3. SPRING | 7. FLANGE |
| 4. DIAPHRAGM | 8. VENT HOLE |

Figure 346. Thermostat Cross-Section Example

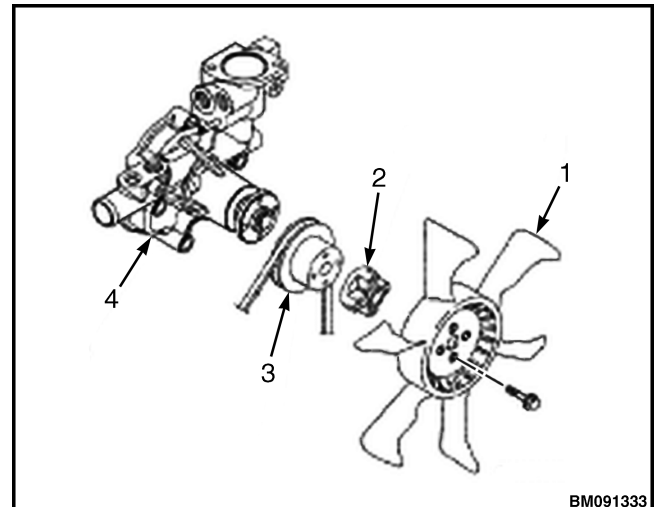


- | | |
|----------------------------|------------------------------|
| 1. THERMOSTAT COVER BOLT | 6. COOLANT PUMP COVER GASKET |
| 2. THERMOSTAT COVER | 7. COOLANT PUMP GASKET |
| 3. THERMOSTAT COVER GASKET | 8. TEMPERATURE SWITCH |
| 4. THERMOSTAT | 9. TEMPERATURE SWITCH GASKET |
| 5. THERMOSTAT O-RING | 10. COOLANT PUMP O-RING |

Figure 347. Thermostat and Coolant Pump

Coolant Pump

The centrifugal-type coolant pump (item 6, Figure 347) is installed at the front of the engine block. The inlet for the pump is connected to the bottom of the radiator by a hose. From the pump, coolant passes through the passages in the engine block to the top of the radiator. The coolant pump circulates the engine coolant through the cylinder block and the cylinder head and returns the engine coolant to the radiator.



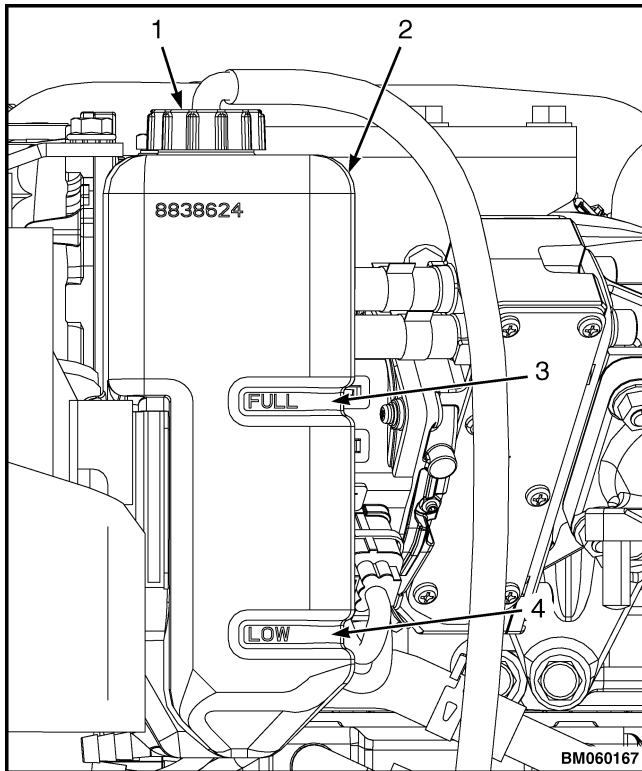
- | |
|-----------------|
| 1. FAN |
| 2. SPACER |
| 3. V-PULLEY |
| 4. COOLANT PUMP |

Figure 348. Coolant Pump and Fan

Coolant Recovery Reservoir

The coolant recovery reservoir (item 5, Figure 345) contains the overflow of engine coolant from the radiator. As the engine gets hot the coolant expands. During expansion coolant moves from the radiator to the reservoir. When the engine stops the coolant becomes cool and contracts. Coolant in the reservoir then flows back into the radiator.

NOTE: If engine coolant needs added to the system, add it to the reserve tank not the radiator.



1. CAP
2. COOLANT RECOVERY RESERVOIR
3. FULL MARK
4. LOW MARK

Figure 349. Reserve Tank

Coolant

One method of heat transfer for the engine is by conduction. Since engine temperatures are highest where combustion takes place a network of coolant passages are located around the combustion

chambers in the cylinder head and around the cylinder walls in the engine block. The engine coolant flows through these passages and extracts the heat. The coolant is formulated with a chemical composition where the boiling point is raised above that of water. The coolant is allowed to increase in pressure above atmosphere as it approaches its boiling point.

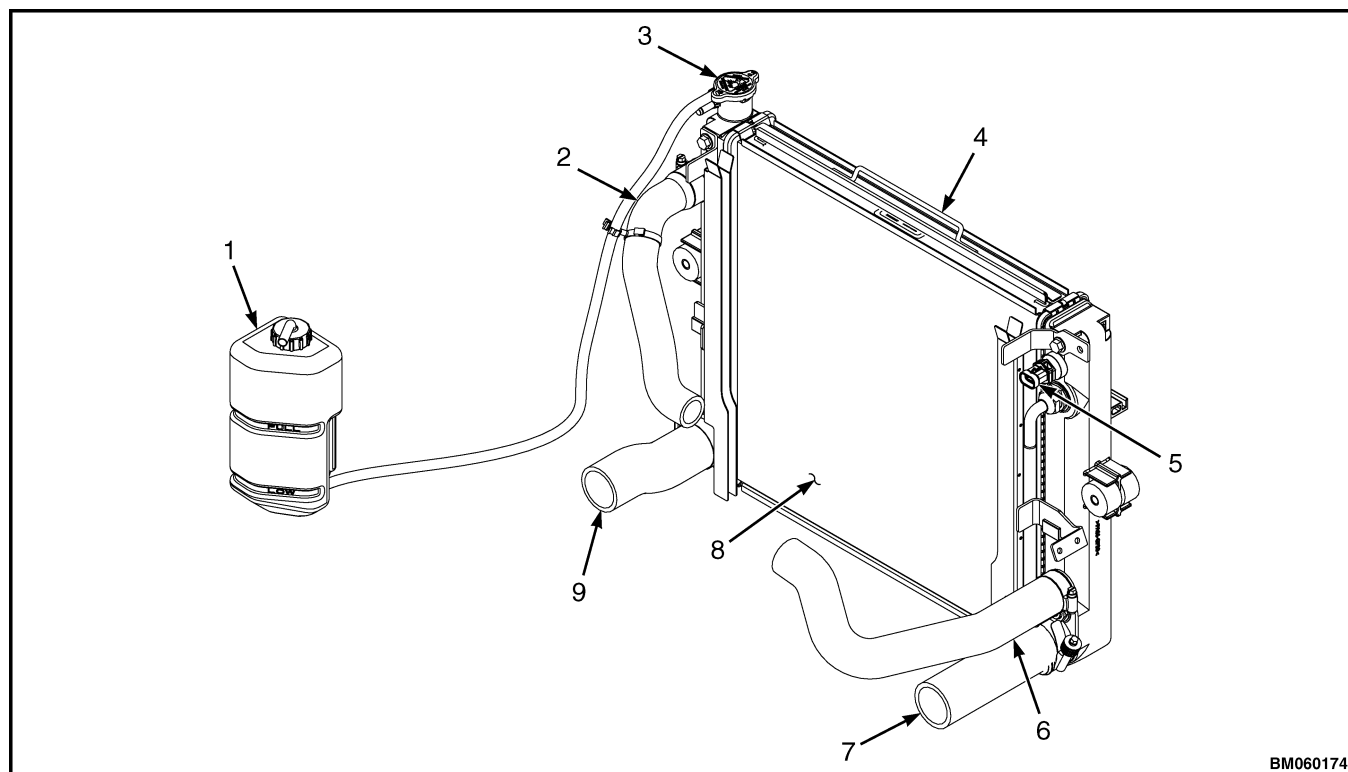
The coolant is a mixture of water and antifreeze. The antifreeze prevents the coolant from freezing in cold weather, and thereby preventing damage to the engine and radiator. The antifreeze also prevents rust and lubricates the water pump.

RADIATOR DESCRIPTION 202001-167

RADIATOR

The radiator is the heat exchanger for the cooling system. The fan causes air to flow through the radiator and reduces the temperature of the coolant. The auxiliary coolant reservoir is connected to the radiator by a hose. As the engine gets hot the coolant expands. During expansion, coolant moves from the radiator to the reservoir. When the engine stops, the coolant becomes cool and contracts. Coolant in the reservoir then flows back into the radiator. In this way, the radiator is kept full with coolant during normal operation. The aluminum radiator is also an oil cooler. Oil from the transmission flows through a second set of coils in the radiator tank to help reduce transmission oil temperature.

Engines with the Diesel Oxidation Catalyst (DOC) require the use of a Charge Air Cooler (CAC).



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- | | |
|-------------------------------|------------------------|
| 1. COOLANT OVERFLOW RESERVOIR | 6. LOWER RADIATOR HOSE |
| 2. UPPER RADIATOR HOSE | 7. CAC COLD SIDE |
| 3. RADIATOR CAP | 8. RADIATOR |
| 4. RADIATOR SCREEN AND HANDLE | 9. CAC HOT SIDE |
| 5. COOLANT LEVEL SENSOR | |

Figure 350. Radiator Assembly with CAC

Radiator Cap

The radiator cap (item 3, Figure 350) is a pressure-vent type that lets the pressure in the cooling system increase to 103 kPa (15 psi). The pressure in the system prevents vapor from forming in the coolant flowing to the engine coolant pump. This action maintains the efficiency of the engine coolant pump and performance of the cooling system. The increase in pressure also raises the boiling point of the coolant mixture to approximately 129°C (264°F) at sea level.

The radiator cap has a pressure valve and a vacuum valve. The pressure valve is held against its seat by a spring. The pressure valve opens when the pressure in the cooling system exceeds 103 kPa (15 psi). The vacuum valve is held against its seat by another spring. The vacuum valve opens to relieve the vacuum created when the coolant temperature decreases. This vacuum can cause the radiator top hose to collapse.

Charge Air Cooler (CAC)

The CAC is part of the radiator (air to air heat exchanger). Incoming air goes through a filter, through the turbocharger and into the radiator to be cooled and condensed before it enters the engine intake manifold.

Radiator Screen (Optional)

The optional woven steel mesh radiator screen (item 4, Figure 350) is positioned between fan and radiator core to catch debris before it reaches the radiator. The radiator screen fits into the fan shroud, includes a handle, and it is inserted vertically from the top. The screen is just under the rear crossmember of the Overhead Guard (OHG). For this reason the screen has a segmented frame that will allow it bend during removal and installation.

Front end

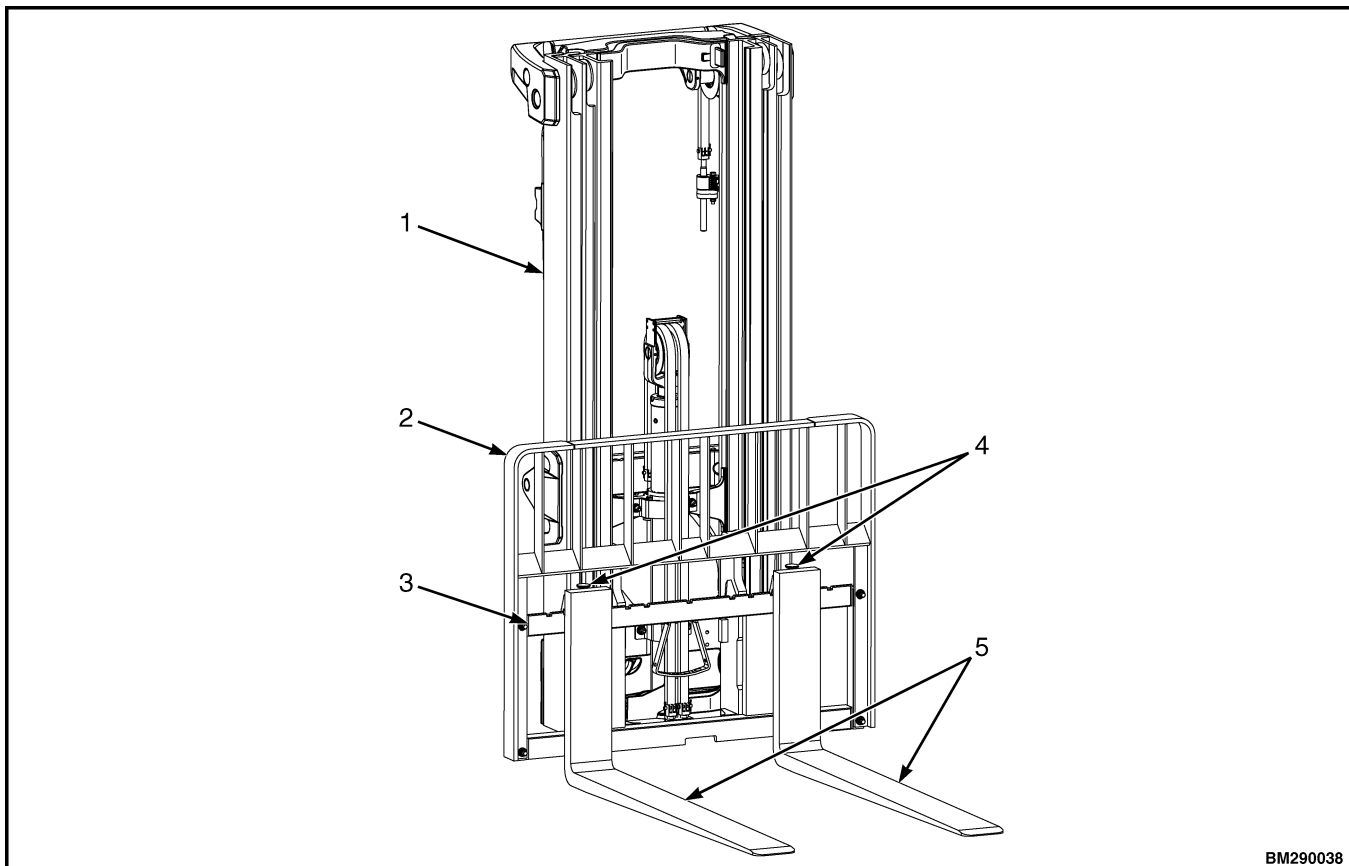
FORK DESCRIPTION 202001-168

FORK DESCRIPTION

The forks are attached to the forklift carriage, they make direct contact with a load for transport, and are designed to carry a load from the bottom. The forks are connected to the carriage by the fork hooks and lock pins. The lock pins are installed through top fork hooks and fit into slots in the top carriage bar. Hook forks will slide along carriage bars to adjust for load to be lifted.

Forks can be adjusted by lifting up the lock pin and sliding them on the carriage bar. Once forks have been moved, ensure the lock pins are engaged in the carriage bar. Two fork types are typical on this lift truck: Bolzoni and Cascade. The difference is that the Bolzoni has a lever type lock pin and release mechanism and the Cascade has a mushroom, pull-up type lock pin and release mechanism.

NOTE: If the lock pin does not remain engaged in the carriage slot, replace with a new pin.



BM290038

1. MAST
2. LOAD BACKREST
3. STANDARD CARRIAGE

4. LOCK PIN ASSEMBLY
5. FORKS

Figure 351. Mast, Carriage, Forks

Hook type forks interface with the carriage and mount to the carriage rails. The hook feature is an industry standard and allows adjustment of fork position. The forks slide along the frame for fork spread changes or sideshift. The taper of the forks refers to the increase in thickness from the fork tip to the heel. Standard taper forks are the most common fork type on trucks less than 3,500 kg (7,716 lbs) and are best suited for standard palletized loads. Polished and full bottom taper forks are used for atypical loads that require more finesse and accuracy. The tips of the forks are thinner allowing greater flexibility in loads to be moved and the wider fork provides greater load stability.



WARNING

Do not try to move a fork without a lifting device. Each hook fork for these lift trucks can weigh 45 to 115 kg (99 to 254 lb).

NOTE: Forks are to be replaced as a pair only (not individually) and must be removed or installed by trained personnel only.



WARNING

Never repair damaged forks by heating or welding. Forks are made of tempered steel using special procedures. Always replace damaged forks as a pair.

Fork Inspections and Service

Please refer to **Front End 4000SRM2303** for details on fork service and inspection.

Fork Classification

There are 5 classes of forks, each further divided into an A or B version. The 5 classes are determined by the rated capacity of the forklift and can be determined by measuring the carriage plate height. The carriage is typically 400mm (16 inches), 500mm (20 inches) or 635mm (25 inches) in height. These sizes cover over 90% of forklifts and are also known as class 2, 3 or 4 respectively.

NOTE: Typical forks on this truck are type 2A or type 3A.

The A or B version is determined by the fork drop (D), and is measured from the top of the lower hook to the floor. The measurements are defined in ISO standard 2328.

Class	Carriage Height (C)	Fork Drop (D)
1A	330mm (13 in.)	76mm (3.0 in.)
1B	330mm (13 in.)	114mm (4.5 in.)
2A	400mm (16 in.)	76mm (3.0 in.)
2B	400mm (16 in.)	152mm (6.0 in.)
3A	500mm (20 in.)	76mm (3.0 in.)
3B	500mm (20 in.)	203mm (8.0 in.)
4A	635mm (25 in.)	127mm (5.0 in.)
4B	635mm (25 in.)	254mm (10.0 in.)
5A	710mm (28 in.)	127mm (5.0 in.)
5B	710mm (28 in.)	257mm (10.1 in.)

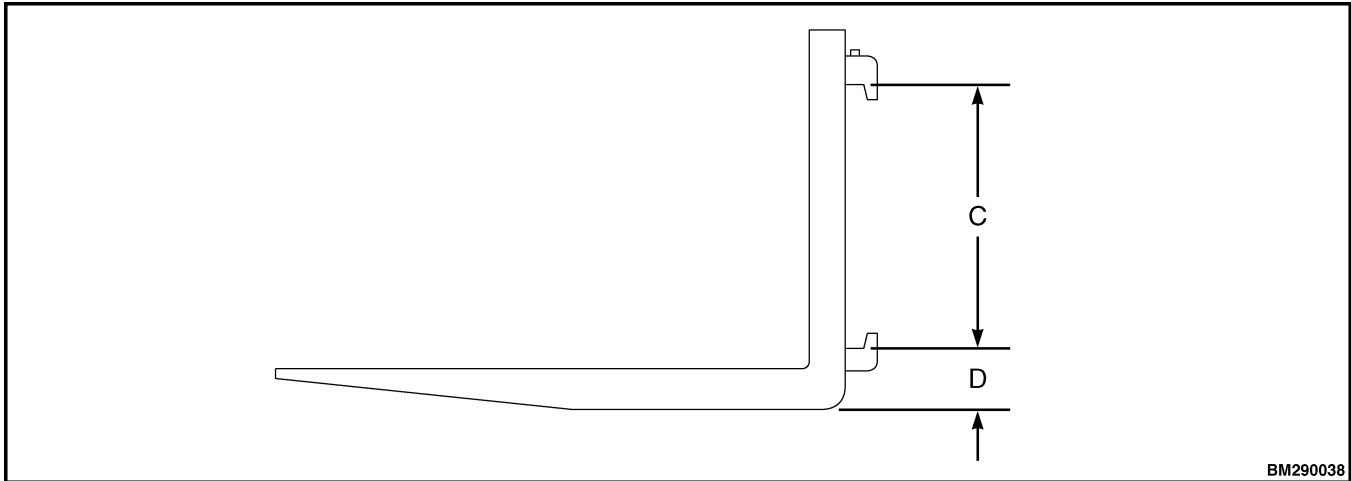
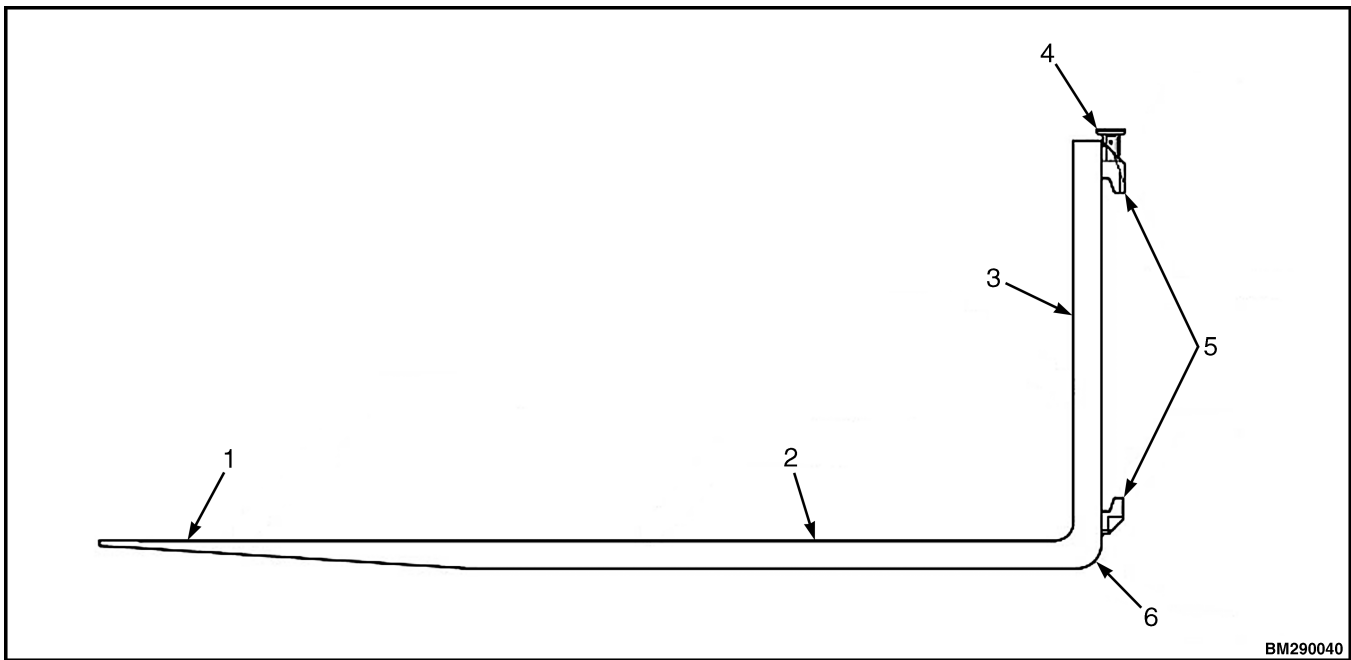


Figure 352. Fork Classification

The carriage height (C) is measured from the top of the lower hook to the bottom of the upper hook. The fork drop (D) is measured from the top of the lower hook to the floor.

Fork Terminology

A forklift fork is comprised of different areas that are generally named as shown in the following graphic.

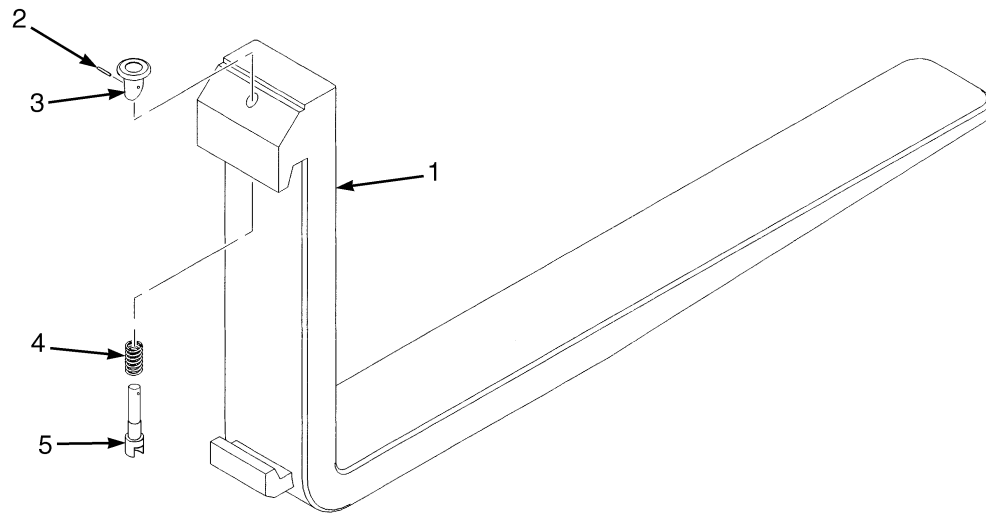


- 1. TIP
- 2. BLADE
- 3. SHANK

- 4. LOCK PIN
- 5. HOOKS
- 6. HEEL

Figure 353. Fork Terminology

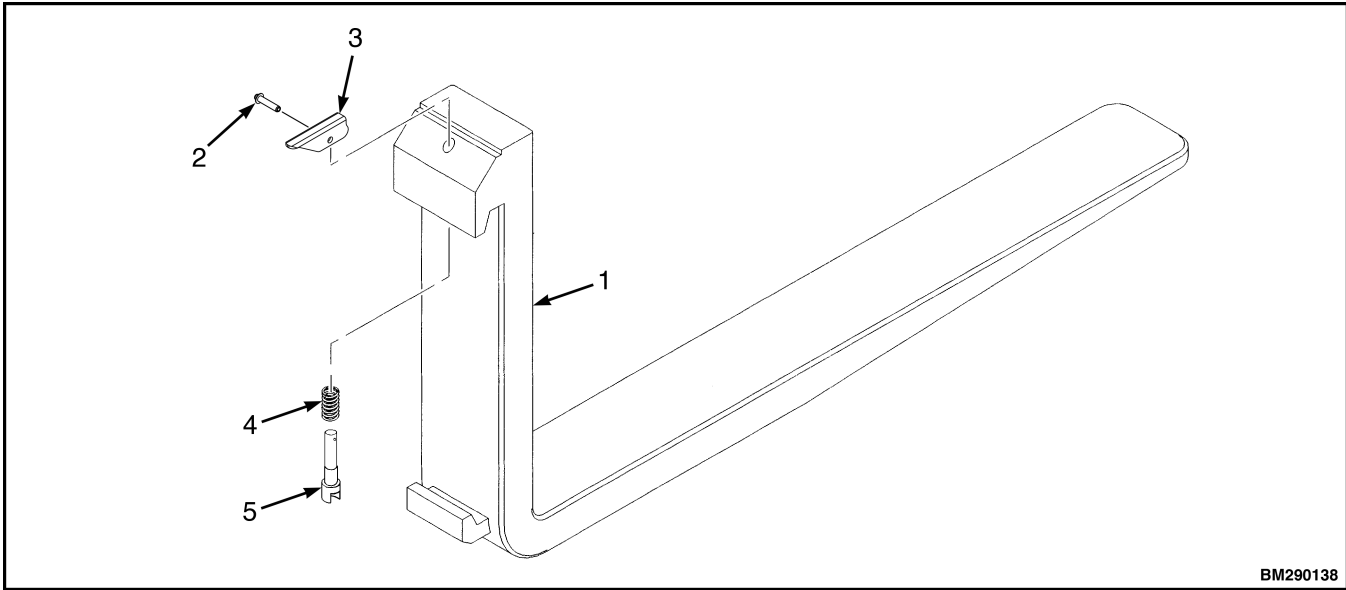
- Tip – The free end of the blade that is inserted into the load
- Blade – The horizontal portion of the fork upon which the load is supported.
- Shank – The upright (vertical) portion of the fork to which the supporting hooks are fixed.
- Lock Pin – Device for locating the fork on the carriage (typically at the top of the shank on the hook).
- Hooks – Lugs attached to the shank to support and retain the fork on the carriage. They may be made as non-integral hooks (attached to the shank) or as integral hooks (formed integrally with the shank).
- Heel – The radiused portion of the fork connecting the blade to the shank.



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- | | |
|-----------------|-----------|
| 1. FORK | 4. SPRING |
| 2. RETAINER PIN | 5. PIN |
| 3. LOCK PIN | |

Figure 354. Cascade Forks



- | | |
|---------------|-------------|
| 1. FORK | 4. SPRING |
| 2. ROLL PIN | 5. HEAD PIN |
| 3. LOCK LEVER | |

Figure 355. Bolzoni Forks

Fork Tip Options

Fork tips are designed to make insertion into loads easier.

There are several fork tip available for different uses. Some examples are shown below.

- Style 1 - Most common tip. The front of the fork is flat with a gently rounded edge.
- Style 2 - Fairly sharp fork without the flat front section (popular for block forks).
- Style 3 - Almost completely flat across the entire width of the tip and are standard on forks over 7-inches (180mm).

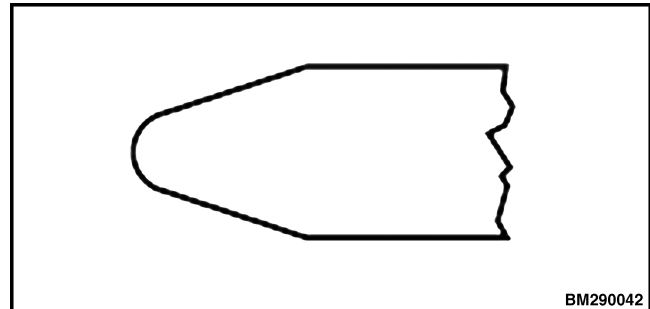


Figure 357. Tip Style 2

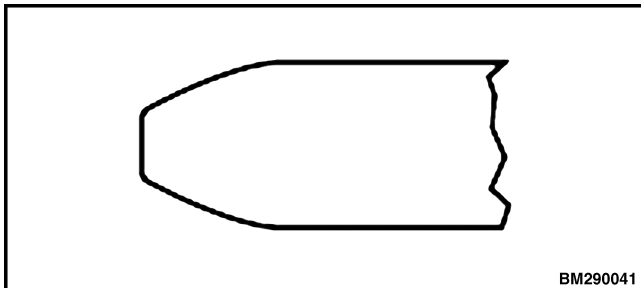


Figure 356. Tip Style 1

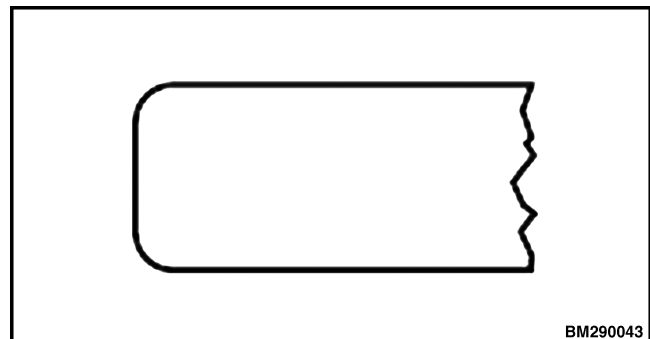


Figure 358. Tip Style 3

Fork Bevel Options

Forks can also come in different bevels to enable a load to be picked up in different ways. Typically the main difference is how thin they are at the tip in order to pick up a given load. Forks having the top of the blade polished reduce friction when handling a load. Bevel examples are shown below.

Standard Taper, No Bevel

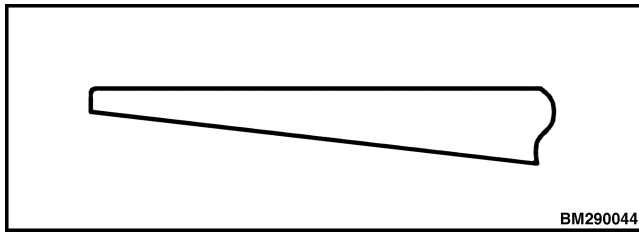


Figure 359. Standard Bevel, No Bevel

Standard Taper, with Bevel

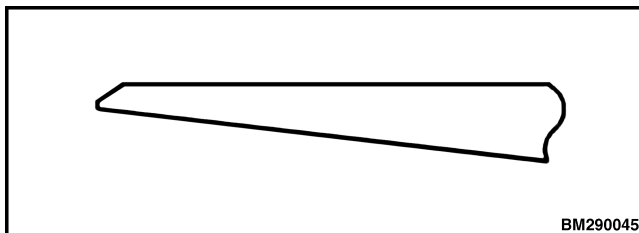


Figure 360. Standard Taper, with Bevel

Full Taper and Polish with Top Bevel

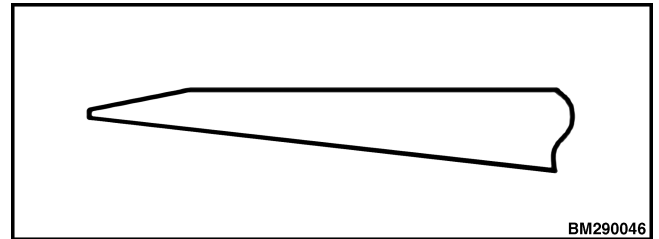


Figure 361. Full Taper and Polish with Top Bevel

Chisel Tip

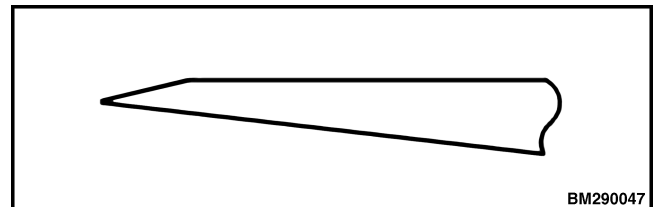


Figure 362. Chisel Tip

Fork Taper Options

Examples of different fork taper options are shown below.

