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Mission Generation Vehicular Equipment Maintenance Journeyman

Volume 1. Base Construction, Aircraft and Flight Line Servicing, and Military Series Vehicles

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CONGRATULATIONS! After completing the prerequisite courses X2T35X and Y2T35X, you are now ready to expand your knowledge and continue learning about the Vehicle Maintenance career field, specifically, mission generation vehicles and equipment. These vehicles are important assets for the Air Force. Without them, we could not meet the demands of maintaining and operating an active flight line. This volume, career development course (CDC) Z2T351, *Mission Generation Vehicular Equipment Maintenance Journeyman*, on construction, aircraft and flight-line servicing, and military series (M-series) vehicle systems will help you become proficient in your career field. Volume 1 contains four units. The units include fundamentals and maintenance of several different vehicles within the mission generation specialty.

Unit 1 covers base construction vehicles, to include the crane, grader, crawler tractor, and skid steer. It contains ten lessons to familiarize you with the fundamentals and maintenance of these vehicles.

Unit 2 deals with aircraft servicing vehicles, such as the towing tractor and deicer, which are used to ready the aircraft for takeoff. It consists of six lessons on these two vehicles.

In Unit 3, we discuss flight-line servicing vehicles and equipment that keep the flight line ready to safely support aircraft by keeping it clear of debris and snow. We'll spend six lessons discussing the regenerative sweeper, snow blower, and Windrow sweeper.

Finally, in Unit 4, we'll discuss M-series vehicles, including high-mobility multipurpose-wheeled vehicle (HMMWV), 2 ½-ton and 5-ton cargo trucks, and mine-resistant ambush-protected (MRAP) vehicles. Six lessons will familiarize you with M-series fundamentals and maintenance.

The job knowledge you gain in this course, coupled with the on-the-job training you receive in your workcenter, will provide the basic skills required for you to become a successful journeyman in your career field. Remember that CDCs are meant to provide an educational foundation; they are not intended to replace specific information or procedures found in technical orders (TO) and service manuals. Always use the appropriate technical reference when accomplishing repairs.

A glossary is included for your use.

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NOTE:

In this volume, the subject matter is divided into self-contained units. A unit menu begins each unit, identifying the lesson headings and numbers. After reading the unit menu page and unit introduction, study the section, answer the self-test questions, and compare your answers with those given at the end of the unit. Then complete the unit review exercises.

Acknowledgment

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Unit 1. Base Construction Vehicles

MAINTENANCE ON AN AIR FORCE installation is similar to that of a major corporation. Someone must repair and maintain structures, utilities (electricity and gas), roads, flight lines, and parking lots. In order to accomplish these tasks, the use of several types of specialized vehicles is required. These vehicles fall under the 2T351 career field and are known as base construction vehicles. In this unit, we will discuss four of these vehicles: crane, grader, crawler tractor, and skid steer.

1–1. Crane

In today's Air Force, cranes are used for a variety of purposes from construction to aircraft maintenance to crash recovery missions. As a maintenance person, it is your responsibility to make sure a crane is safe to use and can perform the tasks it was designed to perform. Cranes come in a variety of shapes and sizes. Some cranes are designed to be driven to the job site, while others have to be hauled.

The crane we will be discussing is the Arva crane, AT3035 military model (fig. 1–1). The main purpose of the Arva crane is to lift objects and move them safely from one location to another. The crane can also be equipped with an optional swing away 15 ft. jib (extension). Each manufacturer designs its cranes to be flexible and meet specific industry standards. The Arva crane is capable of lifting up to 7½ tons. In this section, you will learn the various systems that make up the Arva crane, beginning with the carrier assembly.

Figure 1–1. Arva 7.5 ton crane.

001. Carrier assembly

The carrier assembly is a welded box-type frame with two axles and is specially configured for military applications. You can think of the carrier assembly as the *truck* part of the crane. It includes the engine, transmission, drive axles, and other associated parts. The carrier, along with the turntable and upper structure, make up the crane. The carrier measures 19½-feet (ft.) long and 8 ft. wide; the complete crane is 26ft. long and 8 ft. high. The Arva crane's dimensions were deliberately designed to make it transportable by a C–130 aircraft.

Engine

The engine is a computer-controlled 5.9 liter in-line six-cylinder turbo diesel. It is mounted facing rearward, in the rear of the vehicle. The engine is capable of running on standard diesel, biodiesel, and North Atlantic Treaty Organization (NATO) single battlefield fuel (Jet Propulsion [JP]–8). The engine also features a two-speed remote throttle control. The remote throttle is controlled by a rocker switch located on the left side of the dash control panel. Push the rocker switch up one position for the medium throttle preset which maintains engine speed at approximately 1,600 revolutions per minute (rpm). Push the switch all the way up for the high-preset throttle (approximately 2,400 rpm).

NOTE: Operate the engine at a minimum of 1,600 rpm while lifting.

Digital engine monitor

The digital engine monitor is located on the right side of the dash control console. It is a multifunction tool that enables the equipment operator to view the different engine parameters. The operator can view either one or four engine parameters at a time and retrieve diagnostic trouble (fault) codes (DTC). The monitor has a keypad for navigating the various menus. The monitor also displays "wait to start preheating" on the display during the engine preheating cycle. Wait until this display message clears before starting the engine.

Engine control module

The monitor communicates with the engine control module (ECM) using the Society of Automotive Engineers (SAE) J1939 controller area network (CAN). The CAN system uses a two-wire, high-speed network system to communicate with the crane's ECM. The monitor is capable of communicating with the ECM using four different J1939 versions (i.e., 1, 2, 3, or 4). The different versions are used by different manufacturers to communicate trouble codes to the module. The unit defaults to version 4, which is the most widely used version. The monitor must be set to the same version as the ECM or it will not communicate. If a *noncritical fault* is detected, the monitor will display WARNING followed by the alphanumeric fault code and the code description. If a *critical fault* is detected, the monitor will display SHUTDOWN followed by the code and its description. Stored fault codes can be retrieved through the "stored codes" menu on the monitor.

Transmission

The engine drives the torque converter and transmission. This automatic transmission has three forward and three reverse gears. Shifting the transmission is accomplished through the use of a direction-and-transmission control lever. The direction-and-transmission control lever controls the travel direction and speed of the crane. The operator must rotate the end of the lever for a speed change. In order to move out of the neutral position, the operator must lift the lever. The direction-and-transmission control lever is located to the left of the steering wheel on the steering column. Incorporated into the lever is a neutral safety lock. The operator must turn the lever clockwise with the shifter in neutral to lock the lever.

The transmission incorporates a drive axle range, which provides the functions of a transfer case within the transmission assembly. It provides two-wheel drive high range or four-wheel drive low range. These two drive axle ranges are selected manually by an electric rocker switch located on the control console (right of the operator armrest). The rocker switch energizes the four-wheel drive solenoid located in front of the transmission. When the solenoid is energized, the magnetic field moves a spool within the four-wheel drive solenoid valve assembly. Transmission fluid then flows through the passageways within the spool and is directed to the hydraulic range (hi-lo) and axle disc (two-wheel/four-wheel) actuators to change ranges. The hydraulic range and axle-disc actuators are located on the transmission. If the four-wheel drive solenoid malfunctions, the transmission will default to four-wheel drive low.

CAUTION: To prevent transmission damage, the vehicle *must* be stopped when shifting ranges.

Drive axles

The crane uses two heavy-duty, full-floating axles. The front axle utilizes a limited-slip differential, while the rear axle uses a locking differential for maximum traction. Both axles can be used for steering, and each hub contains a final drive assembly. The final drive assemblies consist of planetary gears incorporated into each axle hub, which provides an increase in torque to the wheels. The planetary gears are splash lubricated with 90-weight oil. The fill plug in each axle hub allows the technician to check and service the oil level.

Suspension

The Arva crane has no suspension. The front axle (fig. 1–2) is bolted directly to the main frame of the carrier, and the rear axle (fig. 1–3) is an oscillating type. There is a pivot point located between the axle and the carrier frame, which allows the axle to pivot (like a teeter-totter). This oscillating movement allows the rear wheels to maintain contact with the ground, even in rough or uneven terrain. The rear axle pivots along the longitudinal center line of the crane when maneuvering. The rear axle pivots 4 inches (in.) in either direction for a total of 8 in. of total travel.

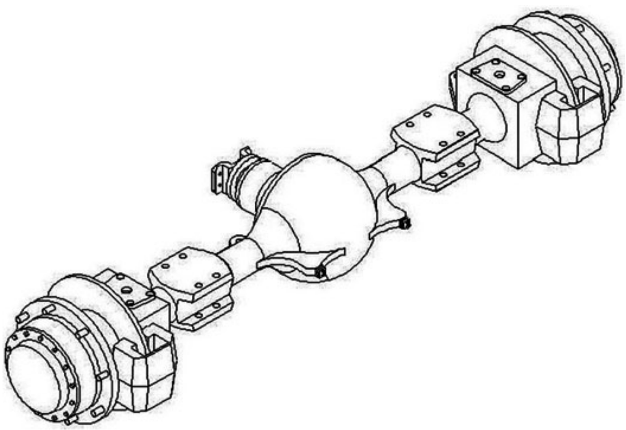


Figure 1–2. Front axle assembly.

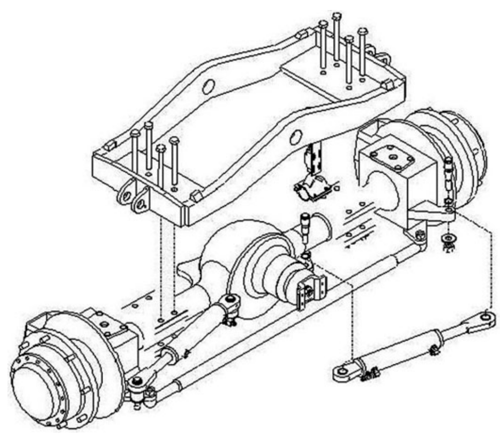


Figure 1–3. Rear axle assembly.

Axle-lock cylinders (fig. 1–4) may be used for additional stability in lieu of outriggers when doing an “on-rubber” lift or when the load being lifted must be transported to another site. The axle locks provide more stability when lifting on tires alone. The axle locks are two double-acting hydraulic cylinders mounted between the frame and the rear axle.

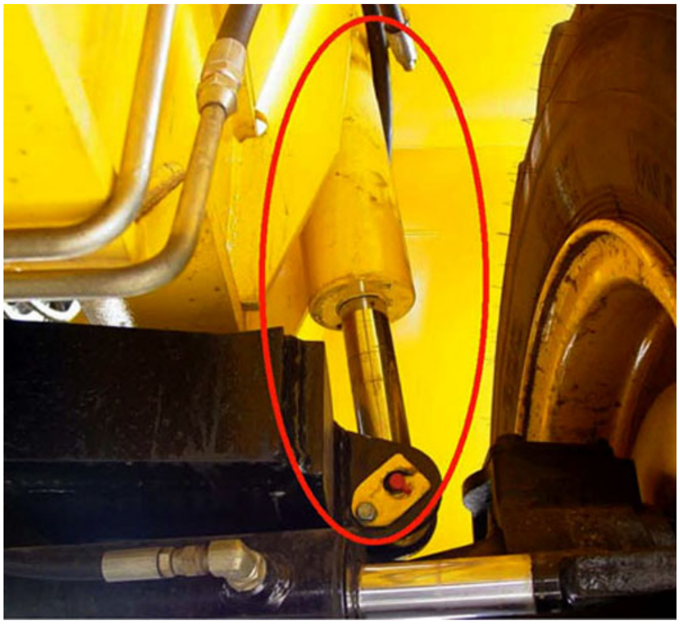


Figure 1–4. Axle locks.

Axle-lock cylinders are connected to the transmission hydraulic system, separate from the main hydraulic system. The cylinders lock the rear axle to the frame and prevent the rear axle from oscillating. The axle locks are actuated by a three-position electric rocker switch located on the right-side console next to the outrigger controls. Caution must be observed when lifting objects without outriggers.

CAUTION: Do *not* exceed tire sidewall rating when accomplishing an on-rubber lift.

Brakes

The service brake system is hydraulically operated and receives fluid from the main hydraulic system. The main hydraulic pump is a tandem-gear–type pump that incorporates two pumps in one housing. The pump has two different fluid output ratings, 15 and 31 gallons per minute (gpm). The 15 gpm hydraulic pump supplies fluid for the service brakes. The service brake system components consist of an accumulator charging valve, two accumulators, a modulating brake pedal valve, and four disc brake assemblies. There is one disc brake assembly located at each axle end. Fluid from the hydraulic pump is directed to the accumulator charging valve. The accumulator charging valve charges the two accumulators, which supply pressurized fluid to apply the service brakes. It is important to note, the *accumulators* supply the brake fluid pressure required for proper brake operation, *not* the hydraulic pump. The hydraulic pump and the charging valve charge the accumulators. The pressure stored in the accumulators will also allow the operator to safely stop the crane in the event of a hydraulic system failure. A modulating brake pedal valve directs pressurized fluid from the accumulators to the disc brakes during application.

The parking brake is manually actuated by a push/pull-type button located on the dash control panel (right side). The parking brake button glows red when the parking brake is applied. The parking brake is a spring-applied/hydraulically released disc-type brake that is mounted to the output of the transmission. The parking brake must be applied for the engine to start. The transmission and parking brake are interlocked for safety. The transmission will disengage when the parking brake is applied and will not engage until the brake is released.

Steering

The steering system on the Arva crane is part of the main hydraulic system and receives fluid from the 15 gpm pump. This system incorporates a steering control valve, which directs fluid to either side of the steering cylinders depending on the direction of the turn. The steering control valve is located at the end of the steering column inside the cab. The steering control valve also acts as a pump for the steering system during an engine or main hydraulic pump failure. Four double-acting cylinders (two per axle) are used to steer the crane, depending on the selected mode of steering.

The following three steering modes are used on the crane:

1) Two-wheel conventional steering.
2) Four-wheel coordinated steering.
3) Four-wheel crab steering (fig. 1–5).

Two-wheel conventional steering is when the front wheels steer only. Four-wheel coordinated steering is when the front and rear wheels turn in opposite directions. This mode of steering provides the sharpest turns. Four-wheel crab steering is when the front and rear wheels turn in the same direction. This mode of steering is also known as four-wheel oblique steering. A three-position electric rocker switch located to the left side of the dash control panel controls the three modes of steering.

CAUTION: Do *not* change modes of steering while crane is in motion.

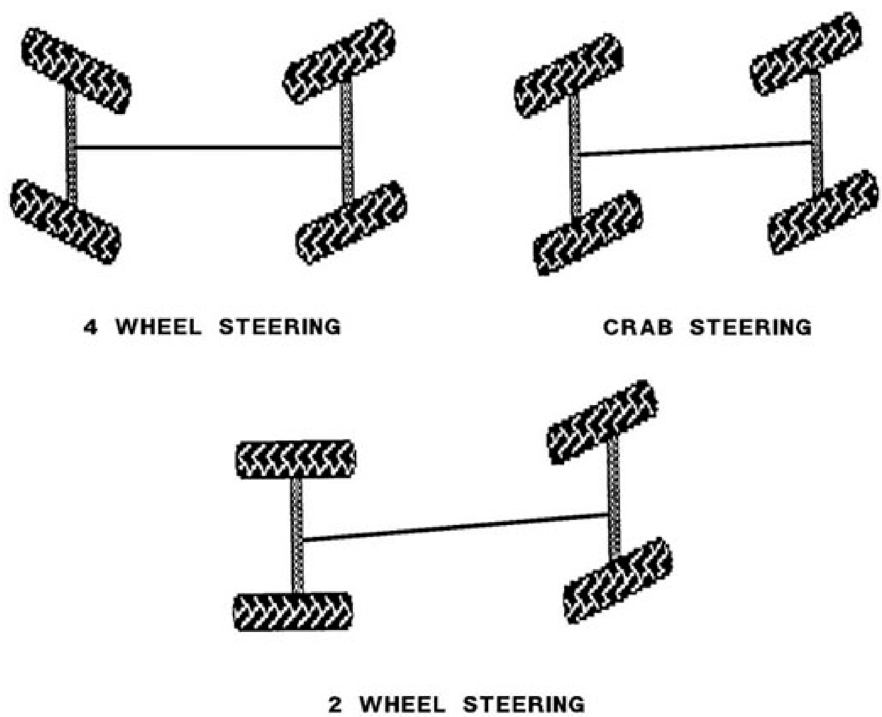


Figure 1–5. Steering modes.

Additionally, the crane utilizes a “rear-wheel steer not centered” indicator light that will illuminate when the rear wheels are not in the centered position. This light is located on the dash control console (top left side). The indicator light is controlled by a microswitch (normally closed) and is mounted on the left side of the rear axle.

CAUTION: Change steering modes *only* when rear tires are in the *centered* position.

002. Crane functions

The crane functions consist of lifting and positioning loads. In this lesson, we will cover the parts and systems associated with this lifting and repositioning; such as hydraulics, outriggers, the turntable, the boom winch, boom functions, and the two-block system. These components work together to enable the crane to lift and position loads safely under varying conditions.

Hydraulic system

The 60-gallon hydraulic reservoir is located next to the turntable on the right side of the crane. The main hydraulic pump (fig. 1–6) is a tandem-gear–type pump and is gear driven off the torque converter. As mentioned earlier, the tandem-gear pump has two fluid output ratings: 15 and 31 gpm. The 15 gpm pump supplies fluid for the winch boost, outriggers, steering, and the service/park brake, and the 31 gpm pump supplies fluid for the main control valve functions.

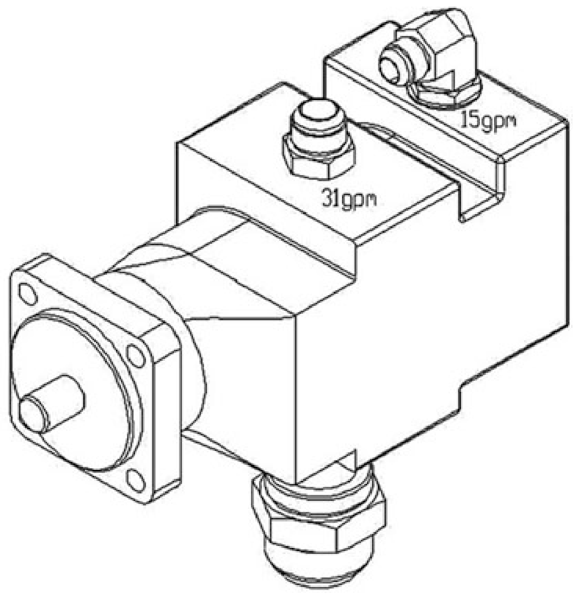


Figure 1–6. Hydraulic pump.

Figure 1–7. Joystick manipulator.

Two joystick manipulators (fig. 1–7) control the boom hydraulic functions. They are located next to each armrest in the operator's compartment. The joystick manipulators control *pilot pressure* to the main control valve assembly, which manipulate the main control valve spools. The left joystick controls boom extend/retract and boom swing, and the right joystick controls winch and boom lift/down. The joysticks are disabled by the joystick lock-out rocker switch located on the bottom left of the dash control panel. Always disable joysticks before exiting equipment.

Main control valve

The main control valve assembly (fig. 1–8) is mounted under the vehicle on the inside frame rail (right side). There are four closed center-type spools within the main control valve assembly. The spool valves are closed by spring pressure and are opened by pilot pressure. The valves control winch, boom lift/down, boom extend/retract, and boom-swing functions. There are also pressure relief valves incorporated in the control valve assemblies.

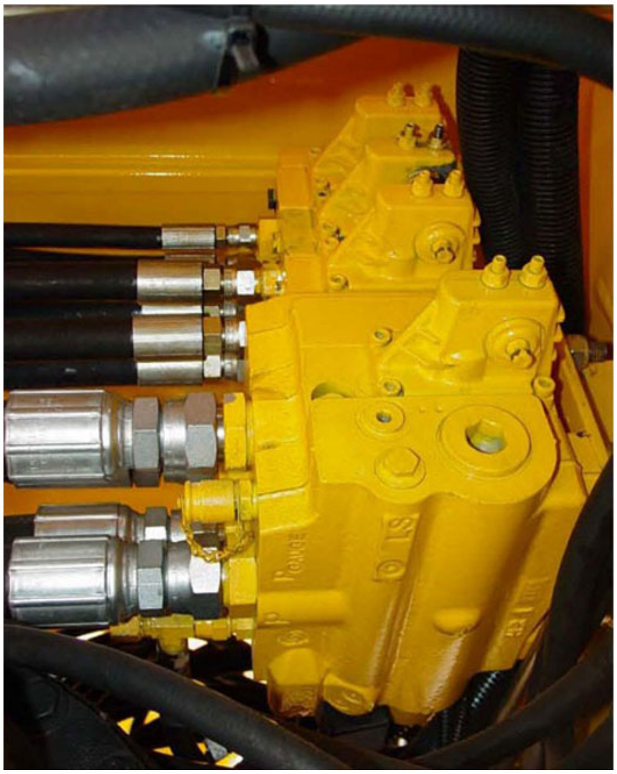


Figure 1–8. Main control valve.

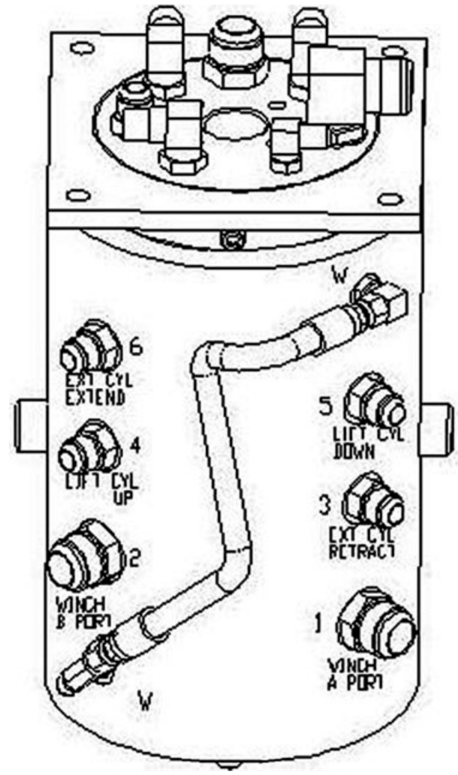


Figure 1–9. Rotary manifold.

Rotary manifold

The crane is equipped with a *rotary manifold*, also known as the hydraulic swivel (fig. 1–9). This allows the boom to continuously rotate 360 degrees (°) without twisting or breaking the hydraulic lines and hoses to the turntable assembly or upper structure.

The rotary manifold directs hydraulic fluid to all upper-structure hydraulic actuators. It consists of an inner spool, outer casing, and O-ring seals. Fluid lines from the carrier are connected to the inner spool that remains stationary with the carrier. The outer casing rotates around the outside of the inner spool with the turntable and upper structure. The inner spool has multiple groves around its body O-rings to seal fluid from leaking into other sections of the spool. Each groove is connected by a port and a line from the carrier. The outer casing fits over the inner spool and rotates with the boom. Each groove on the inner spool matches a port in the outer casing. The lines connected to the outer casting are directed to the upper-structure actuators. The hydraulic functions that require the fluid to be directed through the rotary manifold are the winch, boom lift/lower and boom extend/retract.

Outriggers

Hydraulic outriggers (fig. 1–10) are used to provide stability during lifting operations. The Arva crane utilizes four independently controlled outriggers, one for each corner of the vehicle. Each outrigger uses one double-acting cylinder with a hold valve to lock it in position. The outriggers must be fully extended to provide support for the crane when lifting heavy loads. The carrier must be leveled prior to extending the boom or lifting heavy loads. Each outrigger is independently actuated by a three-position rocker switch located to the right of the operator on the outrigger control console.

Figure 1–10. Outriggers.

Operators must know if the crane is level *before* lifting a load. The Arva crane has bubble indicators (fig. 1–11) mounted just behind the operator's seat (right side). The bubble indicators indicate when the platform is level. The crane *must* be leveled during the positioning of the outriggers.

CAUTION: Failure to ensure the crane is level could cause a personnel accident or injury or equipment failure during lifting operations.

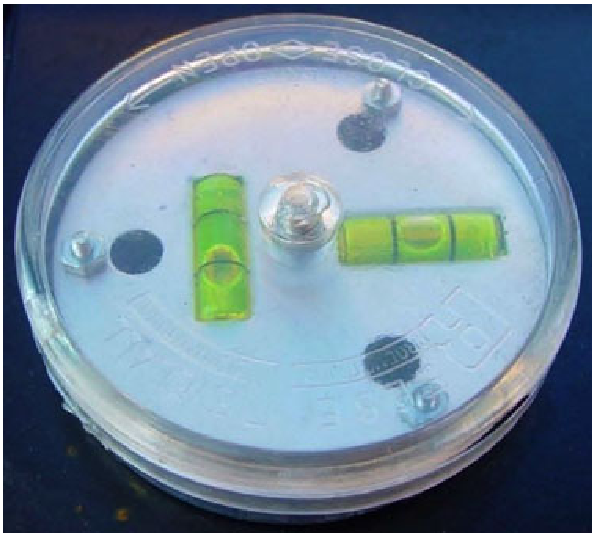


Figure 1–11. Bubble indicator.

Turntable assembly

A crane that is only capable of lifting and lowering cargo isn't very useful. A device called a turntable assembly (fig. 1–12) allows the boom to swing in a complete circle so the cargo can be placed anywhere the crane's boom can reach. The turntable assembly attaches the boom assembly to the carrier assembly. The turntable utilizes a swing bearing and a hydraulically driven gear reducer to accomplish the boom-swing function. There is also a counterweight mounted to the rear of the turntable assembly to offset the weight of the load being lifted.

Figure 1–12. Turntable assembly.

Swing-bearing assembly

The component that carries the weight of the upper structure and allows the boom to rotate 360° continuously in either direction is the swing-bearing assembly (fig. 1–13). It is composed of two races: outer and inner. The outer race is part of the bull gear and is bolted to the turntable assembly. The inner race is bolted to the carrier assembly, between the races are ball bearings, which allows the turntable to easily swing in either direction.

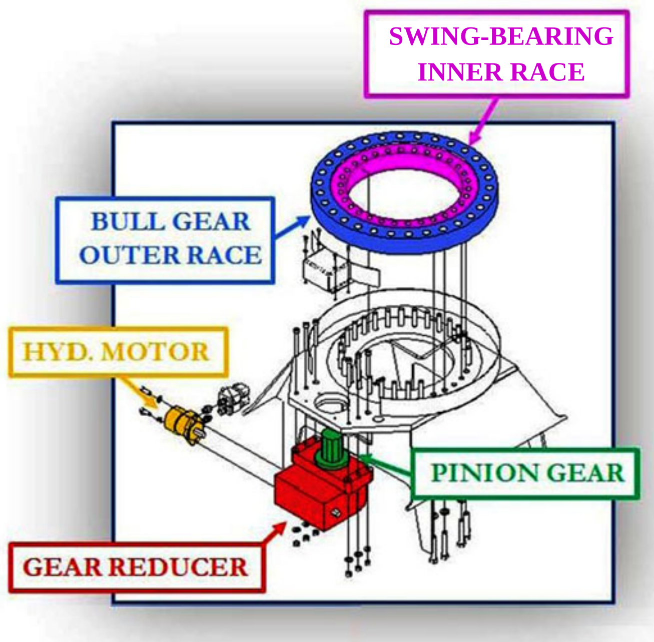


Figure 1–13. Swing-bearing and boom-swing components.

Boom swing

Boom swing is accomplished by a high-torque gerotor-style motor that drives a self-locking worm-gear drive in a gear reducer (fig. 1–13). A worm-gear drive is self-locking when the output cannot drive the input. This means that if the boom were to try to turn without the reducer or turn against it, it would be unable to do so. Therefore, if the hydraulic motor stops so does the boom.

The gear reducer, which is mounted to the carrier assembly, also incorporates a fail-safe brake located between the drive motor and the gear reduction. The brake is a spring-applied and hydraulically released disc-type brake. The worm gear drives a pinion (output) gear within the gearbox. The pinion gear meshes with the bull gear (part of the swing bearing) that is mounted to the turntable. The bull gear is actually the outer race of the swing-bearing assembly. When the pinion gear rotates, the bull gear is forced to move. This action causes the turntable and boom assembly to rotate 360° in either direction depending on the rotation of the pinion gear. The maximum rotational speed of the turntable assembly is 2 rpm.

Collector ring

A collector ring (fig. 1–14) allows all upper-structure wiring to continuously rotate 360° without twisting and breaking. It uses slip rings (commutator rings) and brushes similar to those of an alternator's slip rings and brushes.

Figure 1–14. Collector ring.

It is located in the middle of the turntable assembly, just under the hydraulic swivel (rotary manifold). The contact brushes are self-cleaning. If an operator were to experience any electrical malfunctions in the turntable or upper structure, the operator should rotate the boom several times to clean the contacts between the brushes and commutator rings within the collector-ring assembly. This procedure should eliminate most turntable or upper-structure electrical malfunctions.

Upper structure

The upper structure (fig. 1–15) provides a high point from which to lift objects. It is mounted to the turntable assembly by one large pin. The upper structure consists of two segments: a base and a fly-tip section.

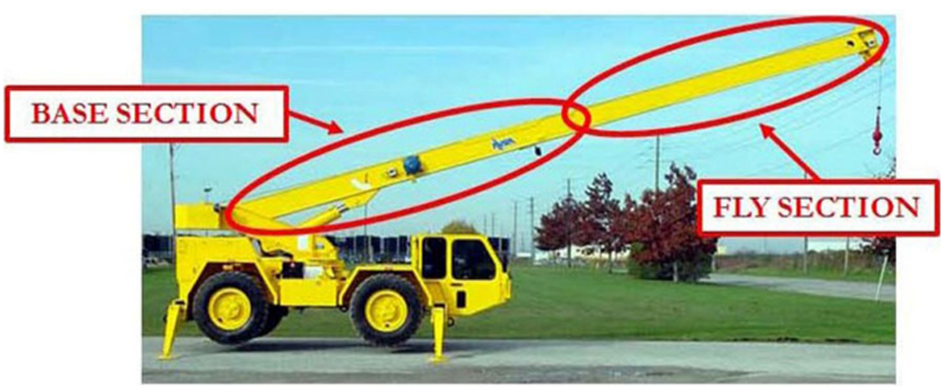


Figure 1–15. Upper structure.

The fly segment slides in and out of the base section. The boom is extended by the use of one double-acting cylinder. The ram is mounted to the fly section, and the cylinder is mounted to the base section of the upper structure. The boom sections are held in alignment by pads. These pads also provide a replaceable wear surface and help to reduce the slap that occurs when a swing movement is performed. The pads on the bottom are called slide pads. These pads are the wear surface of the boom sections and must be lubricated with grease. The pads on the side sections of the boom are called side pads. These pads are also used to maintain alignment of the boom sections. The side pads do not require lubrication. The upper structure is lifted by a single double-acting cylinder and uses a counterbalance valve to lock the cylinder in place for safety.

CAUTION: Crane booms are *not* intended to withstand side pulling of a load. Side pulling may cause the boom sections to collapse.

One of the simplest safety devices on the crane is the boom-angle indicator (fig. 1–16). It indicates the angle of the boom in relation to a horizontal plane. It consists of a pendulum and a numbered scale located on the left side of the boom (base section). As the boom rises, the pendulum will remain pointing down at the numbered scale indicating boom angle. The pendulum must swing freely without binding. The operator must be able to read the boom angle accurately in order to decide if a load may be lifted safely.

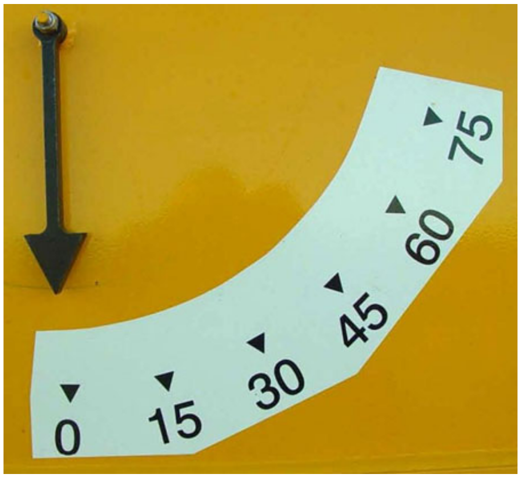


Figure 1–16. Boom-angle indicator.

Winch and load-hoist cable

The winch is used to perform the lifting function of the crane. It is slow in movement, which allows for maximum operator control. The winch is mounted at the rear of the turntable in front of the counterweight. During normal operation, the 31 gpm pump supplies fluid for the winch. The operator can increase the speed of the winch by using the Winch Boost function. The Winch Boost function is selected by a push button on top of the right joystick manipulator. When the operator presses the Winch Boost button, 12 volts direct current (VDC) is supplied to the winch boost solenoid. The solenoid energizes and moves a hydraulic spool valve. The spool valve diverts fluid from the 15 gpm pump to the winch circuit. As a result, a total of 46 gpm of hydraulic fluid will flow to the winch hydraulic motor during Winch Boost.

The winch in the Arva crane incorporates a load-hoist brake, which suspends the load. The load-hoist brake is a wet multiple-disc–type brake. It is spring-applied and hydraulically released by pilot pressure. The load-hoist brake is located within the winch cable-drum assembly.

The load-hoist cable runs from the winch over the top of the boom to the hook block. The tip of the boom is equipped with pulleys that provide smooth, rotating surfaces for the load-hoist cable to ride on.

Sheaves and reeving

Notice that on many cranes the cable is fed over pulleys (called sheaves) on the boom tip. The cable is then routed down to another sheave on the hook-block, then is routed back up and around another sheave on the boom tip before it's finally secured to the hook-block. This is known as *reeving*. Specifically, reeving is the process of running cable through sheaves, which increases the lifting capacity of the winch.

Hook-block system and parts

If you were to look at a hook-block system being suspended, it would appear to be held by three cables. The number of times reeving is accomplished is known as *parts*. The previous example refers to a three-part reeve. The disadvantage of reeving with several parts is that it slows down the action of the hook-block. A three-part reeve would provide the winch stronger lifting capability, but the winch must spool in 3 ft. of cable to achieve 1 ft. of lift.

Rated capacity indicator and anti-two-block system

A digital load indicator is used on the Arva crane, which allows the operator to see a digital readout of the weight being lifted. This prevents operators from lifting loads that exceed the weight limitations for their current crane configuration. The Arva crane is specifically equipped with the Wylie W3350R Radio rated capacity indicator (RCI) system (fig. 1–17).

Figure 1–17. Rated capacity indicator and anti-two-block display.

This system provides continuous information relating to crane loading and warns the operator when crane limits are approaching or have been exceeded. The RCI display unit is located on the right side of the dash control panel. The RCI system incorporates an anti-two-block (A2B) system. The A2B system prevents the operator from raising the hook-block into the boom tip or lowering the boom tip onto objects.

RCI

The RCI system is a length, load, angle, radius, lifting capacity, and two-block indicator. This system automatically monitors the load applied to the crane and continuously compares the current load with the maximum permitted load for each crane position.

CAUTION: The Wylie Radio RCI system is to be regarded *only* as an *aid* to the operator. The indicator equipment will *not* necessarily prevent crane damage due to overloading.

Display unit

The display unit (fig. 1–17) contains a microprocessor computer with operating software, which has four operating modes:

1. Normal.
2. Diagnostic.
3. Calibration.
4. Limits setting.

The liquid crystal display (LCD) screen provides the crane operator with critical information necessary to operate the crane safely and within the maximum permitted load specified by the crane manufacturer. The display unit operates off the crane's 12-volt power supply. Supply voltage must be a minimum of 11 volts and must not be greater than 30 volts.

There are two warning lights (A2B and limits) and an internal buzzer that warn the equipment operator when the crane is approaching or exceeding the crane limit capacity. The limit warning light blinks when the load on the hook is between 85 and 99.9 percent of the rated capacity, accompanied by an audible warning that is inside the display unit.

When the load on the hook is above 100 percent of the crane's rated capacity, or when the operator has reached a predetermined set limit (set in the limits setting mode), the limit warning light and audible alarm will be on continuously. The A2B condition light appears when such a condition is detected by the system.

The display unit has six buttons used to navigate and set up the operating modes. Consult the operator's manual for procedures to set up the operating modes.

Transmitters

Transmitters send radio signals to the RCI system's computer. There are *two* transmitters found on the Arva crane. One is mounted on the fly tip (A2B transmitter), and the other is mounted on the base section (reeling drum transmitter). They are powered by the crane 12-volt power supply (11-volt minimum/30-volt maximum). Each transmitter identification number is stored in the computer's memory during the calibration process. The RCI computer will only respond to signal outputs from stored transmitters. This prevents interference from other cranes operating within the same vicinity.

CAUTION: The RCI system is *not* suitable and should *not* be used in explosive atmospheres. Transmitter radio signals can trigger detonation.

Load-pin sensor

The load-pin sensor is mounted on the left of the fly-tip section in the head sheave. It sends an electrical signal to the A2B transmitter. The transmitter sends a radio signal to the RCI system's computer that is proportional to the actual load in the load-hoist rope system of the crane.

Reeling drum

The reeling drum (fig. 1–18) cable has an extension capacity of 110 ft. Cable guides must be bolted in front of the reeling drum and in front of every boom section to keep the cable in a straight line. Sagging of the reeling-drum cable wire would cause nonlinearity of the length measurement. All cable guides must be in perfect alignment; both vertically and horizontally and parallel to the boom. Cable guides allow easy flowing of wire and help keep the boom-length measurement linear. The reeling-drum cable delivers power to and provides a ground for the radio load pin and A2B transmitter.

Figure 1–18. Reeling drum.

Boom-length sensor

The boom-length sensor (fig. 1–19) is a gear-driven potentiometer. The boom-length sensor is mounted in the reeling-drum housing. As the boom extends, the reeling drum unwinds and the potentiometer is driven. The output signal of the potentiometer is sent to the transmitter, which is proportional to the extension of the boom.

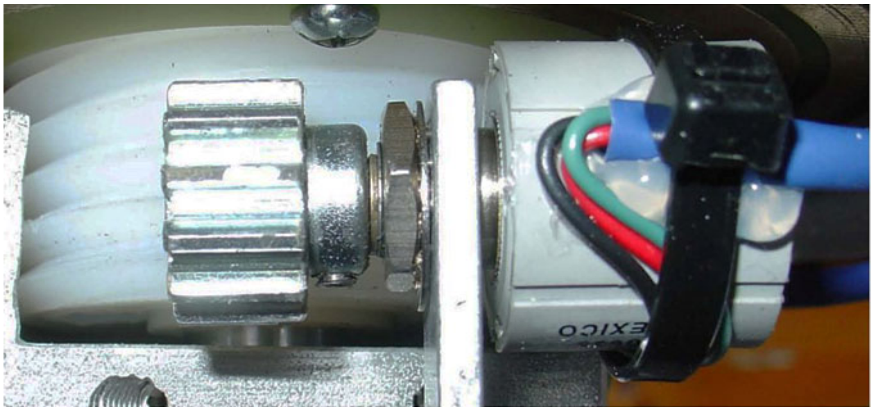


Figure 1–19. Boom-length sensor.

Boom-angle sensor

The boom-angle sensor is an inclinometer that provides a signal to the reeling-drum transmitter. In turn, the transmitter sends a radio signal to the RCI system's computer that is proportional to the boom angle. The boom-angle sensor is located in the reeling drum.

Slew detection kit

The slew detection kit consists of two proximity switches and a junction box. The two proximity switches (fig. 1–20) monitor the turntable position and send an ON or OFF signal to the RCI computer. The RCI computer only detects three boom positions: over-front, over-side, or over-rear. The two proximity switches are wired into a junction box mounted to the left of the turntable assembly.

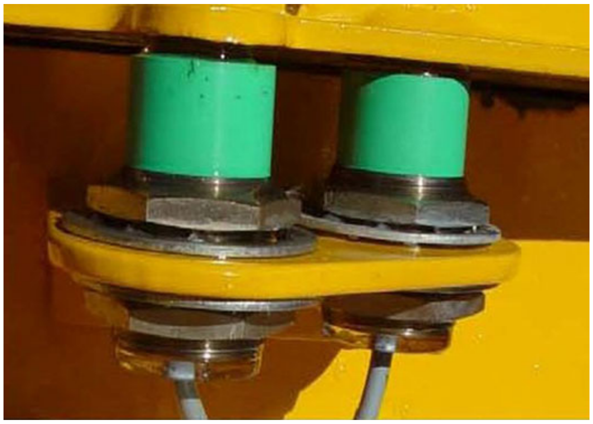


Figure 1–20. Proximity switches.

A2B system components

The Arva crane uses an A2B safety system incorporated into the RCI system. The purpose of this safety system is to prevent the operator from raising the hook-block into the boom fly tip or lowering the boom fly tip onto objects. A two-block condition is when the hook-block or other obstruction touches the fly-tip section of the crane. If there was no safety system, damage to the crane or personnel death could occur.

CAUTION: Keep in mind, the A2B system is only an aid to the operator. The operator ***must*** ensure crane motions occur smoothly and at a safe speed.

A2B microswitch

The A2B microswitch (fig. 1–21) is a spring-loaded, normally open, held-closed–type switch. The contacts of the switch are held closed by the A2B switch hoop. The A2B microswitch provides an electrical signal to a transmitter. The A2B microswitch is mounted on the tip of the fly section (bottom right). The A2B transmitter covered in the RCI system sends a signal to the display unit in the event a two-block situation occurs.

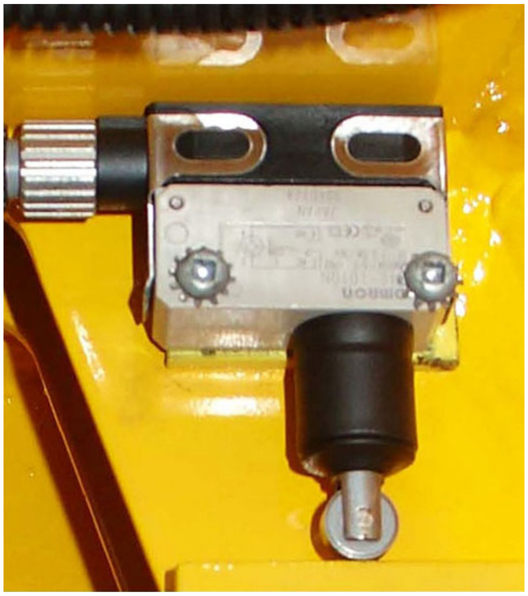


Figure 1–21. A2B microswitch.

Pilot cut-out solenoid valve

The pilot cut-out solenoid (fig. 1–22) is energized during normal operation. It *disables* the three following hydraulic functions when the solenoid is de-energized during a *two-block condition*:

1. Winch up.
2. Boom down.
3. Boom extend.

The pilot cut-out solenoid and hydraulic valve are mounted under the vehicle on the front right frame rail (inside).

Figure 1–22. Pilot cut-out solenoid valve.

Swing cut-out solenoid valves

The left and right swing cut-out solenoids (fig. 1–23) are energized during normal operation. They *disable* two hydraulic functions when *de-energized*: (1) swing left and (2) swing right.

The left and right swing cut-out solenoids and their hydraulic valves are mounted to the swing hydraulic motor, which is located to the right side of the crane.

Figure 1–23. Swing cut-out solenoid valves.

Overload/A2B relay

The overload/A2B relay controls 12-volt power to the pilot (the lower-pressure hydraulic circuit used to control main hydraulic circuit functions) and both swing cut-out solenoids. If there were to be a problem with this relay, the crane would lose the following five functions:

1. Winch up.
2. Swing left.
3. Swing right.
4. Boom down.
5. Boom extend.

The overload/A2B relay is located on the electrical fuse panel, under the outrigger control panel.

A2B system operation

When the operator accidentally lifts the hook-block too high, the hook-block touches the hoop (boom tip). The hoop lifts and the A2B microswitch contacts open. The A2B transmitter monitors the A2B microswitch and senses an open circuit. The A2B transmitter then sends a radio signal to the RCI computer, signaling a two-block condition. The RCI computer removes 12 volts from the overload/A2B relay. The overload/A2B relay then removes power from the pilot and swing cut-out solenoids. When the pilot and swing cut-out solenoids de-energize, five functions are disabled.

When the pilot cut-out solenoid de-energizes, the pilot cut-out hydraulic valve opens and vents three joystick pilot pressure lines to the hydraulic reservoir, which results in the winch raise, boom down, and boom-extend functions being disabled. When the swing cut-out solenoids (left hand and right hand) de-energize, the swing cut-out hydraulic valves (check-balls) block the fluid flow to the swing hydraulic motor and the swing-left and swing-right functions are disabled. The RCI display unit's A2B condition light appears and the audible alarm sounds, identifying a two-block condition has occurred.

The RCI display unit's BYPASS key is used to override an A2B condition and momentarily enables all A2B cut-out functions. While in an A2B condition, the operator must press the BYPASS key while performing the desired function.

WARNING: Misuse of override function can result in ***injury or death*** to personnel or damage to equipment. Extreme caution should be taken.

003. Crane maintenance

Before we cover isolating procedures, a word about safety is necessary. Never service the hydraulic system with the crane running unless it is absolutely necessary. These procedures are general in nature and may not apply to the crane at your base. Always consult the appropriate technical order (TO) for specific guidance.

WARNING: Before disconnecting any hydraulic lines, relieve all hydraulic pressure. Pressurized oil can cause severe personal injury or death.

Perform an operational inspection to check for leaks or defects which might result in an unsafe operation. The Arva crane is capable of lifting 7½ tons, so distortion or cracks on the main frame may be present. It is critical that the main frame be inspected. Crane lubrication is also critical for the mechanical system. Cleanliness is also important; keeping dirt out of the working parts will preserve the life of the crane. Dirt causes wear to metal joints, causing premature failure.

Swing bearing

The swing bearing is the *most* critical maintenance point of the crane. Stress loads are concentrated at the center line of rotation. Inspect the swing-bearing mounting bolts for looseness. There are 30 high-strength (grade 8) bolts mounted in a circular pattern that hold the turntable to the swing bearing. The swing-bearing mounting bolts should be torqued every 500 hours of operation or semiannually.

Pay special attention to the following when inspecting the swing-bearing mounting bolts:

- Verify that periodic maintenance of the turntable bearing bolts has been performed. Periodic maintenance is critical to ensure safe operation of the crane.
- Check the bolt hole for any signs of lubrication that may cause a variation from dry torque values.
- Verify high-strength bolts are replaced with bolts of the same classification.

Remember to follow the procedures and specifications outlined in the technical order, paying particular attention to the safety precautions.

Upper structure

Inspect the upper boom for twists and its welds for cracks. As mentioned earlier, the base of the boom is mounted to the turntable by one large pin; verify it is secured and is thoroughly lubricated.

Also mentioned earlier, the Arva crane uses special pads: boom side pads and boom slide pads. Periodically inspect the boom wear pads for wear, damage, and proper lubrication.

Load-hoist cable

The load-hoist cable should be inspected for proper cable reeving and sufficient lubrication. The cable was thoroughly saturated with lubricant when manufactured. It has a fiber core and its purpose is to retain lubricant. Lubrication is vital in the protection of the cable and in reducing its wear. Refer to the applicable TO for methods of lubricating the load-hoist cable.

Adjusting the load-hoist cable

When adjusting the length of the load-hoist cable, ensure the cable is secured to a socket on either the hook-block or to the fly-tip section depending on the crane configuration. It is very important that the cable is secured to the socket correctly as shown in figure 1–24. The wedge of the socket should firmly seated. At least 6 in. of cable should be secured to the free end of the wire rope to act as a stop. Additionally, the clamp that secures the free end of the wire rope should not crush the loaded side of the cable.

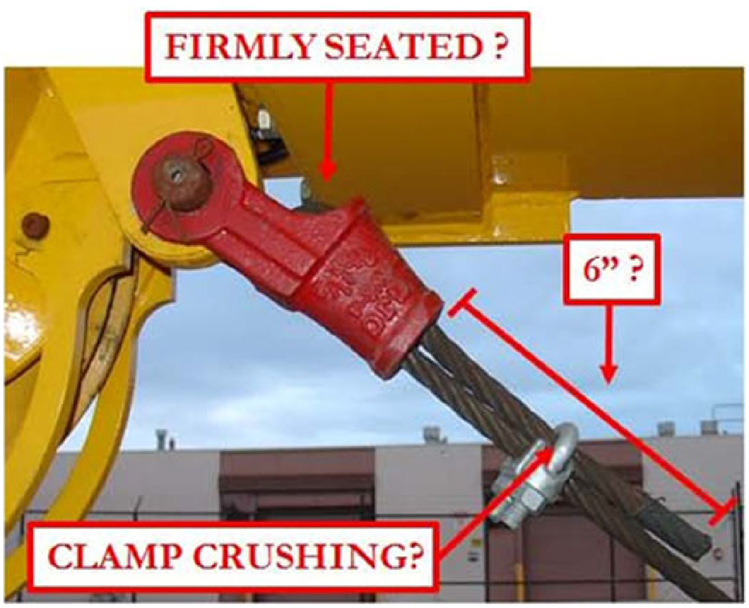


Figure 1–24. Securing the load-hoist cable.

The load-hoist cable *must* be replaced if crushed, kinked, or bird caged (fig. 1–25).

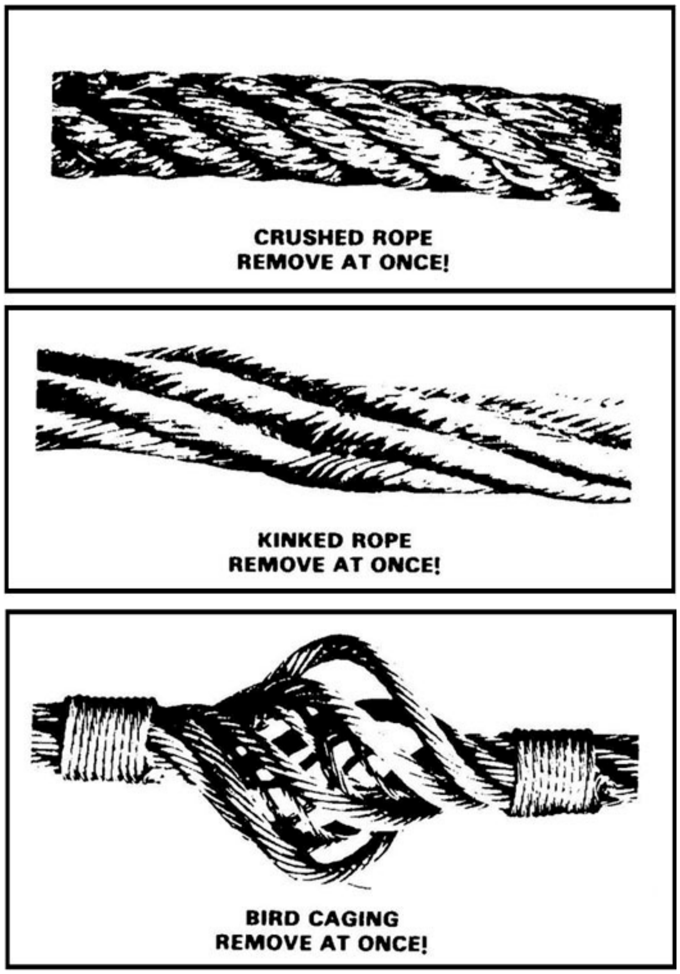


Figure 1–25. Damaged load hoist cable.

Air Force Instruction (AFI) 24–302, *Vehicle Management*, specifies that the using organization is to maintain and install the load-hoist cable. Verify that the load-hoist cable is properly adjusted.

WARNING: Wire cables, by their construction, have the potential for producing piercing points along their length. Wires break and stick out of the cable. Never handle the load-hoist cable without wearing leather gloves.

Diagnosing electrical malfunctions

Some of the most common electrical problems you may encounter are the result of corrosion in the collector ring (refer back to fig. 1–14). This occurs if the upper structure has not been rotated for some time. Repair, in this case, is simply a matter of several complete rotations of the upper structure.

The cleaning action of the brushes should clean the slip-ring surfaces. If this does not correct the problem, it may be necessary to inspect the spring-loaded contact brushes. Make sure the brushes are centered in the bands and free of foreign material. If it becomes necessary to replace the brushes, follow the technical order procedures. Also, make sure the set screws on the collector-ring frame are tight. Otherwise, the wiring harness may wrap up as the upper structure rotates.

Diagnosing computer system malfunctions

The RCI system is relatively trouble-free; however, some *common* troubleshooting problems are listed in the following table.

Common RCI System Problems	
Component	**Action You Take**
RCI system display unit fails to turn ON	1. Check circuit breaker (CB) 145. 2. Inspect display-unit fuse. 3. Check supply voltage. 4. Check for proper ground connection.
RCI system display unit fails to function properly	Reset the system (simultaneously press TARE and DISPLAY buttons). **NOTE:** If the fault or problem persists, remove power supply from the RCI system for a few seconds, and then power it back again.
All A2B condition cut-out functions disabled	1. Verify that the hook-block is *not* lifting the A2B switch hoop. 2. The preset limit in the RCI limit may have been met (reset limit). 3. The overload/A2B relay may have malfunctioned. 4. Inspect CB 142 for proper operation.
Only swing left or right function disabled	1. Check the supply voltage to the swing cut-out solenoids. 2. Check proper ground connection to the swing cut-out solenoids.
Only winch raise, boom down/extend functions disabled	1. Check the supply voltage to the pilot cut-out solenoids. 2. Check proper ground connection to the pilot cut-out solenoids.

Always consult the applicable service manual or technical order when diagnosing the RCI system. Improper testing could damage expensive electrical components and affect the vehicle's mission-capable rate.

Troubleshooting hydraulic malfunctions

A thorough visual inspection is a good starting point to analyze a hydraulic malfunction. Make sure the fluids are the correct type and at the proper level. Perform an operational check to determine the exact status of each system and to verify the problem. Before troubleshooting hydraulic malfunctions, study the manufacturer's schematic. This will help clarify specific circuits and components during your troubleshooting.

As previously stated, safety is important especially when working around hydraulic system components. Always follow the step-by-step procedures in the appropriate technical order.

Some *common* hydraulic system problems are listed in the following table.

Common Hydraulic System Problems	
Component	**Problem Area**
All boom functions inoperable	Main relief valve misadjusted or malfunctioning. No pump output.
Erratic motor or cylinder operation	Relief valve pressure set too low. Aerated fluid.
Boom swing inoperable	Motor leaking internally. Hydraulic swivel leaking internally. Mechanical fault in swing-gear reducer. Spool valve damaged. **NOTE:** There is no hold valve to lock the swing motor.

Common Hydraulic System Problems	
Component	**Problem Area**
Boom hoist inoperative	Counterbalance valve inoperative or misadjusted. Hydraulic swivel leaking internally.
Boom drifts down	Counterbalance valve leaking internally. Hoist cylinder leaking internally.
Winch will not develop maximum line pull	Main relief valve set too low. Winch motor excessively worn or damaged. Pump worn or damaged. Hydraulic swivel leaking internally.
Load will not raise or lower	Winch relief valve misadjusted or malfunctioning. Pump defective.
Load will raise but will not lower	Winch hold valve is sticking. Load-hoist brake is not releasing.

For specific component replacement, refer to the applicable technical order. After any component replacement, perform an operational check to verify the problem is corrected.

Adjusting the hydraulic system

There are only a few adjustments that can be made to the crane's hydraulic system. For example, during your troubleshooting, the results of a pressure test may indicate that a relief or control valve needs an adjustment. Relief valves are typically adjusted by rotating an adjusting screw. The main control valve assembly, on the other hand, can be adjusted by using a wrench and turning a hex head. However, these adjustments should only be performed by a qualified technician.

Load test

AFI 91–203, *Air Force Consolidated Occupational Safety Instruction*, outlines the requirements for load-testing lifting devices to include the Arva crane. Prior to being returned to service, extensively repaired or modified cranes will be load-tested at not less than 100 percent or no more than 110 percent of rated capacity by a qualified technician.

Examples of repairs requiring load-testing would be if the hoist cable or lift cylinder were replaced. Any time a component responsible for lifting the load is rebuilt or replaced, a load test must be done. Upon completion of the test, the load-test date will be stenciled on the lower boom assembly in accordance with TO 36–1–191, *Technical and Managerial Reference for Motor Vehicle Maintenance*. For nuclear-certified hydraulic mobile cranes, perform an annual load-test at not less than 100 percent and no more than 110 percent of the rated capacity in conjunction with the annual inspection. Test loads must not exceed 110 percent of the rated capacity at any selected working radius as determined by the crane's load chart.

It is the using organization's responsibility to have its crane load-tested by a qualified technician and to obtain a certification. The using organization *must* then provide a copy of the certification to Vehicle Management to be placed in the vehicle's historical record. Vehicle Management is responsible for ensuring the using organization accomplishes load-testing as required, stenciling the boom with the certification date, and ensuring the test records are filed in the vehicle record and at the using organization.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

001. Carrier assembly

1. The Arva crane's dimensions were designed for what specific purpose?

2. What types of fuel can be used in the Arva crane?

3. What may be viewed on the digital engine monitor?

4. The digital engine monitor communicates with the ECM using what?

5. The Arva crane transmission has how many forward and reverse gears?

6. What drive ranges does the Arva crane drive axle range provide?

7. What type of differentials does the Arva crane use?

8. What type of suspension does the Arva crane have?

9. What are the axle locks used for?

10. Which hydraulic pump provides fluid for the brake system?

11. What brake system component provides the pressure for brake operation?

12. List and describe the three modes of steering used on the crane.

002. Crane functions

1. What type of hydraulic pump does the Arva crane use?

2. What is used to control boom hydraulic functions?

3. How are the main control valve's spool valves actuated?

4. What component allows 360° movement of the boom without damage to hydraulic lines or hoses?

5. What type of hydraulic cylinders is used to actuate the outriggers?

6. What tells the operator the crane is level?

7. What component allows the boom to rotate 360° in either direction?

8. When is a worm-gear drive self-locking?

9. The bull gear is part of what component?

10. What component allows the upper-structure wiring to rotate 360° without twisting or breaking?

11. How is the boom extended?

12. What is the purpose of the load-hoist brake?

13. Define reeving.

14. Under what conditions does the limit warning light blink?

15. What RCI sensor sends a signal proportional to the load being lifted by the load hoist?

16. What RCI sensors are located in the reeling drum?

17. What is the purpose of the A2B system?

18. The pilot cut-out solenoid disables what hydraulic functions?

19. Where are the swing cut-out solenoids located?

20. The overload/A2B relay affects what five crane functions?

003. Crane maintenance

1. Before working on a hydraulic system, what is the first thing you do and why?

2. What is considered the most critical maintenance point of the Arva crane?

3. What special attention items must be checked when inspecting the swing-bearing bolts?

4. What should be inspected on the load-hoist cable?

5. How much cable should be secured to the free end of the wire rope before tightening the clamp?

6. What types of damage will require the load-hoist cable to be replaced?

7. If the collector ring becomes corroded, how is the surface cleaned?

8. What should you check first if all A2B condition cut-out functions are disabled?

9. What hydraulic system problems can cause all boom functions to stop operating?

10. What type of problem would result from a sticking winch hold valve?

11. When is a load-test required to be performed on a crane?

1–2. Grader

The grader, sometimes referred to as a motorized scraper or road grader, is a very versatile piece of equipment. It is used to level construction sites, grade inclines, smooth roads, plow snow either with the blade or with a V-plow, or tear up soil (with a ripper/scarifier) so other equipment can be used.

004. Grader fundamentals

The John Deere grader (fig. 1–26) is powered by a six-cylinder, four-stroke, turbocharged diesel engine. It supplies the power to move the vehicle and operate the hydraulic pump.

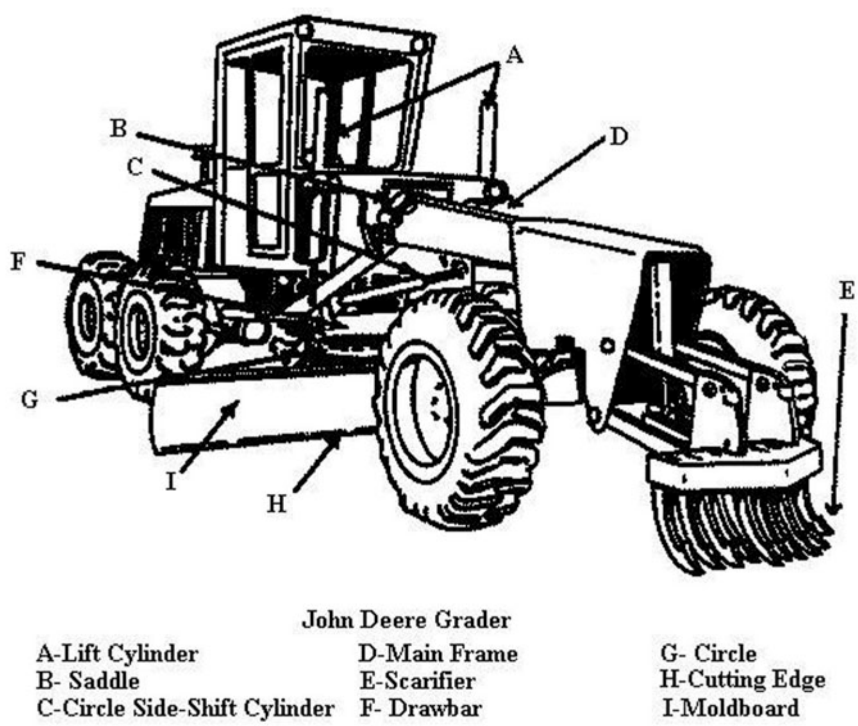


Figure 1–26. Grader.

The major components of the drivetrain (powertrain) include the engine, transfer drive, power shift transmission/differential, and tandem drive.

Engine

The cylinder block is a one-piece design that utilizes wet sleeves in the cylinder bores. The engine's valve mechanism is overhead design; that is, the camshaft is located in the block and pushrods and lifters are used to open the valves. The camshaft is powered from the crankshaft by a set of timing gears (no chain). Additionally, the crankshaft timing gear also drives the fuel injection pump gear and the oil pump gear. There are also two idler gears (fig. 1–27) that complete the timing gear train. Many of the engine subsystems operate very similar to ones you learned about so far during your maintenance training.

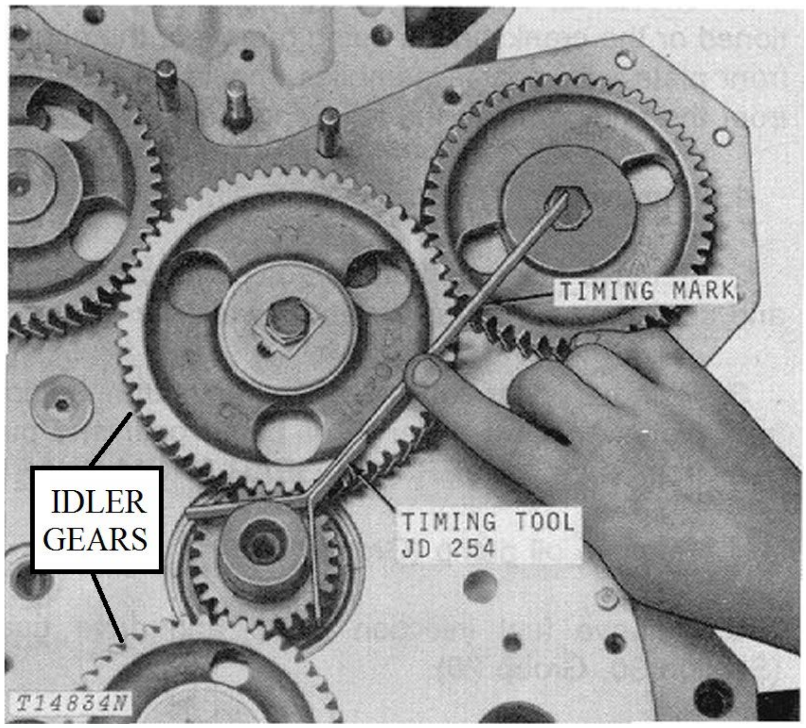


Figure 1–27. Engine timing gears.

Cooling system

The grader has a tube-and-fin vertical-flow radiator. The pressure cap on the radiator is rated at 6–7 pounds per square inch (psi). If the pressure in the cooling system exceeds the pressure cap's spring, the pressure valve of the cap will rise and allow coolant to vent out to the ground through the overflow hose (no coolant recovery tank). The centrifugal-type water pump is bolted directly to the engine block and is driven by the fan belt. A bypass line from the water pump allows the circulation of coolant through the engine when the thermostat is closed. The thermostat is mounted in its own water manifold that is attached to the engine block and head.

Fuel system

The fuel system is located at the very rear of the grader slightly above the transfer drive. Two fuel lines (supply and return) connect the fuel tank to the fuel system. The supply line of some models contains a small filter screen, which seldom needs cleaning.

Transfer drive

Refer to figure 1–28 as we discuss the transfer drive and figure 1–29 for overall drivetrain information. Located at the rear of the grader, the transfer drive receives power from the engine and transmits it to the transmission.

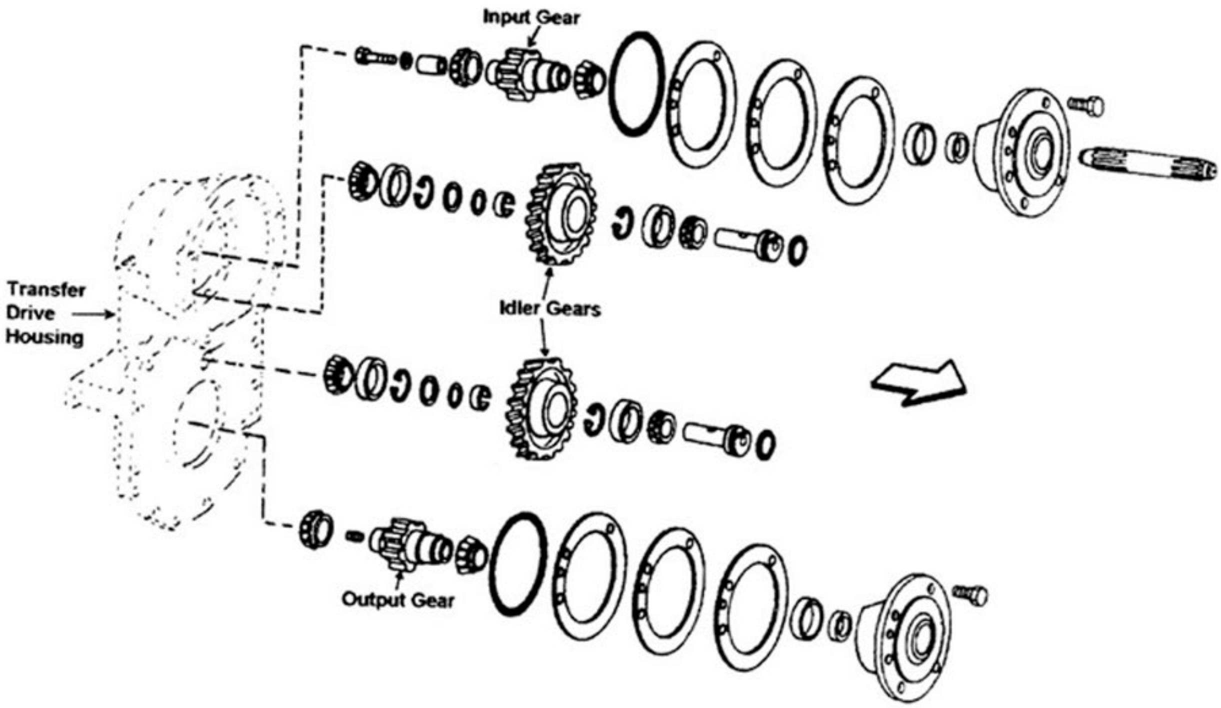


Figure 1–28. Exploded view of transfer drive major components.

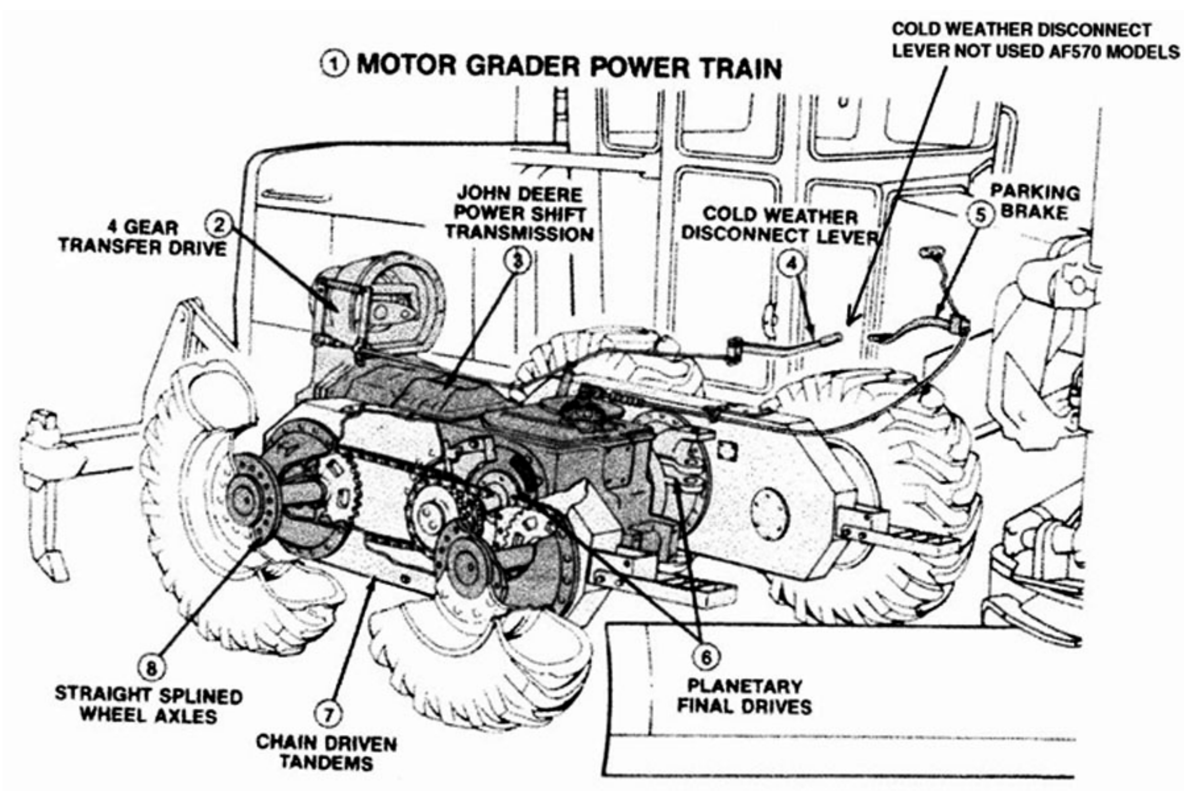


Figure 1–29. Grader drivetrain components.

Gears

Four main gears in the transfer drive (fig. 1–28) transmit the engine's power to the transmission. The input gear of the transfer drive is driven by the engine crankshaft. The input gear then drives the two idler gears, which in turn drives the output gear. The output gear drives the transmission's input shaft.

Keep in mind that all four gears inside the transfer drive are always meshed together, and they do not provide any gear reduction. The transfer drive output gear rotates at the same speed as the input gear (1:1 ratio). As a result, the engine crankshaft and the transmission input shaft rotate at the same speed.

Lubrication

The transfer drive assembly is lubricated by transmission oil. A steel oil line connects the transmission to the transfer drive's upper housing and splash-lubricates the components in the transfer drive. An orifice provides a flow rate of 5 gpm to the transfer drive. Oil returns to the transmission sump by gravity through a large, flexible drain line connecting the lower transfer drive housing and transmission sump together.

Power-shift transmission

In an earlier volume, you learned about automatic transmissions and the workings of their internal components—clutches, bands, and planetary gear sets. The power-shift transmission operates on some of these same principles, yet it is not an automatic transmission. It does *not* have a torque converter or create a fluid coupling. It is located under the engine. When the grader is placed in gear, there is a direct mechanical drive through the transmission and the vehicle keeps moving until it is shifted into neutral or the inching pedal is depressed. This is unlike a vehicle that is equipped with an automatic transmission that has the ability to sit stationary while in gear because of the torque converter.

Forward and reverse speeds

The power-shift transmission provides eight forward and four reverse speeds. Speed ranges and direction are manually controlled by the two selector levers located in the operator compartment. One of the levers controls direction (forward/reverse), and the other one controls the eight speed ranges (both control levers have a neutral position). The transmission can be shifted into different speeds or a change of direction can be made while the grader is moving. However, the grader cannot be shifted into reverse if the speed lever is in 5th through 8th speed range.

On-the-go shifting

Shifting "on-the-go" and under load is accomplished by two compound planetary gear sets (a compound unit is two planetaries combined). The planetary gear sets are controlled by three clutches and four brakes (holding clutches), which are applied hydraulically by pressurized oil from the transmission pump. The clutches, when applied, drive a certain planetary member.

The brakes, when applied, will hold a planetary member. The transmission control system directs and releases oil pressure to and from the appropriate brakes and clutches depending on the position of the transmission controls or the inching pedal. The transmission control system is made up of a series of valves and valve bodies in addition to the pump.

Three basic subassemblies

The power-shift transmission can be divided into three main subassemblies: main clutch housing, planetary pack, and differential. First, we will discuss the main clutch housing, then move on to the other two subassemblies.

Main clutch housing and main clutch pack

The main clutch housing (fig. 1–30) bolts directly to the transmission main case and also to the transfer drive. This housing contains the main clutch pack (fig. 1–31).

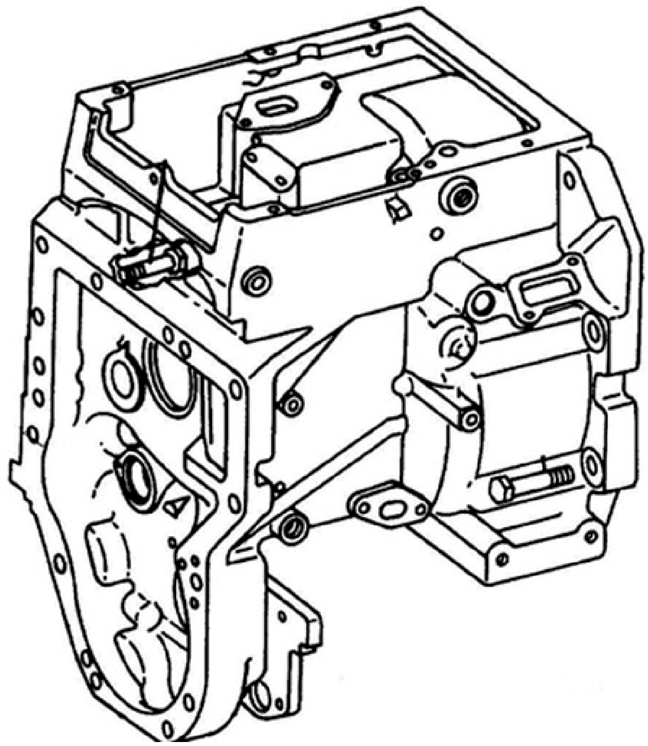


Figure 1–30. Main clutch housing.

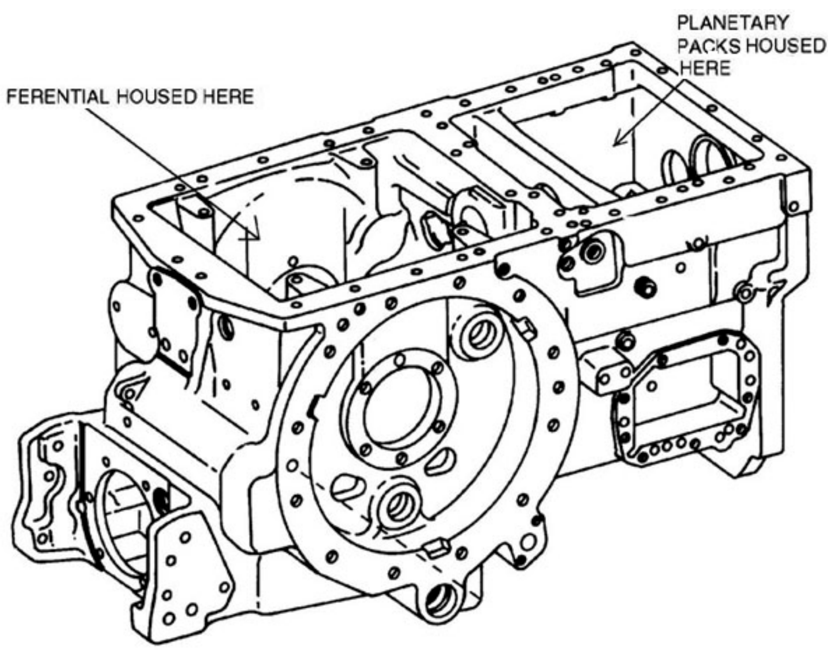


Figure 1–31. Main clutch pack.

Engine power (torque) is transmitted to the clutch pack from the transfer drive through an input shaft. The main clutch pack contains two hydraulically operated clutches (C1 and C2). The low-range clutch is C1 and the high-range clutch is C2. These two clutches operate independently of each other. Either or both may be engaged or disengaged at any time. Notice that the gear-type transmission oil pump is located in the front section of the clutch pack.

Clutch engaged

When the clutch is engaged, transmission oil under pressure enters the transmission control system through an oil passage in the clutch drum. The oil enters the cavity behind the clutch piston compressing the clutch disks and clutch plates against the pressure plate. Since the clutch drum is rotating at engine speed, the clutch plates also rotate at engine speed because they are mechanically connected (tanged) to the clutch drum. The clutch disks will also rotate at engine speed if they are compressed (when the clutch is applied) against the clutch plates. The clutch disks are mechanically connected (splined) to the clutch's output shaft. This arrangement causes the clutch's output shaft to rotate at engine speed when the clutch is applied.

Output shaft

Each clutch has its own output shaft. When C1 or C2 is engaged, its output shaft rotates at engine speed. Each of the output shafts is splined to one of the sun gears in the planetary pack. Therefore, when C1 is engaged, one of the sun gears is driven. When C2 is engaged, another sun gear is driven. Neutral occurs when both C1 and C2 are not engaged. You will recall from your earlier studies that different gear ratios can be obtained by holding one of the planetary members while another is being driven. The same planetary gear principles apply to this transmission as well.

Planetary pack

The planetary pack (fig. 1–32) is located in its own section of the transmission main case.

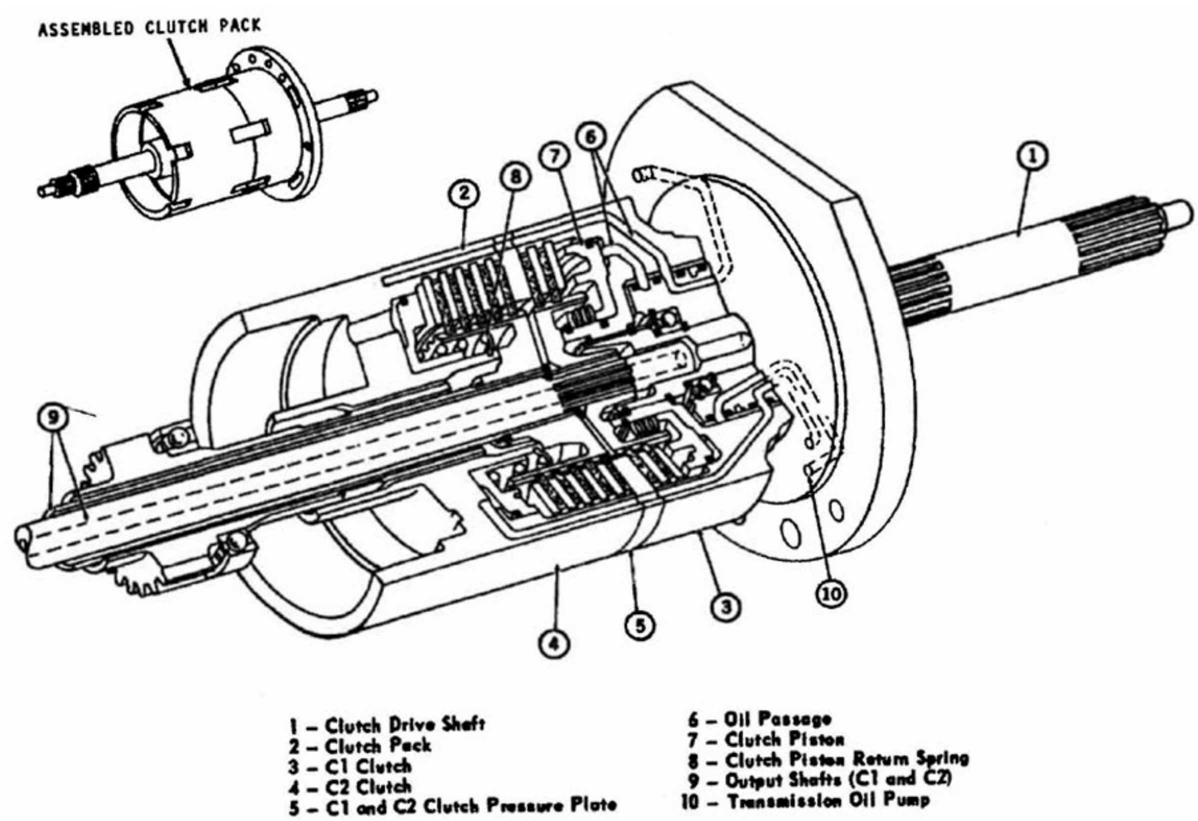


Figure 1–32. Transmission main case.

The complete planetary pack (fig. 1–33) contains four planetary units combined into two sets of each, or in other words, two compound gear sets.

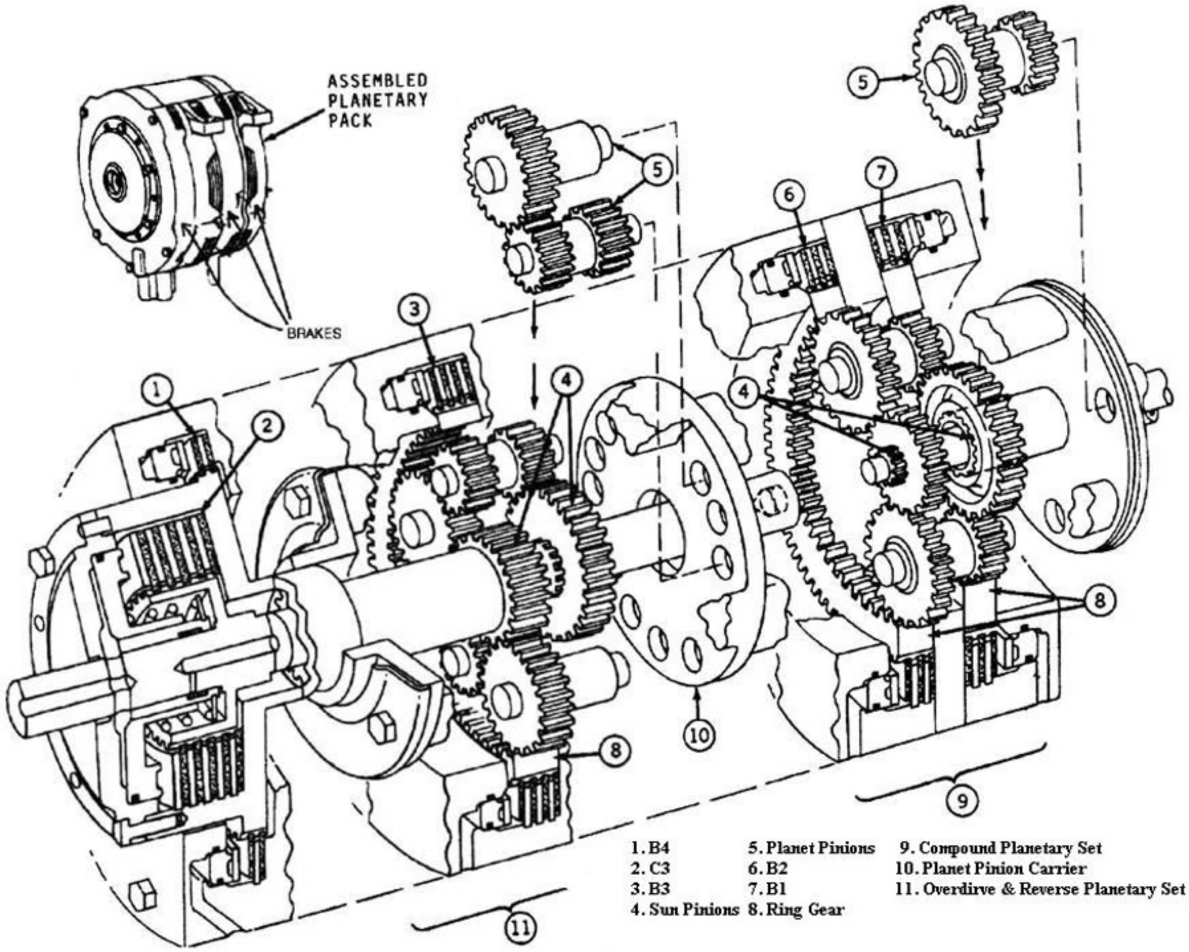


Figure 1–33. Planetary pack.

Both compound units use the same single common planet carrier. The single planet carrier links both compound units together "in series" so to speak. This means that the output, or torque, of the first compound unit is used as the input driving force for the second compound unit. Also notice that different size sun gears and planetary pinions are used among the gear sets. This causes different gear ratios between the four planetary units. Keep in mind that eight speeds are available from this transmission because of how the planetary system is constructed. That is, there are four single planetary units, the gear sizes are different among the planetary units, and the compound planetaries are linked together.

Four brakes

The planetary pack contains four disc-type brakes (fig. 1–33) that hold or lock planetary members. These brakes are sometimes referred to as holding clutches in other manufacturer's transmissions. Other transmissions use bands as a way to hold planetary members to keep them from turning. However, this particular transmission is designed to use only "brakes" (no bands) as a means to hold certain planetary members.

Notice that these disc-type brakes are constructed of a series of steel plates and friction plates backed by a hydraulic piston in their own housings. When hydraulic pressure is applied to the piston, the plates are squeezed or sandwiched together, causing them to hold whichever planetary member they control. The four brakes are designated as B1, B2, B3, and B4.

Brakes B1, B2, and B3 each hold one of the ring gears in order to prevent them from turning. Brake B4 locks one of the sun gears to prevent it from turning. The transmission hydraulic control system supplies fluid pressure to apply the brakes as needed, depending on which gear range and speed is selected by the grader operator.

C3 driving clutch

The other major component in the planetary pack is a driving clutch known as C3 (refer back to fig. 1–31). The function of C3 is to lock together the sun gears of the overdrive and reverse planetary unit. This action forces both of the sun gears to rotate together. When the two sun gears rotate together, a direct drive condition is achieved in that planetary. Fluid pressure that is applied to C3 is controlled by the transmission hydraulic control system. C3 operates independently of C1 and C2.

Power flow through the main clutch pack and the planetary pack

Clutches and brakes must be engaged to obtain various transmission speeds. As mentioned before, the transmission hydraulic control system controls the actual engagement of clutches and brakes. Here are two examples of how power is transferred through the transmission: first-speed forward and third-speed reverse.

First-speed forward

When the transmission controls are placed in the first-speed forward position, the transmission hydraulic control system engages C1 in the clutch pack and B1 and C3 in the planetary pack (fig. 1–34). The flow of engine power is from transfer-drive to C1 in the clutch pack. The C1 clutch shaft then transmits power to the C1 sun gear in the planetary pack. Since B1 restrains one ring gear from turning, the planet pinions "walk around" the ring gear, forcing the pinion carrier to rotate in the same direction as the sun pinion, but at a slower rate of speed. The planet pinion carrier transmits power to the overdrive and reverse planetary set. When C3 is engaged, both sun gears of the overdrive and reverse planetary set are locked together. This causes a direct drive condition and power flow goes straight through the overdrive and reverse planetary set.