Standard Taper

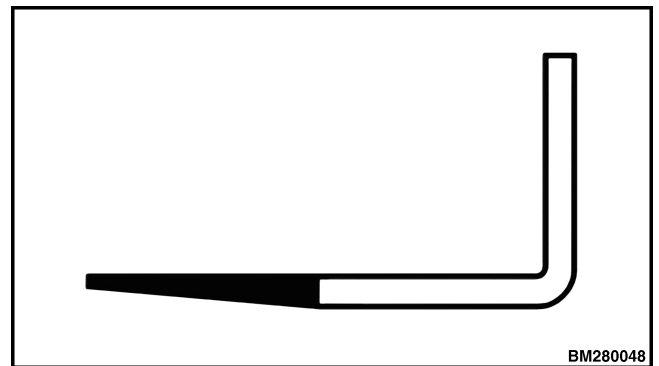
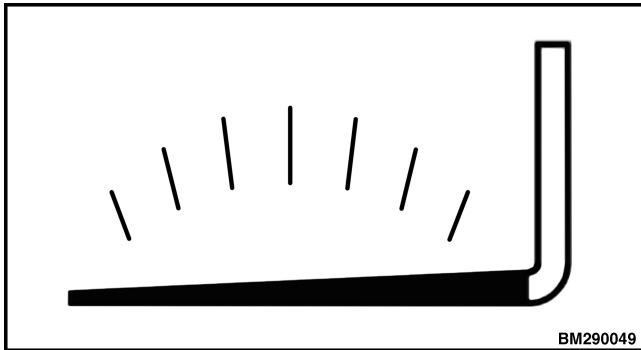
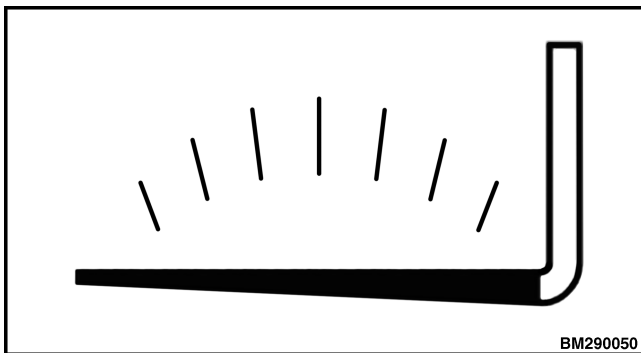
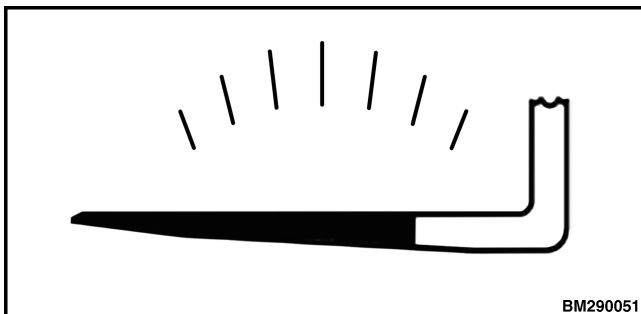


Figure 363. Standard Taper

Full Top Taper and Polish**Figure 364. Full Top Taper and Polish****Full Bottom Taper and Polish****Figure 365. Full Bottom Taper and Polish****Two-Stage Taper and Polish****Figure 366. Two-Stage Taper and Polish****Fork Identification**

Forks are manufactured in accordance with the current version of the International Standards Organization (ISO) 2328-2330 and the American Society of Mechanical Engineers (ASME) B56.11.4 and each fork is permanently marked in order to allow their identification. If marking is not clearly legible, forks shall be withdrawn from service. This information may be located on either side of the fork. The following features are on one side of the fork shank:

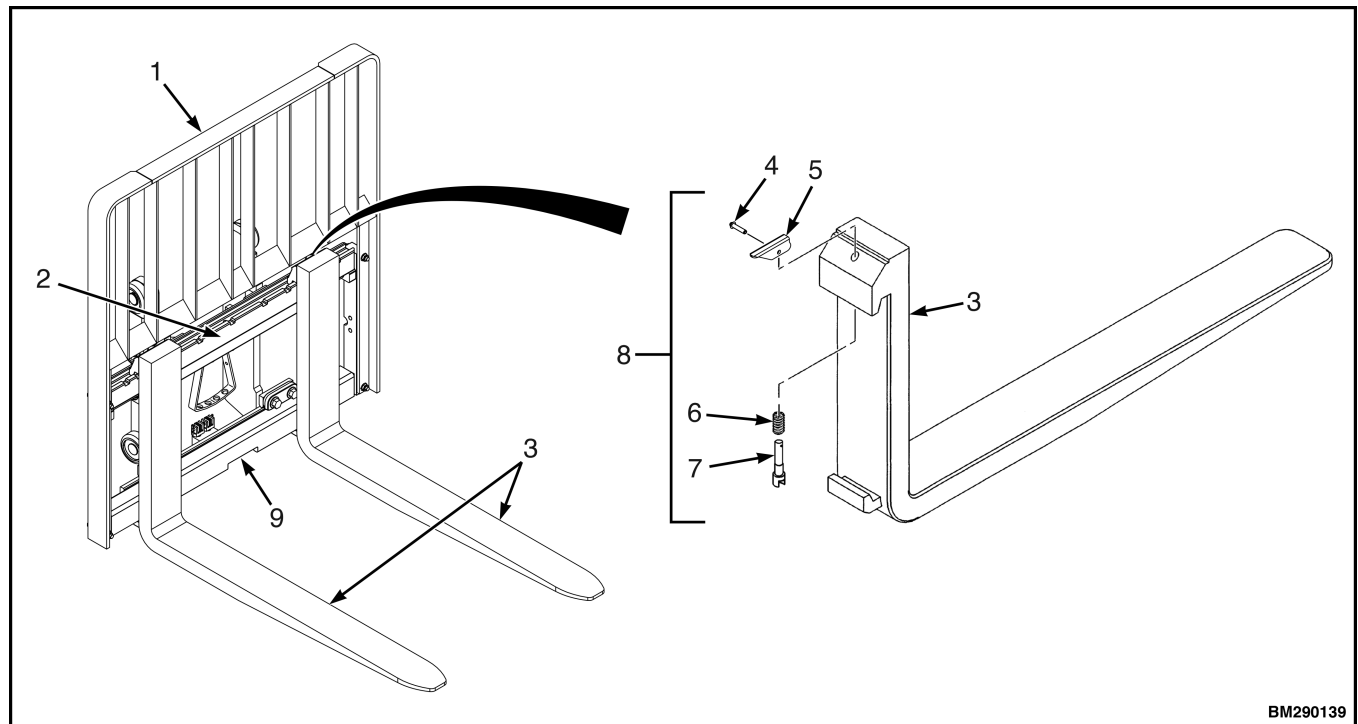
- Capacity
- Load center
- Manufacturer
- Year
- Month
- Day

Miscellaneous Forks

Other non-standard or specialty forks are listed below.

- Pin-type forks with a lower hook.
- Pin-type forks with lower hook sliding on rollers.
- Forks with load-bearing lower hook are used with a rotator for container rotating or emptying.
- Drum handling forks are used for lifting one or two drums at one time.
- Coil handling forks are used to handle steel coils, reels etc.
- Forks with 3rd hook are used with a rotator for container rotating or emptying.
- Bolt-on forks are fixed to the lift truck carriage or fork carrier with bolts.
- Blank forks are without hooks. Welded or bolt-on, used on clamping or fork positioning attachment or for special mounting applications.

Standard Carriage and Forks



BM290139

1. LOAD BACKREST
2. CARRIAGE
3. FORKS
4. PIN
5. LOCK LEVER

6. SPRING
7. PIN
8. LOCK PIN ASSEMBLY
9. FORK REMOVAL NOTCH

Figure 367. Standard Carriage and Forks

CARRIAGE DESCRIPTION 202001-169

CARRIAGE DESCRIPTION

The carriage is a platform located in front of the forklift mast that is used to mount objects to be controlled by the mast. This includes the forks of the forklift, the load backrest and attachments to the mast chains.

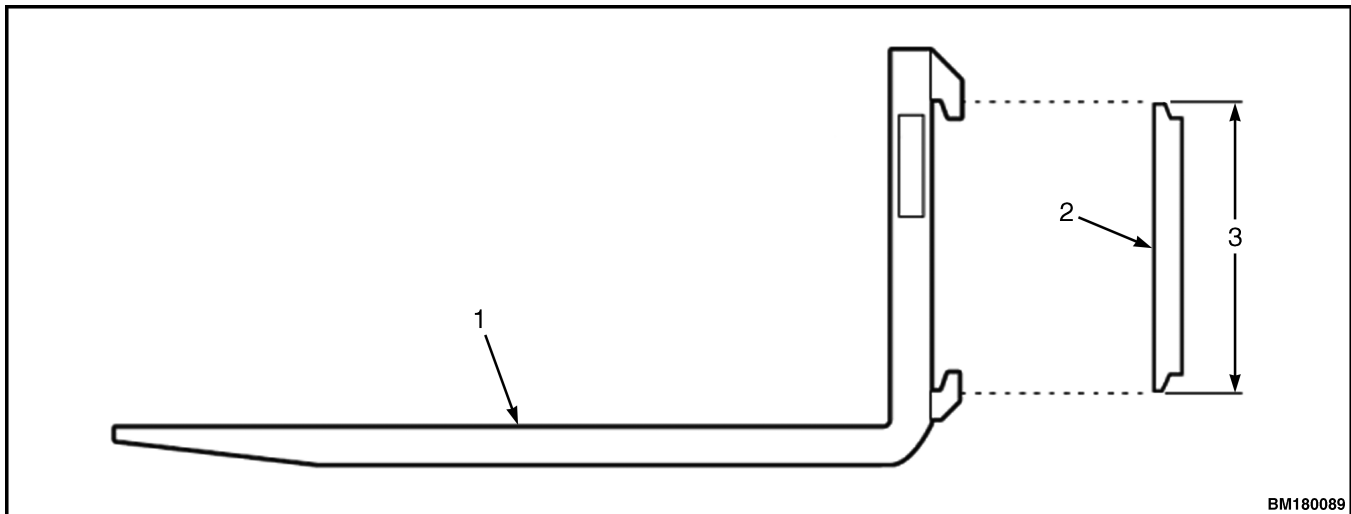
The carriage is a part of the mast assembly and moves within the vertical channels of the inner weldment. Load rollers, attached to the carriage, travel in the channels of the inner weldment. Forks or other types of load handling equipment are attached to the carriage. A Load Backrest (LBR) extension may be attached to the carriage and adds support for a load that has multiple pieces.

The free-lift chains connect at one end to the mid-crossmember of the inner mast. Two chain sheaves are installed on a crosshead on the cylinder rod of the free-lift cylinder. The chains go over sheaves on the crosshead and connect to the carriage. The three hydraulic cylinders are connected by hoses and tubing. When the mast is extended, oil from the main control valve flows to all cylinders at the same time. The free-lift cylinder extends first because it lifts the least amount of weight and has a lower operating pressure and raises only the carriage.

Carriages are available in a standard version, an Integral Sideshift (ISS) which allows the carriage to be shifted left or right, and an Integral Sideshift with Fork Positioner (ISSFP) that allows both the carriage and forks to be moved independent from one another.

Carriage Classification

Carriages are available in different classes as shown below.



- 1. FORK
- 2. CARRIAGE

- 3. CARRIAGE HEIGHT

Figure 368. Carriage Classification

Mounting Class	Height of Carriage	Truck Capacity	Load Center
II	407mm (16 in.)	998-2,495 kg (2,200-5,500 lbs)	500mm (19.7 in.)
III	508mm (20 in.)	2,495-4,989 kg (5,500-10,998 lbs)	500mm (19.7 in.)

NOTE: The carriage class gives you a general idea of the forklift’s lifting capacity, but it is only one factor. Refer to your forklift’s data plate for the most

accurate capacity information. The carriages used on this truck are either Class 2 or Class 3.

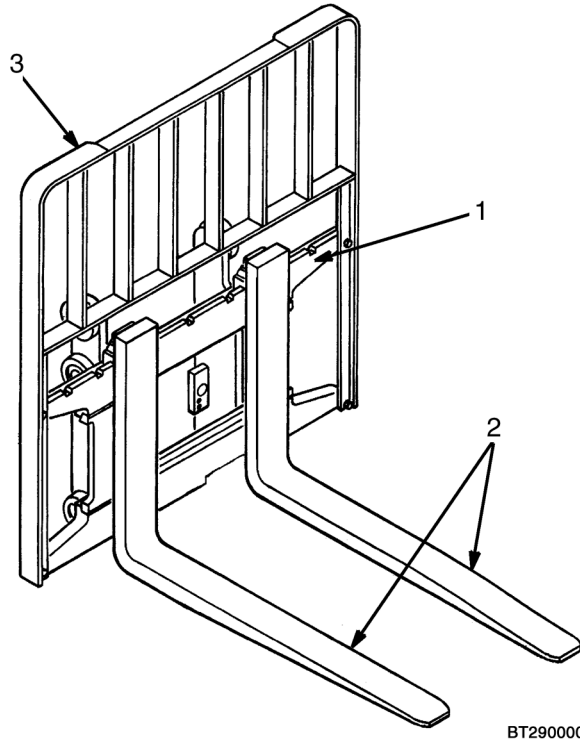
Standard Carriage

The standard carriage is fitted with six load rollers, three on each side. Only the top load rollers have an external snap ring. All the load rollers have shims for adjustment. Two chain anchors at the bottom rail attach the carriage to the double chains and are secured with castle nuts and cotter pins.

The primary function of the carriage assembly is providing a mounting location for front end

attachments (forks, roll clamp, box clamp, slip sheet, rotator).

A secondary function of the carriage assembly is providing mounting for the load backrest. In addition, along the top crossbar of the carriage there are detents for manual adjustment of the forks. Each fork can be moved left or right.



- 1. STANDARD CARRIAGE
- 2. FORKS

- 3. LOAD BACKREST EXTENSION

Figure 369. Standard Carriage

Load Backrest (LBR) Extension

The load backrest provides a structure against which loads may rest during backward tilt operations. Load backrests are typically not used with specialty attachments.

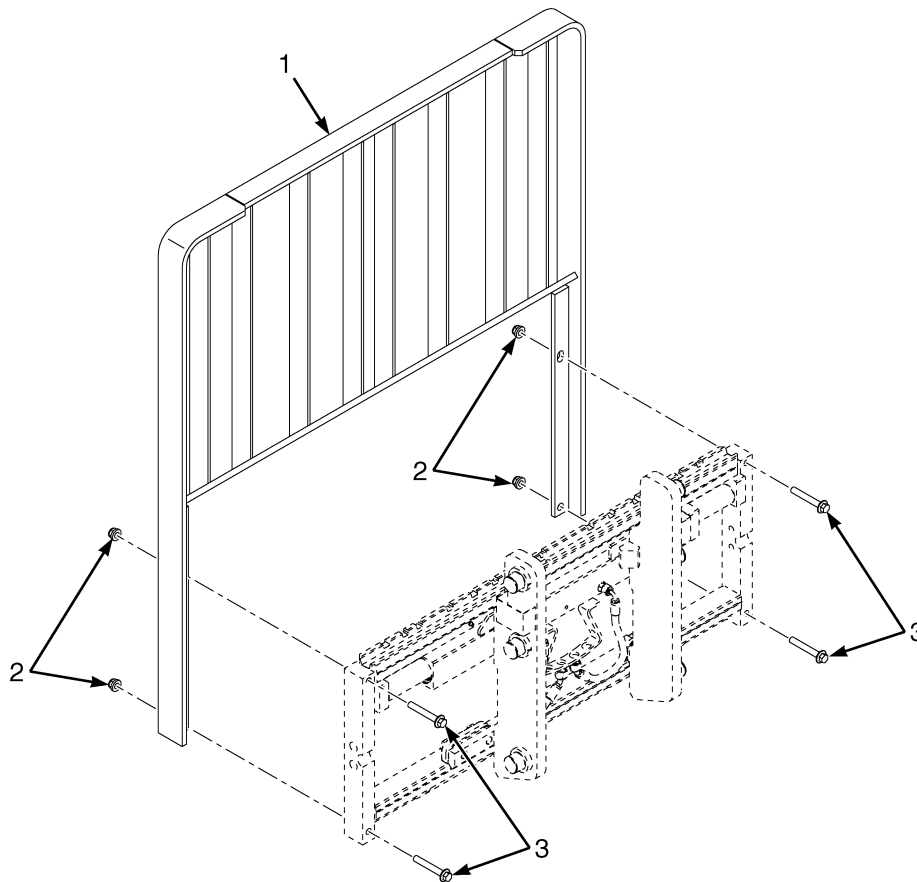
The load backrest attaches to the upper and lower carriage bars using 4 pairs of nuts and bolts. The fasteners are protected from damage by being mounted inboard and set back from the load. The height of the load backrest is measured from the top of the forks to the top of the load backrest.

A drop center load backrest is designed with a lower profile center section to clear the racking supports of specific applications.



WARNING

The load backrest is heavy and must be removed with a lifting device.

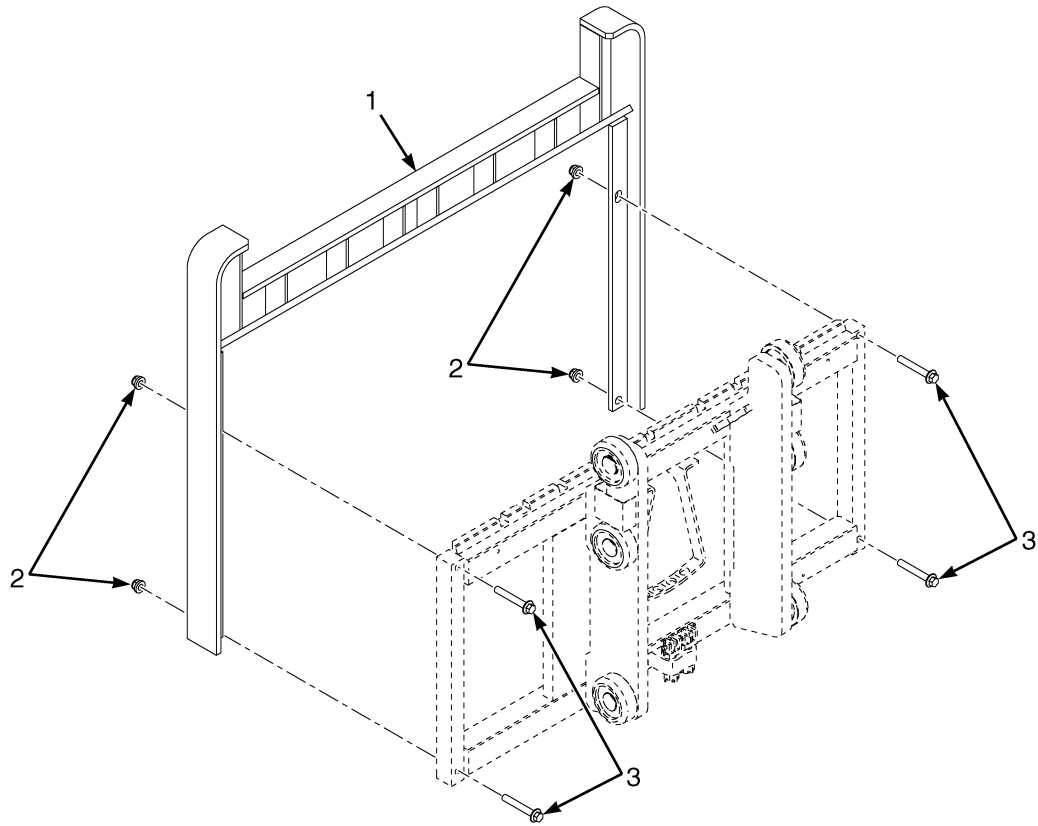


- 1. LOAD BACKREST
- 2. LOCKNUT

- 3. CAPSCREW

BP290398

Figure 370. Load Backrest Extension



BP290399

- 1. LOAD BACKREST
- 2. LOCKNUT

- 3. CAPSCREW

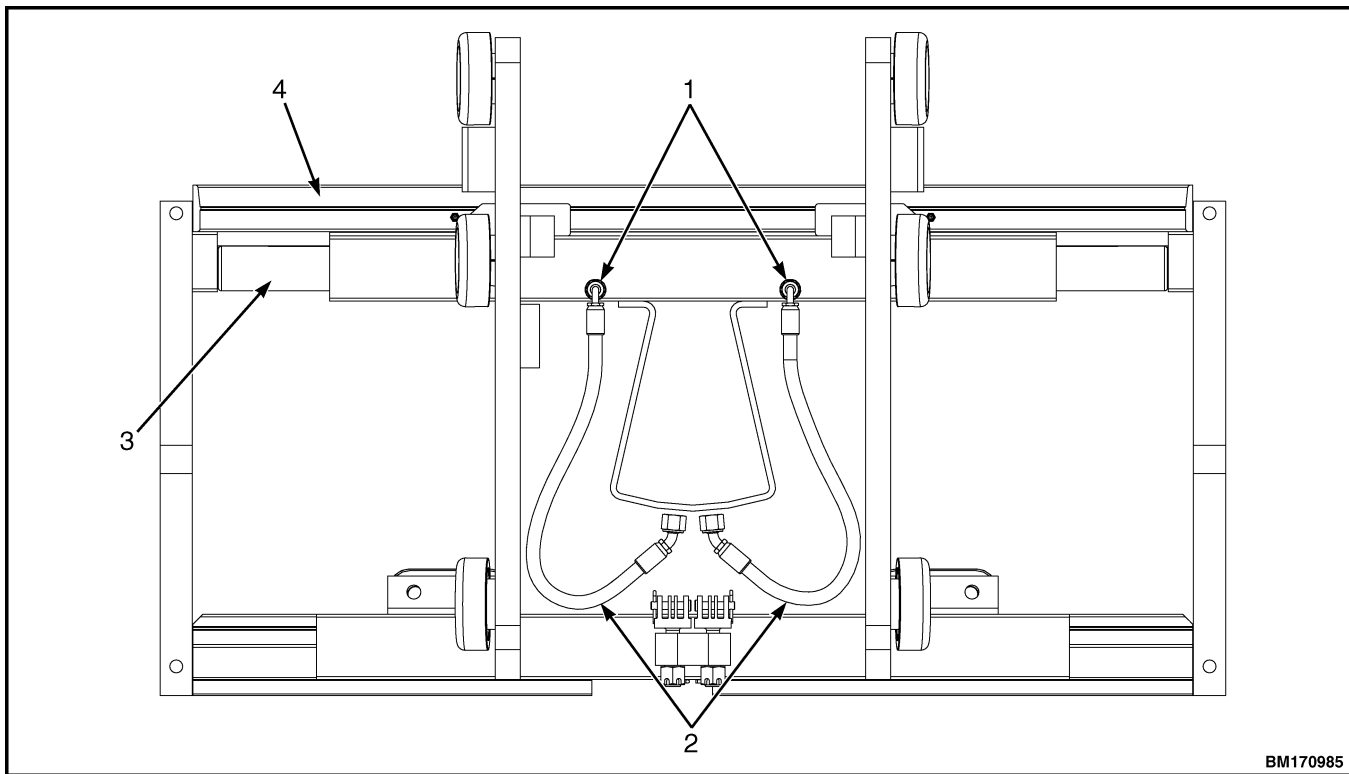
Figure 371. Load Backrest Extension, Drop Center

Integral Sideshift (ISS) Carriage

The integral sideshift carriage allows the operator move the forks and load from side to side. This function makes it easier for the operator to align the forks with a load or align the load with a stack. The integral sideshift carriage is a complete inner carriage and outer frame assembly. The sideshift cylinder, positioned on the upper carriage frame,

moves the outer frame assembly on the inner carriage.

Forks are held in position on the carriage by the fork hooks. They are locked into place by lock pins that fit through the top fork hooks and into slots in the top carriage bar. The fork positions on the ISS must be adjusted manually.



BM170985

1. HOSE FITTINGS
2. HYDRAULIC HOSES

3. CYLINDER
4. CARRIAGE

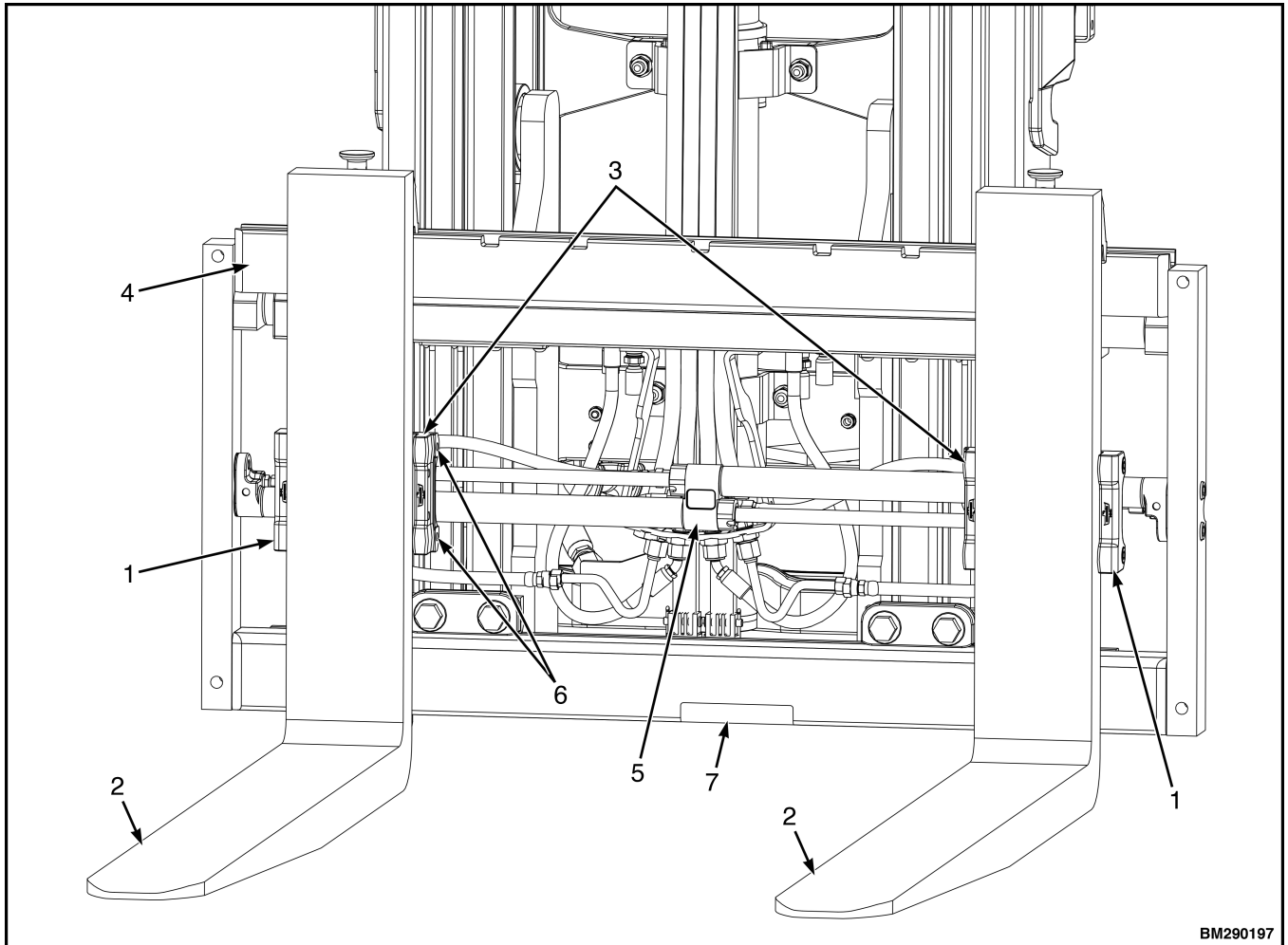
Figure 372. Integral Sideshift Carriage

Integral Sideshift Carriage with Fork Positioner (ISSFP)

Forklift fork positioners are hydraulic systems that are fixed to the lift truck and used to alter the spread of the forks. They are particularly useful when having to handle several different pallet widths or loads and removes the need to manually adjust the fork positions.

The fork carriers, operated by two hydraulic cylinders, allow the use of the original lift truck forks.

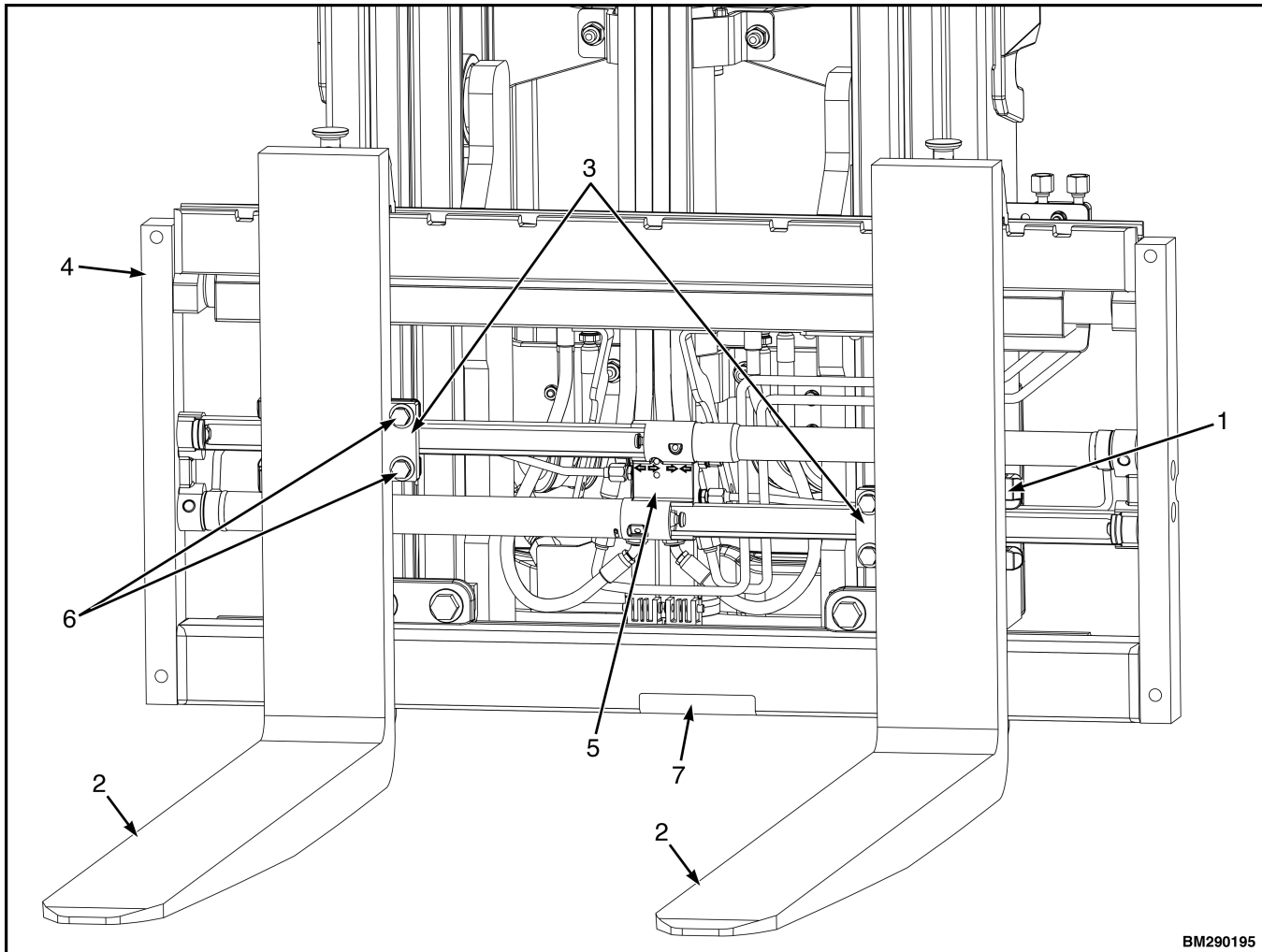
The fork spread control is achieved with the manual hydraulic levers, the Mini-Lever Module (MLM), or joysticks.



BM290197

- | | |
|-----------------------|-----------------------|
| 1. OUTER FORK CARRIER | 5. FORK POSITIONER |
| 2. FORKS | 6. CAPSCREWS |
| 3. INNER FORK CARRIER | 7. FORK REMOVAL NOTCH |
| 4. SIDESHIFT CARRIAGE | |

Figure 373. ISS with Cascade Fork Positioner



BM290195

- | | |
|-----------------------|-----------------------|
| 1. OUTER FORK CARRIER | 5. FORK POSITIONER |
| 2. FORKS | 6. CAPSCREWS |
| 3. FORK LOCK | 7. FORK REMOVAL NOTCH |
| 4. SIDESHIFT CARRIAGE | |

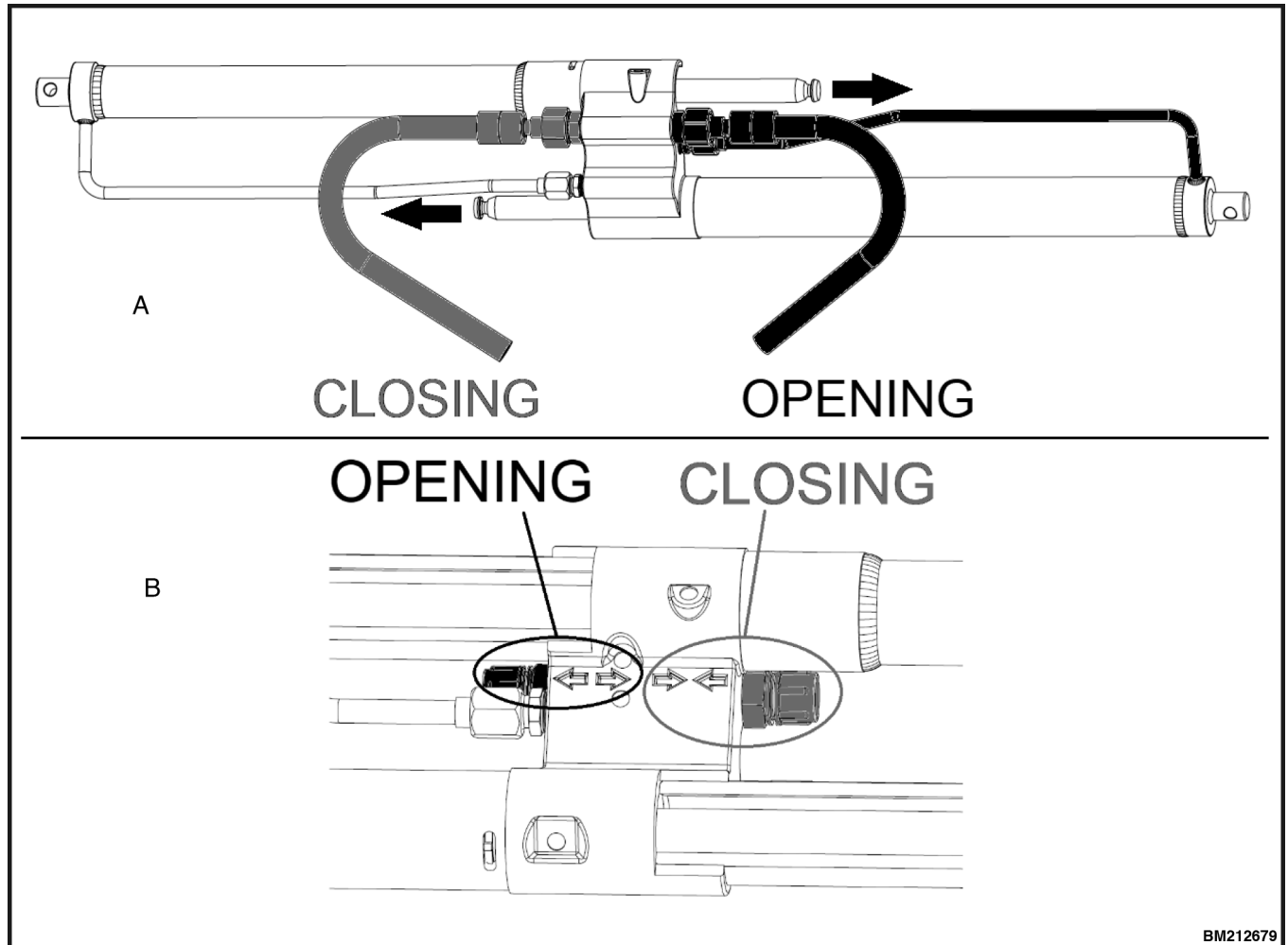
Figure 374. ISS with Bolzoni Fork Positioner

Bolzoni Fork Positioner Specifics

It is important to check the weight and center of gravity do not exceed the limits of the carriage, which includes the hydraulic supply inlets and on side blocks that suited to the load to be handled. The actuators and guide tubes are mounted on a central body, which also includes the hydraulic supply inlets, and on side blocks that include the fastening screws to the sides of the carriage frame.

The fork positioner consists of a pair of fork supports, each sliding on its own, see Figure 375 and Figure 376.

The fork spread control is achieved with the manual hydraulic levers, the Mini-Lever Module (MLM), or joysticks.



BM212679

A. BACK VIEW

B. FRONT VIEW

Figure 375. Bolzoni fork positioner-hydraulic open/close

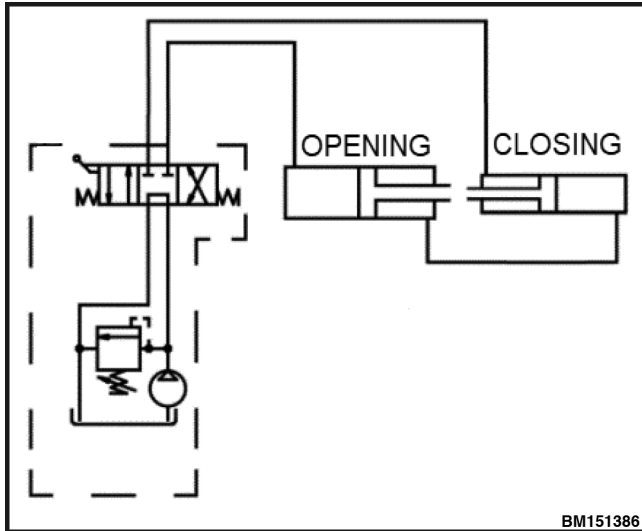


Figure 376. Bolzoni Fork Positioner Schematic

MAST DESCRIPTION

202001-294

MAST OVERVIEW

The primary function of the mast is to lift and lower loads. The mechanical advantage of the mast is achieved by a set of hydraulic cylinders operating parallel to the mast. The set of lifting cylinders includes a free-lift cylinder in the center and two full-lift cylinders arranged on either side of the outermost mast channels. The lift cylinders are only mounted to the mast assembly. Two single-stage main lift cylinders and a free-lift cylinder are used to raise the carriage and extend the intermediate and inner mast. The Full Free-Lift (FFL) mast is called a full free-lift mast because the carriage can travel to the top of the inner mast without extending the inner mast. The masts are telescopic and have load rollers and strip bearings. The cylinder base mounts at the base of the mast and the cylinder is secured near the rod end. Both mounts are fixed points to keep the cylinder operating parallel with the vertical mast. The base

of the outermost mast channels on either side mount at pivot points on the drive axle.

The load rollers are installed at the top of the outer and intermediate masts. Load rollers are also used at the bottom of the intermediate and inner masts. These load rollers travel along the flanges of the mast channels. The angle of the load rollers permits them to control the forces from the front, back, and sides of the mast. The strip bearings are installed at the top of the outer and intermediate masts and help keep the correct clearance between the masts. The load rollers and strip bearings are adjustable with shims.

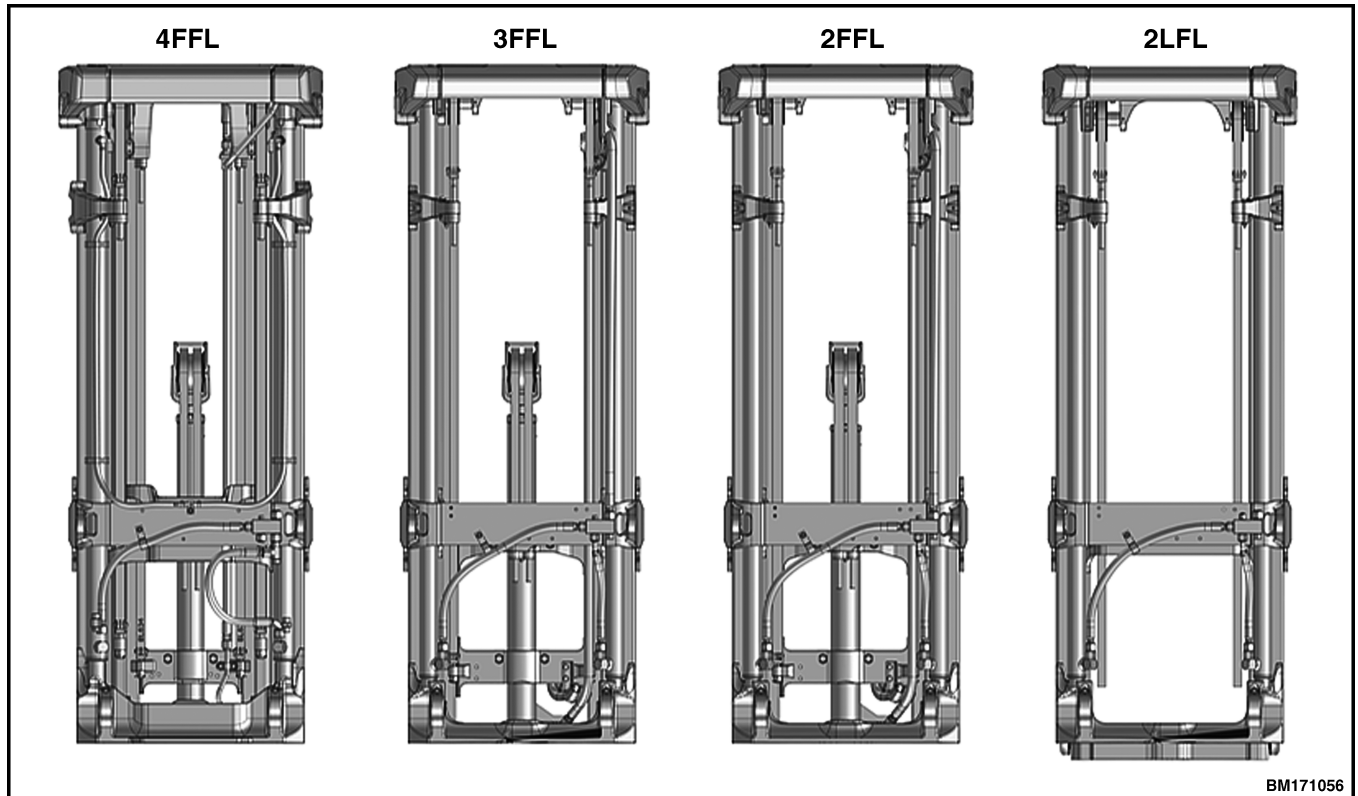
The two main lift cylinders are installed at the back of the outer mast. The base of each main lift cylinder sits in a mount on the bottom crossmember of the outer mast. The top of each main lift cylinder rod fits into a guide in the top crossmember of the intermediate mast. The free-lift cylinder is installed to the inner mast. Each lift cylinder has an internal lowering control valve. A single external lowering control valve is connected by tubing and hoses to all of the lift cylinders.

The two main lift chains are connected to mounts that are welded near the top of the main lift cylinder shells. The lift chains go over sheaves at the top of the intermediate mast and fasten at the bottom of the inner mast.

The free-lift chains connect at one end to the mid-crossmember of the inner mast. Two chain sheaves are installed on a crosshead on the cylinder rod of the free-lift cylinder. The chains go over sheaves on the crosshead and connect to the carriage.

Masts are available in four types with multiple heights within each type:

- **Four stage with full free-lift (4FFL)**
- **Three stage with full free-lift (3FFL)**
- **Two stage with full free-lift (2FFL)**
- **Two stage with limited free-lift (2LFL)**



BM171056

Figure 377. Mast Types

Mast functions are controlled by the hydraulic mechanical levers, Mini-Levers Module (MLM), or joysticks. The mast also provides mounting points for front end components and assemblies. The carriage assembly (including equipped attachments, load backrest, and hydraulic cylinders) mount to the mast.

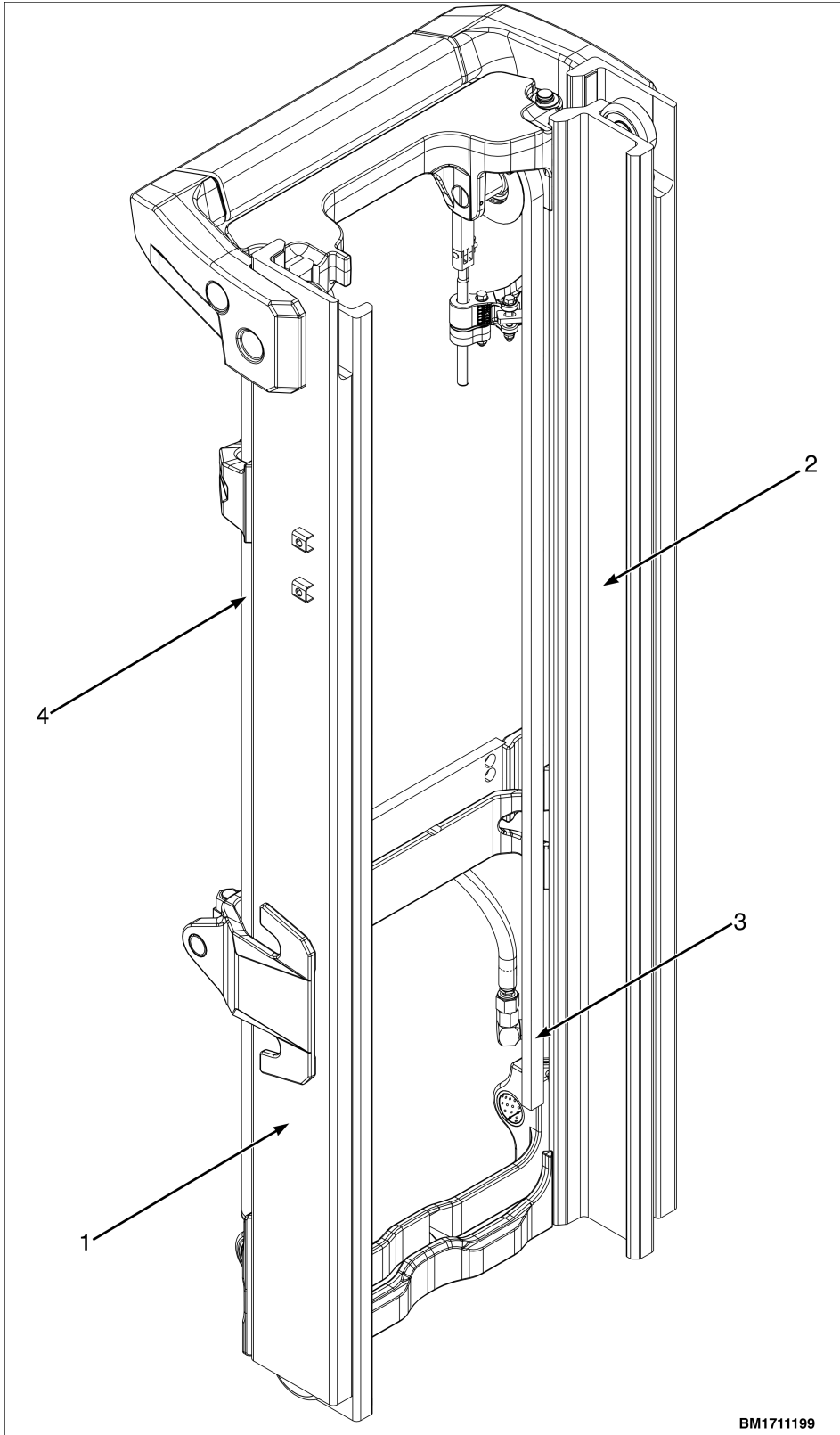
2-STAGE LIMITED FREE LIFT (LFL) MAST DESCRIPTION **202001-170**

2-STAGE LFL MAST DESCRIPTION

This module will discuss the various functions and components specific to the two-stage limited free-lift

mast. For a general overview and description of the mast, see Mast description.

Mast functions are controlled by the hydraulic mechanical levers, Mini-Levers Module (MLM), or joysticks. The mast also provides mounting points for front end components and assemblies. The carriage assembly (including equipped attachments, load backrest, and hydraulic cylinders) mount to the mast.



BM1711199

Figure 378. Two-Stage LFL Mast

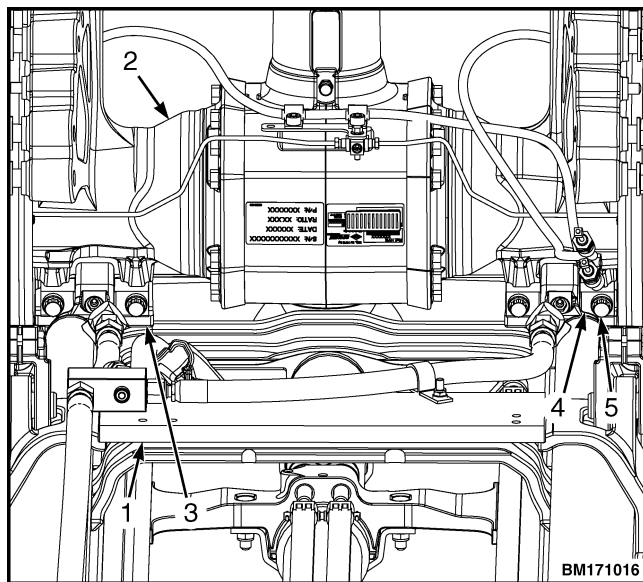
Legend for Figure 378.

NOTE: GRAPHIC IS FOR ILLUSTRATIVE PURPOSES ONLY, VARIATIONS ARE POSSIBLE.

- 1. OUTER MAST
- 2. INNER MAST

- 3. LIFT CHAIN(S)
- 4. MAIN LIFT CYLINDER(S)

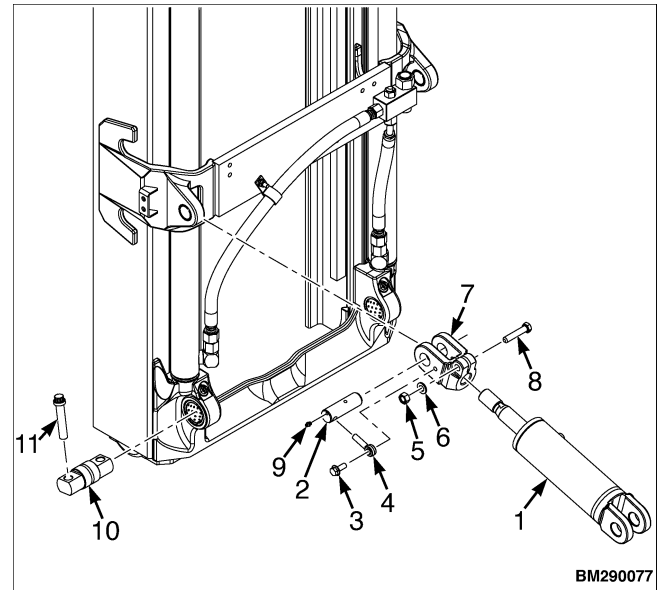
The lower crossmember of the outer mast has castings to mount the mast pivot pins. The pivot pins are installed in the castings and the mast is mounted on the J-hangers of the drive axle housing. Capscrews secure the mast pivot pins to the drive axle housing.



- 1. MAST
- 2. DRIVE AXLE
- 3. HANGER MOUNTS
- 4. MAST PIVOT PIN
- 5. CAPSCREW

Figure 379. Mast Mount on Drive Axle

The mast can also be tilted forward to ease picking or placing a load and tilted back to keep a picked load safe against the carriage load backrest. Tilt is achieved by another set of hydraulic cylinders operating perpendicular to the mast. The tilt cylinders are mounted on either side of the outermost mast channels. The rod end of the tilt cylinders mount about 1/3 of the way up the mast and the cylinder base mounts at the front cowl. Both mounts are pivot points to allow minor change to their working angle.



- 1. TILT CYLINDER
- 2. PIVOT PIN
- 3. CAPSCREW
- 4. PIN ANCHOR
- 5. NUT
- 6. WASHER
- 7. ROD END
- 8. CAPSCREW
- 9. GREASE FITTING
- 10. MAST MOUNTING PIN
- 11. CAPSCREW

Figure 380. Tilt Cylinder Mounting

The tilt cylinders can be engaged to tilt the mast forward during picking or placing a load. Then the tilt cylinders can be engaged to tilt the mast back once a load is picked up and being moved.

The tilt cylinders operate in two directions. There is a port at the base of the cylinder and another at the rod end of the assembly. Hydraulic oil entering the port at the base of the cylinder feeds under the piston and causes the rod to extend while oil exhausts through the rod end port. Hydraulic oil entering the port at the rod end causes the rod to retract into the cylinder.

Basic Operation

The two hydraulic lift cylinders are connected by hoses and tubing. When the mast is extended, oil from the main control valve flows to both cylinders at the same time. As the main lift cylinders extend, the inner mast is raised by the main lift chains. Both lift cylinders are protected from sudden rapid pressure loss by hydraulic velocity fuses.

During lowering, the oil from the lift cylinders flows through the lowering control valves to the hydraulic tank.

Each main lift cylinder has an orifice system and a check valve in the bottom of the rod assembly. When the cylinder is fully extended, any oil between the rod end and the gland is forced through the check valve. The orifice system provides a hydraulic cushion when the cylinder reaches the bottom of its stroke.

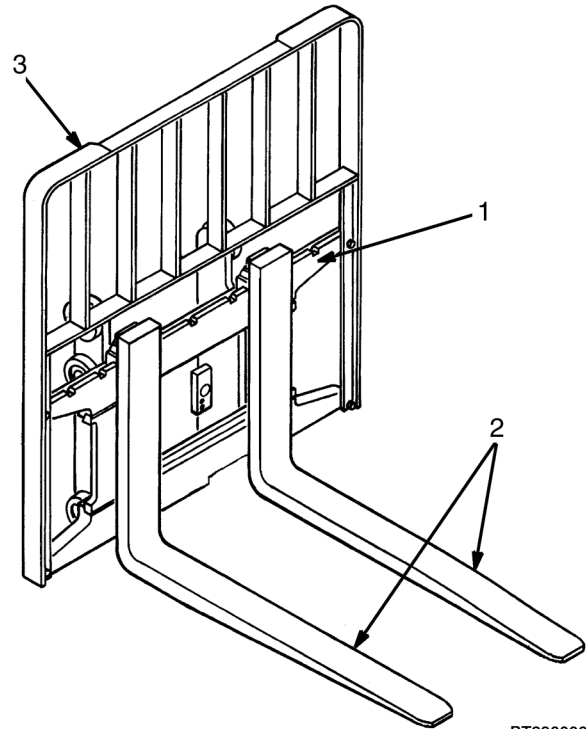
Two Stage Limited Free-Lift

The two stage LFL includes one inner channel weldment and a single outer channel weldment. The LFL travel is equal to the height of the mast where the carriage moves up independent of the mast channel.

The primary function of the carriage assembly is to provide a mounting location for the front end attachments (fork tines, roll clamp, box clamp, box clamp, slip sheet, rotator). The most common front end attachment are the fork tines.

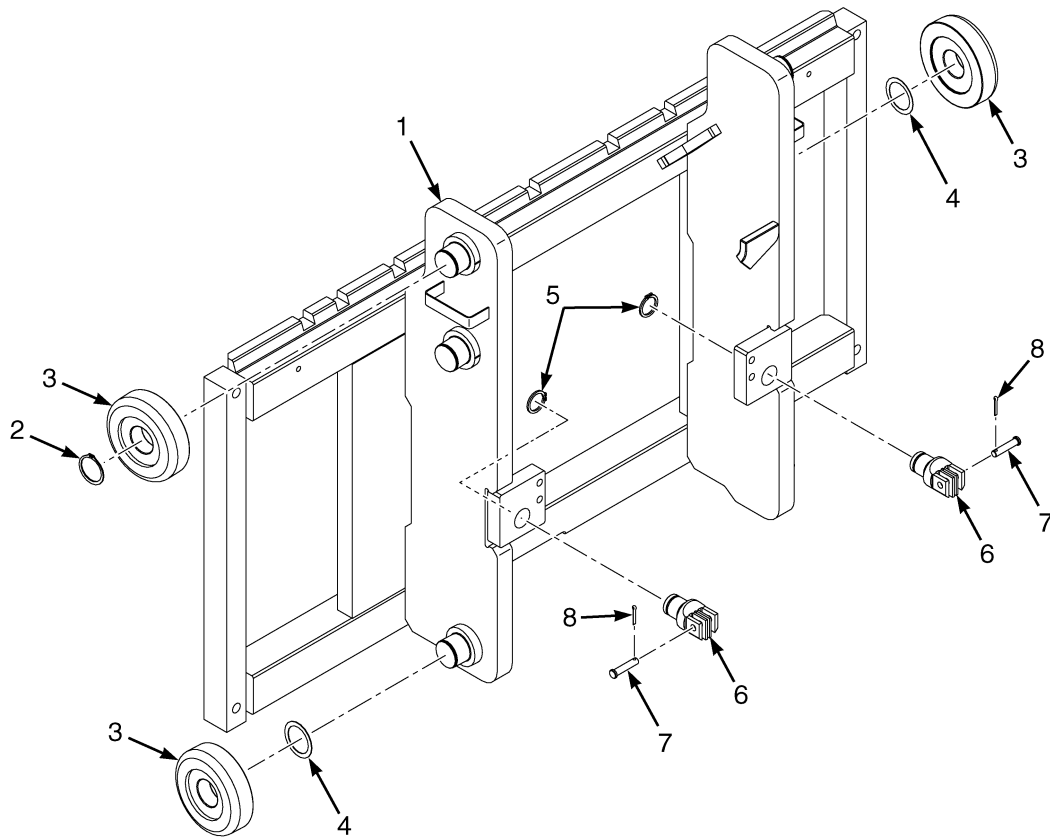
Multiple load rollers are a part of the carriage assembly. The load rollers are positioned laterally,

facing out to mate with the inner most mast channel. The carriage moves with the mast inner channel during lift, lower and tilt. Front end attachments hang on the carriage.



1. STANDARD CARRIAGE
2. FORKS
3. LOAD BACKREST EXTENSION

Figure 381. Carriage, Forks, and Backrest Example



BP001289

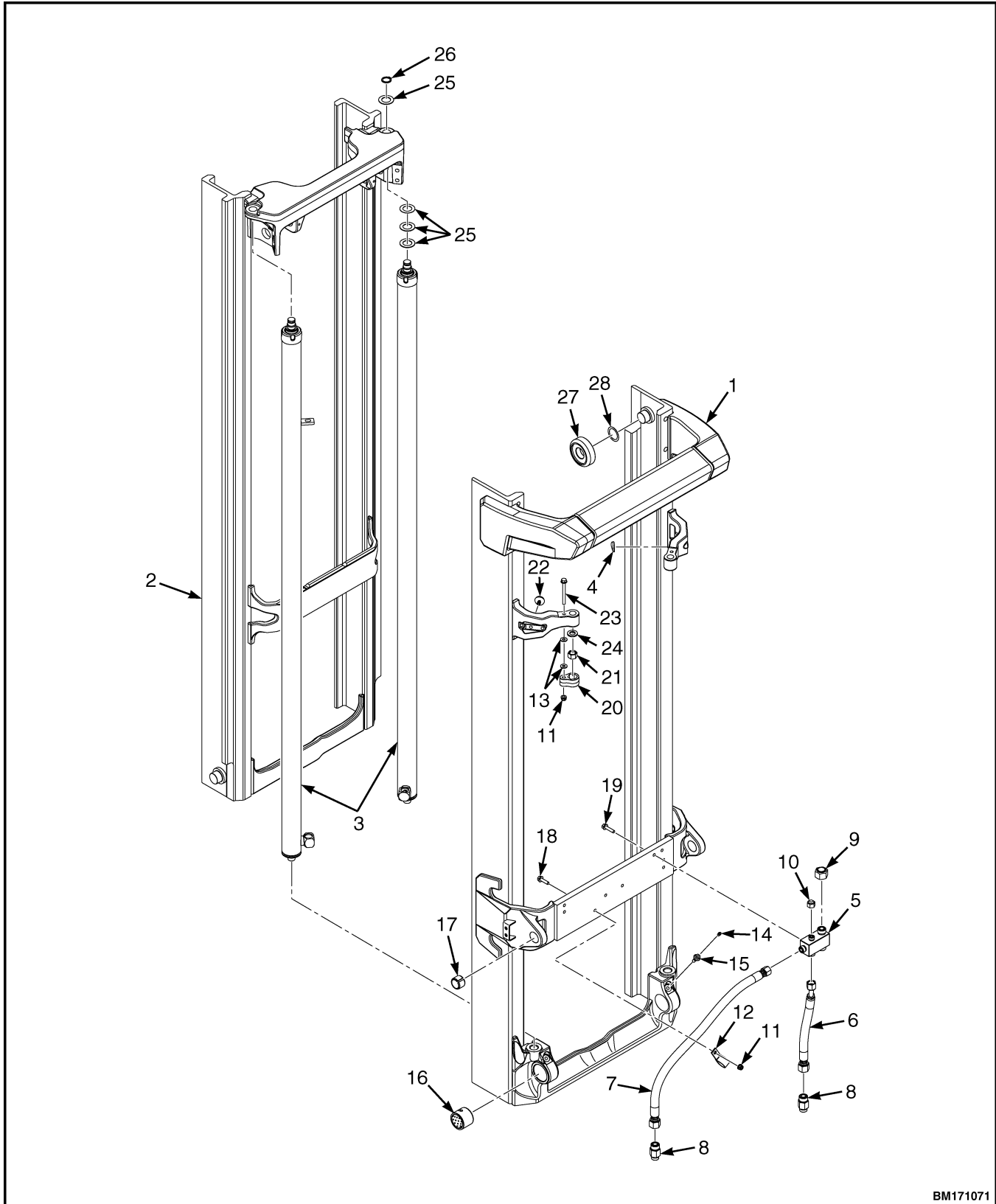
- 1. STANDARD CARRIAGE
- 2. SNAP RING
- 3. LOAD ROLLER
- 4. SHIM

- 5. SNAP RING
- 6. CHAIN ANCHOR
- 7. PIN
- 8. COTTER PIN

Figure 382. Standard Carriage

There are four load rollers the three mating channels ride against a set of load rollers to keep the mast moving smooth and predictably during lift and lower. On the right and left channels of the inner weldment at the bottom section, load rollers

are mounted facing outward. On the outer weldment right and left channels at the top are two rollers mounted facing inward. The inner weldment nests inside the outer and is kept in alignment by the load rollers.

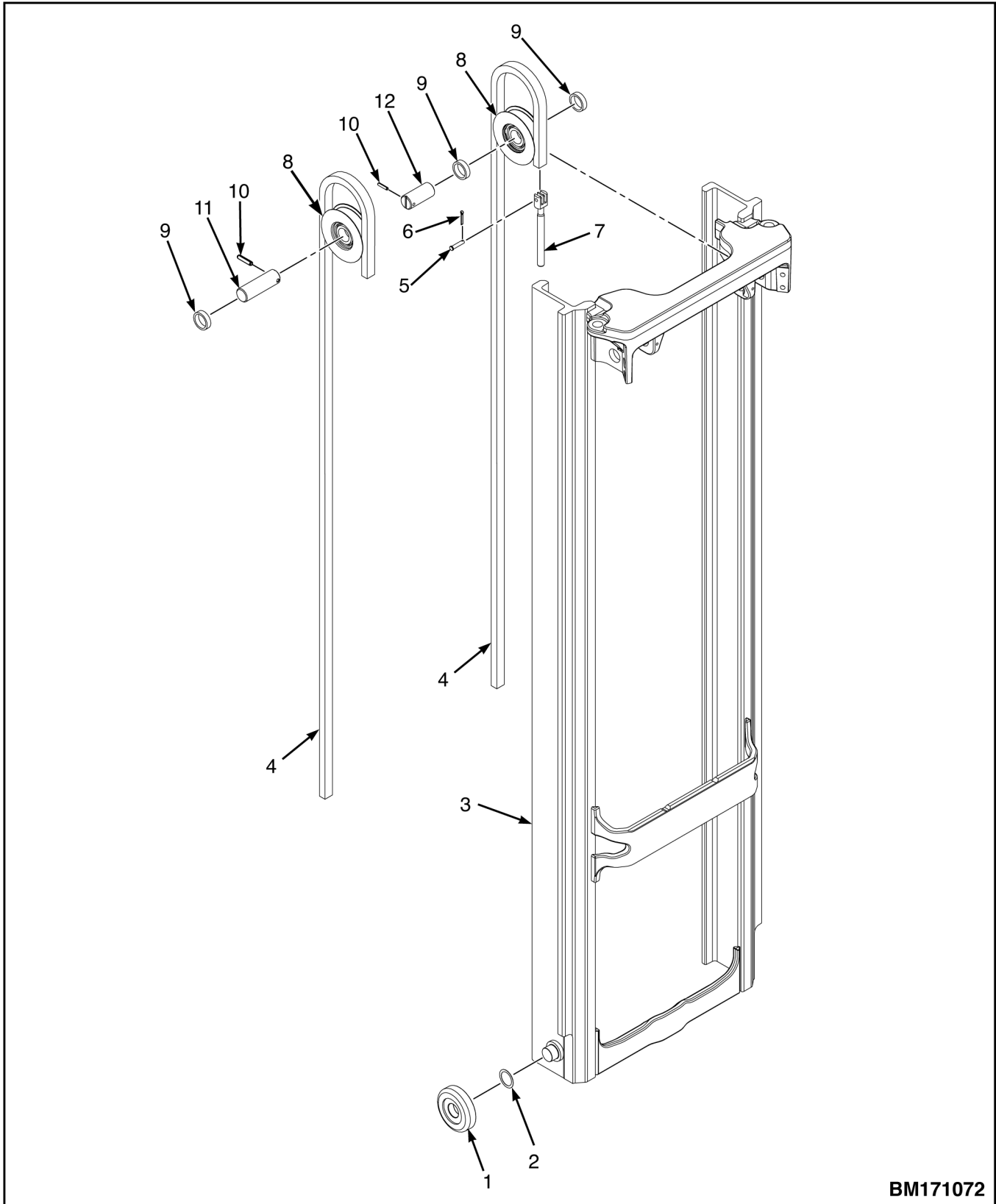


BM171071

Figure 383. Main lift cylinders and outer mast

Legend for Figure 383.

- | | |
|----------------------------|-----------------|
| 1. OUTER MAST | 15. WASHER |
| 2. INNER MAST | 16. BUSHING |
| 3. LIFT CYLINDER | 17. BUSHING |
| 4. NUT | 18. CAPSCREW |
| 5. MANIFOLD | 19. CAPSCREW |
| 6. HOSE | 20. RESTRAINT |
| 7. HOSE | 21. NUT |
| 8. HYDRAULIC VELOCITY FUSE | 22. RUBBER PAD |
| 9. FITTING | 23. CAPSCREW |
| 10. CAPSCREW | 24. CABLE |
| 11. LOCKNUT | 25. SHIM |
| 12. CLAMP | 26. SNAP RING |
| 13. LUBE FITTING | 27. LOAD ROLLER |
| 14. LUBE CAPSCREW | 28. SHIM |



BM171072

Figure 384. Inner Mast Components

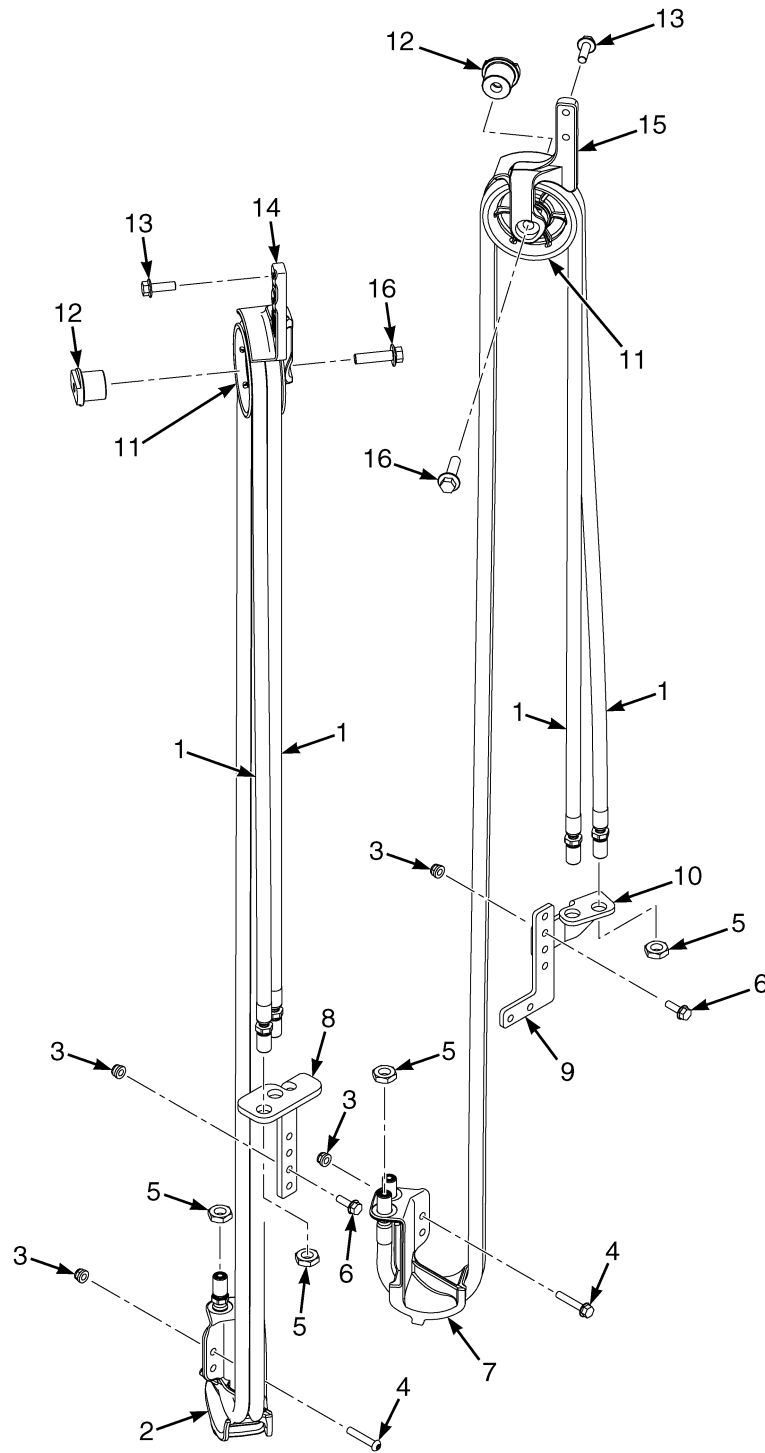
Legend for Figure 384.

- | | |
|-----------------|--------------------------|
| 1. LOAD ROLLER | 9. BUSHING |
| 2. SHIM | 10. ROLL PIN |
| 3. INNER MAST | 11. HOSE SHEAVE PIN (LH) |
| 4. CHAIN | 12. HOSE SHEAVE PIN (RH) |
| 5. PIN | 13. WEAR STRIP |
| 6. COTTER PIN | 14. SHIM |
| 7. CHAIN ANCHOR | 15. O-RING |
| 8. CHAIN SHEAVE | |

Mast Hydraulic Components

The main lift cylinders are mounted to the left and right channels of the mast. Lift chains and hydraulic hoses are routed over and anchored at the top of each lift cylinder.

Two Stage LFL Header Hose



BP171001

Figure 385. Two Stage LFL Header Hose

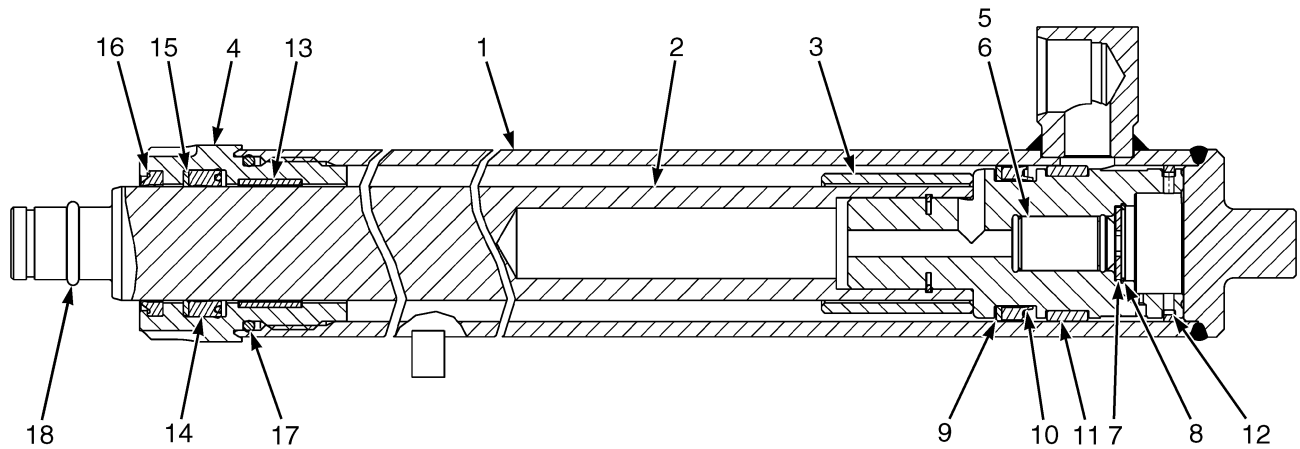
Legend for Figure 385.

- | | | |
|-----------------|-----------------|---------------|
| 1. HEADER HOSES | 6. CAPSCREW | 12. STUBSHAFT |
| 2. BRACKET | 7. BRACKET | 13. CAPSCREW |
| 3. LOCKNUT | 8. BRACKET | 14. BRACKET |
| 4. SCREW | 9. BRACKET | 15. BRACKET |
| 5. NUT | 10. BRACKET | 16. CAPSCREW |
| | 11. HOSE SHEAVE | |

Main Lift Cylinders

A pair of hydraulic cylinders (main lift cylinders) are used to lift and lower the mast. The lift cylinders can be engaged to raise the mast during lift. Then the lift cylinders can be engaged to lower the mast back once a load is picked and being moved.

The lift cylinders operate in two directions. There is a port at the base of the cylinder and another at the rod end of the assembly. Hydraulic oil entering the port at the base of the cylinder feeds under the piston and causes the rod to extend while oil exhausts through the rod end port. Hydraulic oil entering the port at the rod end causes the rod to retract into the cylinder.