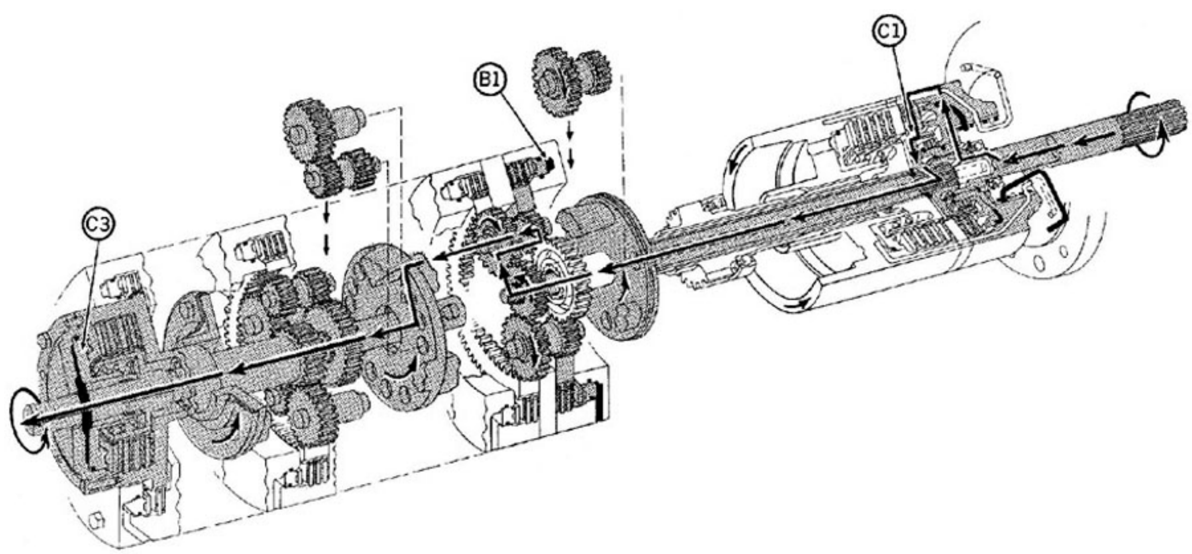


Figure 1–34. Power flow during first-speed forward.

Third-speed reverse

When the transmission controls are placed in the third-speed reverse position, the hydraulic transmission control system engages C2 in the clutch pack and B1 and B3 in the planetary pack (fig. 1–35). The flow of engine power is from the transfer drive to C2 in the clutch pack. The C2 clutch shaft transmits power at engine speed to the C2 sun pinion in the planetary pack. Since B1 restrains one ring gear from turning, the planet pinions "walk around" the ring gear, forcing the pinion carrier to rotate in the same direction as the sun pinion, but at a slower rate of speed. The planet pinion carrier transmits power to the overdrive and reverse planetary set. When B3 is engaged, one ring gear is restrained from turning. As the pinion carrier rotates, the planet pinions, in mesh with the ring gear, are forced to rotate on their axis, driving the inner planet pinions, which in turn force the sun gear to rotate in the opposite direction from the pinion carrier.

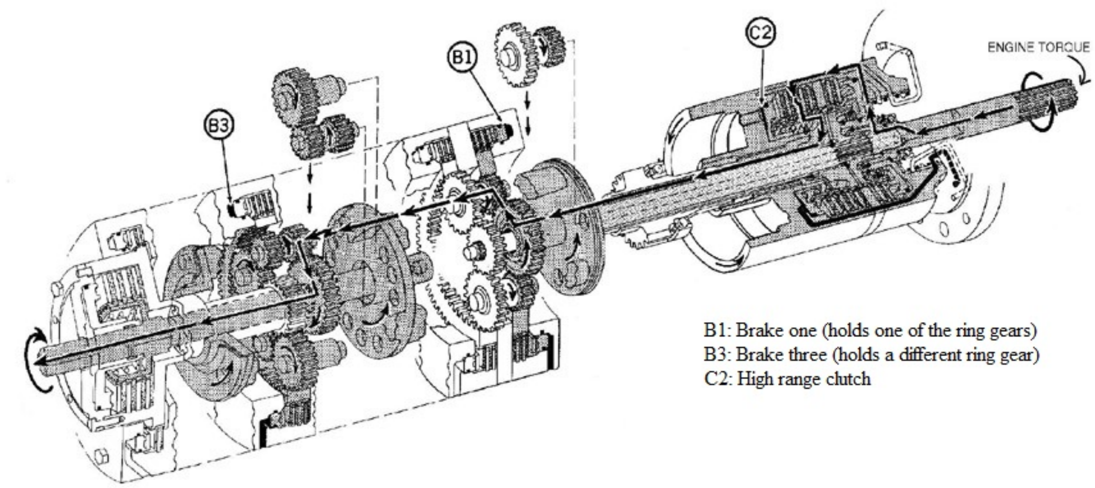


Figure 1–35. Power flow during third-speed reverse.

Differential

After the engine power (torque) is transmitted to the transmission, it is then transmitted to the differential (fig. 1–31). The differential is mounted in its own section in the forward portion of the transmission case. You learned about differential components in an earlier volume. There is, however, one unique feature about this differential, and that is the differential-lock mechanism.

The function of the differential lock is to lock the driving wheels together in order to provide good traction while on slippery surfaces, such as heavy mud. The right or left wheels can slip (just like a conventional differential) when the differential lock is not engaged while the grader is driving on an unstable surface. However, when the differential lock is engaged, all rear wheels turn together at the same speed because the differential-lock mechanism mechanically couples the driving axles. It should be pointed out that the differential lock is designed for use only when the grader is moving straight ahead. It should *not* be used when making turns or damage to the differential can occur. The differential lock is actuated hydraulically by the operator with a foot pedal in the cab.

The grader is equipped with a mechanical "tow disconnect" mechanism that is used to disengage the transmission from the differential for towing purposes. The mechanism is controlled by a hand lever that is located on the right side of the transmission case. Moving the lever to the "tow" position shifts a collar on the reduction shaft to disconnect the reduction gear from the shaft. The reduction shaft is splined where it fits into the planetary pack of the transmission. You can think of the reduction shaft as the transmission's output shaft. After all, the reduction shaft and gear are what drives the differential ring and pinion.

Tandem casings

From the transmission and differential assembly, we go to the tandem casings (fig. 1–36). They are part of the final drive system. These structures house the sprockets and chains used to drive the four rear wheels of the grader. Each rear wheel has its own axle on which a large sprocket is mounted. Each casing has a shaft leading from the differential that provides the power to the casing. This axle from the differential also has a sprocket mounted on it.

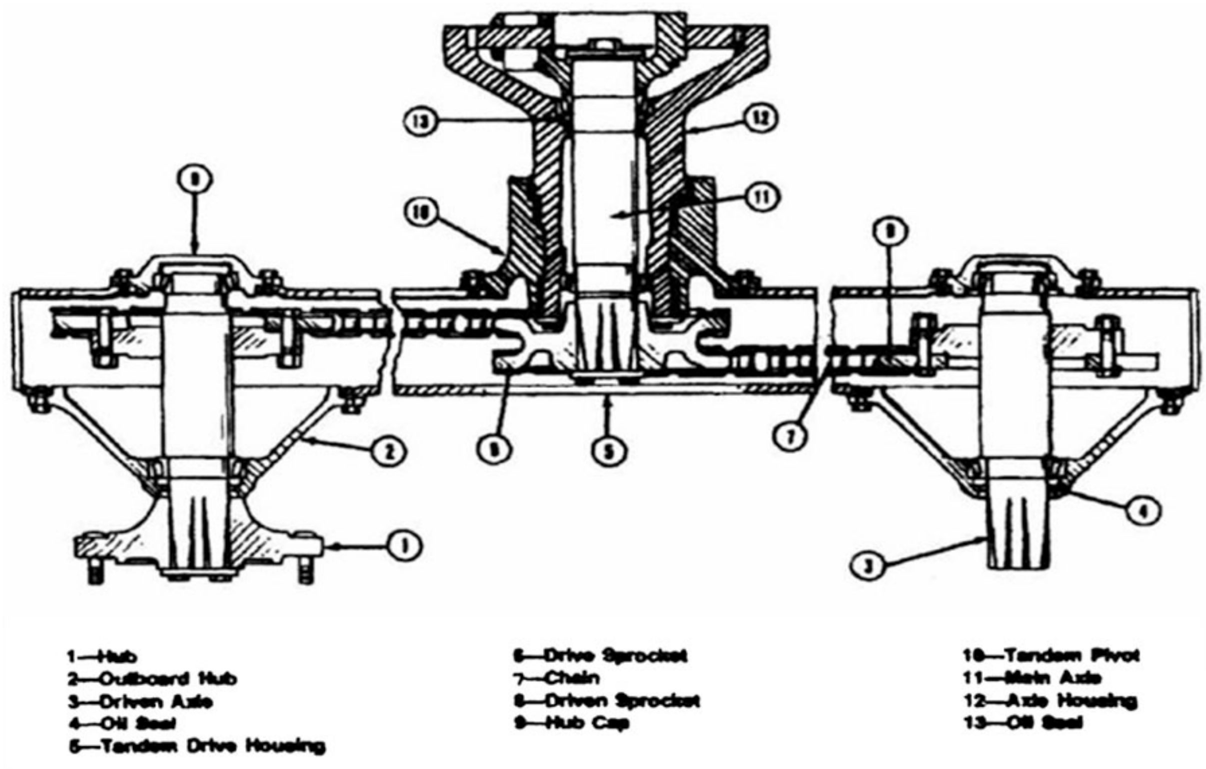


Figure 1–36. Cross section of tandem casing.

A chain, similar to an oversized bicycle chain, connects the three sprockets in each casing together. Oil in the casing splashes on the components during operation to lubricate the chain and sprockets. There is no adjustment for wear on the chain and sprocket assemblies. When wear exceeds the operational limits of the equipment, all sprockets and chains must be replaced.

Transmission hydraulic control system

The transmission hydraulic control system generates, directs, and controls the pressure and flow of oil in the transmission. Transmission oil lubricates and cools the transmission parts and applies the clutches and brakes that we have been discussed thus far. The major components of the system include the transmission oil pump, oil pressure regulating valve, accumulator, transmission control valve, and inching pedal valve. However, in the table below we'll only discuss the oil pump, control valve, and inching pedal valve.

Transmission Hydraulic Control System Major Components	
Component	**Description**
Transmission oil pump	It is located in the main clutch housing and is driven by the transfer drive output shaft. The gear-type pump is able to deliver 15 gpm at 1,900 rpm with 170–180 psi. In addition to supplying pressure for the transmission, the pump also supplies oil for the main hydraulic pump of the grader.
Transmission control valve	It consists of the transmission control valve housing and the shift valve housing, which are assembled together and located on the left side of the transmission case. The control valve is very similar to the valve body of an automatic transmission. There are several spool valves that move in and out of their bores to control oil flow and direct it to the appropriate brakes and clutches.
Inching pedal valve	It is provided for emergency stops (E-Stop) and for inching the vehicle in close quarters. The valve is bolted to the main clutch housing and is actuated by a mechanical cable, which is connected to the foot pedal on the left side of the floorboard in the operator compartment. This valve controls the oil pressure to certain clutches.

Electrical system

The electrical system is a 12-volt negative ground system. There are two types of battery installations: parallel and series. One system uses two 12-volt batteries connected in parallel; the other has two 6-volt batteries connected in series. Both types use a 55-ampere alternator and a heavy-duty starter. Lighting and warning devices consist of: headlights, tail lights, work lights, dash lights, beacon light, and a back-up beeper. Other accessories include the horn, wiper motor, and heater fan.

Hydraulic system

The grader's hydraulic system (fig. 1–37) is a closed-center, constant pressure system. "Closed center" means that oil does not flow through the operating valves while they are in the neutral position. "Constant pressure" means that as long as the engine is running, a standby oil pressure of 2,300 to 2,400 psi is maintained in certain sections of the system. In the following lessons you will learn the fundamentals of several of the grader's many hydraulic components.

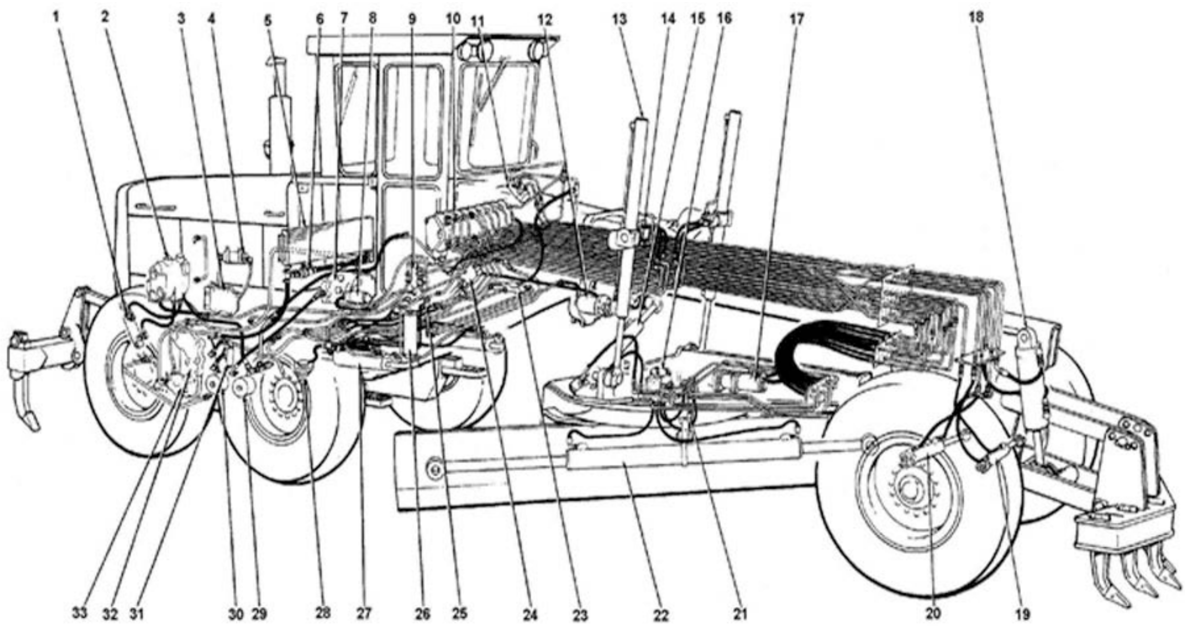


Figure 1–37. Hydraulic system

Reservoir and transmission pump

The transmission sump also serves as the hydraulic system reservoir. The gear-type transmission oil pump supplies the main hydraulic pump with fluid. In fact, think of the transmission oil pump as a "*transfer* pump" or "*primer* pump" for the hydraulic system.

Main pump

An eight-cylinder, variable displacement, radial piston pump, is mounted in front of the radiator and driven by the engine crankshaft through a small drive shaft. The pump (fig. 1–38) (stroke control valve not shown) operates on the rotating cam principle. Eight pistons are located in their bores within the fixed housing. The pump shaft has an eccentric cam, which rotates in the fixed housing. As the pump shaft turns, its eccentric contacts the pistons and forces them outward in their bores to pump oil. The pistons then move inward by spring force, causing intake oil to be drawn into the bore, ready for the next pumping stroke.

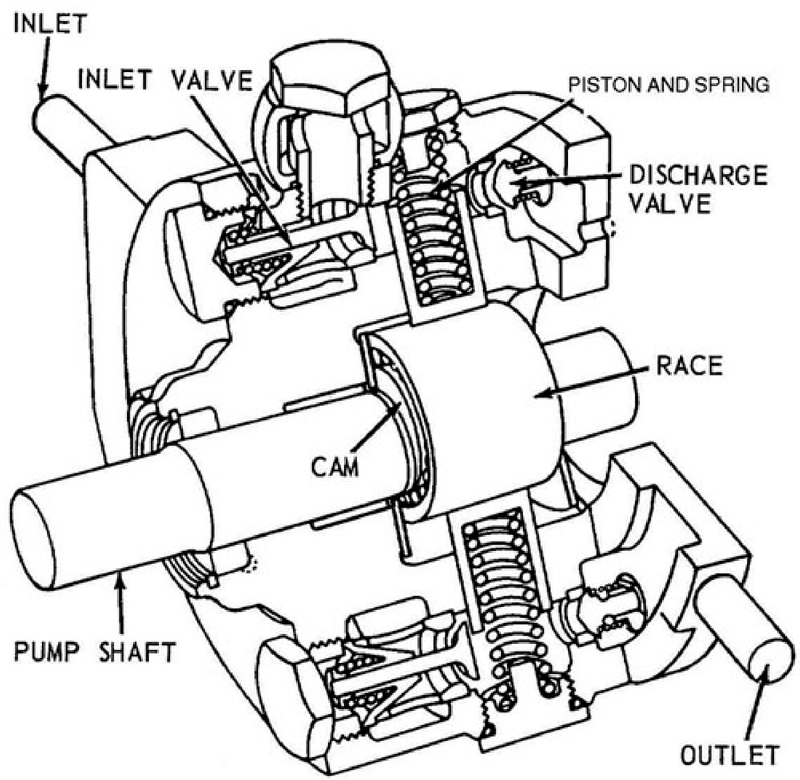


Figure 1–38. Cutaway of hydraulic pump.

Stroke control valve

A stroke control valve is fastened to the pump. This control valve allows the main pump to have variable displacement capabilities; otherwise, the pump would be a fixed displacement pump. The stroke control valve controls oil output by holding the pistons away from the driving cam, thus the length of the piston stroke is controlled. This is done automatically, using hydraulics.

The stroke control valve admits oil into the crankcase at the center of the pump. This oil is under sufficient pressure so that it holds the pistons away from the cam. This causes the pump to reduce its output even though the drive shaft keeps turning. When there is a demand elsewhere in the hydraulic system, the control valve releases the oil pressure from the pump's crankcase, allowing a longer piston stroke to pump more oil.

Filters

The grader has two hydraulic filters: one for the transmission and one for the hydraulic system. Both are located side-by-side on the right side of the transmission case.

Valve stack

Oil flow to operate most of the hydraulic cylinders and motors of the grader is controlled by the valve stack (fig. 1–39). Located behind the instrument panel, it is made up of nine main (ten with the optional scarifier) function control valves assembled into one unit. Each control valve is responsible for providing pressure to operate a specific hydraulic function. These double-acting spool-type control valves are actuated by the hand control levers in the operator compartment.

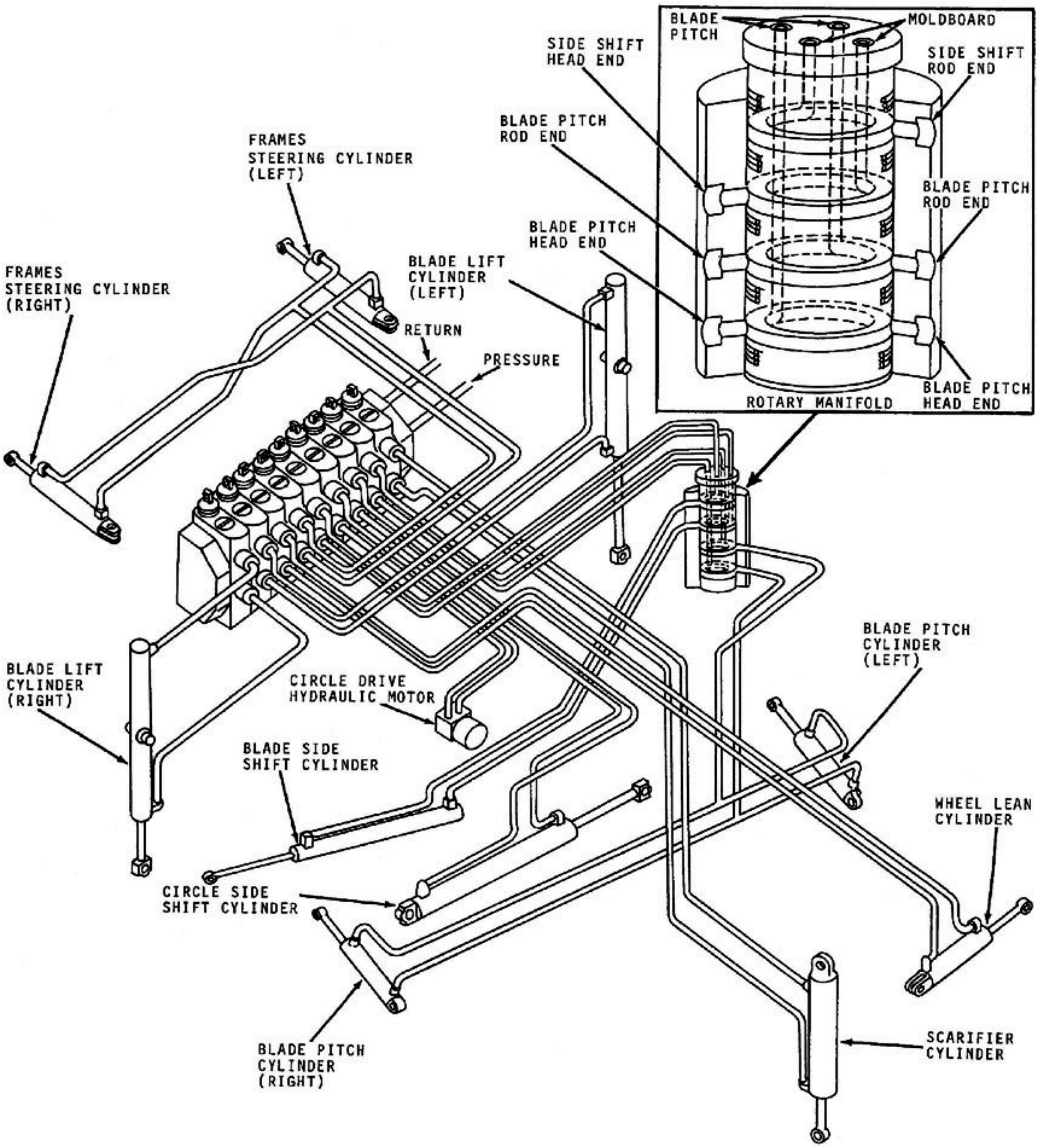


Figure 1–39. Hydraulic valve stack and rotary manifold (Inset) diagram.

The valve stack controls the following functions:

- Circle drive rotation (hydraulic motor).
- Blade lift (two double-acting cylinders).
- Wheel lean (one double-acting cylinder).
- Blade pitch (two double-acting cylinders).
- Blade side shift (one double-acting cylinder).
- Frame steering (two double-acting cylinders).

- Circle side shift (one double-acting cylinder).
- Optional scarifier or snowplow lift (one double-acting cylinder).

Rotary manifold

The rotary manifold (fig. 1–39 [Inset]) prevents the blade pitch and blade side-shift cylinder hydraulic lines from twisting as the circle drive is rotated. In other words, it is a hydraulic swivel.

Priority circuits

The grader has certain hydraulic circuits that are considered priority circuits. Priority circuits always take “hydraulic precedence” over all other hydraulic circuits. The priority circuits are the brakes, steering, and differential lock. These circuits will always receive more main pump pressure over the other hydraulic circuits during times of high load and demand. A pressure control valve is located near the right frame underneath the cab. One of the valve’s ports is connected by a line directly from the main hydraulic pump. The rest of the valve’s ports are connected to the other hydraulic circuits. This valve ensures that pump output pressure oil is always available to the priority circuits no matter what other grader functions are in use.

005. Grader maintenance

You have already learned the fundamentals of electrical components, including the charging system and its troubleshooting, in previous lessons. We have also discussed the hydraulic system which is mostly trouble-free, so most of the maintenance consists of troubleshooting and repairing hydraulic leaks. In this lesson, we briefly look at the grader electrical system and then finish with its hydraulic system maintenance.

Troubleshooting and repairing the electrical system

There are two versions of the electrical, or charging, system used on the grader. One version uses an alternator with a remote-mounted external regulator. The other version has the voltage regulator attached to the rear of the alternator housing, which is also considered an external regulator.

In both cases, the voltage regulators are sealed solid-state components and the operation of both versions are the same. Figure 1–40 shows the basic wiring of a grader’s charging system with a remotely mounted regulator.

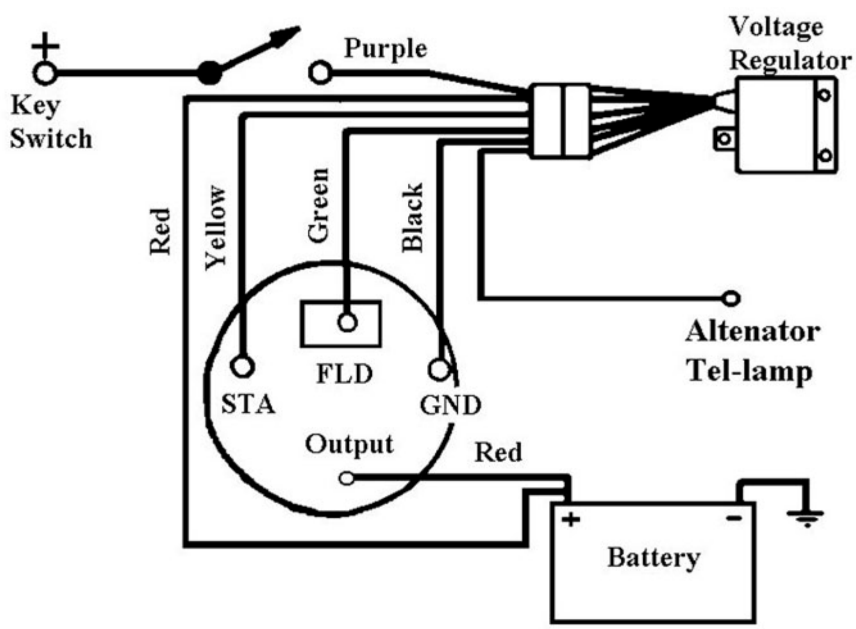


Figure 1–40. Wiring diagram—remote-mounted regulator.

Troubleshooting the electrical system is similar to any other charging system. First, perform some of the normal preliminary checks, such as the condition of the drive belt and the batteries. Also, check all electrical connections in the charging system. Perform voltage-drop tests as necessary to locate any areas of high resistance of the wiring and connections. If there are no problems found, perform a regulator bypass test. This test should isolate either a faulty alternator or regulator and its wiring.

To perform the regulator bypass test follow these steps:

1. Disconnect the green field wire from the alternator.
2. Unplug the voltage regulator connector.
3. If the regulator is mounted to the back of the alternator, remove it from the alternator and disconnect its wires.
4. Start the engine.
5. Connect a jumper wire from the alternator's output terminal to the alternator's field terminal.

If the alternator begins to charge excessively, the voltage regulator is probably faulty and should be replaced. If the alternator does not fully charge while it is full-fielded (bypassed), remove it for repair or replacement. Check the technical order for more detailed testing.

Hydraulic system troubleshooting and repair

As stated earlier, leaks are the biggest problem with the hydraulic system. Leaks develop because of faulty seals, cylinders, or lines. As far as inoperable components, there are some important system tests required to diagnose transmission hydraulics and main hydraulic problems. Remember, the transmission and main hydraulic systems are tied together.

CAUTION: When performing hydraulic tests, it is extremely important to follow step-by-step procedures and safety precautions listed in the technical order. Doing so will prevent damage to the equipment and vehicle. It will also prevent personal injury.

Troubleshooting

Troubleshooting begins with you; therefore, you must have a thorough understanding of the grader's hydraulic system and how it works. Study all of the technical information pertaining to the system. The technical order, training literature, service bulletins, and a hydraulic schematic provide excellent sources of information. You should also know the type of hydraulic fluid that the system requires for efficient operation. To begin troubleshooting, start with a visual test, then perform specific tests when needed.

Visual inspection

Perform a thorough visual inspection anytime a hydraulic problem is encountered. Since the transmission case serves as the hydraulic reservoir, you *must* check the transmission/hydraulic oil level and the condition of the oil. This check is performed with the engine *off* and grader *level*. If the engine has been running, allow 10 minutes before performing a visual inspection for the oil to drain down into the transmission case.

Look and smell the oil to see if it is burnt. Burnt oil can easily be detected by its smell. If the fluid has been burnt, check the oil cooler and radiator for airflow restrictions. Look for dirt, leaves, bugs, or anything that would reduce airflow through the oil cooler, causing the oil to overheat. Another part of your visual inspection is checking the transmission and hydraulic lines and hoses. Walk around the grader and look for kinks in hoses and any source of external leakage. Pay special attention to all the connection ports at valves and cylinders.

More specific tests

Troubleshooting may include performing tests that are more specific. The technical order provides procedures for performing several pinpoint tests for the transmission and hydraulic system. The purpose of these tests is to check pressure and oil flow amounts from different transmission and hydraulic circuits. These tests are generally performed during a specific engine rpm and when the hydraulic oil is at a certain temperature. When checking pressures, make sure you use a pressure gauge that is able to withstand the proper amount of pressure. The technical order will specify the gauge size for each test. Oil flow is generally checked with a flow meter that is capable of measuring oil flow in gpms. With the proper adapters, the flow meter can be connected in series with a specific hydraulic line in which the oil flow is to be measured.

NOTE: When checking pressures at the transmission, make sure the gauge is attached to the correct port. You must verify the grader's serial number because there were a few slightly different versions of transmission cases used. Checking oil pressures from the wrong port causes misdiagnosis.

Adjustments

There are only a few adjustments that can be made to the hydraulic system. However, during troubleshooting, the results of a pressure test may indicate that a relief or control valve needs adjusting. Most of these valves are adjusted by disassembling them and adding or removing shims, as necessary. Additionally, a few adjustments can be made by rotating an adjusting screw, for example, the standby-pressure adjusting screw on the main hydraulic pump.

Repair

Hydraulic system repair consists of replacing hydraulic cylinders, hoses, O-ring seals, gaskets, fittings, valves, pumps, and other components. In the case of a major component failure, such as a main pressure pump or the transmission, you will remove and replace the component. Many vehicle management shops do not have the necessary special tools and equipment to overhaul these components. However, if your shop does have the necessary equipment, perform component overhaul. The procedures for rebuilding components are covered in detail in the technical order.

Cleanliness is important when it comes to repairing the hydraulic system. During repair procedures, you will disconnect hydraulic lines or valves. This will expose the inside of the system to the outside environment. Do not forget that dirt is the worst enemy of a hydraulic system. Small particles can score valves, seize pumps, and clog orifices—all of which will make additional work for you. You must keep dirt and other contaminants out of the system. Before disconnecting any of the hydraulic components, it is a good idea to steam clean the area that you will be working. Once lines or other components are disconnected, protect openings with a suitable plug or clean rag.

CAUTION: When removing hydraulic lines or cylinders, block up the part of the grader that the cylinder operates. For example, if you are going to remove the cylinder that raises the blade, make sure the blade is secured so it won't fall. If you are going to be disconnecting any lines that are part of the blade cylinder's circuit, the blade needs to be blocked up as well.

Troubleshooting drivetrain system malfunctions

Whenever any power-shift transmission malfunctions are encountered, first perform a good visual inspection to determine if any external leaks are present. If there are no external leaks, there may be internal leakage or component failure. Some common malfunctions you may come across are listed in the following table.

Power-shift Transmission Malfunctions	
Condition	**Problem Area**
Grader fails to move	Engine disconnect clutch disengaged. Towing disconnect collar disengaged. Transmission oil pressure low. Check transmission oil level, filter, or filter bypass valve.

Power-shift Transmission Malfunctions	
Condition	**Problem Area**
Grader jumps during inching pedal valve engagement	Pedal valve sticking. Broken pedal valve spring or springs. Remove and service the valve.
Grader creeps excessively	Pedal valve out of adjustment. Warped clutch or brake discs. Perform “drag test” to locate defective component.
First, second, third, fourth, and seventh gears do not function	Loose oil line to bearing cap. Broken sealing ring at bearing retainer and/or at reduction gear shaft. Leakage in planetary clutch pack. Clutch pack sealing rings worn or broken.
Transmission oil temperature exceeds 160° Fahrenheit (F)	Plugged transmission filter. Oil cooler core dirty or obstructed. Warped clutch or brake discs. Perform “drag test” to locate defective component.
Low-oil pressure	Restricted oil filter. Stuck transmission oil filter relief valve; worn or broken spring. Sticky oil cooler relief valve or broken spring. Wrong or torn gaskets behind clutch valve housing, pressure-regulating valve housing, or shift valve housing. Torn gasket in oil pump manifold.
Grader shifts oddly	A shift valve in the transmission control valve is sticking, allowing a partial flow of oil. Run pressure test to isolate sticking valve. Remove and service, if necessary.
Grader shifts too slowly	Stuck pressure-regulating valve or weakened spring is causing low-control system pressure. Adjust pressure-regulating valve. Remove and service, if necessary. Accumulator spring is broken causing low pressure. Remove and service the accumulator.

Performing a transmission drag test

The *drag test* can help you determine whether or not the clutches or brakes have been damaged by heat. Discs damaged by heat can cause excessive drag. Power-shift transmissions normally display some drag in the clutches and brakes. This drag is due to the presence of oil in the clutch packs and brakes. Excessive drag, due to warped discs, will increase as the engine rpms increase. It is very important that the proper oil level, oil temperature, and engine rpm be attained before running the test.

NOTE: Tire pressures will affect the test; therefore, check the pressure of each tire before beginning the test.

The steps in performing the drag test include:

1. Run the test on a hard, level area, such as dry, compacted clay or a hard-surfaced road.
2. With the engine speed at 1,500 rpm, the transmission temperature should be between 100 and 160°F.
3. To check clutch C1, place the speed selector lever in third-speed forward. With the grader moving in third-speed forward, depress the clutch pedal. If C1 is dragging, the grader will keep moving forward but at a slower speed than before depressing the clutch pedal.
4. To check clutch C2, place selector in second-speed forward. While moving in second-gear forward, depress the clutch pedal. If C2 is dragging, however, the grader will keep moving forward but at a faster speed than before depressing the clutch pedal.

5. To check clutch C3, and brakes B4 and B3, place selector in neutral. With the grader standing still, place the selector in first-speed forward. DO NOT depress the clutch for this test. If C3 or B4 is dragging, the grader will move forward. If B3 is dragging, the grader will move backward.

There is no test to see if brakes B1 or B2 are dragging. These brakes are visible when the transmission rear cover is removed. If the discs are warped, they will usually be tight on the B1 and B2 ring gear and thus feel tight to finger pressure. If the brake discs are in *good* condition, the discs and plates can easily be moved back and forth with *finger pressure*.

Troubleshooting steering system malfunctions

Just like drivetrain troubleshooting, perform a complete visual inspection of the steering system. Some common malfunctions are listed in the following table.

Steering System Malfunctions	
Condition	**Possible Problem and Fix**
Steering wheel does not center or steering is erratic	Binding in valve linkage. Broken centering springs. Gerotor gear splines misaligned. Realign the valve or replace the springs.
No response or excessive force is required when steering wheel is turned	Low-pump pressure. Transmission level is low. Blockage in lines or steering cylinders. Dirt in the system. Drain, flush, and refill with clean oil. Disassemble and clean parts, if necessary.
No response when steering wheel is turned	Sleeve and spool valve locked. Pump failure. Hose or filter clogged. Steering column shaft broken or not engaged in spool splines. Disassemble, repair, or replace worn component(s).
Unit steers when steering wheel is not moved	Sleeve, spool, or gerotor set worn or broken. Excessive internal leakage. Disassemble, repair, or replace worn component(s). Perform “steering valve” test.
Steering wheel continues to turn at a rapid rate when steering linkage is against stops	Excessive internal leakage. Disassemble and replace worn component(s). Perform “steering valve” test.

Performing steering-valve tests

Perform the steering-valve tests if you suspect the system has excessive internal leaks or if steering functions have become very erratic. Be sure to follow step-by-step procedure outlined in the technical order when troubleshooting the steering system. Two tests that can be performed are the gerotor and valve spool leak tests.

Gerotor leak test

The following test will help determine if the steering valve is faulty. Operate the grader to obtain a transmission oil temperature of 150°F. Then perform the following steps:

1. Cycle the steering valve from lock to lock (left to right and vice versa) approximately 15 times to bring oil temperature in the valve to the same temperature in the transmission sump.

2. Turn the steering wheel to the extreme left and apply 60 in. pounds (lb.) (light hand pressure) of torque to the steering shaft. Record the number of full steering wheel rotations in one minute.
3. Turn the steering wheel to the extreme right and apply 60 in. lbs. (light hand pressure) of torque to the steering shaft. Record the number of full steering wheel rotations in one minute.
4. If the number of rotations is higher than *20* when turning to the extreme left *or* extreme right, the steering valve is unserviceable and *must* be replaced or rebuilt.

Valve spool leak test

This test checks for internal leakage in the steering valve. Like the previous test, make sure the oil temperature is within operating specifications. Then perform the following steps:

1. Operate the valves and position the wheels in the straight-ahead position.
2. Raise the front axle off the ground using the blade functions.
3. Run the engine at half-throttle with the steering valve in the neutral position, then record steering cylinder rod movement during a five-minute time period.
4. If the steering cylinder rod exceeds 1½ in. of movement in five minutes, the valve is unserviceable and must be replaced or rebuilt.

NOTE: Before removing the steering valve from the vehicle, verify that the steering cylinders and lines are not leaking.

Self-Test Questions

Complete these questions, then check your answers at the end of the unit

004. Grader fundamentals

1. What kind of valve train does the grader engine have?

2. What component transmits power from the engine to the transmission?

3. How are the components in the transfer drive lubricated?

4. Where is the power-shift transmission's torque converter located?

5. How many speeds does the power-shift transmission provide?

6. What are the three main assemblies of the power-shift transmission?

7. Where are the C1 and C2 clutches located?

8. What component is splined to the output shaft of the C1 clutch?

9. How many planetary units are located in the planetary pack?

10. Which brakes are responsible for holding each of the ring gears?

11. What clutch and brake components are actuated when the power-shift transmission is in first-speed forward range?

12. What component drives the transmission oil pump?

13. Where is the transmission control valve located?

14. What is the purpose of the inching pedal valve?

15. What might happen if the differential lock is engaged while the grader is making a turn?

16. Where is the tow disconnect lever located?

17. What component houses the chain and sprockets that are used to drive the four rear wheels of the grader?

18. What component primes the main hydraulic pump with oil?

19. What is the function of the stroke control valve?

20. Where are the hydraulic filters located?

21. How many control valves make up the valve stack?

22. How many double-acting hydraulic cylinders are used to lift the blade?

23. What component prevents the blade side-shift cylinder's lines from twisting?

24. What hydraulic circuits are considered "priority circuits"?

005. Grader maintenance

1. When performing a voltage regulator bypass test, where do you connect the jumper wire?

2. What are the procedures for checking the transmission/hydraulic system oil level on the grader?

3. How are most relief valves on the grader adjusted?

4. What is the "worst enemy" of a hydraulic system?

5. When diagnosing a grader that fails to move, what are some common problems you should inspect?

6. A wrong or torn gasket behind the clutch valve housing would cause what type of power-shift transmission malfunction?

7. What test can help determine if clutches or brakes have been damaged by heat?

8. When checking clutch C1, what position should you place the speed selector in?

9. How do you check to see if brakes B1 and B2 are dragging?

10. When troubleshooting a steering system malfunction, what problems do you have if there is no response when turning the steering wheel?

11. When performing a gyrator leakage test, what is indicated if the number of steering wheel rotations exceeds 20 after the steering wheel is turned to the extreme left or extreme right?

12. What test will check for internal leakage in the steering valve?

1–3. Crawler Tractor

The crawler tractor is heavy and powerful. Most weigh in at nearly 22 tons and utilize a heavy-duty diesel engine and planetary gearing to provide the pulling or pushing power. You can use an optional ripper attachment mounted on the rear of the machine for breaking up dirt or other materials.

In this lesson, we discuss the Fiat Allis crawler tractor (fig. 1–41) with a bucket attachment. Many of the fundamentals you learn in this unit can be applied to almost all models of crawler tractors. The discussion on the operating controls is just to familiarize you with tractor operation. It is vital that you know how to operate a piece of equipment before you attempt to isolate or repair its various systems.

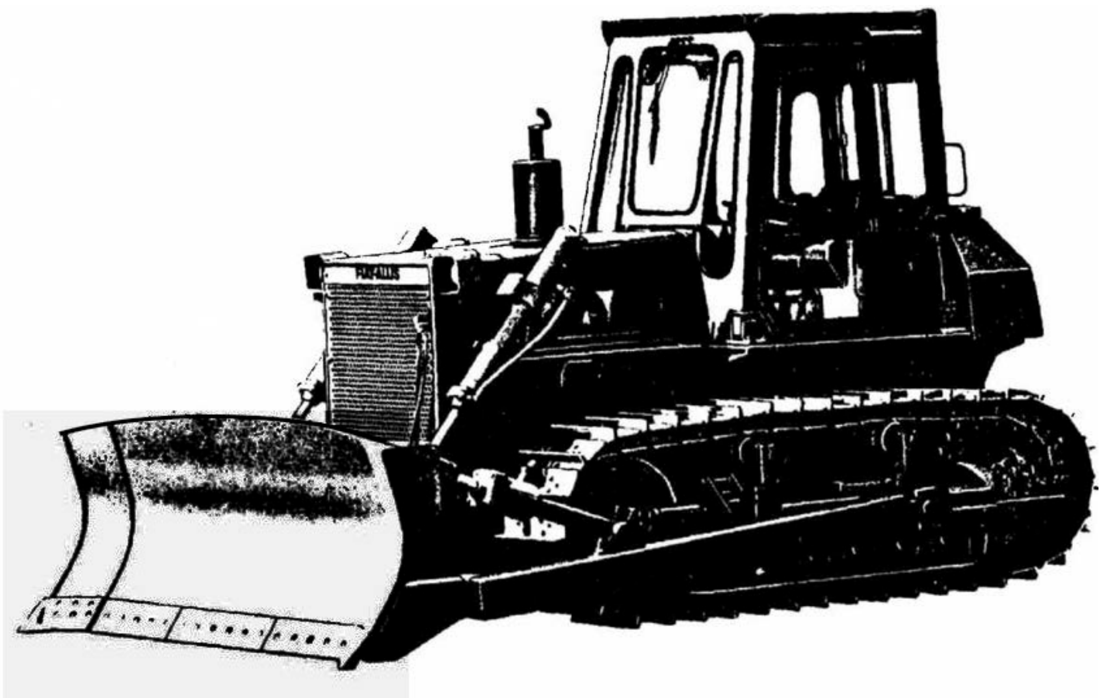


Figure 1–41. Fiat Allis crawler tractor.

006. Cab controls

Operating the tractor is greatly simplified through extensive use of hydraulic controls in the cab. This lesson covers the operator's compartment (cab) which includes: the electronic data monitor (EDM), transmission shift lever, gearshift and parking-/emergency-brake lock lever, throttle lever, attachment control levers, and attachment control lock lever. Attachments for the tractor include: multipurpose bucket, clamshell attachment, and a winch. And, of course, safety is discussed.

Operator's compartment

Most of the control cables, as used on previous older model earth-moving tractors, have been replaced with *hydraulic* controls, resulting in much smoother and precise tractor operation. The operator's compartment is the reference point as you study the tractor. Directions on the tractor are given as if you are viewing the compartment from the operator's seat. Figure 1–42 shows the layout of the operator's compartment.

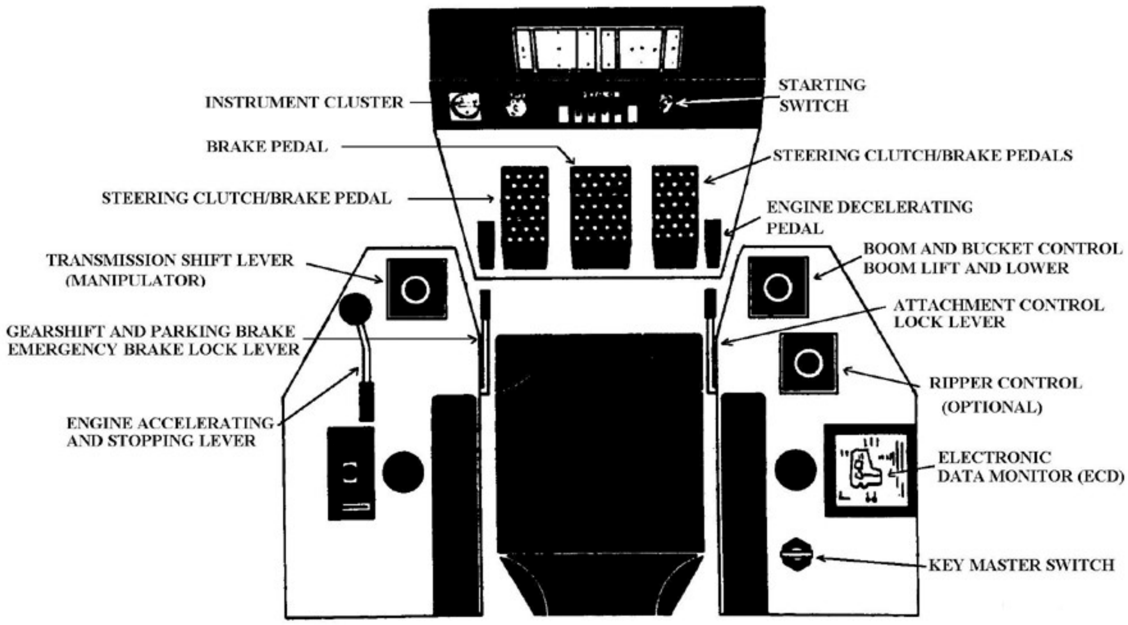


Figure 1–42. Operator's compartment.

Steering clutch and brake pedals

Steering this tractor is an experience in itself, particularly if you have never operated any type of track vehicle. You steer the tractor using the foot pedals on the floorboard. If you want the tractor to go left, push the left brake pedal down and the left track will slow down or stop. Pushing the brake harder increases the degree of the turn. The same is true for right turns; press the right brake pedal and the right track slows or stops.

In more technical terms, steering is accomplished using *two multidisc steering clutch packs*, which are manipulated by the operator's foot pedals. Depressing one of these pedals disengages the corresponding steering clutch, allowing the affected track to slow down. By further depressing the pedal, the corresponding track brake is applied and the tractor easily steers in tight spaces. Depressing the large *center* pedal slows *or* stops both tracks simultaneously.

EDM

Most tractors are equipped with the typical vehicle malfunction warning systems in addition to a unique operator warning system called the EDM. This system, located to the right of the operator, sounds a buzzer and illuminates a light if a fluid level or a fluid pressure problem occurs in the engine, transmission, or torque converter.

Transmission shift lever

Use the transmission shift lever (referred to as the manipulator), which is located on the console to the left of the operator, to select the range and travel direction of the crawler tractor. You can select the range and travel direction with the tractor either sitting idle or in motion. There are three forward and three reverse positions.

When you move this lever, you are *hydraulically* moving the spools in the transmission control valve, which are located on the lower left side of transmission. This changes the direction or path of the hydraulic fluid. This action, in turn, controls the transmission clutches. The shift lever is locked into its position by oil pressure on the bottom side of the spool valve. Anytime the transmission oil supply is lost, the shift lever automatically returns to the neutral position. When the shift lever is placed in neutral, the external contracting-type parking brake is automatically applied by springs. This design eliminates the need for a separate parking-brake switch or lever.

Gearshift and parking-/emergency-brake lock lever

You prevent the operation of the transmission shift lever by pulling the lock lever up. When this lever is in the raised position, fluid flow from the main supply pump going to the gearshift manipulator is blocked, *preventing* you from shifting the transmission *or* releasing the parking brake. Normal transmission function and release of the parking brake resumes when you put the lever in the down position.

Throttle lever

The throttle lever on the operator’s left console panel controls engine speed and engine shutdown. Pulling the lever closer to the operator increases the engine’s rpm; pushing the lever away from the operator lowers the rpm. Push the lever to the extreme left to shut down the engine. You will also find two deceleration pedals on the floorboard. These levers are used to slow the engine during turns or going down a hill. The throttle lever and deceleration pedals are connected by linkage to the fuel injection pump located on the right side of the engine.

CAUTION: Remember to disconnect the throttle linkage in accordance with the technical order before attempting to tilt the operator’s cab. Failure to do so can seriously damage the throttle linkage and/or the injection pump.

Attachment control levers

The boom controls are located on the operator’s right. Moving this control lever backward or forward lifts or lowers the boom. This control lever returns to neutral once the boom is fully lifted. Moving the lever to the right or left positions operates the bucket dump.

A bucket “float” position is controlled by a button that is on the top of the control lever. The hydraulic system attachments are controlled by a two-spool main control valve; one for boom raise/lower and one for bucket dump and retract. This vehicle has two hydraulic boom cylinders, which lift the bucket arms, and two hydraulic bucket cylinders that allow you to change bucket configurations.

Multipurpose bucket

Before we discuss the bucket, it is important that you understand the difference between a bulldozer and the crawler tractor being discussed. This crawler tractor has a multipurpose bucket to perform several functions without changing attachments. A bulldozer typically has a straight blade used for pushing and leveling materials only.

Clamshell attachment

This hydraulic attachment gives the operator the option of changing bucket configurations by simply opening or closing the bucket clam shell using one double-acting hydraulic cylinder on each side of the bucket. The clamshell can be used in the closed position for a conventional bucket or opened to expose the dozer blade or a grapple.

Winch

A hydraulically driven winch, located on the rear of the tractor, is provided for pulling objects behind the tractor. A manual lever on top of the winch is used to engage and disengage the winch clutch. Leaving this lever in the disengaged position allows the winch to free wheel, if needed. The winch has an internal brake that is spring applied and hydraulically released. Fluid flow from the cab control valve releases the brake, allowing winch operation. A hydraulic relief valve is incorporated to protect the hydraulic circuit in the event of a winch overload.

Attachment control lock lever

This safety device prevents operation of the bucket or ripper attachment. Pulling the lever up blocks fluid from the attachment operations. Normal operation of the attachments resumes when you place the lever in the down position.

Safety

We cannot stress safety enough, specifically around the hydraulic system. A hydraulic system under pressure can be deadly. If you find it necessary to raise the boom to make repairs, make sure holding devices are in place to prevent the boom from falling. On this model, a safety bar is designed for and placed on the right lift arm. Always remember to follow all manufacture's safety procedures that apply to the machine you are working.

007. Powertrain and final drive assembly

By this point, you should have a good understanding of the crawler tractor functions and capabilities. Now let's discuss the components that make the crawler tractor perform as designed. These systems/components include the power train and final drive assembly components, which include: the engine, cooling system, electrical system, hydraulics, transmission/converter, drive gears, steering components, and braking system.

Engine

Diesel engines are used over gasoline engines in heavy equipment because they have a high-torque output at lower engine rpms. One example of a crawler tractor engine is the in-line six-cylinder, four-stroke, turbocharged 8.1-liter diesel engine. The peak torque range is at 2,000 rpm where the engine produces 168 horsepower (hp).

Cooling system

As with most conventional cooling systems, the crawler tractor uses the standard belt-driven fan to draw air across the radiator to cool the engine. However, some models of crawler tractors are equipped with a unique radiator cooling fan system that can be *reversed* to meet changing weather conditions. The fan is designed to *pull* cold air through the radiator to *remove* the heat (summer-time operation) or *blow* the hot air from the engine out through the radiator to keep the coolant in the radiator warm (winter-time operation). The fan is equipped with spring-loaded, rotatable blades, which are mounted to the fan hub. You can change the direction of the airflow by pushing the blades toward the center of the hub against the spring. This releases the roll pin from its slot so the blades can be rotated 180°. Remember all the blades have to be rotated in the same direction. Keep the fan blade direction in mind the next time you are fixing a tractor that is in the shop for overheating. The fan should pull the air in the summer and push the air out in the winter.

Electrical system

All of the electrical system components on the crawler tractor, including the starting system, operate on a 24-volt system. This is accomplished by connecting two heavy-duty, 12-volt batteries in series. A single 24-volt, internal-regulated alternator, driven by two belts, recharge the batteries.

CAUTION: To avoid serious personal injury or damage to the equipment, always follow the proper isolation and repair procedures in the technical order.

Hydraulic operation

The hydraulic implement system, transmission, steering, and brake systems use the hydraulic pilot-operated control system. In other words, fluid flow from the pilot pump is used to *actuate* the control spool valve(s) to operate these components, as opposed to cables or linkage that you might find on other equipment. The *gear-type* pilot pump, which is used to operate the attachments, is usually found on the right front of the engine.

Transmission and converter

The transmission provides three forward and three reverse speeds. The speed is controlled by a hydraulic power-shift mechanism, which controls five clutches. Torque multiplication takes place using a single-stage torque converter that is mounted separately from the transmission. A shaft connects the transmission and torque converter. Additionally, the torque converter ring gear drives two, tandem-gear–type pumps. One pump is for main hydraulic supply and torque converter charging. The other pump is for vehicle steering and torque converter scavenging. The converter and transmission hydraulic system oil cooling is accomplished by using a heat exchanger, which uses coolant circulated from the engine.

Drive gears

Once you select a gear, the transmission output shaft turns the pinion gear to transfer power through the bevel gear at right angles. This sends power via the drive gears, as shown in figure 1–43, out to the left and right tracks. After passing through the steering clutch packs, the power goes into the final drive gear case, which is located outside the tractor frame.

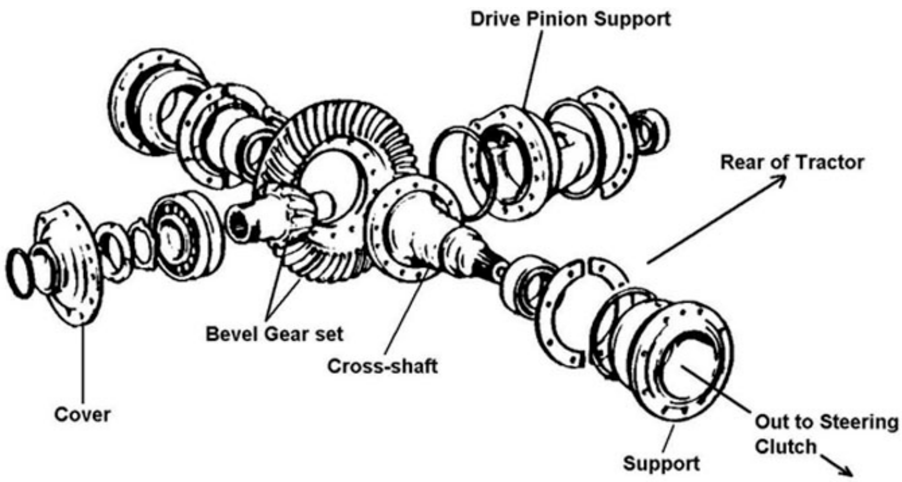


Figure 1–43. Drive gears.

In figure 1–44, you can see how the term "*double reduction*" is actually accomplished with the *straight spur-type drive gears*. This design of the smaller gears (pinion and idler gears) driving the much larger gears (idler and final drive gears) results in a slower speed but an increase in torque. From there, it goes to the sprocket that drives the tracks.

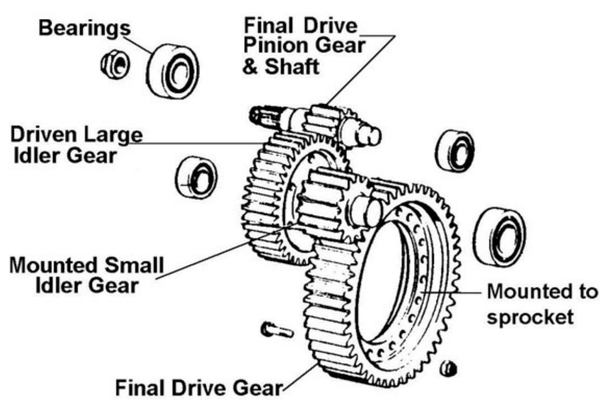


Figure 1–44. Double-reduction spur-type gears.

Steering and braking

Turning the crawler is accomplished by slowing or stopping one track at a time. In order for this to be possible, the steering clutch packs (fig. 1–45) must be allowed to slip or be independently disengaged. When you press on the left- or right-steering pedals, the steering modulating valve opens, causing oil to flow from the transmission to the steering clutch pack. The increased oil pressure in the clutch pack overcomes the spring tension on the pressure plate, causing it to release. The amount of clutch release depends on the amount of pressure applied to the foot pedals. When adjusted properly, *3 in.* of steering/brake pedal movement causes *complete release* of the clutch pack.

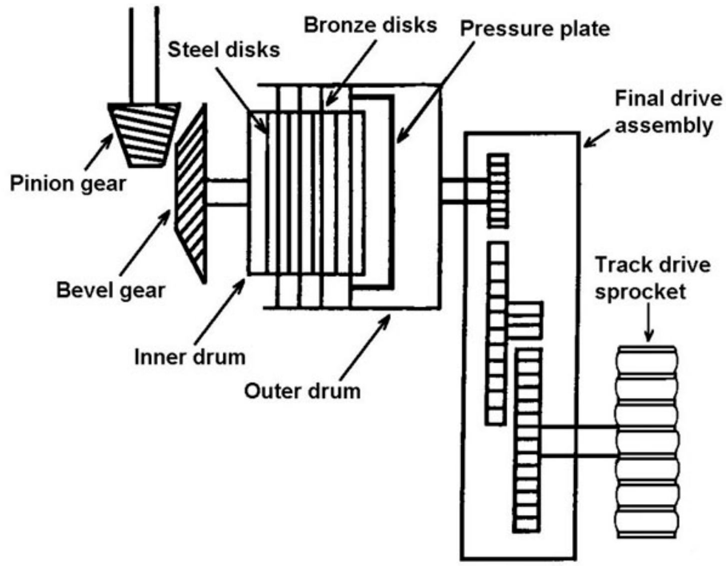


Figure 1–45. Steering clutch.

Steering clutch

The steering clutch pack (fig. 1–46) is composed of an inner drum, steel clutch discs (*driving member*), bronze clutch discs, a pressure plate, springs, and an outer drum. The inner drum is splined and driven by the bevel gear. Splined to the inner drum are a series of steel discs. Between each of the steel discs is a bronze disc.

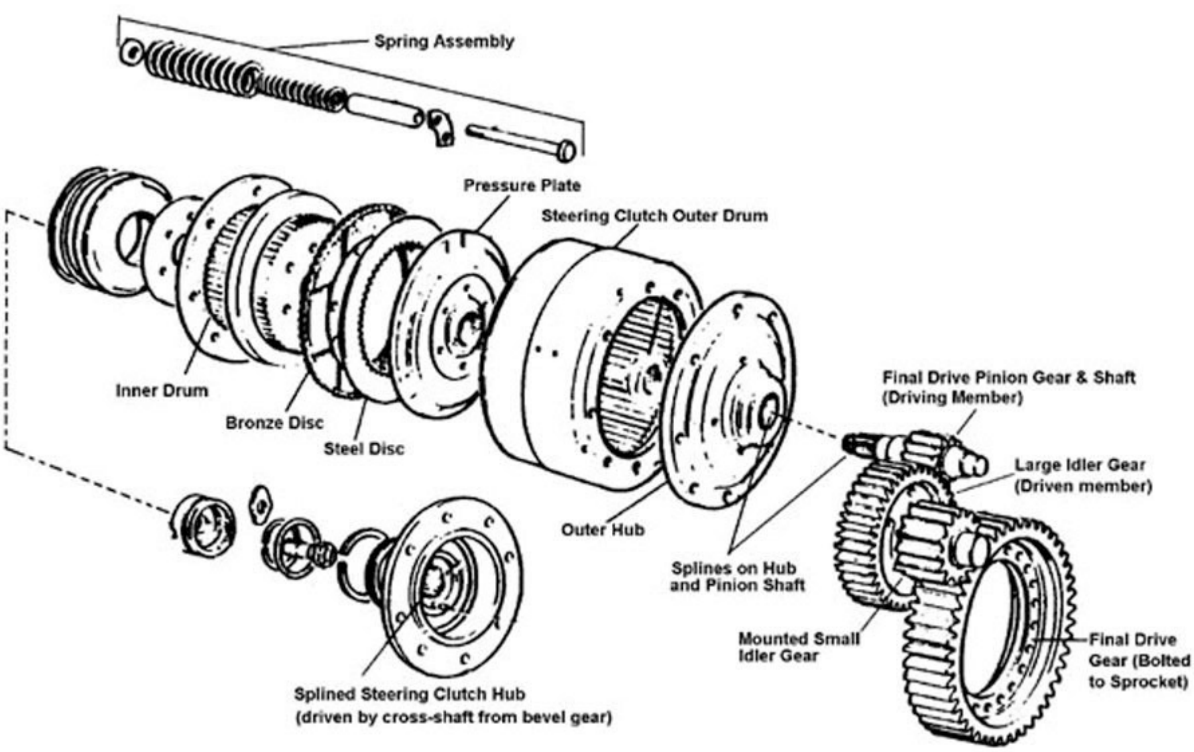


Figure 1–46. Steering clutch with final drive gears.

The bronze discs (driven member) push on the clutch discs with enough pressure to prevent any slippage between the discs. The steering clutches are spring-applied and hydraulically released by fluid pressure from the transmission. As long as the pressure plate engages the clutch pack, the power flows from the bevel gear to the inner drum, through the clutch pack, to the outer drum that is connected to the final drive gears. In figure 1–45, you can see how the clutch pack drives the final drive pinion gear.

Mechanical band brake

If you press the steering/brake pedal more than 3 in., a mechanical band brake will be applied (fig. 1–47). This band brake is an external contracting type that is mechanically applied and hydraulically released. The brake band is positioned around the outer steering clutch drum to *prevent* movement of the outer drum, final drive assembly, and track assembly when applied during turns or when stopping. Even though some hydraulics are used in this brake system, it is still considered a mechanical-type brake system.

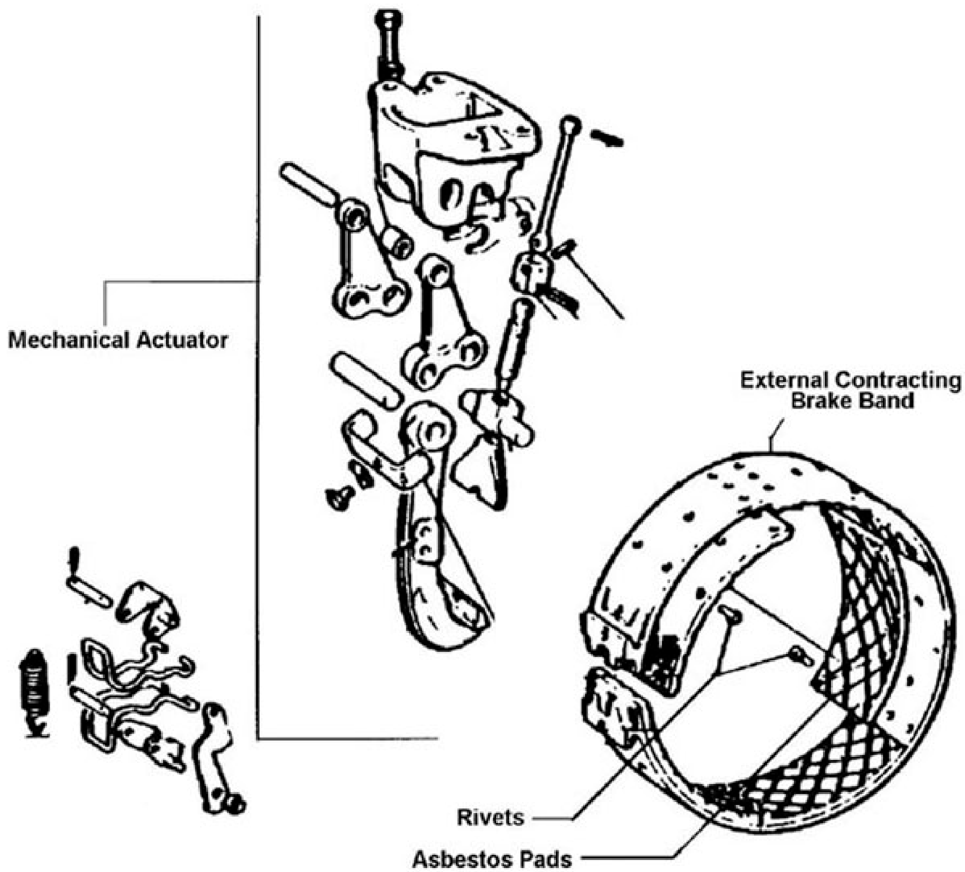


Figure 1–47. Mechanical band brake band.

Automatic brake release

The tractor brakes are released automatically by hydraulic pressure any time you shift the transmission into forward or reverse. Movement of the steering/brake pedal more than 3 in. cuts off oil flow to the hydraulic cylinder holding the brake band in the released position. Spring pressure then causes the band brake to contract around the outer drum, preventing it from moving.

Pivot turn

Application of only one of the brakes allows the tractor to make a pivot turn. The pivot turn is the sharpest turn you can make with a crawler tractor. Pushing the brake pedal closer to the floor increases the degree of the turn by slowing or stopping one of the tracks. The tracks on the crawler cannot be made to rotate in opposite directions. Avoid making sharp turns on asphalt or concrete as such turns can tear up these surfaces.

Drive sprocket

The drive sprockets are the large-toothed wheels located at the rear of the track frame and are the components that provide the connection between the final drive assembly and the track. Left and right final drive output shafts drive the sprockets. The teeth of the sprocket fit over the pin bushings of the track chain. This is based on the same principle as a bicycle sprocket and chain setup. The teeth of the drive sprocket pull on each of the track chains to move the track in the desired direction.

Track chain

In order for the power in the final drive sprocket to be transferred to the track shoes, there must be a way of attaching the shoes to the power source…the track chain (fig. 1–48). The shoes are bolted to the chain with special hardened bolts. The chain is made of hardened steel and is held together with machined pins that are about 1½ in. in diameter.

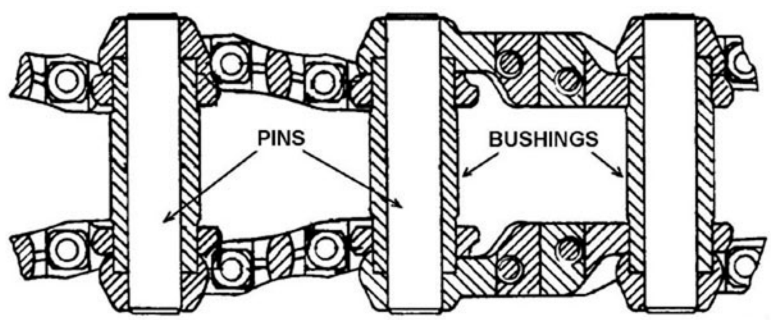


Figure 1–48. Track chain link.

One link and pin are known as the “master link,” which is the initial disassembly point of the track chain. It is used to break the track apart to replace the chain or perform maintenance on any of the track support rollers and guides. Disassembly must be done in accordance with the applicable technical data to avoid damage to the equipment and injury to personnel. As we stated in the previous paragraph, the pin bushings between the track links are driven by the teeth on the final drive sprocket (fig. 1–49).

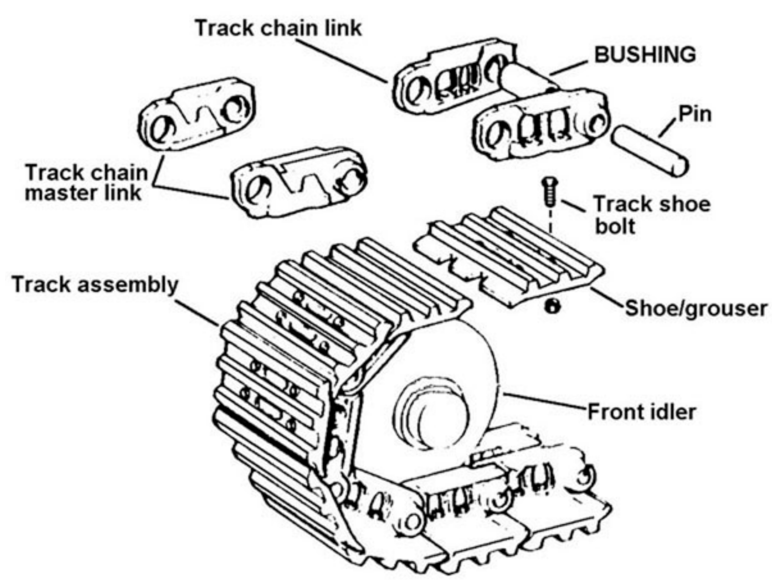


Figure 1–49. Track bushings.

Track shoes

The shoes are the large, flat metal plates that mount on the track chain on which the crawler tractor rides. The shoes have raised bars, called *grousers*, to grip the ground. Different grousers are used for different surfaces. A vehicle that is operated on stable, hard ground, such as a gravel yard, may use three short grousers per shoe. When operating on a soft terrain, a shoe with one very tall grouser may be used for maximum traction (fig. 1–50).

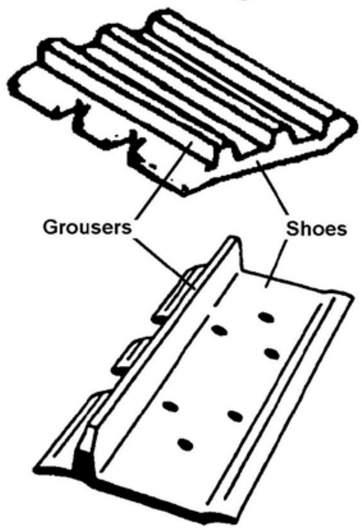


Figure 1–50. Different service grousers.

Offset track shoes

Offset track shoes are similar to standard track shoes with the exception of the shoe bolt holes being offset from the center position. The offset shoes are primarily intended for use on larger tractors.

Track shoe bolts

Track shoe bolts must be kept tight to eliminate a source of damage to the track shoes and links. On a new track, torque the bolts to specifications after each day of operation until they become seated on the shoe.

Reconditioning shoes

Worn track shoes can be reconditioned to regain traction. This consists of welding preformed grouser bars or steel bar stock on the grousers. Recondition grousers when they are worn to within ¾ of an in. of the shoe. Allowing the grousers to wear any closer may cause the loss of the structural strength and bending of the shoe.

Track frame

The track frame provides the needed support and rolling capability for the track to rotate. The track frame is a rigid unit, solid mount, which is composed of an idler roller, carrier rollers, track rollers, recoil spring, track tension adjustment mechanism, and assorted shims and bearings.

Idler roller

The front idler provides a freely rotating combination guide and support for the track chain. In conjunction with the recoil spring, the idler protects the track mechanism from damage or shock. When the front idler receives a shock load, the force is transmitted to the track spring by a slide-mounted mechanism to which the idler is attached (fig. 1–51).

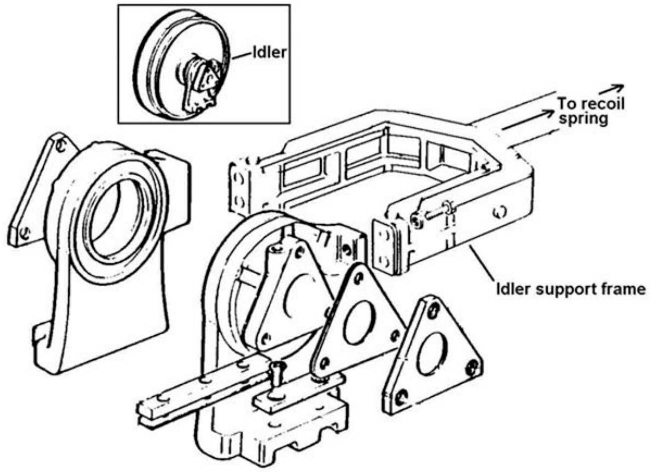


Figure 1–51. Front idler and support frame.

Keeping the idlers in proper alignment is *very* important. A misaligned idler causes wear on the front idler center flange, the sides of the track links, and the sides of the roller flanges. Typically, these idlers are sealed and do *not* require lubrication.

Carrier rollers

The carrier rollers are used to carry the weight of the track over the top of the frame. Without the carrier rollers, the track would have an excessive amount of sag. Operating the crawler in conditions that applies a side thrust to the tracks, such as traversing on an incline, would cause the track to be thrown off the frame.

Track rollers

The track rollers are used to distribute the crawler tractor weight over a large ground area, much the same as a snowshoe allows someone to walk across the snow without sinking. The crawler uses six track rollers that require lubrication with 30-weight oil. Check this fluid level at the pipe plug on the roller. The track rollers may be the single- or double-flanged type (figs. 1–52 and 1–53).

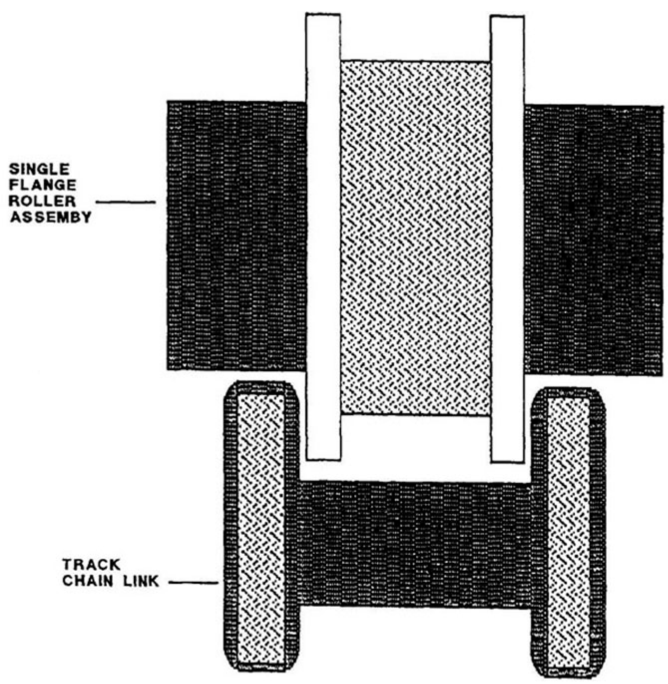


Figure 1–52. Single-flange roller.

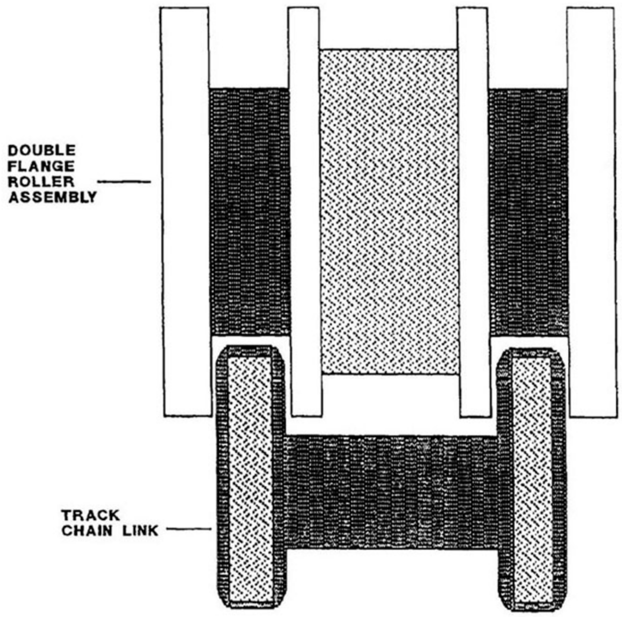


Figure 1–53. Double-flange roller.

Check the carrier and track rollers for signs of uneven wear, freedom of rotation, security of mounting brackets, and alignment. If a roller stops turning for any reason, the track moving across it will wear a flat spot on it. Mud freezing around these components may cause this to happen as well. Typically these rollers are sealed and do not require lubrication.

Recoil springs

The recoil spring and spring seats are located approximately in the center of the track frame group. The length of the recoil spring is adjustable and is controlled by a recoil spring stop. This crawler uses a hydraulic cylinder and relief valve to control this distance. However, you *must inject grease* instead of hydraulic fluid to adjust the recoil spring length.

CAUTION: Use extreme caution around the recoil springs. The assembled spring force ranges from 25,000 to 38,000 lbs.

008. Crawler tractor maintenance

In this lesson, we will discuss how to isolate malfunctions, repair, and adjust the final drive assembly, steering, and track system.

Troubleshooting and repairing the final drive assembly

In most cases, the final drive is a reliable system that will last the life of the tractor. Major component damage in the final drive assembly happens on rare occasions. However, fluid leaks in the final drive assembly are common and what you will typically repair in the field. It is important for you to repair these leaks or you may find yourself replacing components that have overheated from a lack of lubrication. The first step in isolating the source of the leak is by thoroughly cleaning and inspecting the suspected area.

Carefully disassemble and inspect each of the components as you remove them. This requires you to pay close attention to the repair procedures and follow the safety practices listed in the technical order.

The following are just a *few* of the steps performed to repair a leak in the final drive assembly housing:

1. *Release* the track tension.

2. Remove the track.
3. Drain the final drive housing fluid.
4. Remove the bearing covers, bearings, and sprocket.
5. Remove final drive housing cover.
6. Inspect final drive gear components for signs of wear and damage.
7. Remove and replace the final drive housing gasket.
8. Reassemble the components in the reverse order of removal.
9. Torque each of the components to its proper specifications. Improper torque settings will result in premature failure.

Inspect the gears and bearings for wear and damage. Also inspect the bearing and oil-seal surfaces for any scratches, nicks, or burrs that may damage any new components you are installing.

Final drive assembly adjustment

In order to avoid premature wear of the bearings, the final drive inner and outer-sprocket support-bearing preload must be adjusted correctly by installing or removing shims. The first step is to determine the outboard-bearing preload requirements. Check the technical order for specifications and updated procedures. The following procedures were current at the time of this career development course (CDC) publication.

To determine the outboard-bearing preload requirements, follow the procedures for the installation of the cage lock nut. Install the outboard-bearing cage, washer, lock plate, and retaining nut onto the shaft (less the shims) (fig. 1–54) and tighten the nut to specified torque.

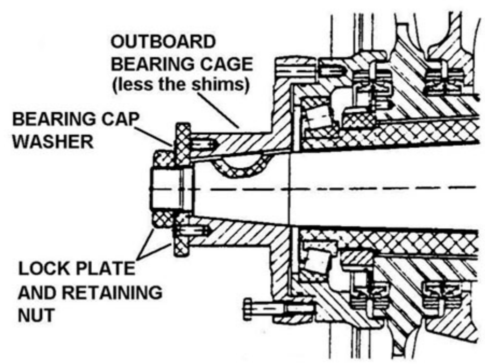


Figure 1–54. Installation of the outboard-bearing cage lock nut.

Remove the bolts and lock washers retaining the bearing cage halves. Flatten the slight taper at the threaded end of three retaining-cap screws with a grinding wheel or file (fig. 1–55).

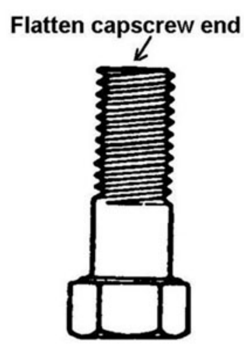


Figure 1–55. Retaining-cap screws.

NOTE: The cap screw ends *must* be perfectly flat or the bearing cage will *not* torque evenly. The cap screw threads and cap screw holes *must* be clean and lubricated.

These old cap screws will be used as your adjustment cap screws and will be replaced in the final adjustment. Install the three cap screws in the threaded holes and properly torque the cap screws in the cross pattern.

Gradually and alternately (cross-pattern) tighten the cap screws (fig. 1–56) to the initial value and in increments until you reach the final torque value in accordance with the technical order specification chart.

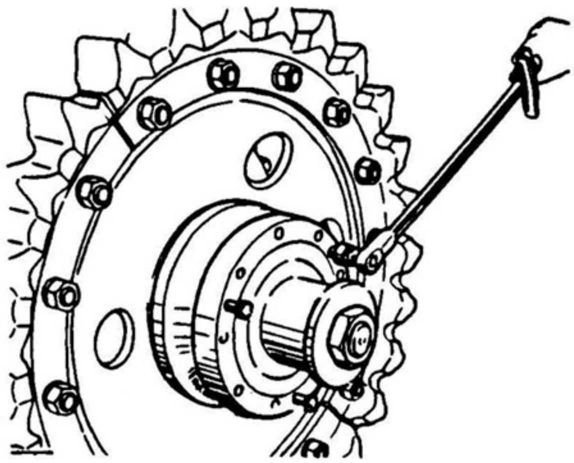


Figure 1–56. Installation of the three cap screws.

Essentially, all of the preceding procedure is performed to seat the outer-bearing cage at a specific torque so that, in the following steps, the gap, which will be left, can be measured. Then, shims will be added to eliminate the gap, and finally the assembly will be torqued to technical order specifications. This process will make sure the bearing is held in place correctly, without binding or being too loose.

Bearing preload

Use a flat-feeler gauge to measure the distance between the cage halves (this is the bearing preload). Use three readings at 120° intervals between the adjustment-cap screws. *Average* the three values to establish the size of the shim pack. A shim pack is nothing more than a series of thin, metal spacers of various thicknesses, used to set the bearing preload.

Shim packs

Install three shim packs (fig. 1–57). Remove the adjustment-cap screws, install the remaining cap screws, and lock washers. Tighten to the proper torque as specified in the technical order.

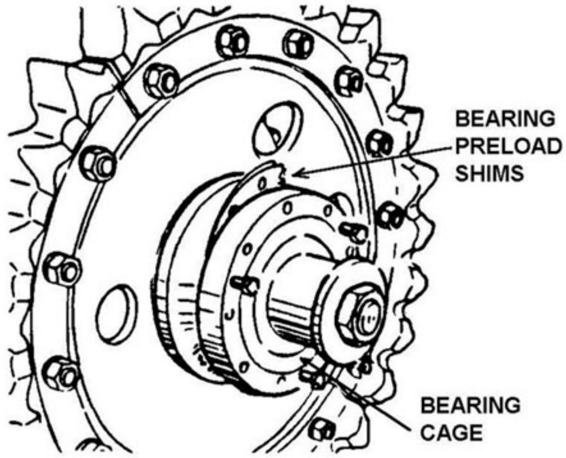


Figure 1–57. Bearing preload shims.

Troubleshooting, adjusting, and repairing the steering system

Before you begin to isolate a steering system problem, check the fluid level and always verify the problem by performing an operational check. One problem that an operator may state is that “my crawler tractor does not steer the same in both directions.” Start your troubleshooting by using the technical order troubleshooting chart.

In this case, the chart will indicate you should check the following:

1. Brake-band adjustment.
2. Linkage within the clutch housing.
3. Clutch-brake pressures.

Steering-brake band adjustment

Adjusting the steering-brake band is simple and does not require major component disassembly. Use the following chart to adjust the steering band.

Steering-Band Adjustment
1. Before making the band adjustment, tilt cab and install cab support lock bar.
2. Locate the band adjusting screw on the top of the steering-clutch cover.
3. Back off adjusting screw and retighten to 57 ft. lbs.
4. Back off adjusting screw two turns.
5. Recheck operation of the steering system.

Steering-clutch and brake-band repair

If the adjustment above does not correct the steering problem, a brake-band replacement and steering-clutch inspection may be required. This is a labor-intensive job that requires the cab to be tilted and the hydraulic oil and fuel tank be removed to gain access to the steering valve and clutch (fig. 1–58).

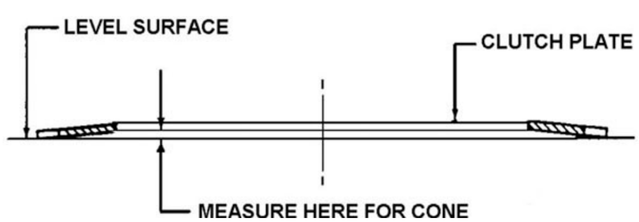


Figure 1–58. Steering-clutch disc measurement.

NOTE: This is a partial listing of the steps required to make the steering system repairs. Always consult the technical order for the vehicle you are repairing. Additionally, it is a good idea to tag the hydraulic hoses and wires before you remove them, making the reassembly easier and faster.

Steering-Clutch and Clutch-Disc Repair	
1.	Remove the steering valve and cover.
2.	Remove the steering clutch and brake-band assembly.
3.	Remove the brake band from the steering clutch.
4.	Disassemble and inspect steering-clutch pack assembly.
5.	Measure each clutch disc (plate) for warpage as shown in figure 1–58.
6.	Replace the disc if the cone measurement exceeds 0.002 in.
7.	Place the steering clutch pack in the press.
8.	Press the clutch pack to obtain a reading between 660 to 880 lbs.
9.	The total thickness of the compressed clutch pack should meet manufacturer's specifications (verify in the technical order). If necessary, you *may have to add or remove clutch discs* at the pressure plate end to obtain this measurement.
10.	Reassemble the components in the reverse order of removal.
11.	Torque to proper specifications.

Troubleshooting track system malfunctions

Typically, some problems you are likely to encounter in the track system are the results of excessive component wear caused by the lack of proper maintenance or improper adjustments. Some problems are easily corrected by adding fluid or a simple track adjustment. Other problems may not be so obvious or easy to fix. When this is the case, your job is to determine the amount of component wear by comparing the measurements you take on the crawler tractor to the ones specified in the technical order.

Master and track links

A good starting point in determining the overall condition of the track system is measuring the master-link pin pitch. You will find the master pin wears more than the other pins due to it having shorter bushings. Measure the master-link pin pitch using the following two steps:

1. Ensure the track is *tight* and the master link is centered *between* the drive sprocket and carrier roller.
2. Measure the master-link pitch between the rear edge of the pin in front of the master pin to the front edge of the master pin with a ruler or tape measure as shown in figure 1–59.

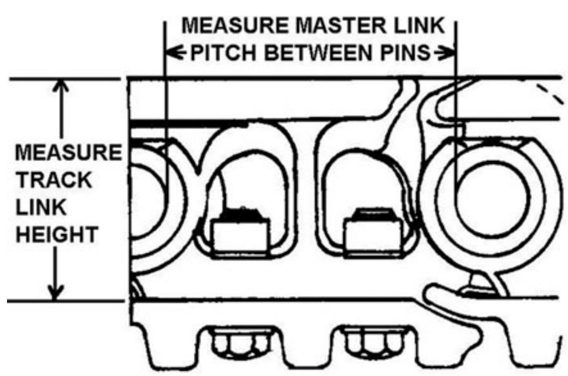


Figure 1–59. Measuring the master-link pin pitch and track-link height.

Measure the track link height to determine the amount of wear using the following steps:

1. Insert a sliding “T” square *or* ruler into the underside of the track link between the links. Make sure the track link is clean and the ruler touches the *bottom* of the shoe.
2. Obtain the measurement between the bottom of the shoe and the bottom of the track link.

The amount of pin and bushing wear is known as “track pitch.” You will find the track becomes longer as the pins and bushings wear. This measurement should be performed in the following manner with minimal track sag:

1. Rotate the track until the chain master link is on the front idler.
2. Make sure the pins you are measuring are at least four links behind the track master link.
3. You obtain this measurement much in the same manner as the master-link pin pitch measurement. However, in this case, you measure from the rear edge of the first pin to the rear edge of the next pin.

Carrier and track rollers

If you find the carrier rollers are worn beyond the manufacturer’s specifications, they must be rebuilt or replaced. Determine the amount of excessive roller wear by using the following steps:

1. Inspect the rollers for flat spots.
2. Measure the roller at the widest wear point with a caliper.

The track rollers are checked much in the same manner as the carrier rollers with one exception: you must elevate the track frame to expose the bottom of the rollers. Do this by following these steps:

1. Remove the adjustment cylinder grease fitting cover bolts and cover, located on the rock guard between the carrier rollers.
2. Slightly and very carefully, loosen the track adjustment cylinder grease fitting.
3. Have an assistant slowly drive the crawler tractor in reverse, as you carefully install a sprag bar between two sprocket teeth (fig. 1–60). This forces the front idler to retract by not allowing the track bushings and sprocket teeth to engage.

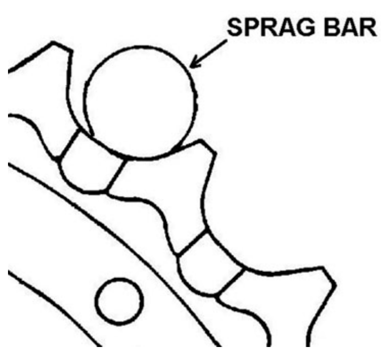


Figure 1–60. Sprag bar installation.

Have an assistant drive the crawler tractor forward just enough for you to remove the sprag bar. Now you have obtained the maximum track sag at the top of the track.