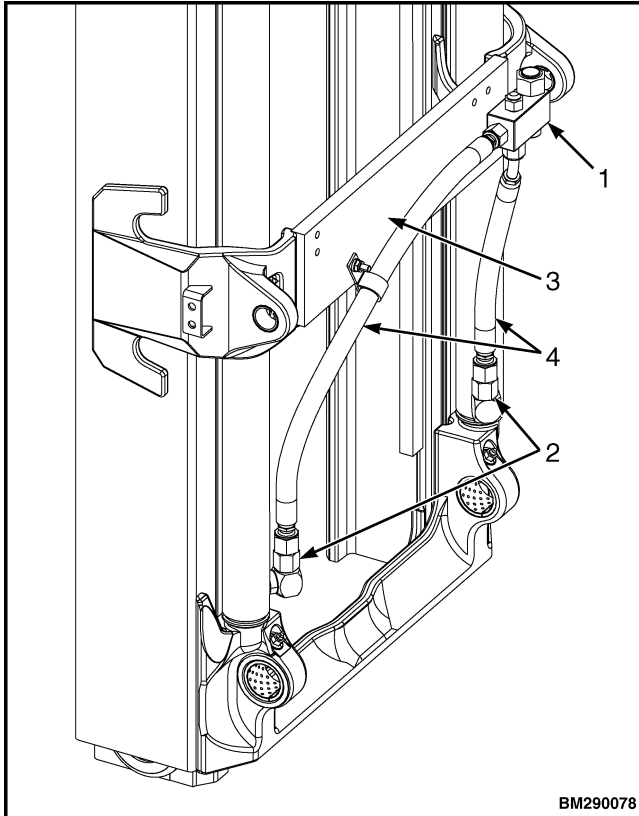
BP170987

- | | |
|---------------------------|------------------|
| 1. CYLINDER TUBE WELDMENT | 10. PISTON SEAL |
| 2. CYLINDER ROD | 11. WEAR RING |
| 3. SPACER | 12. WEAR RING |
| 4. GLAND | 13. WEAR RING |
| 5. CHECK VALVE | 14. ROD SEAL |
| 6. O-RING | 15. BACK-UP RING |
| 7. WASHER | 16. ROD WIPER |
| 8. SNAP RING | 17. O-RING |
| 9. BACK-UP RING | 18. O-RING |

Figure 386. Main Lift Cylinder

Mast Hose Manifold

The hydraulic manifold installed on the mast is a convenient and serviceable method to evenly distributing hydraulic oil. The central location helps with cleaner hose routing on the mast assembly.



1. MANIFOLD
2. HYDRAULIC VELOCITY FUSE
3. MAST
4. HYDRAULIC HOSES

Figure 387. Manifold and Hoses

Velocity Fuse

The velocity fuse is a safety device to prevent a sudden rapid loss of oil pressure in the mast. In the event there is a hydraulic hose in the mast that ruptures, the velocity fuse will close and shut off oil flow when a high flow rate through it is detected. The velocity fuse prevents a picked load from crashing down due to a significant loss of hydraulic oil downstream from the manifold.

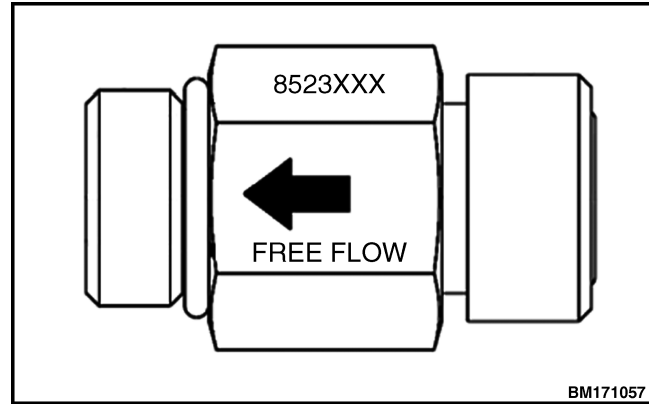


Figure 388. Hydraulic Velocity Fuse

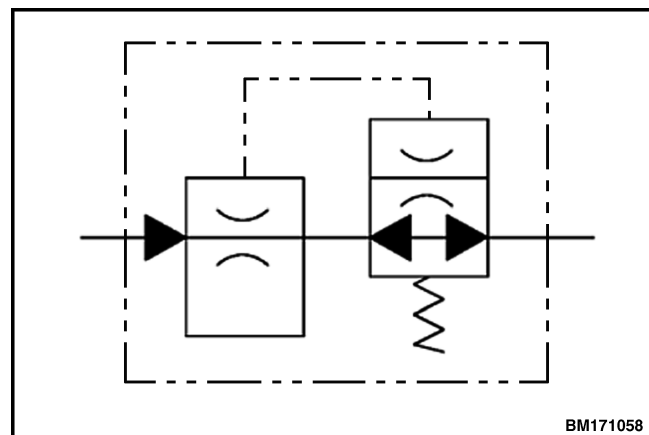


Figure 389. Velocity Fuse ASA Symbol

Hoses and Hose Assemblies

The hoist hoses are the longest of all equipped on a truck. They are arranged up and down the mast and are routed over pulleys mounted on the mast.

Hose part numbers are printed on a tag attached to the hose. The part number identifies the hose and important attributes like installed fittings, protective components, and length. The hose material and construction is also printed on the hose.

High pressure hydraulic hoses supply oil from the mast mounted manifold to the free-lift and main lift cylinders. The mast hydraulic hoses are routed as required.

Hose Fittings

There are a few common hydraulic fitting types. The hydraulic hose fittings are crimped on and non-reusable. When hoses are replaced the fittings can not be removed without damaging and significantly compromising fitting integrity.

Some applications of hydraulic fittings may use Joint Industry Council (JIC) type fittings where the sealing O-ring mates with a flared shoulder. However, most of the hydraulic fittings are O-Ring Face Seal (ORFS).

Mast Mechanical Components

Lift Chain

The primary function of the lift chain is to pull the inner mast channels to height during lifting and help hold the mast load during lowering. A set of lift chains hold the weight of the mast, carriage, and load. One end of the lift chain mounts at an anchor point near the top end of each lift cylinder. The other end of the lift chain mounts at an anchor point on the base of the innermost mast channel. Each of the lift chains moves over chain roller sheaves mounted on the mast.

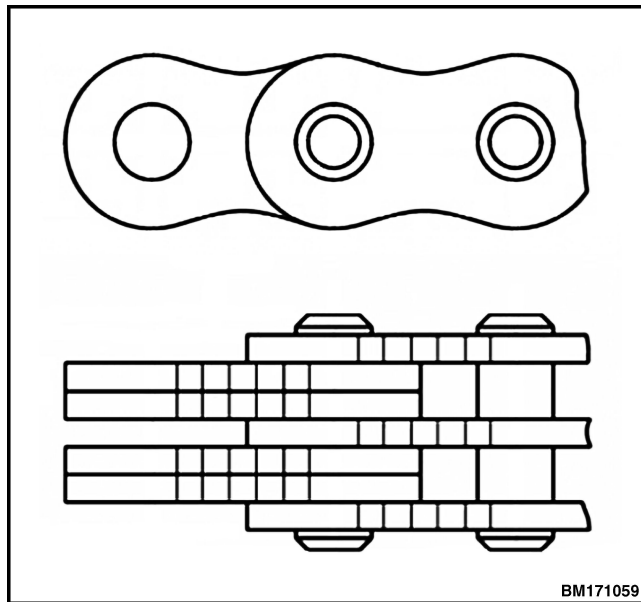


Figure 390. Lift Chain Example

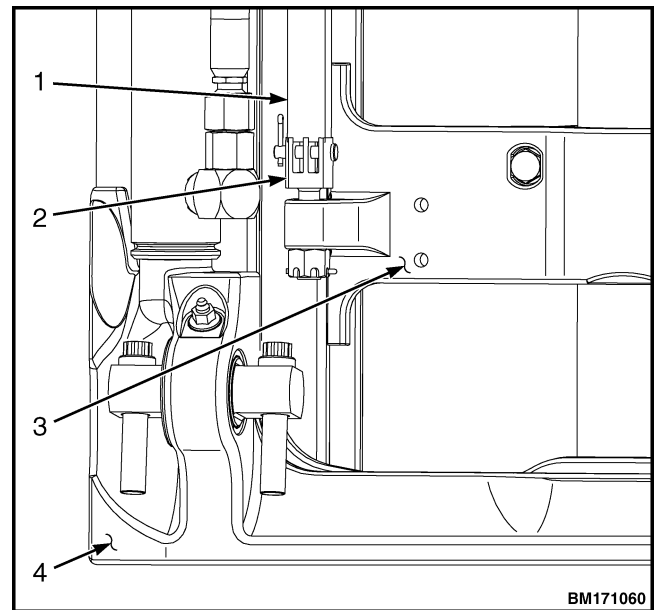
The lift chains are routed over a system of pulleys called chain sheaves. As the lift cylinder rods extend, the power is transferred to the mast by the lift chains. One end of the lift chain is pinned to a chain anchor at the outermost mast channel. Typically, the lift chain anchor is attached to the lift cylinder casing mounted to the outer mast channel. The other end of the lift chain is anchored to the top of the inner most mast channel.

During lifting the carriage assembly rises first with the free-lift cylinder until the end of cylinder travel. Then the main lift cylinder rods extend, causing the next inner channel to be pulled up to lift height.

Like all mast components the lift chain must be inspected for corrosion or damage; greased and the tension adjusted as necessary when performing periodic maintenance.

Chain Anchors

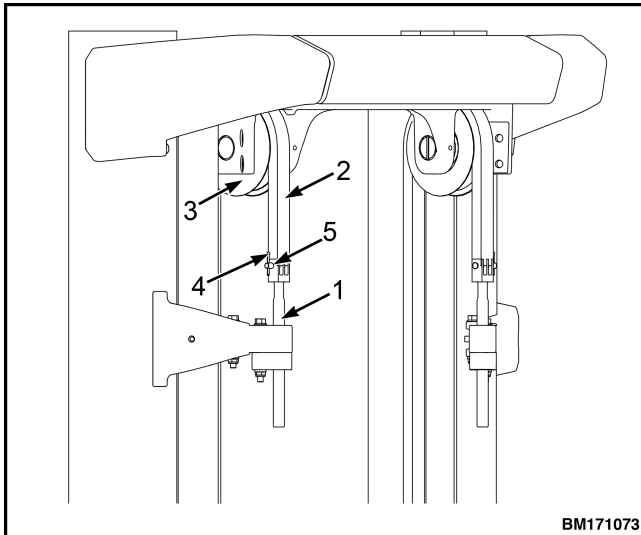
A secondary function of the chain anchor is adjustment of lift chain tension. The chain anchor is threaded so that lift chain tension can be increased or decreased.



- 1. LIFT CHAIN
- 2. CHAIN ANCHOR
- 3. INNER BOTTOM CROSSMEMBER
- 4. OUTER BOTTOM CROSSMEMBER

Figure 391. Chain Anchor (lower)

Like all mast components chain anchors must be inspected for corrosion, greased and hardware torques if adjustment was necessary when performing periodic maintenance.



1. CHAIN ANCHOR
2. MAIN LIFT CHAIN
3. CHAIN SHEAVE
4. CHAIN ANCHOR PIN
5. COTTER PIN

Figure 392. Chain Anchor (upper)

Chain Sheaves

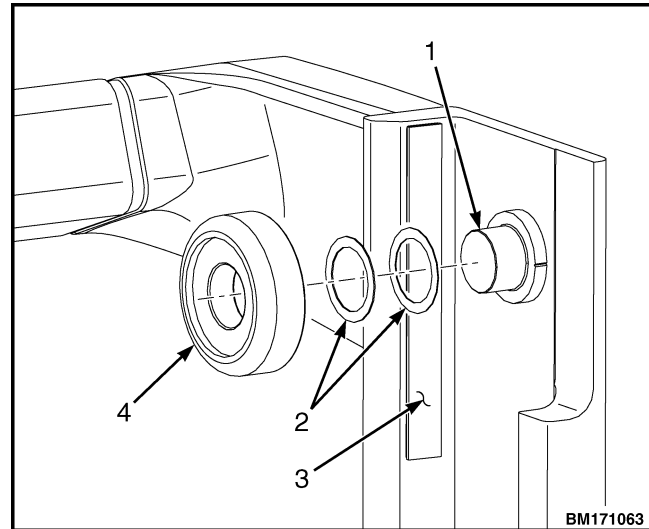
Chain sheaves are pulleys for guiding chain movement on the mast assembly. Chain sheaves are a tough plastic pulley with a center bearing and a mating profile to keep the chain aligned and reduce wear during repeated operation.

Chain sheaves are attached to both inner and intermediate mast inner top cross members and the free-lift cylinder. Like all mast components chain sheaves must be inspected for damage when performing periodic maintenance

Load Rollers

Between each mast channel are load rollers that guide adjacent mast channels as they lift and lower. Load rollers are installed on machined stub shafts welded to the mast channels. The load rollers are tightly toleranced for keeping mast channels in alignment relative to each other. The primary surface of the load rollers is the rolling face that mates with the mast channel. But the secondary surface of the roller axis is also important. Axial

clearance must be controlled with shims. Correctly shimming the load rollers minimizes mast racking during lift and lower. Racking is when one side of an inner channel weldment sticks and causes the channels to walk down during lowering.



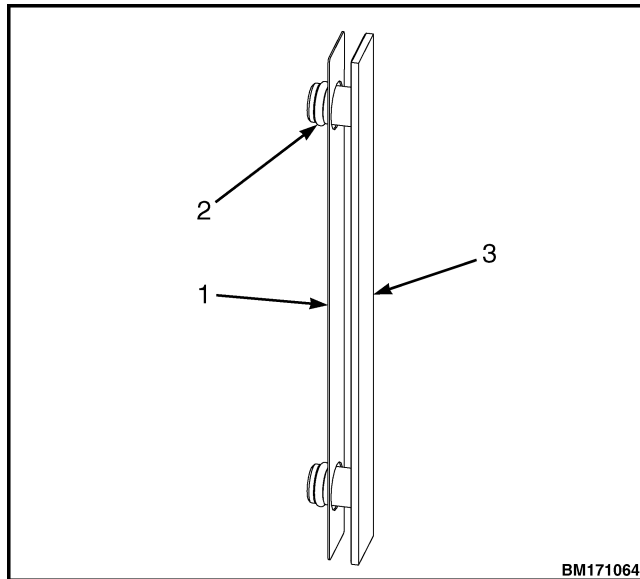
1. STUB SHAFT
2. SHIMS (AS NEEDED)
3. WEAR STRIP
4. LOAD ROLLER

Figure 393. Load Roller and Shims

To accommodate a small degree of variation between mating mast channels, clearance between the face of each load roller and the mating mast channel requires adjustment using shims. Shims are added or removed to adjust the clearance. The shims are made of high spring steel for strength and hardened for wear resistance.

NOTE: Greased mast channels and correct load roller clearance keeps symptoms like racking from occurring.

Wear Strips



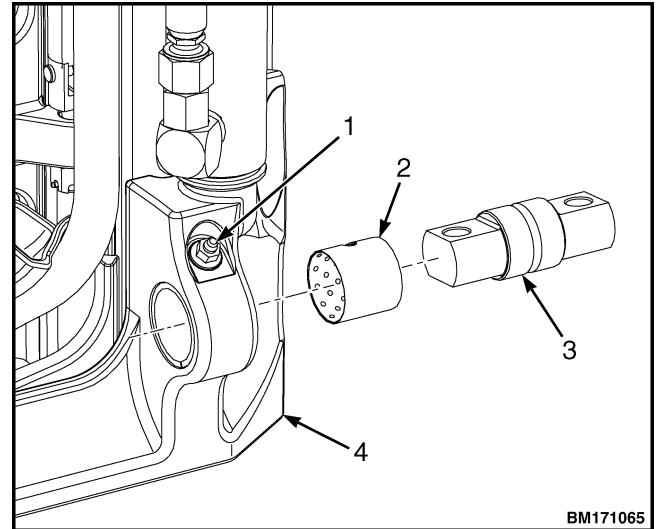
1. SHIM
2. O-RING
3. WEAR STRIP

Figure 394. Wear Strip

Wear strips are attached to the inside of mated mast channels. The base of the strip is steel and topped with a soft metal bearing layer. The wear strip is the axial face of the load rollers mate with. Load rollers of mating channels pass over the wear strip during lift and lowering. The wear strips can also be shimmed. Like all mast components the wear strips must be inspected for unusual wear patterns when performing periodic maintenance.

Mast Mounting Bushings

The pinned connections at the drive axle is where the force of the front end and any picked load is transferred to the truck. These mounts at the axle are also the pivot point when the mast is tilted.



1. GREASE FITTING
2. BUSHING (BRONZE)
3. PIN
4. OUTER MAST, OUTER BOTTOM CROSSMEMBER

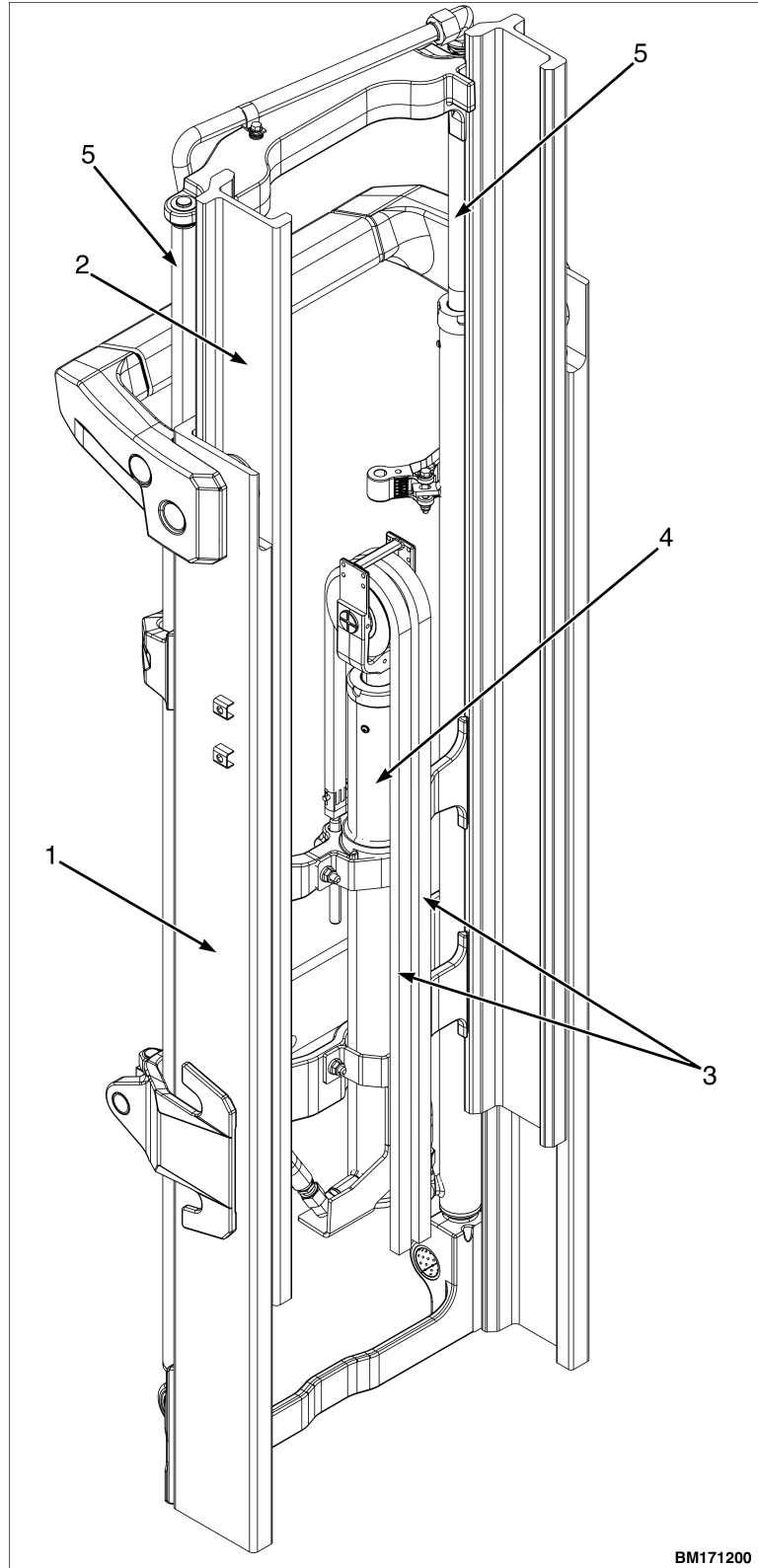
Figure 395. Mast Mounting Bushing

2-STAGE FULL FREE LIFT (FFL) MAST DESCRIPTION 202001-172

2-STAGE FFL MAST DESCRIPTION

This module will discuss the various functions and components specific to the two-stage full free-lift mast. For a general overview and description of the mast, see Mast description.

Mast functions are controlled by the hydraulic mechanical levers, Mini-Levers Module (MLM), or joysticks. The mast also provides mounting points for front end components and assemblies. The carriage assembly (including equipped attachments, load backrest, and hydraulic cylinders) mount to the mast.



BM171200

Figure 396. Two-Stage FFL Mast

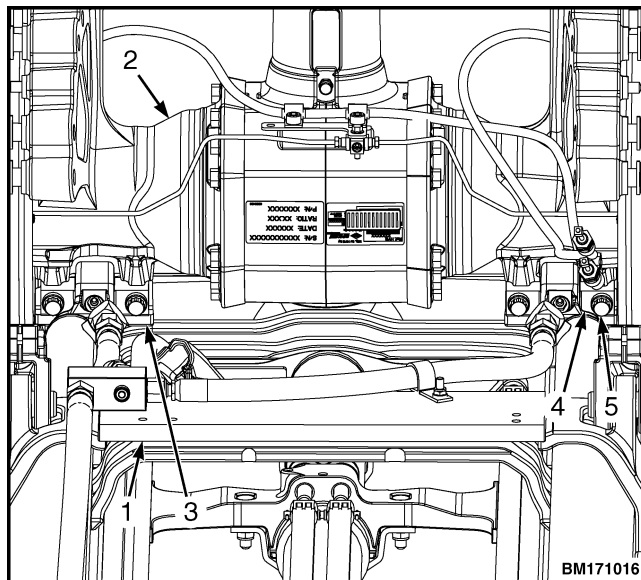
Legend for Figure 396.

NOTE: GRAPHIC IS FOR ILLUSTRATIVE PURPOSES ONLY, VARIATIONS ARE POSSIBLE.

- 1. OUTER MAST
- 2. INTERMEDIATE MAST
- 3. LIFT CHAIN(S)

- 4. FREE-LIFT CYLINDER
- 5. MAIN LIFT CYLINDER(S)

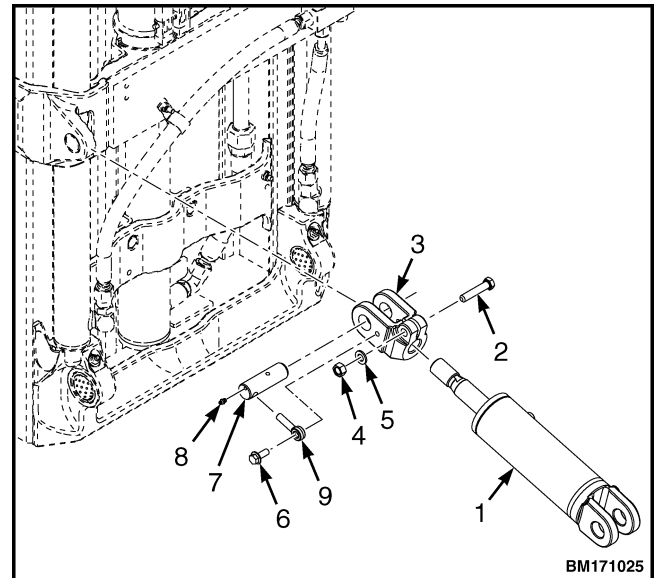
The lower crossmember of the outer mast has castings to mount the mast pivot pins. The pivot pins are installed in the castings and the mast is mounted on the J-hangers of the drive axle housing. Capscrews secure the mast pivot pins to the drive axle housing.



- 1. MAST
- 2. DRIVE AXLE
- 3. HANGER MOUNTS
- 4. MAST PIVOT PIN
- 5. CAPSCREW

Figure 397. Mast Mount on Drive Axle

The mast can also be tilted forward to ease picking or placing a load and tilted back to keep a picked load safe against the carriage load backrest. Tilt is achieved by another set of hydraulic cylinders operating perpendicular to the mast. The tilt cylinders are mounted on either side of the outermost mast channels. The rod end of the tilt cylinders mount about 1/3 of the way up the mast and the cylinder base mounts at the front cowl. Both mounts are pivot points to allow minor change to their working angle.



- 1. MAST TILT CYLINDER
- 2. CAPSCREW
- 3. ROD END
- 4. NUT
- 5. WASHER
- 6. CAPSCREW
- 7. PIVOT PIN
- 8. GREASE FITTING
- 9. ANCHOR PIN

Figure 398. Tilt Cylinder Mounting

The tilt cylinders can be engaged to tilt the mast forward during picking or placing a load. Then the tilt cylinders can be engaged to tilt the mast back once a load is picked up and being moved.

The tilt cylinders operate in two directions. There is a port at the base of the cylinder and another at the rod end of the assembly. Hydraulic oil entering the port at the base of the cylinder feeds under the piston and causes the rod to extend while oil exhausts through the rod end port. Hydraulic oil entering the port at the rod end causes the rod to retract into the cylinder.

Basic Operation

The three hydraulic cylinders (1 free-lift, 2 main lift) are connected by hoses and tubing. When the mast is extended, oil from the main control valve flows to all cylinders at the same time. The free-lift cylinder extends first because it lifts the least amount of weight and has a lower operating pressure. The free-lift cylinder raises only the carriage. After the free-lift cylinder reaches the end of its stroke, the main lift cylinders begin to extend. As the main lift cylinders extend, the intermediate mast is raised by the main lift cylinders and the inner mast is raised by the main lift chains. All cylinders are protected from sudden rapid pressure loss by hydraulic velocity fuses.

During lowering, the main lift cylinders lower first because they have a greater load and higher operating pressure. After the main lift cylinders have retracted, the free-lift cylinder lowers. All oil from the lift cylinders flows through the lowering control valves to the hydraulic tank.

The free-lift cylinder has oil above the piston to provide a hydraulic cushion when the cylinder reaches the top of its stroke. An orifice system in the piston provides the hydraulic cushioning. When the cylinder is fully extended, any excess oil above the piston is forced through the check valve.

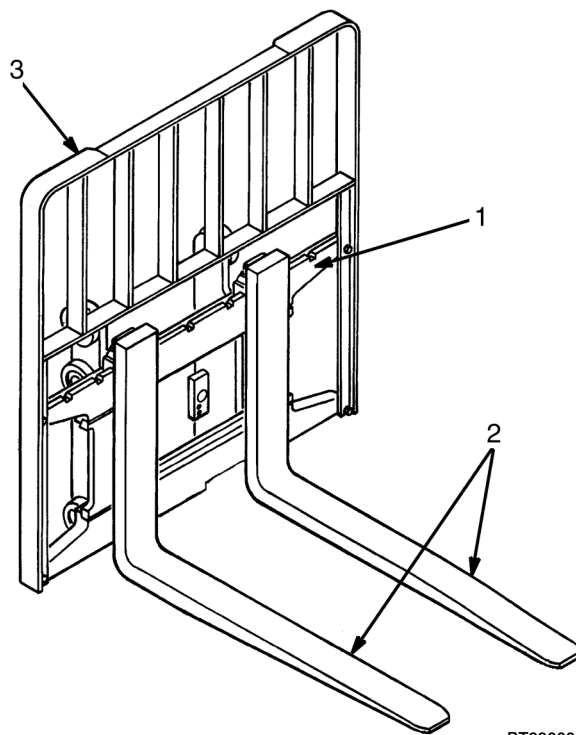
Each main lift cylinder has an orifice system and a check valve in the bottom of the rod assembly. When the cylinder is fully extended, any oil between the rod end and the gland is forced through the check valve. The orifice system provides a hydraulic cushion when the cylinder reaches the bottom of its stroke.

Two Stage Full Free-Lift

The two stage FFL includes one inner channel weldment and a single outer channel weldment. The FFL free-lift travel is equal to the height of the mast where the carriage moves up independent of the mast channel.

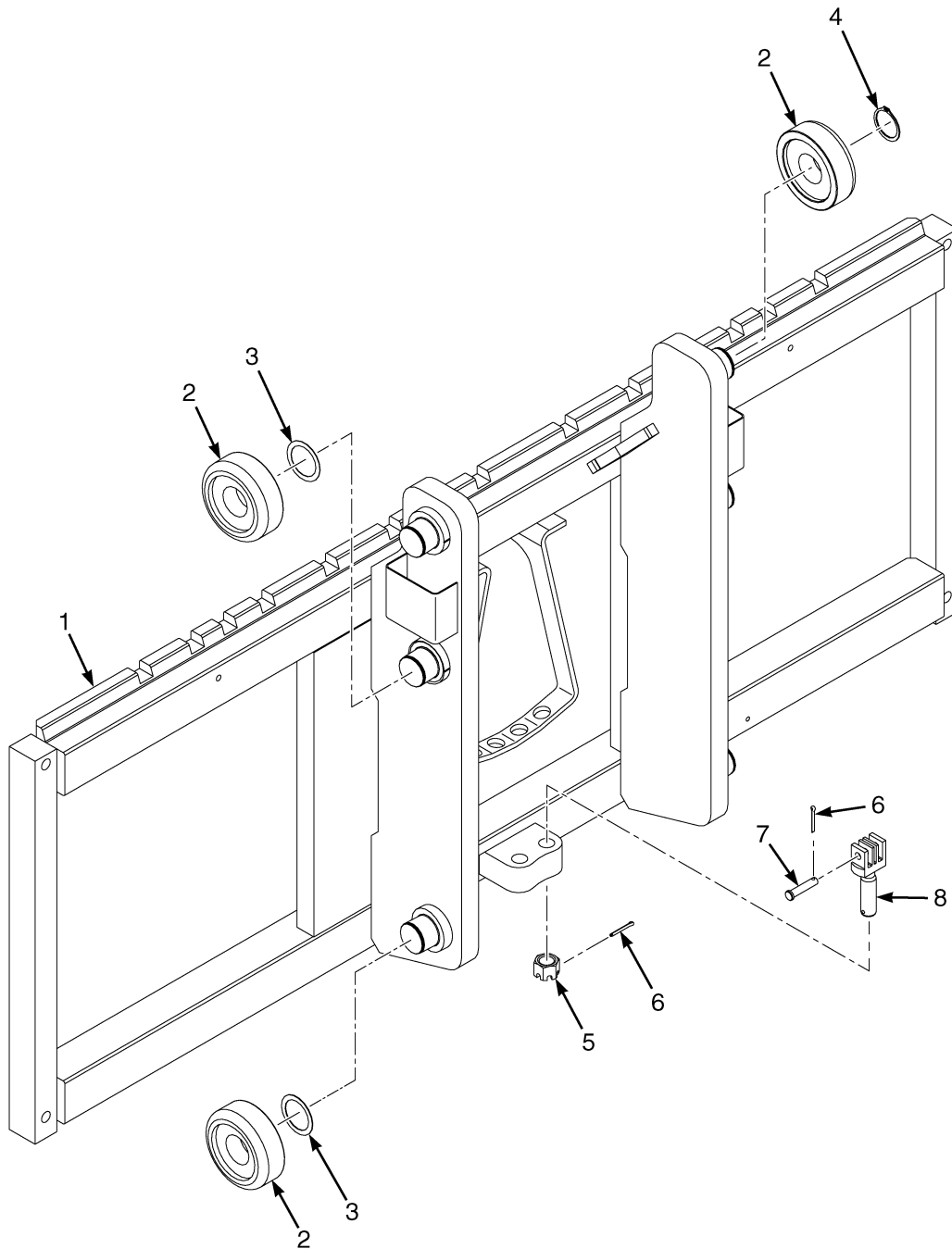
The primary function of the carriage assembly is to provide a mounting location for the front end attachments (fork tines, roll clamp, box clamp, box clamp, slip sheet, rotator). The most common front end attachment are the fork tines.

Multiple load rollers are a part of the carriage assembly. The load rollers are positioned laterally, facing out to mate with the inner most mast channel. The carriage moves with the mast inner channel during lift, lower and tilt. Front end attachments hang on the carriage.



1. STANDARD CARRIAGE
2. FORKS
3. LOAD BACKREST EXTENSION

Figure 399. Carriage, Forks, and Backrest Example



BP171049

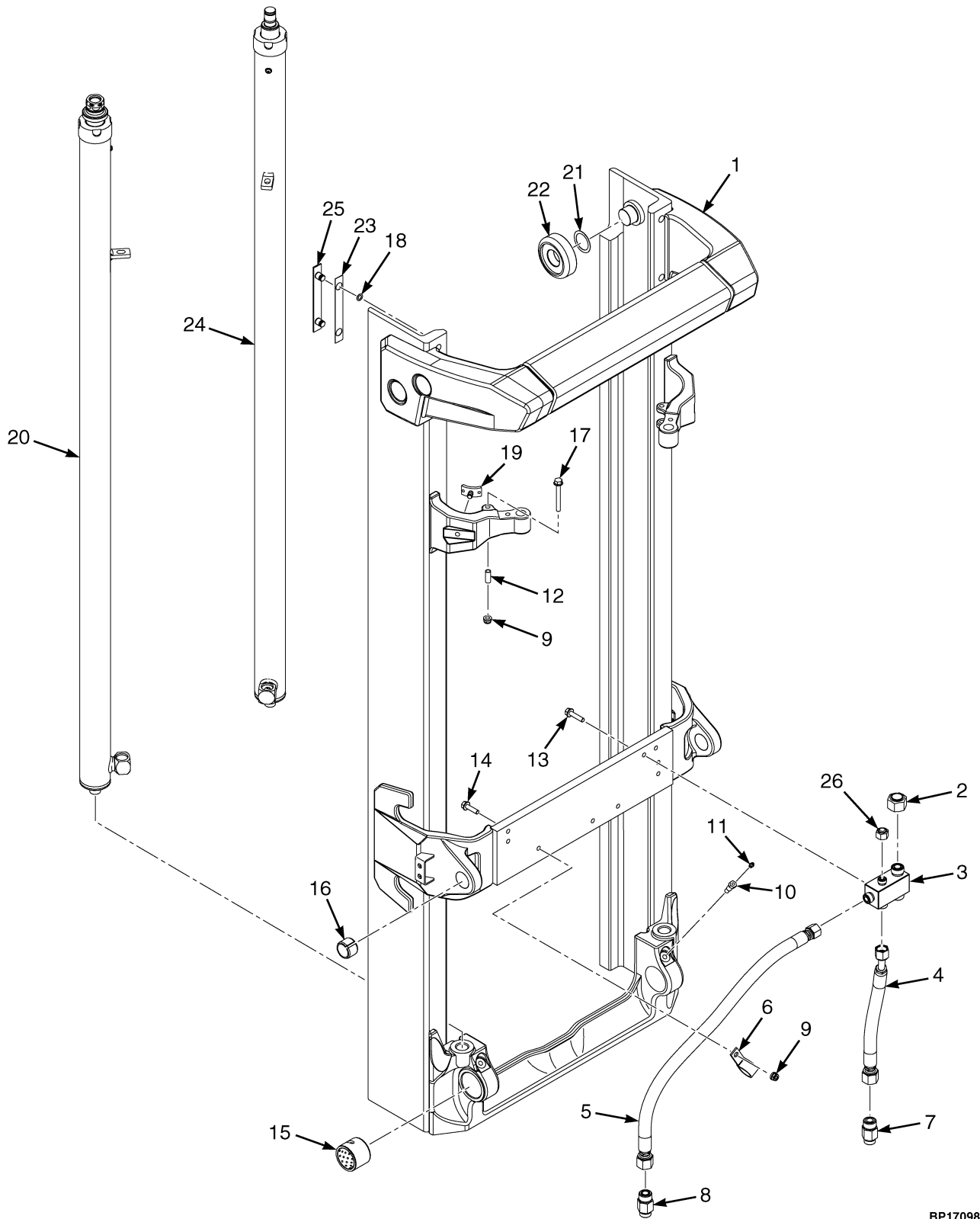
Figure 400. Standard Carriage

Legend for Figure 400.

- | | |
|----------------------|---------------------|
| 1. STANDARD CARRIAGE | 5. CASTLE NUT |
| 2. LOAD ROLLER | 6. COTTER PIN |
| 3. SHIM | 7. CHAIN ANCHOR PIN |
| 4. SNAP RING | 8. CHAIN ANCHOR |

There are four load rollers the three mating channels ride against a set of load rollers to keep the mast moving smooth and predictably during lift and lower. On the right and left channels of the inner weldment at the bottom section, load rollers

are mounted facing outward. On the outer weldment right and left channels at the top are two rollers mounted facing inward. The inner weldment nests inside the outer and is kept in alignment by the load rollers.

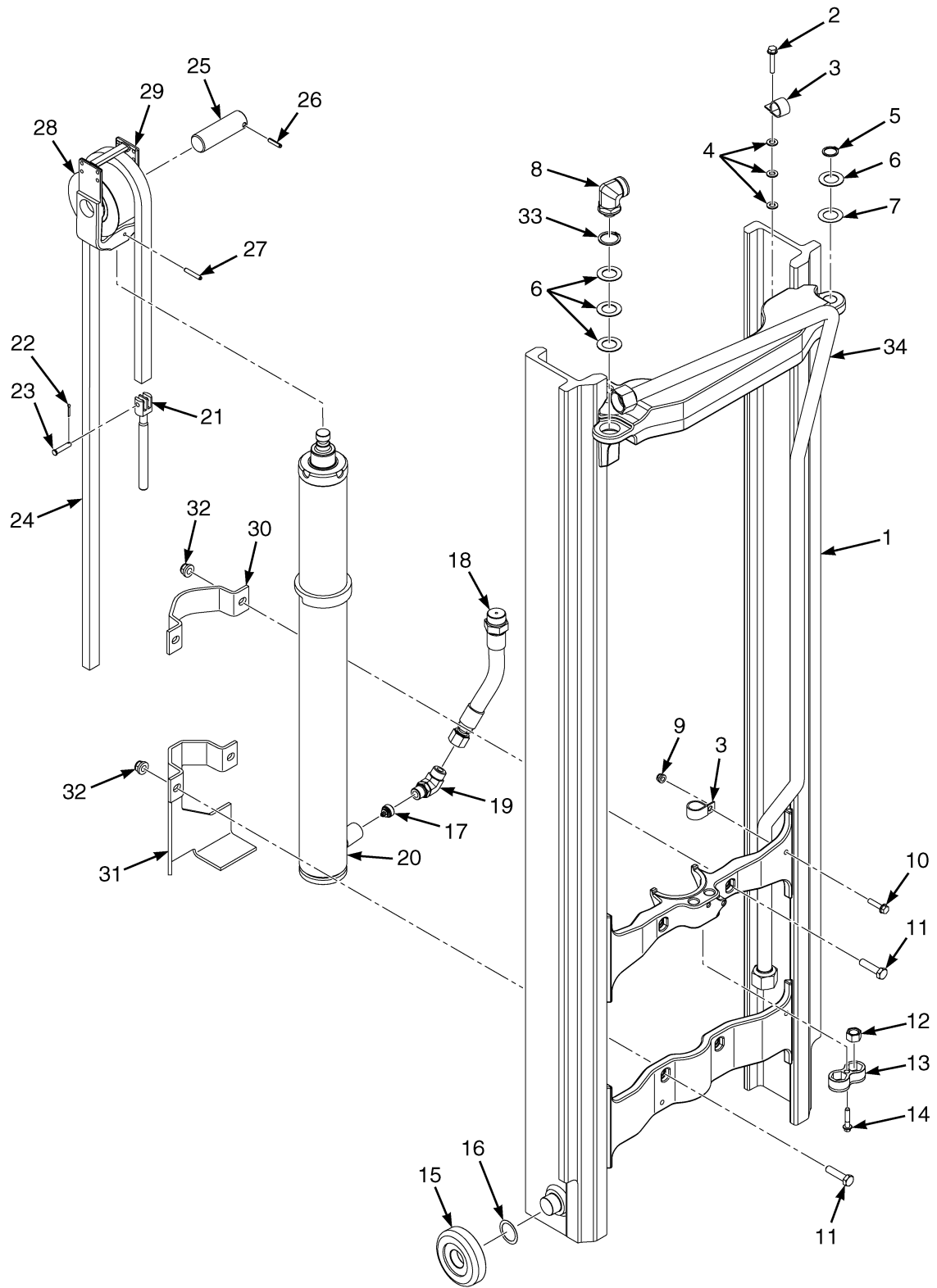


BP170988

Figure 401. Outer Mast

Legend for Figure 401.

- | | |
|----------------------------|-------------------|
| 1. OUTER MAST | 14. CAPSCREW |
| 2. FITTING | 15. BUSHING |
| 3. MANIFOLD | 16. BUSHING |
| 4. HOSE | 17. CAPSCREW |
| 5. HOSE | 18. O-RING |
| 6. CLAMP | 19. RUBBER PAD |
| 7. HYDRAULIC VELOCITY FUSE | 20. CYLINDER ASSY |
| 8. FITTING | 21. SHIM |
| 9. LOCKNUT | 22. LOAD ROLLER |
| 10. CAPSCREW | 23. SHIM |
| 11. GREASE FITTING | 24. CYLINDER ASSY |
| 12. SPACER | 25. WEAR STRIP |
| 13. CAPSCREW | 26. CAP |



BP170989

Figure 402. Intermediate Mast

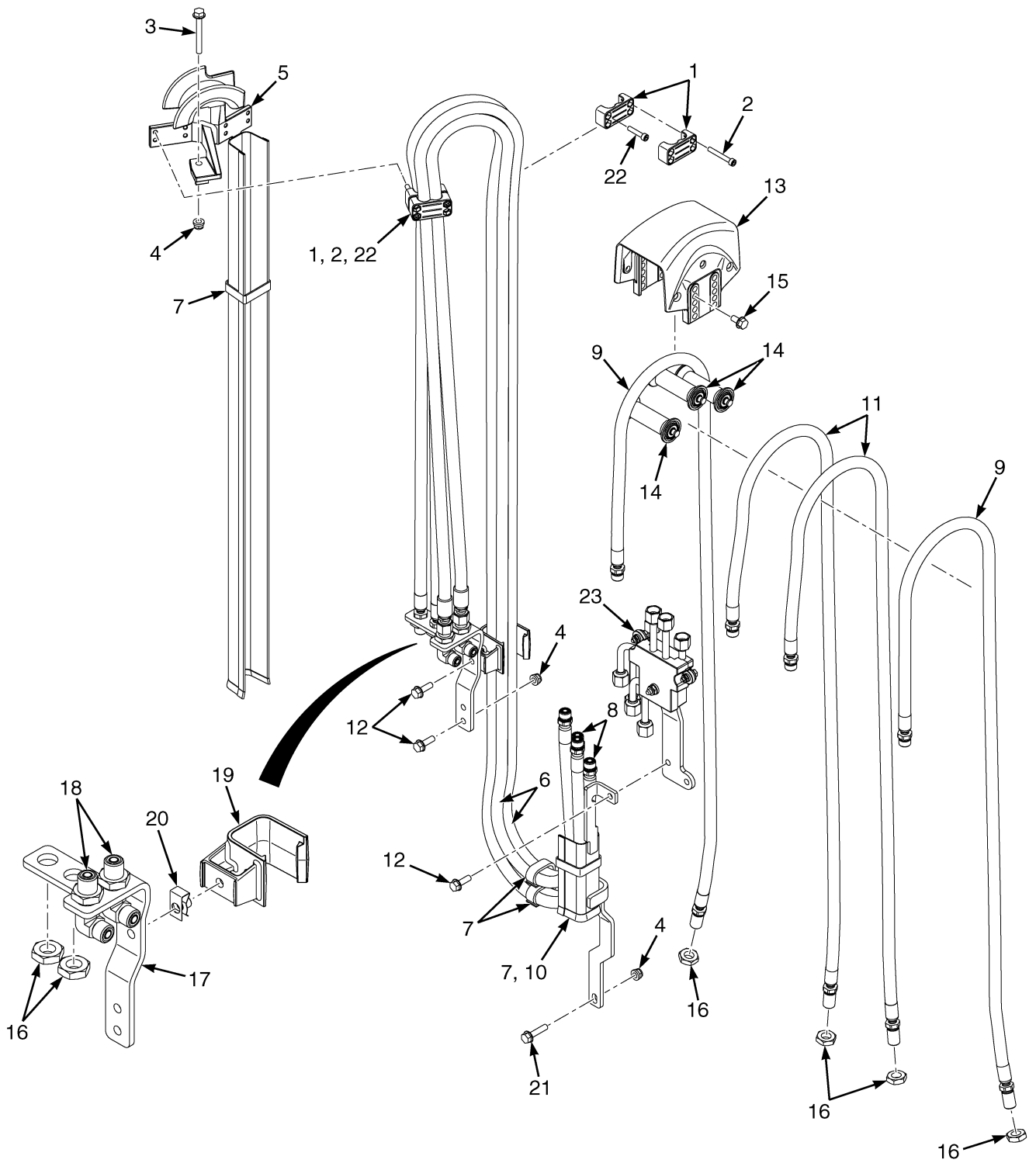
Legend for Figure 402.

- | | | | |
|-------------------------|------------------|-------------------|-------------------|
| 1. INTERMEDIATE
MAST | 9. LOCKNUT | 18. HOSE | 27. ROLL PIN |
| 2. CAPSCREW | 10. CAPSCREW | 19. FITTING | 28. CHAIN SHEAVE |
| 3. CLAMP | 11. CAPSCREW | 20. CYLINDER ASSY | 29. CROSSHEAD |
| 4. WASHER | 12. NUT | 21. CHAIN ANCHOR | 30. CLAMP |
| 5. SNAP RING | 13. CHAIN ANCHOR | 22. COTTER PIN | 31. CLAMP |
| 6. WASHER | 14. CAPSCREW | 23. PIN | 32. LOCKNUT |
| 7. SHIM | 15. LOAD ROLLER | 24. LIFT CHAIN | 33. SNAP RING |
| 8. FITTING | 16. SHIM | 25. PIN | 34. TUBE ASSEMBLY |
| | 17. FLOW VALVE | 26. ROLL PIN | |

Mast Hydraulic Components

The free-lift cylinder is arranged at the center, and the main lift cylinders are mounted to the left and right channels of the mast. Lift chains and hydraulic hoses are routed over and anchored at the top of each lift cylinder.

Two Stage FFL Header Hose



BP171003

Figure 403. Two Stage FFL Header Hose

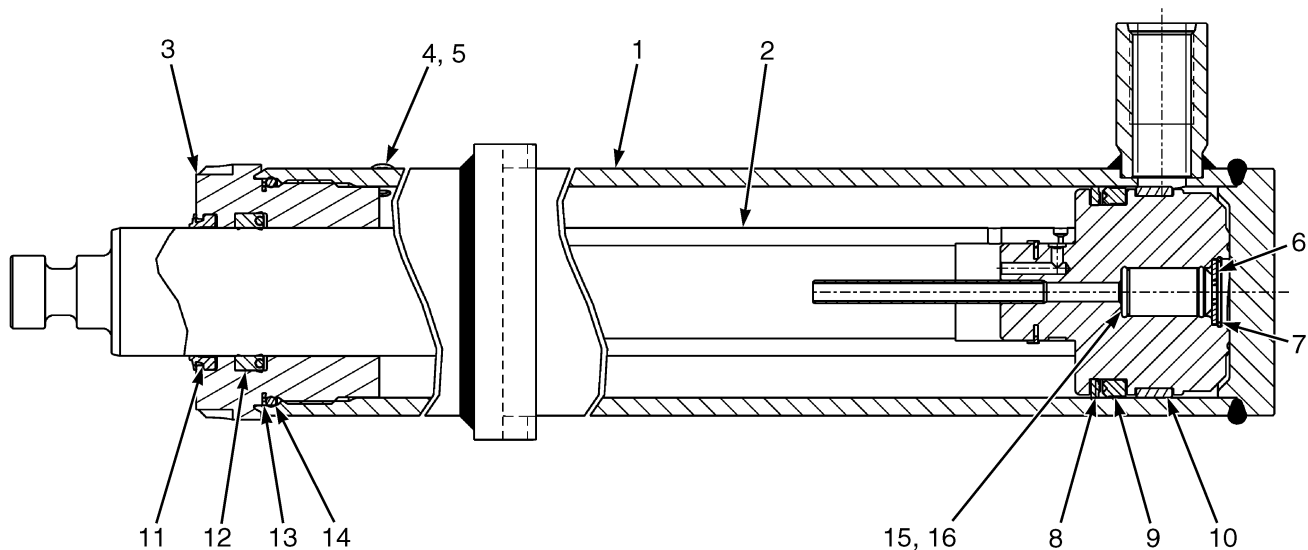
Legend for Figure 403.

- | | | |
|----------------|-----------------|--------------------|
| 1. CLAMP | 9. HEADER HOSE | 17. BRACKET |
| 2. CAPSCREW | 10. BRACKET | 18. FITTING |
| 3. CAPSCREW | 11. HEADER HOSE | 19. MOLDING |
| 4. LOCKNUT | 12. CAPSCREW | 20. NUT |
| 5. BRACKET | 13. CROSSHEAD | 21. CAPSCREW |
| 6. HEADER HOSE | 14. ROLLER | 22. CAPSCREW |
| 7. RETAINER | 15. CAPSCREW | 23. FREE LIFT TUBE |
| 8. HEADER HOSE | 16. NUT | |

Free-Lift and Main Lift Cylinders

A pair of hydraulic cylinders (main lift cylinders) are used to lift and lower the mast. The lift cylinders can be engaged to raise the mast during lift. Then the lift cylinders can be engaged to lower the mast back once a load is picked and being moved.

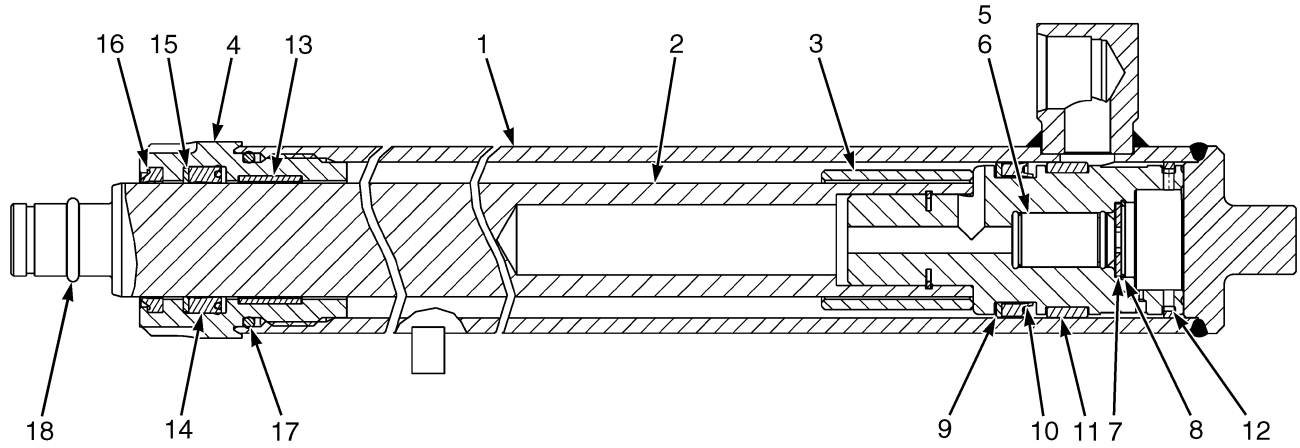
The lift cylinders operate in two directions. There is a port at the base of the cylinder and another at the rod end of the assembly. Hydraulic oil entering the port at the base of the cylinder feeds under the piston and causes the rod to extend while oil exhausts through the rod end port. Hydraulic oil entering the port at the rod end causes the rod to retract into the cylinder.



BP170992

- | | |
|---------------------------|------------------|
| 1. CYLINDER TUBE WELDMENT | 9. SEAL |
| 2. CYLINDER ROD | 10. WEAR RING |
| 3. GLAND | 11. ROD WIPER |
| 4. SEALING RING | 12. ROD SEAL |
| 5. SCREW | 13. BACK-UP RING |
| 6. WASHER | 14. O-RING |
| 7. SNAP RING | 15. CHECK VALVE |
| 8. BACK-UP RING | 16. O-RING |

Figure 404. Free-Lift Cylinder



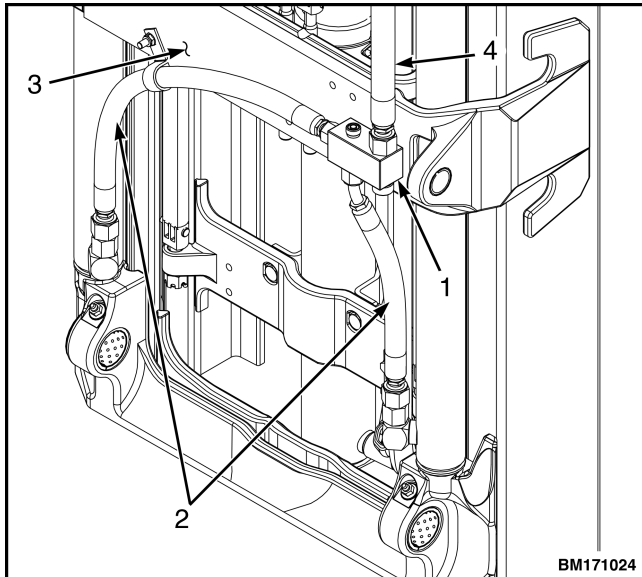
BP170987

- | | |
|---------------------------|------------------|
| 1. CYLINDER TUBE WELDMENT | 10. PISTON SEAL |
| 2. CYLINDER ROD | 11. WEAR RING |
| 3. SPACER | 12. WEAR RING |
| 4. GLAND | 13. WEAR RING |
| 5. CHECK VALVE | 14. ROD SEAL |
| 6. O-RING | 15. BACK-UP RING |
| 7. WASHER | 16. ROD WIPER |
| 8. SNAP RING | 17. O-RING |
| 9. BACK-UP RING | 18. O-RING |

Figure 405. Main Lift Cylinder

Mast Hose Manifold

The hydraulic manifold installed on the mast is a convenient and serviceable method to evenly distributing hydraulic oil. The central location helps with cleaner hose routing on the mast assembly.



1. MANIFOLD
2. HYDRAULIC HOSES
3. MAST
4. LIFT CYLINDER HOSE

Figure 406. Manifold and Hoses

Velocity Fuse

The velocity fuse is a safety device to prevent a sudden rapid loss of oil pressure in the mast. In the event there is a hydraulic hose in the mast that ruptures, the velocity fuse will close and shut off oil flow when a high flow rate through it is detected. The velocity fuse prevents a picked load from crashing down due to a significant loss of hydraulic oil downstream from the manifold.

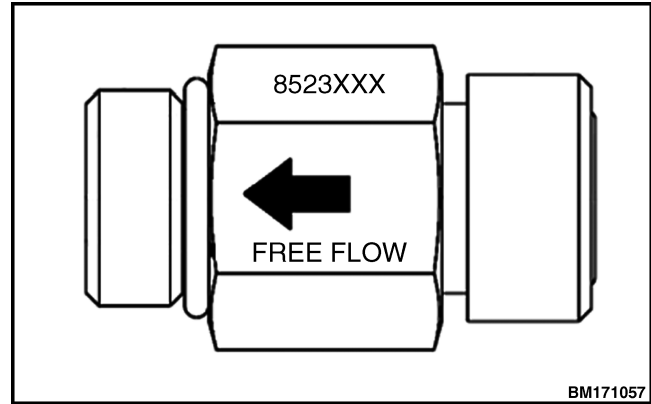


Figure 407. Hydraulic Velocity Fuse

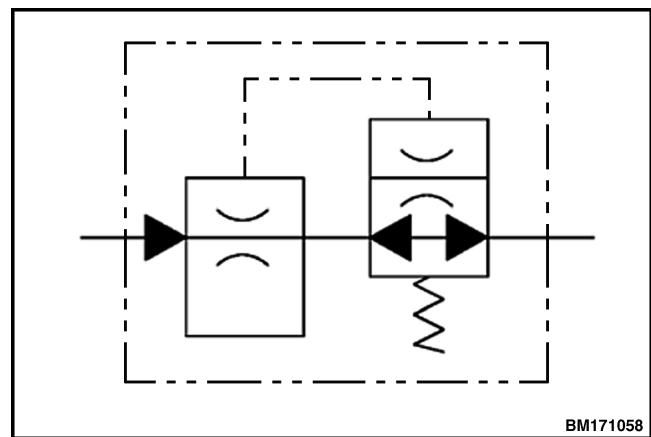


Figure 408. Velocity Fuse ASA Symbol

Hoses and Hose Assemblies

The hoist hoses are the longest of all equipped on a truck. They are arranged up and down the mast and are routed over pulleys mounted on the mast.

Hose part numbers are printed on a tag attached to the hose. The part number identifies the hose and important attributes like installed fittings, protective components, and length. The hose material and construction is also printed on the hose.

High pressure hydraulic hoses supply oil from the mast mounted manifold to the free-lift and main lift cylinders. The mast hydraulic hoses are routed as required.

Hose Fittings

There are a few common hydraulic fitting types. The hydraulic hose fittings are crimped on and non-reusable. When hoses are replaced the fittings can not be removed without damaging and significantly compromising fitting integrity.

Some applications of hydraulic fittings may use Joint Industry Council (JIC) type fittings where the sealing O-ring mates with a flared shoulder. However, most of the hydraulic fittings are O-Ring Face Seal (ORFS).

Mast Mechanical Components

Lift Chain

The primary function of the lift chain is to pull the inner mast channels to height during lifting and help hold the mast load during lowering. A set of lift chains hold the weight of the mast, carriage, and load. One end of the lift chain mounts at an anchor point near the top end of each lift cylinder. The other end of the lift chain mounts at an anchor point on the base of the innermost mast channel. Each of the lift chains moves over chain roller sheaves mounted on the mast.

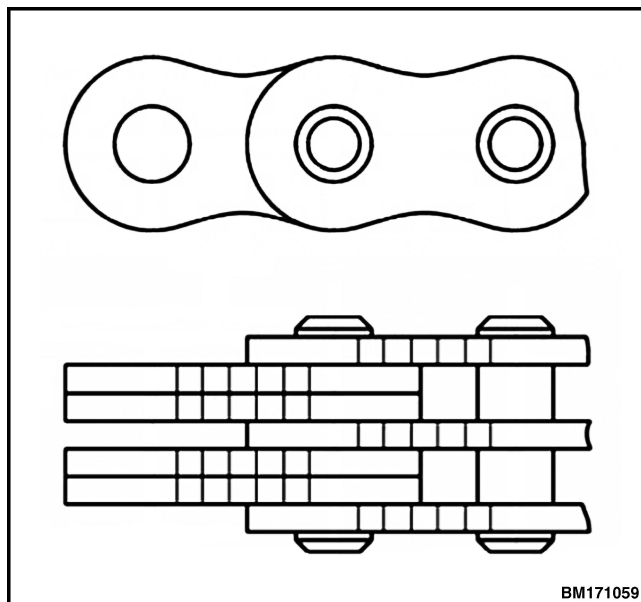


Figure 409. Lift Chain Example

The lift chains are routed over a system of pulleys called chain sheaves. As the lift cylinder rods extend, the power is transferred to the mast by the lift chains. One end of the lift chain is pinned to a chain anchor at the outermost mast channel.

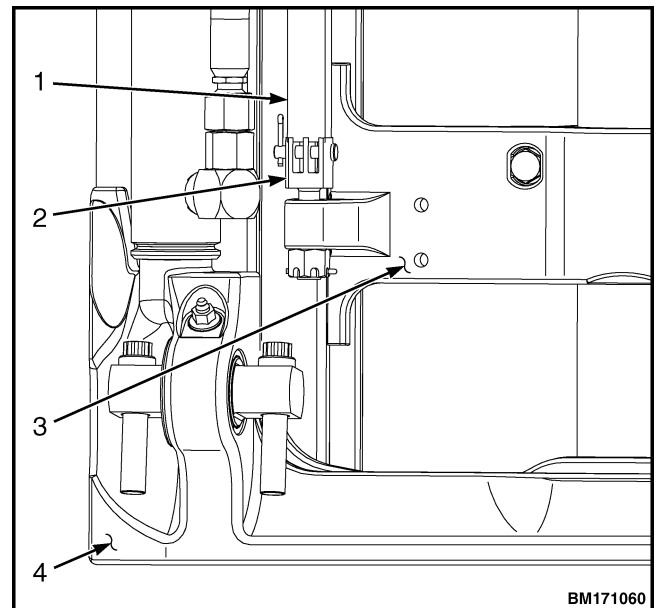
Typically, the lift chain anchor is attached to the lift cylinder casing mounted to the outer mast channel. The other end of the lift chain is anchored to the top of the inner most mast channel.

During lifting the carriage assembly rises first with the free-lift cylinder until the end of cylinder travel. Then the main lift cylinder rods extend, causing the next inner channel to be pulled up to lift height.

Like all mast components the lift chain must be inspected for corrosion or damage; greased and the tension adjusted as necessary when performing periodic maintenance.

Chain Anchors

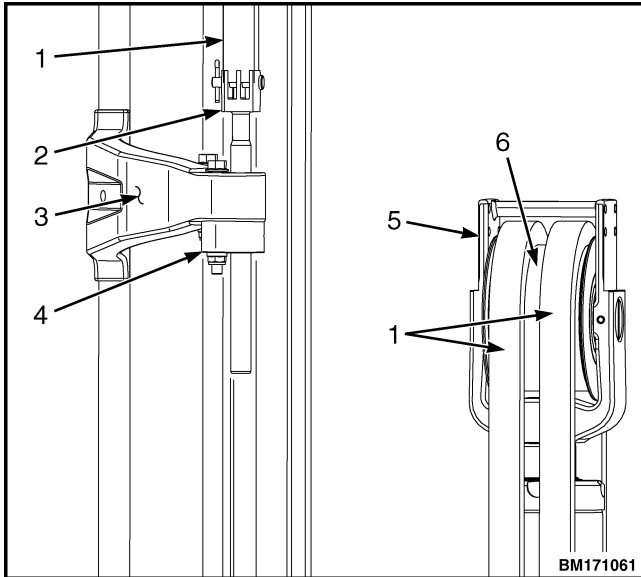
A secondary function of the chain anchor is adjustment of lift chain tension. The chain anchor is threaded so that lift chain tension can be increased or decreased.



1. LEAF CHAIN
2. CHAIN ANCHOR
3. INNER BOTTOM CROSSMEMBER
4. OUTER BOTTOM CROSSMEMBER

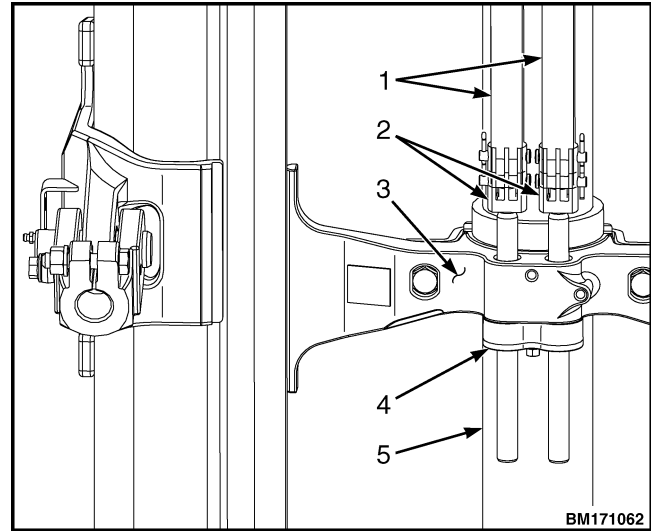
Figure 410. Chain Anchor

Like all mast components chain anchors must be inspected for corrosion, greased and hardware torques if adjustment was necessary when performing periodic maintenance.



1. LEAF CHAIN
2. CHAIN ANCHOR
3. CHAIN SUPPORT ANCHOR
4. CHAIN ANCHOR NUT (SINGLE)
5. CROSSHEAD
6. CHAIN SHEAVE

Figure 411. Chain Anchor Nut (Single) and Crosshead



NOTE: SOME PARTS HAVE BEEN REMOVED FOR CLARITY.

1. CHAIN
2. CHAIN ANCHOR
3. INNER MID CROSSMEMBER
4. CHAIN ANCHOR NUT (DOUBLE)
5. FREE-LIFT CYLINDER

Figure 412. Chain Anchor Nut (Double) and Free-Lift Cylinder

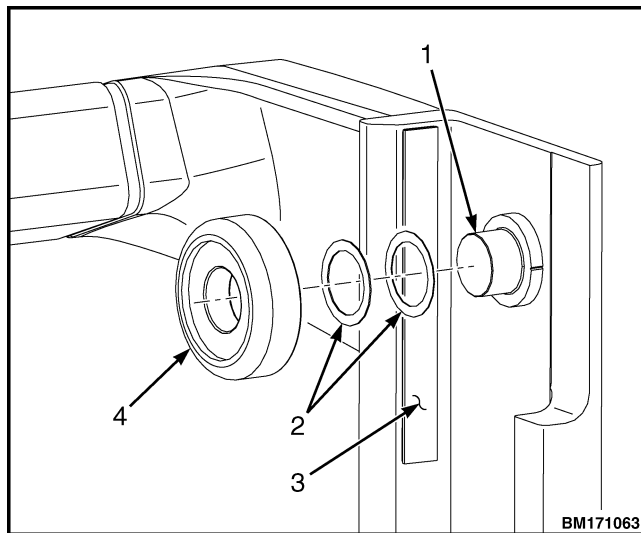
Chain Sheaves

Chain sheaves are pulleys for guiding chain movement on the mast assembly. Chain sheaves are a tough plastic pulley with a center bearing and a mating profile to keep the chain aligned and reduce wear during repeated operation.

Chain sheaves are attached to both inner and intermediate mast inner top cross members and the free-lift cylinder. Like all mast components chain sheaves must be inspected for damage when performing periodic maintenance

Load Rollers

Between each mast channel are load rollers that guide adjacent mast channels as they lift and lower. Load rollers are installed on machined stub shafts welded to the mast channels. The load rollers are tightly toleranced for keeping mast channels in alignment relative to each other. The primary surface of the load rollers is the rolling face that mates with the mast channel. But the secondary surface of the roller axis is also important. Axial clearance must be controlled with shims. Correctly shimming the load rollers minimizes mast racking during lift and lower. Racking is when one side of an inner channel weldment sticks and causes the channels to walk down during lowering.



1. STUB SHAFT
2. SHIMS (AS NEEDED)
3. WEAR STRIP
4. LOAD ROLLER

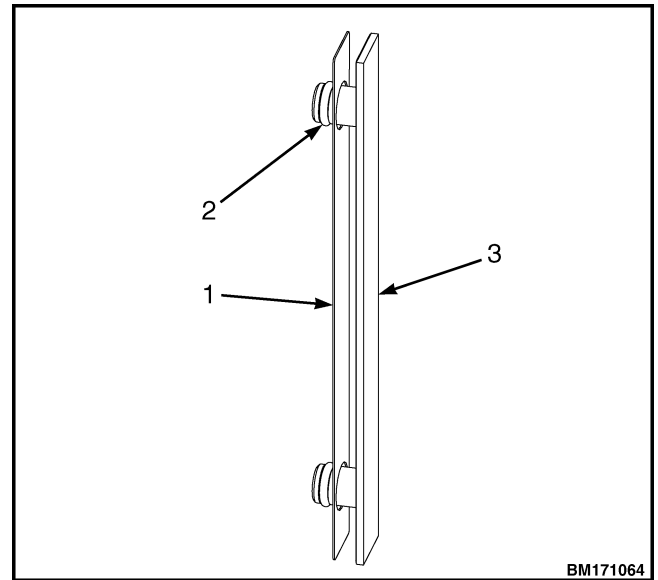
Figure 413. Load Roller and Shims

To accommodate a small degree of variation between mating mast channels, clearance between the face of each load roller and the mating mast channel requires adjustment using shims. Shims

are added or removed to adjust the clearance. The shims are made of high spring steel for strength and hardened for wear resistance.

NOTE: Greased mast channels and correct load roller clearance keeps symptoms like racking from occurring.

Wear Strips



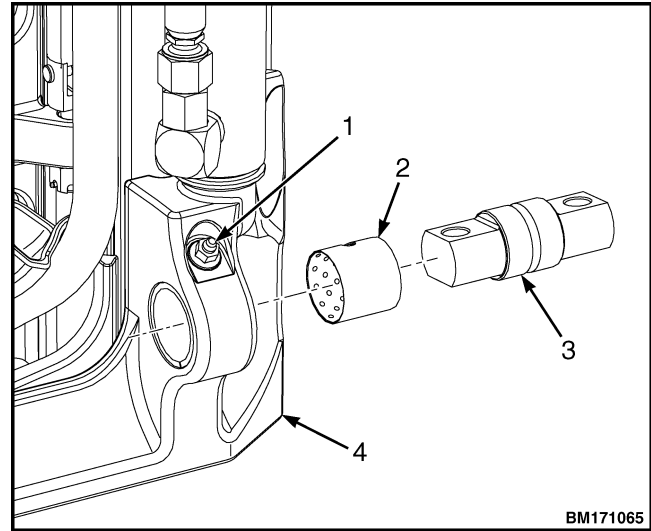
1. SHIM
2. O-RING
3. WEAR STRIP

Figure 414. Wear Strip

Wear strips are attached to the inside of mated mast channels. The base of the strip is steel and topped with a soft metal bearing layer. The wear strip is the axial face of the load rollers mate with. Load rollers of mating channels pass over the wear strip during lift and lowering. The wear strips can also be shimmed. Like all mast components the wear strips must be inspected for unusual wear patterns when performing periodic maintenance.

Mast Mounting Bushings

The pinned connections at the drive axle is where the force of the front end and any picked load is transferred to the truck. These mounts at the axle are also the pivot point when the mast is tilted.



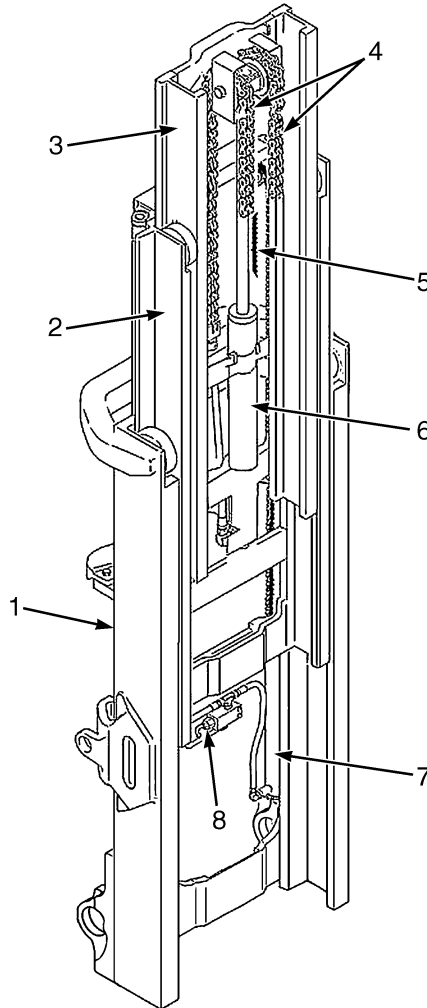
1. GREASE FITTING
2. BUSHING (BRONZE)
3. PIN
4. OUTER MAST, OUTER BOTTOM CROSSMEMBER

Figure 415. Mast Mounting Bushing

**3-STAGE FULL FREE LIFT (FFL) MAST
DESCRIPTION
202001-171**

3-STAGE FFL MAST DESCRIPTION

This module will discuss the various functions and components specific to the three-stage full free-lift mast. For a general overview and description of the mast, see Mast description.



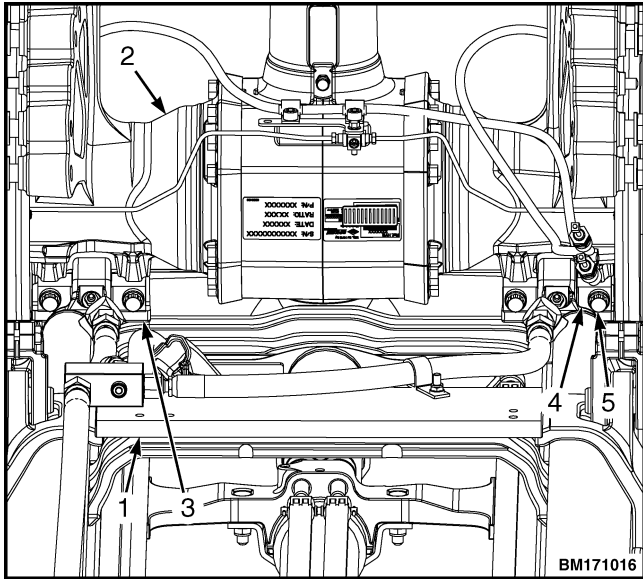
BT290009

NOTE: GRAPHIC IS FOR ILLUSTRATIVE PURPOSES ONLY, VARIATIONS ARE POSSIBLE.