1. Now you have to get all the track sag at the bottom of the track frame. Do this by placing large wooden blocks under the front and rear of the track. Also support the track frame with heavy-duty jack stands. When you have the tracks properly elevated, the track will sag at the bottom enough to expose the bottom of the track rollers.
2. Inspect each roller for flat spots, and then measure each roller with a caliper in the same manner as you did carrier rollers.

Grousers

Measure the grouser height by following these steps:

1. Measure the grouser height from the underside of the shoe to the top of the grouser (fig. 1–61).
2. Do this on several grousers to obtain the average amount of grouser wear. Replace or recondition the grousers, if required, in accordance with the technical order.

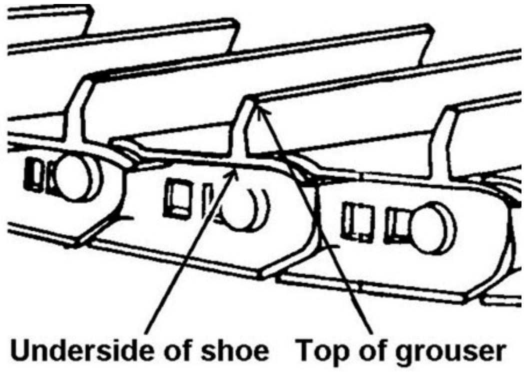


Figure 1–61. Measuring grouser height.

Drive sprocket

Determining the amount of drive sprocket wear requires the measurement of the sprocket in at least three places: pitch diameter, tooth base thickness, and tooth width. Refer to figure 1–62 as we discuss each part of the sprocket. Measure several sprocket teeth to obtain the overall amount of sprocket wear. Then compare the measurements taken with the technical order specifications.

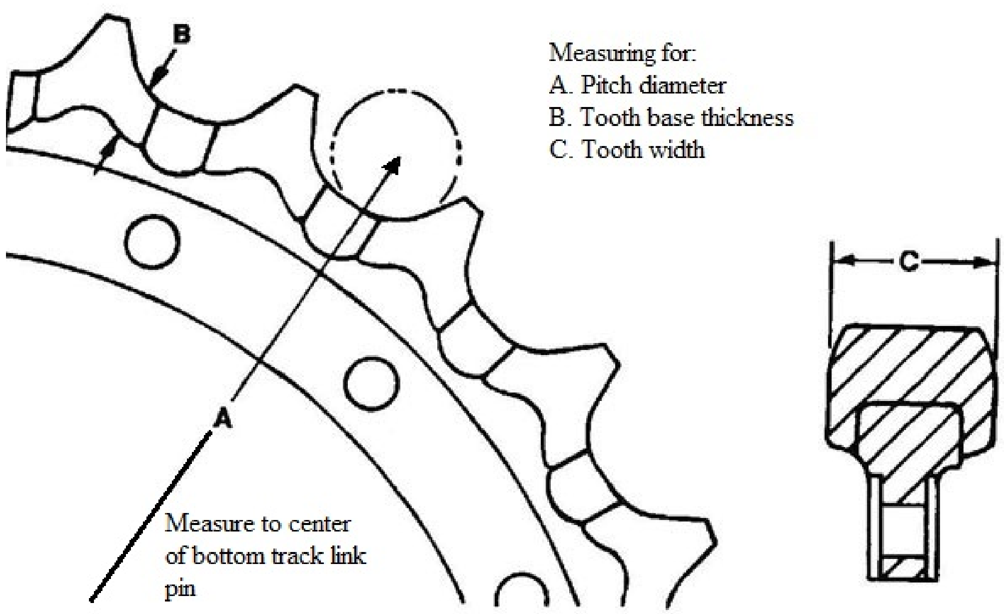


Figure 1–62. Measuring sprocket tooth wear.

Measure the drive sprocket for wear in the following three places. If any measurement fails to meet the technical order specification, part replacement is required.

1. The *pitch diameter* of the sprocket should be measured from the center of the top track link (A) pin to the center of the bottom track link pin.
2. Determine the *tooth base thickness* (B) by measuring the distance between the bottom and the top of the sprocket tooth. Again, change the sprocket ring gear when the thickness does not

meet technical order specifications. The ring gear should also be changed when the hardened layer on the outer surface of the teeth wears off.

3. The *tooth width* (C) is measured from each side of the tooth.

Recoil spring

Adjustment of the recoil springs (known as track sag) is necessary to maintain the proper sag of the track. Track sag is adjusted to match different operating conditions. Operating in an environment of loose sand, mud, snow, and so on requires less track tension. Hard packed surface operation requires a tighter track. Track tension has nothing to do with traction; it is only used to prevent excessive *wear* on the track and track frame components.

If a track is too tight, a great amount of friction will exist between the pins and bushings. This friction causes accelerated wear to the pins, bushings, links, sprocket, and idler. A severely tight track can cause extreme heat and decreases the hardness of the pins and bushings. In extreme instances, pins and bushings may become so hot that they fuse together. An extremely tight track adjustment can also cause damage to the final drive assembly hubs, bearings, and gears.

If the track adjustment is too loose, service life is reduced. Excessively loose tracks fail to stay aligned properly and tend to come off when the crawler tractor is turned. This also causes extreme wear on the idler center flanges, roller flanges, and the sides of the sprocket teeth. A loose track tension adjustment also permits the track chain to jump one or more of the drive sprocket teeth. This occurs when the tractor is moving in reverse. This action causes unnecessary wear to the sprocket teeth and track bushings.

Track tension adjustment varies according to the make and model of the crawler tractor. Check the applicable technical order before making any adjustments. On most crawler tractors, the amount of track sag is measured midway between the two top carrier rollers. However, the measurement for the crawler tractor we are discussing is taken between the idler roller and the first carrier roller. To obtain the most accurate measurement, always make sure the track is free of dirt and debris.

Track sag adjustment

The track sag adjustment procedure is accomplished as follows:

1. Drive the crawler tractor forward onto a level surface.
2. Place a straight edge on the top of the track between the front idler and carrier roller (fig. 1–63).
3. Measure the distance between the bottom of the straight edge and the top of the track to obtain the amount of track sag.
4. If the track sag is too great, remove the grease fitting cover on the rock guard to expose the adjustment grease fitting. Inject a small amount of grease into the fitting with a handheld grease gun until the proper track sag is reached. Adding grease tightens the track tension, decreasing the track sag.
5. If it becomes necessary to increase track sag, slightly loosen the grease adjustment valve fitting to relieve a slight amount of grease. Tighten the grease adjustment valve fitting and install fitting cover.

CAUTION: The grease in the adjustment cylinder is under extreme pressure from the recoil spring. Loosening the valve fitting too much poses a danger to you.

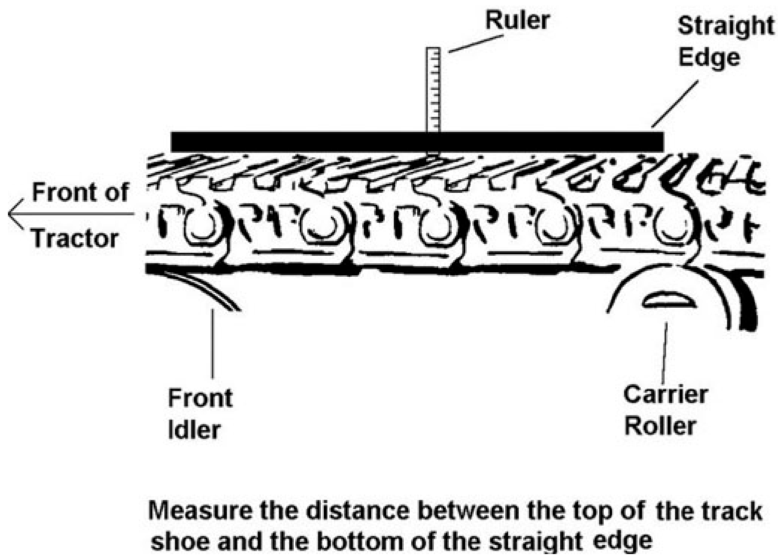


Figure 1-63. Measuring track sag.

Track repair and removal

Track components will eventually wear to the point where the track can no longer be adjusted or the components have exceeded the acceptable wear limits. You should know the overall condition of the track by comparing the measurements you made previously with the wear limits in the technical order. With all these factors in mind, it is time to decide whether to recondition or replace the track.

Track reconditioning consists of replacing pins, bushings, broken sections, and rebuilding the track chains. Since wear occurs on one side of the link pins and bushings, some manufacturers recommend reversing the part. All of the pins and bushings must be pressed out and rotated 180°. This procedure reverses the contact point of the bushings with pins and provides a new surface on the pin and sprocket.

The following is a general outline of the track removal procedures for most crawler tractors with a split master-track link. Always refer to the applicable technical order for specific track removal procedures. Track removal procedures include the following steps:

1. Position the track chain so that the master link is on the rear side of the drive sprocket.
2. Block the chain assembly below the master chain link.
3. Place a block under the final drive assembly and under the rigid crossbeam so that the track assemblies are off the ground.
4. Loosen the tension on the track chain by releasing the track adjustment cylinder grease fitting.
5. Remove the shoe from the master link. Use jack stands that are capable of supporting the weight of the crawler tractor in addition to the blocks.
6. Pry the master link apart. Some crawler tractors have a master pin that requires a hydraulic pin press to remove the pin.
7. Use a suitable hoist and sling to remove the track chain from under the vehicle.
8. Reassemble the components in the reverse order.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit

006. Cab controls

1. What is the difference between the modern crawler tractors and the older model bulldozers?

2. How is the left and right side of the tractor determined?

3. How does an operator control the steering on a crawler tractor?

4. What notifies the operator of a tractor system malfunction?

5. What is the purpose of a transmission manipulator?

6. How many speeds does the transmission have?

7. When is the crawler tractor parking brake automatically applied? What type of parking brake is used on this tractor?

8. What makes the crawler tractor differ from a bulldozer in regards to its capabilities of moving materials?

9. What is the purpose of the clamshell attachment?

10. How is the winch driven, and where is the winch located on the crawler tractor?

007. Powertrain and final drive assembly

1. Why is the crawler tractor powered by a diesel engine rather than a gasoline engine?

2. What makes the crawler tractor cooling system unique?

3. In which direction do you direct the cooling system fan's airflow for summer operation?

4. What voltage is required for the crawler tractor's starting system?

5. What type of hydraulic control system is used for the tractor components and attachments? List the components and attachments that use this system.

6. What type of hydraulic pump is used for the crawler attachments?

7. How is the speed of the crawler tractor controlled?

8. What gear type is used in the final drive assembly of the crawler tractor?

9. How is turning of a crawler tractor actually accomplished?

10. How are the steering clutch packs engaged and released?

11. What is the purpose of the master link in the track chain?

12. What are the grousers, and what is their purpose on the crawler tractor?

13. What is the purpose of the crawler tractor front idlers?

14. Describe how the front idler is able to absorb the forces of an impact without damaging the tractor?

15. What is the likely result of improper front idler alignment?

16. What is the carrier rollers used for on the crawler tractor?

17. What is the track rollers used for on the crawler tractor?

008. Crawler tractor maintenance

1. What is the first step in isolating a fluid leak in the final drive?

2. Premature wear of the final drive inner and outer sprocket support bearings can be avoided by adjusting the bearing preload with what?

3. When determining the amount of bearing preload, what must be done to the three cap screws prior to installing them into the final drive sprocket-bearing cage?

4. When troubleshooting a steering system problem, what is the simplest adjustment you can make that does not require major component disassembly?

5. What action should be taken if the total thickness of the steering clutch pack does not meet the manufacturer's specifications?

6. What causes some of the common problems found in the track system?

7. What is a good starting point in determining the overall condition of the track system?

8. What are the procedures for measuring the crawler tractor master-link pin pitch?

9. Why is it necessary to measure the track link height?

10. What steps do you take to determine excessive carrier roller wear?

11. How does the inspection of the track rollers differ from a carrier roller inspection?

12. Specifically, where is grouser height measured on the crawler tractor?

13. What three measurements are required to properly assess the amount of drive sprocket wear on the crawler tractor?

14. What is adjusting the crawler tractor track recoil spring tension also called?

15. What is the purpose of adjusting track tension?

16. What damage typically results from a track tension that is too tight?

17. What damage typically results from excessively loose track tension?

18. If you have excessive track sag, what is the procedure to tighten the track tension?

19. Track reconditioning consists of replacing and rebuilding what components?

20. Where is the track chain master link placed on the tractor when preparing to split the track on the crawler tractor?

1–4. Skid Steer

In this lesson, we will discuss a piece of equipment that isn't new to the Air Force but may be new to your workcenter. For years, skid steers were purchased and maintained by using organizations as an equipment item. In most cases, vehicle maintenance Airmen were not responsible for their upkeep. However, a few years ago, they were absorbed into the Air Force fleet as registered vehicles and became our responsibility to maintain. The Air Force Occupational Analysis Division surveyed the vehicle maintenance career field, and a training deficiency related to skid steers was identified. As a result, our leadership made the decision to implement training for these vehicles in our journeyman program. You and your peers will be among the first Air Force vehicle maintainers to become trained experts on these unique and highly capable vehicles.

009. Skid-steer fundamentals

As a result of the historically decentralized purchasing, you can expect to encounter skid steers of all ages, makes, and models during your career. To name a few, you're likely to see equipment manufactured by Bobcat, Case, Caterpillar, John Deere, Kubota, and more. The specifics of each system, and their included features, will vary from one machine to the next, but the fundamental characteristics of skid steers will remain relatively consistent. For our discussion, we will focus our attention on the Bobcat S650 skid-steer loader (fig. 1–64).

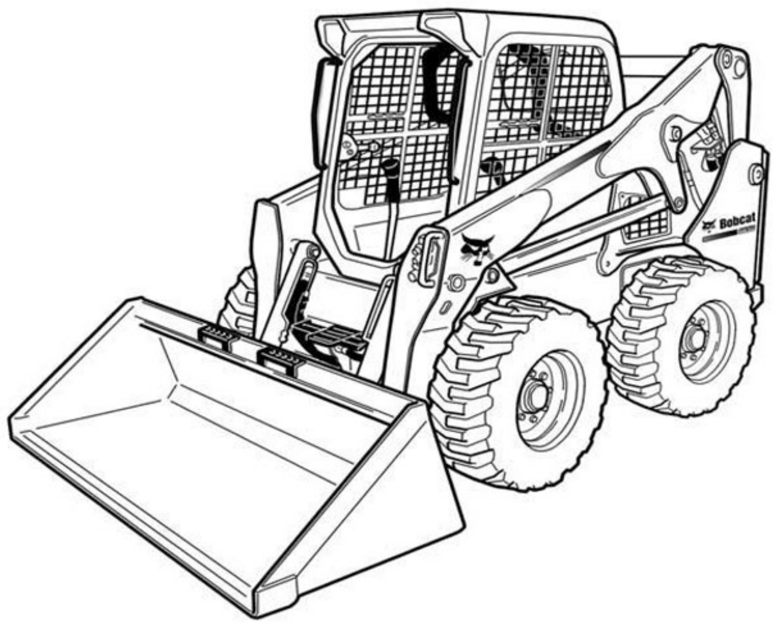


Figure 1–64. Bobcat S650 skid steer.

So what is a skid steer? Skid steers are small, engine-powered machines equipped with lifting arms. These lifting arms attach to a carrier that can readily accommodate a wide variety of attachments to perform different functions. This lesson will discuss the fundamentals of a skid-steer's individual systems.

Engine

While a skid steer may use diesel, gasoline, or liquid propane as a fuel source, a typical model is powered by a four-cylinder, liquid cooled, diesel engine. The S650 is equipped with a 3.3 liter direct injected turbocharged diesel engine manufactured by Kubota. To meet emission requirements, the engine is outfitted with an exhaust gas recirculation (EGR) system. It produces 74.3 hp and 195 ft. lbs. of torque.

Although this may not seem like much power, it's more than enough for a skid steer to earn its keep on the job site. For cold starting, the engine is equipped with glow plugs that will automatically activate, as needed, when the vehicle is placed in RUN mode. The cooling fan is driven hydraulically, and fan speed is determined using inputs from the engine coolant temperature sensor and the hydraulic fluid temperature sensor.

The engine is mounted transversely (crossways) and is accessed by opening the rear door. From here, the operator has access to check and adjust engine fluid levels and perform pre-operation inspections. Additionally, most basic maintenance actions are performed through the rear door. However, when working on the front or bottom of the engine, such as to change the water pump or oil pan gasket, it is often easier to remove the engine because there may not be enough clearance to remove bolts or components. Consult the service manual for detailed instructions and specialty tool requirements.

Hydraulics

Nearly everything on a skid steer is powered by the hydraulic system. The hydraulic fluid reservoir is located behind the operator's cab, under the rear grille, on the right side of the loader, and contains a vented fill cap with a fluid screen to keep contaminants out of the reservoir.

The hydraulic system contains two filters to keep the fluid clean: main and charge flow. The main filter removes contaminants before fluid enters the gear pumps, including oil returning from the main valve. The charge flow filter removes contaminants after the charge pump. The system controls fluid temperature with an oil cooler located underneath the rear grille, between the radiator and air conditioning (AC) condenser.

Hydraulic pump

The hydraulic pump is actually a combination of gear pumps that supply hydraulic fluid to multiple systems. It is attached to the end of the hydrostatic pumps and is located on the right side of the loader between the hydraulic control valve and the engine. A dedicated charge pump provides fluid to the hydraulic fan motor and charge pressure to the hydrostatic pump.

As an option, the S650 can be equipped with a high-flow hydraulic pump. With the high flow, the pump has an additional section that provides increased flow controlled by an external valve, which is actuated from a button in the cab. This option allows the machine to use attachments that require a higher flow rate than the base machine is capable of.

Hydraulic control valve

Located below the operator's cab, on the right-hand side inside the main frame, is the hydraulic control valve (fig. 1–65). It uses spool valves to direct the flow of hydraulic fluid to the lift, tilt, and auxiliary functions. With standard controls, the spools that control lift and tilt functions are operated by linkage connected to the foot pedals.

When equipped with the Advanced Control System (ACS) or selectable joystick controls (SJC), the spools are operated using electronic control handles or levers that send an electronic signal to actuators at the hydraulic control valve (fig. 1–66).

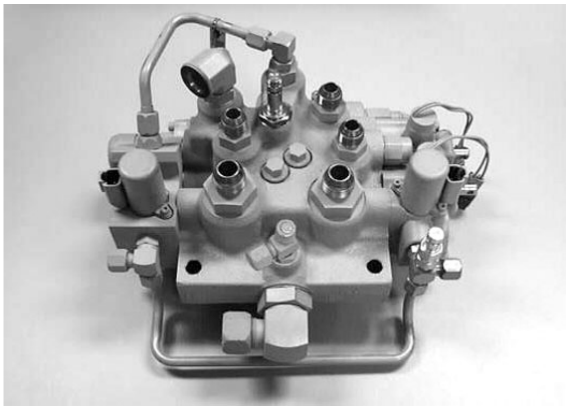


Figure 1–65. Standard hydraulic control valve.

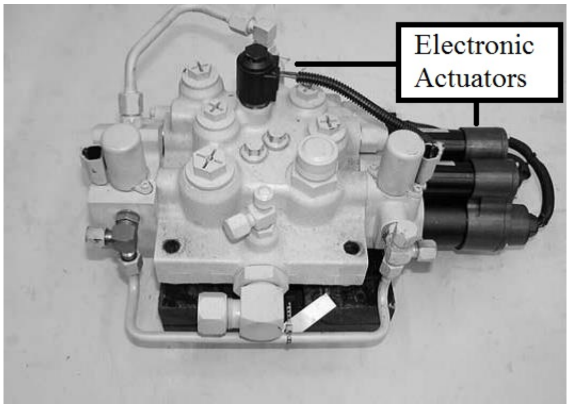


Figure 1–66. ACS or SJC hydraulic control valve.

The auxiliary function operates using pilot pressure. One solenoid is located on each side of the spool. One at a time, these solenoids are activated by a switch on the right-side control handle or lever, sending pilot pressure to one side of the spool and forcing it to shift.

Main relief valve

The adjustable main relief valve is located near the bottom of the hydraulic control valve, facing the front of the loader. It limits hydraulic system pressure by opening at a specified pressure, allowing hydraulic oil to flow back to the reservoir.

Bucket position valve

The bucket position valve allows the operator to hold the attachment at the same angle relative to the ground while raising and lowering the lift arms, without using the tilt function. It is mounted to the inside lower right rear side of the frame.

Bob-tach (power) block

Bob-tach is Bobcat's brand of attachment mounting. Power Bob-tach allows the operator to hydraulically control the levers that actuate the wedges used to secure attachments using a switch on the right switch panel. The power Bob-tach block is located on the right side of the skid steer in front of the engine on the back side of the hydraulic pump.

Front auxiliary hydraulic coupler block

The front auxiliary hydraulic coupler block (fig. 1–67) supplies hydraulic fluid to the attachments. It is located at the front of the left-side lift arm and houses two main auxiliary couplers along with a case drain coupler.

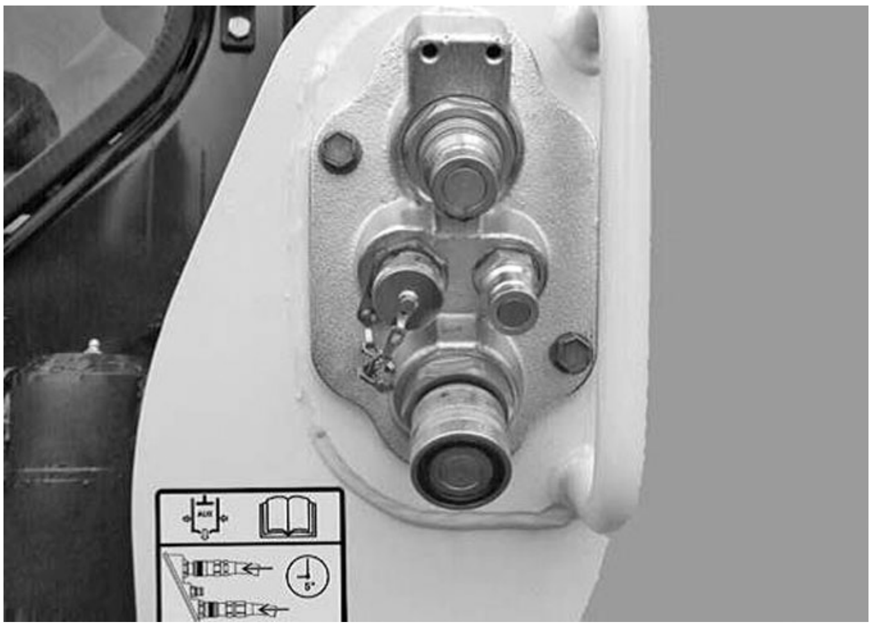


Figure 1–67. Front auxiliary hydraulic coupler block.

Cylinders

The S650 is equipped with up to five double-acting cylinders: two lift cylinders, two tilt cylinders, and one cylinder to actuate the auxiliary Bob-tach wedges (optional).

Rear auxiliary diverter valve

The rear auxiliary diverter valve is optional. It diverts oil from the main inlet to two sets of rear auxiliary couplers: one on each side of the rear-frame uprights. These couplers are used for rear-mounted attachments, and the right side couplers are specifically for older attachments.

Lift arm bypass control valve

The lift arm bypass control valve is located on the right side. It allows the lift arms to be manually lowered. It is operated by pulling on the valve and turning the knob clockwise 90°.

Hydrostatic drive

Skid steers are propelled using a hydrostatic drive system. This system consists of a tandem hydrostatic pump and two hydrostatic motors, allowing forward and reverse motion. The hydrostatic pump is driven by the engine using a drive belt; it supplies fluid to the hydrostatic motors. The belt has a spring-loaded idler, which maintains the correct tension and does not require adjustment. Charge pressure helps replenish fluid lost due to internal leakage within the components. A drain manifold returns hydraulic oil to the reservoir.

Power flow begins at the engine, which drives the hydrostatic pump. The hydrostatic pump provides fluid flow to drive the two hydrostatic motors, which transfer power through the hydrostatic motor carriers to the sprockets. Two chains per motor carrier transfer power from the sprockets to the front- and rear-axle shafts. Axle shafts then transfer power to each individual wheel of the skid steer.

Hydrostatic drive motor

High pressure from the hydrostatic pumps drive the hydrostatic motors. Single-speed motors do not have an internal brake. Two-speed motors contain a spring-applied, pressure-released braking system to stop the loader. This braking system is located on the end of the two-speed motor.

Inside the endcap of the motor, a shuttle valve helps keep the motors cool by mixing case drain oil with cooled, low-pressure oil from the charge circuit. High-pressure oil from the hydrostatic pumps shifts the shuttle valve. If the valve sticks, it may cause a delay or lack of drive, and an overheated hydrostatic motor may result. The two hydrostatic motors are mounted to motor carriers.

Hydrostatic motor carrier

The hydrostatic motor carriers are mounted to the chain case, where the drive chains are housed. The carrier mates the drive motor to the transmission chain case. The motor carrier contains a shaft, which rotates on two tapered roller bearings and has two sprockets that turn the drive chains. A seal isolates chain case oil from hydrostatic motor case drain oil. Carriers are interchangeable between the left and right of the loader.

If equipped with SJC, a speed sensor is installed in the motor carrier housing and senses a disc fixed to the shaft to determine if the drive motor is rotating. The SJC hydrostatic motor carrier also has a brake disc mounted to the shaft if it is a single-speed loader.

Charge pressure

Charge pressure supplies oil to the hydrostatic pumps, which is regulated by a relief valve inside the hydrostatic pump. Charge pressure is used to replenish hydrostatic fluid lost from the drive circuit, pump, and motor due to internal leakage and from the shuttle valve in the hydrostatic motors.

Charge pressure also operates other hydraulic functions, to include shifting the auxiliary spool and provide pilot pressure to open the Bobcat Interlock Control System (BICS) for tilt and lift in the main control valve.

Charge pressure is monitored using a pressure-sender unit on the fan motor. An alarm will notify the operator of charge pressure problems based on preprogrammed settings relative to the loader type and installed options.

Hydrostatic pump

The hydrostatic pump is located in the center of the mainframe mounted to the engine flywheel housing and consists of two hydrostatic piston pumps joined together. These pumps provide bidirectional flow to the two separate motors. Two hand levers control the flow and direction. Each lever controls the pump controlling the corresponding side of the machine.

The pump contains replenishing valves, which provide replacement fluid to the low-pressure side of the hydrostatic circuit. This fluid compensates for normal internal leakage and flow of fluid to the oil cooler. It also keeps high-pressure fluid out of the low-pressure side of the system.

SJC hydrostatic pump

The SJC hydrostatic pump is a fully proportional dual-piston pump housed within one pump casing. The endcaps can be removed to gain access to the rotating assemblies and all ports, which are labeled on the pump casting.

An external charge pump feeds charge pressure to the hydraulic controllers, and when 12 volts is applied, the electrical solenoids shift a spool in the hydraulic controller to direct flow to a servo piston. The servo piston strokes the swash plate in the rotating group. The rotating group provides flow to A or B ports on the pump, which is then sent to the drive motors to obtain forward or reverse drive motor rotation. Swash-plate movement is monitored by swash-plate angle sensors on the bottom of the pump.

Two-speed/brake valve

The two-speed/brake valve (if equipped) is on top of the chain case, in front of the hydrostatic pump. High range is selected by a switch on the handle (manual loaders) or the left joystick (SJC loaders).

Selecting high range causes the Bobcat controller to energize the two-speed solenoid. This causes the valve to shift, which directs charge pressure to the shift spool in each motor, allowing them to move into high range. Selecting low range de-energizes the solenoid, allowing spring tension to return the shift spools to low range.

Drive system

The chain case contains the drive components, including the drive chains, sprockets, axle shafts, hubs, drive motor carrier, and a brake, if single speed (fig. 1–68).

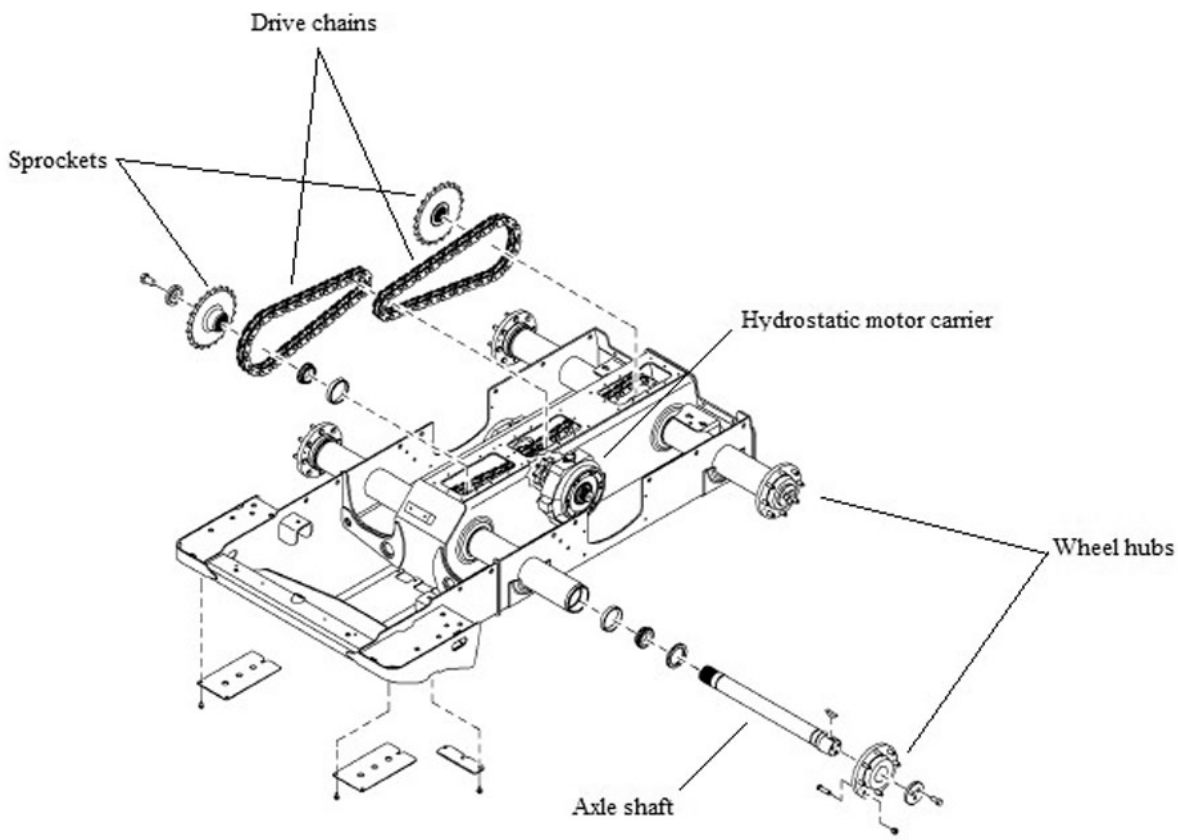


Figure 1–68. Chain case components.

The brake is part of the drive motor in a two-speed system. In either case, the brake is designed to hold the machine in place and is operated by a switch. To lubricate chains and bearings, the case is partially filled with hydraulic fluid. A cover on the bottom of the chain case allows access to a fuel tank drain plug.

Single-speed brake

The single-speed brake is spring-applied and electrically released. A wedge drops into two notched brake discs attached to the carrier shafts to apply the brakes. When the brake is switched off, the main Bobcat controller sends power from a relay to an electric solenoid that pulls the wedge away. The brake will automatically apply if engine speed drops below 700 rpm, the seat bar sensor fails, or if there is a break in the wires to the solenoid.

Two-speed brake

The two-speed brake is spring-applied and pressure-released and is self-contained at the end of each drive motor. The brake block solenoid receives power from a relay to open the circuit and release charge pressure oil from the brakes. The charge pressure oil pushes the spring away from the discs, allowing the motor to move. When the brakes are switched off by the operator, a signal from the Bobcat controller holds the solenoid open, allowing continuous oil flow to hold the spring away from the brake discs. When the signal is interrupted, the solenoid closes the circuit, charge oil is shut off, and the brakes are applied. As with the single-speed brake, this occurs if the engine drops below the specified rpm, the seat bar sensor fails, or if there is a break in the wires to the brake block solenoid.

Tires and wheels

Most skid steers you'll encounter, including the Bobcat S650, have four wheels and tires. The tires typically have an aggressive tread pattern and are of a "high flotation" design for optimal off-road performance. They may be pneumatic, foam-filled, or solid rubber tires, depending on the application and needs of the user.

Tracks

Occasionally, you may come across a skid steer with rubber or metal tracks. This can be accomplished in one of two ways. First, specially designed tracks can be installed over the existing tires, one track per side. These tracks can be purchased from the manufacturer or aftermarket suppliers and installed or removed fairly quickly.

Second, skid steers can be designed and purchased as track vehicles from the manufacturer. While this type of skid steer still employs a hydrostatic drive system, it is different than a wheeled machine. Instead of having chains connecting sprockets on the front and rear axles, the track itself rides along a front idler, top roller, bottom rollers, drive motor, and track frame. This system requires additional maintenance, as proper tension must be maintained on the track. We will discuss track maintenance later in the unit under the drive track adjustment lesson.

Cab controls

Operating a skid steer is quite different from driving a passenger vehicle. In the cab, you will find a combination of buttons, levers, and foot pedals. Control panels, with banks of buttons and lights, are along the roofline on the left and right side. This is where the key is inserted (or the starting password is entered, if equipped with a keyless start panel) to start the vehicle, the brake is released, headlights and beacon lighting are controlled, and the high-flow hydraulics are engaged.

This is also where warning lights will be displayed and where you can access trouble codes in machines equipped with onboard diagnostics. Use the applicable owner's and service manuals to cross-reference any diagnostic codes displayed. Some models will have heating, ventilation, and air conditioning (HVAC); if so equipped, the controls may be located on these panels as well.

Instrument panels

From the operator's seat, there is an instrument panel to the left and the right along the roofline. The left panel is the same in all S650s, regardless of options, while the right panel will vary based on whether the machine was ordered with a standard key, keyless start, or deluxe instrumentation options.

Left panel

The left panel (fig. 1–69) is where most common gauges, indicator and warning lights, and buttons are found. Gauges include an engine temperature gauge and a fuel gauge. Warning lights include a general warning, engine malfunction, hydraulic system malfunction, engine coolant temperature, fasten seatbelt, seat bar up, parking brake applied, lift and tilt valve, and low fuel. Among the indicator lights, you’ll also find turn signals and lights. The screen can display operating hours, engine speed, maintenance clock countdown, battery voltage, and engine preheat countdown, along with settings such as speed management, steering drift compensation, and drive response. The screen will also display any service codes that have been logged. Buttons to actuate the lights, high-flow and auxiliary hydraulics, traction lock override, skid-steer operation, and the parking brake are found on the left panel.

Figure 1–69. Left panel.

Right panel

If equipped with the standard key panel, the right panel will have an ignition switch to turn the electrical system on or off and to start and stop the engine.

The keyless start panel consists of a keypad used to enter a number code or password, a run button to turn on the electrical system, start button to start the engine, and a stop button to stop the engine and turn off the electrical system, or a switch to perform these functions.

The deluxe instrumentation option can be identified by the display screen on the right panel. It also includes a keypad for entering a code or password. The screen displays system setup, monitoring, and error conditions. The keypad, scroll, and enter buttons are used to navigate through the display options. This configuration also includes a run, start, and stop button, or a switch.

Figure 1–70 reflects the different display options.

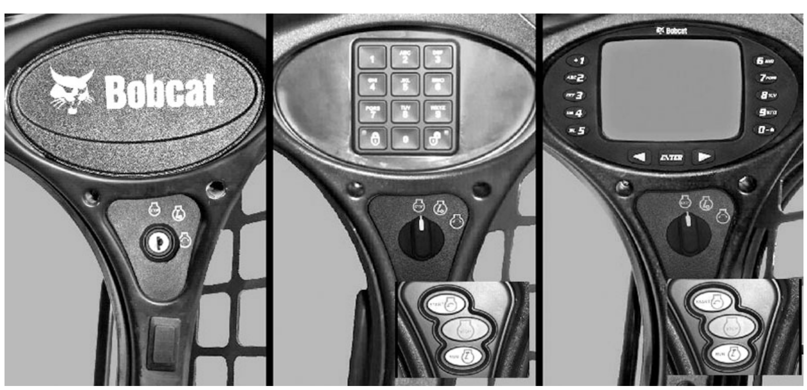


Figure 1–70. Right panels.

Switches

There are switch positions found on the left and right of the seat. These switches may be used to toggle hand and foot controls, select a control pattern, operate safety lighting (four-way flashers, rotating beacon, or strobe light), engage hydraulic bucket positioning, or operate the power Bob-tach system.

Throttle control

Engine throttle is primarily controlled by using a lever found on the right side of the cab. There may also be a pedal attached to the throttle lever to allow the operator to control engine throttle using his or her foot so he or she can maintain positive control of the hand levers or joysticks.

Hand levers

Unless it is equipped with SJC, two large hand levers, one on either side of the seat, is used for driving the skid steer. The left lever controls the left wheels, and the right lever controls the right wheels. Modulating these two levers allows the operator to turn the vehicle as needed.

The levers also have buttons and switches that are easily accessed by using your thumbs. These buttons operate the turn signals, front or rear hydraulics, continuous flow control, attachment functions, and horn. The bucket float control is also found here on ACS machines.

Joysticks

In SJC-equipped machines, the hand levers are replaced with joysticks, and the foot pedals for controlling lift and tilt are removed. With SJC, a switch is used to select between “ISO” and “H” control patterns. “ISO” utilizes only the left joystick to perform all driving functions, whereas “H” uses both joysticks, similar to the hand levers in standard and ACS machines.

Buttons and switches found on the joysticks control the same functions as a standard or ACS configuration, in addition to speed management, steering drift compensation, and drive response.

Look at figure 1–71 for examples of how to control the skid steer with different systems.

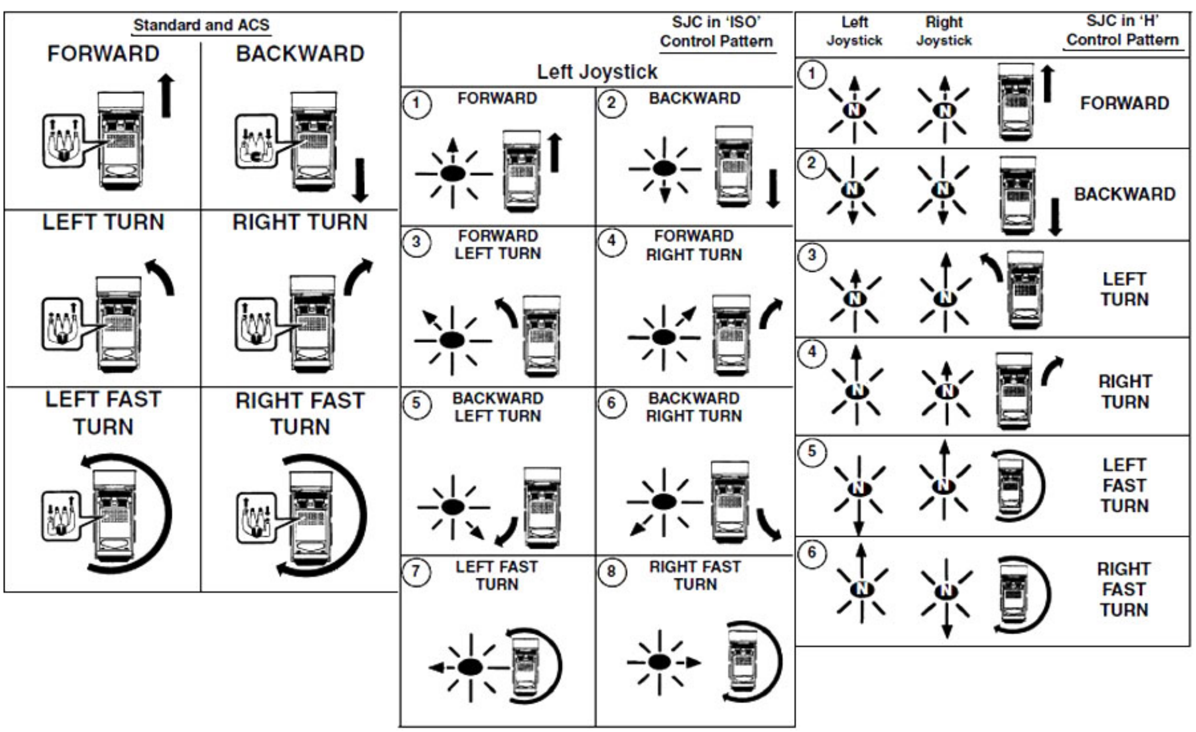


Figure 1–71. Driving the skid steer with hand levers or joysticks.

Foot pedals

Standard and ACS machines will have foot pedals to operate the lift and tilt functions. ACS machines provide the option to transfer lift and tilt control to the lever handles.

Always refer to the machine's operator's manual for specifics prior to operating a skid steer, as functions can vary greatly between makes and models.

Attachment carrier

Now, let's discuss how the attachments mount to the machine's carrier. As discussed previously, Bob-tach is the brand name of Bobcat's attachment system; however, most manufacturers' attachment systems function similarly. Depending on the options the machine is equipped with, securing an attachment is performed manually or with hydraulic assistance, such as with the powered Bob-tach. The method of locking attachments to the carrier is fairly simple, but care must be taken to ensure everything is positioned properly to minimize the risk of injury or damage to the machine or attachment. Whether it is a manual or powered system, there will be three points used to secure the attachment:

- One flange on the attachment that rests on the top edge of the carrier.
- Two wedges that extend from the carrier through holes on the bottom of the attachment.

The flange carries the weight of the attachment, while the two wedges provide stability and a means of locking and unlocking the attachment. In the manual system, the wedges are engaged or disengaged using two manual levers. In the hydraulic system, the levers are connected with a hydraulic cylinder that is actuated from the cab to engage the wedges.

To attach the manual system, begin with the attachment levers up, in the fully raised position, and the carrier tilted forward. Next, position the top of the carrier to rest completely under the flange on top of the attachment. Now, by tilting the carrier backward, the attachment will be lifted and will rest against the carrier frame. In this position, stop the engine, and lower the levers until they are fully engaged in the locked position. To verify, inspect the wedges to make sure they are fully extended through, and in contact with the lower edge of the attachment-mounting frame holes (fig. 1–72). Upon verification, connect the attachment hydraulics to the quick-connectors on the front of the machine.

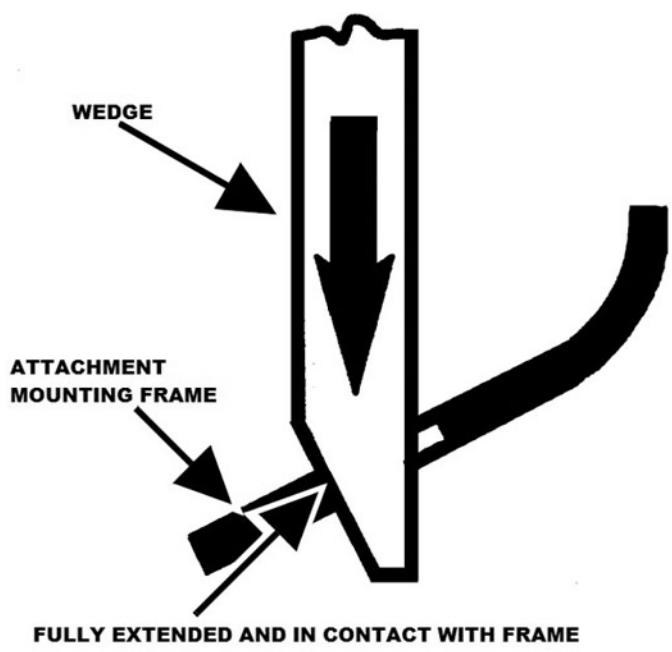


Figure 1–72. Correct wedge engagement with the attachment-mounting frame.

The procedure using the powered system is very similar. The key difference is instead of using manual levers, the operator uses switches or buttons in the cab, with the engine running, to engage the lock wedges into the attachment-mounting holes. It is still important to verify correct engagement before connecting the attachment's hydraulics.

Attachments

The variety and relatively low cost of skid-steer attachments and the ease of changing them are what makes the skid steer such a versatile and valuable piece of equipment. Attachments are available to perform a wide range of earthwork, construction, and agricultural jobs. Most are universal and interchangeable, even between different manufacturers, as long as the machine carrying it is capable of handling the weight and hydraulic requirements.

Typically, attachments connected at the front auxiliary hydraulic coupler block are driven or articulate in some way. An attachment may have one or more hydraulic motors, cylinders, or a combination thereof. Vehicle maintenance Airmen are responsible for maintaining the attachments along with the base machine, so it's important to be able to identify how the attachment functions.

When a customer brings his or her skid steer in for maintenance, make sure he or she provides a good description of the problems exhibited so the mechanic can start troubleshooting in the right place. It's also important for the technician to understand how the machine and attachment hydraulic systems interact so he or she can properly diagnose the root cause and correct the problem.

Electrical system

The S650 has a 12-volt, negative ground, alternator-charging system. It is protected by fuses located in or under the operator's cab. There is also a 100 amp master fuse in the engine compartment, under the air cleaner. The battery is located in the engine compartment as well.

Controllers

All S650 loaders have a gateway and auxiliary controller. On early models, they are located behind an access panel near the operator's left foot, and on later models, they are under the cab on the inner left frame. The gateway controller is the primary controller and provides information to all other controllers.

On ACS and SJC loaders, there will also be an ACS controller that processes information for lift and tilt functions. It is found in a grey, plastic shell with black potting. It communicates with the gateway controller using controller area network (CAN) communication wires and is capable of receiving software upgrades.

SJC loaders also require a drive controller to process drive function information. It is located near the operator's right foot behind an access panel. The drive controller is responsible for monitoring the position of the left joystick, pump swash-plate angles, and wheel speed sensor output. The SJC drive controller works with the ACS controller and communicates with the gateway controller. Like the ACS controller, it is capable of software upgrades. With SJC, both the lift and tilt and the drive functions of the loader are controlled by joysticks.

SJC speed sensors

If the loader is equipped with SJC, the controllers use speed sensors to detect if the drive motor is rotating. Like an anti-lock braking system (ABS) sensor, it is magnetic and counts magnetic pulses on a rotating disc. It is sealed with an O-ring to keep hydraulic oil inside the motor carrier.

The BICS

The BICS is an electronic system that protects the operator. It requires an operator to be seated in the cab with the seat bar fully lowered in order to use the lift, tilt, auxiliary hydraulics, and traction drive functions. It consists of traction lock, seat bar sensor, and the lift and tilt lockouts solenoid. Indicator lights on the left panel correspond to each of these items. The "Press to Operate" button activates the system to allow the operator to control the skid steer.

While BICS is the brand name used by Bobcat, other manufacturers will have similar systems designed to protect the operator.

Seat bar sensor

The seat bar sensor sends a signal that indicates whether the seat bar is in the up or down position. It is located on the left side of the seat bar.

Traction lock

The traction lock control system locks the drive system when the engine stops, similar to the function of a parking brake.

010. Skid-steer maintenance

As with any specialized piece of equipment, it's important to have the correct tools to troubleshoot, repair, or make adjustments to the various systems. While older skid steers that are mostly mechanical may only require basic tools and diagnostic equipment, such as meters and gauges, newer and more advanced skid steers often require specialized tool kits or a laptop with the manufacturer's software loaded.

It will be up to your flight leadership to determine which tools need to be added to your shop's tool crib and which jobs are better performed under contract maintenance. In this lesson, we'll discuss some basic safety principles, followed by electrical, hydraulic, and mechanical maintenance on a Bobcat S650. Next, we'll talk about some general procedures to adjust the tracks on a skid steer. For our purposes, we'll assume that our shop is equipped with all tools and equipment that is recommended by the manufacturer.

NOTE: The following procedures are discussed for educational and familiarization purposes only. Always consult the proper technical order or commercial manual prior to performing maintenance on a vehicle.

Skid-steer maintenance safety

In addition to standard shop safety principles, there are a few additional safety considerations when working with skid steers.

Lift arm support device installation

As a standard practice, do not work on skid steers with the lift arms elevated. If it's absolutely necessary to have the lift arms raised, ALWAYS secure the lift arms with an approved support device. A lift arm support device is included by the manufacturer and stows on the machine when not in use. Procedures to install the support device are in the following paragraphs.

First, remove the attachment from the skid steer. Place jack stands under the rear corners of the frame. The weight of the skid steer does not need to rest on the jack stands. They are placed as a precaution in case the skid steer tips back when the lift arms are elevated.

Remove the lift arm support from the stowed position, usually alongside the cab, below the lift arm. Have a second person assist with installing the lift arm support. One person should remain in the operator seat with his or her seatbelt fastened and the seat bar lowered until the device is safely installed.

The person in the operator's seat can now start the engine and raise the lift arms all the way up. The second person installs the support device over the rod of one of the tilt cylinders. The support device must be tight against the rod (fig. 1–73).

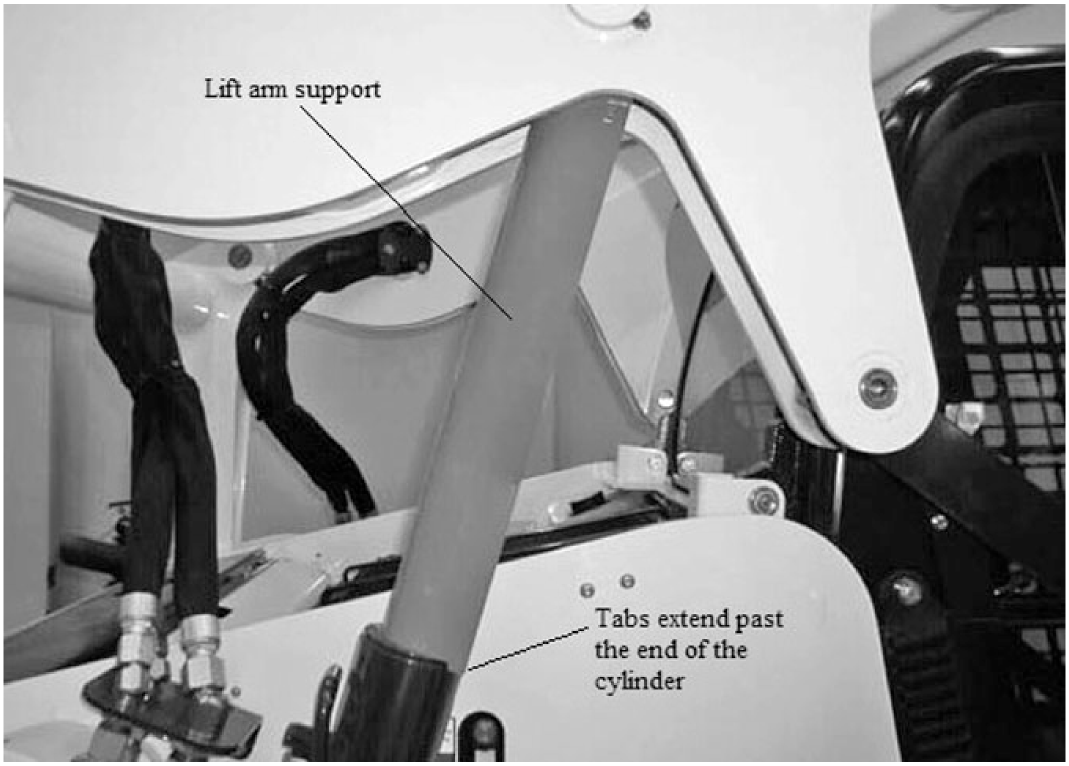


Figure 1–73. Correct wedge engagement with the attachment-mounting frame.

Now slowly lower the lift arms until the weight of the lift arms is resting on the support device. The support device tabs must go past the end of the cylinder.

Removal of the lift arm support device is the reverse of installation.

Raising and lowering the operator cab

More often than not, maintenance on a skid steer will require raising the cab to gain access to components. Since it also functions as a rollover and falling-object protective structure, the cab is quite heavy. Use the following procedures to safely raise the cab.

Begin by positioning the skid steer on a level surface and lowering the lift arms. If the lift arms MUST be up, be sure to install the lift arm support device, as previously discussed.

CAUTION: Stop the engine before raising or lowering the cab. The cab may contact the controls during raising or lowering, causing unexpected movement, and pose a risk of serious injury or death. Place jack stands under the rear corners of the frame, as a precaution.

Next, remove the nuts and washers at each front corner of the cab. The location and number of nuts and washers may vary by make and model. Now slowly lift the cab using the grab handles and bottom of the cab until it is all the way up and the latching mechanism is engaged.

To safely lower the cab, ensure the engine is stopped. Pull down on the bottom of the cab until the latching mechanism stops it. Support the cab and release the latching mechanism. Remove your hand when the cab moves past the latch stop. Use both hands to finish lowering the cab the rest of the way, then install the washers and nuts, and torque to specification.

Electrical maintenance

Electrical systems on skid steers vary greatly in complexity based on the age and equipment options. For instance, an older skid steer with standard controls will be far less elaborate, electrically, than a new model equipped with ACS or SJC and a deluxe instrumentation package.

The first thing you should check when troubleshooting any electrical system is the connectors and wiring associated with the function or component exhibiting problems. This is especially true in skid steers, as they're regularly subjected to highly abusive conditions. Constant vibration from the engine, terrain, and various attachments can wreak havoc on the electrical system by loosening grounds, rubbing wires, and weakening connectors. Excessive amounts of dust, dirt, and water can interrupt electrical flow, create corrosion, or amplify heat, causing damage to sensitive components. Once you've thoroughly inspected the system, move forward in troubleshooting components and correcting the malfunction.

In this lesson, we'll discuss the basics of how to test solenoids and how to inspect the BICS.

Solenoid testing

As you recall, a solenoid converts electric energy to mechanical by energizing an electromagnet to move an armature or plunger. Among other things, a skid steer may use solenoids to open or close spool valves, select high-flow rate hydraulics, choose high or low speed, or engage and disengage the brakes. Although it's a simple task, having the knowledge to test solenoids can save you a lot of time when troubleshooting a skid steer, due to the number in the system.

The first step in testing a solenoid is to disconnect the electrical connector. Then use a test meter to measure the resistance (ohm) across the coil (fig. 1–74). The schematic or service manual for the vehicle should provide a specific ohm reading for the solenoid coil. Remember that low resistance likely indicates a short in the coil, and a high resistance, especially if the meter reads "OL" or outside limits, likely indicates an open circuit.

Figure 1–74. Testing resistance across a solenoid coil.

If the solenoid fails the resistance test (too much or too little resistance), it will most likely require a replacement. However, if the solenoid passes this test, the next step is to remove it from the vehicle and perform a function test. This is accomplished by applying 12 volts directly to the solenoid coil by using jumper wires. When 12 volts is applied, an audible click should be heard, and, if the plunger is visible, you should see it move. If the click is not heard, or the plunger doesn't move, inspect the plunger for corrosion, rust, or dirt restricting its movement. If possible, try cleaning any contaminants off the plunger, apply 12 volts again, and see if the solenoid functions correctly.

BICS function check

Next, we'll discuss how to inspect the BICS and ensure it is operating correctly. A properly functioning interlock system is critical to the safety of skid-steer operators. The BICS must deactivate the lift, tilt, and drive functions as designed during this inspection.

Inspect the BICS

Begin by sitting in the operator's seat. The engine should be stopped with the key on. Lower the seat bar and disengage the parking brake. Press the PRESS TO OPERATE LOADER button. The lights for the SEAT BAR and LIFT & TILT VALVE on the left instrument panel should be off, and the PRESS TO OPERATE LOADER button will illuminate.

Next, raise the seat bar fully. The SEAT BAR, LIFT & TILT VALVE, and PARKING BRAKE lights on the left panel should turn on, and the PRESS TO OPERATE LOADER light will turn off.

Inspect deactivation of auxiliary hydraulics system

Again, lower the seat bar and press the PRESS TO OPERATE LOADER button. Press the auxiliary hydraulics button. The auxiliary hydraulics light will illuminate. When you raise the seat bar, the light must turn off.

Inspect the seat bar

To inspect the seat bar, sit in the operator's seat and lower the seat bar. Engage the parking brake and fasten the seat belt. Now start the engine and operate the skid steer at low idle. Press the PRESS TO OPERATE LOADER button. Now, fully raise the seat bar *while* raising the lift arms. The lift arms should stop. Repeat the test using the tilt function.

Inspect the traction lock

Begin by sitting in the operator's seat and lowering the seat bar. Engage the parking brake and fasten the seatbelt. Now start the engine and operate the skid steer at low idle. Press the PRESS TO OPERATE LOADER button. Raise the seat bar fully, and move the steering levers or joysticks forward and backward slowly. The skid steer should not move (traction lock should be engaged). Lower the seat bar and press the PRESS TO OPERATE LOADER button. Apply the park brake and again move the levers or joysticks forward and backward slowly. Again, the traction lock should be engaged and the skid steer should not move.

Inspect the lift arm bypass control

To inspect the bypass control, raise the arms off the ground about 6 ft. and stop the engine. Turn the lift arm bypass control clockwise one-fourth turn, then pull up and hold the knob until lift arms slowly lower.

Inspect deactivation of lift and tilt functions on ACS- and SJC-equipped machines

Begin by sitting in the operator's seat and lowering the seat bar. Engage the parking brake and fasten the seatbelt. Now start the engine and operate the skid steer at low idle. Press the PRESS TO OPERATE LOADER button. Raise the arms off the ground about 6 ft. Turn the key to off, or press the STOP button, and wait for the engine to completely stop. Now turn the key on or press the RUN button. Press the PRESS TO OPERATE LOADER button, and attempt to lower the arms. They should NOT lower. Next, attempt to tilt the bucket or attachment forward. The bucket should NOT tilt forward.

If any of these safety systems are not operating correctly, *do not* return the skid steer to the operator. Troubleshoot and correct the malfunctions before returning it to service.

Hydraulic maintenance

To keep a skid steer working in proper order, it's important for the hydraulic system to be operating within the specifications. Next, we will discuss the basic tests to help you isolate hydraulic malfunctions.

As with any hydraulic system, a thorough inspection to identify worn or kinked hydraulic lines and hoses and major or minor leaks should be your first step in troubleshooting.

Hydraulic function timing

An easy way to get a snapshot of how well the hydraulic system is performing is by checking the service manual for a function time specification, then perform the function check. For instance, the S650 manual specifies 3.9 seconds to raise the lift arms and 2.6 seconds to lower them. The manual also provides a spec for the bucket dump (2.3 seconds) and bucket rollback (1.7 seconds). Asking another technician for assistance with timing each function can give you clues to isolate malfunctions.

For example, if *all* functions are slow, it most likely indicates a system-wide problem, such as a maladjusted relief valve or failing hydraulic pump. However, if the lift arms are raising and lowering slowly, while bucket dump and rollback functions are normal, it may indicate a problem in the lift arm circuit, such as one or both lift cylinders in need of rebuild due to internal leaking.

Main relief valve testing and adjustment

If there is a hydraulic malfunction, check the flow rate and relief pressure of the hydraulic system. In order to test the main relief valve and perform adjustments, you'll need a hydraulic test kit with the correct fittings and a flow meter capable of *at least* 50 gpm.

Locate the correct hydraulic flow and pressure specifications for the skid steer. The following procedure is the same, regardless of whether the skid steer is equipped with standard controls, ACS, or SJC. This procedure requires one person in the cab of the skid steer and one operating the hydraulic tester.

Begin by raising the skid steer and placing it on jack stands. Position jack stands under the front axle tubes and rear corners of the frame. Next, connect the hydraulic tester to the front auxiliary hydraulic coupler block. Attach the IN port of the tester to the bottom quick coupler (female) and the OUT port to the top quick coupler (male) (fig. 1–75). Make sure the hydraulic tester restrictor is fully open.

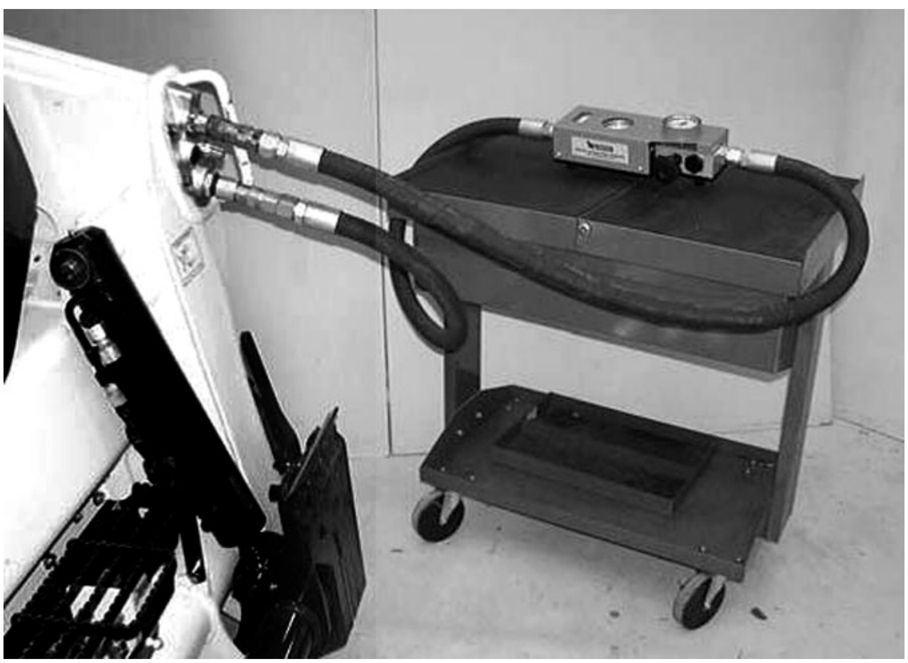


Figure 1–75. Connecting the hydraulic tester to the front auxiliary hydraulic coupler block.

Next, start the engine and run it at low idle. Activate the auxiliary hydraulics using the button on the left panel. An indicator light will verify the auxiliary hydraulics are active. Now, activate the continuous flow control, found in the trigger position of the right steering lever control or joystick.

Check the flow meter on the hydraulic tester to ensure your connections are correct and the tester is functioning correctly. If correct, increase the engine to full speed. Verify the free flow rate with the specification.

The hydraulic fluid temperature will need to reach 140°F. To help warm the fluid, turn the restrictor control on the tester until it reads 1,000 psi. When the fluid reaches proper temperature and with the engine at max speed, turn the restrictor control until the flow drops to zero. Check the relief pressure, and compare it to the specification.

If the relief pressure is correct, stop the engine and disconnect the hydraulic tester. No adjustment is required and the procedure is complete. Continue troubleshooting if a malfunction still exists.

If the relief pressure is incorrect, stop the engine and adjust the main relief valve. Locate the main relief valve below the operator cab, near the bottom of the hydraulic control valve and facing the front of the loader. It will have an adjustment screw and a lock nut (fig. 1–76). Loosen the lock nut, and turn the screw to make the adjustment. Turning it in will increase relief pressure, while turning it out will decrease it. Make small adjustments, followed by rechecking the relief pressure using the test procedures. When you reach the specified relief pressure, the procedure is complete. Make sure the lock nut is tight before lowering the operator cab. Verify whether or not the adjustment corrected the malfunction, and continue troubleshooting if necessary.

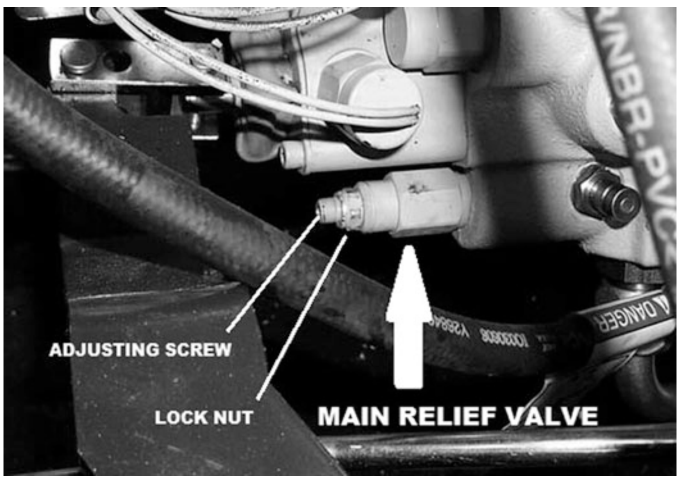


Figure 1–76. Main relief valve.

If you are unable to get proper pressure readings, the main relief valve may need to be replaced. If unable to get proper flow *and* pressure readings, test the hydraulic pump directly to determine if a rebuild or replacement is required. Refer to the appropriate service manual for direct pump testing procedures, if necessary.

Mechanical maintenance

While most problems you encounter on a skid steer will likely fall into the electric or hydraulic categories, occasionally you may have mechanical problems, such as misadjusted or damaged linkage or broken drive chains. So, we will discuss how to rectify these problems.

Control-pedal adjustment

Keeping the control pedals properly adjusted is important not only for operator comfort but also to ensure the tilt and lift valves are travelling full stroke. This adjustment is performed with the lift arms raised and supported and the operator cab raised.

Begin by loosening the two mounting bolts that are under the pedal, from the pedal-mounting bracket. Next, loosen the pivot bolt and nut on the pedal linkage (fig. 1–77).

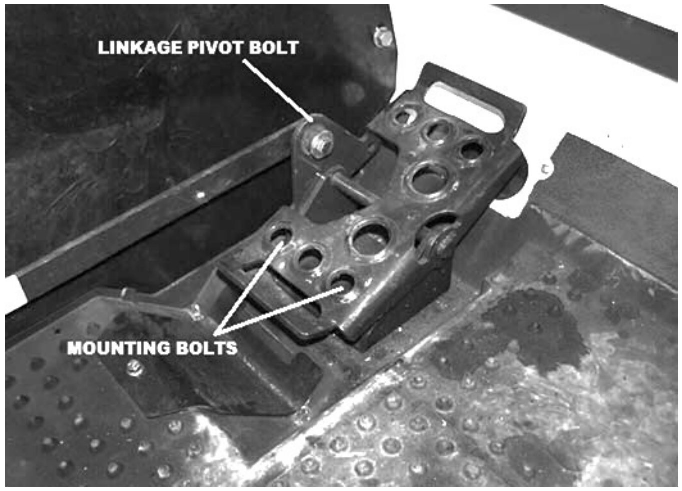


Figure 1-77. Pedal-linkage adjustment.

Inspect the bushing in the pedal for wear, and, if necessary, replace it. Tilt the pedal back and forth until a neutral angle is reached. There should be clearance under the rear of the rear of the pedal. Tighten the two nuts and linkage bolt and nut enough to test the pedal travel. The valve spool must travel full stroke without the pedal hitting the floor panel, and the pedals should be comfortable to actuate from the operator's seat to both extremes. When these two criteria are met, finish tightening the mounting nuts and linkage bolt and nut to proper torque.

Drive-chain replacement

Although the complete process of replacing a drive chain is well beyond the scope of this CDC, the following is a brief overview of the steps involved. This job should only be performed by following the appropriate technical order.

To begin, raise the lift arms and install the lift arm support device. Lift and block the skid steer, then raise the operator cab. Next, follow the steps to remove the control panel (assembly that houses the hand levers and steering linkage). Remove the front or rear chain case cover, along with the center chain case cover, and remove the fluid.

Next, follow the procedures for removing the brake disc, followed by the rear axle and sprocket, then the front, if necessary.

NOTE: To remove the front chain, you must remove the rear axle and drive chain as well.

Installation is the reverse of removal. If you are installing a new chain, you'll need a chain link tool and #120 chain adapter, which allows you to install the master link on the new drive chain.

Drive-track adjustment

If you're working on a tracked skid steer, it's very important to monitor the track tension. Tracks that become loose are prone to derailing or misfeeding on the sprocket. On the other hand, tracks that are too tight may rob power and can cause damage or accelerated wear to the track, bearings, rollers, sprockets, or drive motors.

There are normally two methods of adjusting track tension that you're likely to see on a skid steer. The first is by using a track-adjusting cylinder filled with grease (fig. 1–78). With this method, grease is added to or removed from a cylinder to extend or retract the ram and adjust track tension.

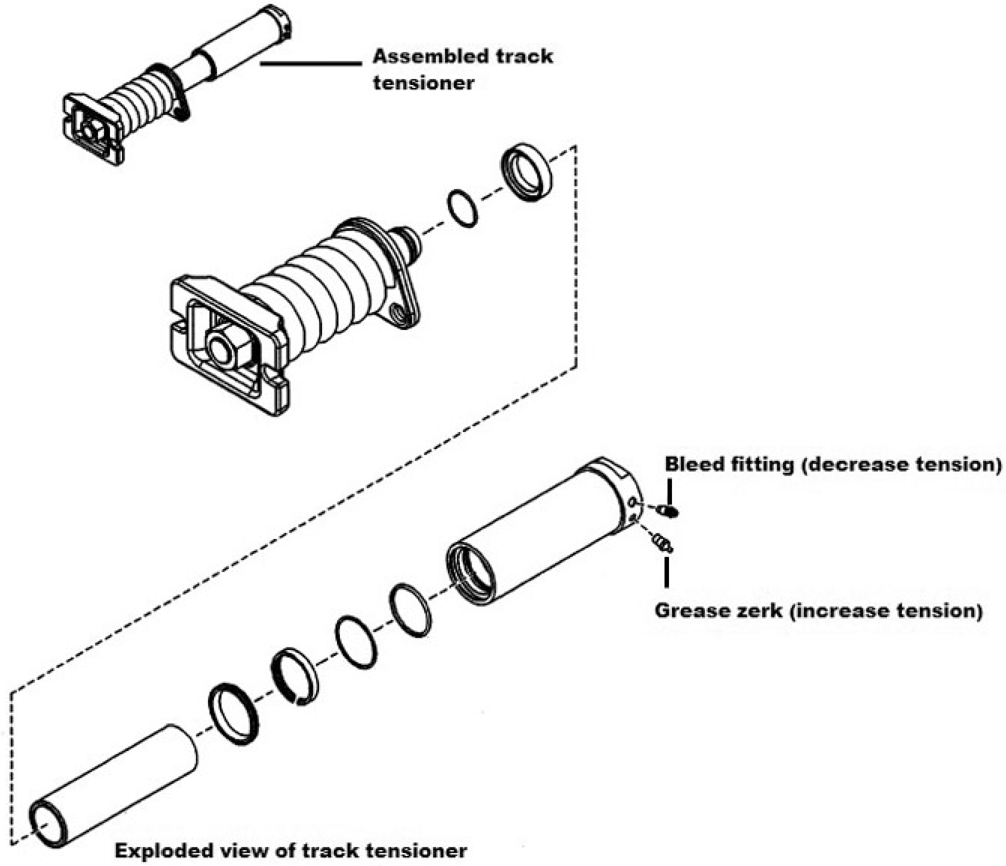


Figure 1–78. Track tensioner (grease-filled cylinder type).

The other method uses a threaded adjuster and jam nut. With this method, rotating the sleeve lengthens or shortens the adjuster, which adjusts the tension. For our purposes, we will focus on adjustments using a grease-filled cylinder.

The first step is to measure the track sag and compare it to the technical order specification or service manual. Unless the technical order or service manual indicates a different method, track sag is usually measured between the contact point of the middle track roller on the bottom and the top edge of the track guide on the track (fig. 1–79).

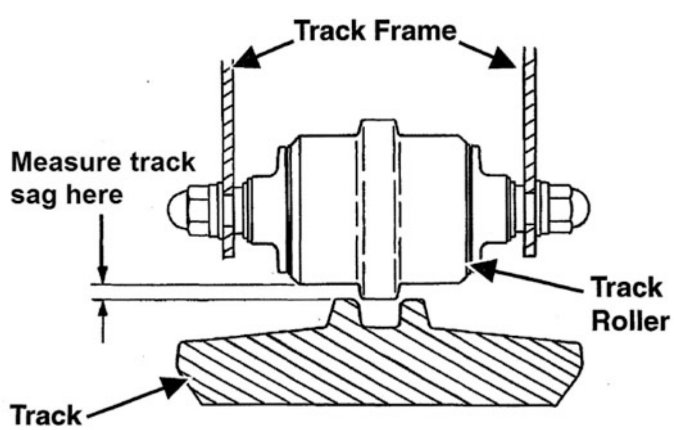


Figure 1–79. Measuring track sag.

To do this, begin by moving the skid steer to a level surface and follow the appropriate procedures to safely lift and place the loader on jack stands. Lift it high enough that the *lowest* part of each track is at least a couple of in. off the ground. Measure between the middle roller and the track. Compare your reading to the technical order's specification and determine if any adjustment is required.

If the track requires adjustment, it will normally be too loose and require tightening. On each side, an access cover is held in place by two bolts. Remove one bolt and loosen the other, so the cover can pivot downward. Using a grease gun add grease through the zerk fitting. Periodically recheck the track tension until it is within spec. Repeat the procedure on the opposite side.

In the event the track is too tight, a bleed fitting is used to remove grease from the cylinder. A special L-shaped tool is used to loosen the fitting and redirect the high-pressure grease as it bleeds out.

CAUTION: The special tool MUST be used because high-pressure grease can cause serious injury! DO NOT loosen the bleed fitting more than one to one and a half turns! When proper track tension is achieved on both sides, verify all fittings are closed and tight, reinstall the access covers, and lower the vehicle.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit

009. Skid-steer fundamentals

1. What inputs on the Bobcat S650 determine the hydraulically driven cooling fan's speed?

2. On the S650, what filter removes contaminants before hydraulic fluid enters the gear pumps?

3. Why would you choose a skid steer with the optional high-flow hydraulic pump?

4. On the S650, what type of valves does the hydraulic control valve use to direct fluid to the lift, tilt, and auxiliary functions?

5. How does the skid-steer's main relief valve limit hydraulic system pressure?

6. What does the bucket position valve do on a skid steer?

7. What skid-steer valve allows the lift arms to be manually lowered?

8. How are skid steers propelled?

9. How are a skid-steer’s hydrostatic drive motors kept cool?

10. How is a skid-steer’s chain case oil isolated from hydrostatic motor case drain oil?

11. Where is the pressure sensor that monitors an S650’s charge pressure located?

12. If so equipped, where is the two-speed/brake valve located on an S650?

13. How is a single-speed brake on an S650 applied and released?

14. Under what conditions will a skid-steer’s brake automatically apply?

15. Which instrument panel on the S650 houses most gauges, indicator and warning lights, and buttons?

16. When looking at the right panel of an S650, how can the deluxe instrumentation option be identified?

17. What is the primary means of controlling engine throttle in a skid steer?

18. Which SJC pattern on the S650 utilizes only the left joystick for all driving functions?

19. What three points are used to secure attachments to a skid steer?

20. What makes the skid steer such a versatile piece of equipment?

21. What electrical controllers do all S650 skid steers have?

22. What is the BICS designed to protect?

010. Skid-steer maintenance

1. What must be done if it's necessary to work on a skid steer with the lift arms raised?

2. Why should the engine be stopped before raising or lowering the skid-steer's operator cab?

3. What is the first thing you should check when troubleshooting a skid-steer's electrical system?

4. When testing a skid-steer's solenoid with a test meter, what measurement should be taken?

5. If the skid-steer solenoid is good, what should occur when 12 volts is applied?

6. When inspecting the auxiliary hydraulic system during the BICS function check, what should happen when your raise the seat bar?

7. When inspecting the traction lock system during the BICS function check, what happens when the steering levers or joysticks are moved forward and backward?

8. What's an easy way to check how well a skid-steer's hydraulic system is performing?

9. When you initially test the S650's main relief valve, where should the hydraulic tester be connected?

10. What can you do to help warm the S650's hydraulic fluid during the main relief valve test?

11. If you cannot get proper flow *and* pressure readings when adjusting the S650 main relief valve, what should be done next?

12. When adjusting skid-steer control pedals, how much stroke must the valve spool reach without the pedals hitting the floor panel?

13. What must be done to remove the front chain on the S650?

14. What can happen if skid-steer tracks become too loose?

15. What is the first step in adjusting skid-steer track tension?

16. If a skid-steer's track tension is adjusted using a grease cylinder, what must be done to *increase* track tension?

17. If a skid-steer's track is too tight, what is the *most* you should open the bleed fitting?

Answers to Self-Test Questions

001

1. To allow the crane to be transportable by a C–130 aircraft.
2. Standard diesel, biodiesel, or JP–8.
3. One or four engine parameters and DTCs.
4. SAE J1939 CAN.
5. Three forward and three reverse.
6. Two-wheel drive high and four-wheel drive low.
7. The front is a limited-slip and the rear is a locking type.
8. It has no suspension. The front axle is bolted directly to the main frame of the carrier and the rear axle is an oscillating type.
9. For additional stability when doing an "on-rubber" lift or when the load being lifted must be transported to another site.
10. The 15 gpm pump.
11. The accumulators.
12. Two-wheel conventional steering is when the front wheels steer only. Four-wheel coordinated steering is when the front and rear wheels turn in opposite directions. Four-wheel crab steering is when the front and rear wheels turn in the same direction.

002

1. Tandem-gear–type.
2. Two joystick manipulators.
3. They are closed by spring pressure and opened by pilot pressure.
4. Rotary manifold.
5. Double-acting cylinders with hold valves.
6. Bubble indicators.
7. Swing-bearing assembly.
8. When the output cannot drive the input.
9. Outer race of the swing-bearing assembly.

10. Collector ring.
11. By using one double-acting cylinder.
12. Hold the suspended load.
13. The process of running cable through sheaves.
14. When the load on the hook is between 85 and 99.9 percent of the rated capacity.
15. Load-pin sensor.
16. Boom length and boom angle.
17. Prevent the operator from raising the hook-block into the boom fly tip or lowering the boom fly tip onto objects.
18. Winch up, boom down, and boom extend.
19. Mounted to the swing hydraulic motor on right side of the crane.
20. Winch up, boom down, boom extend, swing left, and swing right.

003

1. Relieve all hydraulic pressure or severe personal injury or death can occur.
2. Swing bearing.
3. Periodic maintenance of the turntable bearing bolts has been performed; when a high-strength bolt is removed from an assembly, it must be replaced with a bolt of the same classification; and check the bolt hole for any signs of lubrication which may cause a variation from dry torque values.
4. Proper cable reeving and sufficient lubrication.
5. At least 6 in.
6. If the cable is crushed, kinked, or bird-caged.
7. Several complete rotations of the upper structure should clean the collector ring.
8. Verify that the hook-block is not lifting the A2B switch hoop.
9. Main relief valve misadjusted or malfunctioning; no pump output.
10. The crane load will raise but will not lower.
11. Any time a component responsible for lifting the load is rebuilt or replaced, a load-test must be done.

004

1. Overhead valve design.
2. Transfer drive assembly.
3. Splash lubricated from a steel oil line connected from the transmission that provides the fluid.
4. It does not have a torque converter.
5. Eight forward and four reverse speeds.
6. Main clutch housing, planetary pack, and differential.
7. Main clutch pack.
8. A sun gear of the planetary pack.
9. Four.
10. B1, B2, and B3.
11. C1 in the clutch pack, and B1 and C3 in the planetary pack.
12. Transfer drive output shaft.
13. Left side of the transmission case.
14. Provides for E-Stops and for inching the vehicle in close quarters.
15. Damage to the differential can occur.
16. Right side of the transmission case.
17. Tandem casing.
18. Transmission oil pump.

19. Allows the main pump to have variable displacement capabilities and controls oil output by holding the pistons away from the driving cam.
20. Side-by-side on the right side of the transmission case.
21. Nine (main) or 10 (with optional scarifer).
22. Two.
23. Rotary manifold.
24. Brakes, steering, and differential lock.

005

1. From the alternator output terminal to the alternator's field terminal.
2. Check with engine *off* and the vehicle on a level surface. If engine has been running, allow 10 minutes for the oil to drain down before checking.
3. Disassembling them and adding or removing shims.
4. Dirt.
5. Engine disconnect clutch disengaged, towing disconnect collar disengaged, or transmission oil pressure is low.
6. Low-oil pressure.
7. Drag test.
8. Third-speed forward.
9. Remove transmission rear cover and check for disc movement using light finger pressure.
10. Sleeve and spool valve locked, failed pump, or clogged hose or filter.
11. Steering valve is unserviceable and must be replaced or rebuilt.
12. Valve spool leakage test.

006

1. Most of the control cables, as used on previous older model earth-moving tractors, have been replaced with hydraulic controls, resulting in much smoother and precise tractor operation.
2. Directions on the tractor are given as if you are viewing the compartment from the operator's seat.
3. By the pedals on the floorboard.
4. The EDM sounds a buzzer and illuminates a light if a fluid level or fluid pressure problem occurs in the engine, transmission, or torque converter.
5. To select the range and travel direction of the crawler tractor.
6. Three forward speeds and three reverse speeds.
7. When the shift lever is placed in neutral, the external contracting-type parking brake is automatically applied by springs.
8. The crawler tractor has a multipurpose bucket to perform several functions without changing attachments, while a bulldozer typically has a straight blade and is used for pushing and leveling materials only.
9. To give you the option of changing bucket configurations by simply opening or closing the bucket clamshell.
10. Hydraulically driven and is located on the rear of the tractor.

007

1. Because of their high-torque output at a lower engine rpms.
2. The fan system can be reversed to meet changing weather conditions.
3. The cold airflow should be pulled through the radiator where it is removing the heat for summer operation.
4. 24 volts.
5. Hydraulic pilot-operated control system. Hydraulic implement (attachment) system, transmission, steering, and brake systems.
6. Gear-type pilot pump.
7. Hydraulic power shift mechanism, which controls five clutches.

8. Double-reduction spur-type gears.
9. By slowing or stopping one track at a time.
10. The steering clutches are spring-applied and hydraulically released by fluid pressure from the transmission.
11. The master link is the initial disassembly point of the track chain. It is used to break the track apart to replace the chain or perform maintenance on any of the track support rollers and guides.
12. The raised bars on the track shoes, which are used to grip the ground.
13. The idler protects the track mechanism from damage or shock.
14. When the front idler receives a shock load, the force is transmitted to the track spring by a slide-mounted mechanism to which the idler is attached.
15. A misaligned idler will cause wear on the front idler center flange, the sides of the track links, and the sides of the roller flanges.
16. To carry the weight of the track over the top of the frame.
17. To distribute the weight of the vehicle over a large ground area.

008

1. By thoroughly cleaning and inspecting the suspected area.
2. By installing or removing shims.
3. Flatten the threaded end of the three retaining cap screws with a grinding wheel or file.
4. Brake-band adjustment.
5. You may have to add or remove clutch discs at the pressure plate end.
6. Excessive component wear caused by the lack of proper maintenance or improper adjustments.
7. Measuring the master-link pin pitch.
8. Ensure the track is tight and the master link is centered between the drive sprocket and carrier roller. Measure the master-link pitch between the rear edge of the pin in front of the master pin to the front edge of the master pin with a ruler or tape measure.
9. Height determines the amount of wear on the links.
10. Inspect the rollers for flat spots and measure the roller at the widest wear point with a caliper.
11. You must elevate the track frame to expose the bottom of the rollers.
12. From the underside of the shoe to the top of the grouser.
13. Pitch diameter, tooth base thickness, and tooth width.
14. Track sag.
15. Prevents excessive wear of the track and track frame components.
16. A great amount of friction between the pins and bushings causes accelerated wear to the pins, bushings, links, sprocket, and idler.
17. Loose tracks fail to stay properly aligned and tend to come off when the crawler tractor is turned. This can also cause wear on the idler center flanges, roller flanges, and sides of the sprocket teeth.
18. Remove the grease fitting cover on the rock guard to expose the adjustment grease fitting. Inject a small amount of grease until the proper sag is reached.
19. Pins, bushings, replacing broken sections, and rebuilding track chains.
20. On the rear side of the drive sprocket.

009

1. The engine coolant and hydraulic temperature sensors.
2. The main filter.
3. To use attachments that require higher flow rate.
4. Spool valves.
5. By opening at a certain specified pressure and allowing hydraulic oil to flow back to the reservoir.
6. Allows the operator to hold the attachment at the same angle relative to the ground while raising and lowering the lift arms without using the tilt function.

7. Lift arm bypass control valve.
8. Using a hydrostatic drive system.
9. A shuttle valve mixes case drain oil with cooled low-pressure oil from the charge circuit.
10. A seal.
11. On the fan motor.
12. On top of the chain case, in front of the hydrostatic pump.
13. Spring-applied and electrically released.
14. If the engine drops below specified rpm, the seat bar sensor fails, or if there is a break in the wires for the brake block solenoid.
15. The left panel.
16. A display screen.
17. A lever found on the right side of the cab.
18. ISO.
19. The flange on the top edge of the carrier and two wedges that extend from the carrier through holes on the bottom of the attachment.
20. The variety and relatively low cost of skid-steer attachments and the ease of changing them.
21. Gateway and auxiliary.
22. The operator.

010.

1. Secure the lift arms with an approved support device.
2. The cab may contact the controls during raising or lowering, causing unexpected movement, and pose a risk of serious injury or death.
3. The connectors and wiring associated with the function or component exhibiting problems.
4. Resistance across the coil.
5. An audible click should be heard, and, if the plunger is visible, you should see it move.
6. The auxiliary hydraulics light must turn off.
7. The skid steer should not move.
8. Checking the service manual for a function time specification and performing a function check.
9. The front auxiliary hydraulic coupler block.
10. Turn the restrictor control on the hydraulic tester so it reads 1,000 psi.
11. Test the hydraulic pump directly to determine if rebuild or replacement is required.
12. Full stroke.
13. Remove the rear axle and drive chain.
14. Tracks are prone to derailing or misfeeding on the sprocket.
15. Measure the track sag and compare it to the technical order specification or service manual.
16. Add grease through the zerk using a grease gun.
17. One and a half turns.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

1. (001) This part of the Arva crane includes the engine, transmission, and drive axles.
   a. Carrier assembly.
   b. Lower assembly.
   c. Upper structure.
   d. Main carriage.

2. (001) How many engine parameters can the Arva crane's digital engine monitor display at once?
   a. 1 only.
   b. 4 only.
   c. 1 or 4.
   d. 1 to 4.

3. (001) The Arva crane axle-lock cylinders are connected to the
   a. outriggers.
   b. vehicle air system.
   c. main hydraulic system.
   d. transmission hydraulic system.

4. (002) A warning light will blink, accompanied by an audible warning, when the load on the crane's hook is at, or above, what percent of the crane's rated capacity?
   a. 70.
   b. 75.
   c. 80.
   d. 85.

5. (003) This is the *most* critical maintenance point of the Arva crane.
   a. Outriggers.
   b. Collector ring.
   c. Swing bearing.
   d. Rated capacity indicator.

6. (003) All of the following conditions require load hoist cable replacement <u>*except*</u>
   a. kinked.
   b. reeved.
   c. crushed.
   d. bird caged.

7. (003) The procedure to remove corrosion from the crane's collector ring requires
   a. replacing the contact brushes.
   b. cleaning the contacts with sandpaper.
   c. several complete rotations of the reeling drum.
   d. several complete rotations of the upper structure.

8. (003) Who is responsible for having their crane load-tested by a qualified technician, and to obtain a certification?
   a. Civil engineering.
   b. Vehicle management.
   c. Using organization.
   d. Base safety.

9. (004) The camshaft in the grader diesel engine is driven by the timing
   a. gears.
   b. gears and chain.
   c. belt and sprockets.
   d. chain and sprockets.

10. (004) This is the gear ratio between the grader transfer drive's output gear and the input gear.
    a. 1:1.
    b. 1.5:1.
    c. 2:1.
    d. 3:1.

11. (004) These are the three main subassemblies of the grader's power-shift transmission.
    a. Main clutch housing, countershaft, and differential.
    b. Main clutch housing, planetary pack, and differential.
    c. Torque converter, countershaft, and the rear clutch pack.
    d. Torque converter, front clutch pack, and control valve assembly.

12. (004) Which of the grader's power-shift transmission subassemblies uses the same single common planet carrier to link both compound gear sets?
    a. Main clutch pack.
    b. Planetary pack.
    c. Differential.
    d. Placid pack.

13. (004) The differential lock on the grader is actuated
    a. electrically by the use of a switch.
    b. pneumatically by the use of a lever.
    c. mechanically by the use of a spring.
    d. hydraulically by the use of a foot pedal.

14. (005) When a jumper wire is connected from the alternator's output terminal to the alternator's field terminal, which is the faulty component if the alternator begins to charge excessively?
    a. Brushes.
    b. Diode trio.
    c. Voltage regulator.
    d. Field terminal shield.

15. (005) The proper way to check the grader hydraulic system oil level is with the engine
    a. off and grader on a level surface.
    b. off and removing the transfer case check plug.
    c. running, transmission in neutral, and grader on a level surface.
    d. running, transmission in first forward, and checking the transmission dipstick.

16. (005) Which malfunction will *not* cause a grader to fail to move when placed in gear?
    a. Towing disconnect collar disengaged.
    b. Engine disconnect clutch disengaged.
    c. Low transmission oil pressure.
    d. Misadjusted pedal valve.

17. (005) When checking brakes B1 and B2, which type of pressure can move the brake discs and plates back and forth with ease if they are in good condition?
    a. Air.
    b. Foot.
    c. Finger.
    d. Hydraulic.

18. (006) Which type controls are used in place of the older, standard control cables to provide precise operation of the controls on the crawler tractor?
    a. Hydraulics.
    b. Pneumatics.
    c. Electrical relays.
    d. Electrical solenoids.

19. (006) How many steering clutch packs are used in the crawler tractor?
    a. 2.
    b. 4.
    c. 6.
    d. 8.

20. (006) Which foot pedal(s) on the crawler tractor is/are used to slow or stop both tracks simultaneously?
    a. Left.
    b. Right.
    c. Center.
    d. Left and right.

21. (006) Oil pressure on the bottom side of the crawler tractor shift-lever spool valve is used to
    a. apply the parking brake.
    b. release the parking brake.
    c. lock the shift lever into position.
    d. release the shift lever from its position.

22. (007) This type of pilot pump is used on the crawler tractor hydraulic attachments.
    a. Gear.
    b. Vane.
    c. Axial piston.
    d. Radial piston.

23. (007) When adjusted properly, what *minimum* inch-travel is required on the steering/brake pedal to release the crawler tractor steering clutch pack completely?
    a. 1.
    b. 2.
    c. 3.
    d. 4.

24. (007) Recondition a track shoe grouser plate when the grouser is within which inch measurement of the shoe?
    a. 1.
    b. ¾.
    c. ½.
    d. ¼.

25. (007) Which does excessive front idler center flange wear on the crawler tractor indicate?
    a. Poor alignment.
    b. Incorrect track shoes.
    c. A reversed front idler.
    d. Insufficient lubrication.

26. (008) How many measurement readings are averaged to establish the bearing preload shim pack requirements when measuring the distance between the final drive outboard bearing cage halves on the crawler tractor?
    a. 2.
    b. 3.
    c. 4.
    d. 5.

27. (008) Changing the crawler tractor’s track tension, depending on the operating conditions,
    a. improves traction.
    b. reduces track wear.
    c. improves fuel economy.
    d. improves steering and braking.

28. (009) Which function does *not* receive fluid from the S650’s skid steer hydraulic control valve?
    a. Lift.
    b. Tilt.
    c. Drive.
    d. Auxiliary.

29. (009) This is *not* found on the left panel of an S650 skid steer.
    a. Gauges.
    b. Warning lights.
    c. Key/start switch.
    d. Traction lock override.

30. (009) How many points are used to secure an attachment to the S650’s carrier?
    a. Two.
    b. Three.
    c. Four.
    d. Five.

31. (010) Which position should the S650 skid steer hydraulic tester restrictor be in before starting the engine when performing a main relief valve test?
    a. Fully open.
    b. Fully closed.
    c. Slightly open.
    d. Slightly closed.

32. (010) Which is *not* likely to occur if skid steer tracks are too *tight*?
    a. Loss of power.
    b. Sprocket misfeed.
    c. Damaged drive motors.
    d. Accelerated bearing wear.

Student Notes

Unit 2. Aircraft Servicing Vehicles

AS A MEMBER OF THE UNITED STATES AIR FORCE, every Airman supports the mission to fly, fight, and win in air, space, and cyberspace. As a Mission Generation Vehicular Equipment Maintenance Journeyman, one of the ways you contribute to this mission is by maintaining vehicles that service aircraft. In this unit, we will discuss the aircraft towing tractor and deicer, which help support the Air Force flying mission.

2–1. Aircraft Towing Tractor

The Air Force towing tractor is used to tow aircraft, aerospace ground equipment, and various other pintle hook–equipped equipment. These vehicles are designed to be compact and combine engine torque with low-gear ratios to pull heavy loads. There are several different types of towing tractors used in the Air Force. However, in the following lessons, we will focus on the Entwistle MB–4 towing tractor.

011. Aircraft towing tractor fundamentals

The Entwistle MB–4 towing tractor (fig. 2–1) is primarily used for towing military aircraft but can also be used for general equipment towing. The MB–4's towing capacity is 175,000 (175K) lbs. for aircraft and 93K lbs. for all other towing operations.

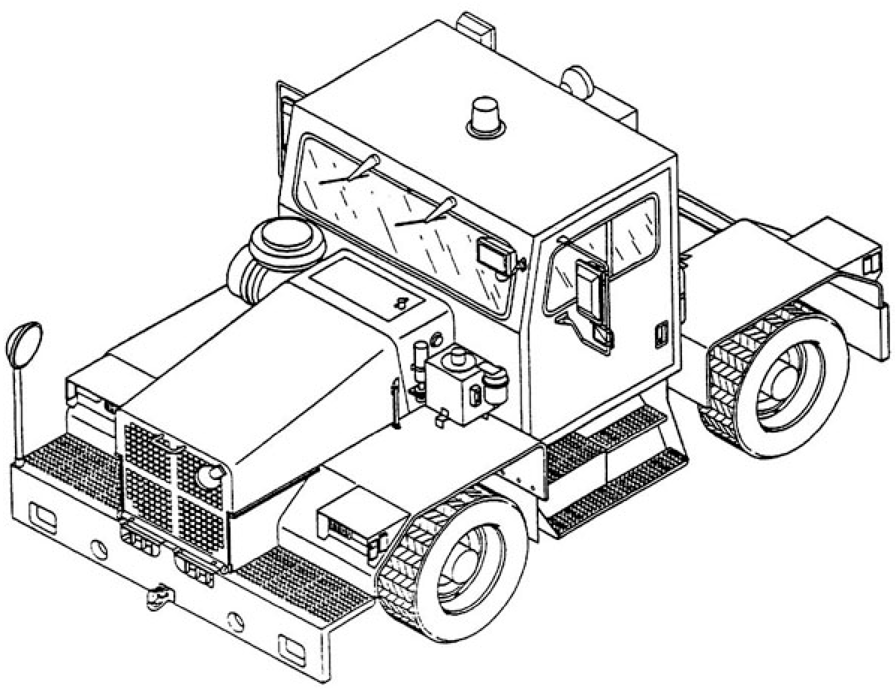


Figure 2–1. MB–4 towing tractor.

Drive train

The MB–4 gross vehicle weight is 20K lbs. and is powered by a six-cylinder turbocharged diesel engine. An automatic transmission with four forward gears and one reverse gear delivers power to a two-speed transfer case. The transmission can be shifted manually by a shift lever located on the dash. The transfer case provides full-time four-wheel-drive in two ranges, high and low.

The electric high-range/low-range control switch, mounted on the dash in the cab, is used to select the desired transfer case range. The high-range/low-range switch electrically activates a valve in the hydraulic manifold. This valve directs fluid under pressure to a cylinder on the transfer case to move a shift fork, shifting it between high and low range. The transfer case is splash-lubricated with 90-weight oil. Figure 2–2 illustrates the layout of the drive train.

CAUTION: Do ***not*** shift the transfer case while vehicle is in motion. Damage to drive train could result!

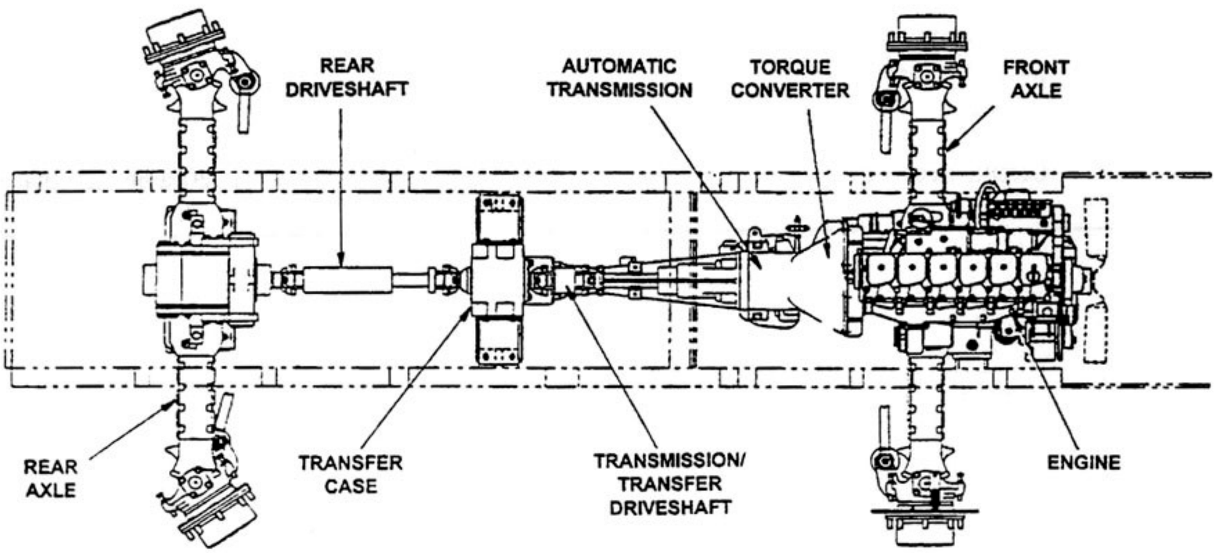


Figure 2–2. Drive train.

Power from the transfer case is transferred to the front- and rear-axle assemblies through drive shafts. The front- and rear-axle assemblies are identical and are mounted to the frame through two compression springs, two suspension links, and a sway bar. On the ends of the axle assemblies are the final drive hubs. The final drive hubs have planetary gears that increase torque at each of the four drive wheels.

Steering system

The steering system (fig. 2–3) uses a hydraulic gerotor control unit and hydraulic fluid under pressure to actuate a steer cylinder mounted on each drive axle. With the engine running, hydraulic pressure is used to reduce the effort required to turn the steering wheel (power-assist steering). If the engine is not running, the wheels can still be turned, but much greater effort is required.

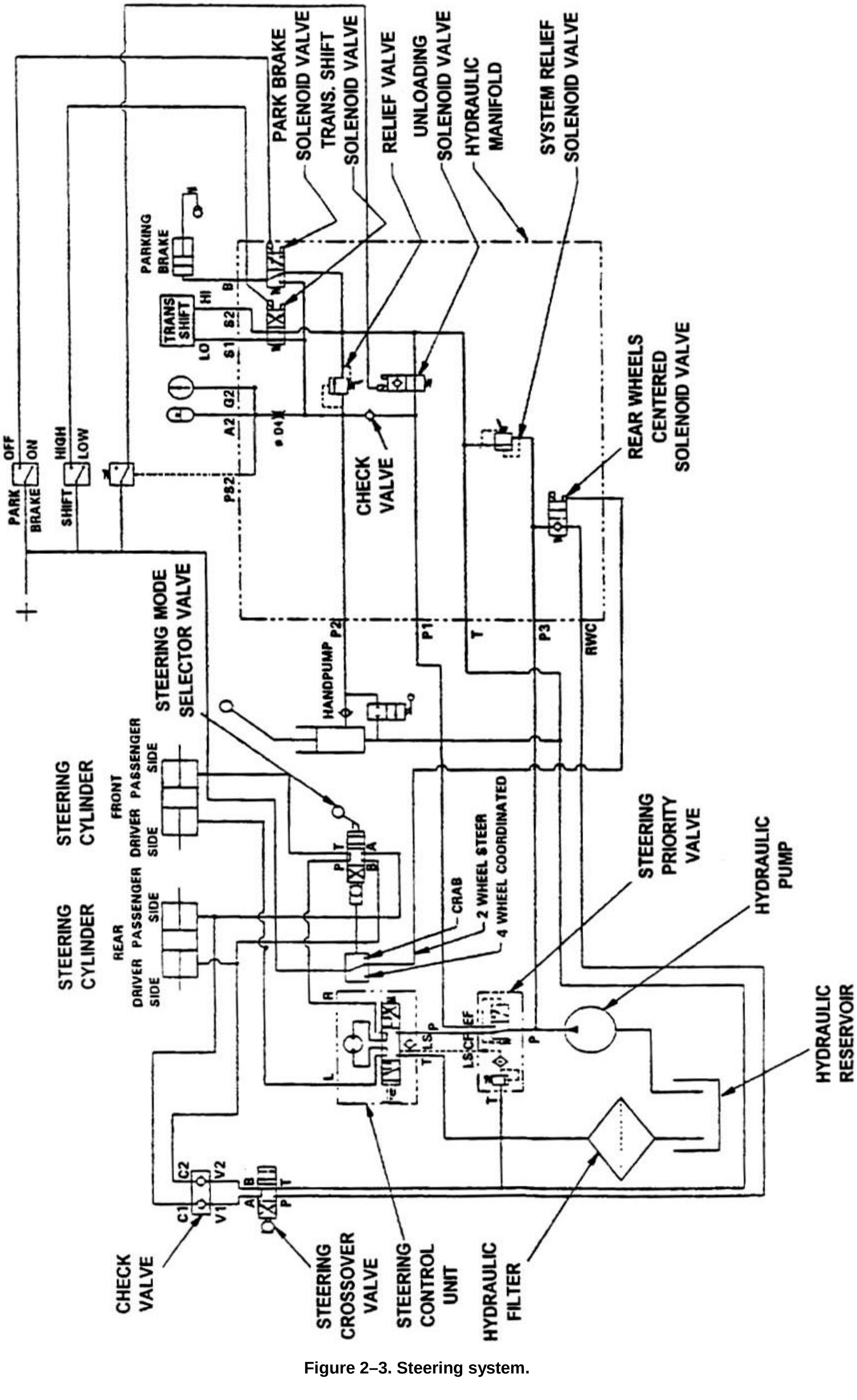


Figure 2–3. Steering system.

There are three steering modes:

1) Two wheel (only the front wheels turn).
2) Four wheel or coordinated (rear wheels are turned in the *opposite* direction of the front wheels).
3) Crab or oblique (rear wheels are turned in the *same* direction of the front wheels).

The steering mode is selected by a control lever mounted in the cab. A wheel-position sensing system illuminates lights on the dash to indicate the mode selected.

Mechanical linkage

The steering wheel is directly coupled to the hydraulic gerotor control unit, which controls the flow of fluid to the front- and rear-steering cylinders through a series of control valves and dividers. Selecting a steering mode will change the hydraulic fluid flow and give the operator the right maneuverability for his or her task.

In the coordinated mode, the rear wheels are turned in the opposite direction of the front wheels for a tighter turning radius. However, in the oblique mode the rear wheels are turned in the same direction as the front wheels to allow the vehicle to travel in a diagonal direction.

Hydraulic system

The hydraulic pump is mounted to and driven by the vehicle’s air compressor. The hydraulic pump draws fluid from an external reservoir located on the right front fender. A separate hose connects the pump to the reservoir and returns the excess fluid back to the reservoir. Fluid from the pump flows through the steering control unit, then returns to the reservoir. Pressurized hydraulic flow is only generated when the engine is running.

The parking brake is spring-applied and hydraulically released. Adjusting the parking brake circuit requires specific procedures and, if performed incorrectly, may cause damage to the brake disc packs. Always follow the technical order procedures.

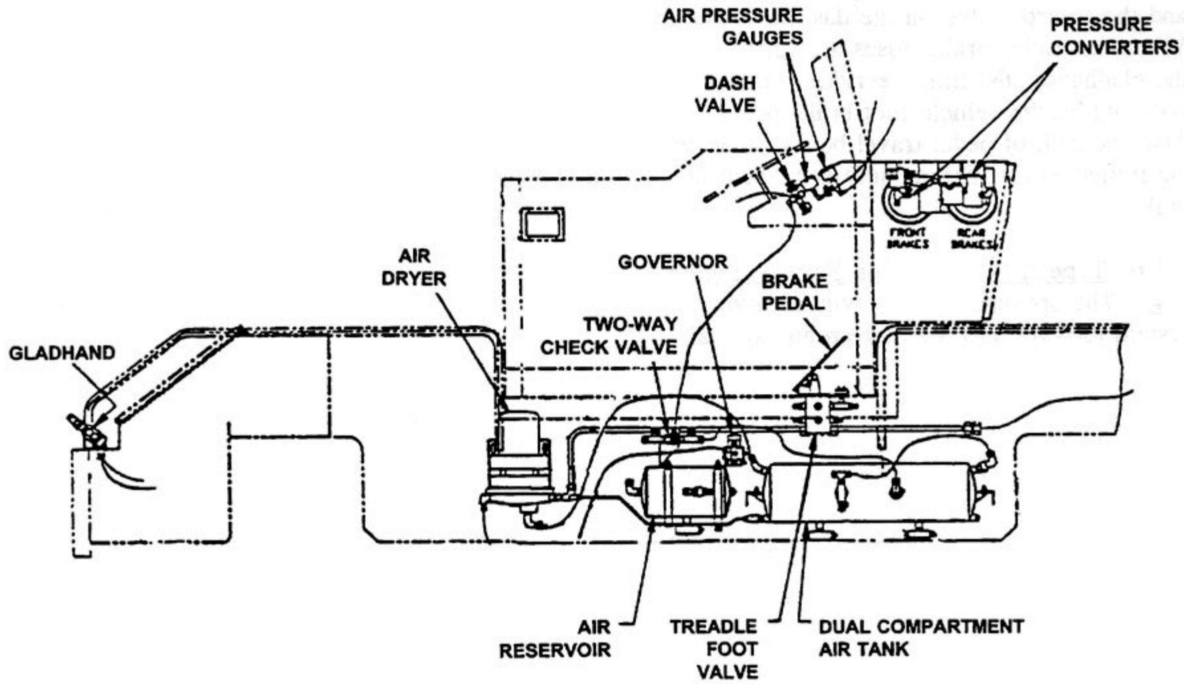
In the event of a hydraulic pump failure or when the vehicle needs to be towed, the hydraulic system includes a hand pump that can be used to manually pressurize the system so the parking brake can be released and the vehicle steered to a safe location.

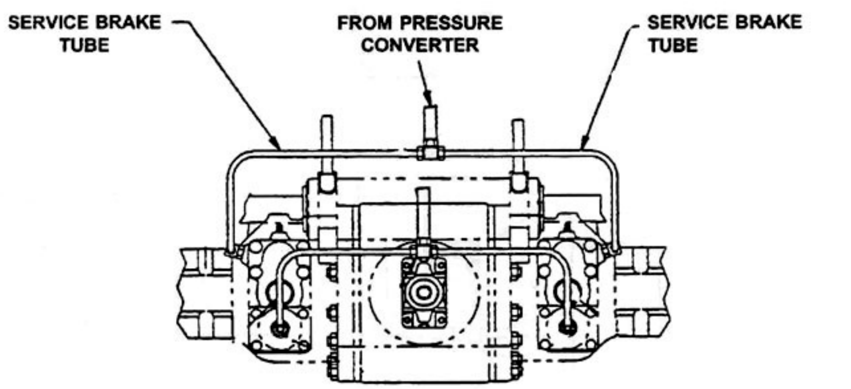
Air and brake system

The MB–4 uses an air-over-hydraulic service brake system (fig. 2–4). An engine-driven air compressor generates pressure for the air portion of the brake system. The air pressure generated is stored in air reservoirs, mounted to the vehicle frame. Each air reservoir is equipped with a heated moisture ejector to automatically remove moisture from the reservoirs. The air compressor runs continually whenever the engine is running. However, the compressor governor limits the air produced. An air dryer is also mounted near the reservoirs and is connected between the compressor and the primary reservoir.

When the brake pedal is depressed, air from the air reservoir is directed through the two-way check valve to the treadle foot valve. The air is directed from the treadle to two pressure converters where it pressurizes the brake fluid in the pressure converter’s reservoirs. This pressurized brake fluid flows through the brake lines to actuate the service brakes located on the front and rear axles. Braking is accomplished by multiple wet clutch disks. If the vehicle is equipped with the trailer option, the first inch of treadle valve travel will direct air pressure to the trailer service brakes *before* the vehicle’s service brakes are applied. Spring-applied and hydraulically released parking brakes are contained in both axles. The parking brake is released using an electrical switch on the dashboard, which energizes the parking brake solenoid valve, allowing fluid pressure to release the brakes. Pressure for the hydraulically released parking brake and the hydraulically shifted transfer case is produced by the hydraulic pump and stored in an accumulator.

Accumulator pressure is controlled by a relief valve (RV) and an electrically controlled unloading valve located in the hydraulic manifold. The accumulator is precharged with 400 psi of dry nitrogen. The parking brake incorporates a hand pump in the cab to pressurize and release the parking brake for towing.





FRONT AXLE

Figure 2–4. Air and brake system.

Electrical system

The MB–4 has a 12 VDC negative ground electrical system. Three batteries, mounted under the cab, supply current for starting and operation of controls, lights, and accessories, all of which are protected by fuses. A battery disconnect switch is located on the cab floorboard. An engine-mounted alternator charges the batteries and supplies current to the electrical system when the engine is running.

Winterization system

The standard MB–4 configuration comes equipped with Type C winterization. Type A winterization is optional.

Type C winterization system

The Type C winterization system includes a 181–203°F engine coolant thermostat and antifreeze protected to –40°F. It also includes ether injection at the intake manifold and has a hard top cab with a personnel heater and windshield defroster.

Type A winterization system

The optional Type A winterization system receives 115-volts alternating current (VAC) from an external source. Connection is made through an extension cord that is attached to a receptacle mounted on the left side of the vehicle. Current flows to the coolant, oil, and battery heaters through a junction box. This system is protected from overload by a circuit breaker mounted on the junction box. The heaters are controlled by a 110 VAC thermoswitch that opens when maximum temperature is reached and closes when the temperature drops below the maximum limit.

Operator control panel

The vehicle controls, instruments, lights, and accessories are all within reach from the driver's seat. Figure 2–5 displays the operator control panel.

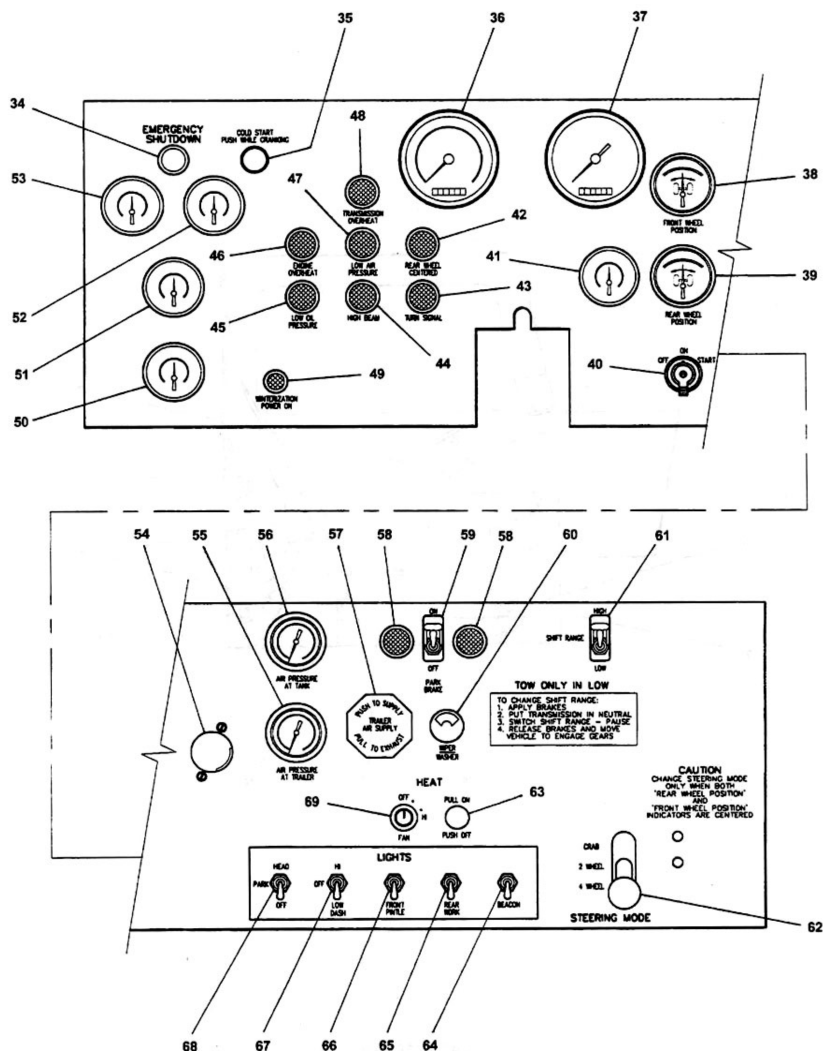


Figure 2–5. Operator control panel.

The following table lists its components and their functions.

MB–4 Towing Tractor's Operator Control Panel		
Number	**Control/Indicator**	**Function**
34	Emergency shutdown	Stops engine in an emergency by shutting off fuel supply.
35	Cold start	Energizes solenoid valve to inject measured amount of ether into diesel engine air connection.
36	Tachometer/Hour meter	Displays engine rpm and total hours engine has operated.
37	Speedometer/Odometer	Displays vehicle speed and total miles vehicle has been driven.
38	Front wheel position	Indicates position of front wheels.
39	Rear wheel position	Indicates position of rear wheels.
40	Off/On/Start switch	Off – Disables electrical system and deenergizes fuel shutdown solenoid. On – Energizes the vehicle's electrical system. Start – Energizes the diesel engine starting circuit.
41	Fuel gauge	Displays approximate level of fuel in tank.
42	Rear wheel centered light	When lit, indicates rear wheels are centered.
43	Turn signal light	When flashing, indicates turn signal light is on.
44	High beam	When lit, indicates high beam headlights are on.
45	Low-oil pressure	When lit, indicates low-engine oil pressure.
46	Engine overheat	When lit, indicates engine is overheated.
47	Low-air pressure	When lit, indicates low-air pressure in system.
48	Transmission overheat	When lit, indicates transmission is overheated.
49	Winterization power	When lit, indicates winterization system extension cord is connected to vehicle and heaters are operating.
50	Oil pressure gauge	Indicates diesel engine oil pressure.
51	Voltmeter	Indicates voltage level of battery.
52	Trans temp gauge	Indicates transmission oil temperature.
53	Water temp gauge	Indicates engine coolant temperature.
54	Panel light	Lights the dash panel controls and indicators.
55	Air pressure gauge	Indicates air pressure at the air system trailer couplings.
56	Air pressure tank gauge	Indicates air pressure at the air system reservoir.
57	Trailer air supply	When pressed with the engine running, activates air system for trailer towing.
58	Park brake indicator	When lit, indicates parking brake is set.
59	Park brake switch	On – Sets parking brake. Off – Releases parking brake.
60	Wiper/Washer	Turns windshield wipers on and off or operates windshield washer.
61	Shift range	High – Shifts transfer case to high range. Low – Shifts transfer case to low range.
62	Steering mode	Crab – Selects oblique steering mode. 2 wheel – Selects two-wheel steering mode. 4 wheel – Selects coordinated steering mode.
63	Heat	Pull on – Turns on cab heater. Push off – Turns off cab heater.
64	Lights – beacon	Turns beacon on and off.
65	Lights – rear work	Turns rear work light on and off.
66	Lights – front pintle	Turns front pintle light on and off.

MB–4 Towing Tractor's Operator Control Panel		
Number	**Control/Indicator**	**Function**
67	Lights – dash	Selects high or low intensity of the panel lights and gauges.
68	Lights – headlights	Turns headlights, marker lights, and taillights on and off.

012. Aircraft towing tractor maintenance

The following lesson covers basic troubleshooting and repair procedures for the aircraft MB–4 towing tractor. Several systems are similar to other vehicles. Therefore, your troubleshooting procedures will be similar. We will discuss troubleshooting the electrical, hydraulic, steering, brakes, and air systems.

Troubleshooting electrical system malfunctions

As part of electrical system troubleshooting, you need to become familiar with the use of schematics and diagrams. For maintenance and troubleshooting, always follow the procedures outlined in the technical order. Remember, all electrical components should be replaced with like units. When repairing or replacing electrical wiring, be sure to use the same size and type wire. Soldering spliced connections is recommended. Using different size and type wires and not soldering splices can increase or decrease resistance, which can affect the operation of electrical components.

The following table lists basic items to check when troubleshooting an electrical system malfunction.

Troubleshooting Electrical System Malfunction	
System	**Check For**
Batteries	Check for loose connectors and corroded battery terminals. This is one of the main causes for poor charging and electrical problems. If the batteries are maintenance free, check the battery condition indicator to ensure they are charged properly. Charge as needed.
Alternator and voltage regulator	Use the basic troubleshooting procedures that you learned in earlier volumes to test the regulator. A high charging rate with fully charged batteries could indicate a defective voltage regulator. The voltage regulator on the MB–4 is inside of the alternator.
Alternator belt tensioner	Check its operation to ensure that the alternator belt is not slipping, causing erratic current flow. If you find the voltage regulator is operating properly, check the alternator to ensure that the coils or diodes are not shorted.
Lights, heater fan, wipers, or the winterization systems	Check the fuse panel for blown fuses or corroded or broken wires. Inspect and test the switch that operates the function to see if it is operating properly.

NOTE: When using battery/charging system test equipment, refer to the manufacturer's operating manual for specifications. Make sure proper personal protective equipment is used.

Troubleshooting hydraulic system malfunctions

Hydraulic system malfunctions typically consist of leaks at hoses and fittings. Make sure the fluid is the correct type and at the proper level. Follow the procedures in the technical order if a pressure gauge must be connected. As with any type of hydraulic system, make sure you follow all safety precautions.

Check for the following basic hydraulic system problems listed in the table below.

Hydraulic System Problems	
Problem	**Cause and Fix**
Foamy or milky hydraulic fluid	Caused by air leaks, low-fluid level, cracked hydraulic pump housing, or water contamination. Visually inspect system components and check for fluid aeration. Flush system, if contaminated; refill with clean fluid.
Oil leak	Caused by an overfilled reservoir, loose hose connections, or cracked component housing/fittings. Adjust fluid level, tighten fittings, repair or replace components as necessary.

Hydraulic System Problems	
Problem	**Cause and Fix**
Noisy hydraulic pump	Low-oil level, hose touching the vehicle body or frame, or worn internal parts in pump. Fill oil to proper level, reposition hose, or replace worn pump and flush the system. Refill with clean fluid.

The problems we discussed are general in nature. For specific troubleshooting or component replacement procedures, refer to the appropriate technical order. After any component repair or replacement, recheck the system to make sure the problem is corrected.

Troubleshooting steering system malfunctions

When a vehicle is turned with a steering system malfunction, the first thing that needs to be done is a road test (only if this is not a safety issue) to assess the problem.

Check for the following steering system conditions listed in the table below.

Steering System Conditions	
Symptom	**Cause and Fix**
Hard steering	This problem may be as simple as the tires are not properly inflated. However, other items that need to be checked are the hydraulic oil level, steering valve, steering cylinder, and the hydraulic pump.
Wheel kickback	This problem may be caused by air in the system, low-hydraulic fluid level, or a loose hydraulic line, causing air to be drawn into the hydraulic system. Check for a loose or bad steering cylinder, loose ball joints, worn kingpins, and bad steering valve.
Steering mode problem	If your vehicle does not steer properly (two wheel, crab, or oblique), check the steering selector valve, priority valve, and steering control valve for proper operation. Make sure the hydraulic fluid is properly serviced and the recommended type of fluid is used. Using the wrong fluid may cause severe damage to components or erratic hydraulic functions.

NOTE: Many malfunctions can have causes that affect one or more systems. Always check the troubleshooting chart in the technical order when isolating malfunctions. After any repairs are made or components are replaced, recheck the system for proper operation. Verify the wheel alignment, if necessary.

Troubleshooting brake and air system malfunctions

CAUTION: *Do not* road test any brake system malfunctions on any vehicle if the vehicle cannot be safely operated. Repair any malfunctions that may hinder safely stopping the vehicle before road testing.

Here are only two of many possible brake or air system problems you may see in the field:

1. Poor or no brakes—Check the brake fluid level, air pressure, treadle control valve, flow control valve, pressure converter, and brake disc set adjustments. Remember these brakes are air over hydraulic, which means that if there is low-air pressure, the hydraulic portion may not function properly. Check the air compressor, reservoir, and hoses for any leaks that would prevent the air system from reaching the proper pressure.
2. Vehicle pulls left or right when braking—This could be a result of brake control(s) out of adjustment or worn brake disc(s). Follow the procedures in the technical order when checking the adjustment of the brake controls and disc sets for wear. Adjust or replace as required. Also check the brake fluid level to ensure there is no restriction or air in the system.

If the brake discs need to be replaced, follow the procedures in the technical order. The service brakes on the Entwistle MB–4 are located in the front- and rear-axle assemblies.

Adjusting the hydraulic, steering, and brake systems

Sometimes troubleshooting will lead to the adjustment of specific system components. Therefore, we will discuss hydraulic, steering, and brake system adjustments on the MB–4 in this lesson.

Hydraulic adjustment

Normally, the hydraulic system is trouble-free and does not require major service unless there is major component damage or the system is contaminated. There are no hydraulic adjustment procedures covered in the technical order. Most components are not adjustable and would require a rebuild or replacement in the event of a component failure.

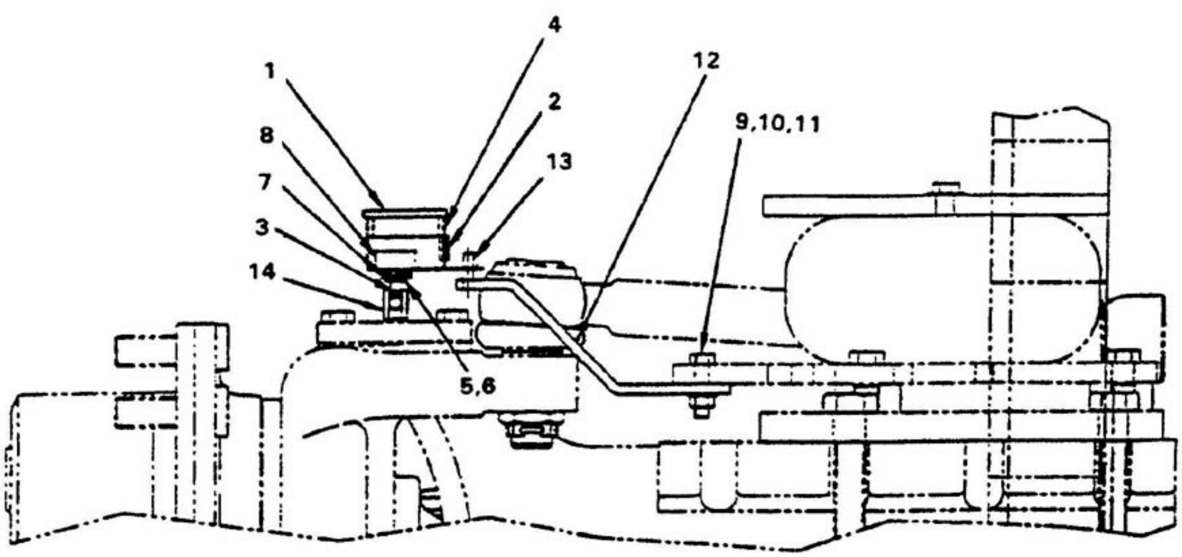
The Entwistle MB–4 hydraulic system is used for steering and uses an electrical-wheel position sensing system. This system will lock out certain hydraulic steering functions unless the wheels are positioned correctly. Therefore, technicians may mistake steering problems as a hydraulic malfunction when the problem lies in the position of the wheels.

The electrical adjustments must be set to specification before the hydraulics can work correctly. However, if the electrical switches are adjusted correctly and hydraulic components still do not work, further diagnosis is required.

Steering system adjustments

In order for the hydraulic system to work effectively, the steering system adjustments must be correct. The following adjustments are for the front- and rear-wheel position sensing systems.

Follow these procedures to adjust the front-wheel position sensors (fig. 2–6):



Legend

1. Cap
2. Grommet
3. Set screw
4. Shield
5. Nut
6. Washer, plain
7. Ear stop
8. Potentiometer
9. Locknut
10. Washer, plain
11. Capscrew
12. Bracket
13. Pin
14. Linking shaft

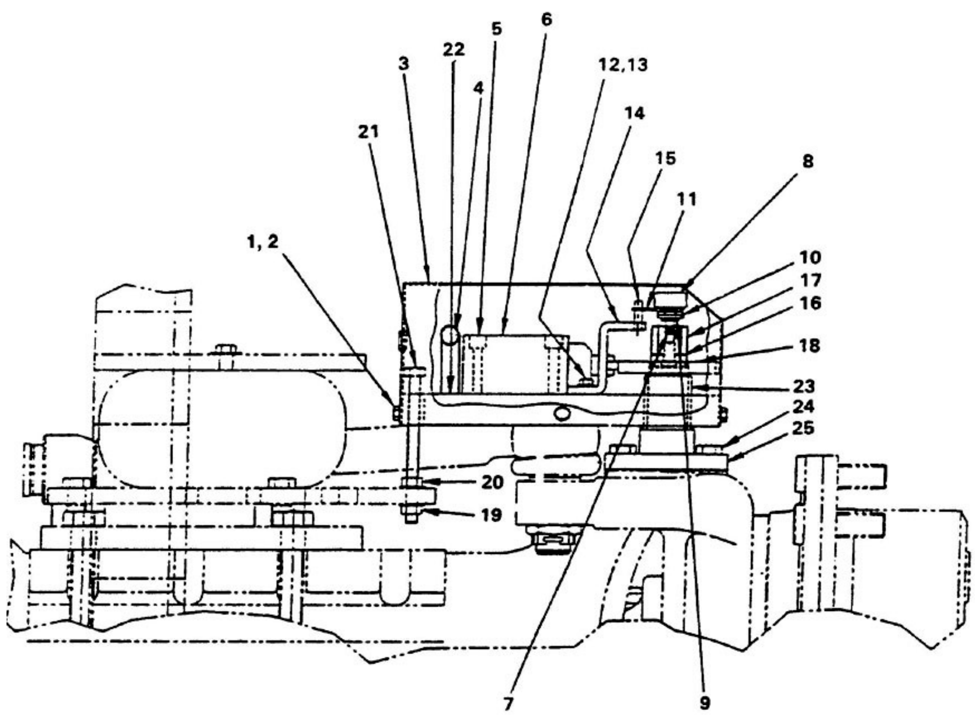
Figure 2–6. Front-wheel position sensing system.

1. Center tire to vehicle by measuring and achieving an equal distance between the tire and the frame at both the front and rear of the tire.

2. Loosen the set screw (3). Turn ignition switch ON.
3. With an assistant in the cab observing the front-wheel position gauge, adjust the potentiometer (8) shaft until the gauge indicates “*center*” position (fig. 2–5, item 38).
4. Retighten set screw. Turn ignition switch OFF.

Follow these procedures to adjust the rear-wheel position sensing system (fig. 2–7):

1. Center tire to vehicle by measuring and achieving an equal distance between the tire and the frame at both the front and rear of the tire.
2. If installed, remove cap screws (1), washers (2), and lift cover (3).
3. Ensure actuating piston of centering valve (6) is centered in the recessed face of cam (18). Adjust position with socket head screw, if necessary.
4. Loosen set screw (7). Turn ignition switch ON.
5. With an assistant in the cab observing the rear-wheel position gauge (fig. 2–5, item 39), adjust the potentiometer (8) shaft until the gauge indicates “center” position.
6. Tighten set screw. Turn ignition switch OFF.
7. Install cover (3) with cap screws (1) and washers (2).



Legend

1. Capscrew	10. Washer	18. Cam
2. Washer	11. Ear stop	19. Nut
3. Cover	12. Capscrew	20. Nut
4. Grommet	13. Washer	21. Capscrew
5. Socket head screw	14. Bracket	22. Plate
6. Centering valve	15. Pin	23. Bearing
7. Set screw	16. Socket head screw	24. Capscrew
8. Potentiometer	17. Collar, potentiometer	25. Mount, cam
9. Nut, seal		

Figure 2–7. Rear-wheel position sensing system.

Axle brake adjustment

If the axle brake adjustment is incorrect, it may cause poor or uneven braking and premature brake failure. Therefore, complete the following axle brake adjustment whenever the service brake discs are replaced (fig. 2–8).

1. Disconnect the parking brake hydraulic tube and remove adaptor from the flange hole.
2. Remove cover plug from the brake control cover.
3. Attach dial indicator to the end of the fork shaft to measure travel of the shaft.
4. Insert a bolt (***M14 X 1½ inch***) into the flange hole to its maximum depth to release the brake. Then unscrew the bolt until the dial indicator reads between 0.075 and 0.083 in. If necessary, tighten or loosen the adjustment nut to obtain the proper reading. Turn nut clockwise to reduce dial indicator reading (1/4 turn equals approximately 0.010 in.).
5. Remove dial indicator.
6. Reinstall dial indicator and repeat step 4.
7. Remove dial indicator and machine bolt from flange hole.
8. Install cover plug, adaptor, and parking brake tube.
9. Cycle park brake switch to bleed air from system.

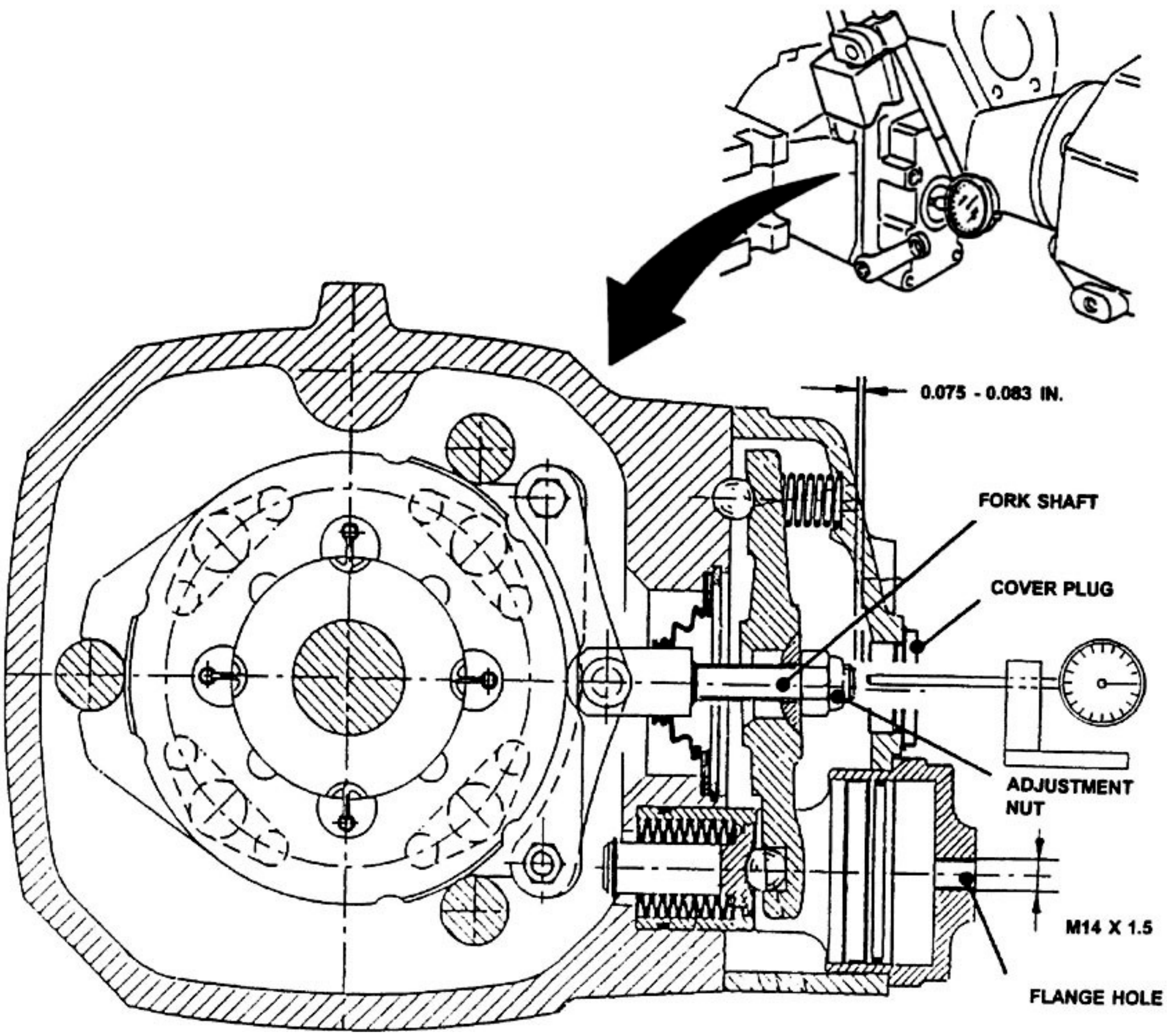


Figure 2–8. Axle brake adjustment.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

011. Aircraft towing tractor fundamentals

1. What is the MB–4's towing capacity?

2. How many gears does the MB–4's transmission have?

3. What type of MB–4 control unit is used to actuate its steering system?

4. How is the MB–4's hydraulic pump driven?

5. How is MB–4's parking brake system controlled?

6. What type of service brake system is used on the MB–4?

7. What happens during the first one in. of treadle valve travel if the MB–4 is equipped with the trailer option?

8. What protects the MB–4's optional winterization system from overload?

012. Aircraft towing tractor maintenance

1. What maintenance practices are used when repairing or replacing electrical wiring?

2. What problems would cause hydraulic fluid to look foamy or milky?

3. What can cause steering wheel kickback?

4. What should you check if the vehicle will not steer correctly in the two-wheel, crab, or oblique steering modes?

5. When troubleshooting brake system malfunctions, what action should be completed before performing a road test?

6. What MB–4 system will lock out certain hydraulic functions unless the vehicle's wheels are positioned correctly?

7. When adjusting the MB–4's front-wheel position sensing system, how do you know the final adjustment is correct?

8. What adjustment should be made whenever the service brake discs are replaced?

2–2. Aircraft Deicer

Aircraft are engineered to exact specifications to provide adequate lift for flight and to maintain control of the aircraft once in flight. When ice or snow builds up on an aircraft, it disrupts airflow and can hinder or prevent safe operation of an aircraft. Because of this, it is critically important for the ice and snow buildup to be removed. This is the function of the Global GL1800AP truck-mounted deicer (fig. 2–9).

Figure 2–9. Global GL1800AP deicer.

The deicer maneuvers around an aircraft while deicing and inspecting the plane. One operator drives the vehicle, while the other dispenses fluids, air blasts, or a combination of both. The vehicle has many unique features and subsystems to accomplish this task. These include the electrical, hydraulic, dispensing, and heater subsystems. Understanding how the vehicle and subsystems function is an essential part of troubleshooting the vehicle. In this section, we will discuss some of the deicer features and fundamentals as well as address the different subsystems.

013. Deicer features and fundamentals

The vehicle chassis can be either a Freightliner business-class M2 or an International 4700-series truck. The manufacturer makes sure both models have a front and rear heavy-duty spring package to accommodate the total weight of the deicer. All of the subassemblies connect to a subframe. The subframe increases the vehicle's capability to support the boom and is attached to the vehicle frame using six shear plates. A torsion bar assembly uses the subframe and rear springs to enhance vehicle stability.

The torsion bar (fig. 2–10) mounts to the subframe over the rear axle. As the deicer moves over an uneven surface, the deicer fluid sloshes side to side, creating an uneven load. To balance the uneven load, the torsion bar pushes down on the rear leaf springs, preventing the spring from compressing. This action by the torsion bar turns the subframe and rear suspension into one solid unit, eliminating the need for outriggers.

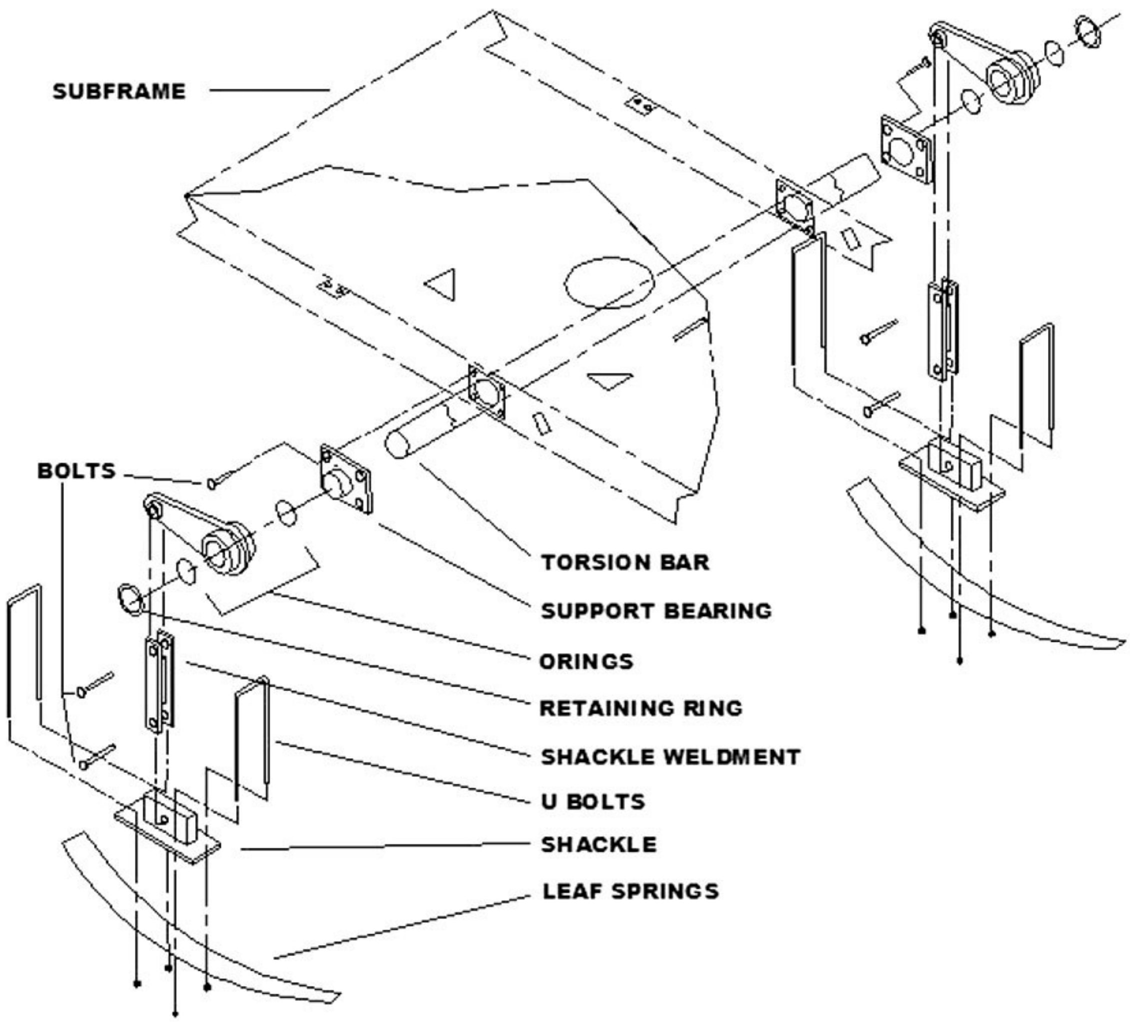


Figure 2–10. Torsion bar.

Controlling the vehicle speed not only increases the vehicle stability but is vital for a stable boom platform. When the boom is out of its rest (saddle), a boom-down indicator switch on the rear side of the saddle sends 12 volts to a relay, which sends 12 volts to the chassis electronic control module (ECM). The ECM activates a cruise control software feature that limits the engine rpm, which limits the vehicle speed to four miles per hour (mph).

Control panels

Figure 2–11 displays two main and six operator control panels, which are listed below:

- Two main control panels: main and heater.
- Six operator controls panels: left, right, AirPlus!, dispensing, truck, ground control.

The main electrical and heater control panels are located in the auxiliary engine compartment. The six operator control panels are in various locations. The ground control panel is on the rear of the driver side of the vehicle.

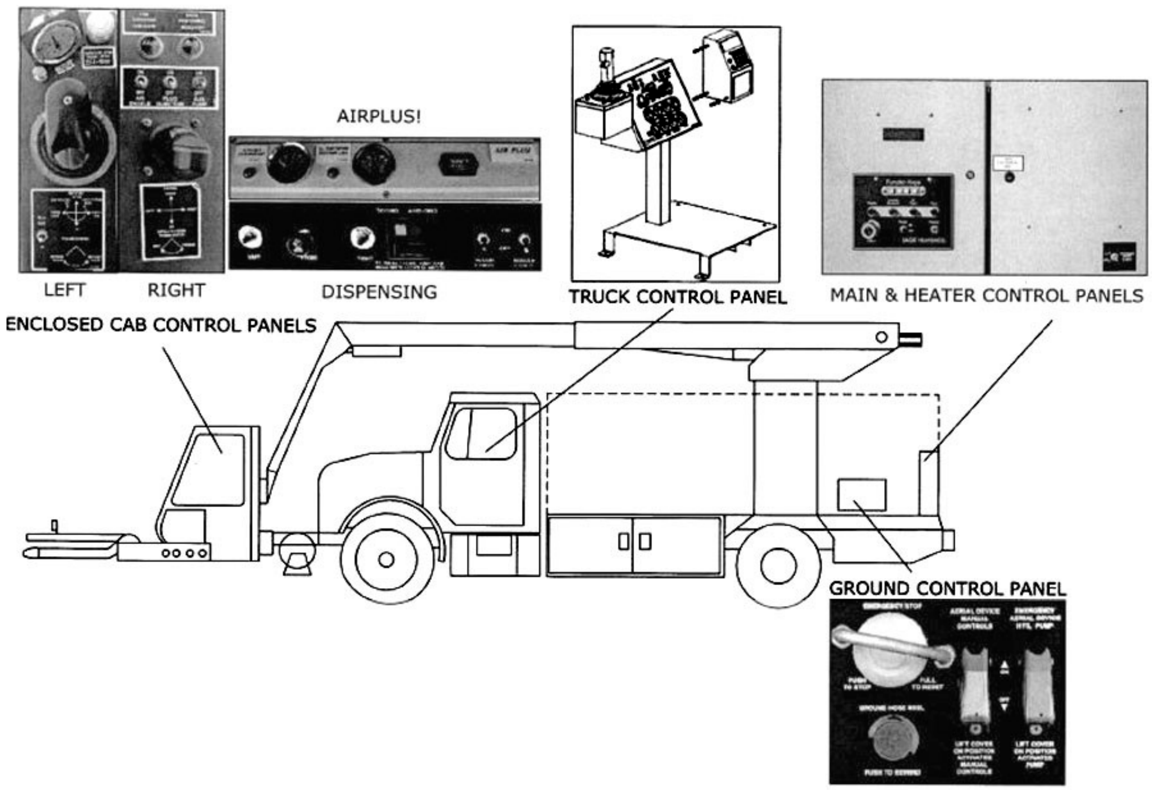


Figure 2–11. Control panel.

There are four control panels in the fluid efficient delivery system (FEDS) enclosed cab and one in the vehicle truck cab.

The four control panels in the enclosed cab are the left-and right-hand joystick, the *AirPlus!,* and dispensing controls. The left-hand joystick controls the boom functions. The right-hand joystick moves the monitor assembly. The monitor assembly consists of the Task Force and Scorpion nozzles. The Task Force is the top nozzle of the assembly and dispenses either deicing or anti-icing fluids. The Scorpion nozzle blasts air from the *AirPlus*! system.

The *AirPlus!* system control panel is located above the enclosed cab door. There are two gauges and lights on it that allows monitoring of the self-contained oil lubrication system. The right-side overhead control panel is the dispensing control panel. The panel has floodlights and wiper switches, along with the dispensing selector switch.

The truck cab control panel (fig. 2–12) is where the auxiliary engine and heater is controlled. There are a few important switches and indicator lights to discuss. First is the auxiliary engine switch that provides voltage to start the auxiliary engine and run the subsystems. Second is the pump switch which controls the auxiliary engine speed and dispensing subsystem. Just to the right of the pump switch is the heater switch.

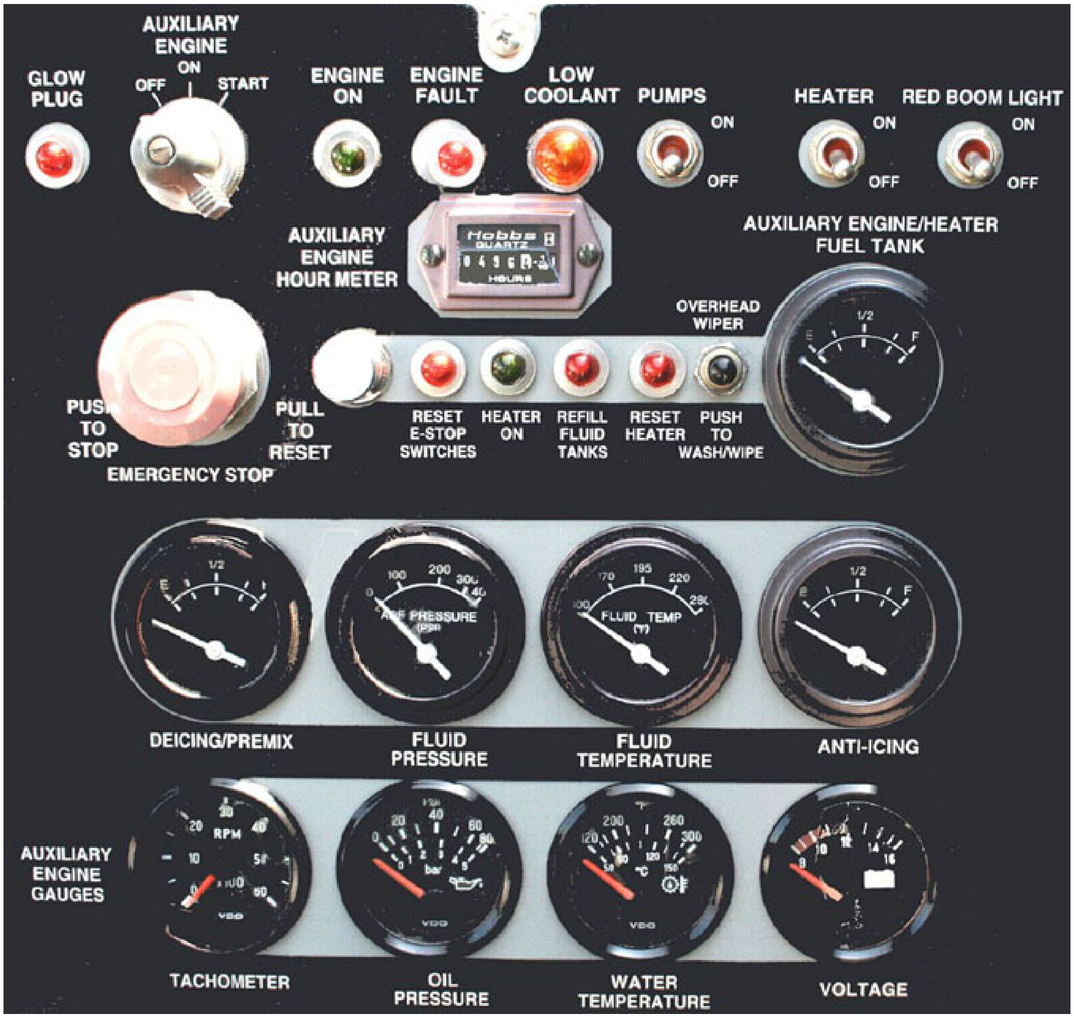


Figure 2–12. Truck control panel.

The first important light to discuss is the red “refill fluid tanks” light, which illuminates when the dispensing anti-icing, deicing subsystems, or the hydraulic system has a low-fluid level. We will discuss more about this light throughout the related lessons. The second light is the “reset E-stop” light. There are three E-stop switches that illuminate this light: one in the enclosed cab, one on the truck control panel in the cab, and one on the ground control panel. Anytime any one of these switches are depressed, the red E-stop light illuminates and the auxiliary engine shuts down or will not start.

Electrical system

Two batteries under the cab on the driver’s side supply 12 volts for the chassis electrical system. A battery in the auxiliary engine compartment supplies 12 volts for all the global subsystems. An isolator switch next to the auxiliary engine is for jump-starting (fig. 2–13). To jump-start either engine, turn the isolator to the “Connected” position.

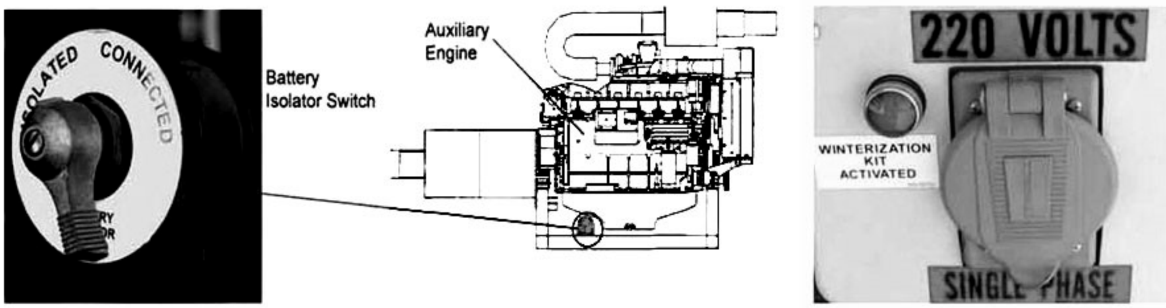


Figure 2–13. Isolator switch and winterization connection.

The isolator switch provides additional amperage but does not increase voltage. After the engine starts, move the switch to the “Isolate” position. The isolator switch should be in the “Isolate” position at all times, except when jump-starting. Leaving the switch in the “Connect” position with both engines running can cause damage to the charging systems.

At the left rear of the vehicle is the winterization system. An external 220 VAC plug-in station supplies the winterization system's power. A yellow light on the winterization box illuminates when connected to an external voltage supply.

Auxiliary engine

Regardless of whether it’s built on an International or Freightliner chassis, all GL1800AP deicer auxiliary engines are six-cylinder turbocharged diesels, built by Deutz. However, the engine uses a different ECM, depending on who manufactures the chassis.

International-chassis deicers use an A Proportional Engine Control System (APECS) 3000 ECM, bolted to the side of the auxiliary engine. Freightliner-chassis deicers use a Deutz ECM mounted to the boom pedestal. Both ECMs control the auxiliary engine speed, idles at 1,250 rpm, and increases to 2,150 rpm when the pump switch is activated.

To protect the engine, the APECS 3000 ECM engine protection program uses three switches to monitor engine condition: an oil pressure, coolant temperature, and coolant-level switch. If the ECM recognizes low-oil pressure, high-coolant temperature, or low-coolant level, the auxiliary engine shuts down. A red light emitting diode (LED) on the side of the ECM module will continuously flash a number “4” fault code. Once you turn OFF the ignition switch, the code will erase.

The Deutz ECM engine protection program reads the same three switches; however, only two will cause the auxiliary engine to shut down: the oil pressure and coolant temperature switches. The ECM illuminates the red fault light, located on the truck cab control panel, if there is an unsafe condition. The coolant level switch controls the orange warning light on the truck control panel.

Enclosed cab

The enclosed FEDS cab protects the operator from the elements while deicing aircraft. Both the vehicle and deicing operators can communicate using cab-to-cab headphones. In front of the FEDS cab door is the monitor assembly. To enter the enclosed cab an operator must lower the monitor nozzle assembly from its vertical stowed position. To lower the monitor nozzle assembly, turn ON the auxiliary engine ignition switch and activate the nozzle stow switch on the right side of the enclosed cab. Once in the enclosed cab, you will find the previously mentioned control panels.

AirPlus! system

The *AirPlus!* system dispenses high volume/low pressure unheated air. The air travels at 700 mph at 11–13 psi out of the Scorpion nozzle. The *AirPlus!* system’s main component is the supercharger. Located under the enclosed cab operator seat is the *AirPlus!* supercharger assembly. It consists of a hydraulic motor, belts, gear reduction supercharger, and an oil pump. The hydraulic motor drives the supercharger with a heavy-duty belt and drives the oil pump with a regular V-belt. A scatter shield is between the seat and supercharger assembly; it protects the operator from injury during a supercharger failure.

Figure 2–14 depicts the *AirPlus!* self-contained lubrication system. The oil reservoir for this system is located behind the enclosed cab left-side vent panel. Oil flows from the oil pump through an oil cooler and in-line filter to the pressure regulator. The pressure regulator maintains oil pressure at 45 psi before going to the supercharger. An oil pressure switch, oil temperature sending unit, and a vacuum switch monitor the oil system.

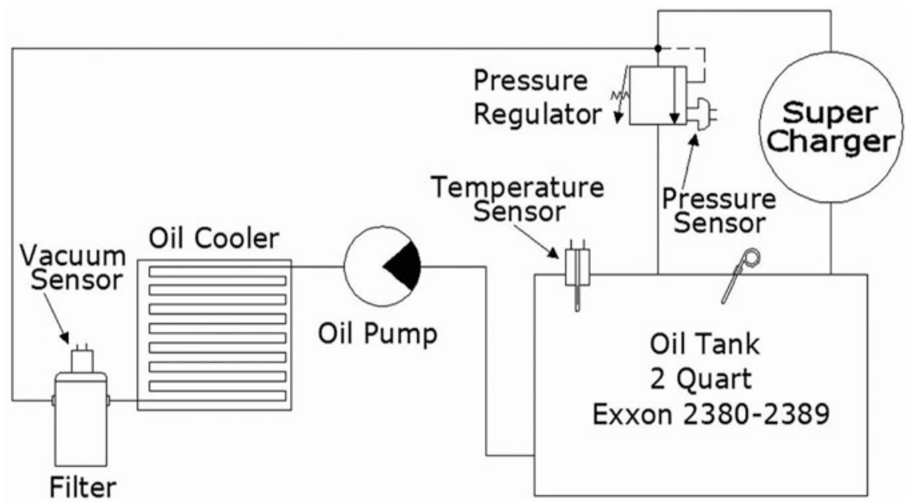


Figure 2-14. AirPlus! oil system.

Recently, Global has manufactured deicers equipped with superchargers that are self-lubricating, eliminating the oil reservoir, cooler, pump, and regulator. If your trucks are equipped with this system, there is no need to monitor the oil pressure. The only gauge necessary is the oil temperature.

CAUTION: Do *not* operate the air system with personnel or debris in the air-blast radius.

Hydraulic system

The hydraulic system is the heart of the deicer. It affects every subsystem is some manner, which is why it is so important to understand hydraulic system fundamentals. In this lesson, we will cover components common among multiple systems and the hydraulic pumps. We will cover more specific hydraulic functions in the lessons on boom functions, dispensing, and heater systems.

Hydraulic tank

The hydraulic tank is located on the driver side rear of the vehicle. It is vented and holds 65 gallons. There is a sight gauge at the rear of the tank and a hydraulic low-level switch on the backside of the tank. The low-level switch works with a six-second time delay (TD) relay to protect four hydraulic pumps. Both the hydraulic low (HL) switch and TD relay control the HL relay electrical circuit.

HL level

Figure 2–15 shows how the HL-level circuit works. In the first part of the circuit, supply voltage from the ignition switch goes through CB 4, the enclosed cab E-Stop switch, the HL coil, through the TD relay, and stops at the open HL-level switch. Supply voltage also goes through the normally closed HL-level relay contacts, the two E-Stop switches, and the engine run relay (ERR) coil to ground. With supply voltage and complete ground at the ERR coil, the normally open contacts in the second part of the circuit closes. With these contacts now closed, auxiliary engine battery voltage goes to the auxiliary engine ECM, allowing the auxiliary engine to start.

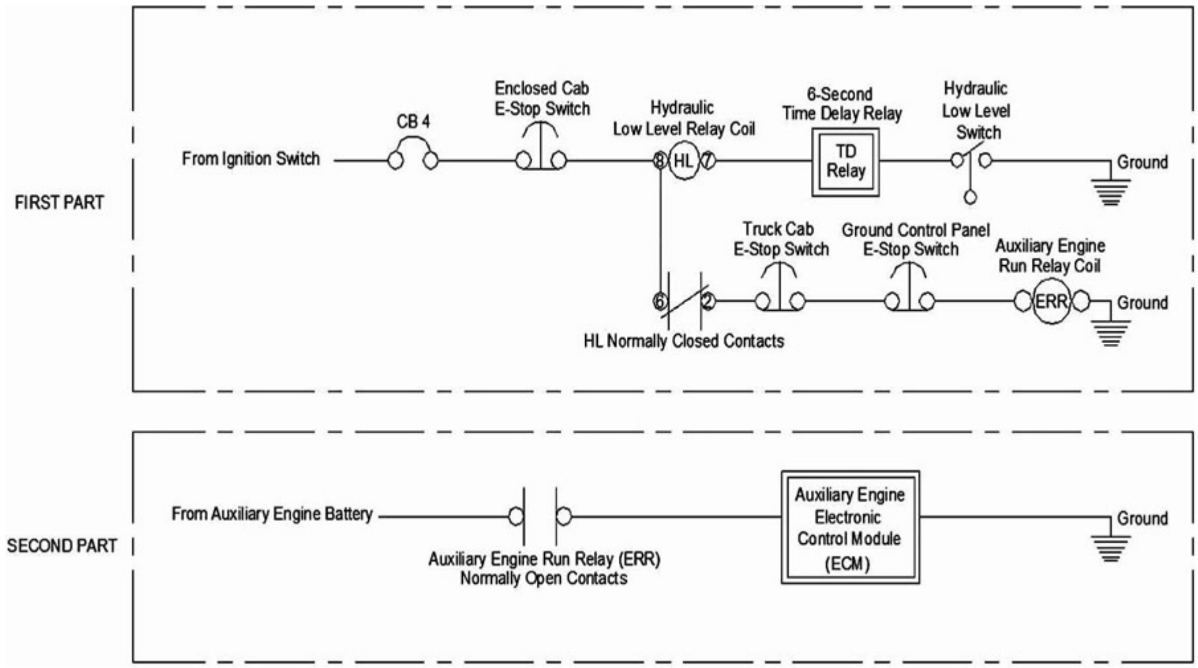


Figure 2–15. Hydraulic low-level circuit.

The TD relay provides the six-second delay to account for fluid sloshing in the tank during operation. As fluid sloshes, the low-level switch may momentarily close. The TD relay prevents premature shutdown of the auxiliary engine.

The following conditions occur when the HL-level circuit activates:

1. The auxiliary engine will crank but not start.
2. The red refill tank and E-stop lights illuminate.

Pumps and circuits

Three of the four hydraulic pumps (5, 90, and 100 series) are mounted to, and driven by, the auxiliary engine. All three pumps have maintenance shut-off valves in the supply lines on the backside of the hydraulic tank. The fourth pump, the emergency pump, mounts under the boom control valve manifold and allows for operation of the boom in the event of an engine malfunction or emergency shutdown.

5-series pump

The third and smallest of the three pumps attached to the auxiliary engine is the 5-series boom pump. Under normal operation, the 5-series pump supplies hydraulic fluid to the boom functions. Figure 2–16 shows how hydraulic fluid travels from the pump to the boom hydraulic control manifold.

Although not depicted in figure 2–16, the control manifold contains a deadman control valve. The deadman circuit is designed to prevent the boom hydraulic system from activating until the operator squeezes the trigger switch on the boom joystick. This system ensures the boom will not move if someone unintentionally moves the joystick.

When the deadman circuit is not activated, fluid flows through the deadman control valve, through the control manifold, the return filter, and returns to the tank. Once the deadman control valve closes, the hydraulic fluid is sent to the different circuits and proportioned to the active boom function(s). We will discuss the deadman circuit in more detail during the electrical lesson. When the auxiliary engine fails to drive the 5-series pump, the operator can use the emergency pump to operate the boom functions.

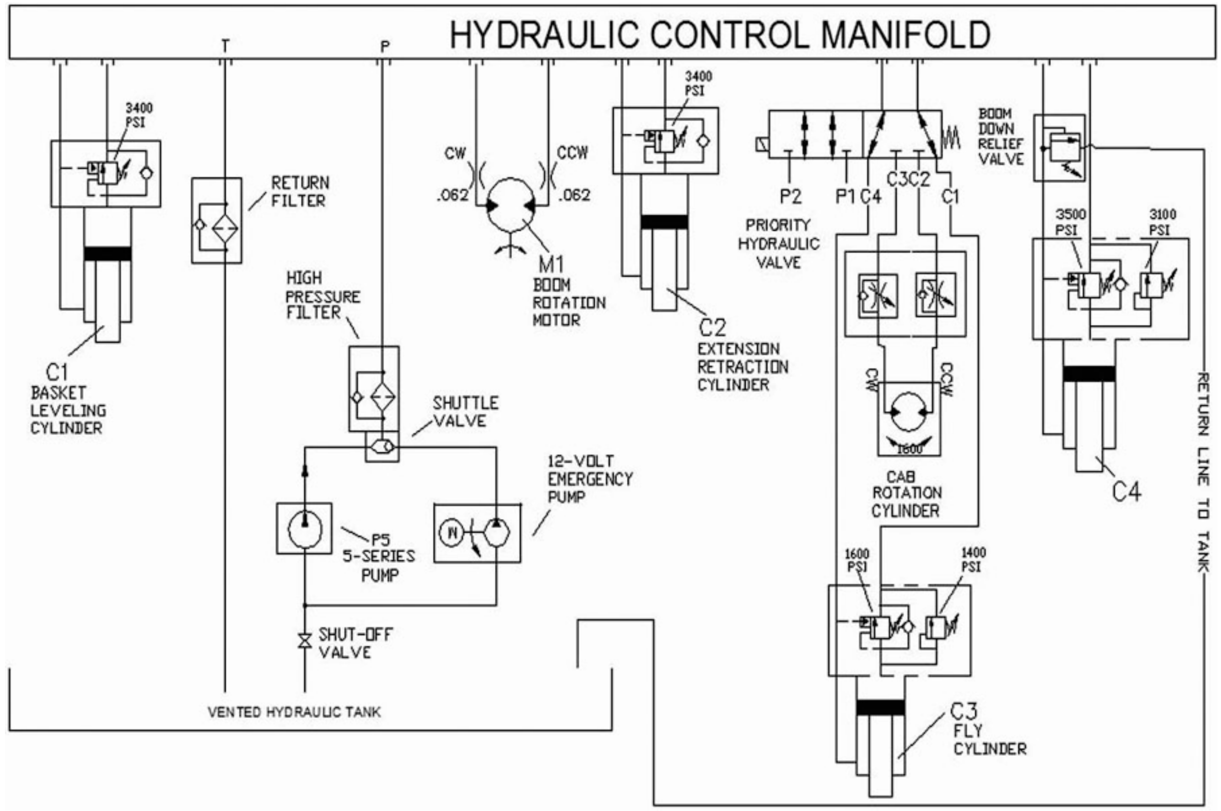


Figure 2–16. 5-series hydraulic circuit.

Emergency pump

The emergency pump is a low-volume gear pump attached to a 12-volt electrical motor. The pump supplies enough fluid to operate the boom for short periods of time. A shuttle valve mounts between the outlet lines of the emergency and 5-series hydraulic pumps. The shuttle valve enables only one pump to supply fluid to the hydraulic control valve manifold. An operator can activate the emergency pump from the enclosed cab or the ground control panel.

90 series

The middle of the three hydraulic pumps attached to the auxiliary engine is the 90 series and is used for dispensing and heater systems (fig. 2–17). Fluid from the pump goes to the mono block on the pump skid. The pump skid is located on the passenger side of the vehicle and houses three pumps and the fire suppression system. The mono block distributes the fluid to four hydraulic motors: deicing, anti-icing, heater fuel pump, and heater air blower. Each hydraulic motor has an individual electrically operated hydraulic control valve to activate the system.

Three of the control valves are mounted in the mono block. The heater blower motor control valve mounts near the heater system. There are two adjustable flow control valves on the bottom of the mono block. The valves maintain the motor speed for the anti-icing and heater fuel pump hydraulic circuits.

100 series

The first hydraulic pump, directly attached to the auxiliary engine flywheel, is the 100 series, which operates the *AirPlus!* system. This pump supplies hydraulic fluid to one motor under the enclosed cab operator’s seat. To inspect the motor, remove the operator’s seat and scatter shield.

90- and 100-series basics

The 90- and 100-series hydraulic pumps are variable displacement piston-type pumps. They can produce 7,000 psi of hydraulic pressure. To extend the life of the pumps, Global designed the hydraulic systems to operate at less than one-half of the pumps' maximum capacity. Additionally, both pumps share a hydraulic oil cooler. The oil cooler system has a temperature-controlled fan to keep the hydraulic fluid at an optimal temperature of 160°F.

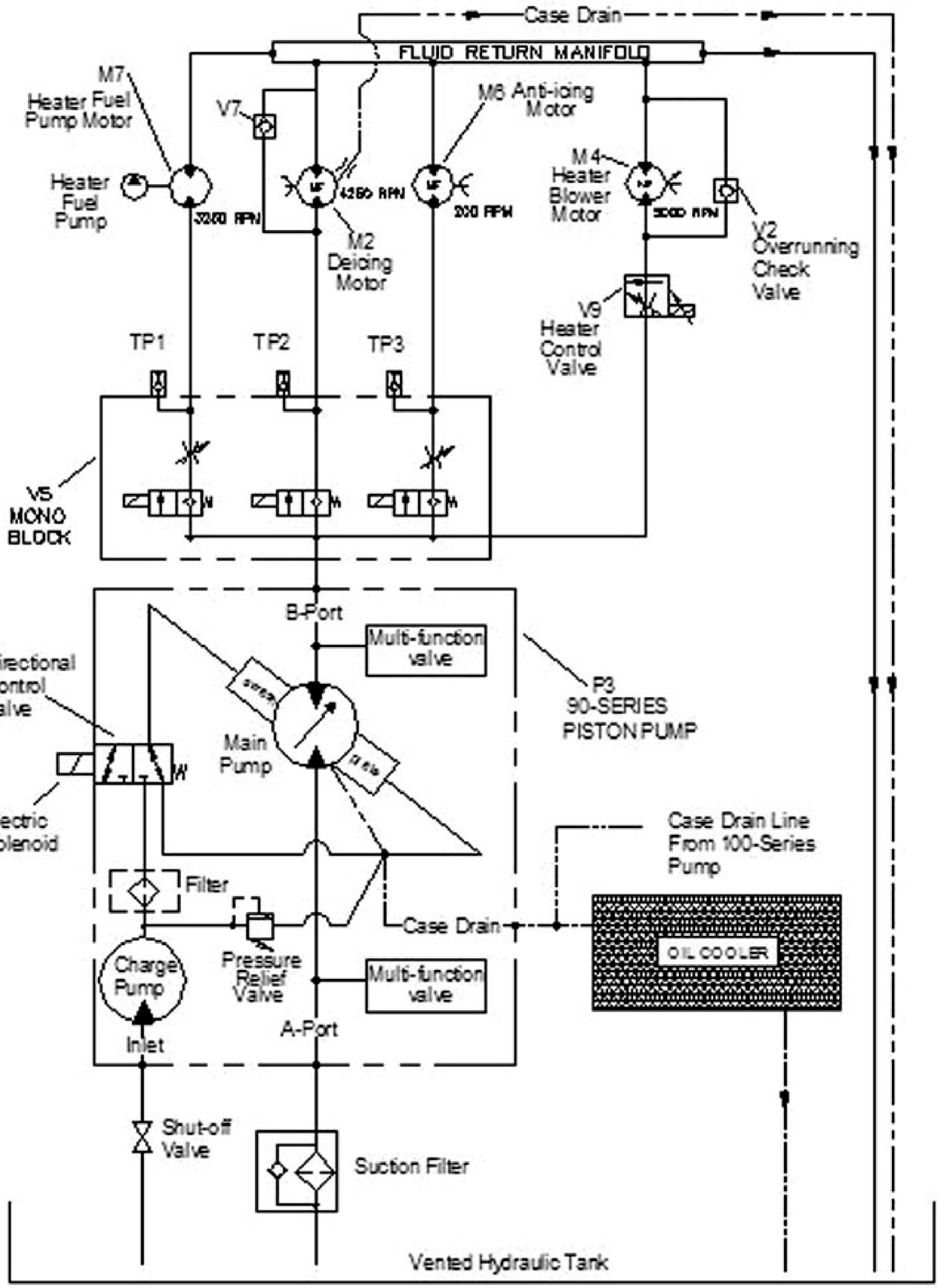


Figure 2–17. 90-series hydraulic circuit.

Fire suppression system

The deicer's Ansul fire suppression system (fig. 2–18) consists of a firebox, gas charge cylinders, dry chemical fire bottles, cables with temperature sensitive fusible links, and discharge nozzles. The system design allows for automatic or manual discharge of a dry chemical agent.

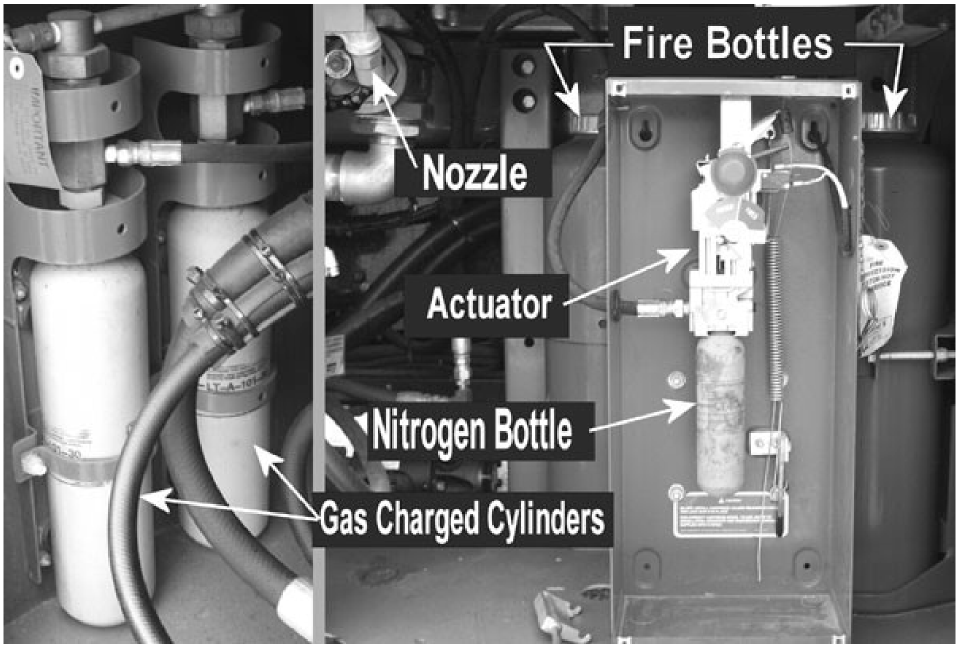


Figure 2–18. Fire suppression system.

The firebox contains a spring-loaded actuator, nitrogen bottle, and cable-release handle. The actuator arm has a mechanical lever to lock the spring tension in the coiled position. Cables with temperature-sensitive fusible links keep the spring in the coiled position. With the mechanical lever locked, the actuator is ready for operation.

When a fusible link melts, or the manual release button on the front of the firebox is pressed, the fire suppression system is activated. The mechanical lever of the actuator releases the needle. The needle moves down, piercing the nitrogen bottle. The nitrogen gas travels through the outlet line to break the bursting seals on top of the two gas-charged cylinders. The gas-charged cylinders pressurize the two dry chemical fire bottles: one bottle for the auxiliary engine compartment and the other for the pump skid. With the fire bottles pressurized, the fire extinguishing agent flows though piping to the fire nozzles. The nozzles distribute the agent throughout the auxiliary engine and pump skid compartments.

014. Deicer boom fundamentals

This lesson introduces the deicer boom components and its operation fundamentals. The deicer uses five cylinders and a motor to operate the boom.

To describe the boom assembly, we will begin with the pedestal. The pedestal is the foundation of the entire boom assembly (fig. 2–19). It is mounted over the rear axle, which supports the boom assembly weight. The turret assembly is mounted on top of the pedestal. In between the turret and pedestal are a bull gear (swing bearing) and a mechanical stop.

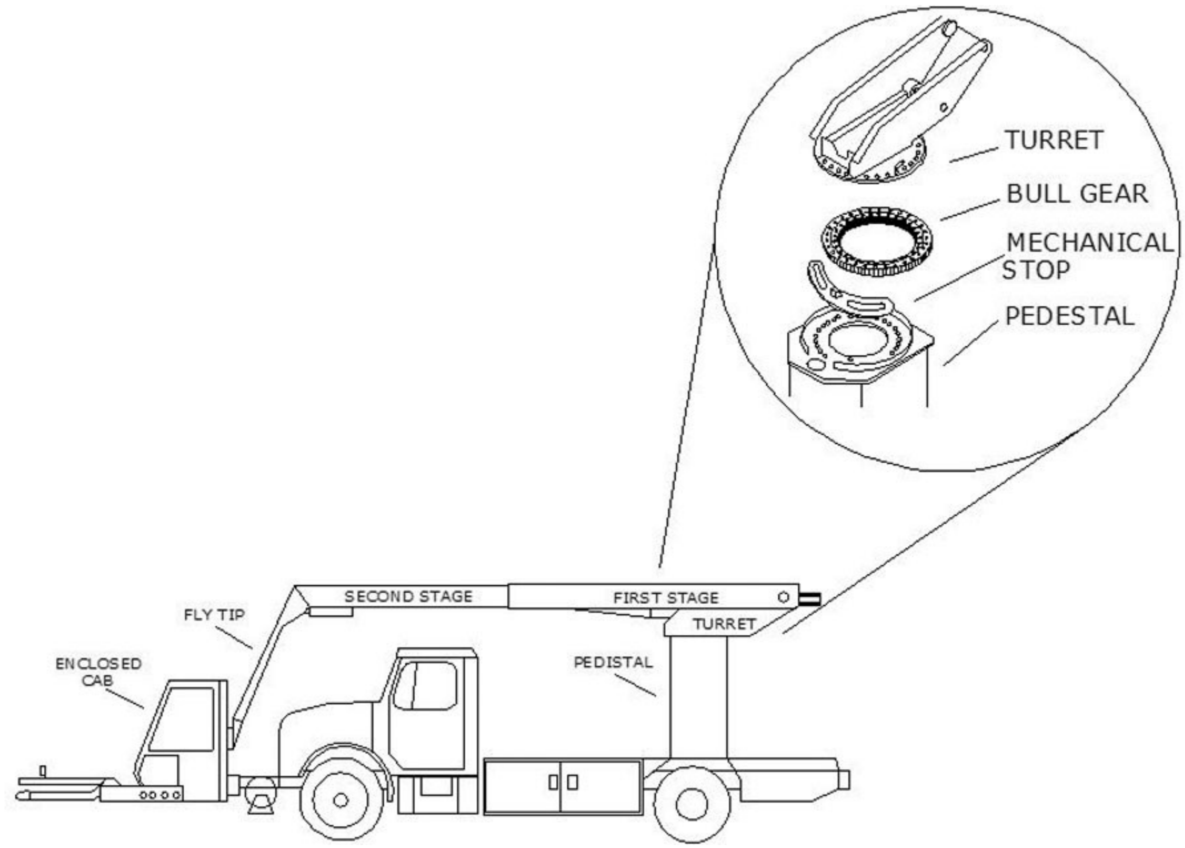


Figure 2–19. Boom assembly.

Fixed to the turret is a telescoping two-stage boom. The first stage of the boom connects to the turret. The second stage rides on wear pads inside the first stage and uses a cylinder to extend the boom 6 ft. On the end of the second-stage boom is the fly tip. The fly tip articulates the enclosed cab for precise movement. The enclosed cab can rotate from side to side. Lastly, the enclosed cab has an automatic leveling system. This system levels the enclosed cab anytime the boom angle changes.

To use these boom functions, an operator uses a joystick from the enclosed cab, the truck cab, or the manual levers on the hydraulic control valve assembly near the ground control panel. The boom functions include the following:

1. Fly articulation.
2. Basket leveling.
3. Boom rotation.
4. Boom elevation.
5. Enclosed cab rotation.
6. Boom extension and retraction.