- | | |
|----------------------|---------------------------|
| 1. OUTER MAST | 5. MAIN LIFT CHAIN(S) |
| 2. INTERMEDIATE MAST | 6. FREE-LIFT CYLINDER |
| 3. INNER MAST | 7. MAIN LIFT CYLINDER(S) |
| 4. FREE-LIFT CHAIN | 8. LOWERING CONTROL VALVE |

Figure 416. Three-Stage FFL Mast

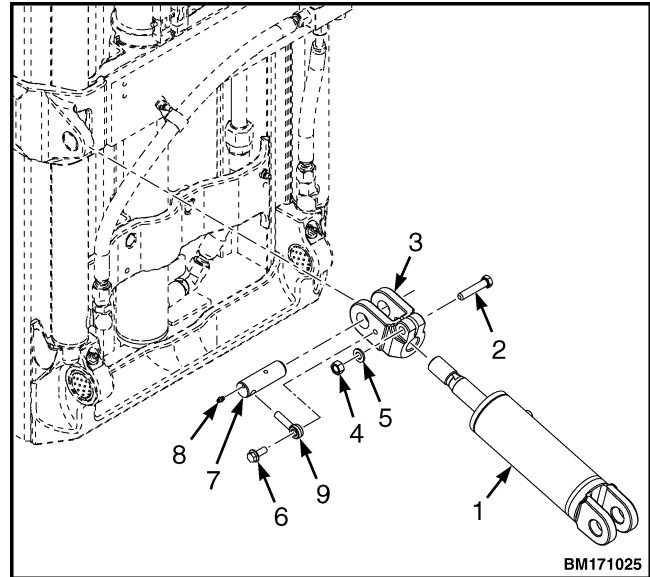
The lower crossmember of the outer mast has castings to mount the mast pivot pins. The pivot pins are installed in the castings and the mast is mounted on the J-hangers of the drive axle housing. Capscrews secure the mast pivot pins to the drive axle housing.



1. MAST
2. DRIVE AXLE
3. HANGER MOUNTS
4. MAST PIVOT PIN
5. CAPSCREW

Figure 417. Mast Mount on Drive Axle

The mast can also be tilted forward to ease picking or placing a load and tilted back to keep a picked load safe against the carriage load backrest. Tilt is achieved by another set of hydraulic cylinders operating perpendicular to the mast. The tilt cylinders are mounted on either side of the outermost mast channels. The rod end of the tilt cylinders mount about 1/3 of the way up the mast and the cylinder base mounts at the front cowl. Both mounts are pivot points to allow minor change to their working angle.



1. MAST TILT CYLINDER
2. CAPSCREW
3. ROD END
4. NUT
5. WASHER
6. CAPSCREW
7. PIVOT PIN
8. GREASE FITTING
9. ANCHOR PIN

Figure 418. Tilt Cylinder Mounting

The tilt cylinders can be engaged to tilt the mast forward during picking or placing a load. Then the tilt cylinders can be engaged to tilt the mast back once a load is picked up and being moved.

The tilt cylinders operate in two directions. There is a port at the base of the cylinder and another at the rod end of the assembly. Hydraulic oil entering the port at the base of the cylinder feeds under the piston and causes the rod to extend while oil exhausts through the rod end port. Hydraulic oil entering the port at the rod end causes the rod to retract into the cylinder.

Basic Operation

The three hydraulic cylinders (1 free-lift, 2 main lift) are connected by hoses and tubing. When the mast is extended, oil from the main control valve flows to all cylinders at the same time. The free-lift cylinder extends first because it lifts the least amount of weight and has a lower operating pressure. The free-lift cylinder raises only the carriage. After the free-lift cylinder reaches the end of its stroke, the main lift cylinders begin to extend. As the main lift cylinders extend, the intermediate mast is raised by the main lift cylinders and the inner mast is raised by the main lift chains. All cylinders are protected from sudden rapid pressure loss by hydraulic velocity fuses.

During lowering, the main lift cylinders lower first because they have a greater load and higher operating pressure. After the main lift cylinders have retracted, the free-lift cylinder lowers. All oil from the lift cylinders flows through the lowering control valves to the hydraulic tank.

The free-lift cylinder has oil above the piston to provide a hydraulic cushion when the cylinder reaches the top of its stroke. An orifice system in the piston provides the hydraulic cushioning. When the cylinder is fully extended, any excess oil above the piston is forced through the check valve.

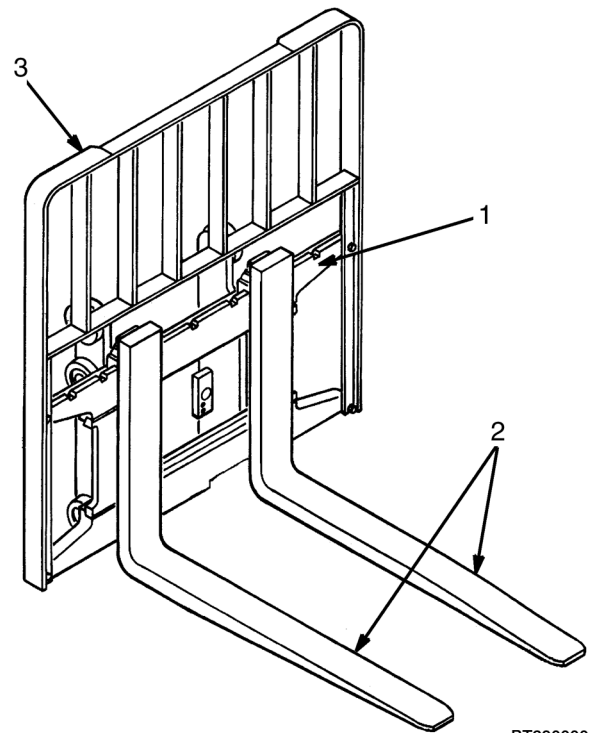
Each main lift cylinder has an orifice system and a check valve in the bottom of the rod assembly. When the cylinder is fully extended, any oil between the rod end and the gland is forced through the check valve. The orifice system provides a hydraulic cushion when the cylinder reaches the bottom of its stroke.

Three Stage Full Free-Lift

The three stage FFL includes two inner channel weldments and a single outer channel weldment. The FFL free-lift travel is equal to the height of the mast where the carriage moves up independent of the mast channel.

The primary function of the carriage assembly is to provide a mounting location for the front end attachments (fork tines, roll clamp, box clamp, box clamp, slip sheet, rotator). The most common front end attachment are the fork tines.

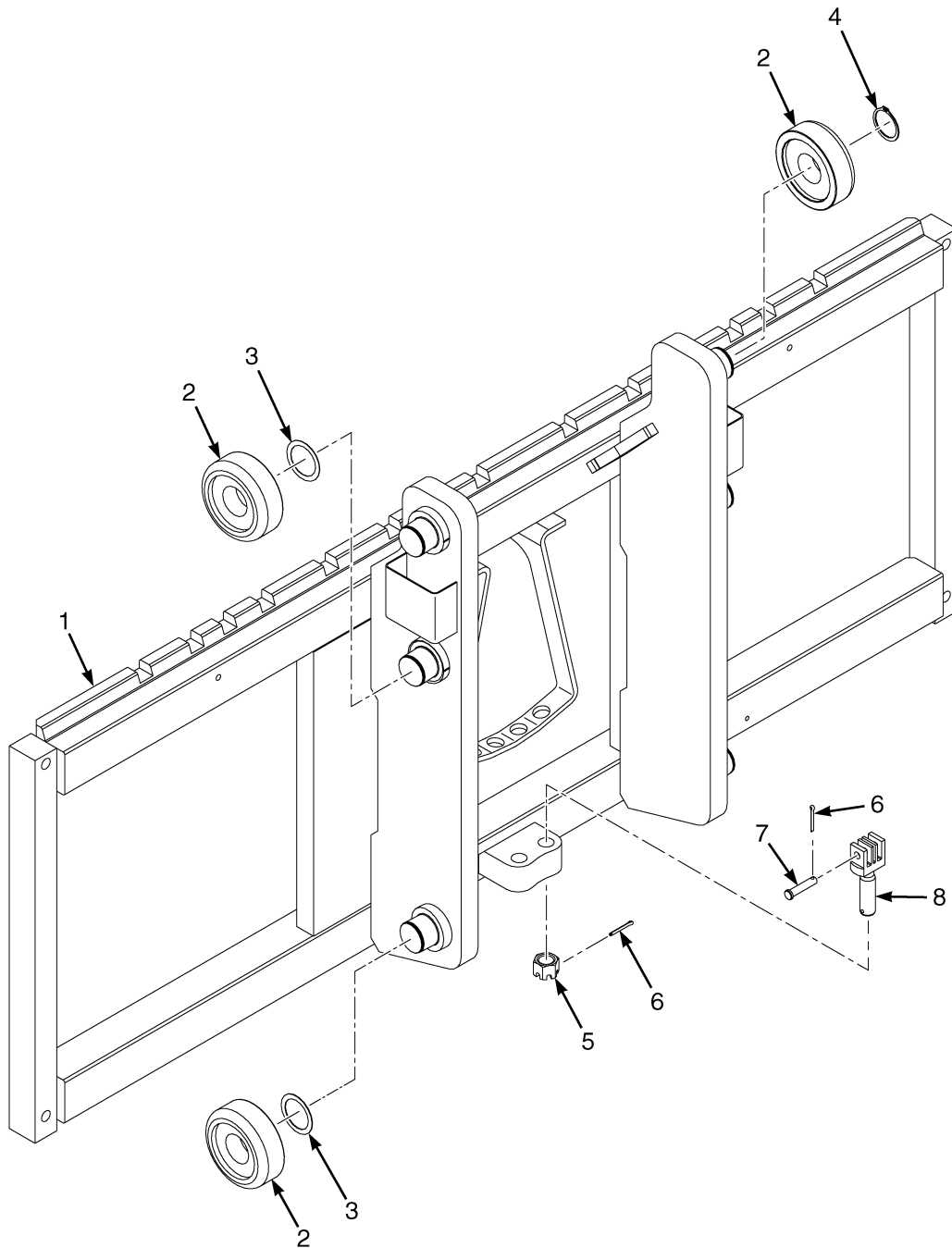
Multiple load rollers are a part of the carriage assembly. The load rollers are positioned laterally, facing out to mate with the inner most mast channel. The carriage moves with the mast inner channel during lift, lower and tilt. Front end attachments hang on the carriage.



BT290000

1. STANDARD CARRIAGE
2. FORKS
3. LOAD BACKREST EXTENSION

Figure 419. Carriage, Forks, and Backrest Example



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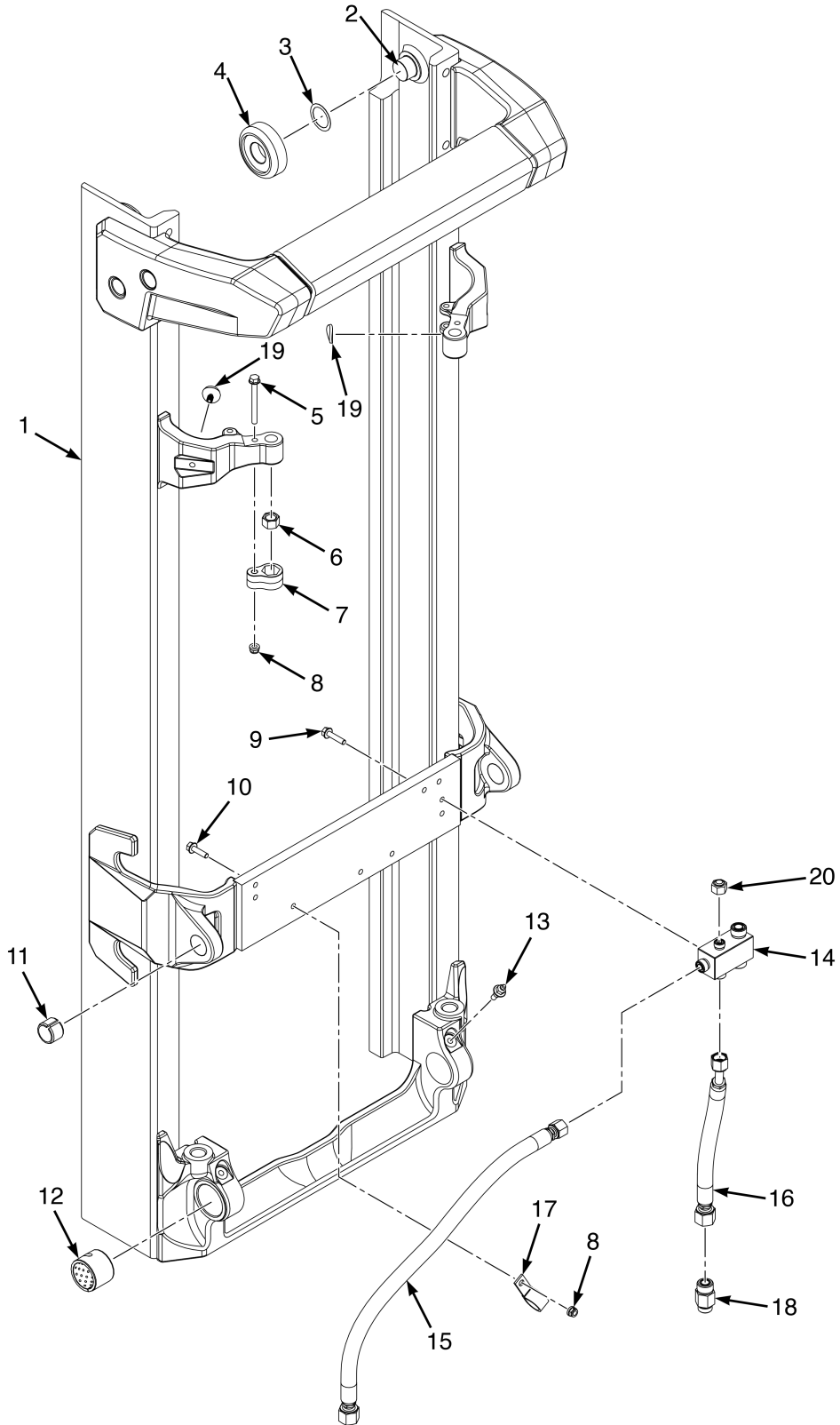
Figure 420. Standard Carriage

Legend for Figure 420.

- | | |
|----------------------|---------------------|
| 1. STANDARD CARRIAGE | 5. CASTLE NUT |
| 2. LOAD ROLLER | 6. COTTER PIN |
| 3. SHIM | 7. CHAIN ANCHOR PIN |
| 4. SNAP RING | 8. CHAIN ANCHOR |

There are four load rollers the three mating channels ride against a set of load rollers to keep the mast moving smooth and predictably during lift and lower. On the right and left channels of the inner weldment at the bottom section, load rollers

are mounted facing outward. On the outer weldment right and left channels at the top are two rollers mounted facing inward. The inner weldment nests inside the outer and is kept in alignment by the load rollers.

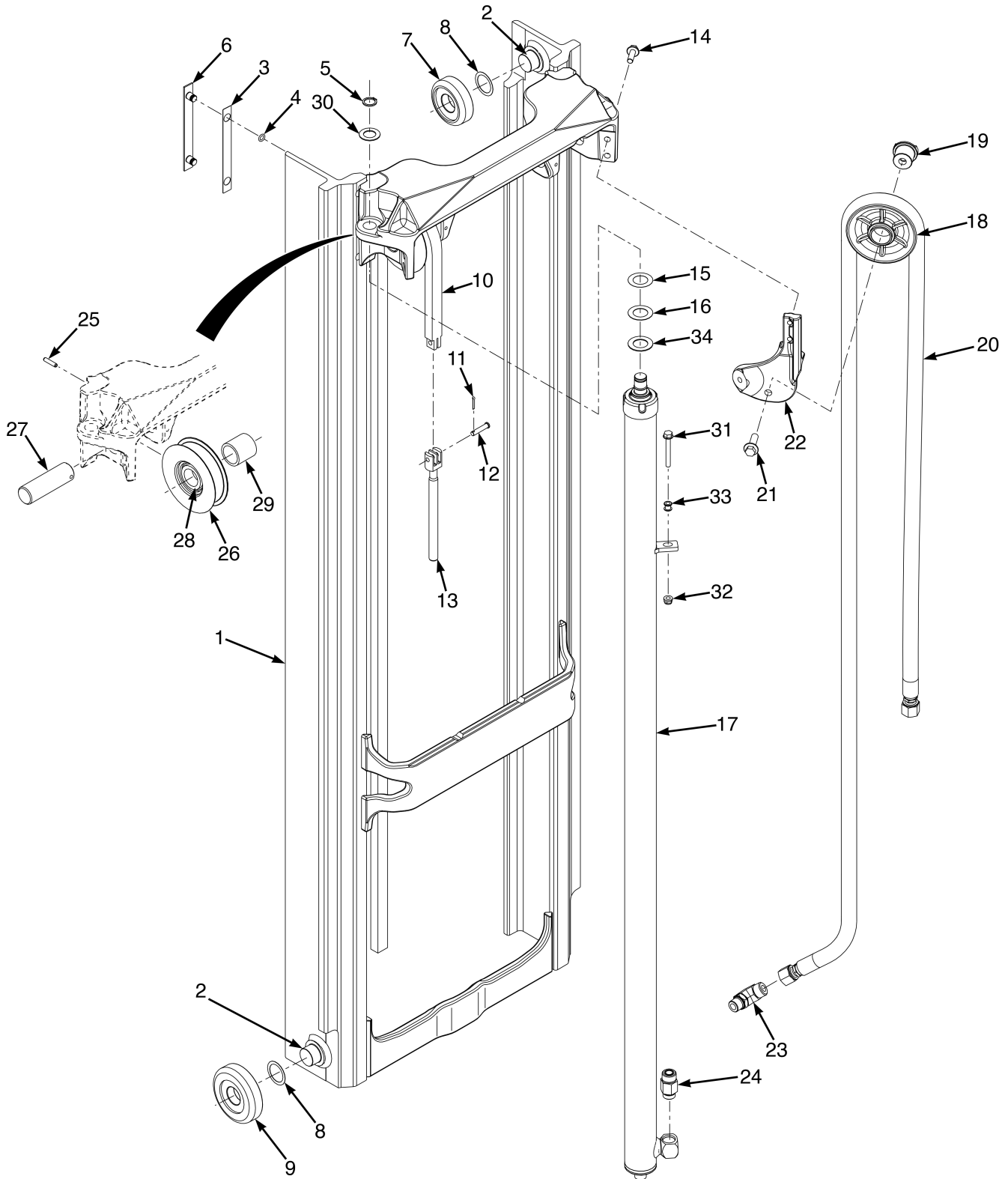


BP170995

Figure 421. Outer Mast

Legend for Figure 421.

- | | |
|----------------|------------------------------------|
| 1. OUTER MAST | 10. CAPSCREW |
| 2. LOAD ROLLER | 11. BUSHING |
| 3. SHIM | 12. BUSHING |
| 4. RUBBER PAD | 13. CAPSCREW |
| 5. CAPSCREW | 14. MAST CONNECTION BLOCK MANIFOLD |
| 6. NUT | 15. HOSE ASSY |
| 7. RESTRAINT | 16. HOSE ASSY |
| 8. LOCKNUT | 17. CLAMP |
| 9. CAPSCREW | 18. HYDRAULIC VELOCITY FUSE |



BP170996

Figure 422. Intermediate Mast

Legend for Figure 422.

- | | | | |
|-------------------------|-------------------|--------------------------------|---------------------|
| 1. INTERMEDIATE
MAST | 9. LOAD ROLLER | 18. HOSE SHEAVE | 26. CHAIN SHEAVE |
| 2. WEAR STRIP | 10. LEAF CHAIN | 19. STUB SHAFT | 27. HOSE SHEAVE PIN |
| 3. SHIM | 11. COTTER PIN | 20. HOSE ASSY | 28. SPACER |
| 4. O-RING | 12. PIN | 21. CAPSCREW | 29. SPACER |
| 5. SNAP RING | 13. CHAIN ANCHOR | 22. BRACKET | 30. SHIM |
| 6. WASHER | 14. CAPSCREW | 23. FITTING | 31. CAPSCREW |
| 7. LOAD ROLLER | 15. SHIM | 24. HYDRAULIC
VELOCITY FUSE | 32. LOCKNUT |
| 8. SHIM | 16. SHIM | 25. ROLL PIN | 33. GROMMET |
| | 17. CYLINDER ASSY | | |

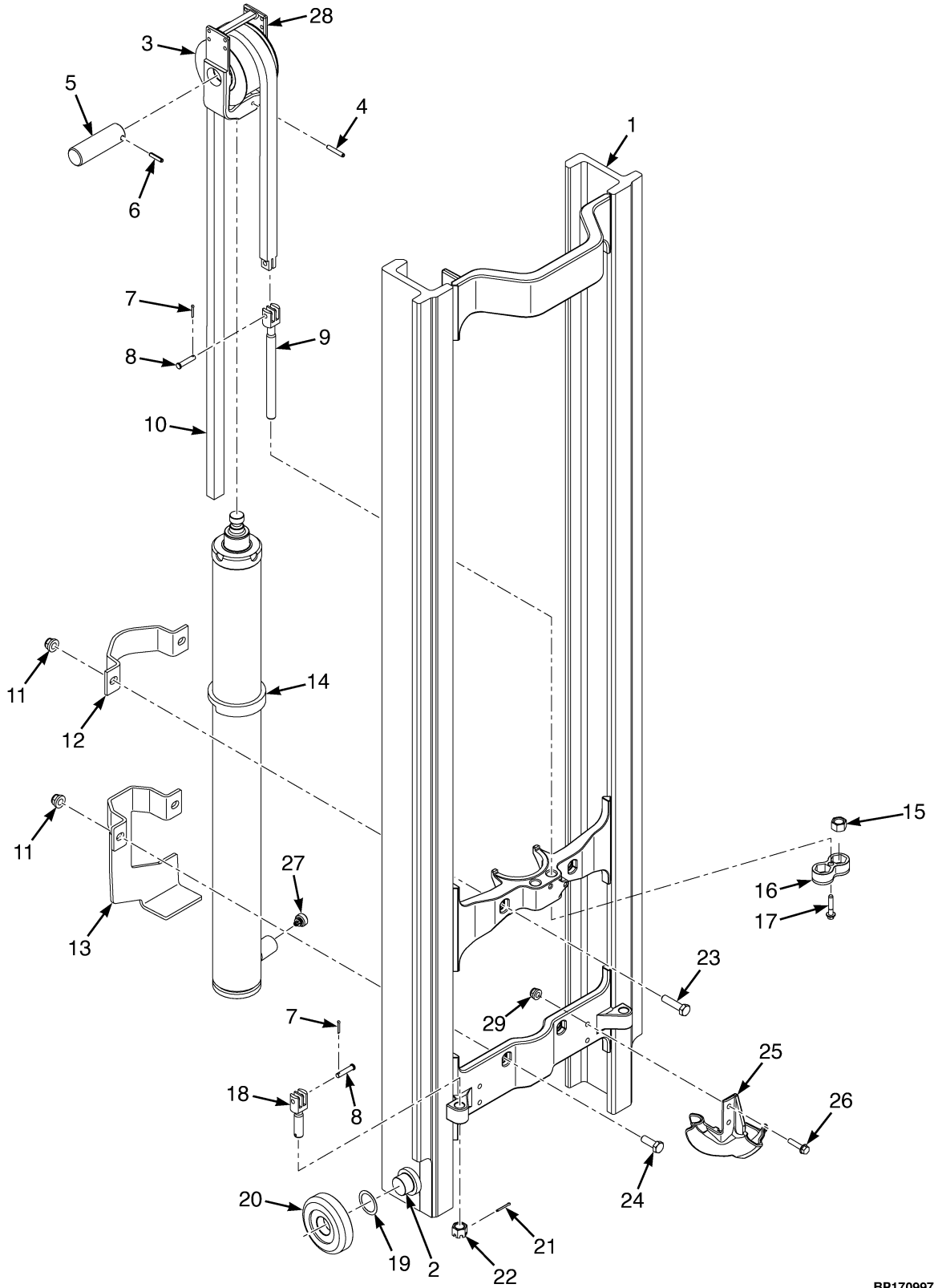


Figure 423. Inner Mast

BP170997

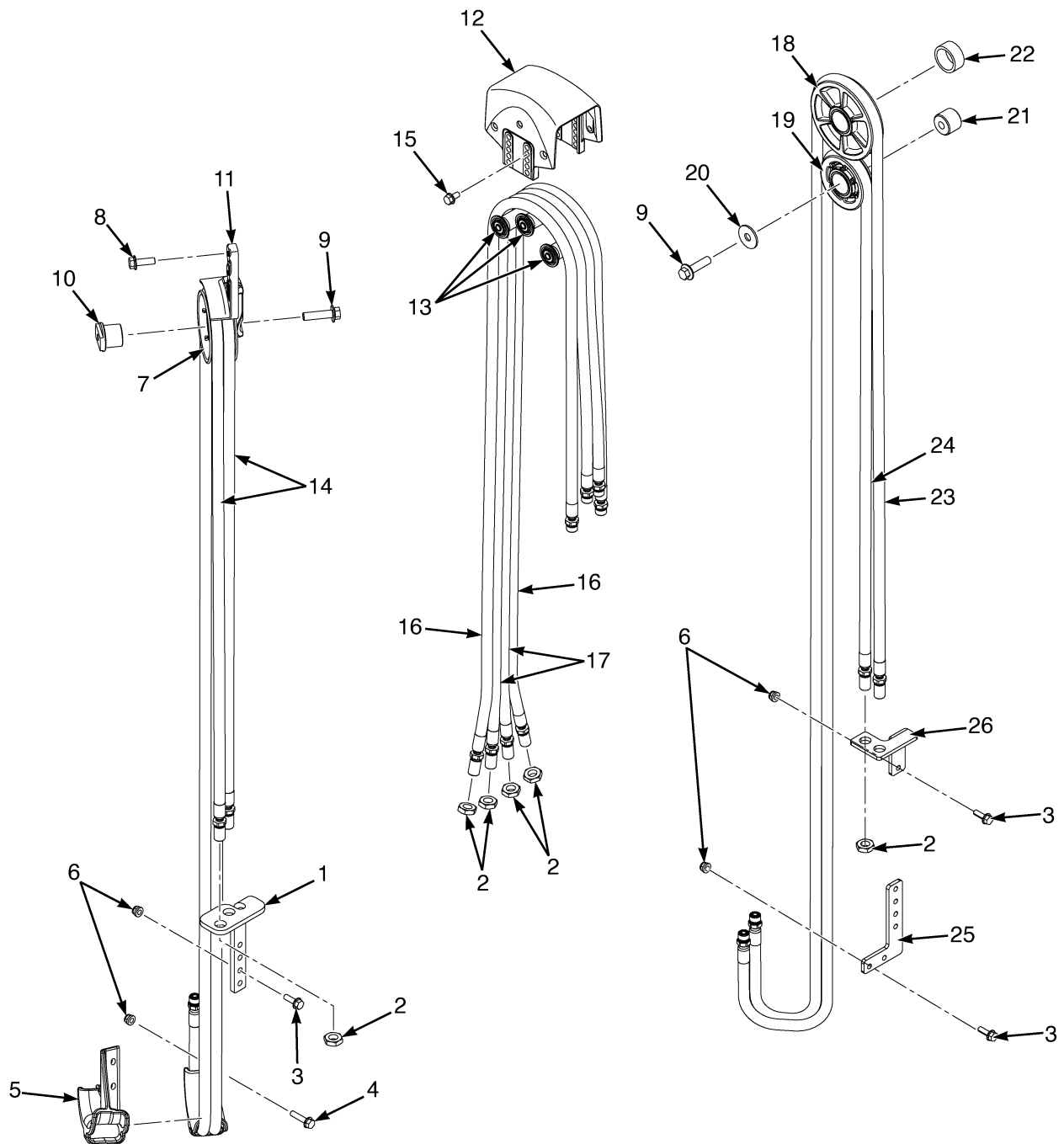
Legend for Figure 423.

- | | | | |
|--------------------|-------------------|------------------|----------------|
| 1. INNER MAST | 8. PIN | 15. NUT | 22. NUT |
| 2. CROSSHEAD | 9. CHAIN ANCHOR | 16. CHAIN ANCHOR | 23. CAPSCREW |
| 3. CHAIN SHEAVE | 10. LEAF CHAIN | DOUBLE NUT | 24. CAPSCREW |
| 4. ROLL PIN | 11. LOCKNUT | RESTRAINT | 25. CASTING |
| 5. HOSE SHEAVE PIN | 12. CLAMP | 17. CAPSCREW | 26. CAPSCREW |
| 6. ROLL PIN | 13. CLAMP | 18. CHAIN ANCHOR | 27. FLOW VALVE |
| 7. COTTER PIN | 14. CYLINDER ASSY | 19. SHIM | |
| | | 20. LOAD ROLLER | |
| | | 21. COTTER PIN | |

Mast Hydraulic Components

The free-lift cylinder is arranged at the center, and the main lift cylinders are mounted to the left and right channels of the mast. Lift chains and hydraulic hoses are routed over and anchored at the top of each lift cylinder.

Three Stage FFL Header Hose



BP171002

Figure 424. Three Stage FFL Header Hose

Legend for Figure 424.

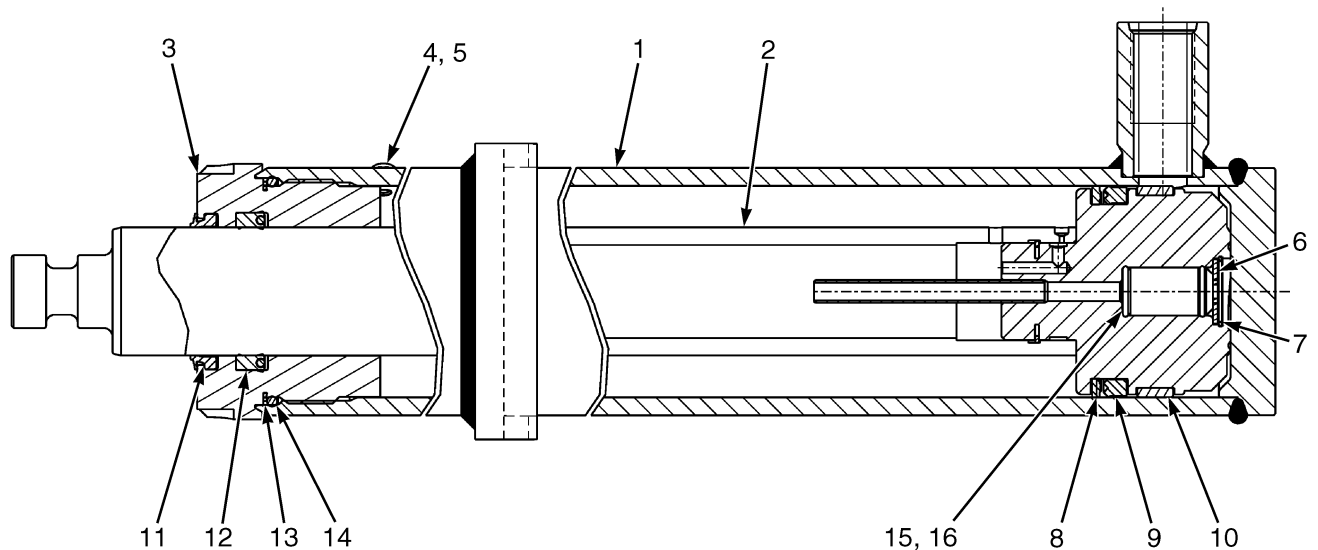
- | | | |
|----------------|---------------------------|-----------------|
| 1. BRACKET | 9. CAPSCREW | 18. HOSE SHEAVE |
| 2. NUT | 10. STUB SHAFT | 19. HOSE SHEAVE |
| 3. CAPSCREW | 11. BRACKET | 20. WASHER |
| 4. CAPSCREW | 12. HOSE GUIDE CASTING | 21. STUB SHAFT |
| 5. BRACKET | 13. FREE-LIFT HEADER HOSE | 22. SPACER |
| 6. LOCKNUT | ROLLER | 23. HEADER HOSE |
| 7. HOSE SHEAVE | 14. HEADER HOSE | 24. HEADER HOSE |
| 8. CAPSCREW | 15. CAPSCREW | 25. BRACKET |
| | 16. HEADER HOSE | |
| | 17. HEADER HOSE | |

Free-Lift and Main Lift Cylinders

A pair of hydraulic cylinders are used to lift and lower the mast. The lift cylinders can be engaged to raise the mast during lift. Then the lift cylinders can be engaged to lower the mast back once a load is picked and being moved.

The lift cylinders operate in two directions. There is a port at the base of the cylinder and another at the

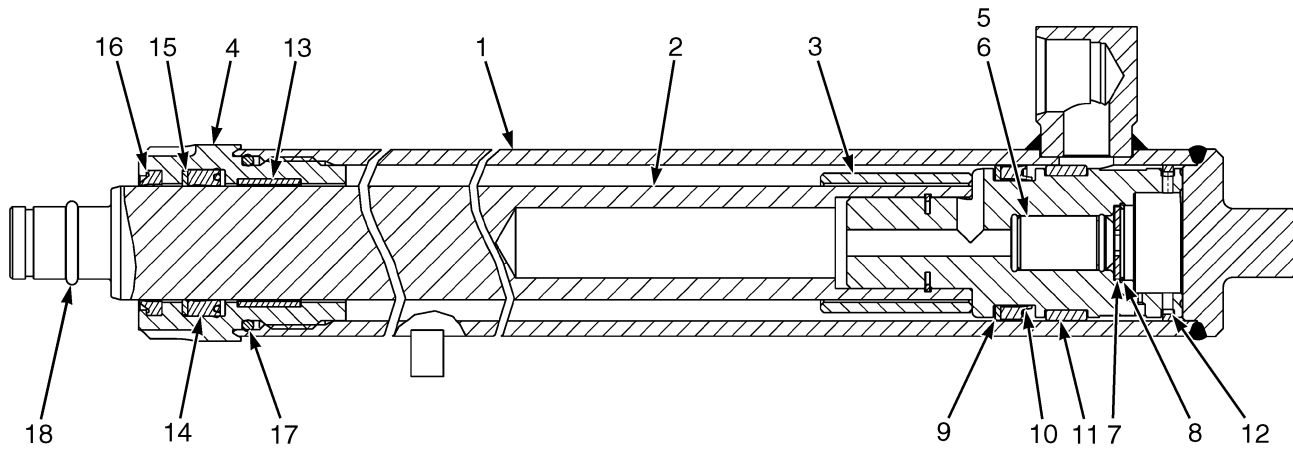
rod end of the assembly. Hydraulic oil entering the port at the base of the cylinder feeds under the piston and causes the rod to extend while oil exhausts through the rod end port. Hydraulic oil entering the port at the rod end causes the rod to retract into the cylinder.



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- | | |
|---------------------------|------------------|
| 1. CYLINDER TUBE WELDMENT | 9. SEAL |
| 2. CYLINDER ROD | 10. WEAR RING |
| 3. GLAND | 11. ROD WIPER |
| 4. SEALING RING | 12. ROD SEAL |
| 5. SCREW | 13. BACK-UP RING |
| 6. WASHER | 14. O-RING |
| 7. SNAP RING | 15. CHECK VALVE |
| 8. BACK-UP RING | 16. O-RING |

Figure 425. Free-Lift Cylinder



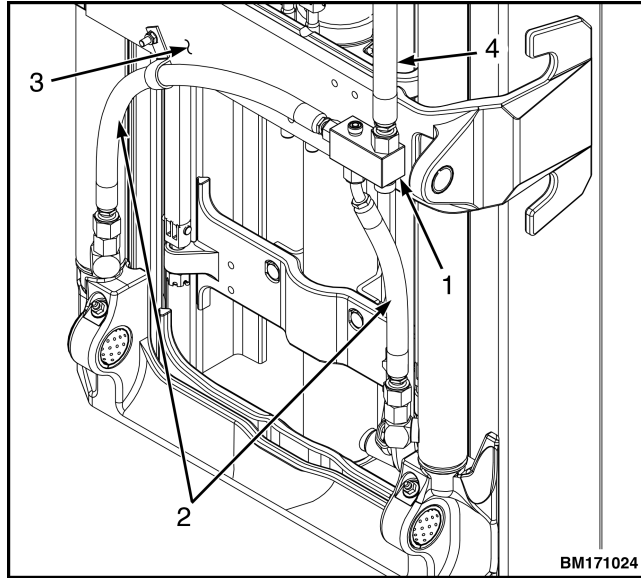
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- | | |
|---------------------------|------------------|
| 1. CYLINDER TUBE WELDMENT | 10. PISTON SEAL |
| 2. CYLINDER ROD | 11. WEAR RING |
| 3. SPACER | 12. WEAR RING |
| 4. GLAND | 13. WEAR RING |
| 5. CHECK VALVE | 14. ROD SEAL |
| 6. O-RING | 15. BACK-UP RING |
| 7. WASHER | 16. ROD WIPER |
| 8. SNAP RING | 17. O-RING |
| 9. BACK-UP RING | 18. O-RING |

Figure 426. Main Lift Cylinder

Mast Hose Manifold

The hydraulic manifold installed on the mast is a convenient and serviceable method to evenly distributing hydraulic oil. The central location helps with cleaner hose routing on the mast assembly.