Parker series–6 manifold

The 5-series hydraulic pump supplies fluid to the Parker series–6 manifold (fig. 2–20). The manifold distributes fluid to six different hydraulic actuators (all boom functions). The boom functions will *not* operate without the deadman solenoid being energized. The solenoid requires 12 volts to operate.

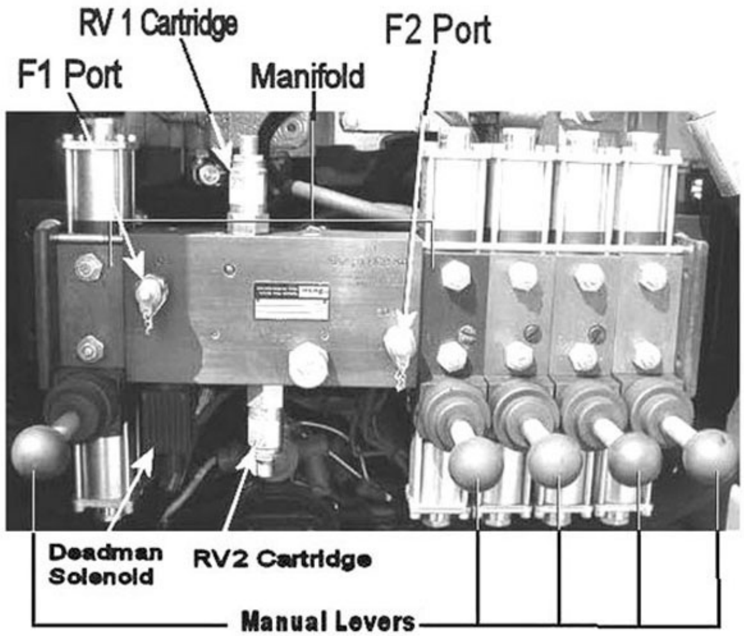


Figure 2–20. Parker series 6 manifold.

The operator must use the boom joystick deadman switch or aerial device manual toggle switch on the ground control panel to activate the deadman solenoid. This will allow the operator to use the manual levers at the ground control manifold to operate the boom functions. The manifold has function solenoids, a deadman solenoid, spool valves, and RVs. Under normal electrical operation, each boom function solenoid is controlled with a valve driver board (VDB).

Boom elevation

Boom elevation is also referred to as "topping." The deicer maximum working height is 47 ft. The boom uses one double-acting hydraulic cylinder to raise and lower the boom. The boom elevation cylinder is equipped with a pilot-operated check valve (hold/lock valve). This valve prevents the boom elevation cylinder from retracting and the boom from falling in the event of a hydraulic failure. As we discussed earlier, a slow vehicle speed provides a stable platform for when the boom is elevated. The speed control feature is activated by the boom-down indicator switch (fig. 2–21).

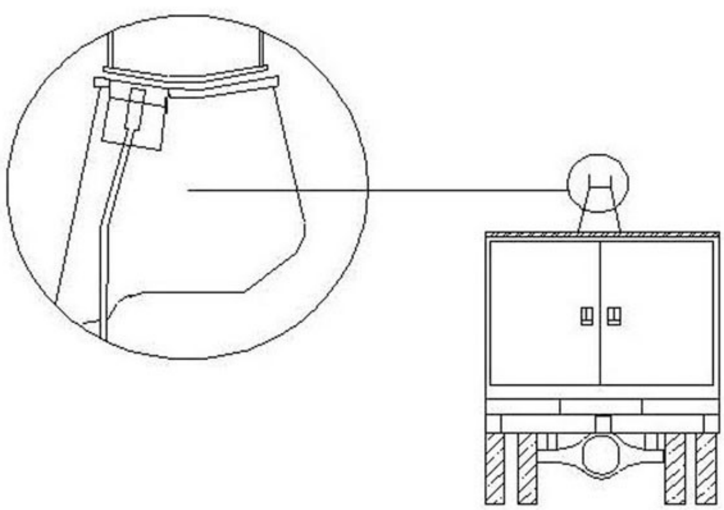


Figure 2–21. Boom-down indicator switch.

Boom extension and retraction

As already discussed, the boom consists of a telescopic two-stage boom. One double-acting cylinder is used to extend the second stage by 6 ft. The second stage slides in and out of the first stage. Shimmed wear pads prevent metal-to-metal contact and keeps the boom segments aligned.

On the driver's side of the second stage is a movable cat track (fig. 2–22). The cat track provides a means of extending and retracting the boom without damaging the hoses and cables that lead to the enclosed cab. The lines route through the center of the pedestal to the cat track and then to the enclosed cab.

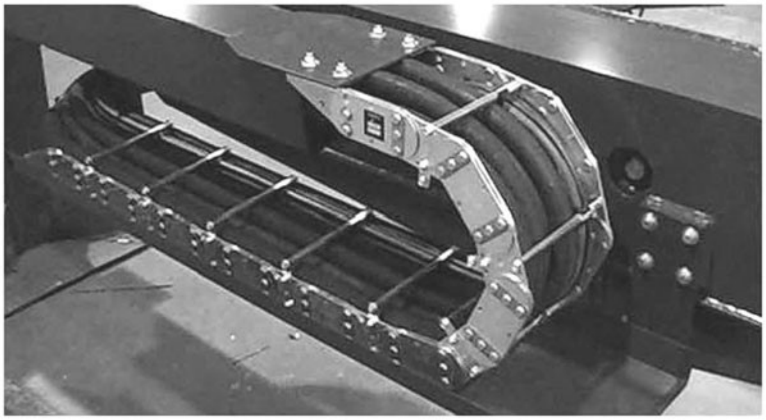


Figure 2–22. Cat track.

Boom swing

On the upper portion of the pedestal is a stationary hydraulic motor and gearbox assembly (fig. 2–23). This assembly controls the boom swing function. When the operator activates the boom swing function, the hydraulic motor rotates the pinion gear in the gearbox. The pinion gear meshes with a bull gear and rotates the turret assembly. As the bull gear rotates the turret assembly, the sliding mechanical stop (fig. 2–23), stops the boom rotation at 185° in either direction.

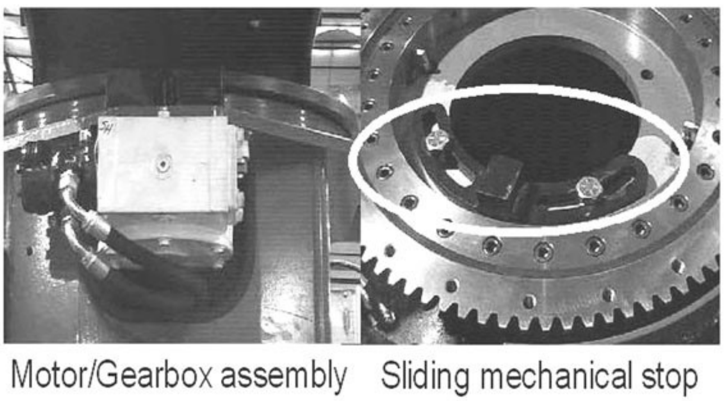


Figure 2–23. Gearbox and bull gear assembly.

Fly tip

The fly tip is located between the second stage and the FEDS cab. The fly tip moves the end of the boom and the enclosed cab up and down, giving the operator precise movement around aircraft. Like the boom elevation, the fly function uses one double-acting cylinder.

Enclosed cab rotation

The enclosed cab rotation feature uses a unique double-acting cylinder known as the helical hydraulic rotary actuator (fig. 2–24). Unlike typical hydraulic cylinder rams, this cylinder ram is spiral cut. A sealed gland pack moves up or down on the spiral cut ram. The ram ends attach to the outside housing of the enclosed cab assembly, rotating the entire housing as the cylinder ram rotates.

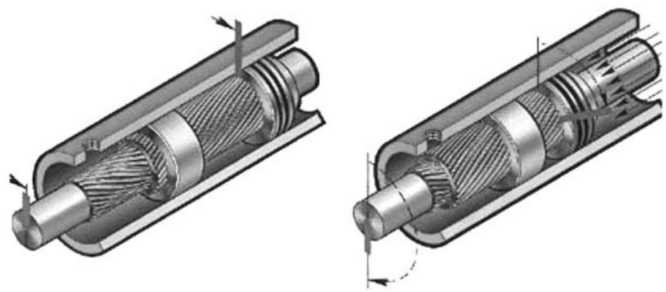


Figure 2–24. Helac Corporation rotation actuator.

Two adjustable flow control valve cartridges under the priority valve determine the enclosed cab speed. The priority valve on the end of the second boom hydraulically separates the enclosed cab rotation and fly functions. These two boom functions share the same VDB and electrical circuit but not the same hydraulic actuators. The enclosed cab rotation and fly functions *cannot* operate at the same time.

Enclosed cab leveling

The enclosed cab leveling system uses a basket-leveling sensor. The sensor mounts on the end of the fly tip. The sensor signals the leveling VDB when a 6° angle change occurs. Any time the leveling sensor signals the VDB and an operator activates the deadman solenoid or fly function, the enclosed cab levels itself by using one double-acting cylinder.

SAFETY PRECAUTION: When adjusting the basket-leveling sensor the enclosed cab can move automatically, causing personal injury or death. Make sure you follow the instructions in the service manual before attempting to adjust the basket-leveling sensor.

Function speed

The VDB controls the amount of current flow to the functional solenoids on the Parker series–6 manifold. The VDB settings can be adjusted; decreasing the amount of current will slow the function speed; increasing current will make the functions operate faster.

Because the fly and enclosed cab rotation functions share the same VDB, only one function can use the VDB setting to adjust the function speed. The fly function uses the VDB to control the lifting and lowering speed, while the enclosed cab rotation uses two hydraulic flow control valves to control the rotation speed. The table below lists the boom functions and speed specifications.

Boom Functions and Speed Specifications	
Boom Function	**Speed Specifications**
Fly tip	21 seconds up/down (adjusted by the VDB).
Boom elevation	40 seconds up/down (adjusted by the VDB).
Boom swing	34 seconds from 0 to 90 degrees (adjusted by the VDB).
Boom extension/retraction	14 seconds to full extension/full retraction (adjusted by the VDB).
Enclosed cab leveling	No speed specification—Adjust to achieve safe, smooth cab leveling (adjusted by the VDB).
Enclosed cab rotation	5 seconds stop-to-stop (adjusted by the flow control valves).

Boom electrical circuit

There are two separate circuits within the boom electrical system: deadman and joystick. Both circuits need to work properly in order to safely operate the boom functions. No boom function will operate unless the deadman solenoid is energized, so we will discuss the deadman circuit first.

Deadman

To activate the deadman circuit (fig. 2–25), squeeze either of the deadman (red trigger) switches on the joysticks or activate the aerial device manual switch on the ground control panel. This action sends supply voltage to an electrical relay in the main control panel. The relay controls an electrical solenoid on the hydraulic manifold (Parker series–6 control valve manifold). The solenoid moves a directional control valve, sending hydraulic fluid to the boom function directional control valves in the hydraulic manifold. When the solenoid is *not* energized, the spool valve directs hydraulic fluid to the hydraulic tank; therefore the hydraulic system does not create the necessary pressure to operate any boom functions.

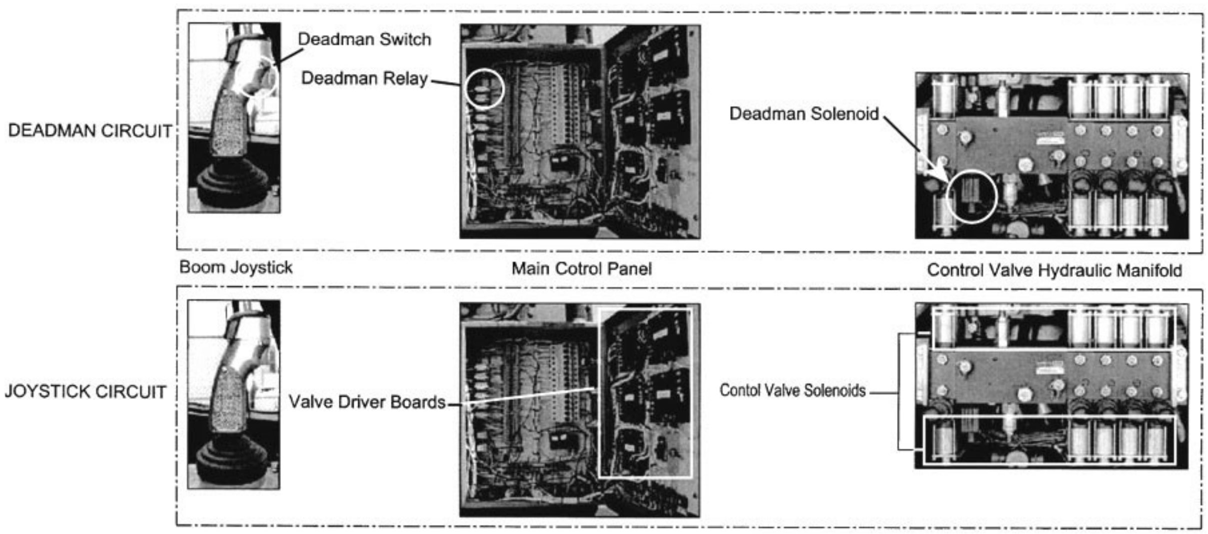


Figure 2–25. Deadman and joystick system.

Joystick

It is easier to understand the joystick electrical circuit if we break it into three parts: the control units, input circuits, and output circuits. The control units for all six boom functions are the five VDBs. The joysticks are the inputs and the control valve solenoids are the outputs.

Control unit/VDB

Use figure 2–26, and the VDB voltage table below, as we explore the joystick electrical circuit. When you turn the auxiliary engine ignition switch ON, the VDB “VS” terminal receives supply voltage. Once the VDB receives supply voltage, it produces a reference voltage at the + (positive) terminal of the input circuit. Reference voltage goes through the joystick resistor to the – (negative) terminal.

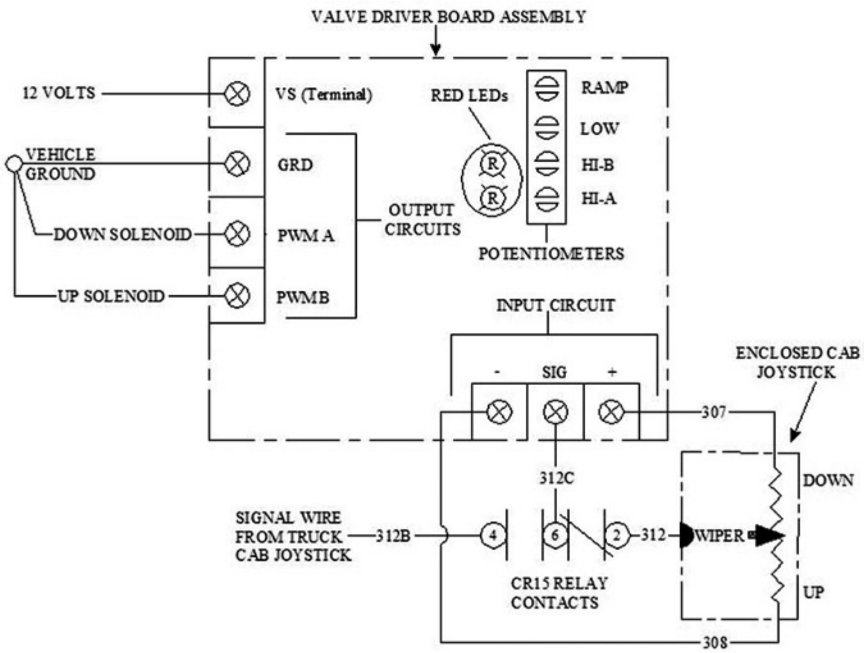


Figure 2–26. Valve driver board assembly.

VDB Voltage Table			
Supply Voltage	**Reference Voltage**	**Signal Voltage**	**Output Voltage**
12 ± 2 volts	6 ± 0.30 volts	3 ± 0.36 volts	* 0 – 6 volts
* The output voltage is an *estimated valve for training use only*.			

Input

The input circuit starts at the joystick wiper. Voltage from the wiper goes through wire 312, the normally closed terminals 2 and 6, of circuit relay (CR) 15 contacts, wire 312C, and to the VDB “signal” (SIG) terminal. This voltage at the SIG terminal is called signal voltage. Based on the amount of signal voltage, the VDB will determine which output circuit to activate. With no outside influence, the joystick wipers rest in the middle of the resistor. The VDB recognizes this amount of signal voltage (3 ± 0.36 volts) as the neutral position.

Output

The output circuit starts at the pulse width modulated (PWM) terminals on the VDB assembly. PWM A output circuit controls the amount of current flow to the boom-down solenoid. The PWM B output circuit controls the amount of current flow to the boom-up solenoid. When a PWM output circuit is energized, a corresponding HI–A or HI–B red LED illuminates.

Here’s how the boom up-and-down functions work. Move the joystick to the boom-up position, the joystick wiper moves down, reducing the amount of signal voltage to the SIG terminal. With less than 3 ± 0.36 volts, the VDB activates the PWM B circuit. The boom-up control valve solenoid moves the hydraulic spool valve in the hydraulic manifold, sending hydraulic fluid to the cylinder, raising the boom. Move the joystick to the down position, the opposite reaction occurs. The remaining boom functions operate in the same fashion.

015. Deicer dispensing and heating system fundamentals

The dispensing system has two subsystems to deliver fluid: deicing and anti-icing. The two types of fluid in the dispensing system require different methods of delivery. However, the two subsystems have a few common components.

One of the common items is a single, stainless-steel 1,800-gallon dispensing tank assembly behind the truck cab. The tank assembly is a one-piece design divided internally to create two tanks. The larger section is the 1,650-gallon deicing tank, and the smaller one is the 165-gallon anti-icing tank. Although the total capacity of the tanks is 1,815 gallons, the manufacturer decided to round the model name down to 1800 for ease of identification.

Deicing system

On the passenger side of the deicing tank is a low-level switch. The switch is part of the deicing low-level electrical circuit. This electrical circuit protects the deicing pump and the heater system when the fluid level is less than 150 gallons by shutting down the pumping function. When the low-level switch closes during deicing operations, the low-level electrical circuit activates, which deactivates several relays. The relays open and close their contacts to perform the following:

- Disable the 90-series pump solenoid.
- Disable the deicing hydraulic motor solenoid.
- Deactivate the auxiliary engine high-throttle circuit.
- Remove a signal input to the heater ECM.
- Illuminate the red refill tank light.

During deicing operations, deicing fluid sloshing around in the tank can close the low-level switch, shutting down the system prematurely. To eliminate the situation on newer vehicles, Global installed a time delay relay in series with the low-level switch.

Selector switch and valves

A selector switch on the dispensing panel controls the deicing and anti-icing system. To select the deicing system, the operator presses the selector switch to the deicing position. While the operator holds the switch, an electrical motor and actuator assembly moves the ball valve lever. The lever opens the deicing ball valve, while closing the anti-icing ball valve. The operator continues to hold the switch until the amber light illuminates.

Fluid flow

Figure 2–27 depicts the deicing and anti-icing subsystems. Deicing fluid travels from the tank through the enclosed cab heater core and back to the tank. Fluid continues to the ground gun, fluid inject valve, and the foot-operated rocker pedal. The operator can use the rocker foot pedal to vary the amount of deicing fluid dispensed through the Task Force nozzle. The operator can also change the spray pattern with the thumb switch on the right-hand control panel nozzle joystick.

Pressure regulator

With the ground gun and rocker pedal closed, deicing fluid pressure increases. When fluid pressure reaches 180–200 psi, the pressure regulator opens. The regulator will maintain system pressure between 180–200 psi until the ground gun or Task Force nozzle is used, decreasing the system pressure, allowing the pressure regulator to close. Deicing fluid circulates from the tank, through the pump, heater coils, pressure regulator, and back to the tank. As we discussed in the above paragraph, when an operator presses the rocker pedal, system pressure decreases causing the pressure regulator to close, directing all the fluid to the Task Force nozzle. When the rocker pedal closes and pressure builds up, the pressure regulator opens again.

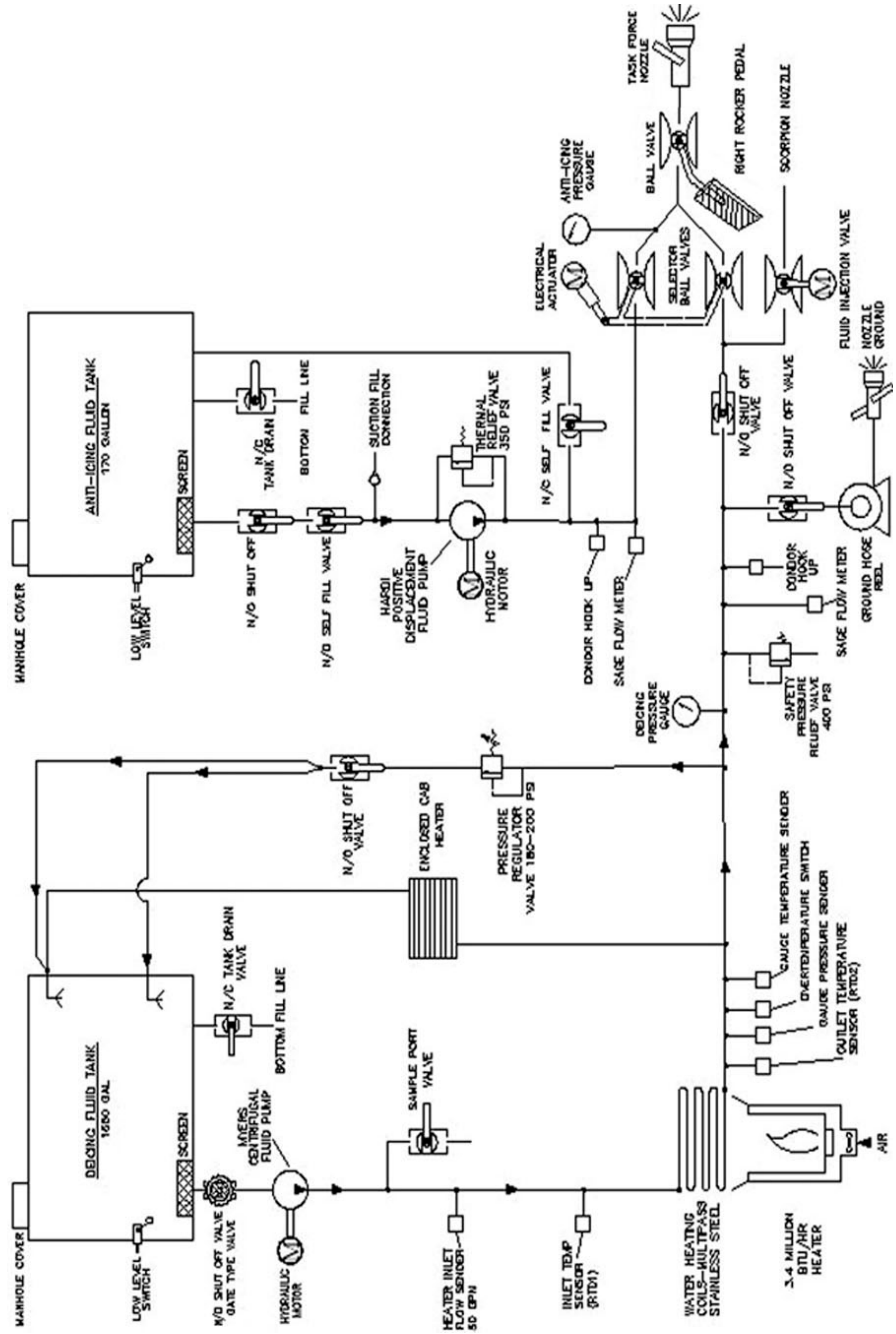


Figure 2–27. Dispensing system.

Safety RV

Deicing system pressure will greatly increase if the pressure regulator fails or the shut-off valve located behind it is closed. This excess pressure will open the safety RV. Fluid exiting the safety relief valve goes directly to the ground. The safety RV is factory set; *do not* attempt to adjust the valve.

Fluid inject system

The fluid inject valve injects approximately 9 gpm of heated deicing fluid in the *AirPlus!* Scorpion nozzle. The fluid inject valve is under the enclosed cab near the rocker pedal. The fluid inject valve is a motorized ball valve design. An operator can only activate the fluid inject system when using the *AirPlus!* system.

Anti-icing system

On the driver's side of the anti-icing tank is a low-level switch. The switch is part of the anti-icing low-level electrical circuit. The circuit is designed to protect (shut down) the anti-icing pump anytime the fluid level is less than 20 gallons. When the low-level switch closes during anti-icing operations, the low-level electrical circuit activates a relay, which disables the anti-icing solenoid on the mono block and illuminates the red refill tank light. The auxiliary engine and other systems are not affected when this low-level circuit activates.

Dispensing switch and valves

Use the same selector switch on the dispensing control panel to activate the anti-icing system. To select the anti-icing system, hold the switch in the anti-icing position until the blue light illuminates. While an operator holds the switch, the electrical actuator opens the anti-icing ball valve and closes the deicing ball valve. The operator *must* depress the rocker pedal all the way to the floor in order to activate the anti-icing system. You *cannot* vary the amount of anti-icing fluid from the Task Force nozzle.

Fluid flow and self-fill system

Anti-icing fluid travels from the tank through the maintenance valve, self-fill valve, piston-type pump, selector ball valve, and rocker pedal. Global designed the anti-icing system with the options to fill the anti-icing system from overhead manhole covers or with 55-gallon drums. The self-fill system allows the operator to connect a 55-gallon drum to the suction fill connection. Follow the instruction found on the pump-side access door to properly operate the self-fill system.

Thermal RV

The thermal RV mounts between the inlet and outlet of the anti-icing six-piston diaphragm pump. The thermal RV protects the pump from excess pressure. Excess pressure in the anti-icing derives from heat transfer. During heater operation, 180°F deicing fluid circulates back to the tank. Some of the heat transfers through the wall in the tank assembly to the anti-icing fluid. Heated anti-icing fluid that is trapped between the selector valve and the pump can create enough pressure to damage the diaphragms in the pump. The thermal valve protects the pump before the pressure causes damage. When the thermal valve opens, it sends the excess pressure from the outlet side into the suction side of the system.

Deicer heater system

The Sage Company manufactures the computer-controlled 3.4 million British thermal unit (BTU) heater system, which heats the deicing fluid to 180°F, as mentioned before. The ECM has a 16-stage (fig. 2–28) software program to control the heater's air and fuel systems. The program uses various inputs and outputs to determine the correct BTU demand for each stage.

Heater Stages

Note: The values in the following chart for the Blower Signal and Blower Speed are approximate except for Stage 14. Use the value listed in the chart for Stage 14.

Stage	Air Pressure (psi)	Fuel Pressure (psi)	Burner Number On	Blower Signal	Blower Speed (rpm)
14 - Default	0.75	0	0	500	1000
14 - Light Off	1.25	150	1	1000	1,600
1	3.5	200	1	2100	2,800
2	4.5	250	1	2300	3,200
3	5.5	300	1	2500	3,700
4	6.75	150	1 and 2	2700	4,000
5	7	200	1 and 2	2800	4,200
6	7.1	250	1 and 2	2900	4,300
7	7.5	300	1 and 2	3100	4,400
8	8.1	200	1, 2 and 3	3200	4,500
9	8.25	250	1, 2 and 3	3300	4,600
10	8.5	300	1, 2 and 3	3400	4,700
11	9	200	1, 2, 3 and 4	3500	4,800
12	10	250	1, 2, 3 and 4	3600	4,900
13	10.5	300	1, 2, 3 and 4	3800	5,000
15 - Post Purge	9	0	All burners Off	3200	4,500
16 - Post Purge	5	0	All burners Off	2300	3,200

Outlet set point — 180°F
Efficiency factor — 0.85%
All nozzles are 5 gph with a 60 degree spray angle
= Reference only

Figure 2–28. Heater stage table.

There are four burners at the plenum side of the heater assembly. Each burner is numbered 1–4 for easy identification. Each assembly also has one fuel tube, a spray nozzle, and a fuel solenoid. Number 1 burner has a few more components, such as a cadmium (CAD) cell, igniter, and exciter. The heater system ignites the number 1 burner first; when a flame is established, the other burners will ignite in order. The number 1 burner is the first to ignite and the last to turn off. Mounted on top of the plenum is the air blower, which charges the plenum with air. The plenum supplies all four burners with pressurized air.

Heater control panel

The heater control box houses the heater ECM, relays, display screen, and lights. On the front side of the panel are four lights, the ECM function keys with display screen, and two switches. The four heater lights supply status information. The function keys and the screen provide a means to interface with the ECM. The first switch is the E-stop button. The E-stop button will only shut down the heater system, not the auxiliary engine. The second switch is the power switch. ***Do not*** use the power switch as the primary method to activate the heater system; use the heater switch in the ***truck control panel***. Figure 2–29 illustrates the location of components in the heater control box; refer to this figure as we cover the latch relay, undervoltage relay, and the direct current (DC)/DC converter.

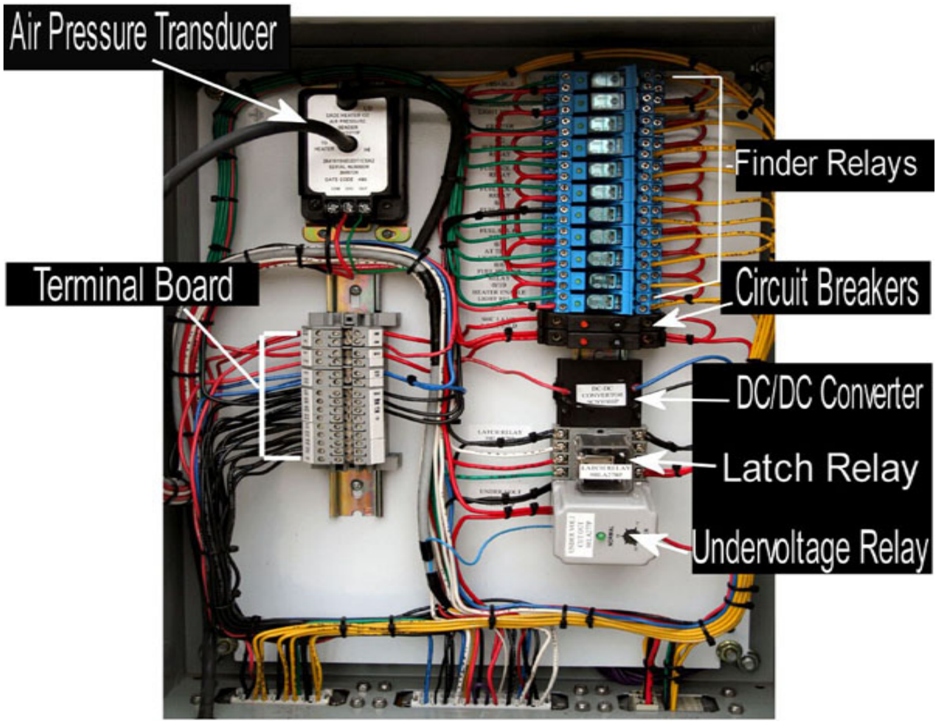


Figure 2–29. Heater components.

Latch relay

The latch relay circuit controls the air blower system. The ECM manages the post-purge cycle with the latch relay. The ECM controls the latch relay's coil ground circuit. Each time the ECM conducts the post-purge cycle it deactivates the other relays in a programmed sequence and ensures the latch relay coil is grounded for 150 seconds before deenergizing the latch coil. The next relay to discuss is the undervoltage relay.

Undervoltage relay

The heater ECM can lock up and cause the heater to overheat when supply voltage falls below 10 volts. Sage Company incorporates an undervoltage relay to prevent this overheating condition. The coil of the undervoltage relay shares the same supply voltage as the ECM. When the coil supply voltage is below 10 volts, the relay opens a set of contacts. The open contacts remove supply voltage from the fuel burner solenoids, shutting down the heater fuel system. The last component to discuss is the converter.

DC/DC converter

The DC/DC converter does not change DC to any other form of current flow. The converter is actually a voltage conditioner. The converter receives fluctuating voltage and "conditions" it to a constant supply voltage. The converter supplies conditioned voltage to the remote temperature detectors (RTD), flow meter, and heater ECM.

Inputs

The heater system uses many inputs to manage heater operations. Each sensor or switch has a specific task to perform. All the input information allows the ECM program to manage the heater system to a target of 85 percent efficiency rate.

Remote temperature detectors

Two of the most important inputs are from the RTDs. RTD 1 measures the temperature of the deicing fluid entering the heater coils, while RTD 2 measures the temperature exiting the heater coils. The heater program uses both sensors to adjust output BTU demand. Each sensor signals the ECM with a

5-volt reference. The amount of reference signal to the ECM changes as the heater temperature increases or decreases.

Flow meter

The flow meter is mounted before the heater coil inlet and measures deicing fluid flow. On the end of the sensor is a paddle wheel. As the fluid flows past the paddle wheel, the wheel rotates, pulsing signal voltage to the ECM. The faster the paddle wheel rotates, the faster the signal pulses, indicating more fluid flow. The ECM translates the amount of pulses to determine the rate of flow.

CAD cell

The CAD sulfide flame detector is a photoconductive flame detector. Simply put, it is a light-sensitive switch. This switch closes when the number 1 burner is ignited. The ECM sends reference voltage to the CAD cell. The reference signal grounds at the terminal board when the CAD cell closes. The ECM recognizes a voltage drop when the switch closes and no voltage drop when the switch is open. As long as the CAD cell stays closed, the heater will continue to run.

Air pressure switch

The air pressure switch is mounted on top of the plenum next to the air blower. Like the CAD cell, the ECM sends a reference voltage to the air switch. The air switch closes when the plenum is charged with enough air. The ECM recognizes a voltage drop when the switch closes and no voltage drop when the switch is open.

Air and fuel pressure transducers

The transducers measure the amount of pressure in each system. Both transducers vary the 5-volt reference signal to the ECM. The ECM changes air and fuel pressure to meet heater demands. Each sensor indicates how much the ECM altered each pressure setting.

Outputs

The heater controls the heater outlet temperature using various output voltages. Each output responds to the ECM command. To manage the output circuits, the ECM varies the amount of voltage to the control valve solenoids or provides a ground path for the relay coils.

Control valve solenoids

The ECM varies the amount of voltage to the air and fuel control valve assemblies. Each assembly has a circuit card called a driver head that attaches to each solenoid. The driver head varies the amount of voltage to the electrical solenoid, which moves the hydraulic control valve. The hydraulic control valve changes the amount of hydraulic fluid flow to the air or fuel pump hydraulic motors.

Relays

The ECM controls the ground circuit of each relay coil. Once the relay coil circuit is completed, the relay contacts close, providing voltage to either a light or a solenoid. The ECM uses the relays to control all four burner fuel solenoids. The fuel solenoid controls when the fuel goes to the burner fuel nozzle. This is how the ECM manages outputs to operate the heater in stages.

Safety devices

The following three safety devices protect the heater system:

1. Fire switch.
2. Over-temperature.
3. Stack switch.

The switches are the mechanical backup systems. The ECM does not monitor the position of these switches and will not log a fault code when they are activated.

Fire switch

The fire switch mounts on the actuator unit of the fire suppression system. The switch closes when the actuator is in the "cocked" position. The fire switch is connected in series with the pump switch. The heater system *will not* start until both switches (fire and pump) are closed.

Over-temperature

The over-temperature unit consists of a thermal sensor and two switches. The unit's thermal sensor mounts in the heater outlet piping. The two adjustable switches are the low- and high-limit:

- The *low-limit switch* is a normally closed switch. A 5-volt reference from the ECM goes to the low-limit switch. When the deicing temperature reaches 225°F, the switch opens, which means the ECM does not sense a voltage drop. The ECM shuts off the heater and begins the 150-second post-purge cycle.
- The *high-limit switch* contacts remain closed until output the deicing fluid temp reaches 235°F. The switch provides a 12-volt power supply for the actuator relays. If the ECM fails to react to the low-limit switch, the high-limit switch opens, removing power from the actuator relays.

Stack switch

The stack switch is a normally closed switch that opens when the heater exhaust temperature increases *above* 1,400°F. Both the high-limit and stack switches remove supply voltage from the output relays, in particular the fuel solenoid relays, which shuts down the heater. The high-limit and stack switches are the last line of defense to prevent heater damage if the ECM fails to shut down the heater system.

Heater fuel system

The fuel system supplies all four burners with the correct amount of fuel pressure during the different stages of operation. Refer back to figure 2–28 to see the different fuel pressure settings for each stage.

Heater operation

The following four cycles are part of the heater operation:

1. Five-second safety check.
2. 45-second countdown.
3. Run.
4. 150-second post-purge.

Starting the heater begins the five-second safety check. The safety check is an operational check of the input and output devices to ensure they are within working parameters. If there is a problem, in addition to logging a fault code, the ECM prevents the heater from progressing to the 45-second countdown cycle.

The 45-second countdown begins once the safety check ends. The ECM activates the air system, fuel pump, and a 45-second timer. At 15-seconds of the countdown, the ECM activates the exciter and fuel pump and adjusts the output settings to stage 14. This stage provides the correct amount of air and fuel pressure to ignite the heater.

At 0 seconds, the ECM activates number 1 burner fuel spray nozzle solenoid. The ECM continues to add fuel for 10 seconds or until the CAD cell closes. If the heater fails to ignite, the ECM will perform a second attempt. If both attempts fail, the ECM will illuminate the fault light and begin the 150-second post-purge cycle. If the number 1 burner ignites, the ECM will turn off the exciter and begin the RUN cycle.

During the RUN cycle, the heater transitions to stage 13 (refer back to figure 2–28). The heater will transition through the stages to control the output temperature as the input deicing fluid temperature increases. When the inlet and outlet deicing fluid temperatures are both at 180°F during stage 1, the heater ECM ends the RUN cycle and begins the 150-second post-purge.

The 150-second post-purge cycle turns off the number 1 burner fuel solenoid and the fuel pump. The ECM uses a latch relay to keep the air blower energized for 150 seconds. During the 150-second time period, the air blower slows as the post-purge cycle transitions to stages 15 and 16. Once the post-purge cycle ends, the heated deicing fluid is ready for deicing aircraft. Figure 2–30 depicts the heater operation.

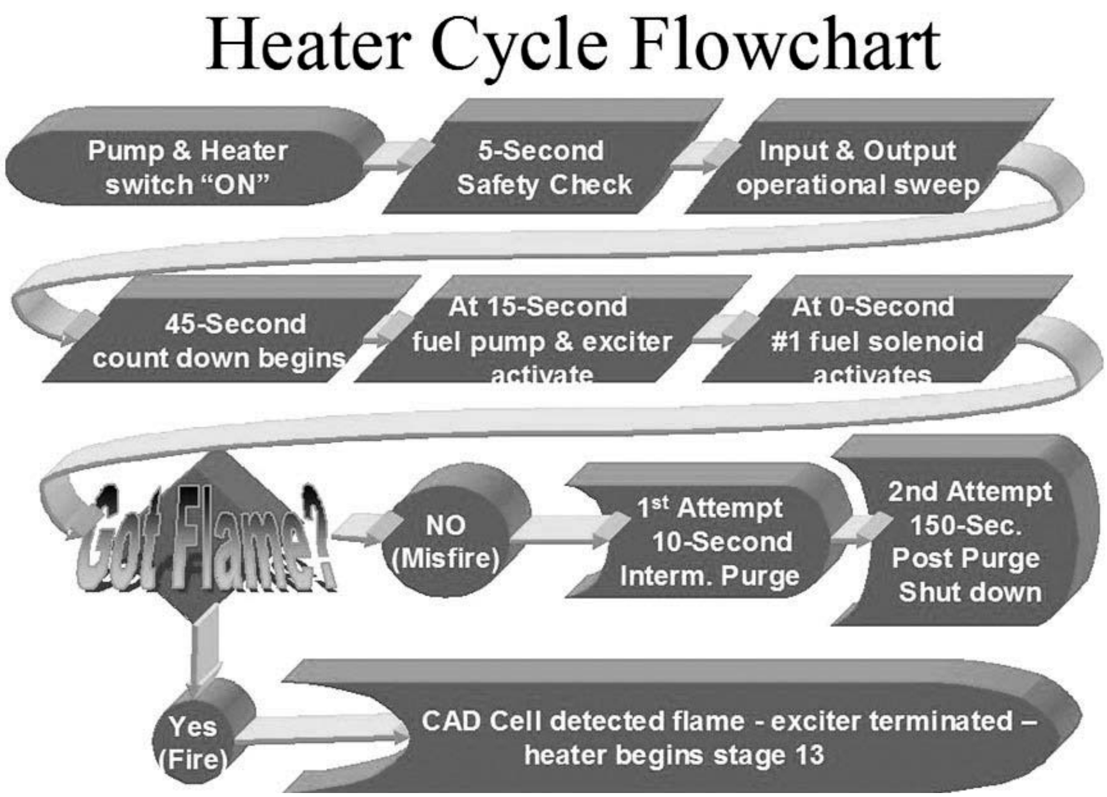


Figure 2–30. Heater cycle flowchart.

016. Deicer maintenance

This lesson covers how to isolate malfunctions and repair the boom, hydraulic, deicing, anti-icing, and heater systems. First, we will discuss an approach to isolate a boom malfunction. This approach will allow you to determine whether the boom malfunction is in the electrical or hydraulic system. Second, we will determine the best course of action to isolate and repair a boom malfunction. Finally, you will learn how to adjust electrical switches, specifically the VDB.

Troubleshooting a boom malfunction

When attempting to troubleshoot a boom malfunction, it is a good idea to try to define the problem in simple terms. Begin with operating the boom in accordance with the service manual. If a boom function does not move when using one of the joysticks, activate the aerial device manual control switch on the ground control panel. Operate the boom function using the levers on the hydraulic manifold. If the boom function operates, the problem is more likely electrical rather than hydraulic. If you determine the electrical system is at fault, the best place to start is the deadman circuit.

Isolating and repairing the deadman circuit

Begin inspecting the deadman circuit by looking at the auxiliary engine battery. Check the battery for a full charge and make sure it is in good condition. The next component to inspect is the auxiliary engine ignition switch. Use a multimeter to measure 12 volts at the switch. The switch supplies

12 volts to the deadman and joystick electrical circuits. Once you complete these inspections and voltage checks, perform three function checks.

Figure 2–31 shows a troubleshooting flowchart. It will help you quickly identify malfunctions in the deadman circuit. You will need an assistant, the electrical schematic, a multimeter, and a fully charged 9-volt battery. Make certain the auxiliary engine ignition switch is ON while troubleshooting the deadman circuit.

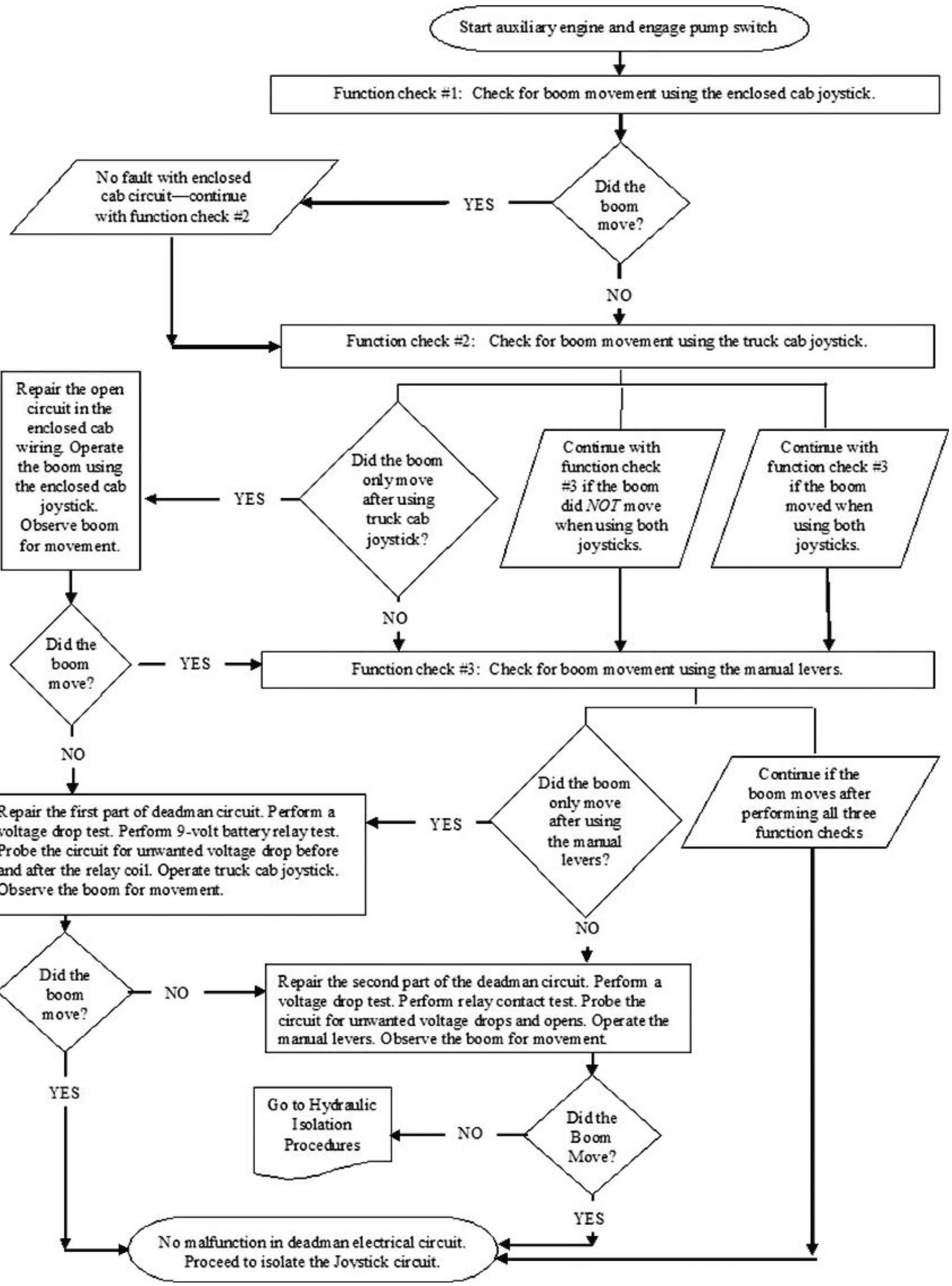


Figure 2–31. Deadman troubleshooting flowchart.

Use the multimeter to test for 12 volts at the deadman switch (fig. 2–32) you want to test. Place the multimeter test leads at the deadman relay coil 8 and 7 terminals. Have the assistant close the deadman switch while you measure the amount of voltage drop across the terminals. If the voltage drop is greater than acceptable ranges specified in the technical order, isolate and repair any ground, short, or open circuits in the first part of the deadman circuit.

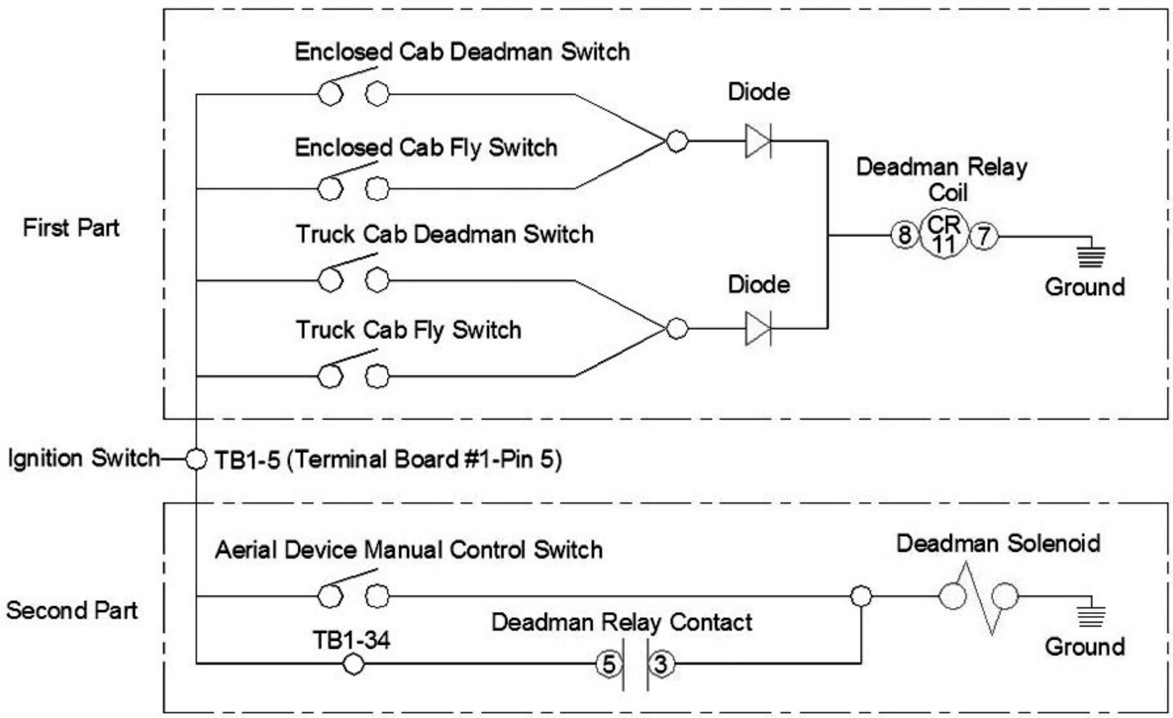


Figure 2–32. Deadman electrical circuit.

You can test the deadman relay using a 9-volt battery. Battery polarity does not matter when performing this test. Remove the relay from the terminal socket and place the relay coil 8 and 7 terminals on the 9-volt battery terminals. Look and listen for the relay contacts to change position. Replace the relay if the contacts do not move position. If the contacts move during the 9-volt battery test, the deadman circuit is good and the second part of the deadman electrical circuit must be troubleshot and fixed.

To repair the second part of the deadman circuit, first measure the voltage drop at the deadman solenoid. Pull back the weather pack seals on the deadman solenoid connection and place the multimeter test leads on the wire terminals. Have your assistant close the deadman switch while you measure the amount of voltage drop across the deadman solenoid terminals. If the voltage drop is greater than acceptable ranges specified in the technical order, isolate and repair any unwanted ground, short, or open circuits in the second part of the deadman circuit.

To isolate the deadman relay contacts, remove the deadman relay and perform the 9-volt battery test. With an energized coil, measure the amount of resistance at the 5 and 3 terminals. The contact should not exceed more than ½ ohm. Replace the relay if it is not within specifications. Repair any malfunctions and test the boom for proper operation. If the deadman circuit is within specifications and the boom is still not operating correctly, inspect the joystick circuit.

Isolating, repairing, and adjusting the joystick electrical circuit

As previously mentioned, it is easier to troubleshoot the joystick circuit when you break it into the following three sections:

1. Control unit (VDBs).

2. Input circuits.
3. Output circuits.

It is best to isolate the VDB assembly first, since both input and output circuits receive voltage from the VDB. Use the joystick diagnostic flowchart in figure 2–33 and the VDB voltage table in lesson 014, to perform all three system checks.

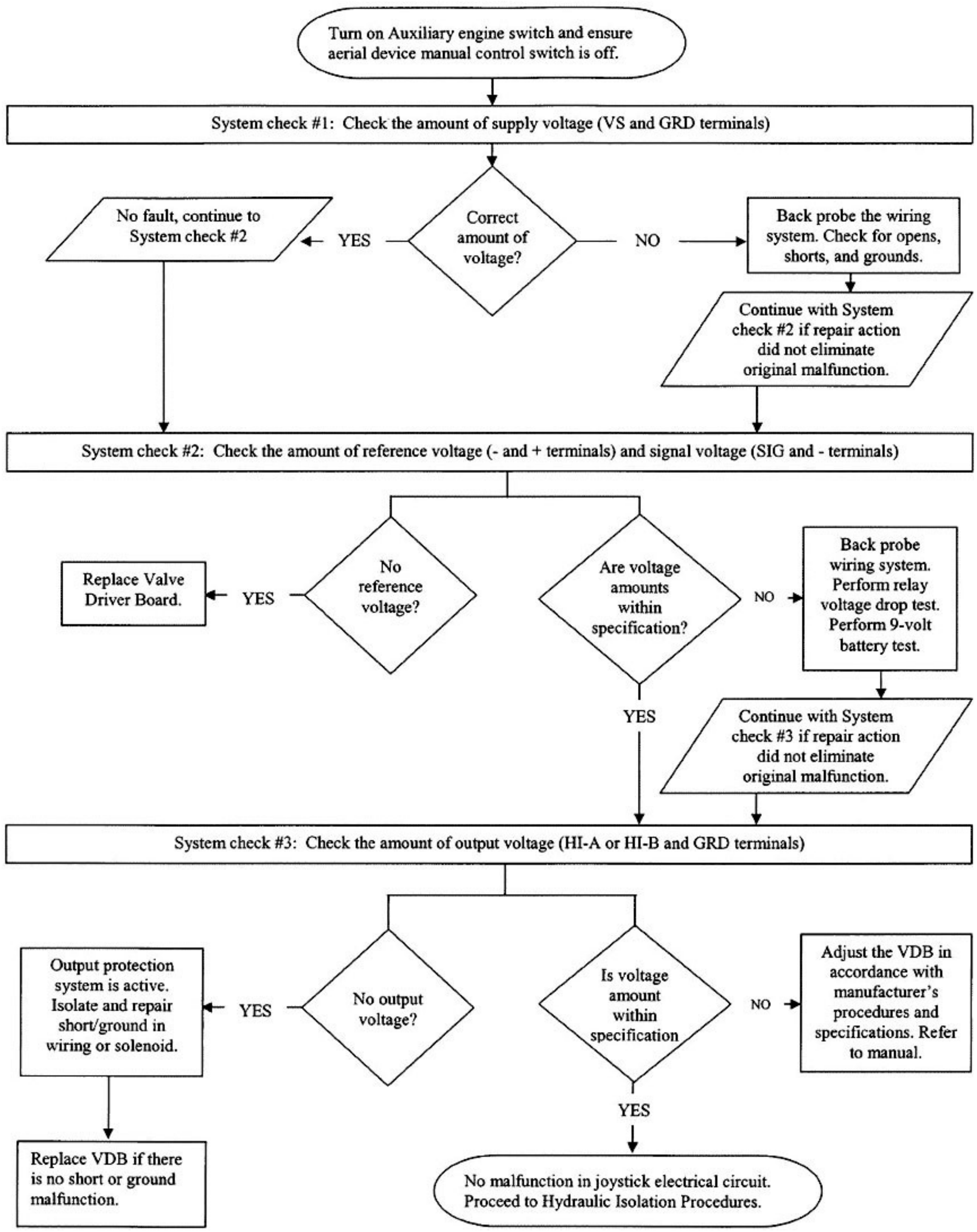


Figure 2–33. Joystick diagnostic flowchart.

There is a built-in protection system in all VDBs. The protection system safeguards against excessive current flow. The VDB automatically turns off the output circuit if there is a short-to-ground malfunction in the valve solenoid wiring. Do not deem a VDB unserviceable before troubleshooting the output circuits. Lastly, adjust the VDB command setting if the boom functions do not operate within specified time limits.

Adjusting the VDBs

The table below lists and explains the four VDB adjustable command settings, each providing a specific function. There is one potentiometer adjusting screw (trimpot) for each of the adjustable command settings.

Four VDB Adjustable Command Settings	
Command Setting	**Description**
LO	Sets the low threshold for each function. The low threshold is the *minimum* amount of current flow for the boom function to start moving.
HI-A and HI-B	Set the *maximum* amount of current flow.
RAMP	Smooths abrupt changes in the output command signal. It adjusts the output duration from threshold to maximum (accel) and from maximum output to threshold (decel).

NOTES:

- Both the LO and HI commands manage the speed of each boom function.
- ***Always*** verify the command setting before adjusting the other commands.
- Follow the instructions in the service manual and/or technical order.

Every boom function is timed for proper operation. Have the assistant operate the boom functions from the enclosed cab while you time each function with a stopwatch. Annotate each boom function speed. Refer to the service manual for the proper boom function speed. Adjust each boom function to service manual specifications.

Troubleshooting hydraulic system malfunctions

Like the electrical system, performing function and system checks is the easiest approach to isolate and repair the hydraulic system. Of the three separate hydraulic systems, the 5-series and 90-series systems are the most important. The 5-series system, which operates the boom, can cause serious injuries or major aircraft damage if it does not operate properly. The 90-series hydraulic system will cause malfunctions in the heater, deicing, and anti-icing system when it is not operating properly. The first system to isolate, repair, and adjust is the 5-series hydraulic system. Use the Global troubleshooting guide in figure 2–34 to troubleshoot the 5-series hydraulic system.

Problem	Possible Cause	Testing/Corrective Action
Low hydraulic pressure at the boom control valve only. Hydraulic pressure drops at low rpm. Unit operates very slow.	Unloader spool stuck in the unload position. Main hydraulic pump is worn or the truck transmission torque converter is slipping.	Build up pressure by retracting the boom extend cylinder and continuing to retract it, then release. Check the pressure filter. Remove the unloader spool and clean if necessary. Measure pump flow rate. Replace or repair if necessary.
Excessive hydraulic fluid on cylinder rods, or fluid leaks from cylinder. Cylinder rod creeping.	Worn cylinder rod seal. Worn piston seals.	Rebuild the cylinder, replacing the rod seal and wiper. Rebuild cylinder, replacing the piston seals.
Cylinder holding valve fluid leak. Any fluid leak between cylinder case and head.	Counterbalance valve out of adjustment. Worn O-ring seal.	Adjust counterbalance valve to the setting indicated on the Hydraulic Schematic. Rebuild cylinder, replacing the O-rings.

Figure 2–34. Global hydraulic diagnostic table.

5-series system

If the electrical system is not suspected to be the cause of a malfunction, the 5-series boom hydraulic system will take little time to troubleshoot. To successfully troubleshoot the boom function, perform a few system checks. The system checks verify pressure settings at the boom main RV and enclosed cab-leveling RV.

The two RVs are on the hydraulic control valve manifold (Parker 6 mid-inlet assembly), RV1, and RV2. RV1 regulates the boom main system pressure, and RV2 regulates the enclosed cab-leveling system pressure. The two RVs control the maximum pressure for the entire boom hydraulic system.

Make certain the auxiliary engine is at high-engine speed while operating the boom. Operate the boom functions as directed, but do not adjust the RVs until you check both RV1 and RV2. If their pressure settings are not within specifications, adjust the appropriate RV. The “Device Relief” adjustment instructions are as follows:

1. To adjust the boom function pressure, install a 5,000 psi gauge at the "F02" test port (fig. 2–35) on the Parker 6 mid-inlet assembly.
2. Start the auxiliary engine and activate the pump switch. Activate the deadman circuit from the ground control panel. Move the fly function manual control lever down and hold it down during the entire adjustment period. Observe the pressure setting; it should be 3,200 psi. If the pressure is not correct, adjust RV1. Once the pressure setting is correct, release the fly manual lever and deactivate the deadman circuit. Turn off the pump switch and allow the engine to idle for five minutes before turning off. Remove the gauge.

To adjust the basket leveling pressure, install a 5,000 psi gauge at the “F01” test port on the Parker 6 mid-inlet assembly. Follow step 2 instructions, only this time hold the basket-leveling manual lever ***up***. Adjust RV2 to 2,500 psi. Ensure you hold the leveling control up during the entire adjustment period.

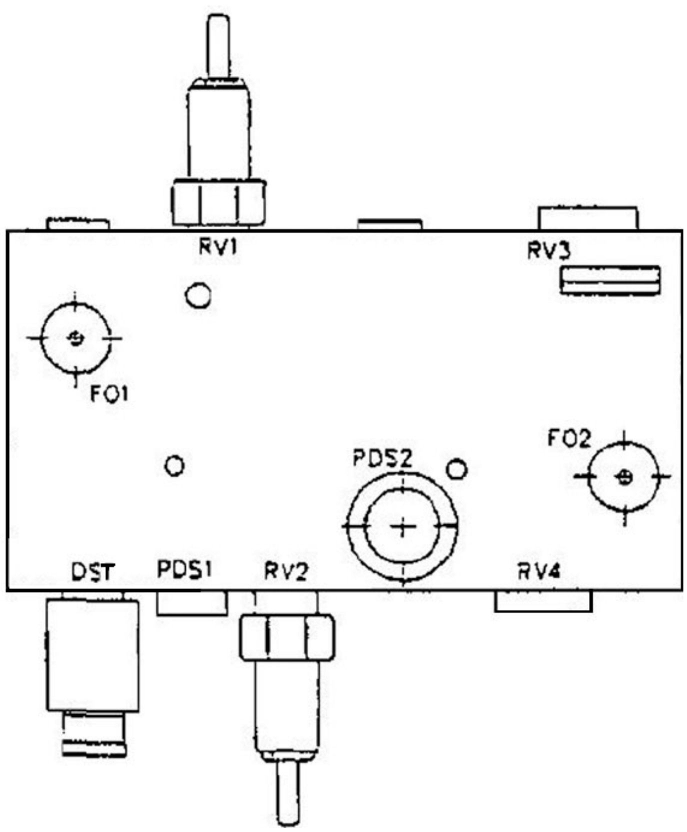


Figure 2–35. Relief valve adjustment.

90-series system

The required deicing pump rpm is determined by the required deicing fluid flow rate and pressure at the heater outlet. The higher the demand of deicing fluid pressure at the heater outlet, the faster the pump will have to turn to maintain the fluid flow. The hydraulic motor that drives the deicing pump is a fixed displacement motor. The deicing pump rpm should be 4,250 rpm with a heater outlet pressure of 180–200 psi, while the auxiliary engine is running at 2,150 rpm.

To check the deicing pump speed, a photo-tachometer and reflective tape are needed. Place a piece of reflective tape on the deicer pump input shaft. Start the auxiliary engine and activate the pump switch. Measure the speed of the deicer pump with the photo-tachometer. If the deicing pump speed is not within specification, adjust the 90-series pump using the “Fluid Pumps Hydraulic Setup” instructions in your service manual.

*hydraulic circuit for other malfunctions. Consult the 90-series service manual.

Troubleshooting dispensing system malfunctions

The best tool to isolate and repair the dispensing subsystems is the red refill light. Remembering each different system affected when the light illuminates can save time. How to troubleshoot the dispensing system when the red refill tank light is not illuminated will be covered in this lesson.

Deicing system

Use the simple-to-complex approach to isolate and repair the deicing system. This means starting with the simplest checks first, then continuing to the more complex ones. You will need the dispensing system schematic, a malfunction isolation checklist, and a basic understanding of the deicing system. Follow the procedures outlined in the service manual to adjust the 90-series hydraulic pump and deicing pump speed. Using a checklist similar to one listed in figure 2–36 will guide you through the entire deicing system.

If you find a misadjusted pressure regulator valve, the following steps describes the pressure regulator adjustment:

1. Verify the auxiliary engine is running, the pump switch is ON (high throttle–2,150 rpm), deicing fluid is dispensing from the Task Force nozzle, and deicing pump speed is set at 4,250 rpm.
2. Locate the pressure regulator valve.
3. Remove the acorn nut from the top of the valve.
4. Loosen the locknut on the compression screw.
5. Adjust the compression screw until the pressure is 180–200 psi. Turn the screw clockwise to increase pressure. Turn the screw counter clockwise to decrease the pressure.
6. Tighten the locknut and recap the acorn nut.
7. Operate the deicing system and ensure the pressure is 180–200 psi with the spray guns closed.
8. If the pressure is not correct, repeat steps 2–7.
9. After final adjustment, turn OFF the pump switch and allow the engine to idle for five minutes before shutdown.

DEICING SYSTEM MALFUNCTION CHECKLIST

PART 1

Instructions:

1. Start the auxiliary engine.
2. Activate the pump switch.
3. Note system pressure.
4. Answer questions in sequence.
5. Consult PART 2 if you answer "NO" to any question.

1.1	No System Pressure	YES	NO
	Is there more than 150 gallons of deicing fluid in the tank?		
	Is the deicing hydraulic motor and pump rotating?		
	Are all the maintenance and shut-off valves in the correct position?		
	Are the 90-series hydraulic pump pressures at specifications?		
1.2	**Low System Pressure**	**YES**	**NO**
	Is there more than 150 gallons of deicing fluid in the tank?		
	Are all the maintenance and shut-off valves in the correct position?		
	Is the deicing pump rotating at the correct speed?		
	Is the pressure regulator adjusted correctly?		
1.3	**High System Pressure**	**YES**	**NO**
	Is the tank return shut-off valve in the closed position?		
	Is the deicing pump rotating at the correct speed?		
	Is the pressure regulator adjusted correctly?		

PART 2

NOTE: ***NOT*** **all the possible causes and corrective actions are listed.**

1.1.1	Possible Causes	Corrective Actions
	Low level electrical circuit at fault. ○ Faulty low level switch. ○ Faulty relays. ○ Faulty wiring.	Repair shorts or grounds in electrical circuit.
	Broken motor and pump shafts or coupler.	Replace broken components.
	No voltage at deicing electrical solenoid.	Repair, opens, shorts or grounds in electrical circuit.
	No voltage at 90-series pump solenoid.	Repair, opens, shorts or grounds in electrical circuit.
	Maintenance and shut-off valves are closed.	Ensure valves are in the correct position.
	Faulty 90-series hydraulic system.	Ensure shut-off valve is open. Isolate hydraulic charge pump circuit. Isolate both A & B-Port hydraulic circuits.
1.2.1	**Possible Causes**	**Corrective Actions**
	Maintenance and shut-off valves are partly closed.	Ensure valves are in the correct position.
	Maladjusted 90-series charge and B-port pressure settings.	Adjust charge pump to 270-300 psi. Adjust B-port pressure to correct setting.
	Maladjusted pressure regulator valve.	Adjust system pressure to 180-200 psi.
1.3.1	**Possible Causes**	**Corrective Actions**
	Tank return shut-off valve is closed.	Ensure shut-off valve behind pressure regulator is in the open position.
	Maladjusted 90-series charge and B-port pressure settings.	Adjust charge pump to 270-300 psi. Adjust B-port pressure to correct setting.
	Maladjusted pressure regulator valve.	Adjust system pressure to 180-200 psi.

Figure 2–36. Deicing system malfunction checklist.

Anti-icing system

Like the deicing system, the simple-to-complex approach is the best method to isolate problems and repair the anti-icing system. Again, you will need the dispensing system schematic, a malfunction isolation checklist, and basic understanding of the system. Using a checklist, similar to the one listed in figure 2–37 will guide you through the entire anti-icing system.

ANTI-ICING SYSTEM MALFUNCTION CHECKLIST		
PART 1		
Instructions: 1. Start the auxiliary engine. 2. Activate the pump switch. 3. Operate the anti-icing system. 4. Note system pressure. 5. Answer questions in sequence. 6. Consult PART 2 if you answer "NO" to any question.		
1.1 No System Pressure	**YES**	**NO**
Is there more than 20 gallons of fluid in the tank? Is the anti-icing hydraulic motor and pump rotating? Are all the shut-off and self-fill valves in the correct position? Are the 90-series hydraulic pump pressures within specifications?		
1.2 Low System Pressure	**YES**	**NO**
Is there more than 20 gallons of fluid in the tank? Are all the shut-off and self-fill valves in the correct position? Is the anti-icing pump rotating at the correct speed?		
1.3 High System Pressure	**YES**	**NO**
Are both self-fill valves in the correct position? Is the anti-icing pump rotating at the correct speed?		

PART 2		
NOTE: *NOT* all the possible causes and corrective actions are listed.		
1.1.1	**Possible Causes**	**Corrective Actions**
	Low level electrical circuit at fault. o Faulty low level switch. o Faulty relays. o Faulty wiring.	Repair shorts or grounds in electrical circuit.
	Broken motor and pump shafts or coupler.	Replace broken components.
	No voltage at anti-icing electrical solenoid.	Repair, opens, shorts or grounds in electrical circuit.
	No voltage at 90-series pump solenoid.	Repair, opens, shorts or grounds in electrical circuit.
	Maintenance and shut-off valves are closed.	Ensure valves are in the correct position.
	Faulty 90-series hydraulic system.	Ensure shut-off valve is open. Isolate hydraulic charge pump circuit. Isolate both A & B-Port hydraulic circuits.
1.2.1	**Possible Causes**	**Corrective Actions**
	Shut-off and self-fill valves are not in the correct position.	Ensure valves are in the correct position.
	Maladjusted 90-series charge and B-port pressure settings.	Adjust charge pump to 270-300 psi. Adjust B-port pressure to ensure deicing pump speed is 4,250 rpm's.
	Maladjusted anti-icing pump speed.	Adjust hydraulic flow control valve until system pressure is 50-55 psi.
1.3.1	**Possible Causes**	**Corrective Actions**
	Self-fill valves are not in the correct position.	Ensure valves are in the correct position.
	Maladjusted anti-icing pump speed.	Adjust hydraulic flow control valve until system pressure is 50-55 psi.

Figure 2–37. Anti-icing system malfunction checklist.

When troubleshooting the anti-icing system, you may need to adjust its system pressure. The *only* way to maintain system pressure is to adjust the anti-icing pump speed.

The following procedure describes the anti-icing system pressure adjustment:

1. While dispensing anti-icing fluid, note the pressure reading on anti-icing gauge. The anti-icing system pressure should be 50–55 psi. If the pressure is incorrect, check the anti-icing hydraulic motor speed.

2. Remove the coupler cover over the motor and pump coupler box and install a small piece of reflective tape on the coupler.
3. Start the auxiliary engine and activate truck cab pump switch.
4. Open the self-fill valve on the pump's outlet line.

CAUTION: Do ***not*** close the self-fill valve; pump damage will occur.

5. Activate the self-fill switch next to the pump; use a photo-tachometer to check coupler speed. Pump rotation speed should be 210 rpm.
6. To adjust the hydraulic motor speed, locate the anti-icing flow control valve cartridge on the bottom of the mono block. Loosen the locknut and adjust the set screw to increase or decrease speed.
7. Turn OFF the self-fill switch and close the outlet self-fill valve.
8. Activate the anti-icing system from the FEDS cab and verify that the pressure is between 50 and 55 psi.
9. Once the pressure is set to the correct specification, turn OFF the cab pump switch, allow the auxiliary engine to idle for five minutes, and turn the engine off.
10. Reinstall the coupler cover.

Troubleshooting heater system malfunctions

The heater ECM has a readily accessible diagnostic interface system. Isolating and repairing the heater system is accomplished through the computer display screen and the function keypad. The diagnostic software program logs fault codes when inputs and outputs are not within working parameters.

Access the fault codes through the computer screen and function keys. The keypads are numbered F-1 through F-4. Read the instructions on the screen to determine which function key to press. Use the *System History* when isolating malfunctions. The ECM only stores five fault codes. The first code indicates the most current malfunction.

Most fault codes identify a particular component malfunction. For example, fault code 10—*Air Switch Fault,* identifies the air switch is closed when it should be open. Fault code 65—*No Air Flow,* identifies the air switch is open when it should be closed. These fault codes are directly related to a component or the component's electrical circuit.

Some fault codes relate to a symptom malfunction. This means the system logs a code based on an event and is not related to a particular component. For example, code *"80"* indicates the heater lost an established flame. The heater was running, but, for some reason, lost the flame, and the ECM cannot determine why it lost the flame. This code requires you to isolate a fuel, air, or CAD cell problem.

The ideal method to troubleshoot the heater is to use the appropriate electrical schematic and Sage Heater service manual. If your shop does not have the current heater appendix, download it from the Air Force Vehicle Management Neighborhood website.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

013. Deicer features and fundamentals

1. What component balances an uneven load and eliminates the need for outriggers on the Global deicer?

2. What component controls the deicer auxiliary engine speed and dispensing subsystems?

3. What is the purpose of the red refill tank light in the deicer truck cab?

4. The Deutz ECM uses which two switches to shut down the auxiliary engine?

5. Where is the *AirPlus!* supercharger located, and how is it driven?

6. Name the components that monitor the *AirPlus!* self-contained oil system.

7. What precaution should be observed when using the *AirPlus!* system?

8. Explain the need for the time delay relay in the deicer hydraulic low-level electrical circuit.

9. Under normal operation, which pump supplies hydraulic fluid to the deicer boom functions?

10. What is the purpose of the deicer deadman circuit?

11. The deicer 90-series pump supplies fluid for what systems?

12. Which deicer pump is directly attached to the auxiliary engine fly wheel?

13. Name the component that both the deicer 90- and 100-series pumps share.

14. What conditions will cause the deicer fire suppression system to activate?

014. Deicer boom fundamentals

1. Why is the deicer boom pedestal mounted over the rear axle?

2. What deicer component does the 5-series pump supply hydraulic fluid to?

3. What solenoid on the deicer series–6 manifold must be energized for the boom functions to operate?

4. What stops boom rotation at 185°?

5. What unique double-acting cylinder provides the deicer enclosed cab rotation feature?

6. What deicer component controls the amount of current flow to the functional solenoids on the Parker series–6 manifold?

7. Which electrical circuits need to work properly in order to safely operate the deicer boom functions?

8. If the deadman solenoid is *not* energized, where does hydraulic fluid flow?

9. How does the VDB determine which deicer output circuit to activate?

10. What happens when the PWM output circuit is energized?

015. Deicer dispensing and heating system fundamentals

1. How does the deicer operator vary the amount of fluid dispensed from the Task Force nozzle?

2. Where does deicing fluid go when the safety RV opens?

3. What deicing system must be in use to activate the deicing fluid inject system?

4. How can you vary the amount of anti-icing fluid dispensed from the Task Force nozzle?

5. What does the deicer heater ECM use to determine the correct BTU demand for each heater stage?

6. How many burners are at the plenum side of the deicer heater assembly?

7. What charges the deicer plenum with air?

8. Explain the function of the DC/DC converter.

9. Which RTD measures the deicing fluid *entering* the heater coils, and which RTD measures the deicing fluid *exiting* the heater coils?

10. Name the deicer switch that closes when the number 1 burner establishes a flame.

11. Which switch is mounted on top of the plenum next to the air blower and receives a reference voltage from the ECM?

12. What does the deicer ECM use to control all four burner fuel solenoids?

13. Name the deicer switches that must be closed before the heater will attempt to start.

14. What deicer switches are the last line of defense in shutting down the heater if the ECM fails to?

15. What are the deicer's four heater cycles?

16. When will the deicer's ECM activate number 1 burner fuel solenoid?

016. Deicer maintenance

1. What can be used to help in quickly identifying deadman circuit malfunctions?

2. What is the first step to accomplish if there is no malfunction in the first part of the deadman circuit?

3. What is the next circuit to isolate if there is no malfunction in the deicer’s deadman circuit?

4. Explain the built-in protection system in the VDBs.

5. Name the items needed to measure the speed of each boom function.

6. What systems are affected if a 90-series hydraulic system is malfunctioning?

7. Explain the purpose for the deicer valves RV1 and RV2.

8. What items are needed to check the deicing pump speed?

9. What is the best tool to isolate and repair the deicer’s dispensing system?

10. What is your first step if the deicing system’s pressure regulator valve is misadjusted?

11. What should the anti-icing pressure gauge read when adjusting the anti-icing system pressure?

12. How do you interface with the deicer’s heater ECM?

13. What is the maximum number of fault codes the deicer’s ECM will store?

14. When will the deicer’s heater ECM log the fault code 80?

Answers to Self-Test Questions

011

1. 175K lbs. for aircraft and 93K lbs. for all other towing operations.
2. Four forward and one reverse.
3. Hydraulic gerotor control unit.
4. By the vehicle's air compressor.
5. Spring-applied and hydraulically released.
6. Air-over-hydraulic.
7. The trailer service brakes actuate before the vehicle's service brakes.
8. Circuit breaker mounted on the junction box.

012

1. Use the same size and type wire and solder spliced connections.
2. Air leaks, low-fluid level, cracked hydraulic pump housing, or water contamination.
3. Air in the system, low-hydraulic fluid level, or a loose hydraulic line, causing air to be drawn into the hydraulic system.
4. Steering selector valve, priority valve, and steering control valve.
5. Repair any malfunctions that may hinder the operator from safely stopping the vehicle.
6. Electrical-wheel position sensing system.
7. The assistant in the cab observes the front-wheel position gauge; it will read "center" position.
8. Axle brake adjustment.

013

1. Torsion bar.
2. Pump switch.
3. Illuminates when the dispensing anti-icing, deicing subsystems, or the hydraulic systems have a low-fluid level.
4. Engine oil pressure and coolant temperature switches.
5. Under the enclosed cab operator seat and belt driven.
6. An oil pressure switch, oil temperature sending unit, and a vacuum switch.
7. Do not operate the air system with individuals or debris in the air-blast radius.
8. Fluid sloshing in the tank causes low-level switch to close. The TD prevents premature shutdown of the auxiliary engine.
9. 5-series pump.
10. Prevents the boom hydraulic system from activating until the operator squeezes a trigger switch on the boom joystick. This ensures the boom functions will not move if someone moves the joystick inadvertently.
11. Dispensing and heater systems.
12. The 100 series.
13. Hydraulic oil cooler.
14. When a fusible link melts or the manual release button on the front of the firebox is pressed.

014

1. To support the weight of the boom assembly.
2. The Parker series–6 hydraulic manifold.
3. Deadman.
4. Sliding mechanical stop.
5. Helical hydraulic rotary actuator.
6. VDB.
7. Deadman and joystick circuits.

8. Returns to the hydraulic tank.
9. By the amount of signal voltage.
10. The HI–A or HI–B red LED illuminates.

015

1. By varying the position of the rocker foot pedal.
2. Straight to the ground.
3. The *AirPlus!* system.
4. You cannot vary the amount of anti-icing fluid that is dispensed from the Task Force nozzle.
5. Various inputs and output.
6. Four.
7. The air blower.
8. The converter receives fluctuating voltage and conditions it to a constant supply voltage.
9. RTD number 1 measures the deicing fluid entering the heater coils, while RTD number 2 measures the fluid exiting the heater coils.
10. CAD cell.
11. Air pressure switch.
12. Relays.
13. Fire and pump.
14. High-limit and stack switch.
15. The 5-second safety check, 45-second countdown, run, and 150-second post-purge.
16. At the 0-second mark of the 45-second countdown.

016

1. Troubleshooting flowchart.
2. Measure the voltage drop at the deadman solenoid.
3. The joystick circuit.
4. The protection system safeguards against excessive current flow. The VDB automatically turns off the output circuit if there is a short-to-ground malfunction in the valve solenoid wiring.
5. An assistant and a stop watch.
6. Heater, deicing, and anti-icing systems.
7. RV1 on the hydraulic control manifold maintains the boom main system and RV2 is for the enclosed cab-leveling system. The two RVs control the maximum pressure for the entire boom hydraulic system.
8. Photo-tachometer and reflective tape.
9. Red refill tank light.
10. Verify the auxiliary engine is running, the pump switch is ON, deicing fluid is dispensing from the Task Force nozzle, and deicing pump speed is set at 4,250 rpm.
11. 50–55 psi.
12. Computer display screen and function keypad.
13. Five.
14. When the heater has lost an established flame.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

33. (011) How is the MB–4 parking brake applied and released?
    a. Air-applied, spring-released.
    b. Spring-applied, air-released.
    c. Spring-applied, hydraulically released.
    d. Air over hydraulics-applied, hydraulically released.

34. (012) This condition will *not* cause a foamy- or milky-looking hydraulic fluid.
    a. Air leak.
    b. Water contamination.
    c. Cracked hydraulic pump housing.
    d. Hydraulic hose that is vibrating excessively.

35. (012) Do this *first* when troubleshooting a MB–4 steering malfunction.
    a. Perform a road test.
    b. Replace the control valve.
    c. Flush the hydraulic system.
    d. Ensure the steering lock is disengaged.

36. (012) When adjusting the MB–4 towing tractor front-wheel positioning system, how do you know the adjustment is correct?
    a. A buzzer in the cab will sound.
    b. Re-measure the distance between the tire and frame.
    c. Assistant in the cab verifies front-wheel gauge reads “center” position.
    d. Assistant in the cab verifies front-wheel gauge reads “median” position.

37. (013) This item on the Global deicer eliminates the need for outriggers.
    a. The torsion bar.
    b. Heavy-duty shocks.
    c. Heavy-duty springs.
    d. Auto-leveling mechanism.

38. (013) Which component maintains the vehicle speed at four mph when the boom is out of its saddle?
    a. Auxiliary engine electronic control module (ECM).
    b. Chassis ECM.
    c. Safety ECM.
    d. Drive ECM.

39. (013) This Global deicer hydraulic pump provides fluid for the boom functions during normal operation.
    a. 5 series.
    b. 90 series.
    c. 100 series.
    d. Emergency.

40. (013) Which Global deicer hydraulic pump provides fluid for the dispensing and heater systems?
    a. 5 series.
    b. 90 series.
    c. 100 series.
    d. Emergency.

41. (013) The Global deicer hydraulic pump that provides fluid for the *AirPlus!* system is the
    a. 5 series.
    b. 90 series.
    c. 100 series.
    d. Emergency.

42. (014) Which Global deicer hydraulic pump provides fluid for the Parker series 6 manifold?
    a. 5 series.
    b. 90 series.
    c. 100 series.
    d. Emergency.

43. (014) To operate a function on the Global deicer boom, the
    a. boom enable solenoid must be deenergized.
    b. boom enable solenoid must be energized.
    c. deadman solenoid must be deenergized.
    d. deadman solenoid must be energized.

44. (014) The Global deicer enclosed cab-leveling sensor signals the leveling
    a. solenoid when a 4 degree (°) angle change occurs.
    b. solenoid when an 8° angle change occurs.
    c. valve driver board (VDB) when a 6° angle change occurs.
    d. VDB when an 8° angle change occurs.

45. (014) Which Global deicer boom function uses two hydraulic flow control valves to control a function speed?
    a. Fly tip.
    b. Boom rotation.
    c. Boom elevation.
    d. Enclosed cab rotation.

46. (015) The Global deicer and heater systems will shut down when the deicing tank fluid level is below how many gallons?
    a. 250.
    b. 200.
    c. 150.
    d. 100.

47. (015) This Global deicing system component will divert deicing fluid directly to the ground.
    a. Overflow regulator.
    b. Pressure regulator.
    c. Safety relief valve.
    d. Thermal relief valve.

48. (015) Which type fluid does the Global deicer fluid inject valve force into the *AirPlus!* Scorpion nozzle at the rate of 9 gallons per minute?
    a. Heated anti-icing fluid.
    b. Heated deicing fluid.
    c. Cold anti-icing fluid.
    d. Cold deicing fluid.

49. (015) How many burners are in the Global deicer heater assembly?
    a. 1.
    b. 2.
    c. 3.
    d. 4.

50. (015) The Global deicer heater electronic control module controls this component to manage the deicer's post-purge cycle.
    a. Undervoltage relay.
    b. Direct converter.
    c. Circuit breaker.
    d. Latch relay.

51. (015) Which Global deicer remote temperature detector (RTD) measures the temperature of the deicing fluid *exiting* the heater coils?
    a. 1.
    b. 2.
    c. 3.
    d. 4.

52. (015) This Global deicer heater component varies the amount of voltage going to the electrical solenoid that moves the hydraulic control valve?
    a. Driver head.
    b. Variable rheostat.
    c. Variable transducer.
    d. Adjustable voltage regulator.

53. (016) This Global deicer 5 series relief valve (RV) controls the hydraulic pressure for the enclosed cab leveling system.
    a. 1.
    b. 2.
    c. 3.
    d. 4.

54. (016) This is the revolutions per minute setting for the Global deicer's pump speed.
    a. 1,250.
    b. 1,850.
    c. 2,150.
    d. 4,250.

55. (016) How do you interface with the Global deicer's heater electronic control module (ECM)?
    a. Scan tool.
    b. Light emitting diodes (LED).
    c. Access module and jumper wire.
    d. Display screen and function keypad.

Student Notes

Unit 3. Flightline Servicing Vehicles and Equipment

IN THE FOLLOWING LESSONS, we will discuss flightline servicing vehicles. These vehicles keep runways clear of debris and provide safe aircraft take-offs and landings. This unit will cover the regenerative sweeper, snow blower, and Window sweeper broom. The snow blower and Windrow sweeper are especially important in cold weather regions, as their function is to remove snow from runways. Learning how to maintain these vehicles is vital to ensuring aircraft take-offs and landings, allowing the Air Force to complete its mission.

3–1. Regenerative Sweeper

The regenerative sweeper's main purpose is keeping aircraft runways clear of potential foreign object damage (FOD). Additionally, it is used to keep base streets clean. It is self-propelled and has the capability to collect the debris it sweeps up, like a much larger version of a household vacuum. In this section, we will discuss the regenerative sweeper's fundamentals, key systems, and repair and adjustment procedures.

017. Regenerative sweeper fundamentals

The Young Manufacturing Company (TYMCO) manufactures the most common regenerative sweeper in the Air Force inventory. The operating principle of a regenerative sweeper is to use high-velocity air and vacuum to clean streets and runways. It combines the street-sweeping capability of gutter brooms with the efficient cleaning of a vacuum system. This lesson covers the sweeper's functions and major components. Figure 3–1 shows the configuration of the sweeper from the top and side views.

Operating speeds

In order for the TYMCO sweeper to perform at peak efficiency, it must operate at the correct speeds. Three factors must be considered when desiring peak efficiency:

1. Auxiliary engine rpm.
2. Type of material being swept.
3. Speed of the sweeper passing over the swept surface.

NOTE: The heavier the material, the slower the speed you must travel using higher auxiliary engine rpm. However, never exceed 2,500 rpm.

Use the following chart for recommended operating speeds:

Recommended Sweeper Operating Speeds		
RPM	**Material**	**MPH**
1,800	Paper, leaves, and light trash.	5–10

Recommended Sweeper Operating Speeds		
RPM	**Material**	**MPH**
2,000–2,200	Normal accumulations of dirt, sand, and gravel.	3–5
2,200–2,500	Heavy accumulations of dirt, sand, and gravel.	1–3

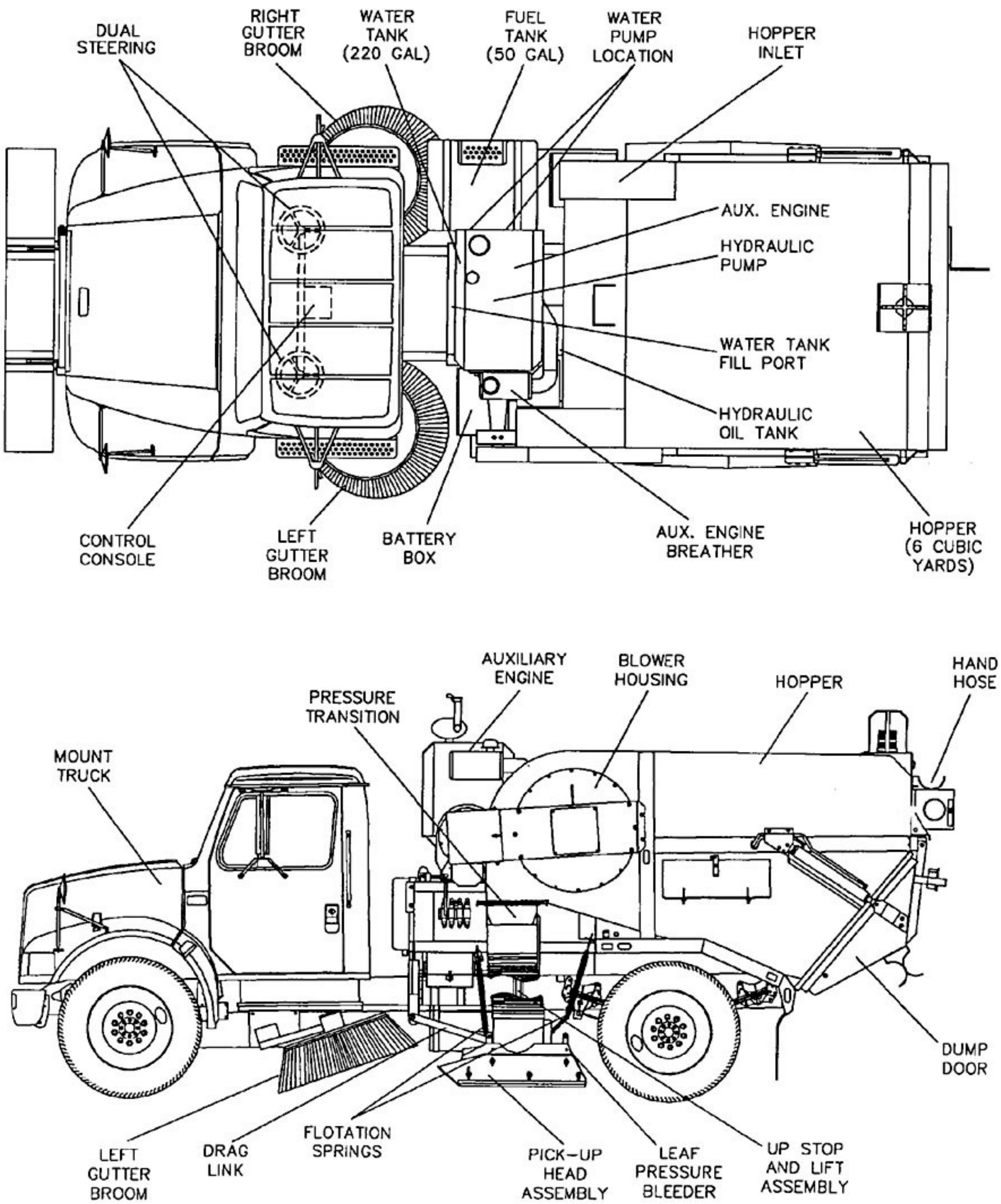


Figure 3–1. Sweeper configuration.

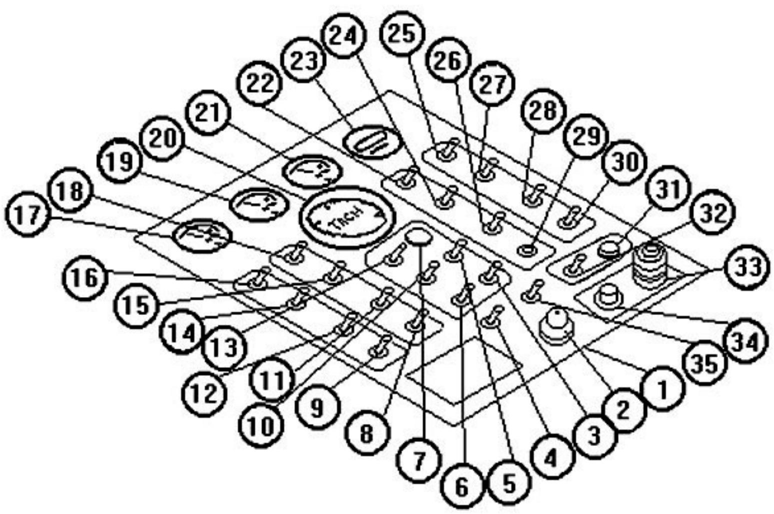
With the vehicle's sweeping speed ranging from 1–10 mph, the sweeper is not meant to sweep an entire 10,000 ft. runway, only specific areas. These areas are where aircraft have their engines running and are parked or moving slowly, such as parking ramps, taxiways, ends of runways, or roads that cross runways. These are where the aircraft engines are most vulnerable to FOD.

Carrier truck

The sweeper can be mounted on a variety of trucks. The primary purpose of the carrier truck is to adequately support and safely carry the sweeper and all of its accessories. The only unique characteristic about the cab is that it can be driven from either side. There are dual steering wheels, accelerator and brake pedals, and a console between the seats to control the auxiliary engine and sweeper functions.

Engines

Both the carrier and sweeper unit are equipped with diesel engines. The type of carrier engine varies depending on the truck manufacturer, while the auxiliary engine is an in-line four cylinder. They both draw their fuel from the same tank; the auxiliary engine will run out of fuel first. The auxiliary engine is located behind the cab and in front of the hopper. The carrier engine provides power for the carrier only, while the auxiliary engine drives the blower and the hydraulic pump for the system. All gauges and necessary components to start and monitor the auxiliary engine are on the control panel (fig. 3–2). The central location of the control panel allows the operator to conveniently operate the entire system from either side of the truck cab.



1. 600 Control Panel
2. Ignition Switch/Sweeper
3. High output Water - Right
4. Engine RPM
5. Hopper Water
6. High output Water - Left
7. Low Water Warning Light
8. Extra Light Switch
9. Left Gutter Broom Tilt
10. Extra Water Switch
11. Extra Light Switch
12. Left Gutter Broom Light
13. Water System Switch
14. Left Gutter Broom Water
15. Work Light Switch
16. Left Gutter Broom Switch
17. Volt Meter
18. Warning Lights/Black box Switch
19. Water Temperature Gauge
20. Tacometer
21. Engine Oil Pressure Gauge
22. Pick-up Head Switch
23. Hour Meter
24. Pick-up Head Water Switch
25. Right Gutter Broom Switch
26. BAH Pick-up Head Switch
27. Right Gutter Broom Water Switch
28. Right Gutter Broom Light Switch
29. BAH Down Indicator
30. Right Gutter Broom Tilt
31. Auxiliary Hydraulic System Run Button
32. Auxiliary Hydraulic/Sweep Switch
33. Automatic Shutdown Warning Light
34. Automatic Shutdown Reset Button
35. Pressure Bleeder Switch

Figure 3–2. Control panel assembly.

Automatic shutdown system

TYMCO sweepers use an automatic shutdown system that shuts down the auxiliary engine if it overheats or loses oil pressure. If this system detects one or both of these conditions, it will stop the engine 30 seconds after detection.

The system employs a circuit breaker with a built-in 30-second timer. With the sweeper engine ignition switch placed in the ON position (engine off), a red light will start blinking. After 30 seconds, the red reset button next to the ignition switch will pop up (fig. 3–2, item 34).

As long as the red button is up, the engine will not start. If the switch is in the “popped” (activated) position, it has detected a problem. If you traced the electrical schematic with the switch activated, electrical current cannot pass through the switch to the fuel injector pump solenoid. If the injector pump solenoid does not receive current, which allows fuel flow, the engine will not start.

Hopper and blower assembly

Once the sweeper engine is started, it uses the same air repeatedly; this is why it is labeled a closed loop system (regenerative). To make this possible, the system ***MUST*** be sealed and the air cleaned within. We will discuss how the air flows through the system with a brief explanation about each component. Airflow in a closed loop system starts and ends at the blower.

Refer to figure 3–3 as we discuss the airflow. As the high-pressure air leaves the blower, it passes through a pressure hose to the pressure chamber of the pick-up head. Air then passes through a set of turning vanes, which distributes the air evenly across the blast orifice. Air is directed at a forward angle to the ground, where it stirs up dirt and debris. The dirt and debris are lifted into the air and pulled up through the suction hose and into the hopper. At the top of the hopper is a screen that removes all the large materials from the air stream. The dirty air that goes through the screen enters the top of the dust separator. Inside the dust separator, the air spins in a circular motion and centrifugal force pulls the fine dust particles out of the air and onto the separator walls. Along the bottom edge of the separator is an opening called the skimmer slot, which dumps the dust into a holding area in the hopper. Clean air then goes to the blower and the cycle starts over again.

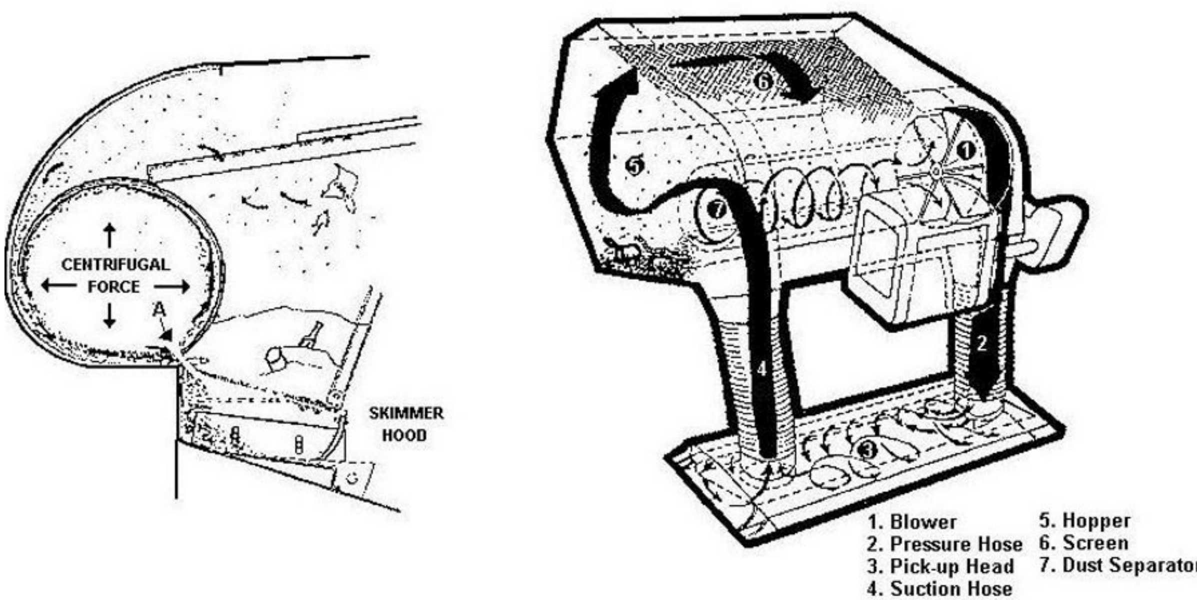


Figure 3–3. Hopper assembly.

The blower is the heart of the system, because it produces the pressurized air and vacuum for the sweeping operation. It is belt-driven by the auxiliary engine and designed for maximum performance with low noise. The blower is constructed of lightweight aluminum for increased efficiency and is geared to spin faster than the engine.

The hopper assembly is a large tank-like structure divided into two sections and is mounted on the rear of the truck. One section holds the debris and dirt swept up by the sweeper. This section is designed so that the weight of the debris is distributed over the rear axle of the carrier. Its shape facilitates dumping of debris directly behind the rear wheels.

NOTE: When the sweeper is parked, open the dump and inspection doors to allow the seals on the doors to expand. This provides a better sealing surface when the doors are closed and allows moisture to escape the hopper.

Pick-up head

The pick-up head (fig. 3–4) is the sweeping and suction component of the system.

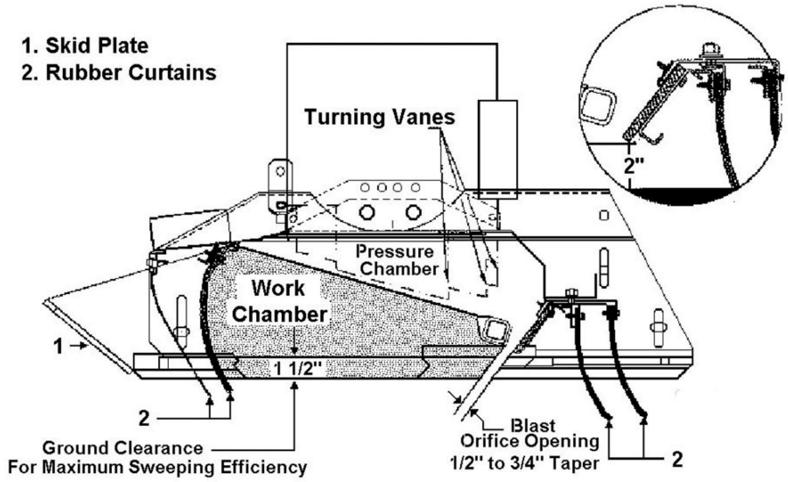


Figure 3–4. Pick-up head.

Several components make up the pick-up head, such as the blast orifice, skid plate, floating springs, and deflector and rubber curtains. The table below lists and describes these components.

Sweeper Pick-Up Head Components and Description	
Component	**Description**
Blast orifice	An adjustable 5/8-inch gap (fig. 3–5) that directs pressurized air from the blower towards the ground, creating an agitating action to loosen and break up debris. It stretches along the back end of the pick-up head, from one side to the other.
Skid plates	Provides the following three functions: 1. Allows adjustment of the height of the blast orifice from the ground. 2. Provides a seal for the sides of the pick-up head. 3. Provides a wearing surface for the pick-up head.
Flotation springs	Used to adjust the pick-up head pressure on the ground; this prevents excessive wear to the skid plates.
Deflector and rubber curtains	Ensures that debris stays in the path of the pick-up head as it is being swept by the gutter brooms. It is attached to the front of the pick-up head and runs forward along the centerline of the truck to the front axle. It also keeps the debris from being thrown under the truck and into passing traffic or pedestrians. The rubber curtain provides the seal for the front and rear of the pick-up head.

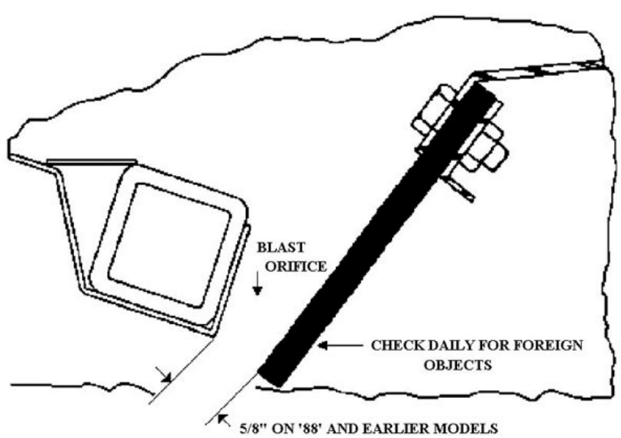


Figure 3–5. Blast orifice.

Pressure and suction hoses

The pressure hose is on the truck's left side. It provides a way for air to get from the blower to the pick-up head. The suction hose is on the truck's right side. It provides a way for debris to get from the pick-up head to the hopper. It can be unlatched for easy cleaning or suction plate installation. The suction plate diverts the suction to a handheld hose on the back of the hopper. The handheld hose is used for cleaning areas the truck cannot reach.

Gutter brooms

The gutter brooms (fig. 3–6) are designed to sweep dirt and debris into the path of the pick-up head. The brooms are hydraulically driven, raised, and lowered. The bristles are made of wire or polypropylene. Refer to the technical order for procedures on how to perform maintenance on the gutter brooms.

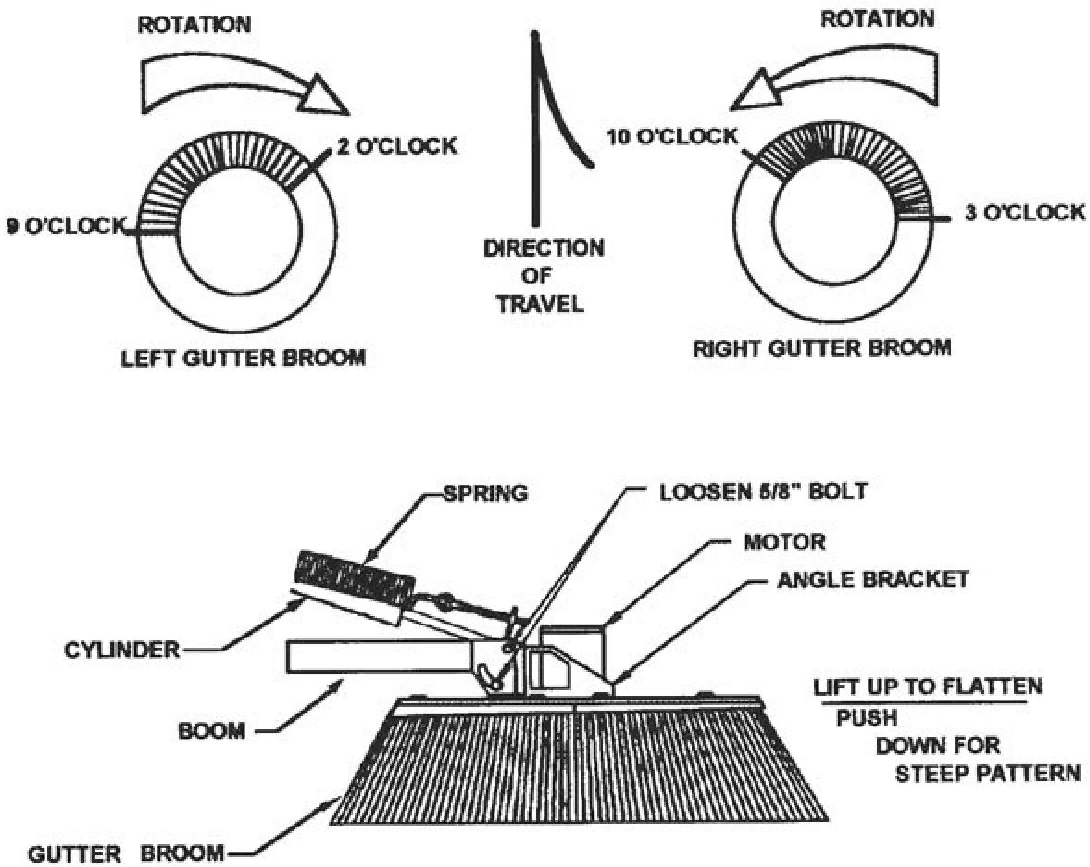


Figure 3–6. Gutter broom.

Hydraulic system

The hydraulic system on the sweeper provides the power necessary to operate the cylinders that open and close the hopper doors, raise and lower the pick-up hood, and drive and position the gutter brooms. Figure 3–7 shows the hydraulic system with a portion of the electrical system included. The reservoir is located on the left side of the truck between the auxiliary engine and the hopper. It holds 9½ gallons of hydraulic fluid with a dipstick on the cap that is used for checking the fluid level.

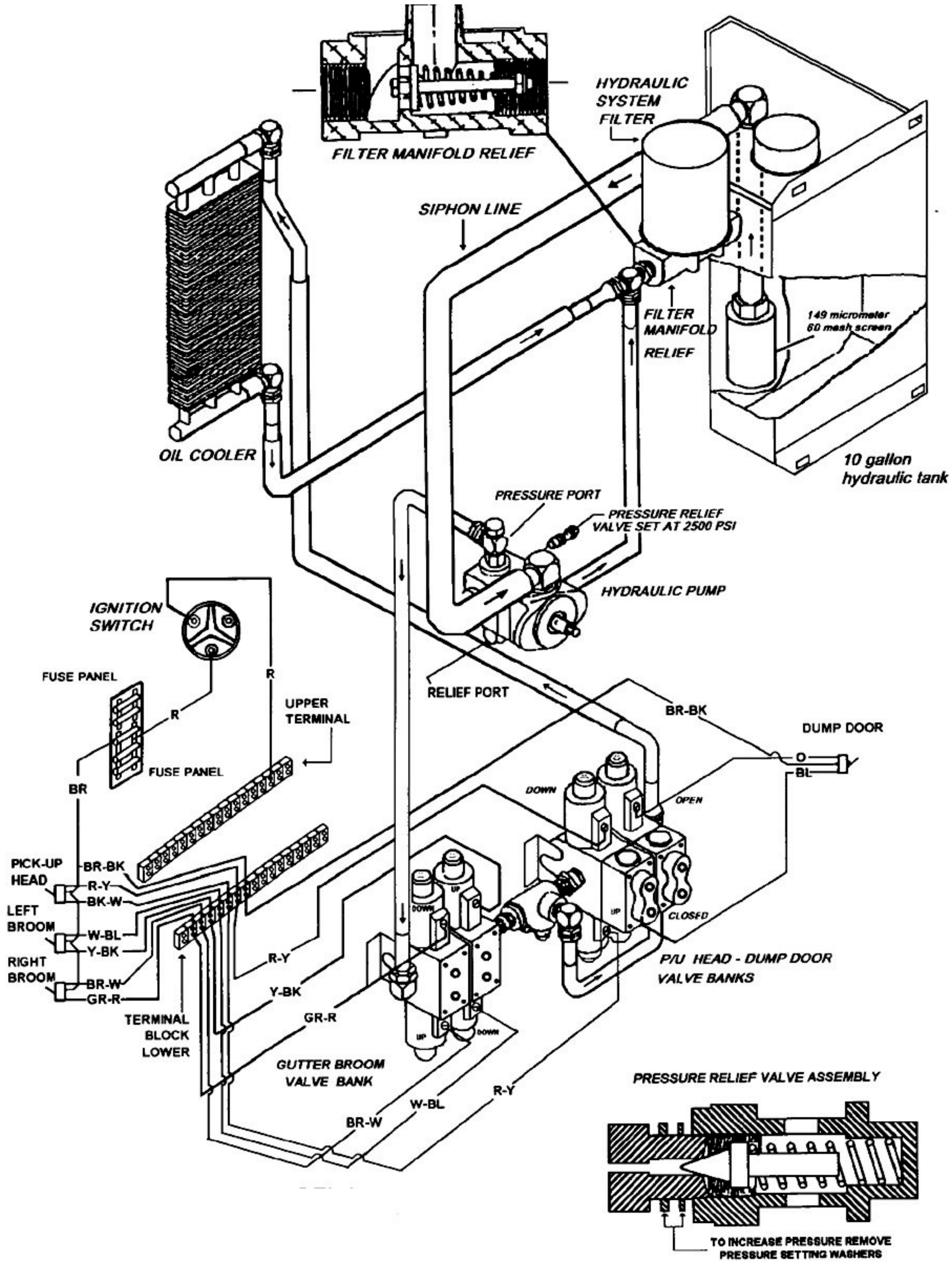


Figure 3–7. Hydraulic system.

NOTE: Do not overfill the reservoir. When the hydraulic fluid heats up during operation, it will expand and overflow from the cap.

Open-center system

The hydraulic system is open-center and uses a vane-type hydraulic pump with a built-in relief valve set at 2,500 psi that is gear-driven by the auxiliary engine. The valve bank consists of four electric solenoid actuated spool-type control valves. They direct fluid to the six double-acting cylinders (two-dump door/two pick-up head/one for each gutter broom) and two torque motors.

Between the gutter broom valves and the valves for the dump door and pick-up head, there is a bypass valve and a secondary pressure relief valve. The bypass valve must be opened (electrically or manually) at the same time the pick-up head or dump door is operated. The secondary pressure relief valve is set at 1,350 psi and is the maximum pressure allowed to any cylinder or seal damage will occur. However, the torque motors use the full 2,500 psi to operate the gutter brooms.

Hydraulic valves

There are three additional hydraulic valves by each gutter broom. They are explained in the table below.

Gutter Broom Hydraulic Valves and Description	
Valve	**Description**
Cartridge	Sends 1,350 psi to each broom cylinder, then allows 2,500 psi to the broom motors. It also protects the system from shock damage when the broom encounters solid objects.
Solenoid lock	Holds the broom up in the stowed position. It must be energized for the broom to go down.
Flow control	Controls the raising speed of the broom. Before the fluid returns to the reservoir, it goes through an oil cooler located in front of the auxiliary engine radiator, then to a return filter.

Water system

The sweeper uses a water system to control the amount of dust produced during sweeping operations. The operator activates a spray of fine water mist on the road surface before the road is swept. Water also aids the dust separator in filtering dust from the air. Electric toggle switches are used to activate each of the four nozzles: one for each broom, one for the pick-up head, and one for the hopper. The hopper water system is used to control internal dust and protect the blower from damage.

Water tank

The capacity of the water tank depends on the model of the sweeper. The model 600, the most common Air Force model, has a tank capacity of 170 gallons. The interior of the tank has a protective coating to prevent corrosion. The tank is fitted with a drain valve to facilitate rapid emptying. The water system components are shown in figure 3–8.

The water pump is a 12-volt, low-pressure pump with an output of 2.8 gpm. It is rated at 30 psi and is located on the left side under the blower and in front of the hopper.

There are four areas where water filters are placed to protect the system. They are listed and described in the table below.

Water Filters and Description	
Filter	**Description**
Metal cone screen	The end of the 2½-inch fire hose that connects to fire hydrants has a metal cone screen that is held in place by an O-ring.
Foot valve/strainer	Located inside the water tank, it prevents large particles from entering the system and prevents backflow, assuring a good water supply in the suction line to the pump.
In-line strainer	Located between the tank and pump, it prevents fine particles from entering the system. Operators must remove and clean this strainer on a daily basis.
Nozzle screens	A small screen under each nozzle cap that keeps the nozzle from becoming plugged.

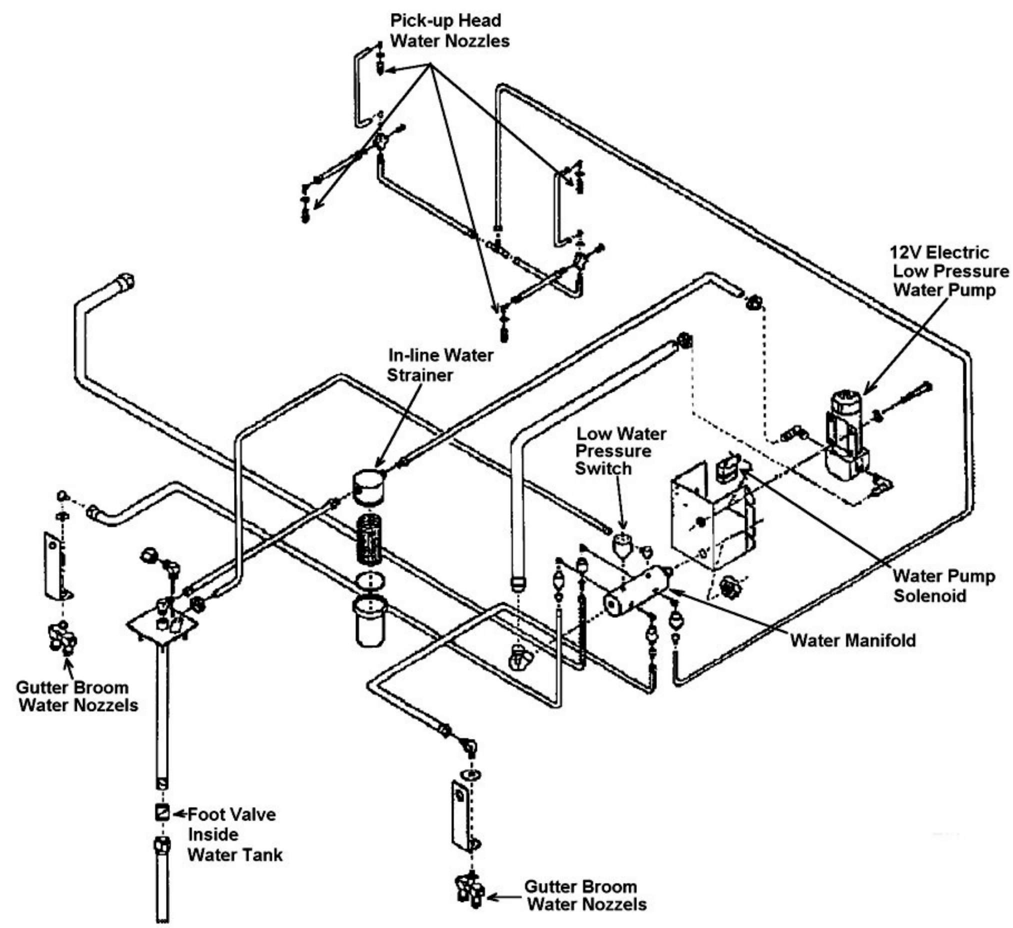


Figure 3–8. Water system.

Water safety system

Some models use an automatic low-water shutdown switch, while others use a float switch in the tank to protect the pump from operating if it loses prime or the tank runs out of water. If the electric pump runs dry for an extended period of time, it may overheat and malfunction. A green indicator light in the cab illuminates to let the operator know that the water pump is not working because the pump has lost its prime or the tank is out of water.

NOTE: To lubricate the pump and internal components of the water system, add one (1) quart of water-soluble oil or the equivalent to the water tank every 150 hours of operation. It is important that the oil be water-soluble.

018. Regenerative sweeper maintenance

The sweeper is designed for ease of access for maintenance as well as efficient function. This allows the vehicle to be in maintenance for minimal time and back to doing its job as soon as possible. In most cases, expensive diagnostic equipment is not required for electrical troubleshooting; it can be accomplishing using a multimeter or test light.

Auxiliary electrical system troubleshooting and repair

If the auxiliary engine overheats or has low-oil pressure, the automatic shutdown timer will activate and the auxiliary engine will shut down in 30 seconds, as we discussed previously. A flashing red indicator light warns the operator that the auxiliary engine is about to shut down. These 30 seconds provide the operator the opportunity to raise the pick-up head and gutter brooms in order to avoid damage while driving the vehicle to the maintenance shop.

Technicians may need the key in the ON position to troubleshoot the auxiliary electrical system. If they forget about the switch while testing the electrical circuits, they may have voltage on a wire one second and lose voltage the next. This will result in a waste of time trying to find broken connections when all they have to do is RESET THE RED BUTTON.

As stated earlier, this switch indicates low-engine oil pressure and/or an overheat condition. To troubleshoot these systems, take the simple steps first and ensure the engine oil and coolant are at the proper levels. If they are, refer to the appropriate technical order to troubleshoot these systems.

NOTE: This step, resetting the red button, often gets overlooked by operators and/or technicians. Forgetting about this switch and troubleshooting elsewhere on the vehicle wastes significant time. Always keep this switch in mind when troubleshooting electrical malfunctions!

Pick-up head adjustment

It is very important to adjust the pick-up head properly to prevent extensive damage to the unit. If you want the vehicle to do its job correctly, these steps MUST be done in the following order:

Step 1

Drive onto a level surface, make sure the pick-up head is in the raised position, and shut off the engine.

WARNING: Place blocks under the front and rear of the pick-up head to protect yourself when you reach under the unit. Do not assume the hydraulics will hold the pick-up head in the raised position. Read the technical order and remember to protect yourself by wearing the proper personal protective equipment when working on the vehicle.

Loosen the skid-plate bolts just enough so the skid plate moves up and down with a slight drag (fig. 3–9). Adjust the skid plates (left and right) so their bottom edges are 1½ inches below the bottom edge of the pick-up head, and then tighten the bolts.

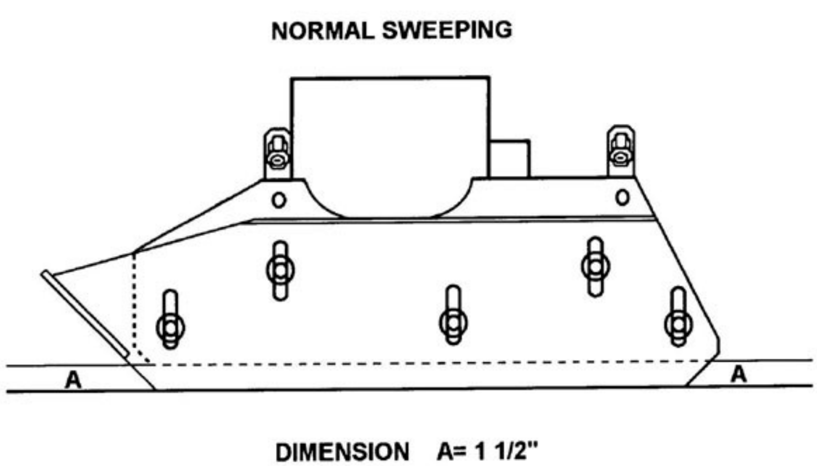


Figure 3–9. Skid-plate adjustment step 1.

This adjustment is checked by reaching under and placing a ruler against the inside surface of the skid plate. Move the ruler up until it touches the bottom edge of the pick-up head (fig. 3–9). It should read 1½ inches. Complete this step on both sides before moving on to step 2.

Another item to inspect at this point is the rubber curtains; make sure they hang down below the skid plate approximately 1½ to 2 inches. Remember the curtains seal the front and rear of the pick-up head and they should last approximately 500 operating hours if the unit is maintained properly.

The setting in figure 3–9 is accomplished for two reasons:

1. The skid plate is the wear surface, and this adjustment gives a 1½-inch clearance before the pick-up head is damaged.
2. To ensure that the blast orifice is adjusted to the manufacturer's recommended 2 inches above the road surface.

Step 2

The following adjustments keep the weight of the pick-up head off of the ground so it will float across the road surface. It is imperative that these steps are completed in order. It is a good idea to read the step-by-step procedures in the technical order before performing them. Refer to figure 3–10 as we discuss these procedures.

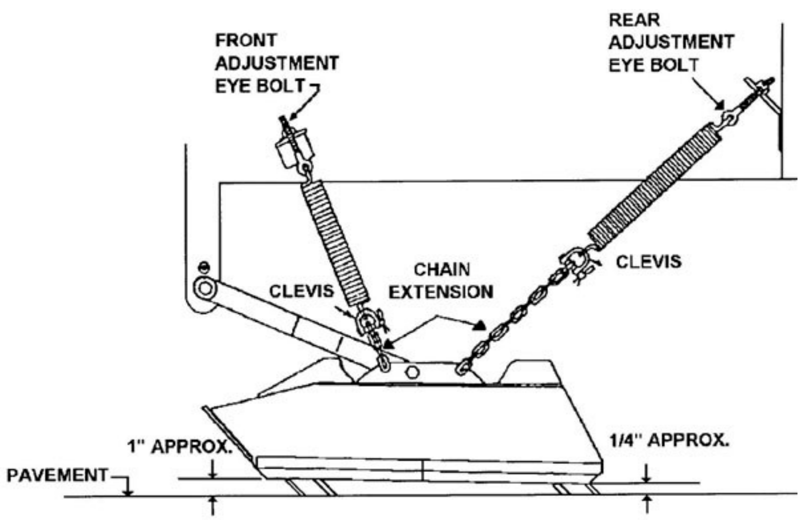


Figure 3–10. Skid-plate adjustment step 2.

Start the auxiliary engine

Start the auxiliary engine, set it to 1,000 rpm, lower the pick-up head, and pull the vehicle forward approximately four feet to ensure the curtains fold or drag underneath the pick-up head. The curtains must fold under to ensure they do not support the weight of the pick-up head, which would prevent proper adjustment.

Measure the front

Start with the left skid plate and measure the front. There should be one inch from the top of the road surface to the bottom of the skid plate. Change the number of chain links at the bottom of the spring to get the measurement close. Then turn the eyebolt nut on top of the spring until the desired measurement is attained.

Adjust the rear

The next adjustment is made at the left rear of the skid plate. Using the rear chain and eyebolt, adjust it to attain ¼-inch distance from the road surface to the bottom of the skid plate. Making this adjustment may slightly change the front measurement. Double check the front.

Step 3

Now that the left side of the pick-up head is adjusted, start on the right side.

First measurement

The first measurement is made at the front of the right skid plate. This measurement should be ¾ inch from the road surface to the bottom of the skid plate (fig. 3–11).

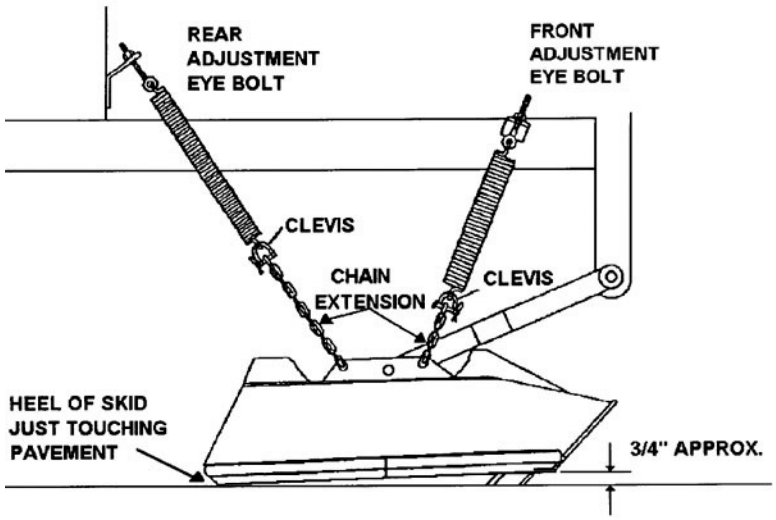


Figure 3–11. Skid-plate adjustment step 3.

Last measurement

The last measurement is at the rear of the right skid plate, where the heel of the skid plate is adjusted so that it is just touching the road surface. After making this adjustment, recheck the front measurement.

To see if the proper flotation characteristics of the pick-up head are obtained, have an operator set the blower engine at 2,000 rpm and pull the vehicle forward approximately four feet. The pick-up head should draw down to the ground, floating on top of the road surface, but you should be able to easily lift one side with your hand.

Water system troubleshooting and adjustment

Water system maintenance involves ensuring there is adequate water in the tank, the filters are cleaned, and the lines are unobstructed. A common adjustment is the nozzle spray pattern. This adjustment is accomplished by loosening the jam nut around the nozzle. Turn the nozzle so it sprays the largest water pattern possible on the ground, then tighten the jam nut. The more dust that gets dampened, the easier it will be for the sweeper system to clean the air before it gets back to the blower to start the cycle over again.

Hydraulic system troubleshooting and adjustment

This system requires little maintenance other than the normal repair of leaking hoses and fittings. The pump, the secondary pressure relief valve, and cartridge valve are preset at the factory. They can be checked and adjusted by following the technical order procedures.

WARNING: The vehicle manufacturer recommends NOT driving the sweeper over railroad tracks, speed bumps, or backing up with the gutter brooms and pick-up head in the down position. Doing so can cause severe damage to these items as well as the hydraulic cylinders attached to them. Proper adjustment of the gutter broom flow control valves is important because it allows the operator to raise the hydraulic components clear of obstructions within the 30 seconds of a shutdown condition. Refer to the proper technical order or service manual to ensure the pick-up head and gutter brooms will fully raise from the lowered position within 30 seconds, yet raise slow enough that the gutter brooms will not cause damage to components when being raised.

Troubleshooting sweeper malfunctions

The following scenario is “played out” to help you understand how to troubleshoot a multisystem malfunction. Certain checks, assumptions, and results are given to lead you through the troubleshooting process.

Let’s say a sweeper comes to the shop and your supervisor asks you to check it out. You look at the Air Force Form 1800, Operator’s Inspection Guide and Trouble Report, and find the following write-ups:

1. The left broom operates harshly when raised and will not come back down.
2. The sweeper is not picking up debris.
3. The water system is inoperative.

You know that the flow control valve is raising the broom too fast when it causes it to slam under the vehicle. You know you can make the valve adjustment, but, first, you have to find out why the broom will not come down.

Broom scenario

With the auxiliary engine running, operate the left broom switch down to lower the broom; the broom spins but stays in the stowed (raised) position. You now know the problem is not hydraulic because the broom is spinning, so the problem must be electrical. Reading the technical order, you see that the wiring to the solenoid lock valve or the solenoid lock valve itself may be faulty.

Take a voltage reading

Stop the engine and take a voltage reading at the solenoid lock valve using a multimeter. Remember that while taking the reading, the broom switch must be activated to energize the solenoid lock valve. If 12–14 volts is indicated, the solenoid lock valve is bad. If no voltage is indicated, inspect the solenoid lock valve wiring for broken connections or bad grounds.

Follow the wiring back to the cab, looking for breaks or bare wires. When you find the cause of the problem, make the necessary repairs. Recheck for a voltage reading at the solenoid lock valve. Start the engine and operate the switch, the broom should come down. Now proceed to adjusting the raising speed of the broom.

Adjust the adjustment knob

With the broom down, shut off the auxiliary engine. Reach under the truck cab just above the broom and locate the flow control valve. Loosen the jam nut using a $^{3}/_{8}$-inch wrench and turn the adjustment knob clockwise one turn to slow the raising speed. Start the auxiliary engine, raise the broom, and check the speed. Repeat these steps until the desired speed is obtained, then tighten the jam nut.

You have completed the repair of the first discrepancy on the 1800 and can now start on the next write-up, “sweeper is not picking up debris.”

Suction scenario

The second discrepancy states that the sweeper will not pick up debris. To troubleshoot the problem, follow these procedures:

1. With the engine off, check the blower belt’s condition and tightness.
2. Unlatch the suction hose, it is not clogged. Things look OK so far, but you still have not found the problem.
3. Start the auxiliary engine and raise the pick-up head. Feel to see if there is air blowing from underneath the pick-up head.

   You hear the blower turning but have little or no air blowing down from the pick-up head. This tells you that there may be a restriction between the blower and the pick-up head. Stop the engine, open the pressure bleeder door, and (with gloves on) reach inside the pressure hose area and feel for debris. You find that paper is obstructing the turning vanes, causing the restriction, and remove it.

CAUTION: ***Always*** wear eye and ear protection when working around the pick-up head while the auxiliary engine is running.

Questions

Ask yourself, “Am I done?” Your answer should be “no.” You have removed the restriction where air can now pass through, but how did the paper get there?

Answer

Good thinking, you remembered how the air flows through the system. The dust separator door must have been left open during operation, or there is a hole in the hopper screen. This is how debris can get into the blower and obstruct the pressure side of the air system. Check these areas and correct the problem. Now check off this discrepancy on the 1800 and start on the last one, which is an inoperative water system.

Water system scenario

To troubleshoot a water system problem, follow these procedures:

1. Check and make sure there is enough water in the tank.
2. Turn the water system ON and see if the pump operates. In this scenario, you find that it does but will not remain running. You see little or no water output at the spray nozzles. It is very unlikely that all the spray nozzles are plugged at the same time, so you need to look elsewhere.
3. Following the path of water through this system, start with the water lines at the tank and work toward the pump. As you inspect the water line inside the tank, you find that the foot valve/strainer is plugged and clean it.
5. Drain the tank to remove any other contaminants and refill it. The water system should now work; however, you should keep in mind that blockages can occur anywhere along the water system from the tank to the spray nozzles.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

017. Regenerative sweeper fundamentals

1. What is the operating principle of the regenerative sweeper?

2. What are the recommended operating speeds of the TYMCO sweeper?

3. What does the auxiliary engine drive on the TYMCO sweeper?

4. What is the purpose of the automatic shutdown system?

5. What is the heart of the TYMCO air system, and what does it produce?

6. What item is the sweeping component of the TYMCO sweeper?

7. What three purposes are the skid plates used for?

8. What purpose does the deflector curtain serve?

9. What are gutter brooms used for?

10. What problem does overfilling the hydraulic tank cause on the TYMCO sweeper?

11. Describe the TYMCO sweeper hydraulic pump.

12. What use does the TYMCO sweeper solenoid lock valve serve?

13. What controls the raising speed of the gutter brooms?

14. What is the purpose of the TYMCO sweeper water system?

15. What does a green light on the TYMCO sweeper center control panel tell the operator?

018. Regenerative sweeper maintenance

1. What should be kept in mind when troubleshooting TYMCO sweeper auxiliary electrical malfunctions?

2. How long will the rubber curtains last if proper adjustments are made to the pick-up head?

3. Why is it important to make pick-up head adjustments?

4. When making pick-up head adjustments, why do you need to pull the truck forward each time the pick-up head is raised and lowered?

5. How do you check to see if the proper pick-up head adjustments have been made?

6. Why should the sweeper *not* be driven over railroad tracks with the pick-up head and gutter brooms in the down position?

7. Why is proper adjustment of the gutter broom flow control valves on the sweeper important?

8. What would cause the gutter broom to spin but not lower?

9. What should done when working around the pick-up head while the auxiliary engine is running?

10. How can debris get into the sweeper blower and obstruct the pressure side of the system?

3–2. Snow Blower

Snow blowers have been used by the Air Force for many years. Numerous improvements have been made because of technological advances and expanded mission requirements. These changes produced a state-of-the-art multipurpose snow removal vehicle, which is designed to clear aircraft runways, taxi ways, ramps, as well as streets and parking lots. Blower and plow attachments are used with a truck to remove snow. The following lessons will introduce you to snow blower fundamentals, its maintenance procedures, and its power unit (multipurpose truck).

019. Snow blower fundamentals

The snow blower (fig. 3–12), also referred as the rotary snow blower, is an asset you are likely to find at many bases that receive heavy amounts of snowfall during cold weather months. Becoming familiar with its operating systems is key to maintaining this vehicle properly, which ensures that base and flightline operations will not be hindered by weather conditions. The snow blower's power unit is a multipurpose truck.

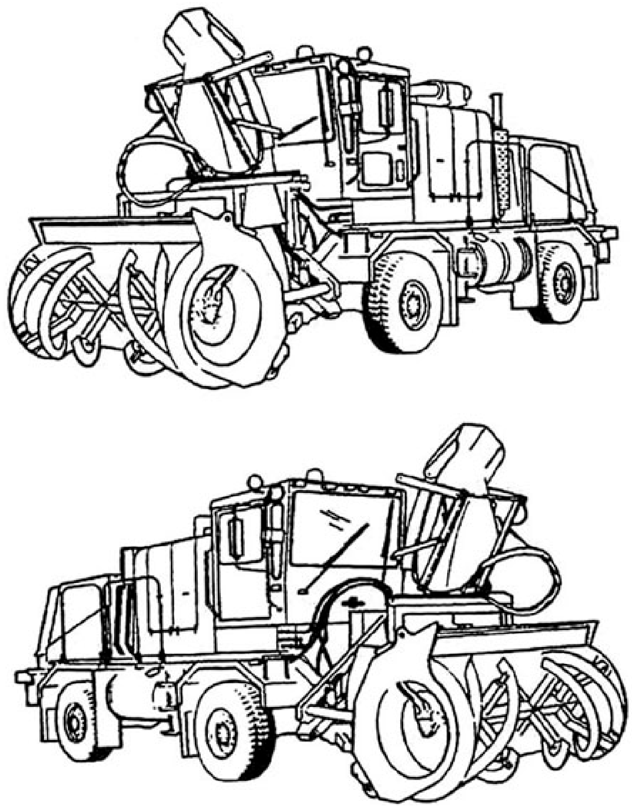


Figure 3–12. Snow blower.

Multipurpose truck

The multipurpose truck is shown in figure 3–13 without attachments. The truck is built to be operator-friendly; therefore, the cab sits at the forward edge of the frame to give the operator the best possible forward and peripheral view. It has one door but seating for two. The instrument panel and controls can easily be seen and accessed by the operator. The windshield is constructed of safety glass, electrically heated, tinted, and inclined forward to provide the operator better vision of the attachments during operation. The vehicle weighs approximately 13 tons and is equipped with a railed catwalk on the left and right sides for easy access to the engines.

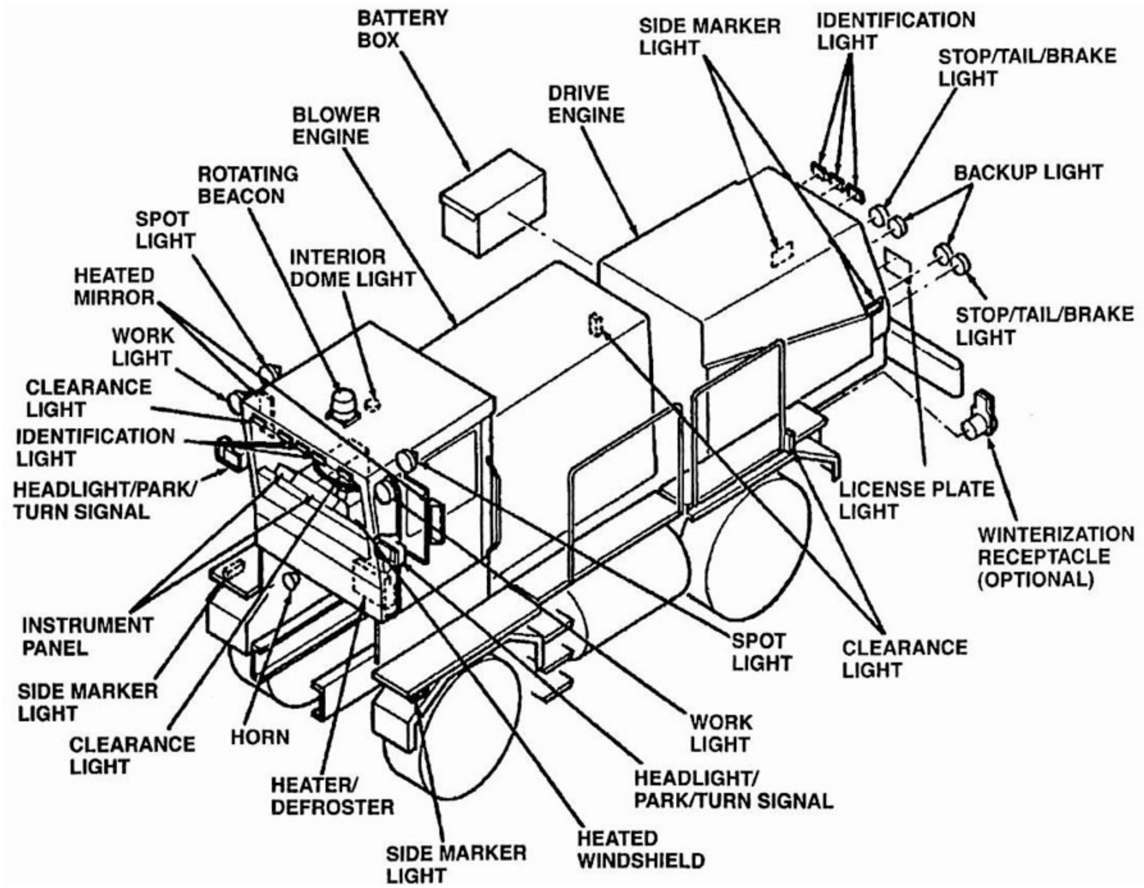


Figure 3–13. Multipurpose truck.

The vehicle houses two diesel two-cycle engines, front and rear.

1. The rear engine powers the vehicle. It is an in-line six cylinder, rated at 300 hp at 2,100 rpm and has 850 ft. lbs. of torque at 1,200 rpm.
2. The front engine drives the blower attachment. A 6V92 turbocharged engine produces 475 hp at 2,300 rpm and has 1,020 ft. lbs. of torque at 200 rpm.

The electrical circuit is a conventional 12-volt negative ground system. Voltage is supplied by four 12-volt batteries, connected in parallel. Two alternators are mounted on the vehicle’s drive engine. One is a 160 amp that supplies voltage to the batteries, starter, heated mirrors, headlights, tail lights, turn signals, spotlights, clearance lights, beacon light, cab interior, reverse alarm, instrument panel, horn, and solenoid valves. The other, a 75 amp alternator supplies voltage to the heated windshield and other functions when the cab switch is engaged and the drive engine is running. All electrical components are protected against overloads by manual reset circuit breakers located on the side of the control panel to the right of the operator.

This vehicle is all-wheel drive with a five-speed Allison transmission and a manually shifted two-speed transfer case. In total, this configuration provides 10 forward and two reverse gears.

Blower system

The rotary blower consists of an auger, impeller, and rotary head. The auger digs into the snow as the vehicle advances. Snow is forced by the auger into the impeller and out of the rotary head. This assembly will cut a path 102 in. wide and project snow up to 173 ft. to the left or right of the truck. It is capable of moving 3,228 tons of snow per hour. Power to drive the impeller section is obtained from the diesel engine and drop box assembly using interconnected drive shafts.

Blower housing

The blower housing (fig. 3–14) is raised and lowered by two double-acting cylinders, which includes the following components listed in the table below.

Blower Housing Components and Function	
Component	**Function**
Augers	Driven by two hydraulic motors and are designed to dig into the snow as the vehicle advances, forcing snow into the impeller.
Caster wheels	There is one caster wheel on each side, which provides a means to adjust the clearance between the scraper blade and the ground.
Impeller housing	Made of steel and surrounds the impeller. It is used to direct snow to the left, right, or up to the chute.
Impeller	A balanced fan used to discharge snow.
Push frame	Made of steel and connects the blower to the carrier.
Scraper blade	Mounted on the bottom of the blower housing and removes snow down to ½ inch from the surface.
Skid plates	Mounted under the blower housing and provide a wearing surface for the blower assembly.

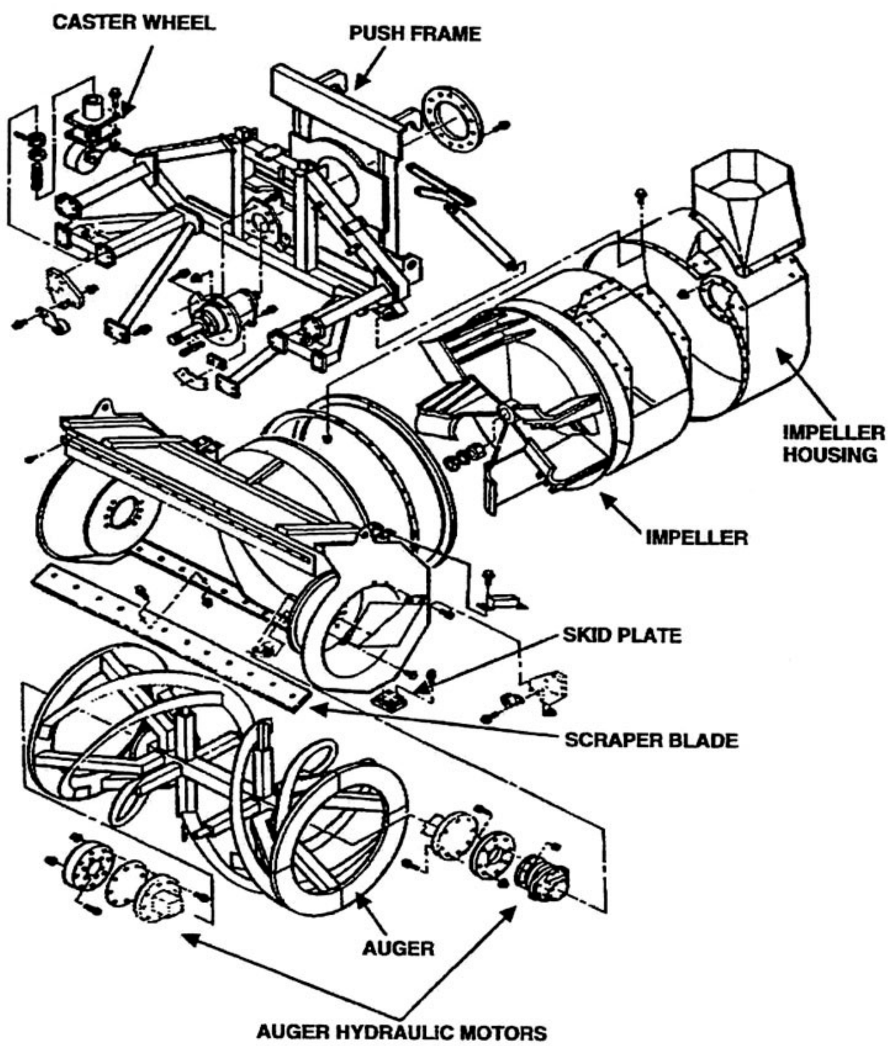


Figure 3–14. Blower assembly, exploded view.

Some models have an optional loading chute (fig. 3–15) mounted on top of the blower assembly. The loading chute can rotate left or right 240° and is for bulk removal of snow during side-by-side vehicle operation. The chute extends and retracts for directional control of the snow.

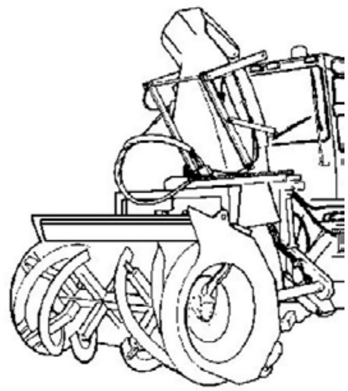


Figure 3–15. Optional loading chute.

Blower drive train

As mentioned earlier, the blower drive train incorporates a diesel engine solely dedicated to the blower attachment. This engine provides power for the impeller and the augers by driving the auger hydraulic pump.

A drop-box clutch, which is operated from the cab using a lever, transfers power from the blower engine to the drop box. The clutch is a dual-plate, snap over center, dry-clutch assembly. The drop box receives blower engine power when the clutch is engaged. Input rpm is reduced, and power is transferred through a helical gear arrangement to a lower output shaft. A safety flange connects the drop box to the drive shaft and protects the drive train from binding at the impeller by using two shear bolts. A drive shaft then transfers power from the drop box to the impeller.

Electrical/control system

All operations are controlled from the cab by electric switches or manual levers. The following illustrations in figures 3–16 and 3–17 give you an idea of where these controls are located.

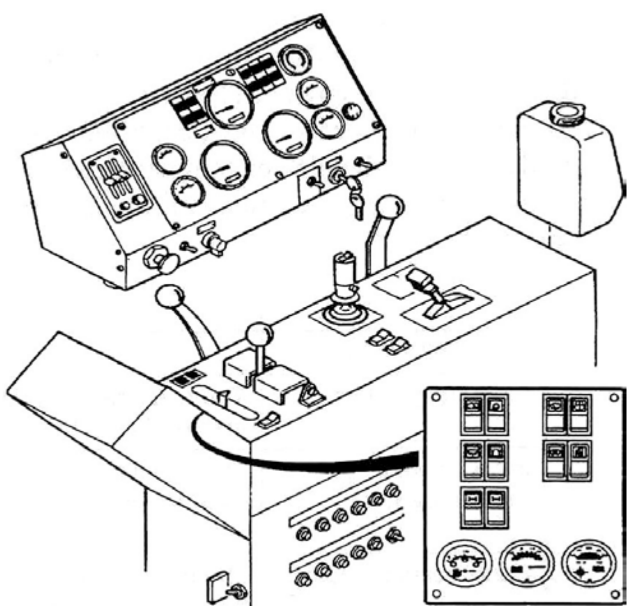


Figure 3–16. Control panel.

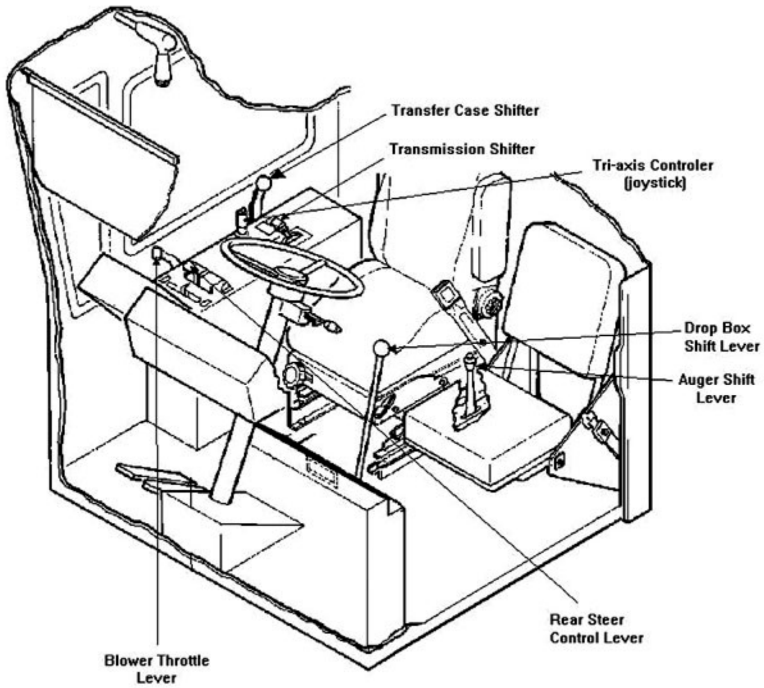


Figure 3–17. Vehicle controls and indicators.

This basic information is on the snow blower, multipurpose vehicle, and snowplow. Even though blowers and plows may look alike, remember that vehicles and equipment continuously undergo upgrades. For this reason, you must consult the proper technical order for the make, model, and type of equipment you are working on.

Blower hydraulics

The blower has two separate hydraulic systems, one for the augers and the other for blower assembly control.

The auger hydraulic operating system starts at the hydraulic reservoir. The reservoir has a 20-gallon capacity and is located behind the front engine. The rotary piston-type pump, driven by the blower engine, supplies up to 33 gpm for the two-speed reversible motors that drive the augers. The system incorporates a cable-operated two-speed valve body, which controls the speed of the auger motors. A safety switch prevents rotation of the auger unless the impeller is engaged.

The blower hydraulic control system's reservoir is located behind the rear engine and has a 20-gallon capacity. This system uses the front half of a tandem-vane pump that is driven by the rear engine. The other half of this pump is used for carrier steering. A solenoid-operated valve body, controlled by switches and a joystick in the cab, operates the blower control cylinders.

The following table lists various cylinders and motors, along with their functions. This information will give you a better picture of what it takes to operate the blower.

Blower Hydraulic Components and Their Functions	
Component	**Function**
Plow lift cylinders	There are two plow lift cylinders. They are double-acting and are used to lift the blower or plow attachments.
Impeller housing rotation cylinder	The impeller housing rotation cylinder is double acting and is used to rotate the impeller housing left or right for 140° of total travel.
Chute rotation motor	The chute rotation motor is reversible and is used to rotate the chute left or right for 240° of total travel.

Blower Hydraulic Components and Their Functions	
Component	**Function**
Leave extension cylinders	There are two leave extension cylinders. They are double-acting and are used to extend, hold, and retract the chute.
Flipper cylinder	The flipper cylinder is double-acting and is used to move the flipper, which is mounted on the end of the chute.

Steering system

Steering is accomplished with either front only or all-wheel steering. With the front-wheel steering, the vehicle can turn a 66 ft. diameter circle. With all-wheel steering, it can turn a 43 ft. diameter circle.

The steering system uses mechanical linkage with hydraulic power assist. With the drive engine running, hydraulic pressure reduces the effort required to turn the steering wheel. If the drive engine is not running, the wheels can still be turned, but greater effort is required. We discuss each part of the steering system in the following paragraphs.

Mechanical linkage

The steering wheel is connected to the steering gear through a universal joint shaft. The front wheels are connected to a steering gear through a drag link and tie-rod combination. The front wheels turn when the steering wheel is rotated right or left. The optional rear steer axle also contains a tie rod to transfer steering to the other side of the axle.

Front-steer hydraulic circuit

Fluid is drawn from the hydraulic reservoir by the rear half of the tandem pump, which is powered by the drive engine. A separate return line connects the pump to the reservoir to return excess fluid to the reservoir. Fluid from the pump flows through the steering gear, then returns to the reservoir. Flow and pressure are only generated when the drive engine is running. The circuit is enclosed but contains a self-purging feature that removes any air that may be present.

Brake system

The vehicle brake system is a conventional-air type. The multipurpose snow vehicle brake system uses two brake chambers on each axle controlled by a pedal-operated brake valve assembly. When the pedal is depressed, the brake valve assembly applies air pressure to the brake chambers, forcing the brake shoes against each brake drum and stopping the vehicle. The rear brakes are equipped with spring brake chambers that provide a parking brake function. A dual air-pressure gauge is located in the cab and provides readings for both the front and rear air brake systems. The red needle indicates rear system pressure, and the green indicates front system pressure. Normal air pressure reading for these systems is 85–120 psi with a minimum of 60 psi. At 60 psi, a low-air pressure warning alarm sounds. At start-up, this alarm sounds until sufficient air pressure is built to safely operate the vehicle.

Service brakes

The service brake system is a split type, with wedge-actuated brake shoes on the front axle and an S-cam-actuated brake shoe system on the rear axle. Each brake system, front and rear, is independent of the other. A failure in one system will not affect the other and will result in only partial loss of braking power.

Parking brakes

The parking brake is spring-actuated and incorporated in the spring brake chambers on the rear axle. When the chambers are pressurized, large coil springs are compressed, releasing the parking brakes. Exhausting air pressure from the chambers allows the spring to expand, engaging the parking brakes. Operation of the parking brake is controlled by a push/pull switch located in the cab. A red parking brake indicator light illuminates to indicate the parking brake is engaged.

Emergency brakes

Emergency braking is controlled by the brake pedal through the function of a spring brake control valve assembly. The spring brake control valve assembly constantly monitors rear axle service reservoir pressure. If a loss of rear axle pressure occurs, the operator is alerted by the LOW AIR indicator and alarm located on the dashboard. If you then depress the brake valve assembly, the spring brake control valve assembly reacts by sensing front axle delivery pressure and applies and releases the rear axle spring brakes until the remaining air is depleted. The rear brake application is in direct proportion to the front axle pressure signal. This action provides the operator with modulated braking and the feel of a normal service brake stop. Loss of front brake circuit pressure causes failure in the front brake system only. The rear axle service brakes still function in a normal manner.

Air system

An air compressor located on the drive engine supplies air pressure for the system. The compressor automatically maintains sufficient air pressure to operate the air system through the function of an air governor. A dual air-pressure gauge and low-pressure indicator are mounted on the instrument panel to enable the operator to monitor the air system. An air dryer is contained in the system to collect and remove any moisture and contaminants present in the system air before it reaches the first air reservoir. The air dryer contains a heater and thermostat assembly to prevent freeze up in the purge drain valve when the dryer is used in severe winter conditions. Each of the three air reservoirs contains a manual drain valve to allow the operator to drain them daily to remove accumulated moisture present in the systems.

Fuel system

The fuel system consists of two 128-gallon diesel fuel tanks plus the necessary piping, valves, fuel/water separators, and fittings to deliver fuel to each engine independently. The fuel tanks are plumbed together by a crossover hose that ensures the fuel level is the same in each tank. Fuel passes through a fuel/water separator and secondary filter before it is delivered to the fuel injection system. Inside each injector is a separate plunger-type pump for that cylinder. This pump delivers a metered amount of fuel under high pressure into the cylinder. Both fuel tanks and fuel/water separator provide drains for removal of condensation and sediment from the system.

Optional equipment

The multipurpose vehicle has an array of optional equipment that may be used during snow removal operation:

Tri-axis controller

The TRI-AXIS CONTROLLER (joystick) located in the cab is a multiposition, spring-loaded momentary switch used to position the blower, optional chute, and optional plow. The functions of the TRI-AXIS CONTROLLER are listed in the table below.

Tri-Axis Controller Functions and Description	
Position	**Function and Description**
Forward	Push the joystick forward to the PLOW DOWN position to lower blower or optional plow. Press the push button FLOAT SET switch while joystick is in the forward position to place blower into float mode.
Backward	Pull the joystick backward to the PLOW UP position to raise the blower or optional plow. Pulling the joystick backward also disengages the float mode.
Left	Move the joystick to the left to rotate the impeller housing or optional chute to the left a maximum of 50°, depending on setting of the CHUTE/BLOWER ROTATE switch. If the optional plow is attached, the plow will rotate to the left a maximum of 35°.
Right	Move the joystick to the right to rotate the impeller housing or the optional chute to the right a maximum of 90°, depending on the setting of the CHUTE/BLOWER ROTATE switch. If the optional plow is attached, the plow will rotate to the right a maximum of 35°.

Loading chute

The loading and spotting chute provides a means to load a parallel-traveling vehicle for bulk snow removal. The chute is capable of 240° of rotation and contains one extendible section and one flipper section. The chute is hydraulically controlled by switches and a joystick located in the cab.

Reversible plow

A hydraulically controlled, reversible plow assembly is available for high-speed snow and slush removal. The reversing feature, 35° right and left of the centerline, allows the operator more flexibility by selecting the direction of snow removal. The controls for the plow are located in the cab for operator convenience. The plow is mounted on adjustable height, self-steering, trailing-type wheels that are designed for carrying heavy loads at high speeds. This plow is also designed to remove snow or slush at speeds of up to 30 mph. Located at the top of the plow is a deflection strip designed to prevent snow from being thrown over the upper edge and onto the windshield.

Multisection plow

The multisection plow (fig. 3–18) is a three-segmented, spring-return, trip-type plow. When the plow encounters an obstacle during forward travel, the affected section of the plow turns upward and slides over the obstruction. The plow is designed to return to its clearing position within 3 ft. after passing over a 6 in. obstruction. Curb protection shoes are provided for protection when bumping against curbs, sidewalks, and other high boarders that are difficult to locate under snow. From the cab, the operator can adjust the plow to an angle of 35° to the right and left of the centerline. The plow comes equipped with two trailing-type caster wheels that permit adjustment to maintain an exact distance between the cutting edge and the roadway. By maintaining a correct adjustment on the caster wheels, wear on the cutting edge is held to a minimum. Located at the top of the plow is a deflection strip designed to prevent snow from being thrown over the upper edge and onto the windshield.

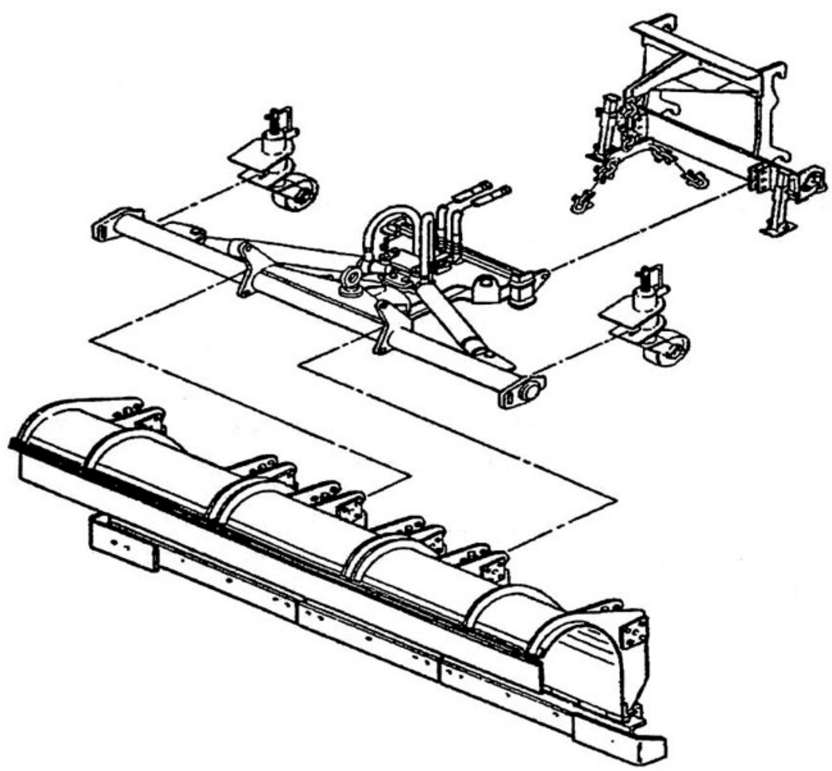


Figure 3–18. Multisection plow.

Winterization system

The winterization system (fig. 3–19) consists of a separate coolant heater and optional oil heater for both drive and blower engines along with an optional battery heater. All of the heaters are wired to a 50-amp receptacle located at the left rear of the vehicle. 115 volts (alternating current) of external voltage is supplied to a receptacle through the 25 ft. long connecting cable that is part of the winterization system package. The winterization electrical components are protected against overloads by manual reset circuit breakers installed on the junction boxes on the vehicle.

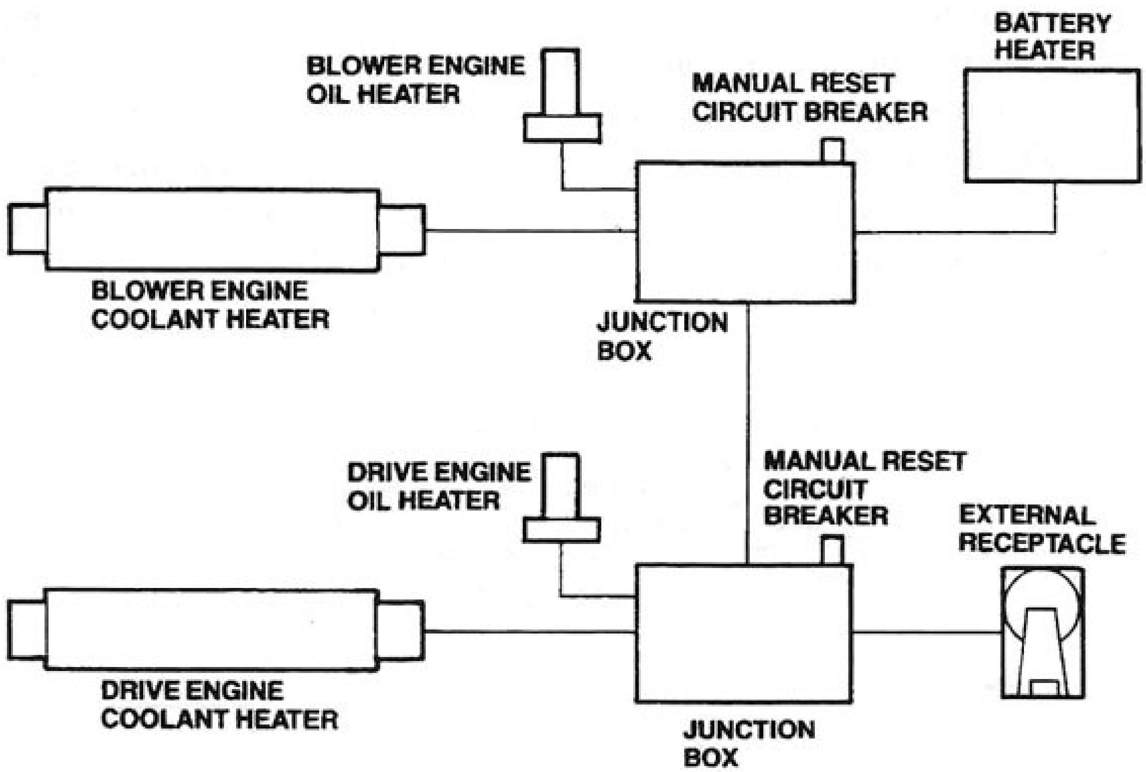


Figure 3–19. Winterization system.

020. Snow blower maintenance

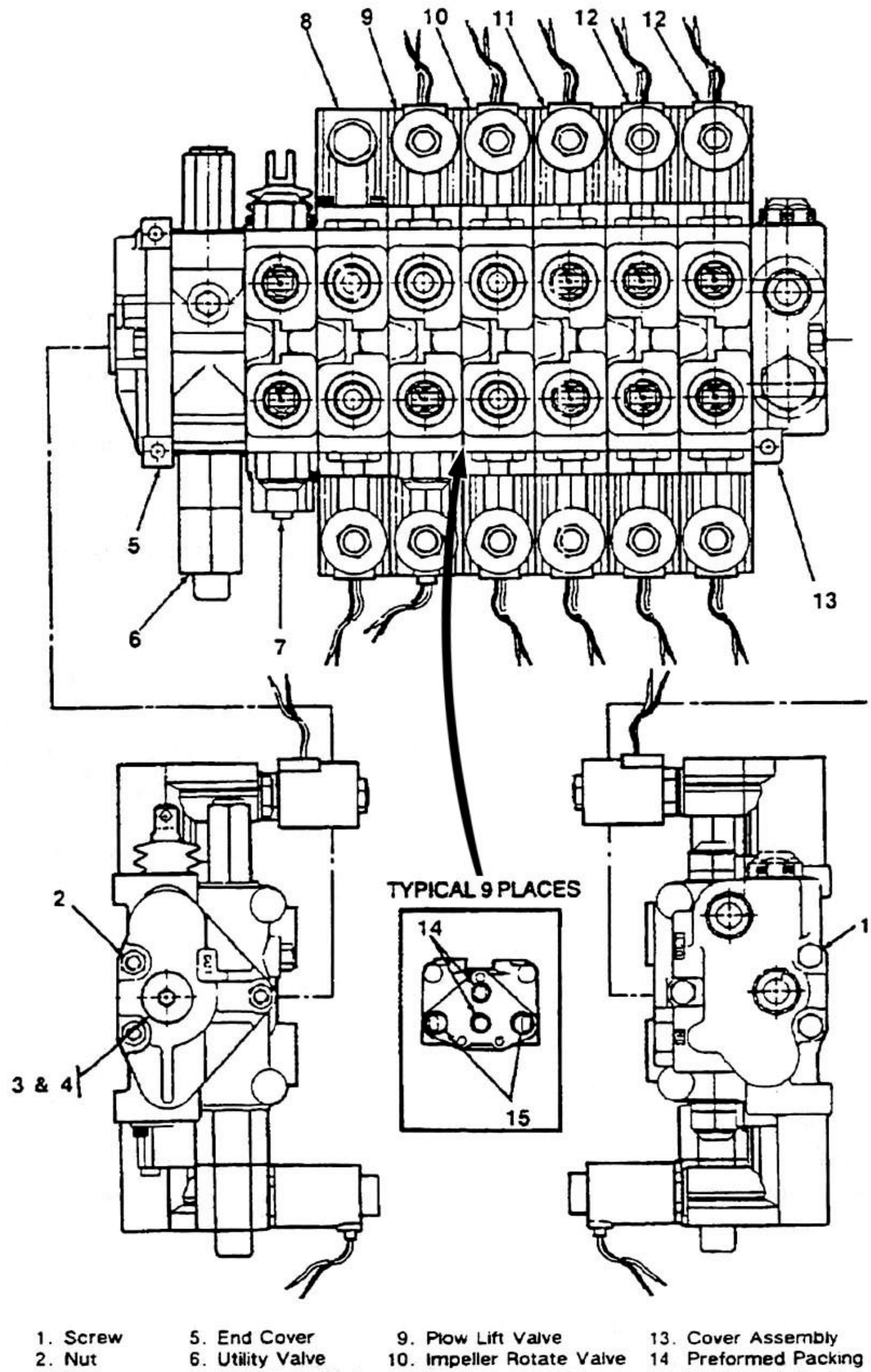
This lesson discusses snow blower fault troubleshooting and repair procedures. A good place to start is the troubleshooting charts in the appropriate technical order. Remember to ***always*** use the correct technical order for troubleshooting and correcting malfunctions on any vehicle.

Inspecting the hydraulic system

As with all hydraulic systems, it is always best to check the reservoir first for the correct fluid level. Also, ensure the manufacturer’s specified oil is being used. Visually inspect the fluid for signs of contamination. Perform a complete visual inspection of the entire system, looking for leaks and broken hoses. Operate through all functions and observe for any performance not meeting specifications.

Troubleshooting the blower/plow hydraulic positioning system

All of the mechanisms used in the blower/plow hydraulic positioning system are controlled through the directional control valve assembly (fig. 3–20).



1. Screw
2. Nut
3. Plug
4. Preformed Packing
5. End Cover
6. Utility Valve
7. Rear Steer Valve
8. Float Valve
9. Plow Lift Valve
10. Impeller Rotate Valve
11. Chute Rotate Valve
12. Chute Extend/ Flipper Valve
13. Cover Assembly
14. Preformed Packing
15. Preformed Packing

Figure 3–20. Directional control valve assembly.

When troubleshooting this system, the directional control valve is a good place to start. The assembly consists of a set of control valve blocks that are attached in parallel. Each block is used to control a separate function of the positioning system. However, the principles of operation are identical in each block.

Troubleshooting the directional control valve

The control valves are actuated by electric solenoids that are energized when the joystick is moved in a function position. For example, if the joystick is pushed forward to the PLOW DOWN position, the corresponding control valve solenoid is energized, allowing 300 psi of pilot pressure to flow through. This moves the spool valve to the open position. As the spool valve opens, 2,000 psi of system pressure is supplied to the selected mechanism. In this case, the hydraulic cylinders that control the plow position.

When isolating blower/plow-positioning malfunctions, use a multimeter to check for voltage at the solenoid that actuates the system being tested. Set the multimeter to the 12-volt range and connect the red lead to the positive wire going to the solenoid. Connect the black lead of the meter to a good ground. With the ignition switch in the RUN position and the joystick in the function position being tested, the meter should read system voltage. If voltage is not available, use the schematic to trace and repair the open circuit. If voltage is available, test the solenoid for proper resistance.

Resistance test

To perform a resistance test, turn the ignition switch to the OFF position and disconnect the two solenoid wires. Change the tester setting to read ohms and connect the leads to the two wires going into the solenoid. The reading should be between 4 and 8 ohms. If the reading is not within this range, replace the solenoid. If the reading is acceptable, check the resistance between one of the solenoid wires and the solenoid case. There should be no reading. If there is any reading at all, there is an unwanted ground and the solenoid should be replaced. If there is no reading, the malfunction is most likely in the hydraulic system.

Field testing

A quick and effective way to field test the solenoids on the directional control valve assembly is to interchange the solenoid in question with one that is functioning properly. Since all of the solenoids are identical on the assembly, changing two solenoid positions can be done in minutes. Once the swap has been made, perform an operational check of the system. If the system that previously failed functions correctly, the problem is the solenoid that was removed from this position. Replace the bad solenoid and perform another operational check. This troubleshooting strategy on the directional control valve assembly is fast, easy, dependable, and requires no test equipment, making it ideal for use in the field. However, it may not always be the most effective strategy. Each scenario must be evaluated to determine the best course of action.

Control valve output pressure

Another check is determining the control valve output pressure. After ensuring the solenoid is operational, connect a high-pressure test gauge to the outlet side of the control valve block being tested. With the drive engine running, place the joystick in the position for that system. The pressure gauge should read approximately 2,000 psi. If the reading shows low-system pressure and the directional control valve inlet pressure is normal, there is an internal problem in the control valve block. Make repairs as needed. If the reading is good, the problem may lie somewhere in the controlled mechanism(s). When you are certain that the system is functioning normally to that point, move on to the controlled mechanisms.

The following are additional checks that can be made:

1. Lift mechanism—if the lift mechanism is inoperative, inspect the hydraulic cylinders for defects. Make repairs as necessary, or replace the faulty items.

2. Impeller housing—if the impeller housing fails to rotate, check the holding valve and hydraulic cylinder for defects.
3. Float mode—if the blower/plow does not operate in the float mode, the likely cause is the hydraulic cylinder.
4. Optional plow—if the optional plow fails to rotate, inspect the holding valve, hydraulic cylinders, and cushion valve.
5. Optional chute—if the optional chute does not rotate, inspect the hydraulic motor. If it fails to extend, check the hydraulic cylinders.
6. Optional flipper —if the optional flipper fails to pivot, check the hydraulic cylinder.

Troubleshooting the blower hydraulic system

With the blower engine running and the drop box engaged, the auger can be operated by placing the shift lever, located on the floor of the cab, in the desired position. If the system fails, check the cable from the shift lever assembly to the two-speed control arm, located on top of the hydraulic pump (fig. 3–21) on the rear of the blower engine. The cable should move smoothly, without binding. Inspect the cable housing for kinks and breaks; replace if necessary.

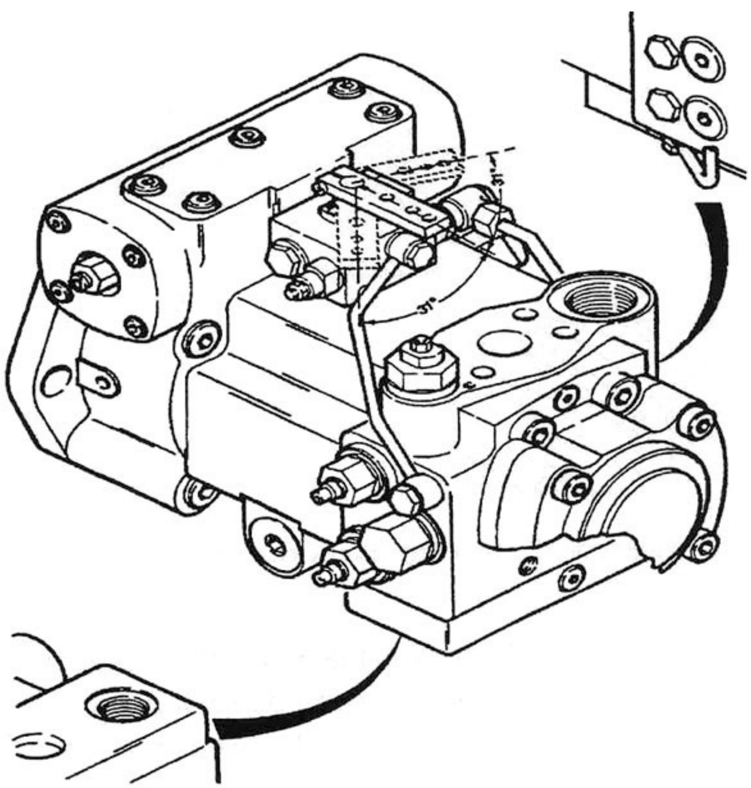


Figure 3–21. Blower hydraulic pump.

Troubleshooting auger malfunctions

A safety device is incorporated into the system to ensure that the auger can only be operated in conjunction with the impeller. This is done by a normally open switch that disables the pump until the drop-box shift lever is placed in the ENGAGE position. With the drop box engaged, the contacts close, allowing current to flow through a solenoid; the solenoid opens the ribbon pump neutral valve, allowing pump operation.

When troubleshooting an auger malfunction, use a multimeter or test light to check for voltage on both sides of the blower clutch ribbon interlock switch. If voltage is not available, use a schematic to trace and repair the open circuit. If voltage is available, perform the same test at the solenoid. If the results are normal, check for proper hydraulic pump output pressure.

Low-fluid pressure

If low-fluid pressure is indicated, additional pump troubleshooting is necessary. If pump pressure is within specification, the fault is likely one or both of the hydraulic motors located on the outside center hubs. If one of the motors fails, the auger will continue to operate, but performance will drastically decrease and if the second motor fails, it is probably due to the increased load. Do not release a vehicle for use with only one motor operational. If it is released with one operational motor, you are guaranteed to see it again, but this time you will have to do twice as much work replacing both motors.

High-speed system

For the auger high-speed system to operate, hydraulic pressure and volume must be increased. For this to occur, two separate functions are executed simultaneously by placing the shift lever in the full forward (high) position. When in the full forward (high) position, the cable shifts the hydraulic pump control arm, which changes the pump plate angle to increase hydraulic pressure. In conjunction, the normally open ribbon two-speed switch, located on the shift lever assembly, is closed to energize the two-speed valve that allows increased fluid volume.

When isolating high-speed system failures, ensure the pump control arm is in the correct position. If it is not in the correct position, a cable adjustment will normally correct the problem. Check the cable for smooth operation as well and make corrections as needed. If the control arm is in the right position, check pump output pressure. Adjust pressure as outlined in the technical order or repair the pump as needed.

Ribbon two-speed switch

Examine the ribbon two-speed switch for proper operation. The switch should close only when the shift lever is placed in the high-speed position. Make adjustments as necessary by moving the switch to the desired location and securing it to the shift housing. A voltage check should show voltage on both sides of the switch when engaged. If voltage is not reflected on either side, use the schematic to trace and repair the open circuit. If voltage is present on one side only, replace the switch. If the voltage check shows voltage on both sides of the switch, perform the same check on the ribbon two-speed valve solenoid. Repair or replace components as necessary.

Troubleshooting rotary blower system malfunctions

Although the impeller and auger work simultaneously and are both powered by the blower engine, they are operated by different means. While the auger is controlled by hydraulic pressure from the blower pump, the impeller is driven by a drive shaft through the drop box.

Figure 3–22 represents the torque derived from the engine ending at the impeller drive shaft. The drive shaft has shear bolts, placed at the safety flange, as a safety feature.

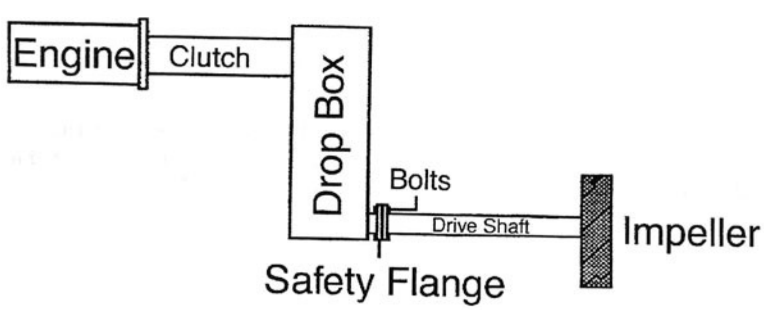


Figure 3–22. Impeller drive system.

The shear bolts are designed to separate the impeller from the drop box in the event that the impeller should seize during operation. If the impeller fails to turn or turns slowly at full blower engine speed, check to see if the shear bolts have separated.

Before replacing the bolts, find the problem that caused them to break in the first place. The logical place to start would be at the impeller blades, since debris can become trapped inside the impeller housing, stopping or impeding impeller rotation. Take time to closely inspect the impeller area for damage that may have occurred as a result. Perform repairs or replacements as needed.

Test for slippage

After inspecting the drive shaft and impeller area, if the impeller still fails to rotate properly, refer to the appropriate technical order and test the drop-box clutch for slippage. Make adjustments or repairs as necessary.

Check drop box for leaks

Inspect the drop box for leaks and external damage. Perform an operational check, listening for any unusual noises caused by worn or damaged gears or bearings.