- 1. MANIFOLD
- 2. HYDRAULIC HOSES
- 3. MAST
- 4. LIFT CYLINDER HOSE

Figure 427. Manifold and Hoses

Velocity Fuse

The velocity fuse is a safety device to prevent a sudden rapid loss of oil pressure in the mast. In the event there is a hydraulic hose in the mast that ruptures, the velocity fuse will close and shut off oil flow when a high flow rate through it is detected. The velocity fuse prevents a picked load from crashing down due to a significant loss of hydraulic oil downstream from the manifold.

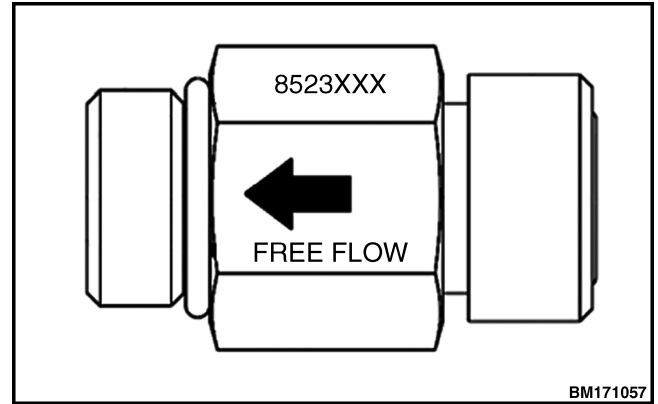


Figure 428. Hydraulic Velocity Fuse

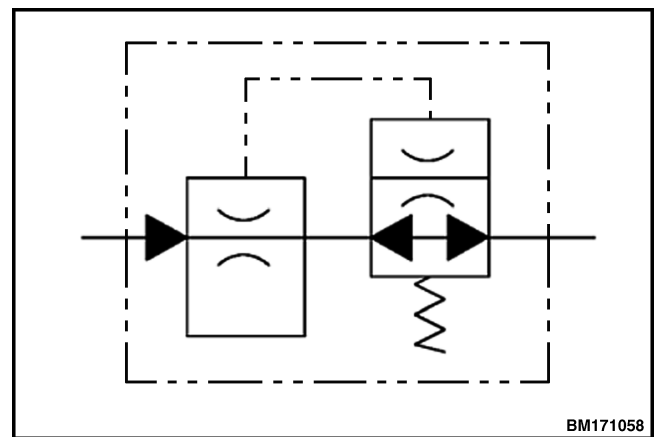


Figure 429. Velocity Fuse ASA Symbol

Hoses and Hose Assemblies

The hoist hoses are the longest of all equipped on a truck. They are arranged up and down the mast and are routed over pulleys mounted on the mast.

Hose part numbers are printed on a tag attached to the hose. The part number identifies the hose and important attributes like installed fittings, protective components, and length. The hose material and construction is also printed on the hose.

High pressure hydraulic hoses supply oil from the mast mounted manifold to the free-lift and main lift cylinders. The mast hydraulic hoses are routed as required.

Hose Fittings

There are a few common hydraulic fitting types. The hydraulic hose fittings are crimped on and non-reusable. When hoses are replaced the fittings can not be removed without damaging and significantly compromising fitting integrity.

Some applications of hydraulic fittings may use Joint Industry Council (JIC) type fittings where the sealing O-ring mates with a flared shoulder. However, most of the hydraulic fittings are O-Ring Face Seal (ORFS).

Mast Mechanical Components

Lift Chain

The primary function of the lift chain is to pull the inner mast channels to height during lifting and help hold the mast load during lowering. A set of lift chains hold the weight of the mast, carriage, and load. One end of the lift chain mounts at an anchor point near the top end of each lift cylinder. The other end of the lift chain mounts at an anchor point on the base of the innermost mast channel. Each of the lift chains moves over chain roller sheaves mounted on the mast.

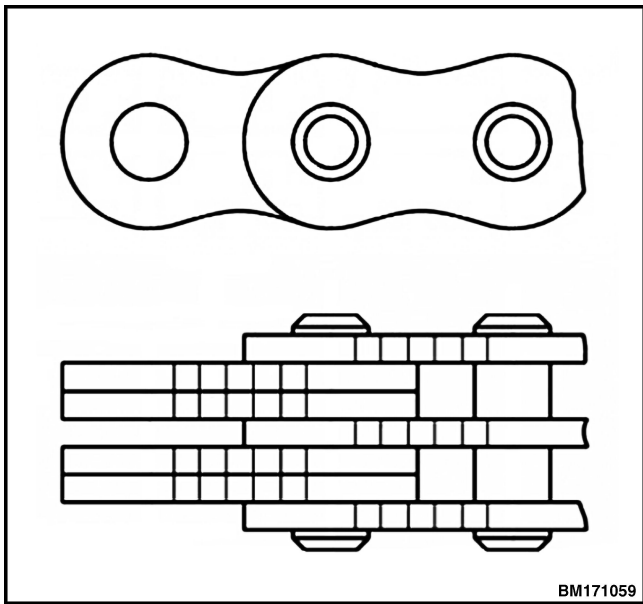


Figure 430. Lift Chain Example

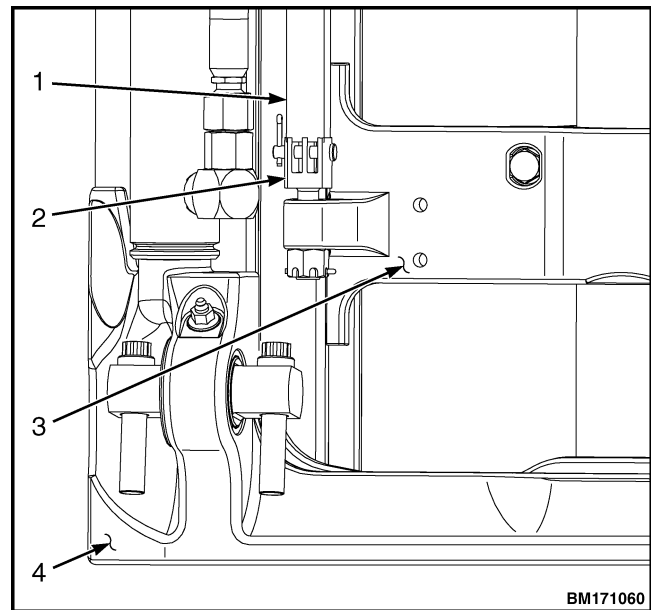
The lift chains are routed over a system of pulleys called chain sheaves. As the lift cylinder rods extend, the power is transferred to the mast by the lift chains. One end of the lift chain is pinned to a chain anchor at the outermost mast channel. Typically, the lift chain anchor is attached to the lift cylinder casing mounted to the outer mast channel. The other end of the lift chain is anchored to the top of the inner most mast channel.

During lifting the carriage assembly rises first with the free-lift cylinder until the end of cylinder travel. Then the main lift cylinder rods extend, causing the next inner channel to be pulled up to lift height.

Like all mast components the lift chain must be inspected for corrosion or damage; greased and the tension adjusted as necessary when performing periodic maintenance.

Chain Anchors

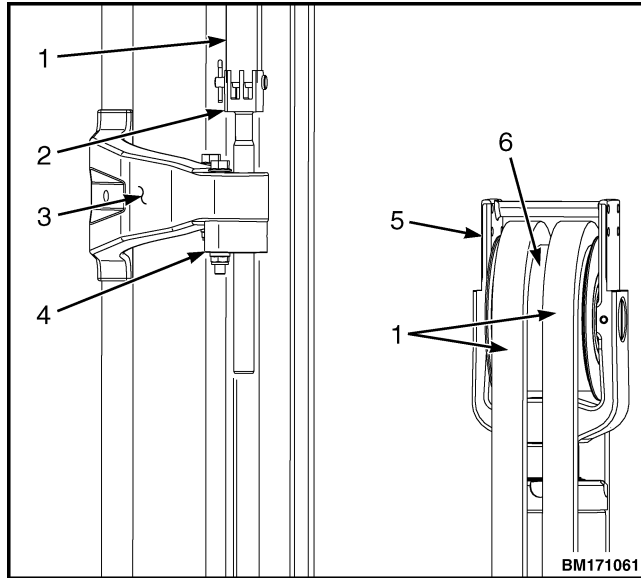
A secondary function of the chain anchor is adjustment of lift chain tension. The chain anchor is threaded so that lift chain tension can be increased or decreased.



- 1. LEAF CHAIN
- 2. CHAIN ANCHOR
- 3. INNER BOTTOM CROSSMEMBER
- 4. OUTER BOTTOM CROSSMEMBER

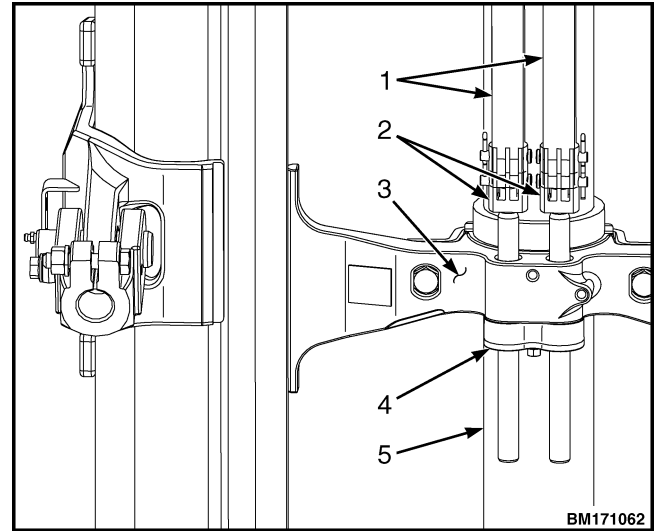
Figure 431. Chain Anchor

Like all mast components chain anchors must be inspected for corrosion, greased and hardware torques if adjustment was necessary when performing periodic maintenance.



1. LEAF CHAIN
2. CHAIN ANCHOR
3. CHAIN SUPPORT ANCHOR
4. CHAIN ANCHOR NUT (SINGLE)
5. CROSSHEAD
6. CHAIN SHEAVE

Figure 432. Chain Anchor Nut (Single) and Crosshead



NOTE: SOME PARTS HAVE BEEN REMOVED FOR CLARITY.

1. CHAIN
2. CHAIN ANCHOR
3. INNER MID CROSSMEMBER
4. CHAIN ANCHOR NUT (DOUBLE)
5. FREE-LIFT CYLINDER

Figure 433. Chain Anchor Nut (Double) and Free-Lift Cylinder

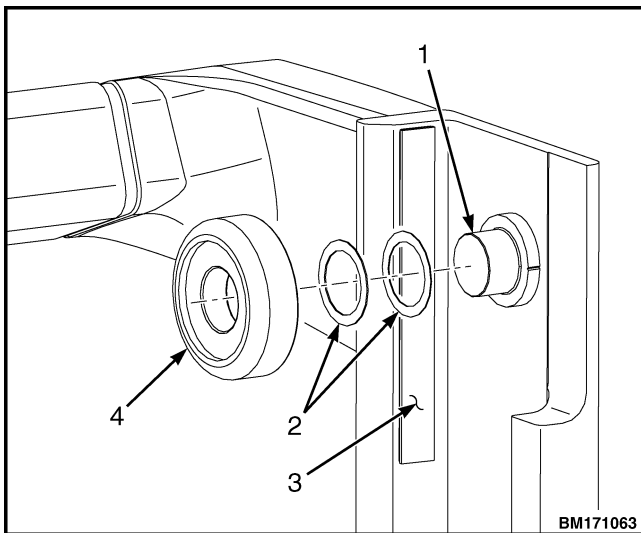
Chain Sheaves

Chain sheaves are pulleys for guiding chain movement on the mast assembly. Chain sheaves are a tough plastic pulley with a center bearing and a mating profile to keep the chain aligned and reduce wear during repeated operation.

Chain sheaves are attached to both inner and intermediate mast inner top cross members and the free-lift cylinder. Like all mast components chain sheaves must be inspected for damage when performing periodic maintenance

Load Rollers

Between each mast channel are load rollers that guide adjacent mast channels as they lift and lower. Load rollers are installed on machined stub shafts welded to the mast channels. The load rollers are tightly toleranced for keeping mast channels in alignment relative to each other. The primary surface of the load rollers is the rolling face that mates with the mast channel. But the secondary surface of the roller axis is also important. Axial clearance must be controlled with shims. Correctly shimming the load rollers minimizes mast racking during lift and lower. Racking is when one side of an inner channel weldment sticks and causes the channels to walk down during lowering.



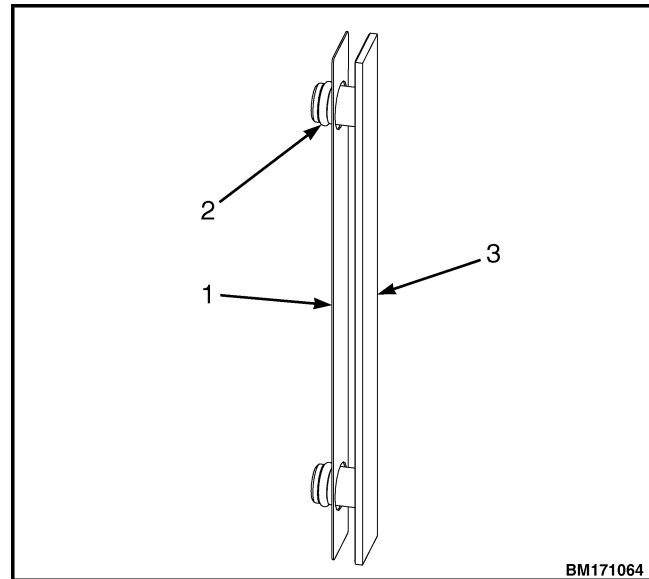
1. STUB SHAFT
2. SHIMS (AS NEEDED)
3. WEAR STRIP
4. LOAD ROLLER

Figure 434. Load Roller and Shims

To accommodate a small degree of variation between mating mast channels, clearance between the face of each load roller and the mating mast channel requires adjustment using shims. Shims are added or removed to adjust the clearance. The shims are made of high spring steel for strength and hardened for wear resistance.

NOTE: Greased mast channels and correct load roller clearance keeps symptoms like racking from occurring.

Wear Strips



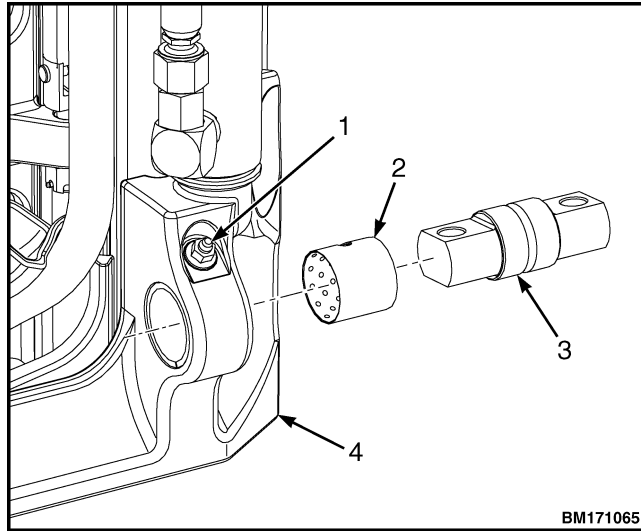
1. SHIM
2. O-RING
3. WEAR STRIP

Figure 435. Wear Strip

Wear strips are attached to the inside of mated mast channels. The base of the strip is steel and topped with a soft metal bearing layer. The wear strip is the axial face of the load rollers mate with. Load rollers of mating channels pass over the wear strip during lift and lowering. The wear strips can also be shimmed. Like all mast components the wear strips must be inspected for unusual wear patterns when performing periodic maintenance.

Mast Mounting Bushings

The pinned connections at the drive axle is where the force of the front end and any picked load is transferred to the truck. These mounts at the axle are also the pivot point when the mast is tilted.



1. GREASE FITTING
2. BUSHING (BRONZE)
3. PIN
4. OUTER MAST, OUTER BOTTOM CROSSMEMBER

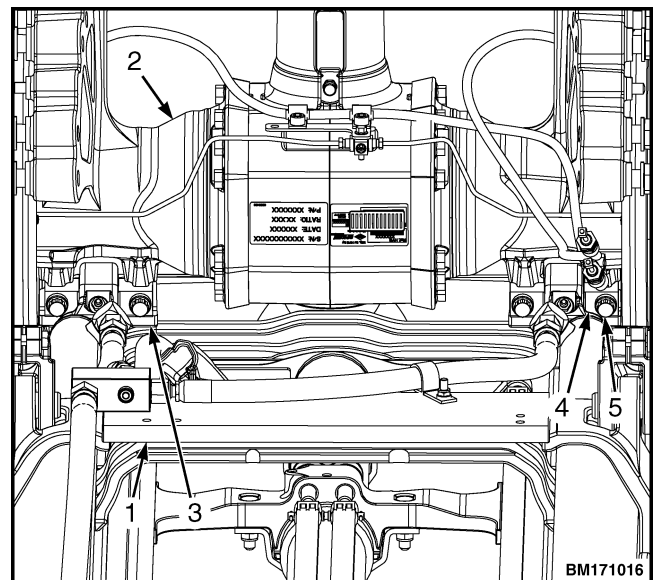
Figure 436. Mast Mounting Bushing

4-STAGE FULL FREE LIFT (FFL) MAST DESCRIPTION 202001-173

4-STAGE FFL MAST DESCRIPTION

This module will discuss the various functions and components specific to the four-stage full free-lift mast. For a general overview and description of the mast, see Mast description.

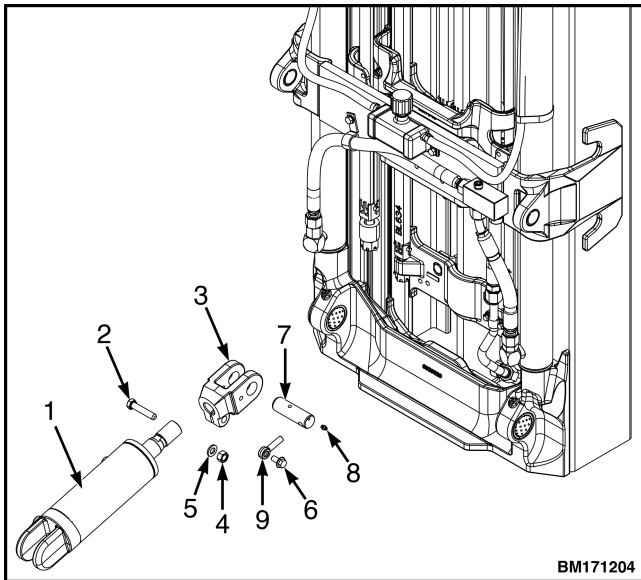
The lower crossmember of the outer mast has castings to mount the mast pivot pins. The pivot pins are installed in the castings and the mast is mounted on the J-hangers of the drive axle housing. Capscrews secure the mast pivot pins to the drive axle housing.



1. MAST
2. DRIVE AXLE
3. HANGER MOUNTS
4. MAST PIVOT PIN
5. CAPSCREW

Figure 437. Mast mount on drive axle

The mast can also be tilted forward to ease picking or placing a load and tilted back to keep a picked load safe against the carriage load backrest. Tilt is achieved by another set of hydraulic cylinders operating perpendicular to the mast. The tilt cylinders are mounted on either side of the outermost mast channels. The rod end of the tilt cylinders mount about 1/3 of the way up the mast and the cylinder base mounts at the front cowl. Both mounts are pivot points to allow minor change to their working angle.



1. MAST TILT CYLINDER
2. CAPSCREW
3. ROD END
4. NUT
5. WASHER
6. CAPSCREW
7. PIVOT PIN
8. GREASE FITTING
9. ANCHOR PIN

Figure 438. Tilt cylinder mounting

The tilt cylinders can be engaged to tilt the mast forward during picking or placing a load. Then the tilt cylinders can be engaged to tilt the mast back once a load is picked up and being moved.

The tilt cylinders operate in two directions. There is a port at the base of the cylinder and another at the rod end of the assembly. Hydraulic oil entering the port at the base of the cylinder feeds under the piston and causes the rod to extend while oil exhausts through the rod end port. Hydraulic oil

entering the port at the rod end causes the rod to retract into the cylinder.

Basic operation

The three hydraulic cylinders (1 free-lift, 2 main lift) are connected by hoses and tubing. When the mast is extended, oil from the main control valve flows to all cylinders at the same time. The free-lift cylinder extends first because it lifts the least amount of weight and has a lower operating pressure. The free-lift cylinder raises only the carriage. After the free-lift cylinder reaches the end of its stroke, the main lift cylinders begin to extend. As the main lift cylinders extend, the intermediate mast is raised by the main lift cylinders and the inner mast is raised by the main lift chains. All cylinders are protected from sudden rapid pressure loss by hydraulic velocity fuses.

During lowering, the main lift cylinders lower first because they have a greater load and higher operating pressure. After the main lift cylinders have retracted, the free-lift cylinder lowers. All oil from the lift cylinders flows through the lowering control valves to the hydraulic tank.

The free-lift cylinder has oil above the piston to provide a hydraulic cushion when the cylinder reaches the top of its stroke. An orifice system in the piston provides the hydraulic cushioning. When the cylinder is fully extended, any excess oil above the piston is forced through the check valve.

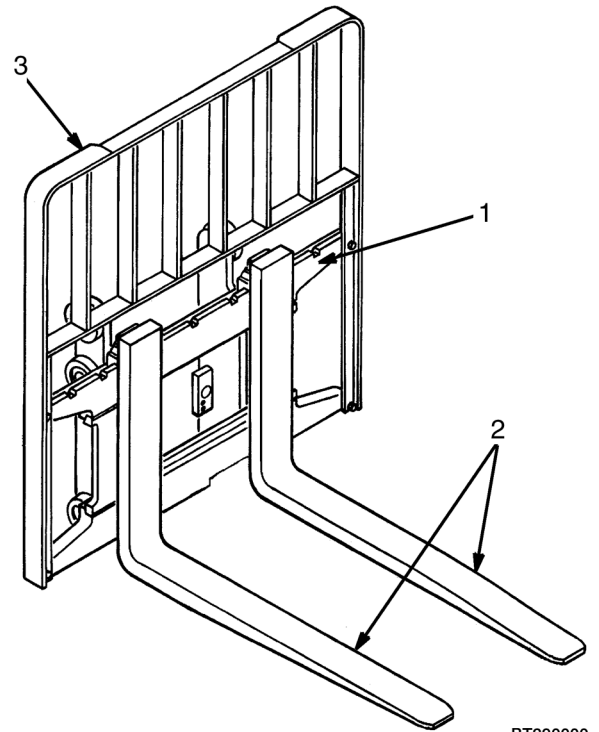
Each main lift cylinder has an orifice system and a check valve in the bottom of the rod assembly. When the cylinder is fully extended, any oil between the rod end and the gland is forced through the check valve. The orifice system provides a hydraulic cushion when the cylinder reaches the bottom of its stroke.

Four stage full free-lift

The four stage FFL includes three inner channel weldments and a single outer channel weldment. The FFL free-lift travel is equal to the height of the mast where the carriage moves up independent of the mast channel.

The primary function of the carriage assembly is to provide a mounting location for the front end attachments (fork tines, roll clamp, box clamp, box clamp, slip sheet, rotator). The most common front end attachment are the fork tines.

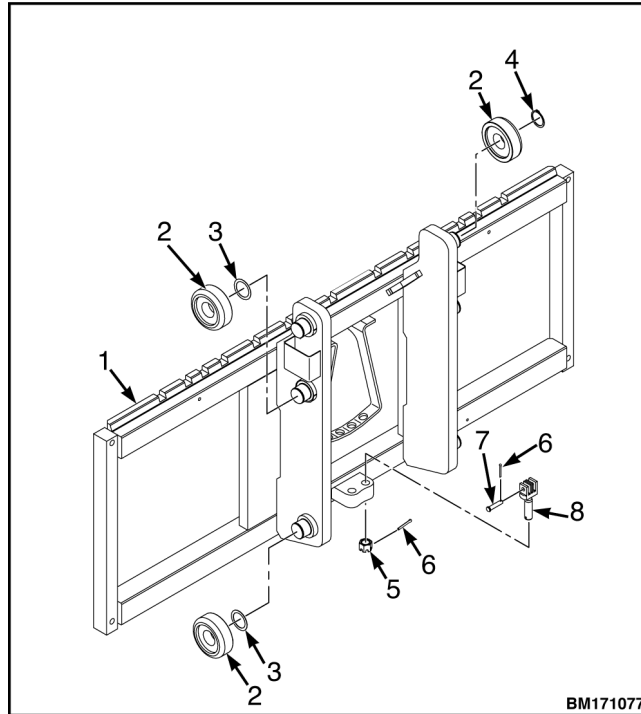
Multiple load rollers are a part of the carriage assembly. The load rollers are positioned laterally, facing out to mate with the inner most mast channel. The carriage moves with the mast inner channel during lift, lower and tilt. Front end attachments hang on the carriage.



BT290000

1. STANDARD CARRIAGE
2. FORKS
3. LOAD BACKREST EXTENSION

Figure 439. Carriage, forks, and backrest example



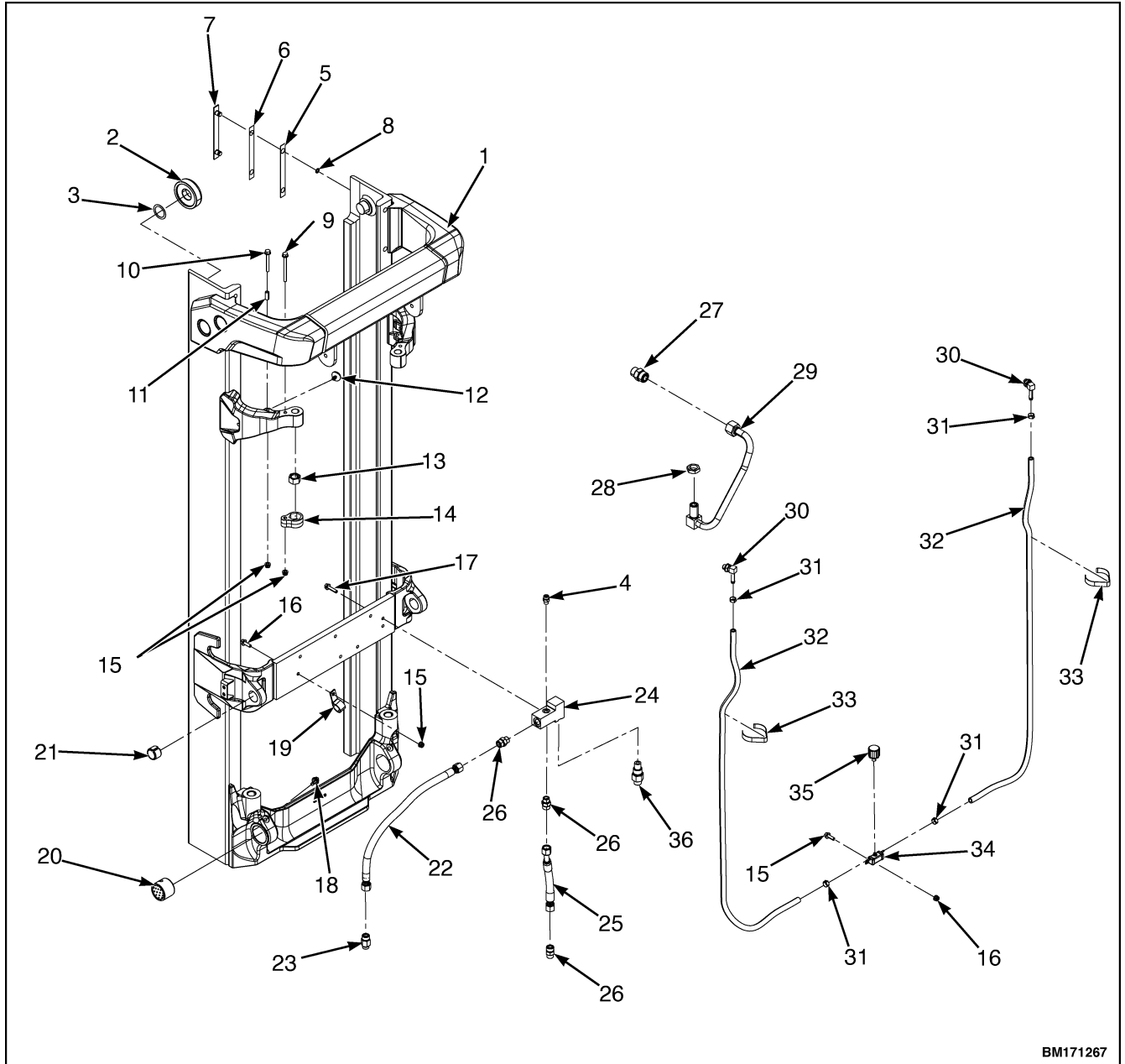
1. STANDARD CARRIAGE
2. LOAD ROLLER
3. SHIM
4. SNAP RING

5. CASTLE NUT
6. COTTER PIN
7. CHAIN ANCHOR PIN
8. CHAIN ANCHOR

Figure 440. Standard Carriage

There are four load rollers the three mating channels ride against a set of load rollers to keep the mast moving smooth and predictably during lift and lower. On the right and left channels of the inner weldment at the bottom section, load rollers

are mounted facing outward. On the outer weldment right and left channels at the top are two rollers mounted facing inward. The inner weldment nests inside the outer and is kept in alignment by the load rollers.

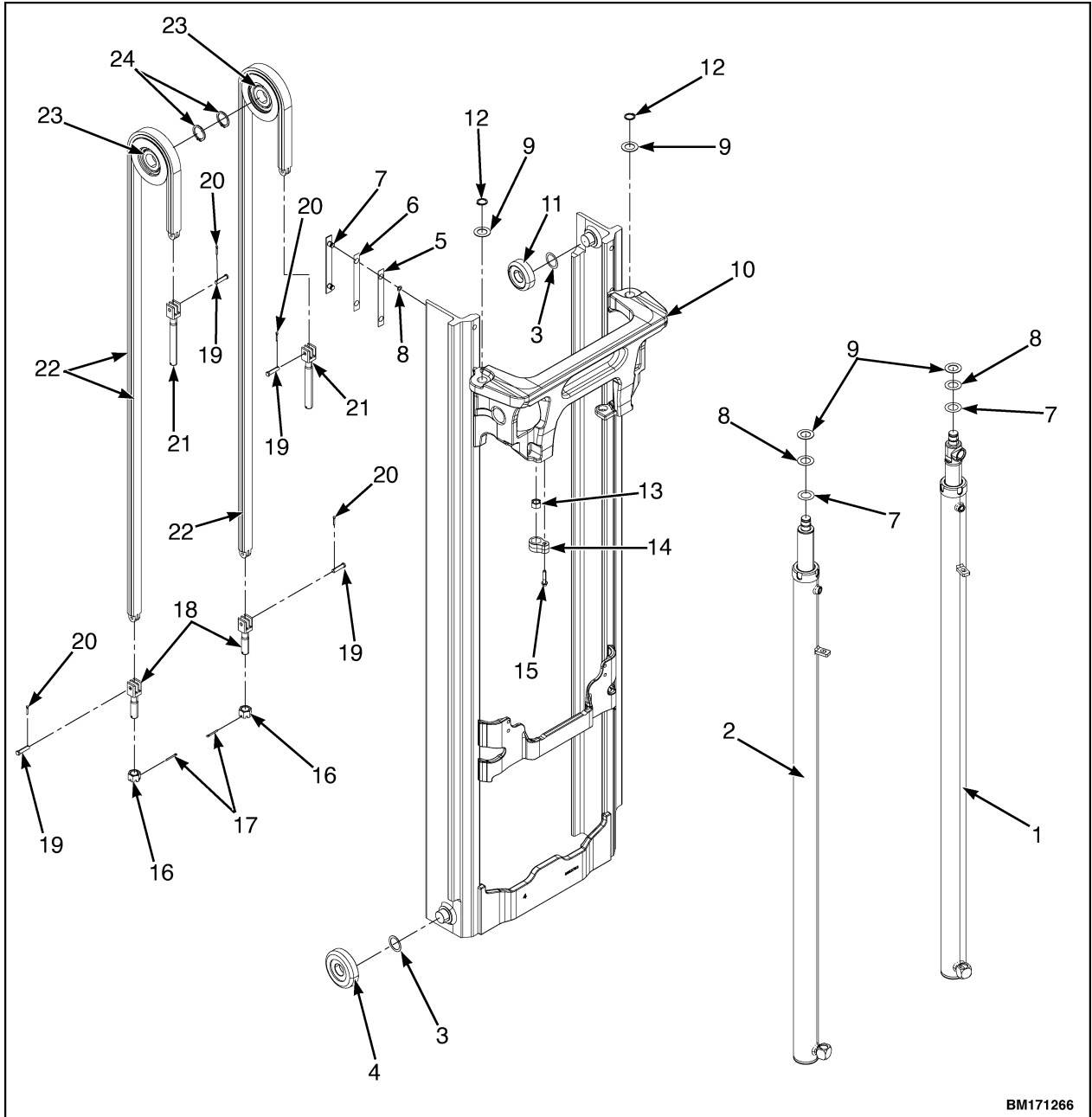


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Figure 441. Outer mast

Legend for Figure 441.