Inspect for damage

If the discharge of snow from the blower system is slow, and you have determined the impeller to be in proper operating order and free of obstructions, inspect the impeller housing liner insulation for wear or damage. Replacing the lining is no small task; so make sure your diagnosis is correct.

Troubleshooting impeller malfunctions

When troubleshooting a vibration problem in the blower system, the two most common problems are damaged or missing impeller blades or a bent auger shaft and/or ribbons.

Inspect the areas thoroughly and look for any foreign matter that might be lodged in or around the impeller or auger. If the blades and surrounding area are in good shape, check the impeller drive shaft and universal joints for damage or wear.

If no defects are discovered, inspect the blower engine and drop box for malfunctions.

Caster wheels are often the cause of the blower unit not removing snow to the proper depth. In most cases, the wheel settings are incorrect and require adjusting. Always perform a thorough inspection of the casters and wheels and correct any discrepancies before starting the adjustments.

Troubleshooting blower engine malfunctions

Troubleshooting engine-starting malfunctions were covered in earlier CDCs; however, there are some problems unique to the snow blower that we will discuss.

Two simple, but important, steps must be taken before the blower engine can start:

1. The impeller drive shaft support must be in the horizontal or “stored” position.
2. The drop-box shift lever must be in the disengaged position.

Both systems have safety switches that are designed into the blower engine starter motor electrical circuit. In the event that the drive shaft support arm or drop-box shift lever is in the wrong position, the starter motor is disabled.

Circuit breaker

When both systems are in their correct positions and the starter motor fails to operate, check the blower engine circuit breaker. If it is tripped, reset it and try starting the engine again. If the circuit breaker is not tripped, check for voltage through the impeller drive shaft support and drop-box shift lever safety switches; notice their proper positioning for engine start as mentioned in the previous paragraph.

Power

With the blower engine ignition switch in the RUN position, use a multimeter or a 12-volt test light to check for voltage at the drop-box clutch neutral start switch. If voltage is not available, use the schematic to trace and repair the open circuit. If voltage is present on the inlet side of the switch, but not available at the outlet side, replace the switch. If voltage is flowing through the switch, perform the same tests on the impeller drive shaft support switch, also called the blower prop shaft interlock switch.

A common problem associated with the impeller drive shaft support safety switch is ice forming between the magnet on the shaft and the sensor on the vehicle cross member. Due to its location behind the impeller housing and just forward of the front axle, it is vulnerable to road slush and ice buildup. When enough buildup occurs, the magnetic signal is lost, leaving the sensor to “think” the shaft is in the upright position, preventing starter motor operation. The solution is to safely deice the components without damaging the components.

Drop-box clutch inspection and adjustment

Refer to figure 3–23 and use the following procedures to inspect and adjust the drop-box clutch.

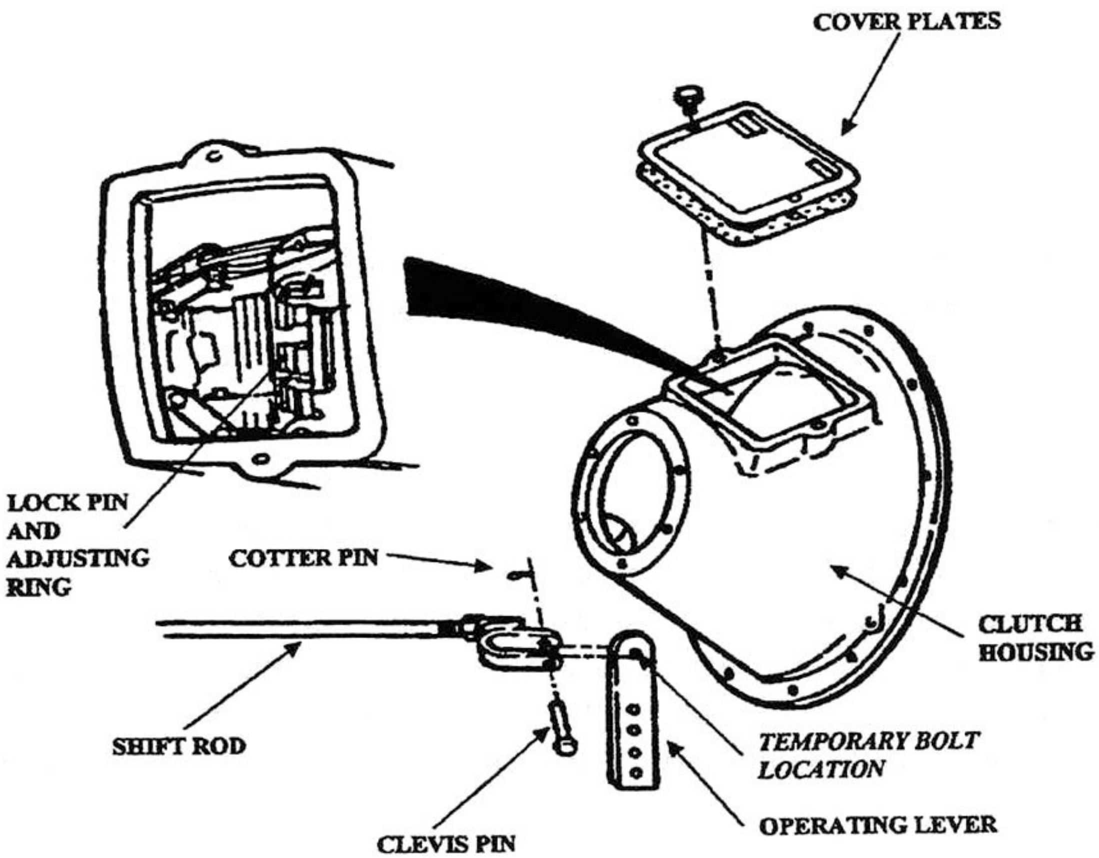


Figure 3–23. Blower clutch assembly.

When the drop-box clutch no longer pulls the load or overheats, check the torque required to apply the clutch.

1. Remove blower engine access covers.
2. Disconnect the shift rod from the operating lever by removing the cotter pin and clevis pin.
3. Install a temporary bolt and nut in the top hole of the operating lever.

4. Place a torque wrench (capable of 100 ft. lbs.) on the temporary bolt, in line with the operating lever. Use the torque wrench to shift the clutch to the engaged position. The correct torque needed to apply the clutch is 100 ft. lbs.

If the torque reading is too high or low, adjust the clutch using the following procedures.

1. Remove screws and clutch housing cover plates.
2. Rotate the clutch until the lock pin is in line with the clutch-housing opening. Do not overtighten the clutch; damage could occur.
3. Depress the lock pin and turn the adjusting ring clockwise to tighten the clutch and counterclockwise to loosen it.
4. Recheck the amount of torque required to engage the clutch. Continue to turn the adjusting ring until 100 ft. lbs. of torque is reached.
5. After correct engagement pressure is reached, rotate the adjusting ring one additional notch beyond the lock pin. Make sure the lock pin engages the adjusting ring.
6. Install the cover plates and screws.
7. Remove the torque wrench and temporary bolt and nut.
8. Align the shift rod on the operating lever and reinstall the clevis pin, securing it with a new cotter pin.

Blower-head adjustment

The blower head (fig. 3–24) is designed to leave a minimum of ½ inch of snow on the pavement during snow removal operations.

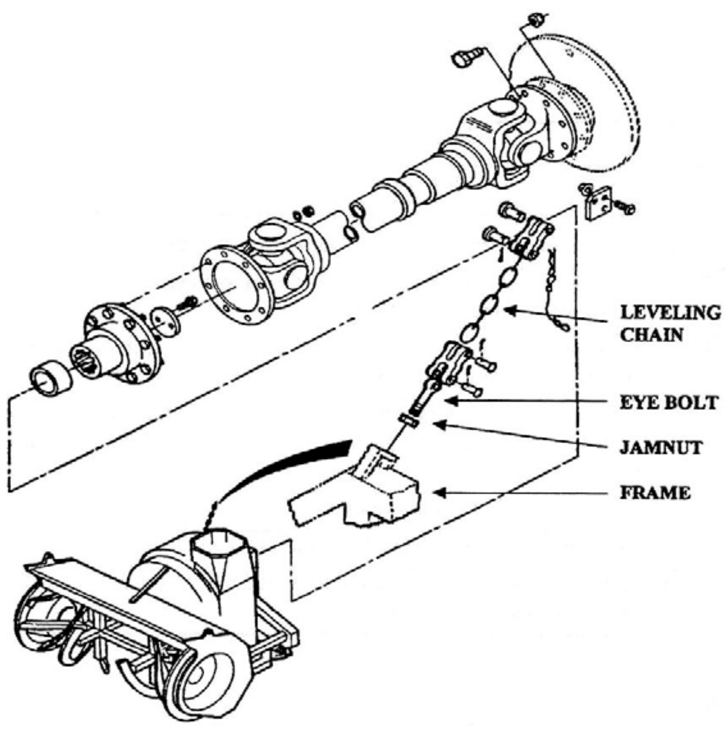


Figure 3–24. Blower head and drive shaft.

The blower-head adjustment procedure is as follows:

1. With the blower head attached to the vehicle, make sure that the blower is in the down position and sitting on a level surface.
2. Make sure the leveling chains are attached to the check plates.

3. Loosen the jam nuts and adjust the eyebolts until the threads are flush with the bottom nut.
4. Raise the blower head to its highest position.
5. Using a suitable lifting device, level the blower head and block it into position.
6. Adjust the eyebolts until the leveling chains are tight.
7. Tighten the jam nuts.
8. Lower and raise the blower head to verify the chain adjustment. If necessary, repeat previous steps until the adjustment is correct.

NOTE: Always refer to the applicable technical order when adjusting the blower-head assembly.

Caster wheel swivel dampener adjustment

When inspecting the caster wheel swivel dampener (fig. 3–25), raise the blower head and check the dampener adjustment by rotating the wheel two revolutions. The wheel should rotate by hand, but it should not spin freely when let go. The adjustment procedures for each caster wheel are identical. To adjust the caster wheels, use the following procedures:

1. Loosen the jam nut.
2. While rotating the swivel, adjust the screw until proper resistance is felt.
3. Tighten the jam nut.
4. Lower the blower head.

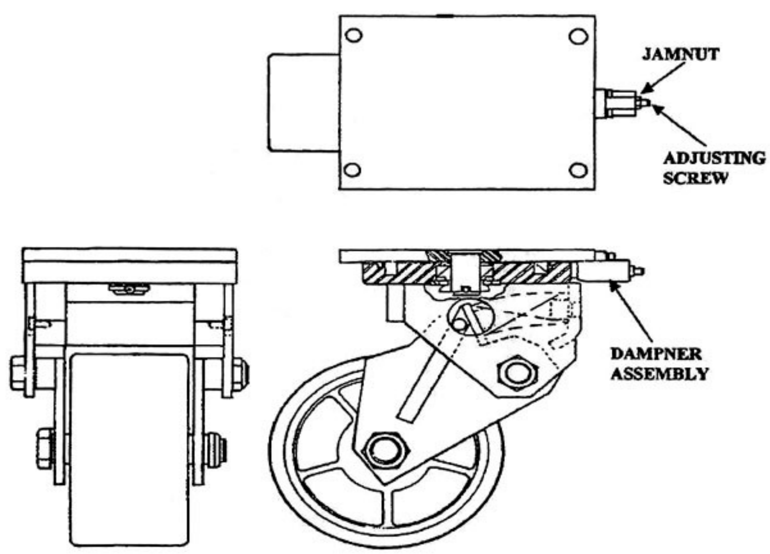


Figure 3–25. Caster wheel dampener.

Caster wheel height adjustment

Adjust the caster wheel height to the proper specifications in the technical order (fig. 3–26). The caster wheel height adjustment procedure is as follows:

1. Raise the blower head and loosen the jam nut.
2. Turn the adjustment screw clockwise to increase the scraper blade clearance or counterclockwise to decrease clearance.
3. Tighten the jam nut.
4. Lower the blower head and recheck the scraper blade clearance. Repeat if necessary.

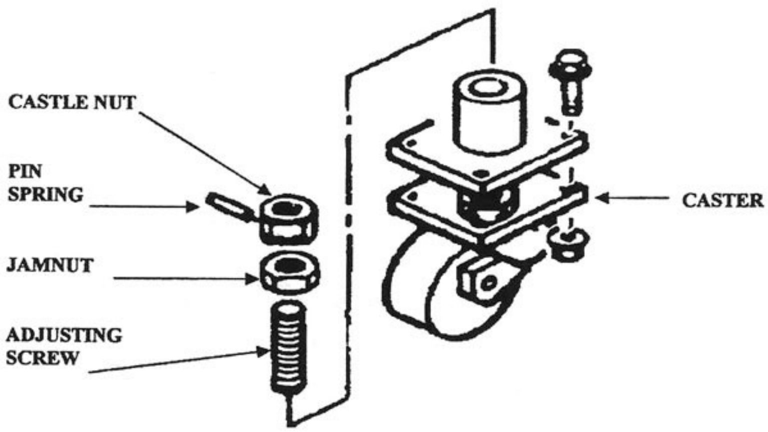


Figure 3–26. Caster wheel height.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

019. Snow blower fundamentals

1. Describe the characteristics of the snow blower cab.

2. What types of engines does the snow blower incorporate, and what are their uses?

3. Why are two alternators used in the electrical system?

4. How is the electrical circuit protected?

5. What are the major components of the snow blower system?

6. How many hydraulic systems does the snow blower have, and what are their uses?

7. What type of brake system does the snow blower use?

8. What is the purpose of the crossover hose that connects the two snow blower fuel tanks?

9. What optional equipment is used on the multipurpose vehicle?

020. Snow blower maintenance

1. Which component would be a good place to start when troubleshooting the blower/plow hydraulic positioning system?

2. What quick field test can be performed on the directional control valve assembly solenoids?

3. What components should be checked if the optional plow fails to operate?

4. What would be the likely cause if the optional chute does not rotate?

5. What checks should be taken when inspecting the snow blower hydraulic system’s two-speed control cable?

6. What safety device is incorporated into the snow blower system to ensure the auger can only be operated in conjunction with the impeller?

7. What happens when one of the snow blower auger motors fail to operate?

8. What two actions must happen before the snow blower auger high-speed system can operate?

9. What are the two methods used to operate the snow blower impeller and auger systems?

10. What safety feature is incorporated into the snow blower impeller drive shaft?

11. When troubleshooting a vibration problem in the snow blower system, what are the two most common problems?

12. What is a common problem associated with the snow blower not removing snow down to the proper depth?

13. What are the two simple steps that must be taken before the snow blower engine can start?

14. What common problem occurs when ice is built up between the snow blower magnet and sensor of the impeller drive shaft support safety switch?

15. How is the snow blower head adjustment accomplished?

16. How does the caster wheel swivel rotate when properly adjusted?

17. What action is taken if the snow plow caster wheel spins freely?

3–3. Windrow Sweeper

The Windrow sweeper, also known as a Sweepster, has the ability to remove up to 5 in. of unpacked snow at speeds of 15 mph and can also sweep light sand and gravel at speeds of 20–30 mph. It is composed of a front-mounted, hydraulically driven broom, and a carrier-mounted power unit. The Sweepster also has a hydraulically driven hurricane-force air blower mounted to the rear of the vehicle.

021. Windrow sweeper fundamentals

The sweeper is truck mounted but can be removed if needed (fig. 3–27). In this lesson, we will discuss the functions and components of the Windrow sweeper.

Figure 3–27. Windrow sweeper mounted on truck.

Control panel

The main control panel (fig. 3–28) is positioned on a stand that is mounted to the floor of the truck cab. It is angled toward the operator for ease of control during use.

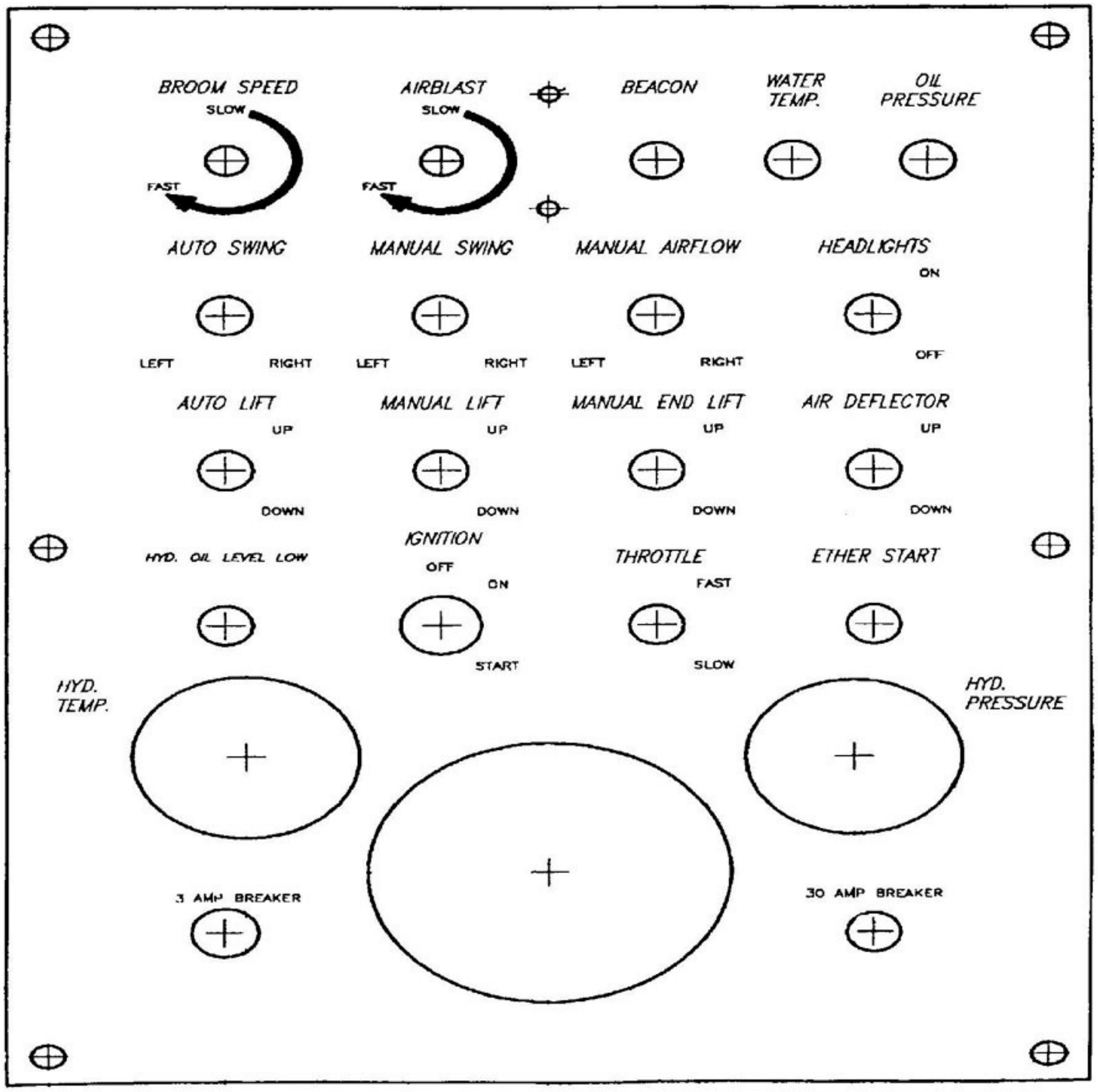


Figure 3–28. Main control panel.

Broom speed dial

The broom speed dial operates the broom from 0–500 rpm. There are three ranges for heavy, normal, and light sweeping. Remember that you only want to run the broom fast enough to do the task, thereby maximizing bristle life. ***Always*** keep the broom speed at zero when starting the unit or the broom will start rotating upon engine start.

Air-blast speed dial

This switch controls the air-blast speed. Air blast is designed to be operated with the auxiliary engine at full throttle. Make sure this switch is OFF when starting the engine and when shutting it down.

30-amp breaker

The 30-amp breaker is wired into all controls on this panel, except the broom and air speed dials. It is a safety device designed to protect the controls from excessive current draw. If this breaker trips, current flow to the controls is cut off. It is reset by pushing it back into its socket. If this problem occurs frequently, troubleshoot the system to determine the problem. We will discuss troubleshooting procedures further in this lesson.

3-amp breaker

The 3-amp breaker is wired into the broom and air speed dials, as well as the blower and broom amplifier cards. Like the 30-amp circuit breaker, if this breaker trips, current flow to the controls is cut off. It is reset by pushing it back into its socket.

Auto swing switch

This three-position switch swings the broom and blower at the same time. The center position allows the operator to stop the broom from swinging if desired. This switch must be in the centered position when starting the auxiliary engine. If not, the broom may swing immediately and cause damage to other equipment or injure personnel. When operating the swing or airflow manually, this switch must be in the center position.

Manual swing switch

This switch allows the broom to swing independently of the air-blast system. In order to use the manual switch, the auto swing switch must be in the center position.

Manual airflow switch

This switch allows the operator to change the direction of the air-blast system without changing the broom angle. In order to use this switch the auto swing switch must be in the center position.

Auto lift switch

This is a three-position switch that lifts the broom and air-blast system at the same time. It must be in the center position when starting the auxiliary engine so the broom does not rise. It must also be in the center position if the manual lift or manual end lift is being used.

Manual lift switch

This is a three-position switch that raises and lowers the broom independent of the air-blast system. Make sure the auto lift switch is in the center position when using this switch.

Manual end lift switch

This is a three-position switch that raises and lowers the air blast without raising the broom. Make sure the auto lift switch is in the center position when using this switch.

Air deflector switch

This up and down switch is self-centering. For best results, run the deflector in the highest position. If excessive amounts of snow and debris are carrying over the broom, adjust the deflector to minimize the carryover.

Oil-level light

This light indicates when the level of the hydraulic oil is low. Occasionally during operation, the light will flicker when turning the vehicle sharply. This is due to fluid moving in the tank and is normal. This light does not show how much fluid is in the tank; you must visually check the reservoir. Do not operate the auxiliary engine with this light continuously on or severe damage to the system may result.

Throttle switch

This is a three-position switch with a neutral center position. When starting the auxiliary engine, this switch must be in the slow position so the engine does not go to full throttle upon startup. Place the switch to the desired throttle position after the auxiliary engine starts.

Ether start button

Use ether only during cold weather starting. This feature can only be used when the ignition switch is in the START position.

Broom

This lesson discusses the broom brush head's broom, casters, stripper bar, and air deflectors. The broom (fig. 3–29) is 16 ft. wide and composed of wire, polyurethane, or a half-and-half mixture of both. A sweep pattern between 2 and 4 in. must be maintained for proper sweeping.

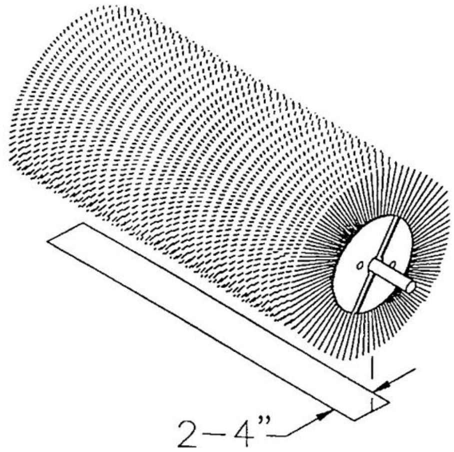


Figure 3–29. Broom brush head.

Caster wheels

The purpose of the caster wheels (fig. 3–30) is to support the weight of the Sweepster broom. Each caster wheel assembly is equipped with a caster brake.

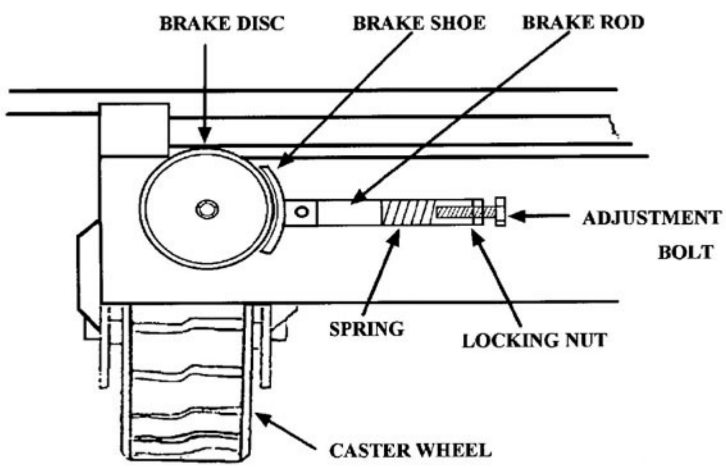


Figure 3–30. Caster wheel and caster brake.

Caster brake

The caster brake (fig. 3–30) is designed to stop caster shimmy. This is accomplished by allowing the brake to tighten against the wide side of the offset on the brake disk when the unit is moving forward. As the unit turns or backs up, the caster brake turns with the spindle. This brings the narrow side of the caster brake offset against the brake pad, which decreases the brake pressure and allows the castor to pivot freely.

Stripper bar

The stripper bar (fig. 3–31) is located on the inside front edge of the brush hood. It is designed to strip debris from the brush head bristles, thus preventing the debris from dropping off behind the brush head. It also prevents the buildup of snow and ice under the hood. Adjust the hood so the stripper bar is ¼ to $^{3}/_{8}$ inches from the bristles.

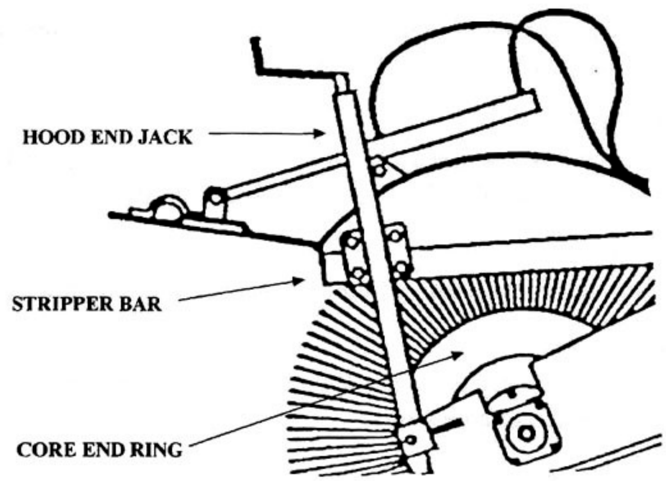


Figure 3–31. Stripper bar.

Air deflector

With the variable brush speed and air deflector, you can prevent the debris from reaching the vehicle, even when sweeping into the wind (fig. 3–32). Slowing the brush prevents debris from being thrown into the air. For sweeping sand and gravel, position the air deflector to the lowered position. For sweeping light snow, position it between the lowered and middle position. For heavy snow and slush, position the air deflector to the raised position.

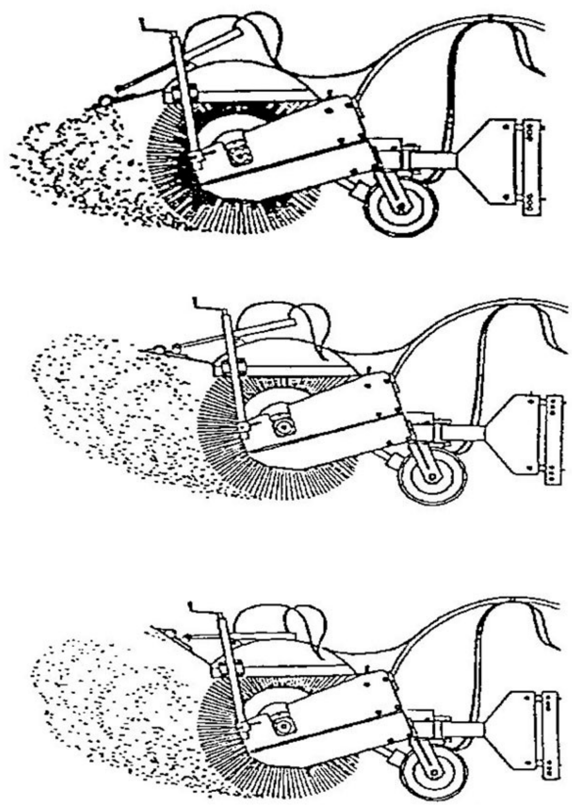


Figure 3–32. Air deflector positions.

Hydraulic system

The hydraulic system's reservoir, pumps, filtration, hydraulic lines, manifold, and motor and air-blast system are the next items we will discuss.

Reservoir

The hydraulic reservoir has a 15-gallon capacity. The fluid level is checked with the use of a sight gauge.

Pumps

There are three hydraulic pumps: brush, air-blast, and compensator. Before adjusting any pump, you must consult the proper technical order for specifications and procedures. All pumps are driven by the auxiliary engine through the pump drive.

Brush pump

The brush pump is set at 5,400 psi (preset at the factory) and only needs to be adjusted after a new one is installed.

Air-blast pump

The air-blast pump is set at 4,500 psi but should never reach this pressure due to it being attached to the blower.

Compensator pump

The compensator pump is set at 2,000 psi and is used for the hydraulic controls.

Filtration

Hydraulic system filtration is accomplished by a filter located on the tank. Change this filter after every 250 hours of operation under normal conditions and every 150 hours under dusty conditions.

Hydraulic lines

The hydraulic system uses both rigid and flexible lines. The flexible lines are used to connect dynamic components to static ones. When connecting quick disconnects, be sure to clean them to prevent contamination of the hydraulic system. When replacing hydraulic lines, ensure they meet proper specifications.

Hydraulic manifold

The hydraulic manifold is located in the auxiliary engine compartment. It contains delta selector valves and delta poppet valves to actuate the hydraulic function that has been selected. When you select a valve, you are opening the return passage and the poppet across from that valve, which is the pressure side.

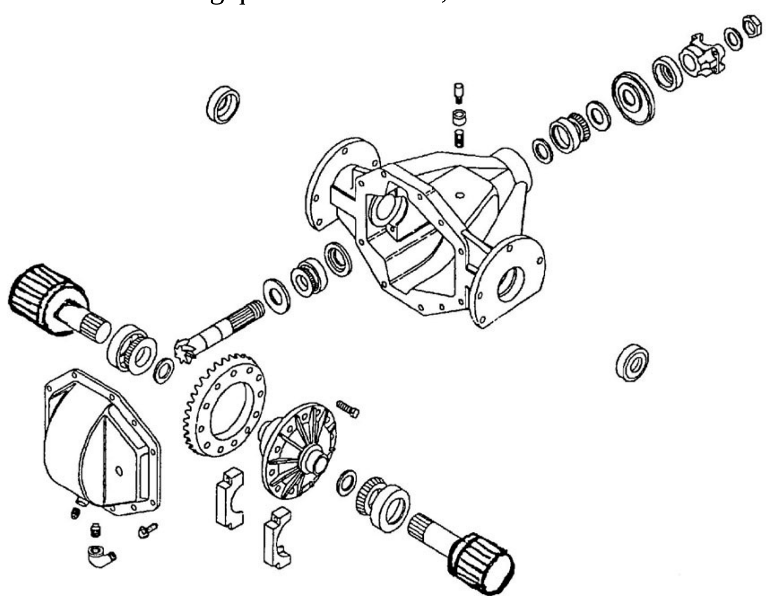


Figure 3–33. Broom differential.

Hydraulic motors

There are two hydraulic motors: broom and air blast. The broom motor drives the differential (fig. 3–33) that turns the broom segments. It uses chain couplers (not shown) to connect the differential to the broom segments. The air-blast motor turns the blower turbine. The motor output shaft is splined to the turbine.

Air-blast system

The air-blast system is a hydraulically driven turbine capable of producing air speeds of 375 mph. Air can be directed as needed using the switches on the control panel.

Auxiliary engine

This diesel engine is operated from the control panel located in the cab and a control panel located on the rear engine cowling (fig. 3–34). Check all fluid levels before operating the unit. The unit is equipped with an engine shutdown module to protect the engine if a loss of oil pressure or overheat condition occurs.

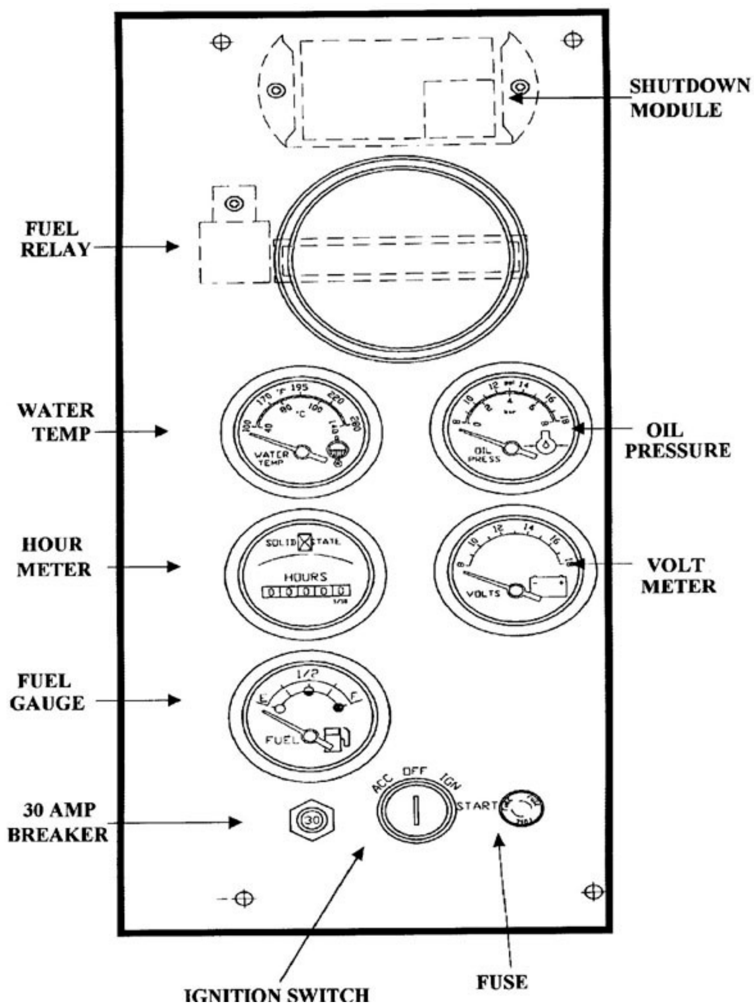


Figure 3–34. Rear engine control panel.

Electrical system

The next system we will discuss is the electrical system, which includes the amplifier cards, proportional coil, and shutdown module. These components are listed and described in the table below.

Sweepster Electrical System	
Component	**Description**
Amplifier cards	They “amplify” the signal from the speed dial and send it to the proportional coil. There are two amplifier cards, one for the broom and one for the air blast. They are used to set maximum hydraulic output flow. They are also used to set the time that it takes for the pump to reach maximum output.

Sweepster Electrical System	
Component	**Description**
Proportional coil	The proportional coil actuates the swash plate. As the swash-plate angle changes, the pump's displacement changes. By varying the displacement, variable broom and air-blast speeds are achieved. It has an override button for easy troubleshooting of the system. All hydraulic functions are electric over hydraulic with no means of manual override, except for the proportional coil.
Engine shutdown module	This is a safety device for the engine. It allows the engine to start and run for 30 seconds without oil pressure. It also shuts down the engine when oil pressure is below 5–10 psi or coolant temperature is above 185–195°F.

022. Windrow sweeper maintenance

Most malfunctions are easily found by following the vehicle system troubleshooting guide in the technical order. The most common problems found on the Windrow sweeper are electrical or hydraulic since all components are either hydraulically powered or electronically controlled. The following information will assist you in troubleshooting and correcting malfunctions that may occur during normal sweeper operation.

Inspection

Inspect the Sweepster using the following steps:

1. Inspect the complete unit for visible damage.
2. Inspect the brush frame for bent or broken parts or cracked welds.
3. Check all mounting hardware, such as nuts, bolts, and clamps. Tighten if required.
4. Inspect all hydraulic hoses for damage. Repair or replace as necessary.
5. Check all hydraulic fittings. Replace damaged fittings and tighten loose ones.
6. Check hydraulic oil level in tank and examine for signs of contamination.
7. Check engine oil level (truck and sweeper engine).
8. Check battery cables, terminals, and the battery box for corrosion.
9. Check oil level in brush gearbox and pump drive gearbox on rear of engine. Oil level should be at the elbow on the front of the gearbox cover. Excess oil will bleed out of the top of the breather plug.

Isolate and repair sweeper malfunctions

When none of the sweeper functions operate, perform the following steps:

1. Check the 30-amp circuit breaker. If the breaker is popped, reset it. If there are still no sweeper functions, check for voltage at both circuit breaker terminals. If there is voltage at one terminal only, replace the circuit breaker. If the circuit breaker will not reset, check for a short in the wiring.
2. If there still are no sweeper functions, check the hydraulic tank for proper fluid level and condition. If fluid is to specifications, check pump pressure.
3. Normal pressure is between 2,000 and 2,200 psi. If pressure is not in this range, reset the pump pressure according to instructions in the manufacturer's service manual.

Nonworking functions

When some sweeper functions do not operate, complete the following:

1. Check the hydraulic cylinder fittings; sweeper fittings have O-ring seal ports. If regular pipe fittings are used, they will cover the oil inlet and outlet holes and the cylinder will not work.
2. Check the wiring harness for loose or broken wires; repair as necessary.
3. Check for voltage at the valve coil and solenoids. If there is no voltage, repair wiring. If there is voltage, replace valve or solenoid.

Throttle actuator is inoperative

When the throttle actuator does not actuate, perform the following steps:

1. Check the 30-amp circuit breaker. If it has popped, reset it and check the throttle actuator.
2. If the throttle actuator still is inoperative after resetting the circuit breaker, use a multimeter or 12-volt test light and check for voltage at both circuit breaker terminals. If there is voltage to only one terminal, replace the circuit breaker. If there is voltage at both terminals, the circuit breaker is good.
3. If the circuit breaker does not stay reset, check for a short in the wiring.
4. If the circuit breaker and wiring are good, check the throttle switch.
5. To check the throttle switch, place it in either the fast or slow position. Check for voltage at the terminal opposite the toggle position; repeat in the other position. If voltage is not present in either position, replace the switch.

Brush does not rotate

When the brush does not rotate, perform the following steps:

1. Check the 3-amp circuit breaker; if popped, reset. Recheck brush operation.
2. If the 3-amp circuit does not reset, check the wiring for a short and repair.
3. If the 3-amp circuit resets but the brush still does not rotate, check both terminals of the circuit for voltage. If there is no voltage at both terminals, replace circuit breaker.
4. If the brush still will not operate, check the 30-amp circuit breaker using the same procedure as you did with the 3-amp circuit breaker.
5. If the brush will still not rotate, check for a burned-out amplifier card by pushing in the manual override button on the proportional coil on the brush pump to actuate the pump. If the brush rotates, the chopper amplifier is burned out and must be replaced.
6. If the amplifier checks good, check the dial speed control. Turn the ignition off and set multimeter to measure ohms. Turn dial to lowest speed; touch the ground lead to the center terminal and the other lead to the right terminal (looking at the back of the dial). Turn the dial to the fastest brush speed, and then check the left terminal. If there is no ohm reading from either terminal, replace the dial.

Electrical components

Most repairs involve an electrical component, hydraulic hose, O-ring, or fitting. All electrical components must be replaced with like units. When repairing electrical wires, it is important to replace the wires with the same size wire and it is recommended to solder splices. Using different size wire and not soldering splices can change the resistance of the circuit and affect the operation of components.

Hydraulic hoses

Replacement hydraulic hoses must be the same size and have the same rating as the one being replaced. Hydraulic fittings may be from different manufacturers but must be in the same configuration.

Brush head and section replacement

The brush head has left and right core assemblies—when changing them, complete one side at a time. Mixing the core assemblies together may damage the sweeper. To replace brush sections, follow the steps in the appropriate technical order.

Adjustments

There are several adjustments that must be accomplished periodically to ensure proper performance of the sweeper and prevent damage or premature wear of components. These adjustments are listed in the following lessons.

Stabilizer hitch bar

This adjustment must be accomplished before adjusting the brush pattern:

1. Visually check to see if the prime mover hitch and quick attach hitch are lined up at the parallel links (fig. 3–35).
2. If it is not parallel, loosen lock nuts and turn stabilizer until the links are parallel and tighten lock nuts to torque specifications.

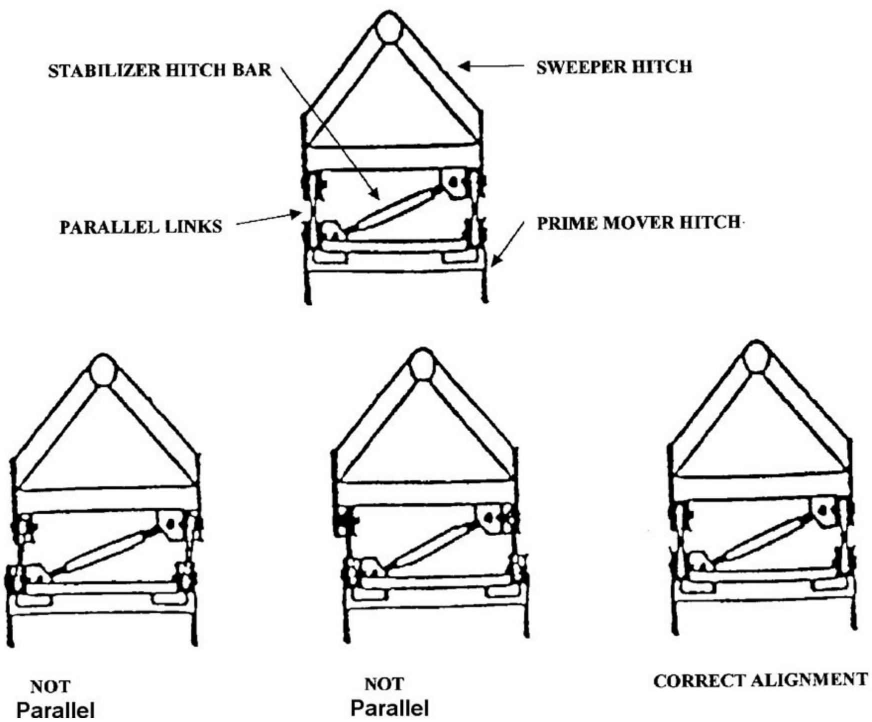


Figure 3–35. Hitch alignment.

To ensure that the stabilizer bar is adjusted correctly, angle the broom completely in one direction, ensuring the caster wheels are in the trailing position, and create a brush pattern by lowering the rotating broom to the ground. Raise the broom and angle it to the opposite direction (fig. 3–36).

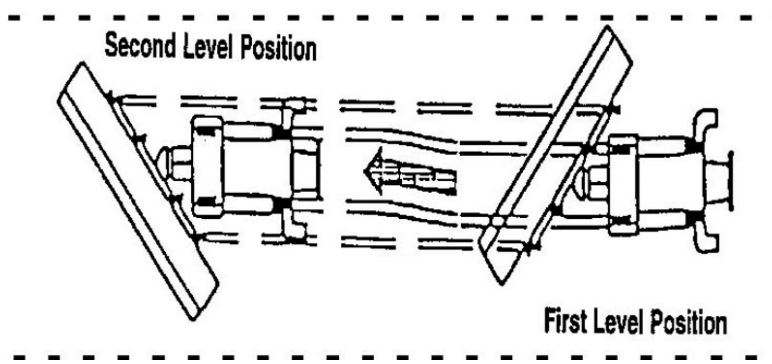


Figure 3–36. Stabilizer bar adjustment.

Reposition the truck so that the casters are in the trailing position once again and create a second brush pattern. Compare the two brush patterns and adjust the stabilizer bar as necessary. Always make sure the caster wheels are in the trailing position and not sitting in a hole or on a hump.

Brush pattern

Perform the following steps to adjust the brush pattern:

1. Fully angle brush head left or right, as shown in figure 3–36.
2. The vehicle and sweeper must be on a level surface when setting the brush pattern.
3. Lower sweeper head and operate; check brush pattern.
4. Fully angle brush head to the opposite side, move the truck, and create another brush pattern, ensuring the caster wheels are in the trailing position. Compare patterns and adjust as needed.
5. Turn the brush-head height adjustment bolt (fig. 3–37) to raise or lower the brush head. Turning the adjustment bolt clockwise will raise the brush head and decrease the brush pattern width. Turning it counterclockwise will lower the brush head and increase pattern width. When adjusting the bolt, take the weight off the brush by raising the brush head with the lift switch at the front of the prime mover.

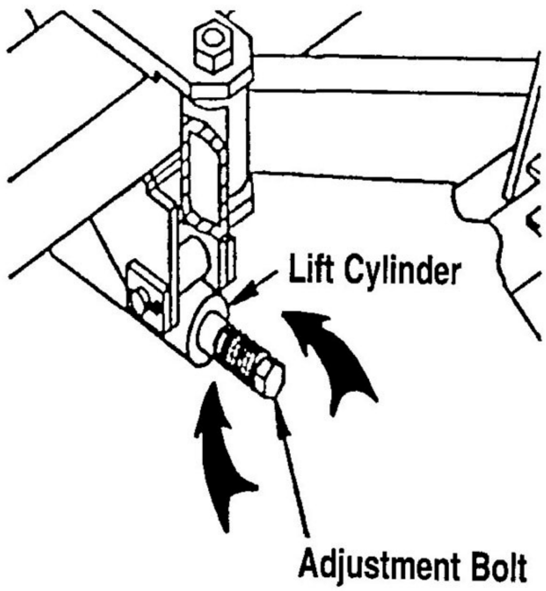
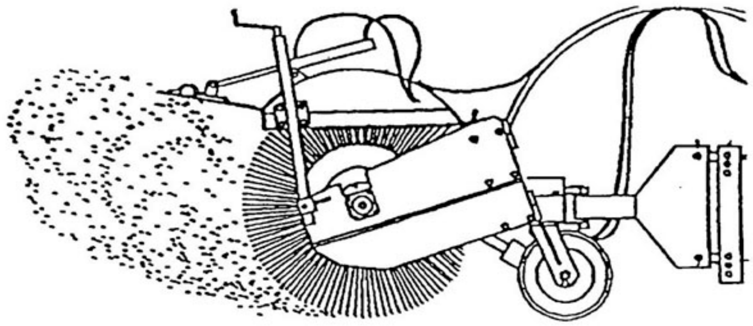


Figure 3–37. Brush-pattern adjustment.

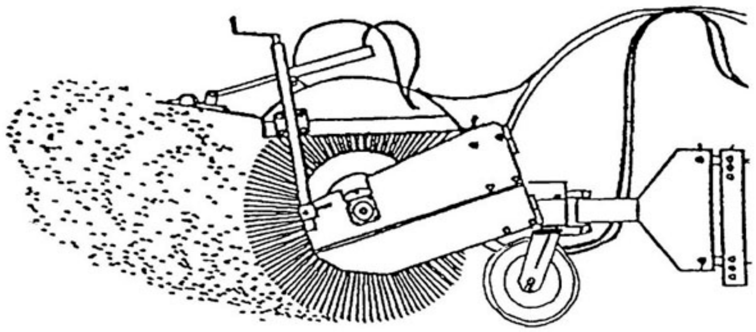
Caster brake

The caster brake must be in the same position as it would be when the vehicle is moving forward (fig. 3–38).

1. Loosen the locking nut and turn the adjusting bolt out until there is no pressure on the spring. (fig. 3–30)
2. Turn the adjustment bolt in until it contacts the spring.
3. After the bolt makes contact with the spring, turn it in (clockwise) 5½ turns and tighten the lock nut.
4. Test drive the vehicle while sweeping. If the casters shimmy, stop the unit and turn adjustment bolt one more complete turn.



CORRECT
POSITION



INCORRECT POSITION

Figure 3–38. Caster wheel positions.

Brush stripper

Perform the following steps to adjust the brush stripper:

1. Loosen the stripper bar mounting bolts (fig. 3–39).
2. Move the stripper bar up or down; check distance between bristles and bar with a ruler.
3. When stripper bar is ¼ to $^{3}/_{8}$ inch from the bristles, tighten mounting bolts to specification.

Figure 3–39. Brush stripper adjustment.

Brush-head swing-frame leveling

Perform the following steps to level the brush-head swing frame:

1. Place a level on top of one of the swing frame tubes (fig. 3–40).
2. Loosen the bolts on the quick hitch.
3. Install the brush head jack (fig. 3–41). Adjust the swing frame by raising the jack until its ¼ inch above level.
4. If there is a gap between the two frames after leveling, use flat washers as shims to fill the gap by sliding them onto the hitch mounting bolts.
5. Tighten mounting bolts to specification.
6. Verify the final adjustment is ¼ inch above level.

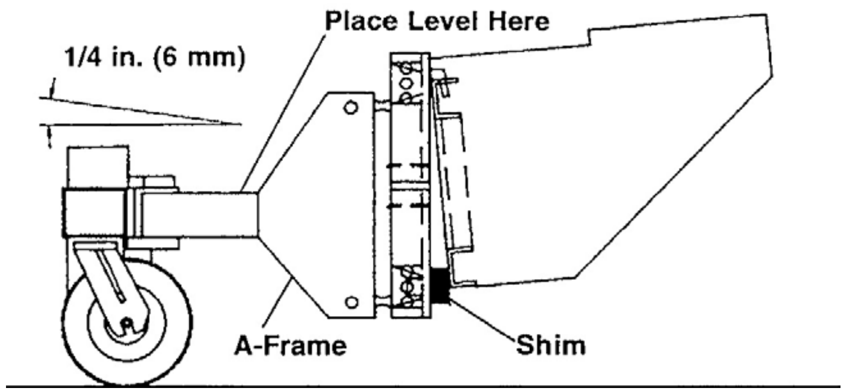


Figure 3–40. Swing-frame leveling.

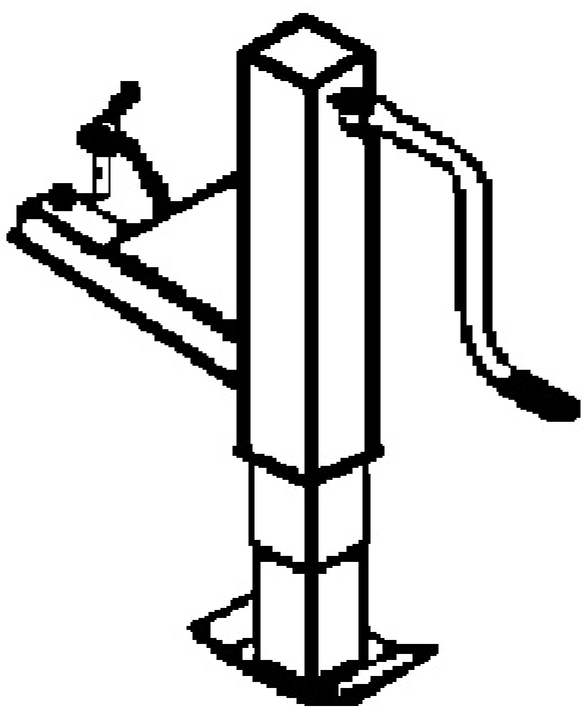


Figure 3–41. Brush-head jack.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

021. Windrow sweeper fundamentals

1. What safety device is designed to protect the Windrow sweeper controls from excessive current draw?

2. What is the 3-amp breaker wired into on the Windrow sweeper electrical system?

3. What switch allows a direction change of the Sweepster's air-blast system without changing the broom angle?

4. What button should be pressed only during cold weather starts?

5. On the sweeper broom brush head, what size sweep pattern must you maintain?

6. What is the purpose of the sweeper casters?

7. What is the purpose of the caster brake?

8. What is the purpose of the brush stripper bar?

9. How many hydraulic pumps are used on the Windrow sweeper?

10. What are the two types of valves used in the sweeper's hydraulic manifold?

11. How is power transferred from the broom hydraulic motor to the broom segments?

12. What protects the sweeper's auxiliary engine if a loss of oil pressure or overheat condition occurs?

022. Windrow sweeper maintenance

1. What are the two most common problems found on the Windrow sweeper?

2. What corrective action would you take if the sweeper hydraulic pump pressure reading is not within the 2,000–2,200 psi range?

3. How would you check the sweeper's throttle actuator if it is still inoperative after resetting the circuit breaker?

4. How do you determine the condition of the sweeper brush if it does not rotate and the amplifier is suspected to be at fault?

5. What happens when you mix (switch) the sweeper's brush-head core assemblies?

6. What adjustment must be accomplished before making a brush-pattern adjustment?

7. How do you make sure the sweeper's stabilizer is adjusted correctly?

8. What is the result of turning the sweeper's brush-head height adjustment bolt clockwise?

9. What position is the caster in when adjusting the sweeper's caster brake?

10. What instrument is used to check the distance between the sweeper's bristles and the bar when making the brush stripper adjustment?

11. What do you do if there is a gap between the sweeper's two brush-head swing frames after leveling has been accomplished?

Answers to Self-Test Questions

017

1. It uses high-velocity air and vacuum to clean streets and runways.
2. 1,800 rpm for light material at 5–10 mph; 2,000–2,200 rpm for normal material at 3–5 mph; and 2,200–2,500 rpm for heavy material at 1–3 mph.
3. It drives the blower and hydraulic pump.
4. Shuts down the auxiliary engine after 30 seconds if it overheats or loses oil pressure.
5. The blower is the heart of the air system. It produces high-pressure air and vacuum for the sweeping system.
6. Pick-up head.
7. (1) Used to adjust the height of the blast orifice off the ground.
   (2) Provides a seal on the sides of the pick-up head.
   (3) Provides a wearing surface for the pick-up head.
8. It ensures that the debris stays in the path of the pick-up head as it is being swept by the gutter brooms.
9. Remove dirt and debris from the street curbing and transfer it into the path of the pick-up head.
10. As the fluid heats up during operation, it expands and pushes out of the cap.
11. It is a vane-type pump with a built-in relief valve set at 2,500 psi and is gear-driven off the auxiliary engine.
12. It holds the gutter broom up in the stowed position.
13. Flow control valve.
14. The water system controls the amount of dust produced during sweeping operations.
15. The water pump is not working because the pump lost its prime or the tank is out of water.

018

1. The red reset button. It may get overlooked and the technician may waste time testing electrical circuits when the button has popped up and it just needs to be reset.
2. Approximately 500 hours of operation.
3. It keeps the weight of the pick-up head off the ground so it will float across the road surface.
4. To fold the curtains under the pick-up head so a proper measurement can be obtained.
5. Lower the pick-up head, set the blower engine rpm to 2,000, pull forward, and see if you can lift one side of the pick-up head.
6. Doing so can cause severe damage to these items.
7. Because it allows the operator to raise the hydraulic components clear of obstructions within the 30 seconds of a shutdown condition
8. The wiring to the solenoid lock valve or the solenoid lock valve itself may be faulty.
9. Always wear eye and ear protection.
10. Dust separator door left open or there is a hole in the hopper screen.

019

1. The cab sits at the forward edge of the frame to give the operator the best possible forward and peripheral view.
2. Two diesel two-cycle engines. The rear engine is used to drive the vehicle; the front engine drives the blower attachment.
3. One 160-amp alternator supplies voltage to batteries, starter, heated mirrors, headlights, tail lights, turn signals, spot lights, clearance lights, beacon light, cab interior, reverse alarm, instrument panel, horn, and solenoid valves. One 75-amp alternator supplies voltage to heated windshield and other functions when the cab switch is engaged and the drive engine is running.
4. Manual reset circuit breakers.
5. Augers, caster wheels, impeller housing, impeller, push frame, scraper blade, and skid plates.
6. Two separate hydraulic systems. One for the augers and one for blower assembly control.

7. Conventional-air type; when the pedal is depressed, the brake valve assembly applies air pressure to the brake chambers, forcing the brake shoes against each brake drum, therefore, stopping the vehicle.
8. To ensure the fuel level is the same in each tank.
9. Tri-axis controller, loading chute, reversible plow, multisection plow, and winterization system.

020

1. The directional control valve.
2. Interchange the solenoid being inspected with one that is functioning properly.
3. Inspect the holding valve, hydraulic cylinders, and cushion valve.
4. The hydraulic motor.
5. Check for smooth movement; replace if there are kinks or breaks in cable housing.
6. A normally open switch.
7. Auger will continue to operate, but performance will be drastically decreased.
8. Hydraulic pressure and volume must be increased.
9. The auger is operated by hydraulic pressure, while the impeller is operated by a drive shaft through the drop box.
10. Shear bolts designed to separate the drive shaft from the drop box in the event that the impeller seizes.
11. Damaged or missing impeller blades or bent auger shaft and/or ribbons.
12. Caster wheel settings are incorrect.
13. The impeller drive shaft support must be horizontal or “stored” and the drop-box shift lever must be in the disengaged position.
14. Magnetic signal is lost, preventing starter motor operation.
15. Ensure blower is in down position, sitting on a level surface. Ensure leveling chains are attached to check plates. Loosen jam nuts and adjust eyebolts until threads are flush with bottom nut. Raise blower head to highest position. Level blower head and block it into position. Adjust eyebolts until leveling chains are tight. Tighten jam nuts. Lower and raise blower head to verify chain adjustment. If necessary, repeat steps until the adjustment is correct.
16. Rotate by hand, but will not spin freely.
17. Raise blower head, loosen jam nut, adjust screw for proper scraper blade clearance, tighten jam nut, lower blower head, and recheck clearance.

021

1. 30-amp breaker.
2. Wired into the broom and air speed dials, as well as the blower and broom amplifier cards.
3. Manual airflow switch.
4. Ether start button.
5. 2–4 in.
6. To support the weight of the Sweepster broom.
7. Stop caster shimmy.
8. To strip debris from the brush-head bristles, thus preventing the debris from dropping off behind the brush head.
9. Three—brush, air-blast, and compensator.
10. Delta selector valves and delta poppet valves.
11. The broom motor drives a differential that turns the broom segments.
12. Engine shutdown module.

022

1. Electrical and hydraulic.
2. Reset pump pressure according to the instructions in the manufacturer’s service manual.
3. Use a multimeter or 12-volt test light to test for voltage at both circuit breaker terminals.

4. Push in the manual override button on the proportional coil of the brush pump to stroke the pump.
5. It may damage the sweeper when used.
6. Stabilizer hitch bar adjustment.
7. Angle the broom completely one direction and make a pattern, repeat on opposite direction ensuring the caster wheels are in the trailing position, then compare patterns.
8. Raises brush head and decreases pattern width.
9. In the same position it would be when the unit is moving forward.
10. A ruler.
11. Use flat washers as shims and slide them on to the hitch mounting bolts.

Complete the unit review exercises before going to the next unit.

56. (017) These allow for a *height* adjustment of The Young Manufacturing Company (TYMCO) sweeper's blast orifice from the ground.
    a. Skid plates.
    b. Caster wheels.
    c. Flotation springs.
    d. Hydraulics cylinders.

57. (017) This Young Manufacturing Company (TYMCO) sweeper valve *must* be opened when the pick-up head is operated.
    a. Bypass.
    b. Cartridge.
    c. Flow control.
    d. Solenoid lock.

58. (017) This Young Manufacturing Company (TYMCO) sweeper's system is used to control the amount of dust generated during sweeping operations.
    a. Water.
    b. Dust control.
    c. Broom cover.
    d. Pick-up head suction.

59. (017) Which type filter in The Young Manufacturing Company (TYMCO) sweeper's water system protects the water pump by removing the *fine* contamination?
    a. Nozzle screen.
    b. In-line strainer.
    c. Thread-on element.
    d. Foot valve/strainer.

60. (018) What does a flashing red indicator light in The Young Manufacturing Company (TYMCO) sweeper cab indicate to the driver?
    a. Empty water tank.
    b. Low hydraulic fluid.
    c. Broom rotation is slower than specification.
    d. Auxiliary engine is shutting down in 30 seconds.

61. (018) During a Young Manufacturing Company (TYMCO) sweeper pick-up head adjustment, the skid plates bottom edges are adjusted so they are lower than the pick-up head bottom edges by this measurement (inch/inches).
    a. 5/8.
    b. 1 1/2.
    c. 2.
    d. 4 1/8.

62. (018) Which measurement, in inches, is The Young Manufacturing Company (TYMCO) sweeper's blast orifice adjusted above the road surface?
    a. 1 1/2.
    b. 2.
    c. 2 1/2.
    d. 3.

63. (018) When making a Young Manufacturing Company (TYMCO) sweeper pick-up head adjustment, the vehicle should be driven forward approximately four feet to ensure the
    a. curtains are folded underneath the pick-up head.
    b. gutter brooms are timed correctly.
    c. water system will spray correctly.
    d. switch will not engage.

64. (019) This type of hydraulic cylinder is used to raise and lower the snow blower housing.
    a. Double-acting.
    b. Single-acting.
    c. Dual vane.
    d. Piston.

65. (019) Which type of hydraulic pump is used to operate the snow blower auger hydraulic system?
    a. Centrifugal.
    b. Gear driven.
    c. Vane driven.
    d. Rotary piston.

66. (019) What is the purpose of the snow blower's air system air dryer?
    a. Absorbs moisture and prevents air surges.
    b. Boosts pressure and dries the supply air to the reservoirs.
    c. Collect and remove moisture and contaminants from the air system.
    d. Removes contaminants from the air system and indicates the moisture content.

67. (020) When the snow blower's blower unit does not remove snow to the proper depth, the probable cause is the
    a. auger bearings are worn out.
    b. drop box needs to be lowered.
    c. impeller blades are worn down.
    d. the caster wheels are out of adjustment.

68. (020) This is the *first* step in the snow blower head adjustment procedure.
    a. Loosen the jam nuts.
    b. Raise the blower head to its highest position.
    c. Place blower head in the down position on a level surface.
    d. Make sure the leveling chains are attached to the check plates.

69. (020) When performing a snow blower caster wheel swivel dampener adjustment, the swivel should
    a. remain snug when rotated by hand.
    b. rotate freely when rotated with a wrench.
    c. remain snug when rotated with a wrench.
    d. rotate freely by hand, but not spin when let go.

70. (021) This size sweep pattern, in inches, must be maintained on the Sweepster broom head.
    a. 1 to 2.
    b. 2 to 4.
    c. 3 to 5.
    d. 4 to 6.

71. (021) What purpose do the Sweepster's caster wheels serve?
    a. Maintain the proper sweep angle.
    b. Maintain the proper sweep pattern.
    c. Support the weight of the stabilizer bar.
    d. Support the weight of the Sweepster broom.

72. (021) The Sweepster's caster brake is designed to
    a. stop caster swivel.
    b. stop caster shimmy.
    c. decrease the broom rotation if its set speed is exceeded.
    d. decrease the Sweepster's speed if it exceeds the set speed for the road conditions.

73. (021) This Sweepster component is designed to remove debris from the brush head bristles.
    a. Stripper bar.
    b. Bristles power brush.
    c. Brush head debris scrubber.
    d. Brush head high-pressure sprayer.

74. (021) Which two hydraulic motors are used in the Sweepster's hydraulic system?
    a. Broom and casters.
    b. Broom and air blast.
    c. Turbine and casters.
    d. Air blast and turbine.

75. (022) If the Sweepster throttle actuator is inoperative and the circuit breaker is set, the next step in troubleshooting is to
    a. check the throttle switch.
    b. replace the circuit breaker.
    c. check for a short in the wiring.
    d. check both terminals of the circuit breaker for power.

76. (022) Which is the next troubleshooting step if the Sweepster brush does *not* rotate and the chopper amplifier is suspected to be at fault?
    a. Inspect the differential.
    b. Replace the 30 ampere circuit breaker.
    c. Push the manual override button to actuate the pump.
    d. Replace the chopper amplifier since it cannot be checked.

77. (022) When adjusting the Sweepster's brush pattern, turn the brush head height adjustment bolt
    a. clockwise to increase pattern and counter clockwise to decrease.
    b. clockwise to decrease pattern and counter clockwise to increase.
    c. to the desired height indicated on the height adjustment marker.
    d. to the desired snow depth indicated on the snow depth indicator.

78. (022) If there is a gap between the two Sweepster's brush head swing frames *after* leveling has been accomplished,
    a. readjust the frames until the gap is no longer present.
    b. no action is required since some gap is to be expected.
    c. use flat washers as shims and slide them onto the hitch mounting bolts.
    d. use rubber or polyurethane split washers as shims and slide them onto the frame adjustment bolts.

Unit 4. Military Series Vehicles

MILITARY-SERIES (M-SERIES) vehicles are designed for tactical use. Each vehicle is unique and designed for a specific use, thereby enhancing the military's capability to support combat operations. However, M-series vehicles do share some of the same subsystems. In the following lessons, we will discuss these common subsystems for different vehicle types. For example, we will discuss the three-lever headlight switch under the high-mobility multipurpose-wheeled vehicle (HMMWV) section. This system is shared by the M35 and the M939 but is not found on some models of mine-resistant ambush-protected (MRAP) vehicles.

Presenting the material in this manner will provide fundamental information on M-series vehicles while preventing redundancy of information. The information covered in this unit is presented in two categories: light- and medium-duty M-series and the MRAP vehicles. In some cases, technicians may not have a chance to work on these types of vehicles while stationed at stateside bases. However, rest assured that when you are stationed overseas or deployed in support of military operations you will need to have this basic knowledge to ensure these vehicles are ready to support the mission.

4–1. Light-Duty and Medium M-Series

Light-duty M-series vehicles include the many variants of the HMMWV. Medium-duty includes the 2½- and 5-ton M-series vehicles. In the following lessons, we will discuss the purpose of each type and some of the vehicle-specific systems. Remember that for the most part, M-series vehicles use some off-the-shelf components and systems incorporated into a military-specific vehicle. We will discuss subsystems in detail.

023. High-mobility multipurpose-wheeled vehicle

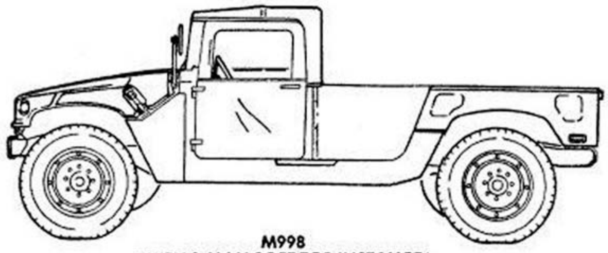
The 1¼ ton, 4x4, M998-series, HMMWV is a tactical vehicle designed for use over all types of roads, as well as cross-country terrain in all weather conditions. These vehicles have four driving wheels powered by a V–8, liquid-cooled, diesel engine.

Four-wheel hydraulic service brakes and a mechanical parking brake are common to all models in the M998 series. Vehicle tie down and lifting eyes provide for air, rail, or sea shipment. Each model has a unique purpose and capability. It also shares some of the same components as other M-series vehicles such as: 12/24 dual-voltage electrical systems and the standardized NATO electrical jump system and the pintle-hook towing assembly.

This lesson provides examples of different models and covers HMMWV fundamentals. Keep in mind we are using Army classifications. After all, this vehicle was initially designed and produced for the US Army.

M998 and Ml038

Shown in figure 4–1, these models are used to transport cargo and troops. The M998 chassis and power train is the base platform for all other HMMWV variants. Some of your variants are just major models with winches added. For example, the M1038 model is a 998 that has a winch used for recovery operations. Both models can also use a troop seat kit for troop transport operations.



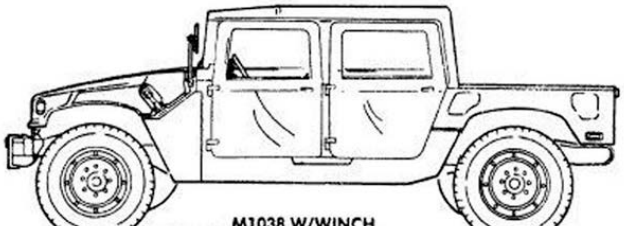
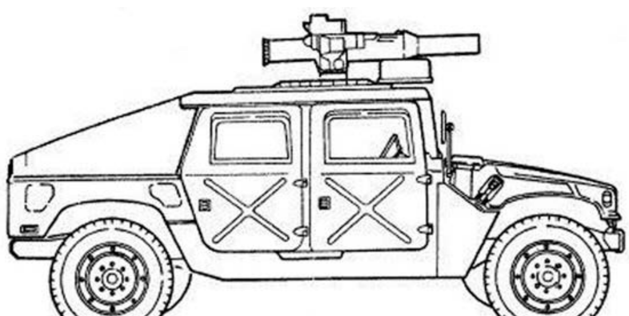


Figure 4–1. M998/M1038 model HMMWV.

M966 and Ml036

Shown in figure 4–2, these models transport, mount, and provide a platform for operating the tube-launched, optically tracked, wire-guided (TOW) missile launcher system. The M966 and M1036 have armor for protection of crew, TOW system components, and ammunition. The M1036 model has a winch used for recovery operations.



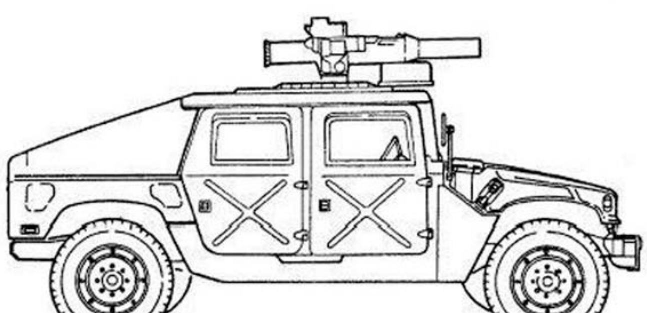


Figure 4–2. M966/ M1036 model HMMWV.

M1116

Another variant you need to be aware of is the up-armored HMMWV. The Air Force model is the M1116. It is built on the heavy chassis and utilizes a turbocharged 6.5-liter engine. The significant difference in this model is the armored body. The factory model has an armored cab and undercarriage. There have been several kits added to supplement or improve the armor over the past few years.

Mechanical system

The mechanical system converts hp, derived from the engine, into a mechanical force called torque that drives the transmission. This torque through the transmission is used to move the vehicle. The mechanical parts that make this happen are referred to as the drive train. Reference figure 4–3 as we cover major components of the mechanical system. The following information is referenced from the M998A2 model.

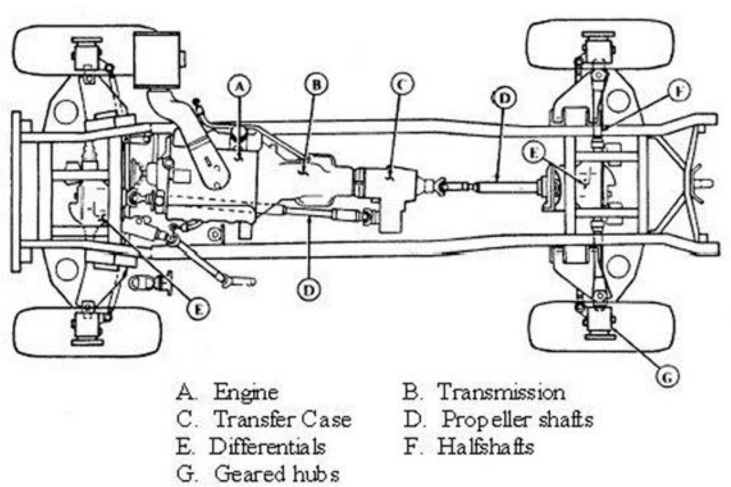


Figure 4–3. HMMWV mechanical system.

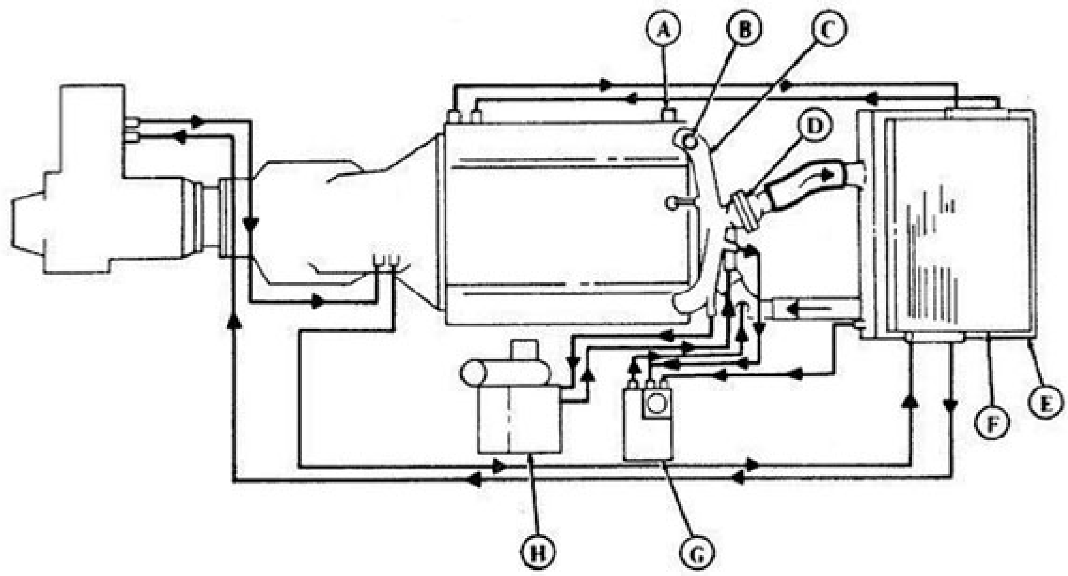
Engine

The water-cooled, naturally aspirated, 6.5 liter, V–8, diesel engine provides up to 160 hp at 3,400 rpm to power the vehicle. The engine is identical on all M998A2 models, except those equipped with a deep-water fording kit, which adds a specially sealed dipstick, dipstick tube, vented crankcase depression regulator valve, and a manual throttle control. Fording is driving through a deep body of water.

The water-cooled, turbocharged, 6.5 liter, V–8 diesel engine on the heavy variants, (M1113/M1114), provides up to 190 hp at 3,400 rpm. The cylinder block is a different design than the 6.5 liter naturally aspirated engine to accommodate the turbocharger components. If equipped with an arctic winterization kit, the engine has a special injection pump, specifically suited for use with arctic grade fuel for long engine run-times. These differences do not affect engine performance.

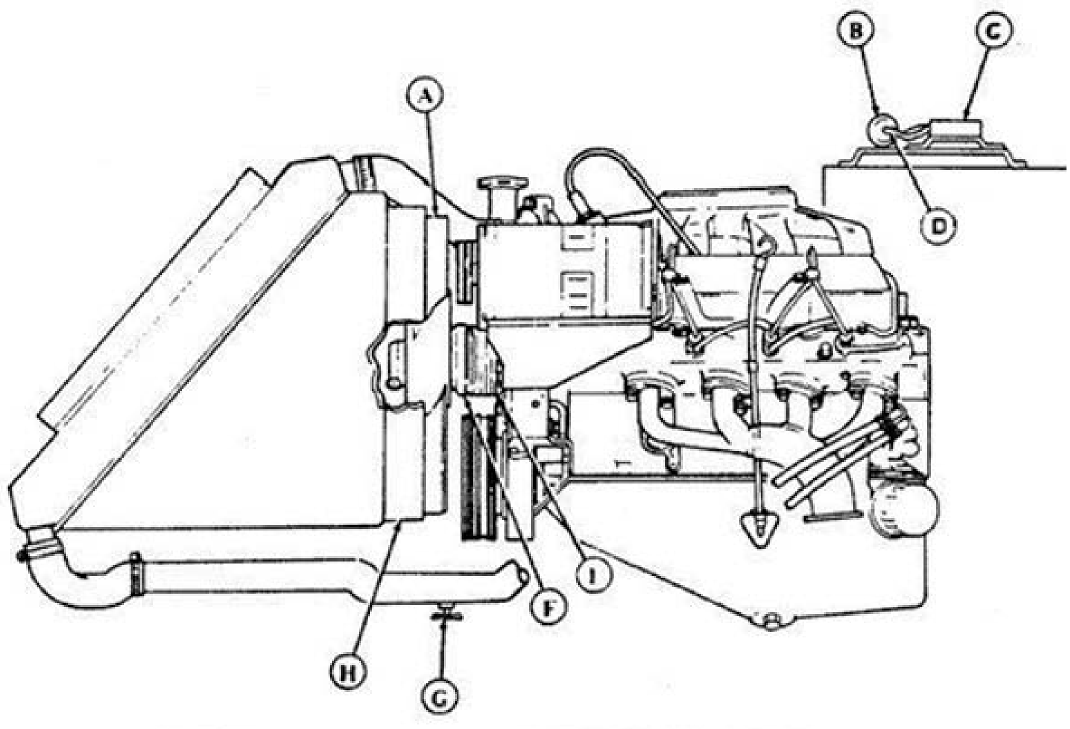
NOTE: In older HMMWV vehicles, you will find a water-cooled 6.2-liter diesel engine, which provides up to 150 hp at 3,600 rpm.

The cooling system is identical on all models covered in this lesson. The location of each of the cooling system components is identified in figure 4–4 and 4–5, which depicts the typical HMMWV cooling system arrangement. These figures also show the locations of the drain cock, oil cooler, and personnel water heater, which are not discussed.



A. Engine temp sending unit
B. Engine temp switch
C. Water crossover
D. Thermostat
E. Radiator
F. Oil cooler
G. Surge tank
H. Personnel water heater

Figure 4–4. HMMWV cooling system (top view).



A. Fan
B. Hydraulic control valve
C. Time delay module
D. Fan clutch solenoid
E. Water pump
F. Fan clutch
G. Drain cock
H. Radiator shroud

Figure 4–5. HMMWV cooling system (side view).

Radiator
The radiator is mounted at a 45° angle for a lower front vehicle profile. The radiator also provides for mounting of the transmission and power-steering oil coolers.

Coolant pump
The coolant pump is mounted at the front end of the engine between the block and the radiator. The coolant pump, which is belt driven, consists of a housing with a coolant inlet and coolant outlet. Internally there is an impeller, which rotates, forcing the coolant through the housing. The coolant pump discharge rate (flow) is 70 gpm and the average coolant capacity is 6.2 gallons, which includes 3.2 gallons in the engine.

CAUTION: The coolant pump used on the M998 and M998A1, 6.2-liter engine is not interchangeable with the M998A2, 6.5-liter coolant pump due to opposite impeller shaft rotation. Using a coolant pump with incorrect shaft rotation will result in the engine overheating, leading to possible damage to internal engine components.

Engine temperature sending unit
The sending unit transmits an electrical signal to a temperature gauge mounted on the vehicle instrument cluster. The sending unit is mounted in a coolant passage on the left front side of the left cylinder head adjacent to injector #1.

Coolant crossover pipe
The coolant crossover pipe collects coolant from the cylinder heads and channels it to the thermostat housing where it is redirected through the cooling system. It has threaded holes for installing a glow plug controller and a fan clutch thermostatic switch.

Fan clutch
The fan clutch is hydraulically actuated by pressure from the hydraulic control valve to control operation of the fan. The power-steering pump provides the hydraulic pressure. The following table lists and describes the components used to operate the fan clutch.

Fan Clutch Components	
Component	**Description**
Fan Thermostatic Switch	Located in the coolant crossover. It sends a signal to activate the hydraulic control valve system, which operates the fan when engine temperature exceeds 230°F and deactivates when engine temperature drops below 190°F.
Hydraulic Control Valve Electrical Solenoid	Opens and closes the control valve port controlling oil flow to the fan clutch.
Hydraulic Control Valve	Directs hydraulic fluid to provide required pressure to activate the fan clutch as required by engine temperature. The power-steering pump supplies hydraulic pressure.
Time Delay Module	Sends a signal to the fan clutch solenoid to temporarily delay fan operation during heavy acceleration in order to free up hp and/or protect the fan from damage during water fording. A safety feature prevents the operator from continuously deactivating the fan clutch to ensure adequate engine cooling and reduce the risk of overheating.

Drive train components
The drive train components on the HMMWV consist of the transmission, transfer case, propeller shafts, differentials, halfshafts, and the geared hubs. Refer to figure 4–3 as you review the driveline components.

Transmission
The transmission changes the engine power (torque) to meet different driving conditions. The automatic transmission has four forward speeds, reverse, park, and neutral. A neutral safety switch

prevents the engine from being started with the transmission selector lever in any position, except park or neutral. The transmission case is cast aluminum and is equipped with integral ribs for maximum strength and durability.

Transfer case

The transfer case provides three ranges of constant four-wheel drive: high, high-lock, and low-lock. It also has a neutral position. High range provides differentiated torque output to the front and/or rear differentials. The high-lock range provides undifferentiated torque output to the front and rear differentials. The low-lock range position provides undifferentiated torque output similar to high-lock range.

Propeller shafts

The HMMWV uses two tubular propeller shafts, sometimes referred to as the "drive shaft", to transmit torque from the transfer case to the front and rear axle assemblies. Universal joints, located at both ends of the front and rear propeller shafts, permit in-line driving power between the transfer case and differentials even though they are mounted at different angles.

Differentials

The HMMWV uses a limited-slip differential in both the front and rear. Aside from the covers, the front and rear differentials are interchangeable and share the same part number. The limited-slip mechanism consists of "*drive* gears" (worms) and "*driven* gears" (worm wheels). The worms drive the worm wheels, but the worm wheels cannot drive the worms.

This gear arrangement is advantageous in distributing torque to both drive axles. It allows the HMMWV to make sharp turns without the gears binding and if one wheel begins to slip, the differential automatically transfers torque to the wheel with the best traction. Therefore, the differential is a torque-biasing, torque-sensing, and load-sensing differential.

Halfshafts

The HMMWV uses three different length axle drive shafts (halfshafts) to accommodate the independent suspension system. The left front and right front halfshafts are unequal in length due to the off-centered positioning of the front differential. The rear halfshafts are equal in length but not the same length as either of the front halfshafts.

1. Short shaft—left front.
2. Intermediate shaft—both rear.
3. Long shaft—right front.

The purpose of the halfshafts (fig. 4–6) is to transfer torque to the wheels from the differential through the geared hub. Each unit is basically a one-piece assembly with boots on both the inboard (differential) and outboard (geared hub) ends. The outer boot encloses a constant velocity joint, which transmits torque through various steering angles to the geared hub. The outer (splined) constant velocity joint end of the shaft assembly is held in place by the axle shaft-retaining bolt located opposite the pipe plug in the geared hub. The inner constant velocity joint end is bolted to the differential output flange through the brake rotor.

NOTE: Removal of either the front or rear halfshaft requires that the respective tire be removed for removal of the access plug and retaining bolt (capscrew). Halfshafts transmit torque from differentials to the geared hubs.

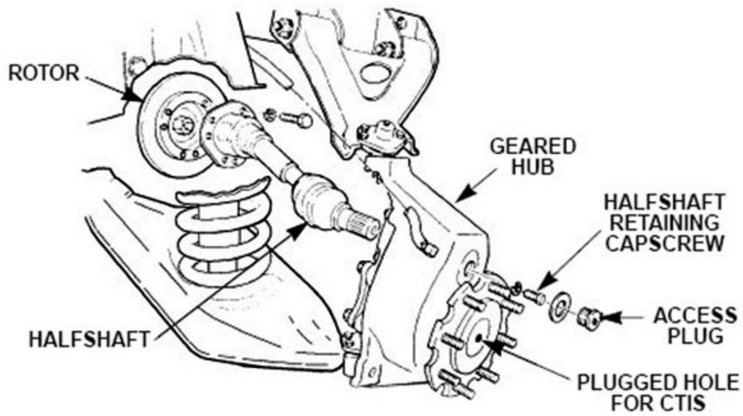


Figure 4–6. Halfshaft.

Geared hubs

Geared hubs (fig. 4–7) serve as front-wheel steering spindles and act as the final drive components to the front and rear wheels. Adjustable steering stops are located on the front-geared hubs to limit the vehicle steering radius. The geared hubs are the final gear reduction units for the HMMWV. Geared hubs are interchangeable from left front to right rear and right front to left rear. Geared hubs on the M998A2 series are not interchangeable with the M998 and M998A1 series. The differences are the input gear, spindle, and steering control arm.

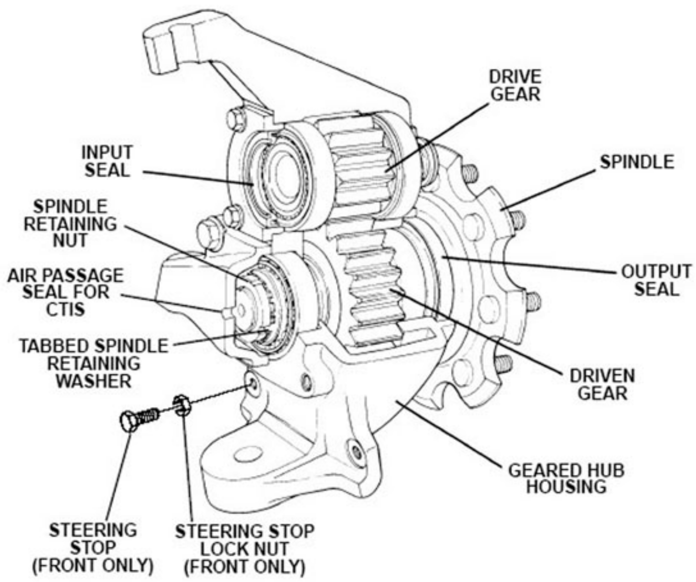


Figure 4–7. Geared hub.

Suspension system

The suspension system is identical for all models. It is an independent coil spring-type system. Refer to figure 4–8 as we discuss the major components of the HMMWV suspension system listed alphabetically below.

A. Ball joints**—**connects geared hubs to control arms, and allows change of angle between geared hub and control arms during suspension movement.

B. Upper control arm**—**connects geared hub to frame rail.

C. Stabilizer bar (front only)—reduces vehicle sway when cornering.

D. Geared hub—serves as a mounting point for wheel and tire assembly and provides a 1.92:1 gear reduction to increase torque to the wheel and tire assembly.

E. Lower control arm—connects geared hub to frame rail.

F. Shock absorber—dampens suspension movement and limits amount of suspension travel.

G. Coil spring—supports weight of the vehicle and allows suspension travel to vary depending on terrain and vehicle loading.

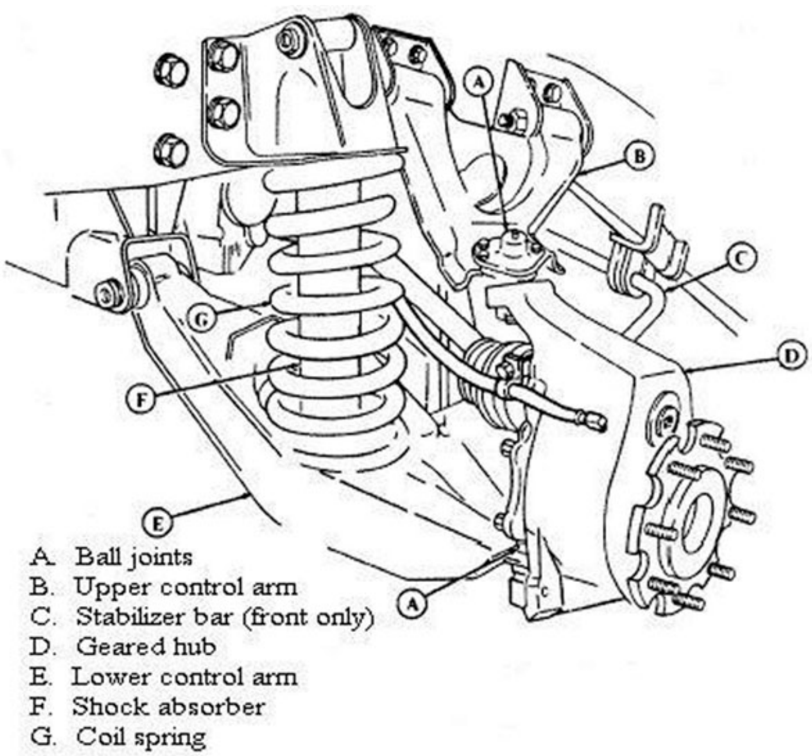


Figure 4–8. HMMWV suspension system.

Steering system

As with the suspension, all HMMWVs use the same type of steering system. A power-steering pump provides hydraulic power for a worm-type (recirculating ball) steering gearbox that has integral power steering. This means the power assist (power steering) components are built into the steering gearbox. The steering linkage is a parallelogram type similar to most commercially designed vehicles.

The demands and stresses placed on an M-series vehicle require more strength and durability than a commercially designed vehicle. Due to operational demands, the HMMWV steering system components are made of heavy-duty parts. Always refer to the service manual or technical order when making repairs and ordering parts for these vehicles.