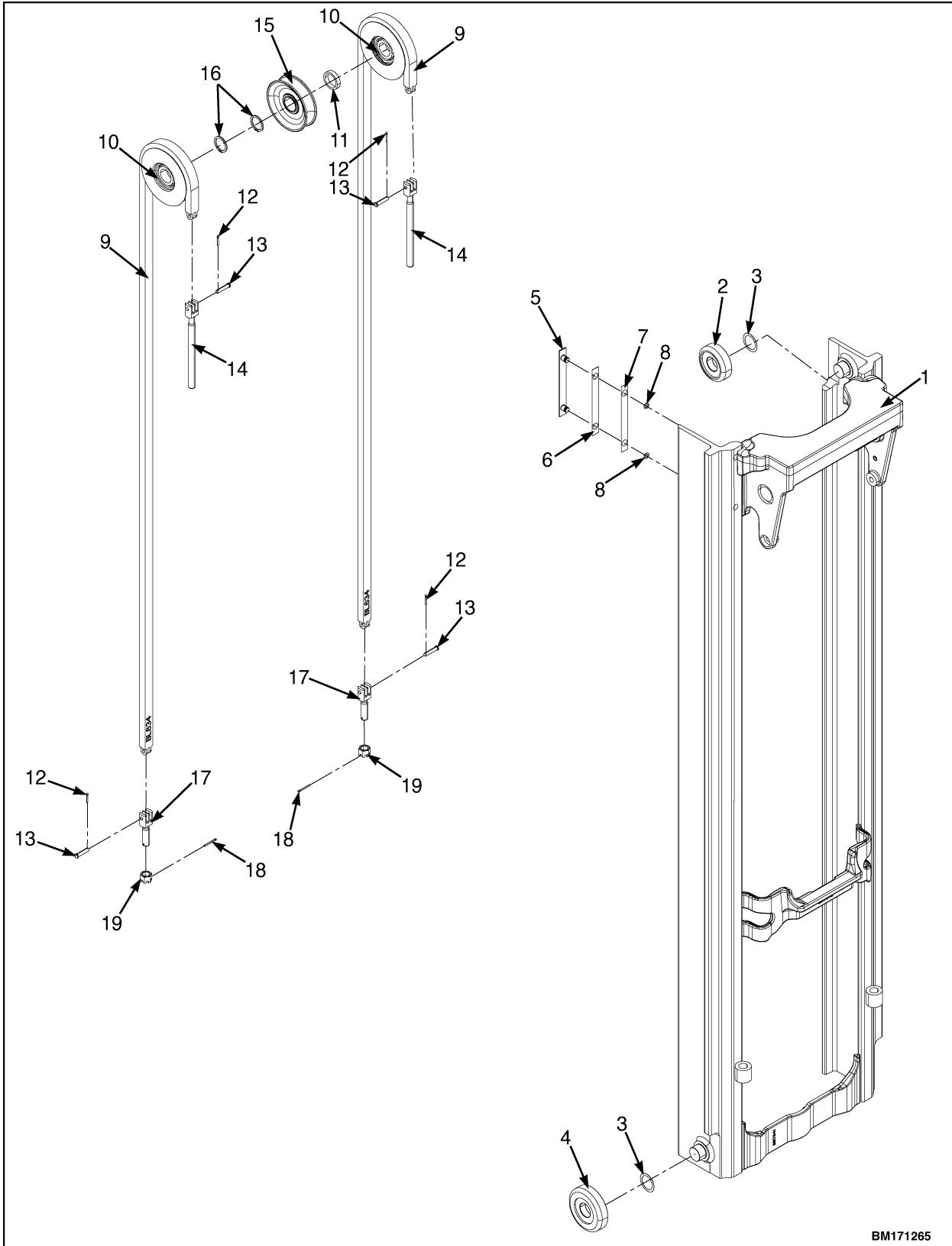
- | | |
|----------------|-----------------------------|
| 1. OUTER MAST | 18. CAPSCREW |
| 2. LOAD ROLLER | 19. CLAMP |
| 3. SHIM | 20. BUSHING |
| 4. LOAD ROLLER | 21. BUSHING |
| 5. SHIM | 22. HOSE ASSY |
| 6. SHIM | 23. HYDRAULIC VELOCITY FUSE |
| 7. WEAR STRIP | 24. VALVE BLOCK |
| 8. O-RING | 25. HOSE ASSY |
| 9. CAPSCREW | 26. FITTING |
| 10. CAPSCREW | 27. O-RING |
| 11. SPACER | 28. LOCKNUT |
| 12. RUBBER PAD | 29. TUBE ASSEMBLY |
| 13. NUT | 30. FITTING |
| 14. RESTRAINT | 31. CLAMP |
| 15. LOCKNUT | 32. HOSE |
| 16. CAPSCREW | 33. RETAINER |
| 17. CAPSCREW | 34. TANK |



BM171266

- | | | | |
|-----------------------|-----------------------|------------------|------------------|
| 1. CYLINDER ASSY (RH) | 7. WEAR STRIP | 14. RESTRAINT | 21. CHAIN ANCHOR |
| 2. CYLINDER ASSY (LH) | 8. O-RING | 15. CAPSCREW | 22. CHAIN |
| 3. SHIM | 9. WASHER | 16. CASTLE NUT | 23. CHAIN SHEAVE |
| 4. LOAD ROLLER | 10. INTERMEDIATE MAST | 17. COTTER PIN | 24. SNAP RING |
| 5. SHIM | 11. LOAD ROLLER | 18. CHAIN ANCHOR | 25. SHIM |
| 6. SHIM | 12. SNAP RING | 19. PIN | 26. SHIM |
| | 13. CASTLE NUT | 20. COTTER PIN | |

Figure 442. Intermediate mast

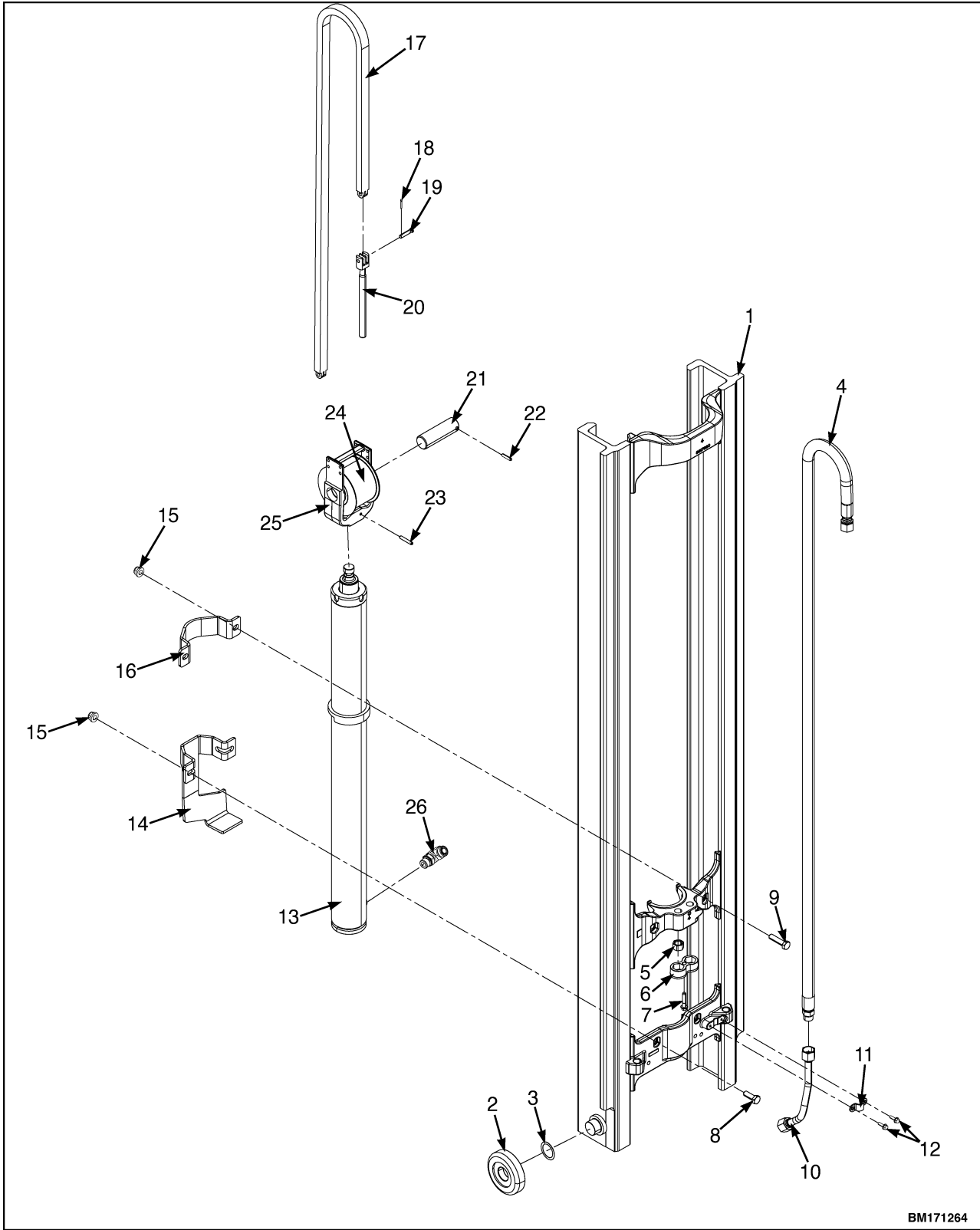


BM171265

Figure 443. Second intermediate mast

Legend for Figure 443.

- | | | | |
|-------------------------|------------------|------------------|------------------|
| 1. INTERMEDIATE
MAST | 6. SHIM | 11. SPACER | 16. SNAP RING |
| 2. LOAD ROLLER | 7. SHIM | 12. COTTER PIN | 17. CHAIN ANCHOR |
| 3. SHIM | 8. O-RING | 13. PIN | 18. COTTER PIN |
| 4. LOAD ROLLER | 9. LEAF CHAIN | 14. CHAIN ANCHOR | 19. CASTLE NUT |
| 5. WEAR STRIP | 10. CHAIN SHEAVE | 15. HOSE SHEAVE | |



BM171264

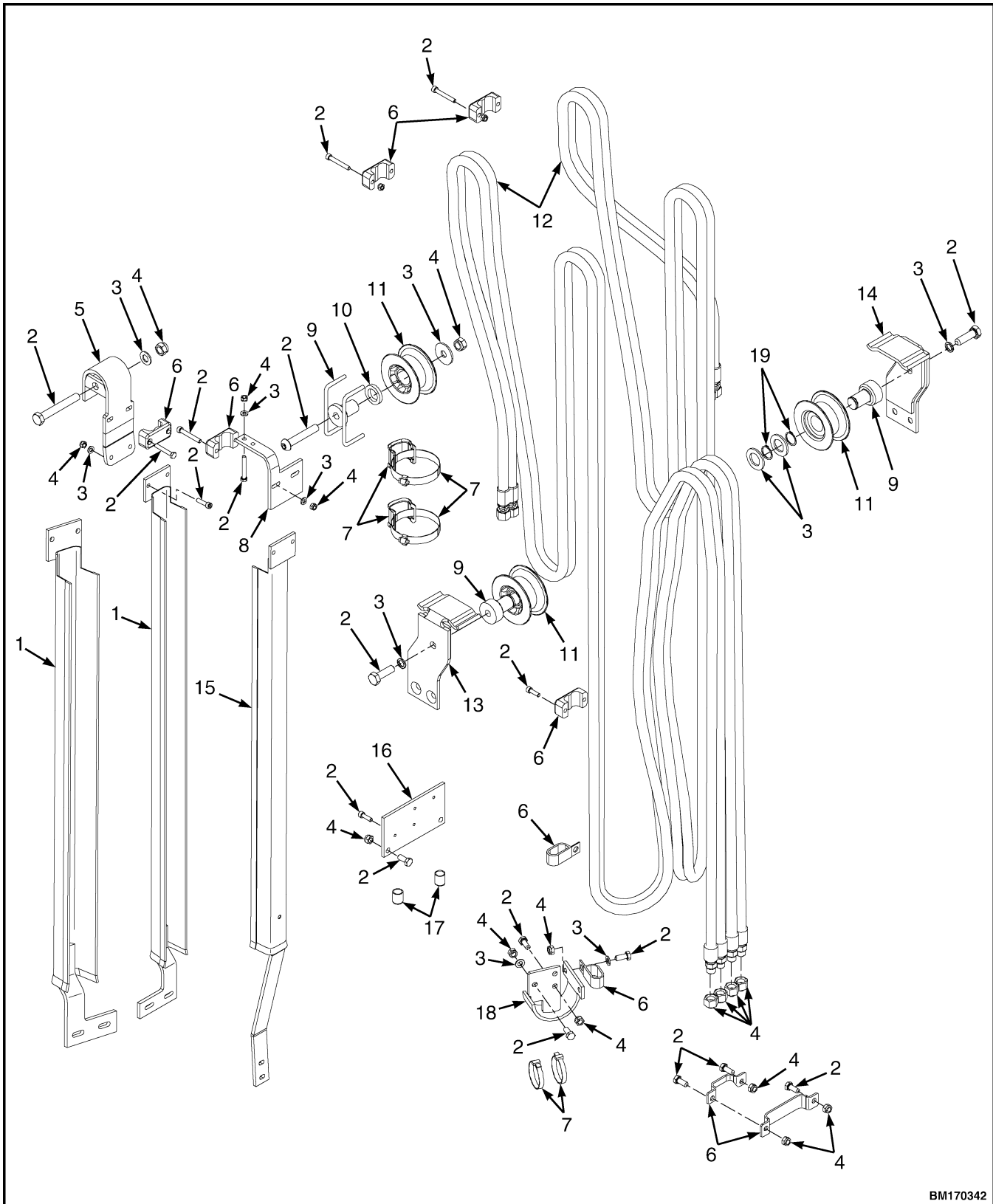
Figure 444. Inner mast

Legend for Figure 444.

- | | | | |
|------------------------|---------------------------|------------------|------------------|
| 1. INNER MAST | 7. CAPSCREW | 14. CLAMP | 21. PIN |
| 2. LOAD ROLLER | 8. CAPSCREW | 15. LOCKNUT | 22. ROLL PIN |
| 3. SHIM | 9. CAPSCREW | 16. CLAMP | 23. ROLL PIN |
| 4. HOSE ASSEMBLY | 10. TUBE ASSEMBLY | 17. LEAF CHAIN | 24. CHAIN SHEAVE |
| 5. CASTLE NUT | 11. BRACKET | 18. COTTER PIN | 25. CROSSHEAD |
| 6. CHAIN ANCHOR
NUT | 12. CAPSCREW | 19. PIN | 26. FLOW VALVE |
| | 13. FREE LIFT
CYLINDER | 20. CHAIN ANCHOR | |

Mast hydraulic components

The free-lift cylinder is arranged at the center, and the main lift cylinders are mounted to the left and right channels of the mast. Lift chains and hydraulic hoses are routed over and anchored at the top of each lift cylinder.



BM170342

Figure 445. Header hoses, hose sheaves, and routing - four-stage FFL Mast

Legend for Figure 445.

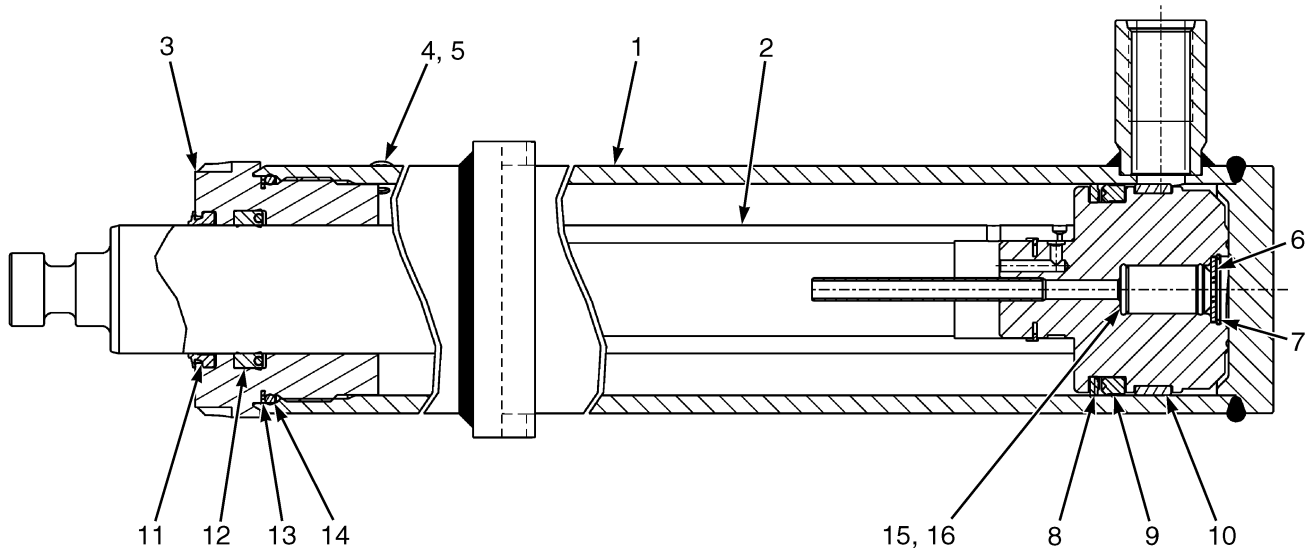
- | | |
|----------------------------------|--------------------------------|
| 1. HOSE CHANNEL (LOAD SIDE) | 11. HOSE SHEAVE |
| 2. CAPSCREW | 12. HEADER HOSES |
| 3. WASHER | 13. RIGHT HOSE GUARD |
| 4. NUT | 14. LEFT HOSE GUARD |
| 5. HOSE CHANNEL BRACKET WELDMENT | 15. HOSE CHANNEL (DRIVER SIDE) |
| 6. HOSE CLAMP | 16. PLATE |
| 7. STRAP CLAMP | 17. CAP |
| 8. HOSE CHANNEL BRACKET | 18. BOTTOM HOSE GUIDE |
| 9. STUBSHAFT | 19. SNAP RING |
| 10. SPACER | |

Free-lift and main lift cylinders

A pair of hydraulic cylinders are used to lift and lower the mast. The lift cylinders can be engaged to raise the mast during lift. Then the lift cylinders can be engaged to lower the mast back once a load is picked and being moved.

The lift cylinders operate in two directions. There is a port at the base of the cylinder and another at the

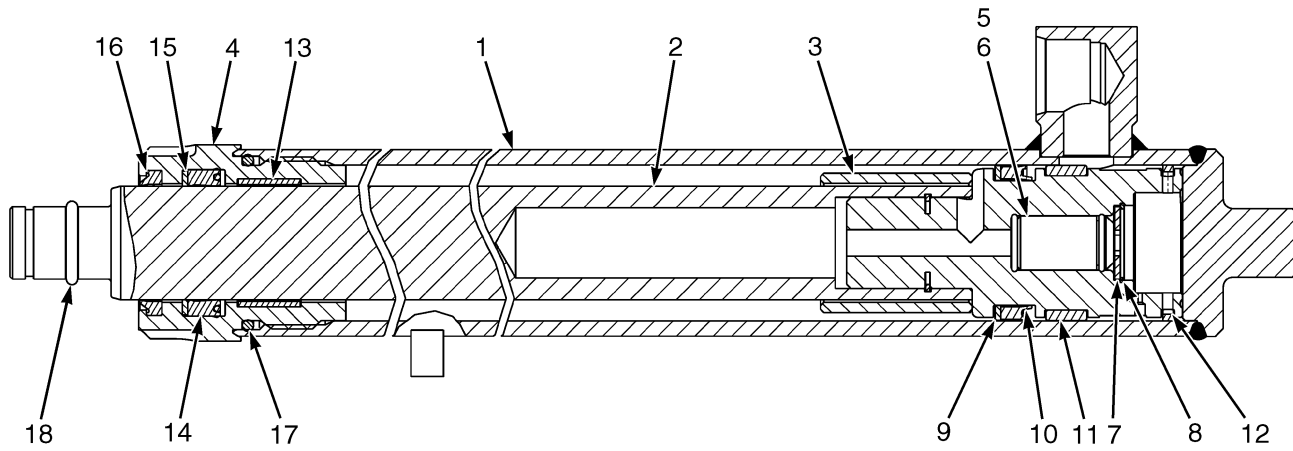
rod end of the assembly. Hydraulic oil entering the port at the base of the cylinder feeds under the piston and causes the rod to extend while oil exhausts through the rod end port. Hydraulic oil entering the port at the rod end causes the rod to retract into the cylinder.



BP170992

- | | |
|---------------------------|------------------|
| 1. CYLINDER TUBE WELDMENT | 9. SEAL |
| 2. CYLINDER ROD | 10. WEAR RING |
| 3. GLAND | 11. ROD WIPER |
| 4. SEALING RING | 12. ROD SEAL |
| 5. SCREW | 13. BACK-UP RING |
| 6. WASHER | 14. O-RING |
| 7. SNAP RING | 15. CHECK VALVE |
| 8. BACK-UP RING | 16. O-RING |

Figure 446. Free-lift cylinder



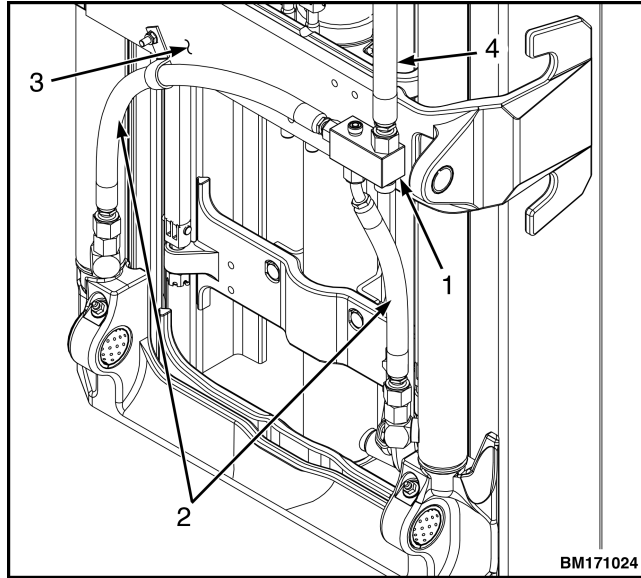
BP170987

- | | |
|---------------------------|------------------|
| 1. CYLINDER TUBE WELDMENT | 10. PISTON SEAL |
| 2. CYLINDER ROD | 11. WEAR RING |
| 3. SPACER | 12. WEAR RING |
| 4. GLAND | 13. WEAR RING |
| 5. CHECK VALVE | 14. ROD SEAL |
| 6. O-RING | 15. BACK-UP RING |
| 7. WASHER | 16. ROD WIPER |
| 8. SNAP RING | 17. O-RING |
| 9. BACK-UP RING | 18. O-RING |

Figure 447. Main lift cylinder

Mast hose manifold

The hydraulic manifold installed on the mast is a convenient and serviceable method to evenly distributing hydraulic oil. The central location helps with cleaner hose routing on the mast assembly.



- 1. MANIFOLD
- 2. HYDRAULIC HOSES
- 3. MAST
- 4. LIFT CYLINDER HOSE

Figure 448. Manifold and Hoses

Velocity fuse

The velocity fuse is a safety device to prevent a sudden rapid loss of oil pressure in the mast. In the event there is a hydraulic hose in the mast that ruptures, the velocity fuse will close and shut off oil flow when a high flow rate through it is detected. The velocity fuse prevents a picked load from crashing down due to a significant loss of hydraulic oil downstream from the manifold.

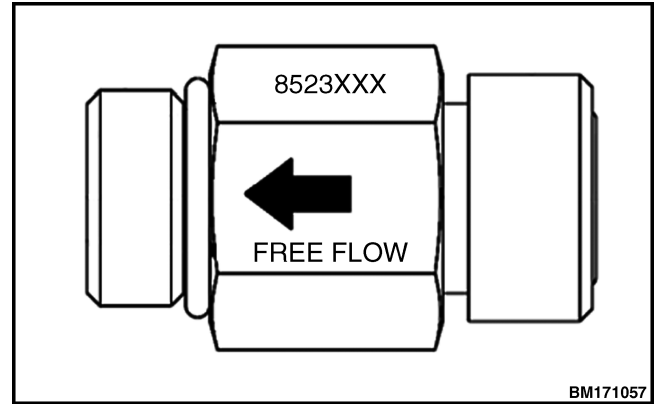


Figure 449. Hydraulic velocity fuse

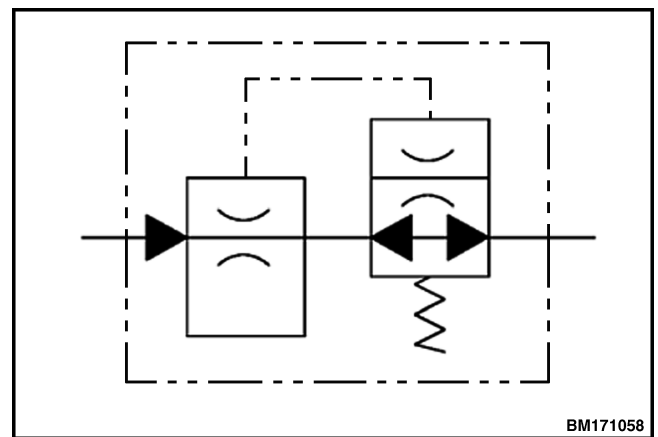


Figure 450. Velocity fuse ASA symbol

Hoses and hose assemblies

The hoist hoses are the longest of all equipped on a truck. They are arranged up and down the mast and are routed over pulleys mounted on the mast.

Hose part numbers are printed on a tag attached to the hose. The part number identifies the hose and important attributes like installed fittings, protective components, and length. The hose material and construction is also printed on the hose.

High pressure hydraulic hoses supply oil from the mast mounted manifold to the free-lift and main lift cylinders. The mast hydraulic hoses are routed as required.

Hose fittings

There are a few common hydraulic fitting types. The hydraulic hose fittings are crimped on and non-reusable. When hoses are replaced the fittings can not be removed without damaging and significantly compromising fitting integrity.

Some applications of hydraulic fittings may use Joint Industry Council (JIC) type fittings where the sealing O-ring mates with a flared shoulder. However, most of the hydraulic fittings are O-Ring Face Seal (ORFS).

Mast mechanical components

Lift chain

The primary function of the lift chain is to pull the inner mast channels to height during lifting and help hold the mast load during lowering. A set of lift chains hold the weight of the mast, carriage, and load. One end of the lift chain mounts at an anchor point near the top end of each lift cylinder. The other end of the lift chain mounts at an anchor point on the base of the innermost mast channel. Each of the lift chains moves over chain roller sheaves mounted on the mast.

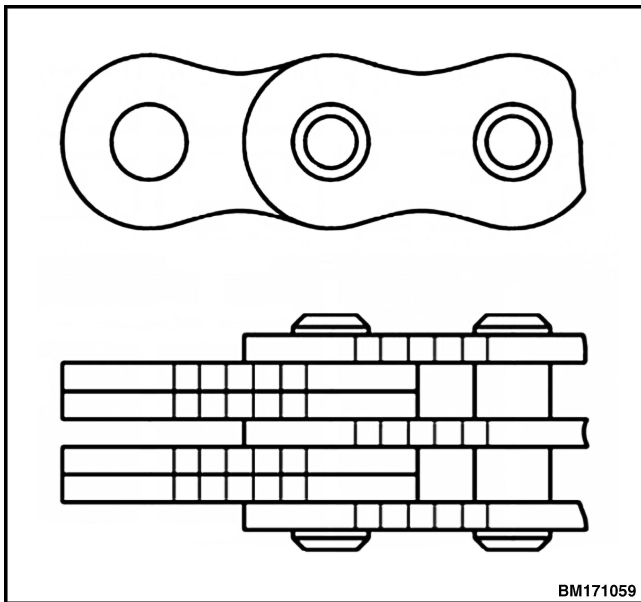


Figure 451. Lift chain example

The lift chains are routed over a system of pulleys called chain sheaves. As the lift cylinder rods extend, the power is transferred to the mast by the lift chains. One end of the lift chain is pinned to a

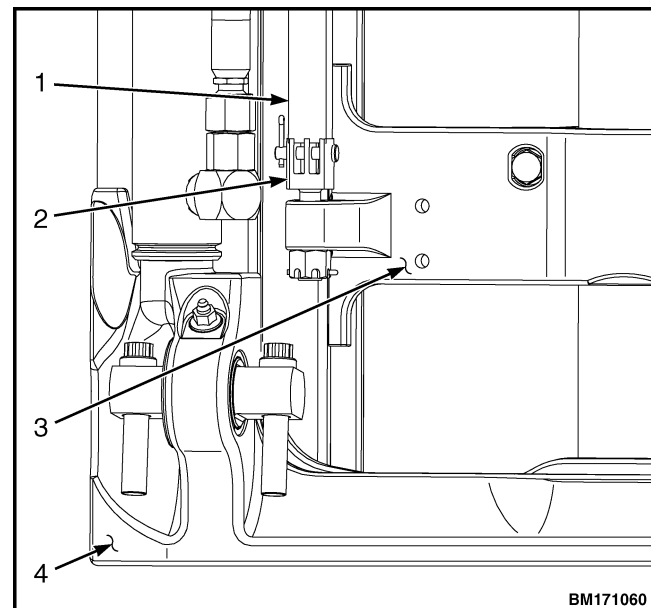
chain anchor at the outermost mast channel. Typically, the lift chain anchor is attached to the lift cylinder casing mounted to the outer mast channel. The other end of the lift chain is anchored to the top of the inner most mast channel.

During lifting the carriage assembly rises first with the free-lift cylinder until the end of cylinder travel. Then the main lift cylinder rods extend, causing the next inner channel to be pulled up to lift height.

Like all mast components the lift chain must be inspected for corrosion or damage; greased and the tension adjusted as necessary when performing periodic maintenance.

Chain anchors

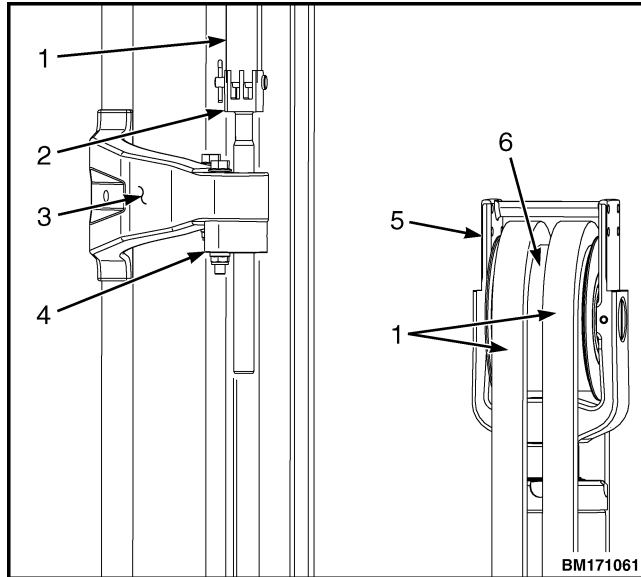
A secondary function of the chain anchor is adjustment of lift chain tension. The chain anchor is threaded so that lift chain tension can be increased or decreased.



1. LEAF CHAIN
2. CHAIN ANCHOR
3. INNER BOTTOM CROSSMEMBER
4. OUTER BOTTOM CROSSMEMBER

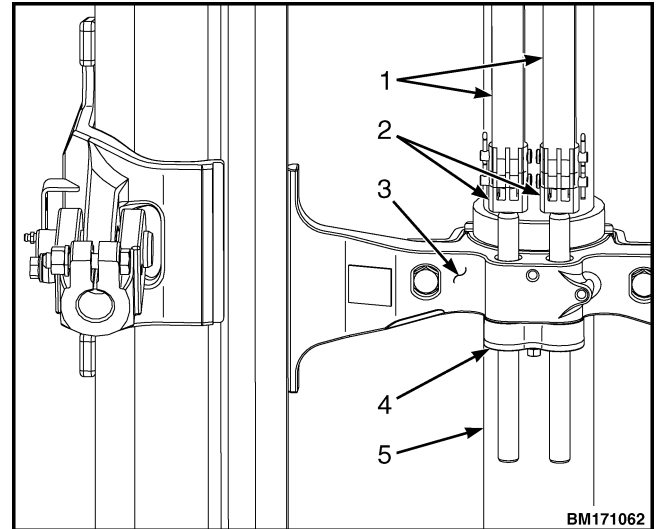
Figure 452. Chain anchor

Like all mast components chain anchors must be inspected for corrosion, greased and hardware torques if adjustment was necessary when performing periodic maintenance.



- 1. LEAF CHAIN
- 2. CHAIN ANCHOR
- 3. CHAIN SUPPORT ANCHOR
- 4. CHAIN ANCHOR NUT (SINGLE)
- 5. CROSSHEAD
- 6. CHAIN SHEAVE

Figure 453. Chain anchor nut (single) and crosshead



NOTE: SOME PARTS HAVE BEEN REMOVED FOR CLARITY.

- 1. CHAIN
- 2. CHAIN ANCHOR
- 3. INNER MID CROSSMEMBER
- 4. CHAIN ANCHOR NUT (DOUBLE)
- 5. FREE-LIFT CYLINDER

Figure 454. Chain anchor nut (double) and free-lift cylinder

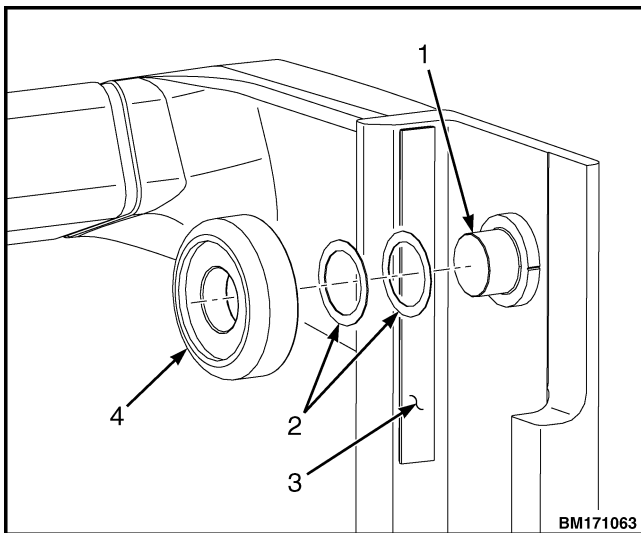
Chain sheaves

Chain sheaves are pulleys for guiding chain movement on the mast assembly. Chain sheaves are a tough plastic pulley with a center bearing and a mating profile to keep the chain aligned and reduce wear during repeated operation.

Chain sheaves are attached to both inner and intermediate mast inner top cross members and the free-lift cylinder. Like all mast components chain sheaves must be inspected for damage when performing periodic maintenance

Load rollers

Between each mast channel are load rollers that guide adjacent mast channels as they lift and lower. Load rollers are installed on machined stub shafts welded to the mast channels. The load rollers are tightly toleranced for keeping mast channels in alignment relative to each other. The primary surface of the load rollers is the rolling face that mates with the mast channel. But the secondary surface of the roller axis is also important. Axial clearance must be controlled with shims. Correctly shimming the load rollers minimizes mast racking during lift and lower. Racking is when one side of an inner channel weldment sticks and causes the channels to walk down during lowering.



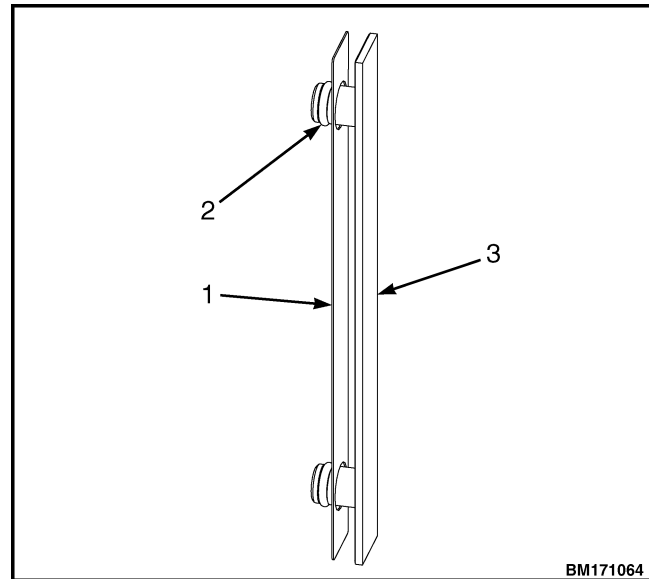
1. STUB SHAFT
2. SHIMS (AS NEEDED)
3. WEAR STRIP
4. LOAD ROLLER

Figure 455. Load roller and shims

To accommodate a small degree of variation between mating mast channels, clearance between the face of each load roller and the mating mast channel requires adjustment using shims. Shims are added or removed to adjust the clearance. The shims are made of high spring steel for strength and hardened for wear resistance.

NOTE: Greased mast channels and correct load roller clearance keeps symptoms like racking from occurring.

Wear strips



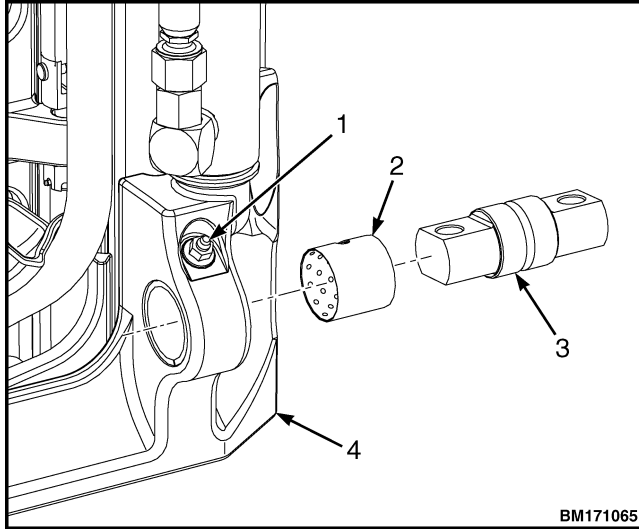
1. SHIM
2. O-RING
3. WEAR STRIP

Figure 456. Wear strip

Wear strips are attached to the inside of mated mast channels. The base of the strip is steel and topped with a soft metal bearing layer. The wear strip is the axial face of the load rollers mate with. Load rollers of mating channels pass over the wear strip during lift and lowering. The wear strips can also be shimmed. Like all mast components the wear strips must be inspected for unusual wear patterns when performing periodic maintenance.

Mast mounting bushings

The pinned connections at the drive axle is where the force of the front end and any picked load is transferred to the truck. These mounts at the axle are also the pivot point when the mast is tilted.



1. GREASE FITTING
2. BUSHING (BRONZE)
3. PIN
4. OUTER MAST, OUTER BOTTOM CROSSMEMBER

Figure 457. Mast mounting bushing

**PAPER ROLL CLAMP DESCRIPTION
202001-174**

This content is under development and will be released when available.

**BALE CLAMP DESCRIPTION
202001-175**

This content is under development and will be released when available.

**ROTATOR DESCRIPTION
202001-176**

This content is under development and will be released when available.



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