Electrical system

All M-series vehicles have standardized wiring plans based on one set of circuit numbers and rubberized, waterproof in-line wire connectors that are the same for every vehicle. This makes it possible to use the same lights, switches, trailer connectors, and so forth across the board, thus simplifying maintenance, spare parts inventories, and tools. To view the standard circuit numbering assignments you can view the "Olive Drab" website at http://olive-drab.com/od_mseries_circuits.php.

NOTE: There are, however, exceptions to this standardization. Early M-series vehicles, for instance, used "Douglas connectors" with metal shells, not the rubber shells. Other vehicles use a multipin "cannon connector" for the lights instead of the rubber connectors and so on. Before doing anything, check the technical order for each particular vehicle.

Lighting system

The lighting system for the HMMWV is similar to all other M-series vehicles. With a requirement for blackout lights, as well as normal lighting operations, the main switch is somewhat cumbersome and confusing to operate. However, as with all M-series systems, once you learn it you can work on all of them.

Headlight switch

Most M-series vehicles have the same three-lever headlight switch (fig. 4–9). There is also a newer push-button type switch, which performs the same functions through the use of buttons instead of levers.

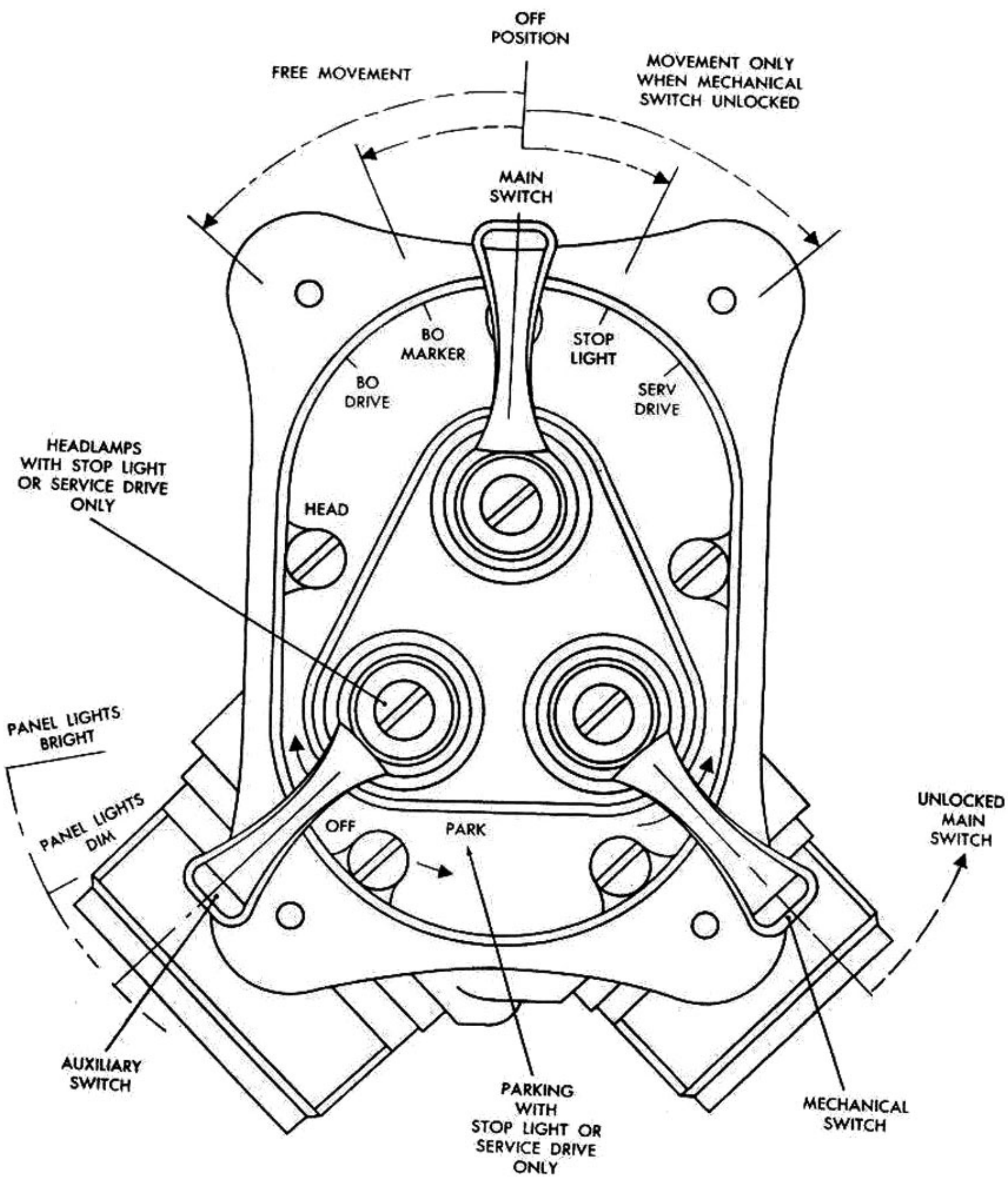


Figure 4–9. Three-lever headlight switch.

The rear of the switch is set up to receive a large cable connector to tie it into the vehicle wiring harness. The circular, threaded rim on the switch back is notched so the connector can only go in one way. Small letters molded into the base material identifies the male pins. The letters are hard to see but they are there, running from A to N with no G or I. The table below explains the connector pins circuit number and circuit usage.

Connector Pins, Circuit Number, and Circuit Usage		
Connector Pin	**Circuit Number**	**Circuit Usage**
A	75	Stop Lamp Switch. Runs through brake light switch to Pin K.
B	40	Panel/Instrument Lights.
C	22	Stop Lights. Energized when brakes applied. Runs to turn signal switch if used.
D	19	Blackout Driving Lamp.
E	20	Blackout Marker and Tail Lamps.
F	15	Battery Power Lead.
H	21	Service Tail Lamps.
J	467	To flasher switch. Energized when stop or head lights on.
K	75	Stop Lamp Switch. Runs from pin A through brake light switch.
L	491	Parking Lights (if used).
M	16	Service Headlamps. To dimmer switch or headlight relay.
N	23	Blackout Stop Lamp.

The circuit numbers are the standard M-series circuits, which are common to most vehicles. If you have the military cables, the circuit numbers will be on metal tags crimped onto each wire in the cable bundle running from the female connector on the wiring harness. If you make up a cable, it would be best to tag the wires the same way since it will make it easier to hook up to other military components (i.e., turn signal switch, flasher, composite lights, etc.).

Although the switch is relatively easy to use, it is designed to facilitate blackout driving conditions. This means you can turn on the blackout lights without having to unlock the switch. The purpose of this is so you don’t inadvertently switch on your main lights at night while you’re trying to go unnoticed.

Figure 4–10 shows the operation of the three-way headlight switch. Operation of the push-button switch (fig. 4–11) is as simple as pushing the button for the mode you need; then push the enter button to activate that mode. Again, keep in mind that the three-way or button-type switch is used on nearly all M-series vehicles.

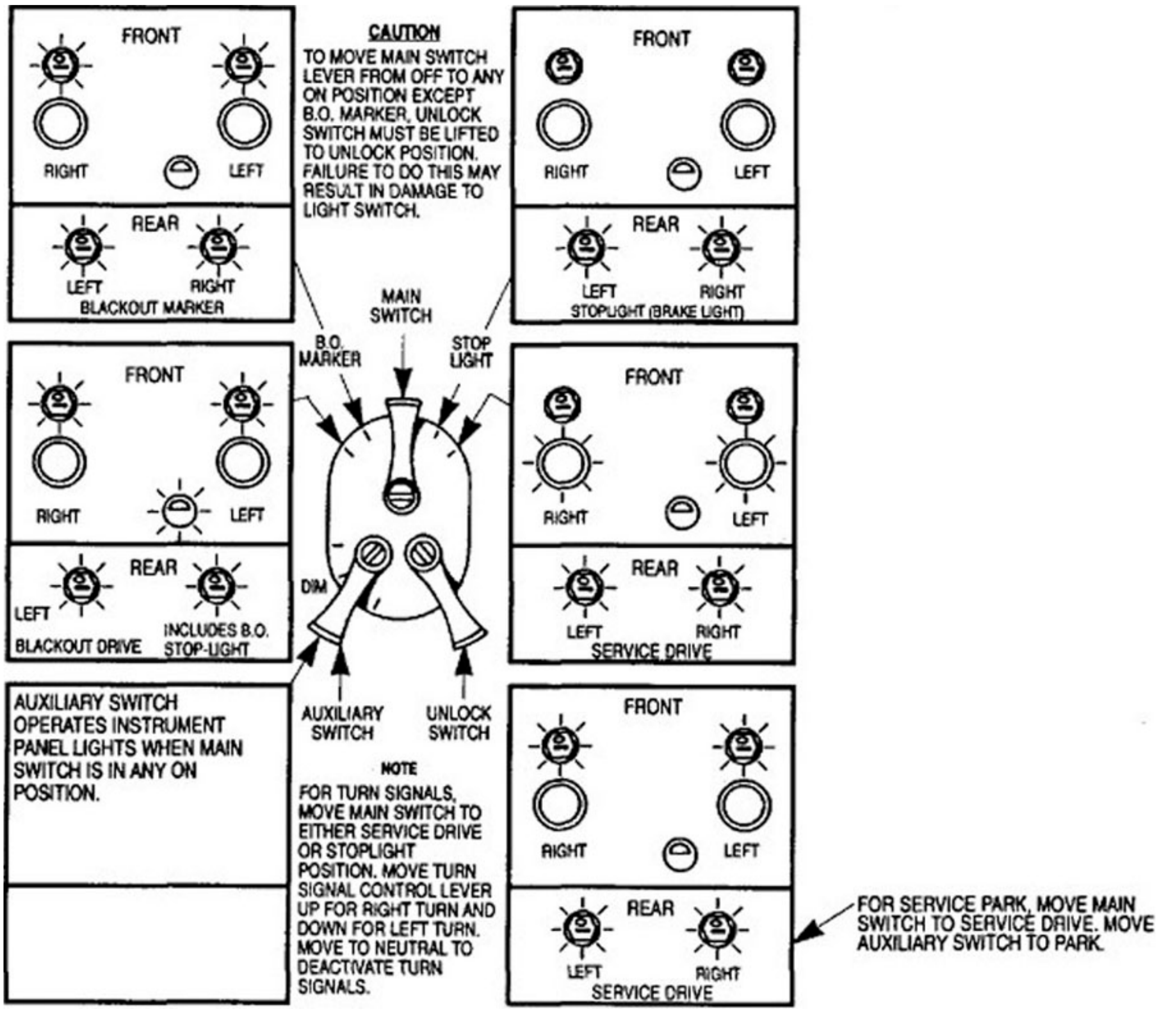


Figure 4–10. Operation of the three-lever headlight switch.

Figure 4–11. Push-button headlight switch.

Vehicle lights location and function

As stated earlier, the HMMWV requires normal lighting as well as blackout light capability. Figure 4–12 shows the location of standard and blackout light assemblies. Since you already know the function of a normal vehicle lighting system, we will briefly discuss the blackout light system.

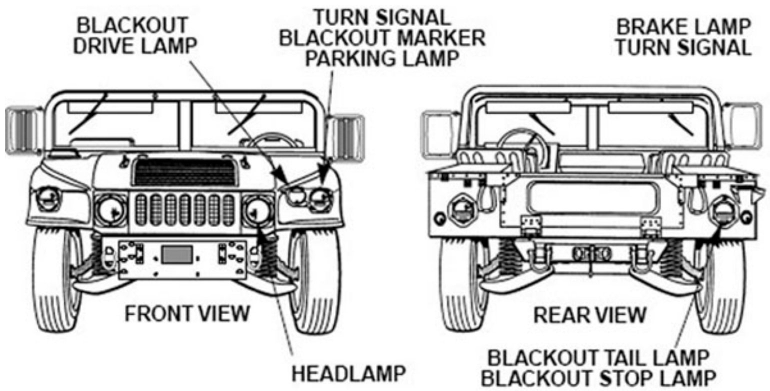


Figure 4–12. HMMWV lighting system.

The purpose of blackout driving lamp and markers is for use in night convoy operations. There are a total of five blackout lights: front blackout driving lamp (1 each), front blackout markers (2 each), and rear blackout markers (2 each).

The blackout lamp (fig. 4–13) contains a low-watt light bulb, and the front of the assembly is hooded to prevent light from omitting upward and its purpose is to provide minimal light for driving in blackout conditions.

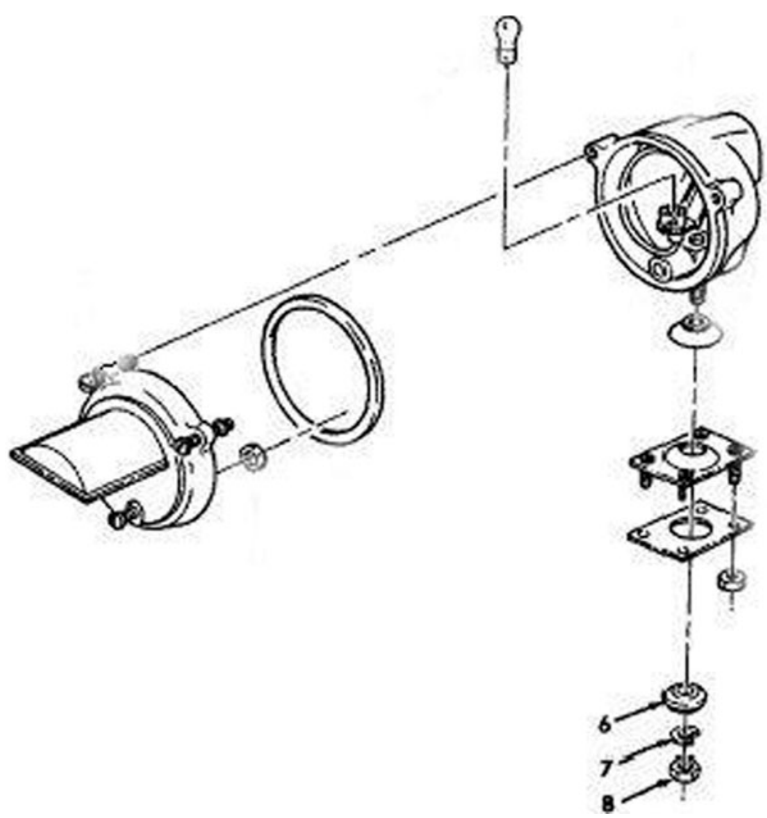


Figure 4–13. Blackout driving lamp.

The blackout marker lights, commonly referred to as “cat eyes,” are incorporated into the front (fig. 4–14) and rear composite light assemblies (fig. 4–15) that also contain the normal vehicle lighting functions (i.e., turn, marker, and stop).

Notice in figure 14 that there is one cat’s eye strip, and in figure 15 there are two. The second, smaller strip on the rear lamp is the blackout stop lamp. Also, notice that the front light assembly in figure 14 has three wires to reflect the blackout stop lamp function, whereas the rear light assembly in figure 15 shows four.

The purpose of the blackout markers is to indicate the distance you are from another vehicle. This is accomplished by using a visual reference point concept by incorporating internal dividers within the light assemblies. This will allow a person directly in front or directly behind to only see certain images at certain distances.

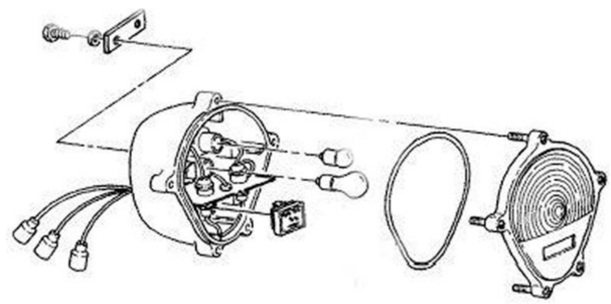


Figure 4–14. Front marker light.

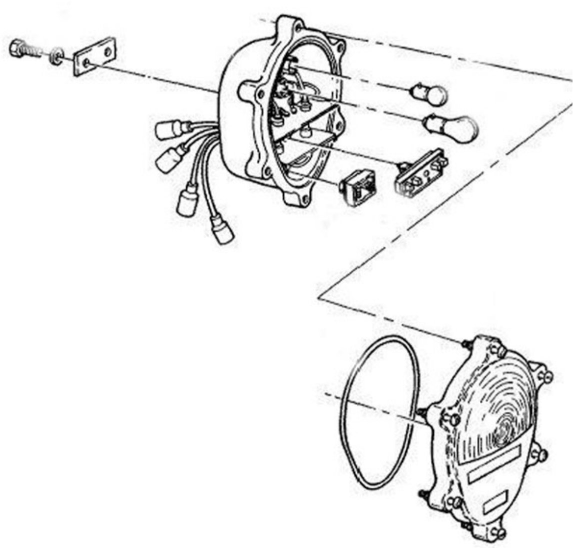


Figure 4–15. Rear marker light.

For example, when following another HMMWV in a night convoy and you see four red (referred to as “cat eye”) blackout markers, you are driving too close to the vehicle in front of you. If you see one red blackout marker on each side, you are too far from the vehicle in front of you. If you can see two red blackout markers on each side of the vehicle, you are about the right distance from the vehicle in front of you. If you don’t see any lights, you’re in trouble! The same principle applies for the front blackout markers: two white lights is too close, one white light is the correct distance.

Turn signal switch

The M-series turn signal switch is made of high-impact plastic and contains leaf switches operated by a plastic cam like cylinder, which is rotated by the operating lever. The M-series turn signal has four modes of operation: off, right turn (lever up), left turn (lever down), and emergency. The emergency switch is activated by pulling out on a casting near the base of the lever, then moving the lever to the extreme up position.

Starting system

The starting system is identical for all vehicles covered in this lesson. As we discuss the starting system components and circuits, refer to figure 4–16. The table below lists and describes each component.

Starting System Components		
Figure Item	**Component**	**Description**
A	Rotary switch	In “START” position, this switch provides battery power to the starter solenoid and to the neutral start switch through circuit 14.
B	Neutral start switch	When transmission is in “N” (neutral) or “P” (park) position, this switch closes a relay in the protective control box through circuit 14 allowing battery power to the starter solenoid.
C	Protective control box	The electronic control center for all electrical circuits. This also prevents the starter from being engaged during engine operation.
D	Starter motor	Cranks the engine for starting and is supplied 24-volt battery power through circuit 6A.
E	Starter solenoid	A magnetic relay that transmits 24-volt battery power to the starter motor.
F	Batteries	There are two 12-volt batteries connected in series that supply 24-volts to the starter system through circuit 6A.
G	Glow plug(s)	Assists in cold starts and is connected through circuit 575 at the protective control box.
H	Glow plug controller	Cycles the glow plugs on and off during cold starts. It is connected to the protective control box through circuit 573A.

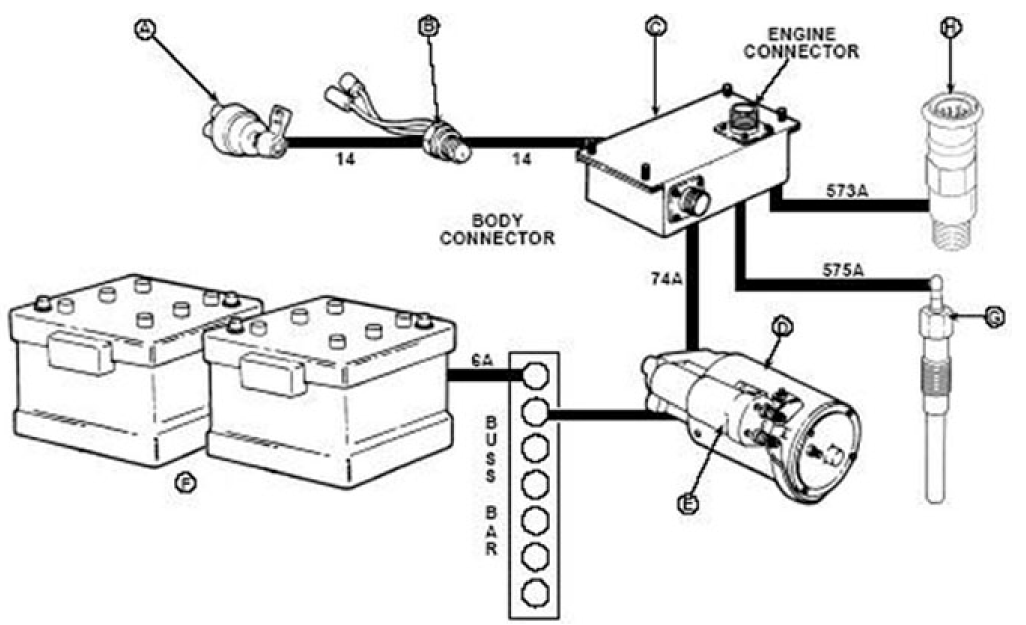


Figure 4–16. HMMWV starting system.

Generating system

The 100- or 200-ampere generating system maintains the battery charge and provides electrical power to operate the vehicle circuits. Major components and circuits of the generating systems are identified in figure 4–17 and are listed in the table below.

Generating System Major Components		
Figure Item	**Component**	**Description**
A	Battery gauge	Indicates electrical system voltage. It is connected to the electrical system through circuit 567.
B	Alternator (100 amp)	Rated at 12/24 volts, 100 amp. Assists and recharges the batteries during operation.
C	Alternator (200 amp)	Rated at 12/24 volts, 200 amp. Assists and recharges the batteries during operation.
D	Circuit 3	Provides a ground circuit to the alternator.
E	Circuit 6B	Provides 12 volts to the one battery that powers transmission functions.
F	Circuit 6E	Provides 24 volts to two batteries to power vehicle electrical functions.
G	Circuit 568	Senses vehicle voltage activating the field current in the alternator to generate current.
H	Protective control box	Protects the vehicle electrical system in the event battery polarity is reversed.
I	Buss bar	Electrical distribution point.

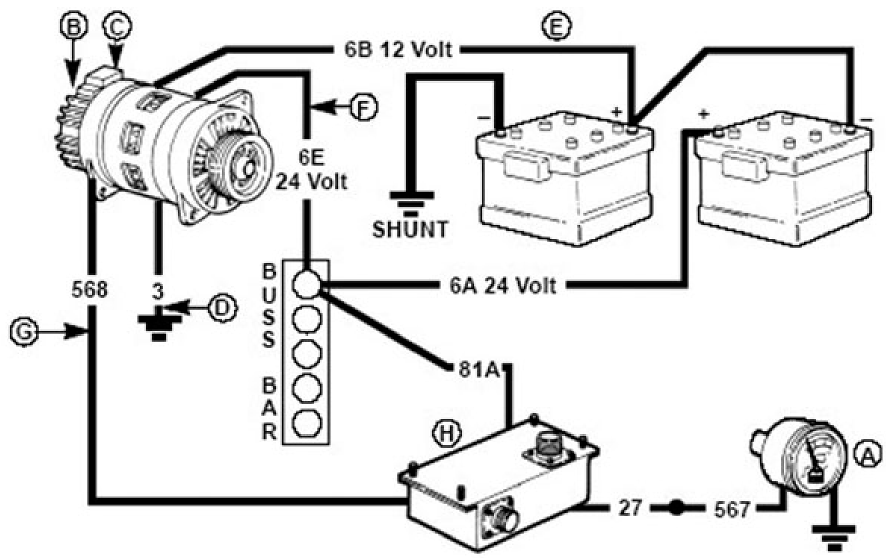


Figure 4–17. HMMWV generating system.

Battery system

The battery system is identical for all vehicles covered in this lesson. As we discuss the battery system, reference figure 4–18. The battery system components are listed and described in the following table.

Battery System Components and Description		
Figure Item	**Component**	**Description**
A	Circuit 6A	Connects the batteries to the starter and to the protective control box through circuit 81A.
B	Batteries	Two 6TN batteries provide 24 volts for the electrical starting system.

Battery System Components and Description		
Figure Item	**Component**	**Description**
C	Slave receptacle	Links an external power source directly to the slaved vehicle's batteries to assist in cranking the engine when the vehicle's batteries are not sufficiently charged.
D	Shunt	Used to measure current draw from batteries when using simplified test equipment for internal combustion engines (STE/ICE).
E	Protective control box	The electronic control center for all electrical circuits and is part of the starting system.
F	Rotary switch	When in "RUN" position, the rotary switch closes circuit 29, activating the instrument panel gauges through circuit 27.
G	Circuit 7	Connects the battery system to the starter negative terminal and chassis ground.
H	Starter solenoid	The junction point for battery positive lead (circuit 6A) and the vehicle electrical feed wire (circuit 81A).

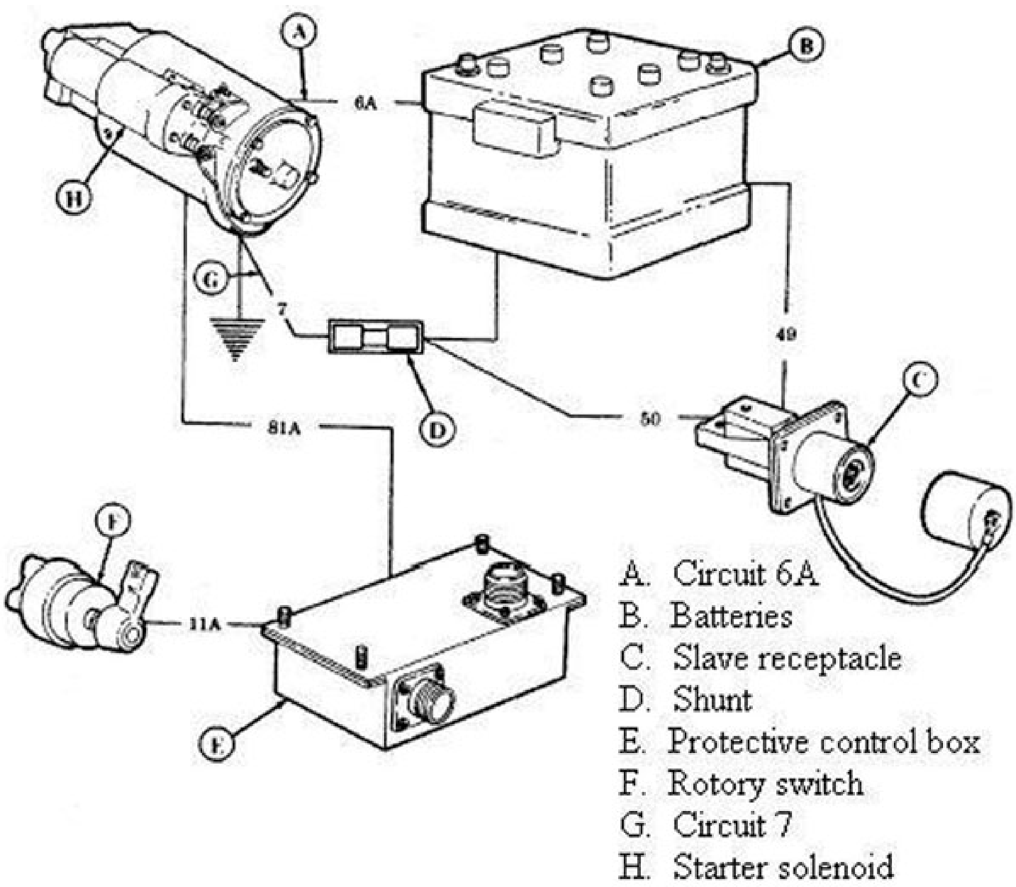


Figure 4–18. HMMWV battery system.

Runflat wheel and tire assembly

The wheel assembly (fig. 4–19), which includes a runflat device, allows the vehicle to be driven under emergency conditions with one or more flat tires. This does away with the immediate need for a spare tire and increases the vehicle mobility with flat tires. The radial tires are a tubeless-type, constructed of five plies consisting of: 1 nylon, 2 polyester, and 2 steel plies.

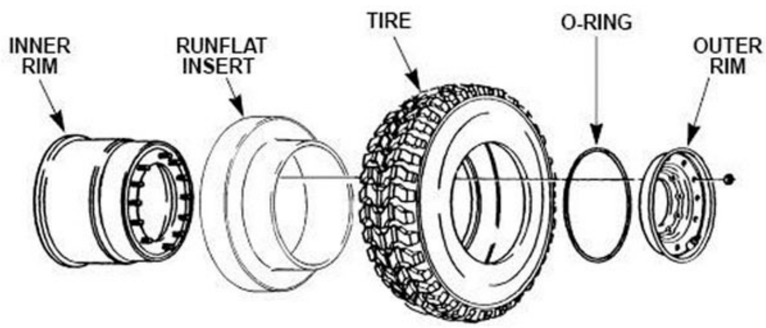


Figure 4–19. Runflat wheel and tire assembly.

In the event of a puncture or pressure loss in one of the tires, the operator can rely on the runflat devices within each tire. The runflat insert enables the vehicle to travel 30 miles at 30 mph with no air pressure in the tire. In the event that only the two rear tires are flat, the maximum speed is 20 mph. The reduced speed is necessary for vehicle control because, unlike the front tires, there is no steering control for the rear tires. Two flat tires in the rear may cause the vehicle to sway from side to side at speeds above 20 mph. Removal of the one-piece runflat assembly requires the use of a special tool called a runflat compressor tool. Figure 4–20 illustrates the use of this special tool.

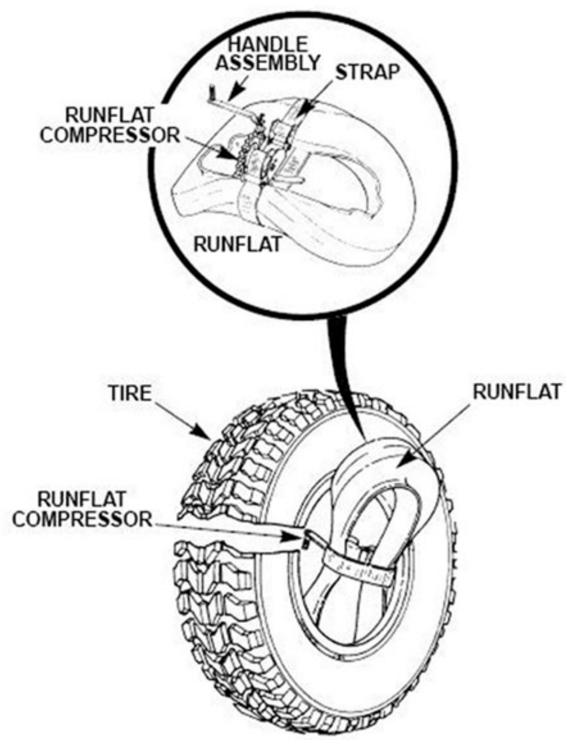


Figure 4–20. Runflat insert removal.

STE/ICE

STE/ICE performs the same function as commercial vehicle troubleshooting systems. It is a testing system that performs tests and measurements on internal combustion engines. STE/ICE measures standard voltage, current, resistance, pressure, temperature, and speed. Special tests, such as compression balance tests and starter system evaluations can also be performed.

Standard equipment functions including vacuum pressure gauge, compression gauge, low-current tester, and multimeter are features of the STE/ICE set. STE/ICE is portable and operates on either the vehicle batteries or an equivalent power source. The STE/ICE system (fig. 4–21) consists of a vehicle test meter (VTM), a transducer kit (TK), four electrical cables, a transit case, test cards, and technical publications.

NOTE: Not all vehicle management shops will have the STE/ICE equipment available. Always refer to the technical order for specific testing procedures.

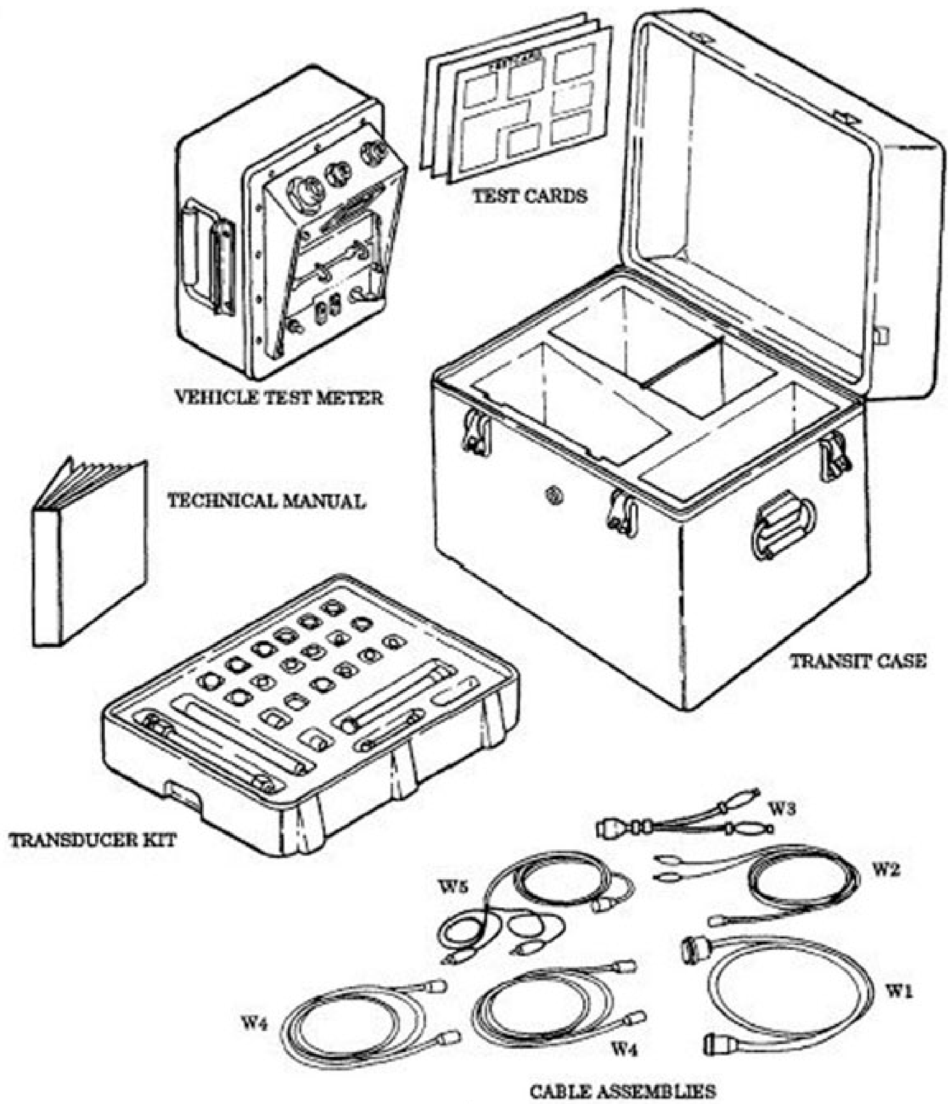
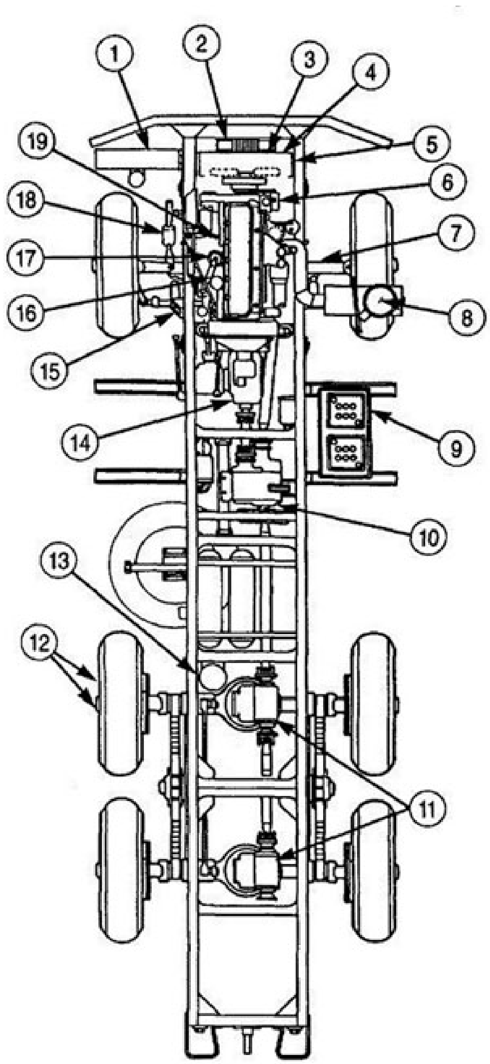


Figure 4–21. STE/ICE system.

024. 2½-ton M-series

This lesson covers the 2½-ton M-series, specifically the M35A3, M35A3C, and M36A3 models, with and without a winch. The 2½ ton plays an important role in equipment and troop transport during Air Force logistical operations. As a vehicle and equipment technician, you must be familiar with these trucks. Figure 4–22 shows the location of most major components on the M35. We will not cover all of these components in this lesson due to redundancy. Instead, we will focus on fundamentals and unique systems.



1. Front winch hydraulic oil reservoir
2. Front winch
3. Transmission oil cooler (oil-to-air)
4. Charged air cooler
5. Radiator
6. Surge tank
7. Front axle
8. Air cleaner
9. Batteries
10. Transfer case
11. Rear axles
12. Wheels/tires
13. Air dryer
14. Automatic transmission
15. Power assist steering cylinder
16. Engine oil dipstick
17. Engine oil fill
18. Drag link
19. Engine

Figure 4–22. Location of major M35 components.

Fundamentals

There are many different models of the 2½-ton truck, but by far the most common is the M35 model. The primary purpose of the M35A3, M35A3C, and M36A3 is to transport troops or heavy loads up to 5,000 lbs. The M35A3 (fig. 4–23) has permanent steel-welded sides and is the preferred vehicle for transporting bulky payloads that may shift during transit.

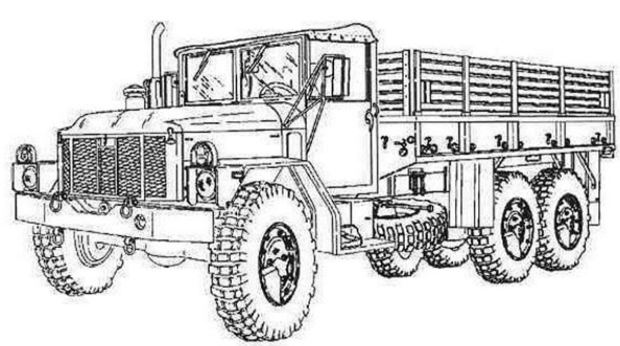


Figure 4–23. M35A3 2½-ton M-series (without winch).

The M35A3C (fig. 4–24) is a cargo truck with sides that are folded down or removed for easy side loading and unloading operations. The M36A3 (fig. 4–25) has a longer wheelbase than the other models and is not suited for operations that require maneuverability in limited spaces. All of these trucks are capable of fording through 30 in. of water without a fording kit and 72 in. of water with a kit. Additionally, these trucks may have a central tire inflation system (CTIS).

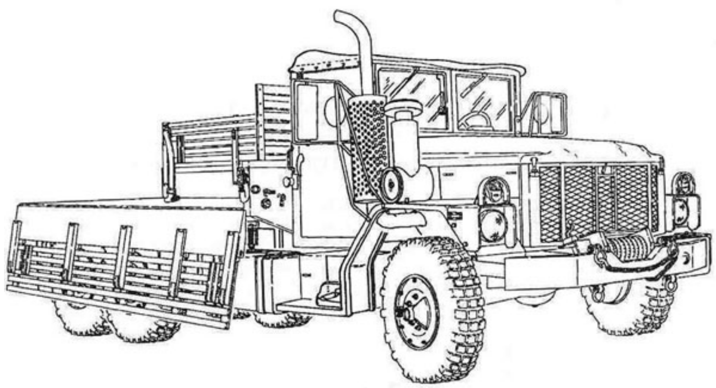


Figure 4–24. M35A3C 2½-ton M-series (with winch).

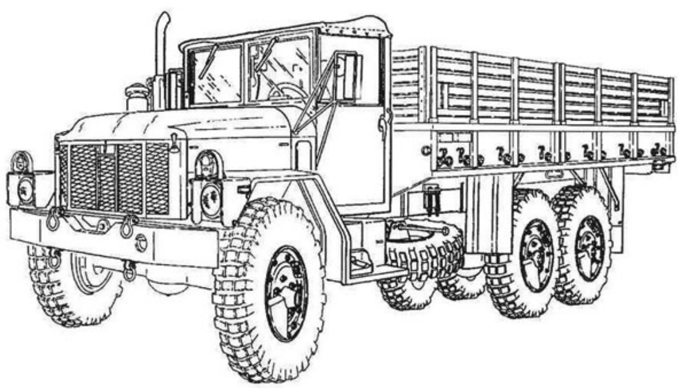


Figure 4–25. M36A3 2½-ton M-series (without winch).

Mechanical system

As we have discussed earlier, you are already familiar with standard mechanical (drive train) components. The 2½-ton M-series incorporates all of these components on a larger scale. The following are some of the specific models of various drive train components you will see in the medium-duty M-series vehicles.

Engine

The engine is a Caterpillar 3116, which has a 403 cubic in. (6.6 liter) displacement. The engine is a four-stroke, in-line 6 cylinder, with direct fuel injection. It is turbocharged with an air-to-air aftercooler system and is rated 170 hp at 2,700 rpm. A gear-type pump supplies the engine lubricating oil, which is both cooled and filtered. Bypass valves provide unrestricted flow of lubrication oil to the engine parts when oil viscosity is high or if either the oil cooler or the oil filter elements become clogged.

Transmission

The transmission is an Allison AT–1545P. It is a four-speed automatic transmission. The transmission fluid dipstick and fill is located below the inspection cover on the passenger-side floorboard.

Transfer case

The transfer case used on the M35A3, M35A3C, and M36A3 trucks is a two-speed Rockwell T–136. Used in conjunction with the transmission, these trucks have a total of eight forward gears and two reverse.

Differential/axle

The front and rear differential/axle is a Rockwell C–240. Both front and rear assemblies are interchangeable.

Electrical system

The M35A3, M35A3C, and M36A3 electrical system operates similarly to other M-series vehicle electrical systems. The purpose of the electrical system is to supply electrical current to start the engine; operate lights, equipment, and accessories; and charge the batteries.

Fuel system

A mechanical governor, transfer pump, and high-pressure injection fuel system provide engine response and fuel economy. The transfer pump draws fuel from the fuel tank and pumps fuel under low pressure to the fuel/water separator where water and contaminants are removed. Filtered fuel is then delivered to the injectors.

The injectors use a plunger-and-barrel system to create the high pressures needed for the injection process to take place. Inside the injector, a spring-loaded needle valve lifts from its seat to allow high-pressure fuel to be injected into each cylinder. Excess fuel is routed from the engine cylinder head back to the governor and then to the fuel tank. A fuel shutoff solenoid mounted on the fuel pump stops the fuel flow to the injectors when the operator turns the accessory switch off.

Cooling system

The M35 has a pressurized cooling system that can safely operate at a temperature higher than the normal boiling point of water, which prevents pitting and wear inside the water pump. Major components of the cooling system are the radiator, charged air cooler, water pump, surge tank, thermostat, fan, and fan actuator.

Air system

The M35A3, M35A3C, and M36A3 trucks are equipped with a compressed air system that supplies clean, dry filtered air to operate air-actuated or assisted accessories throughout the vehicle, including the CTIS system. An engine-driven air compressor supplies air through an air dryer to two air reservoirs where it is stored. The air from the reservoirs is piped along frame rails back to two rear couplings. The left-side air coupling is the service coupling and is used to supply the air to operate the trailer brakes. The right-side air coupling is the emergency coupling, which is used to release spring brakes, if trailer is so equipped, and allows connection of an air hose for manual tire inflation. The air reservoirs also supply air to an air pressure gauge, two air-hydraulic brake boosters, steering assist cylinder, drag link assist, air horns, transfer case air cylinder, front axle engagement switch, and cooling fan actuator and clutch.

Chassis controls and indicators

Before you can maintain a vehicle, you need to know what controls what. You would think since we are all familiar with our personal vehicles, it would be easy to relate personal vehicle controls to government commercial-type vehicle controls. However, this is not true for M-series vehicles. Some of the most common problems in the field are that most technicians have never seen an M-series–type vehicle and, therefore, do not understand the military bells and whistles. The following lessons list the typical chassis controls and indicators that are on the medium-duty M-series vehicles. Reference figures 4–26, 4–27, 4–28, and 4–29 for component location.

Key item and function (part one)

As we discuss the first list of the M35 interior cab components, reference figure 4–26 for items 1 through 9 and figure 4–27 for items 10 through 16. The table below lists and describes the function of each component.

M35 Interior Cab Components (Part One)		
Figure item	**Component**	**Function**
1	Battery/accessory switch	Distributes power to the starter system, instrument panel gauges, fuel pump, and low-pressure warning buzzer.
2	Throttle control	Sets engine speed at desired rpm without maintaining pressure on the accelerator pedal. It locks in the desired position when pulled out. Rotating control handle clockwise or counterclockwise unlocks it.
3	Windshield washer lever	When pulled up, activates spray pump.
4	Air cleaner indicator	Displays yellow band when engine air cleaner filter needs servicing.
5	Fuel shutoff switch	Energizes fuel solenoid to shut off fuel flow from the transfer pump, which stops the engine.
6	Light switch	Operates vehicle lights.
7	Engine start switch	Distributes electrical current to the starter to crank the engine.
8	Personnel heater blower switch	Positioned in HIGH or LOW to control flow of forced air to personnel compartment (cab).
9	Quick-start switch	Is energized and held for two to three seconds to allow the quick-start valve to open and fill with ether. When released, ether is injected through atomizers and into air intake.
10	Electronic control unit (ECU) power button	Turns on the ECU, which controls and monitors CTIS operation.
11	LCD	Provides the operator with current tire pressure and maximum speed for the selected terrain setting.
12	Four terrain buttons	For CTIS (highway, cross-country, mud/snow/sand, and emergency), represents predetermined pressure set points.
13	Temperature control knob	Pulled out all the way to provide maximum amount of heat to personnel compartment.
14	Defroster knob	Pulled out to direct hot air flow onto windshield to prevent frosting.
15	Front-wheel drive lever	Engages or disengages front-wheel drive power.
16	Front-wheel drive indicator light	Indicates front-wheel drive is activated.

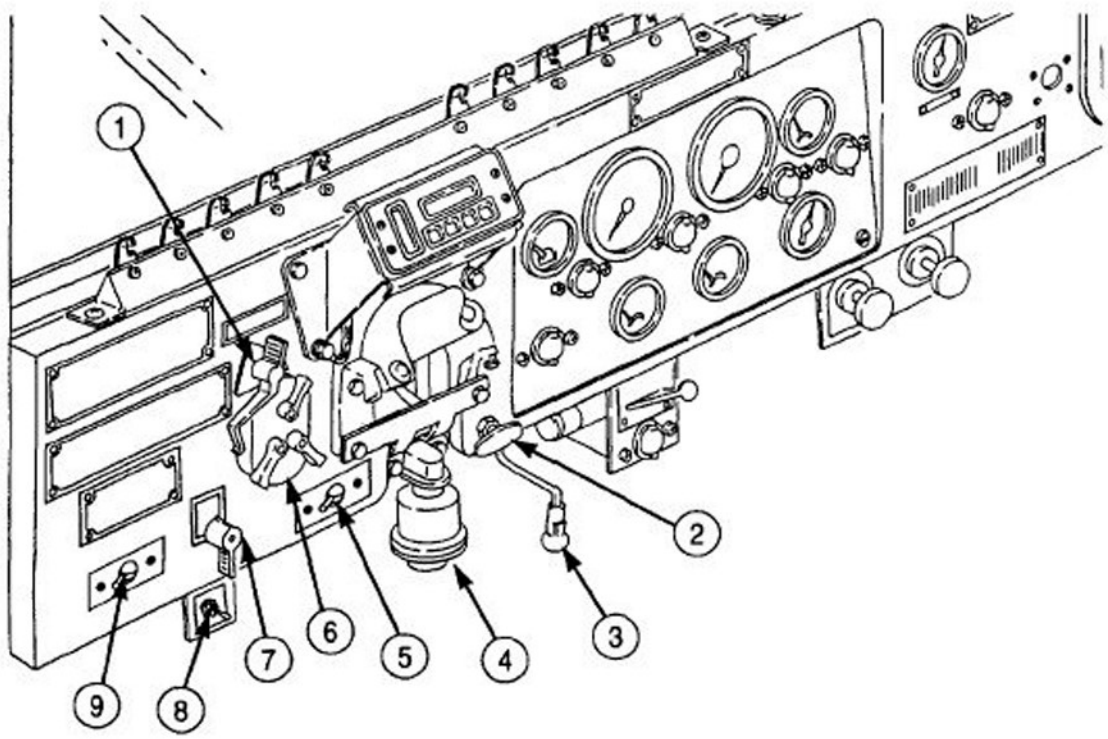


Figure 4–26. M35 cab interior, first view.

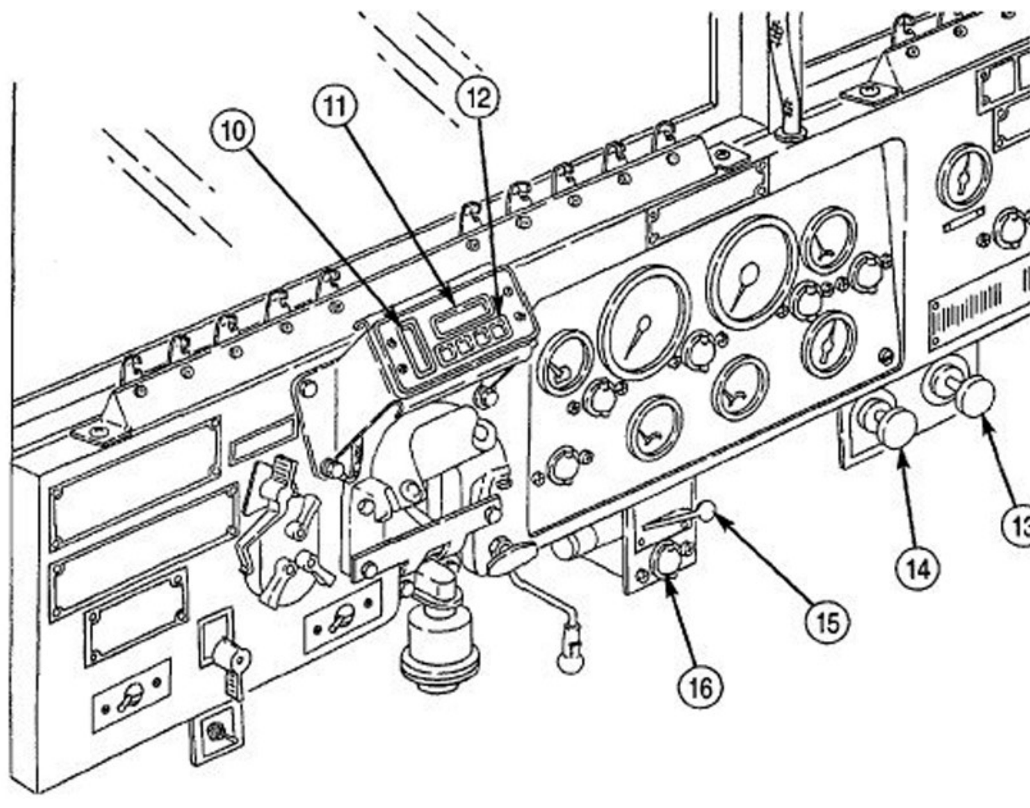


Figure 4–27. M35 cab interior, second view.

Key item and function (part two)

As we continue to discuss the second list of M35 cab interior components, refer to figure 4–28 for items 1 through 12 and figure 4–29 for items 13 through 20.

M35 Interior Cab Components (Part Two)		
Figure Item	**Component**	**Function**
1	Speedometer/odometer	Indicates vehicle speed in mph and total distance traveled in miles. Trip meter indicates distance traveled in kilometers.
2	Tachometer	Indicates engine speed in rpms and operating time in hours and tenths of hours. Normal idle speed is 750–850 rpm.
3	Engine coolant temperature gauge	Indicates engine coolant temperature. Normal operating temperature is 160º–230ºF.
4	Transmission temperature gauge	Indicates transmission oil temperature when engine is running. Normal operating temperature is 160º–300ºF.
5	Low-air pressure indicator light	Indicates air pressure in reservoirs is at, or below, 60 psi.
6	Air pressure gauge	Indicates air pressure in reservoir tanks. Normal pressure is 90–120 psi.
7	Battery gauge	Indicates when batteries are charging or discharging.
8	Parking-brake indicator light	Indicates parking brake has been engaged.
9	Fuel gauge	Indicates fuel level.
10	High-beam indicator	Indicates headlights are on high beam.
11	Oil pressure gauge	Indicates engine oil pressure when engine is running.
12	Diagnostic connector assembly (DCA)	Connects the VTM to the vehicle's test points for simplified test equipment for internal combustion engines, reprogrammable (STE/ICE-R).
13	Dimmer switch	Depressed to raise or lower headlight beam.
14	Service brake pedal	Depressed to slow or stop vehicle.
15	Accelerator pedal	Controls engine speed. When pressed down, engine speed increases. When released, engine speed decreases.
16	Transmission select lever	Used to select vehicle drive gear.
17	Winch air control valve lever	A three-position valve that activates in or out of winch cable.
18	Winch air valve lever	Pulled up and out to engage bypass valve for winch operations.
19	Transfer case shift lever	Pushed down to LOW position for heavy load operations, and pulled up to HIGH position for light load operations.
20	Parking brake lever	Pulled up to apply parking brake. The knob at top of handle is turned to set brake cable tension.

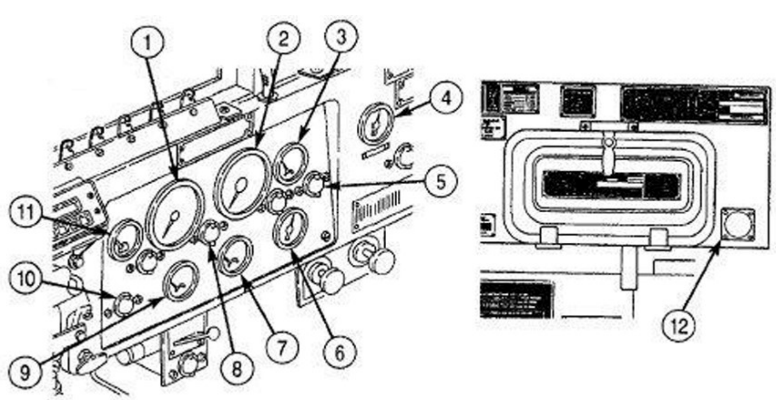


Figure 4–28. M35 cab interior, third view.

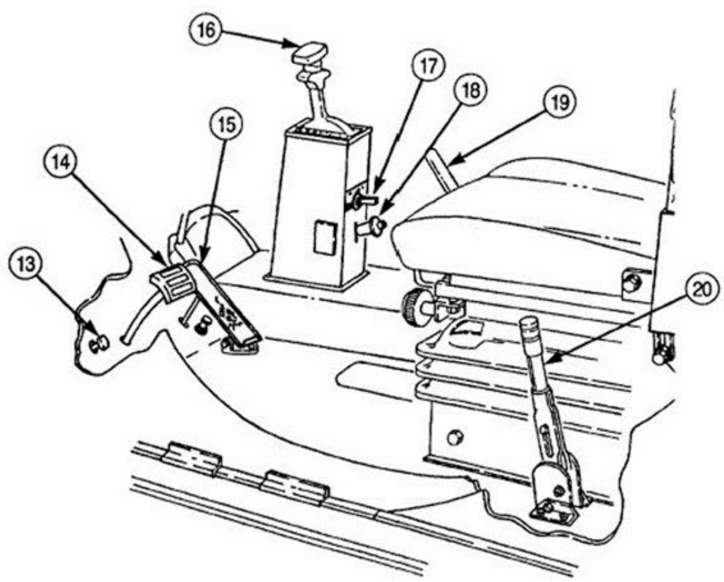


Figure 4–29. M35 cab interior, fourth view.

STE/ICE-R system

The STE/ICE-R system is a reprogrammable version of the STE/ICE system discussed in the HMMWV section of this unit. The STE/ICE-R has two modes of operation: normal and reprogramming. Normal mode is used to test engines and equipment in the same way the STE/ICE does. The reprogramming mode allows one VTM to reprogram up to ten other VTMs.

The STE/ICE-R has three major measurement capabilities:

1. General measurements—voltage, current, resistance, pressure, and speed measurements.
2. Special tests—used to test specific M-series vehicles. After entering a recognized vehicle identification number into the VTM, the STE/ICE-R will automatically use the vehicle information stored in its memory together with test data received to give a result.
3. DCA tests—if the vehicle or equipment to be tested has a permanently mounted DCA the VTM can receive both its power and test data through DCA cable W1.

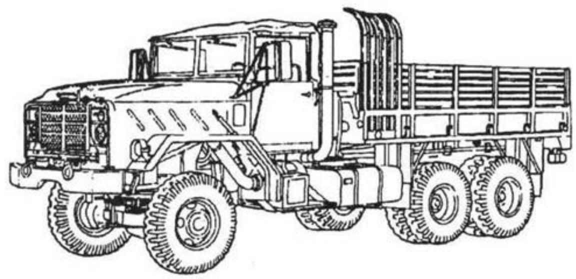
025. 5-ton M-series

This lesson covers the M939, M939A1, and M939A2 5-ton, 6x6 M-series trucks. The M939, M939A1, and M939A2 series of vehicles vary in design and capabilities. The M939 was a redesign and retrofit of the M809 series of vehicles, providing enhanced capabilities. The basic M939 model provided features like automatic transmission, improved power steering, a complete air brake system, an improved cooling system, an improved electrical system, a three crew-member cab, a tilt hood, a hydraulically powered front winch and an STE/ICE diagnostic connector.

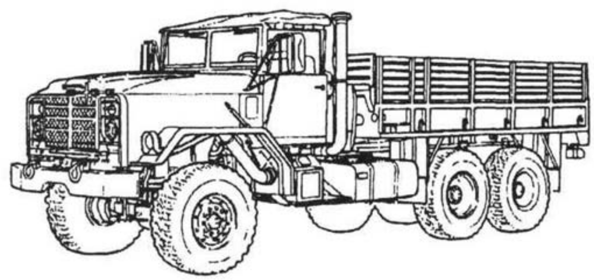
The M939A1 added super single radial tires. The M939A2 added a new CTIS, a new (Cummins 6CTA) 8.3-liter diesel engine, and chemical-agent resistant paint. The following table and figures 4–30 and 4–31 show only a few examples of the different model designs of the M939, M939A1, and M939A2 series trucks, as well as the M936 series wrecker. For an all-inclusive list, reference the appropriate technical order.

M939, M939A1, M939A2 Series Trucks	
Truck	**Model**
Cargo, Dropside	M923
Cargo, Dropside	M923A1
Cargo, Dropside	M923A2

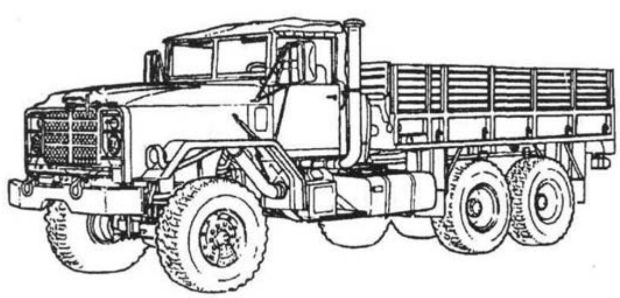
M939, M939A1, M939A2 Series Trucks	
Truck	**Model**
Cargo, Dropside	M925
Cargo, Dropside	M925A2
Tractor	M931
Van, Expansible	M934
Medium Wrecker	M936



M923



M923A1



M923A2

Figure 4–30. M923/A1/A2 dropside cargo.

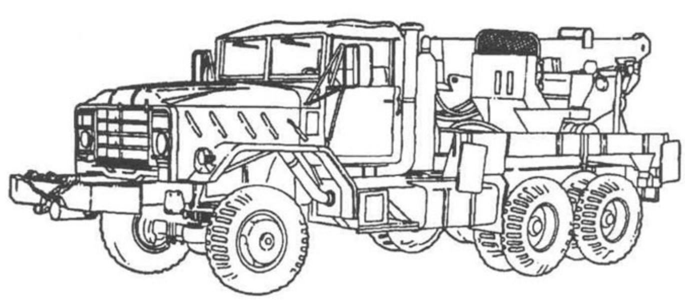


Figure 4–31. M936 medium wrecker.

Mechanical, suspension, drive train, and towing system components

The mechanical, suspension, drive train, and towing system components listed in this lesson are common to most of the M939, M939A1, and M939A2 series trucks. The following are the major 5-ton vehicle components, followed by a brief description. Reference figure 4–32 as we discuss the components. Since you previously learned about some of the components listed in figure 4–32, we will not discuss their function.

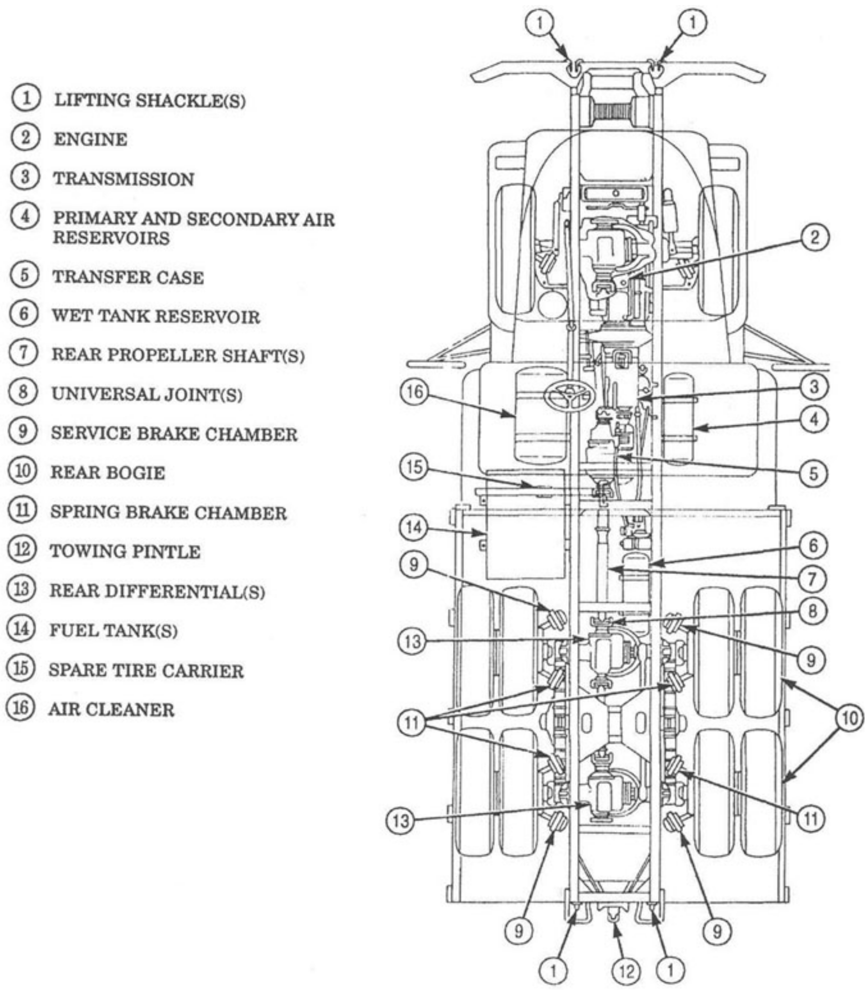


Figure 4–32. Major 5-ton vehicle components.

Major 5-Ton Components	
Component	**Description**
Engine	There are two different Cummins model engines used in the M939, M939A1, and M939A2 series trucks. The M939 and M939A1 series trucks have the Cummins model NHC 250, and the M939A2 series trucks have the 6CTA/8.3-liter diesel engines. The engine provides mechanical power to the vehicle and engine-driven subsystems.
Transmission	All M939, M939A1, and M939A2 series trucks use an Allison automatic transmission. The transmission adapts the engine's output for a varying range of operating speeds.
Transfer case	Directs the engine and transmission output to the specified axles and/or auxiliary equipment.
Rear propeller shafts	Transmits power between the transfer case and forward-rear axle assemblies and between forward-rear and rear-rear axle assemblies.
Rear differentials	Transfers power from the propeller shaft to the axles and provide a straight-through connection to power additional propeller shafts.

Major 5-Ton Components	
Component	**Description**
Rear bogie	The suspension system comprised of both rear axles, upper- and lower-torque rods, springs, and seats that support the rear vehicle weight.
Towing pintle	Provides a secure quick-connect/disconnect for towing vehicles or equipment.
Lifting shackles	Mounted in the front and rear of the truck. They provide towing capability by another vehicle or are used for tie-down attachments when transporting.

Electrical system

The electrical system on the M939, M939A1, and M939A2 series trucks is broken down into the following subsystems:

- Battery.
- Starting.
- Ether starting.
- Generating.
- Directional signal.
- Heating operation.
- Indicator, gauge, and warning.
- Trailer and semi-trailer connection.

Always follow technical order procedures when troubleshooting the electrical system.

Steering system

The steering system on the M939, M939A1, and M939A2 series trucks is hydraulically assisted to provide the operator ease in turning and maintaining control of the vehicle. The major components of the steering systems are as follows:

- Drag link.
- Pitman arm.
- Steering gear.
- Steering wheel.
- Tie rod assembly.
- Power-steering pump.
- Steering arm and knuckle.
- Power-steering assist cylinder.
- Steering column and universal joint.

Air system

The air system on the M939, M939A1, and M939A2 series trucks is similar to a standard truck system. This system also supplies compressed air to air-actuated accessories throughout the vehicle.

NOTE: The M939A2 is equipped with CTIS. Reference the appropriate technical order when troubleshooting the CTIS.

Hydraulic system

Oil pressure (hydraulics) provides operating power for the auxiliary equipment on the M939, M939A1, and M939A2 series trucks. The most common components that use hydraulic power are:

- front winch,

- rear winch (wrecker), and
- wrecker crane.

Front winch

A front winch is installed on M926/A1/A2, M928/A1/A2, M930/A1/A2, M932/A1/A2, and M936/A1/A2 series vehicles. The front winch drive motor hydraulic system converts hydraulic power to mechanical power. The basic operating principles are the same for each model. Reference the front winch system (fig. 4–33) as we discuss the front winch system components listed and described in the table below.

Front Winch System Components		
Figure Item	**Component**	**Description**
1	Clutch lever	A manual control that engages the winch drum gear to the drive gear of the winch motor.
2	Transmission power take-off (PTO) control	A manually operated control lever located inside the cab. The lever permits engagement or disengagement of the transmission PTO.
3	Winch control lever	A manually operated control lever that determines the hydraulic oil pressure flow from the control valve to the winch motor. The flow of the oil determines the direction the winch drum will turn.
4	Transmission PTO	It uses power from the transmission to provide mechanical power to the hydraulic pump.
5	PTO driveshaft	Transmits mechanical power from the PTO to the hydraulic pump.
6	Hydraulic pump	Driven by the PTO driveshaft, the hydraulic pump draws oil from the oil reservoir through hydraulic hoses, then pressurizes and directs oil though the control valve.
7	Oil filter	Filters used or bypass oil from the control valve before the oil returns to the hydraulic oil reservoir.
8	Hydraulic oil reservoir	A storage tank for hydraulic oil.
9	Control valve	A four-port valve that receives pressurized oil from the hydraulic pump and directs it to the winch motor. Additionally, it directs oil returning from the winch back to the oil reservoir. The flow of oil from the valve determines the directional drive of the winch motor.
10	Winch motor	Converts hydraulic power into mechanical power as hydraulic oil is forced through the winch motor.

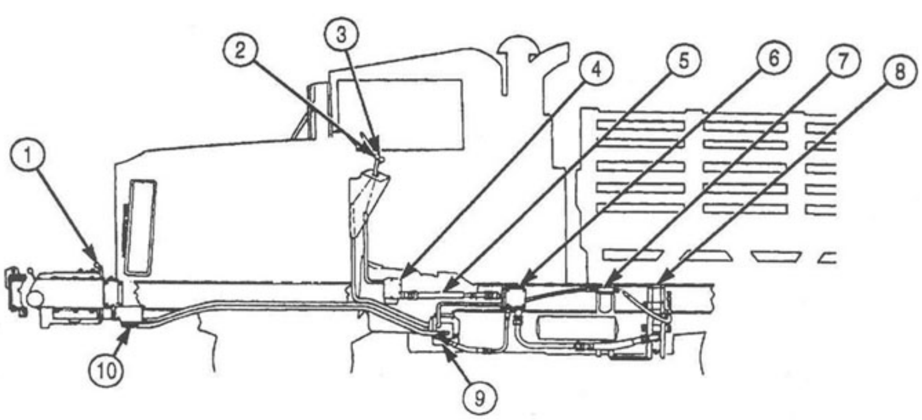


Figure 4–33. Front winch system.

Rear winch (wrecker)

A rear winch is installed only on the M936/A1/A2 medium wrecker and is used primarily to rescue vehicles that are deeply stuck. The rear winch hydraulic system converts engine mechanical power into fluid power using the hydraulic pump. The system then converts the fluid power back to mechanical power at the winch drive motor.

The main difference of the rear-mounted winch from the front-mounted winch is the use of two torque modes. This allows for increased pulling power for heavier loads. Reference the rear winch system (fig. 4–34) as we discuss the system components listed and described in the table below.

Rear Winch System Components and Description		
Figure Item	**Component**	**Description**
1	Transfer case PTO control	A manually operated control lever located inside the cab that permits engagement or disengagement of the PTO.
2	Transfer case PTO	Uses driving power from the transfer case to provide mechanical driving power to the hydraulic pump.
3	PTO driveshaft	Transmits mechanical driving power from PTO to the hydraulic pump.
4	Hydraulic pump	Draws oil from the hydraulic oil reservoir and directs it to the rear winch control valve and winch drive motor.
5	Oil filter	Filters used or bypassed oil from the control valve before it returns to the hydraulic oil reservoir.
6	Hydraulic fluid reservoir	A storage tank for hydraulic oil.
7	Torque control lever	Controls the operating winch drive motor gear ratio. Lever is pulled outward too HIGH for heavy loads or pushed inward too LOW for light loads.
8	Winch directional control lever	A manually operated lever that controls the wind and unwind direction of the rear winch drum. The lever does this by opening and closing the directional control valve to the winch motor and reversing the direction of pressurized hydraulic fluid. The lever is pushed inward to wind and pulled outward to unwind the winch cable.
9	Directional control valve	Receives pressurized hydraulic oil from the hydraulic pump and directs it to the winch motor. The flow of hydraulic oil to and from this control valve provides forward or reverse driving power to the winch motor. The control valve also returns used oil back to the hydraulic oil reservoir from the winch.
10	Torque control valve	Hydraulically controls the hydraulic oil pressure to engage rear the winch drum clutch in high- or low-gear range.
11	Winch motor	Converts hydraulic power back into mechanical power needed to turn the rear winch drum.
12	Control linkage	Connects the transfer case PTO control to the transfer case PTO.

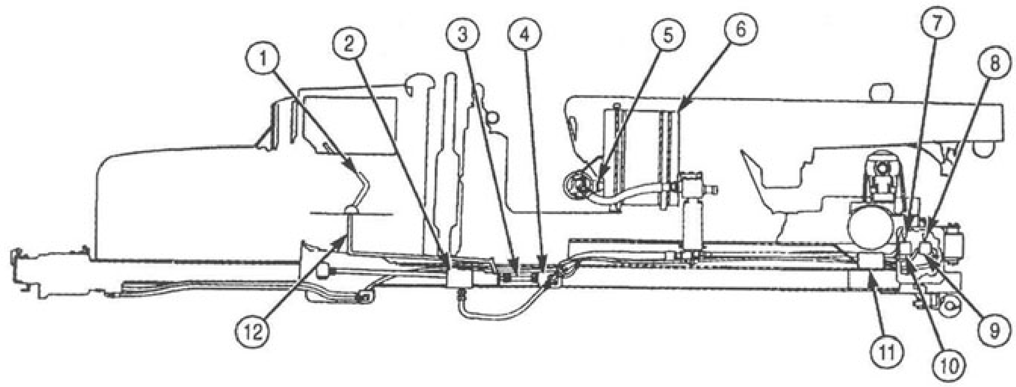


Figure 4–34. Rear winch system.

Wrecker crane

The M936/A1/A2 wrecker is equipped with a hydraulically operated crane that extends a maximum of 18 ft., elevates 45°, and swings 360°. The wrecker is capable of lifting loads up to 20,000 lbs. The crane hydraulic system converts engine power (mechanical) into fluid power (hydraulic) for use by the hydraulic pump. At the pump, oil pressure is supplied to the following four crane control valves:

1. Boom.
2. Hoist.
3. Crowd.
4. Swing.

The major component locations, used for raising and lowering the wrecker boom, are depicted in figure 4–35. Reference it as we discuss the major components listed and described in the table below.

Wrecker Crane Major Components and Description		
Figure Item	**Component**	**Description**
1	Transfer case PTO control	A manually operated control lever located inside the cab that engages and disengages the transfer case PTO.
2	Transfer case PTO linkage	Connects transfer case PTO control to the transfer case PTO.
3	Transmission PTO	Uses transmission-driving power to provide mechanical driving power for the hydraulic pump.
4	PTO driveshaft	Transmits mechanical-driving power from the PTO to the hydraulic pump.
5	Hydraulic pump	Draws oil from the hydraulic oil reservoir and directs it to valves inside the crane control console.
6	Oil filter	Filters used or bypassed oil from the control valve before it returns to the hydraulic oil reservoir.
7	Hydraulic oil reservoir	The storage tank for hydraulic oil.
8	Swivel valve	Permits oil to channel through the pivot post while the crane is swinging, which eliminates twisting of the hydraulic lines connecting the reservoir to the stationary pump.
9	Boom lift cylinder	A hydraulically driven piston that extends upward when the boom control lever is pulled back to the UP position, raising the boom. A check valve located near the hydraulic oil inlet hose prevents the piston from lowering when control lever is in NEUTRAL. Oil returns through the boom control valve back to the hydraulic oil reservoir allowing the piston to lower when the control lever is pushed forward to the DOWN position.

Wrecker Crane Major Components and Description		
Figure Item	**Component**	**Description**
10	Boom hydraulic lines	Carries the hydraulic oil to and from the boom lift cylinder. Oil pumped through the bottom lines pushes the lift cylinder piston upward, and oil pumped through the top lines pushes the lift cylinder piston downward. When this downward action occurs, the oil that originally pushed the cylinder upward is returned to the hydraulic oil reservoir.
11	Boom control lever	A manual control attached to the control valve that determines hydraulic oil flow for the raising and lowering action of the boom. The lever is pulled back to raise the boom and pushed forward to lower the boom.
12	Identification plate	Indicates each control lever.
13	Boom control valve	Located directly below boom control lever. This valve directs hydraulic oil from the hydraulic pump to the boom lift cylinder for lifting or out of the lift cylinder and back to the hydraulic oil reservoir for lowering.

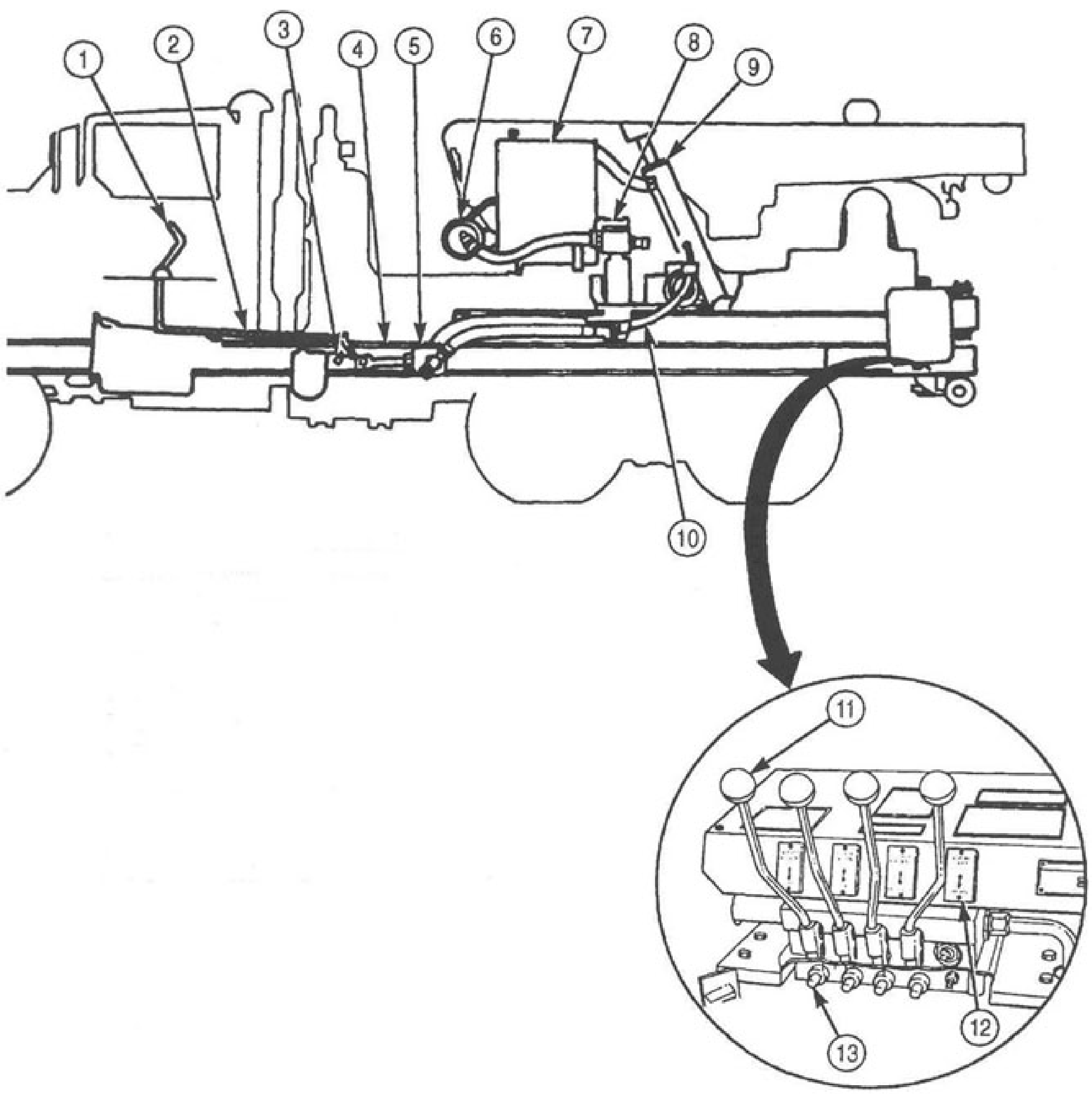


Figure 4–35. Major components for raising and lowering boom.

The major components used for raising and lowering the crane cable and hook for the HOIST actions are depicted in figure 4–36. Reference it as we discuss the major components that are listed and described in the table below.

Major Components For Raising and Lowering The Crane Cable And Hook		
Figure Item	**Component**	**Description**
1	Sheaves	Grooved wheels that guide the hoist cable through the boom.
2	Hoist motor assembly	Converts hydraulic power back into mechanical power that is needed to turn the hoist drum.
3	Upper roller assembly	Prevents cable from contacting inner boom during winding and unwinding.
4	Crane hoist cable drum	Turned by the worm gear in the hoist motor assembly. Drum unwinds cable when turning toward front of vehicle. Drum winds cable when turning toward rear of vehicle.
5	Hoist control lever	A manual control attached to the control valve that determines hydraulic oil flow for the raising and lowering action of the crane hoist cable and hook. Lever is pulled back to raise cable and hook and pushed forward to lower cable and hook.
6	Hoist control valve	A two-way hydraulic valve located under the hoist control lever. The valve directs fluid from the hydraulic pump to the hoist motor assembly and back through the valve to the hydraulic oil reservoir.

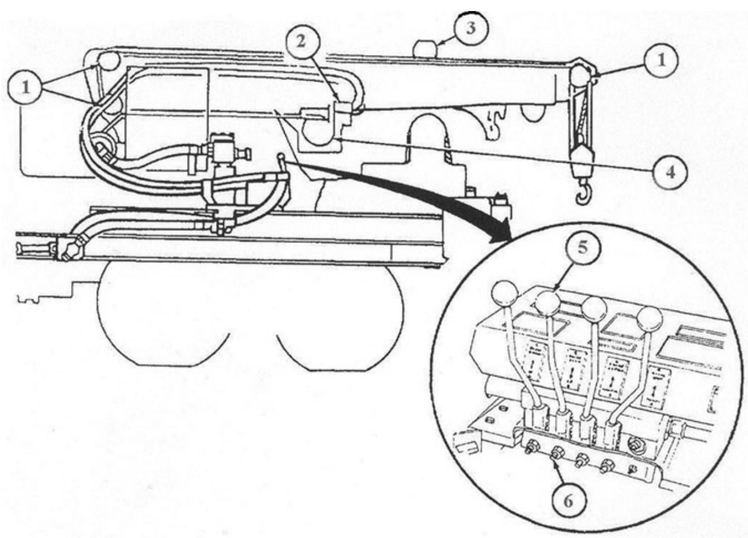


Figure 4–36. Major components for raising and lowering crane cable and hook.

The major components used for extending and retracting the boom for the CROWD action are depicted in figure 4–37. Reference it as we discuss the components listed and described in the table below.

Major Components Used For Extending and Retracting The Boom		
Figure Item	**Component**	**Description**
1	Rollers	Guide inner-boom assembly and permit smooth extension and retraction of boom.
2	Inner boom assembly	Extends when crowd control lever is pushed forward and retracts when control lever is pulled back.
3	Crowd cylinder	A hydraulically driven piston that extends outward when the crowd control lever is pushed forward to the EXTEND position. The piston is hydraulically driven back into the cylinder when the crowd control lever is pulled back to the RETRACT position. This cylinder is contained in the inner-boom assembly.

Major Components Used For Extending and Retracting The Boom		
Figure Item	**Component**	**Description**
4	Crowd control lever	A manual control attached to the control valve that determines oil flow for extending and retracting the crane boom. The lever is pushed forward to extend the boom and pulled back to retract the boom.
5	Crowd control valve	A two-way hydraulic valve located directly below the crowd control lever. This valve directs hydraulic oil from the hydraulic pump to the crowd cylinder to extend and retract the inner boom assembly.

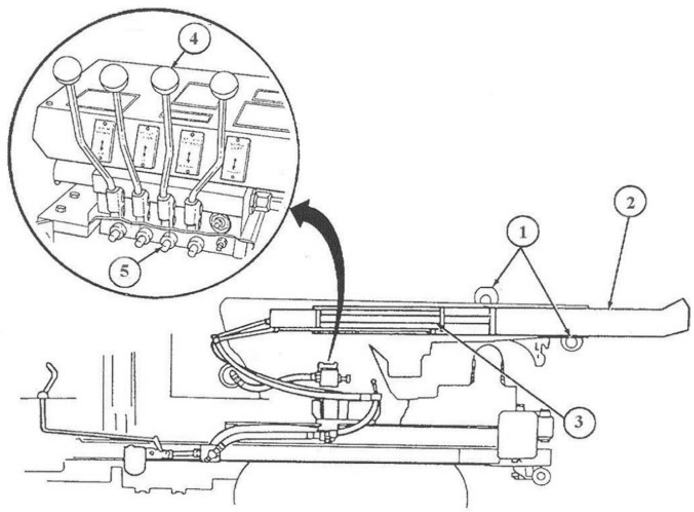


Figure 4–37. Major components for extending and retracting the boom.

Major component used for swinging the crane left and right for the SWING action are depicted in figure 4–38. Reference it as we discuss the components used for swinging the crane that are listed and described in the table below.

Major Component Used For Swinging The Crane		
Figure Item	**Component**	**Description**
1	Swing motor	Converts hydraulic power back into mechanical power needed to turn the crane turntable when hydraulic fluid is forced through its worm gear. This gear turns a large gear at the base of the turntable to swing the crane.
2	Turntable assembly	Driven by the swing motor through a ring gear at the base of the assembly that permits the crane to swing 360°.
3	Swing control lever	It is manually controlled and attached to the control valve that determines hydraulic oil flow for swinging the wrecker boom to the left and right. The swing control lever is pushed inward for left boom movement and pulled outward for right boom movement.
4	Swing control valve	A two-way hydraulic valve located directly below swing control lever. This valve directs hydraulic oil from the hydraulic pump to the swing motor assembly and back through the valve to the hydraulic oil reservoir.

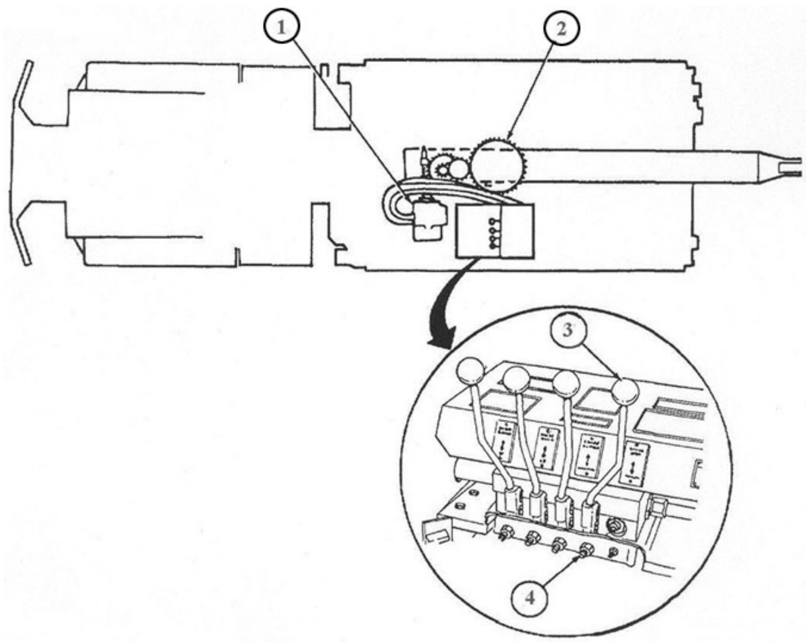


Figure 4–38. Major components for swinging the crane left and right.

026. Isolating and repairing M-series vehicle malfunctions

This lesson covers maintenance procedures on the light-duty and medium series vehicles discussed in this unit. Generally, the troubleshooting and service of the various components is similar for most models. Unless otherwise specified, the following lessons will be general in nature. For any specific procedures, always follow the procedures outlined in the applicable technical order.

Before taking any action to correct a possible malfunction, follow these simple rules:

- Question the operator, if possible, to obtain any information that might help you determine the cause of the problem.
- Never overlook the chance that the problem could be of simple origin. You may be able to correct the problem with a minor adjustment.
- Use all senses to observe and locate troubles (i.e., sight, sound, smell, and touch).
- Use test instruments or gauges to help you determine and isolate the problem.
- Always isolate the system where the malfunction occurred and then locate the defective component.
- Use standard automotive theories and principles when troubleshooting M-series vehicles.

Troubleshooting the mechanical system

You previously learned how to isolate diesel engine maintenance malfunctions. This lesson is not to repeat this information but to show some of the common troubleshooting steps you can take in troubleshooting a vehicle problem.

Some common engine complaints you may come across include: will not crank; cranks but will not start; engine misfires, stalls, or there is a lack of power and acceleration. In this lesson, we will discuss the “engine that cranks but will not start” scenario.

When troubleshooting an engine that cranks but will not start, follow these basic steps:

1. Check the air cleaner indicator. If the color red appears in the indicator window, inspect the air cleaner and element for obstruction. Reset the air cleaner indicator.

2. Open bleeder valve on fuel filter and drain one-half pint of fuel into an approved container. Check for contaminated fuel. Remove fuel tank if water or contamination is present. Clean and flush entire fuel system.
3. Remove and inspect fuel filter element for dirty and clogged condition. Replace if dirty or clogged.
4. Inspect fuel lines and connections for leaks, obstructions, and damage. Tighten loose connections and replace any cracked or damaged tubing. Disconnect lines and check for blockage. Remove blockage, if present. Reattach lines and prime fuel system.
5. Check for white exhaust smoke during cranking. If white smoke is seen, air may be present in the fuel system. Prime the fuel system to remove any trapped air. If white smoke is still seen, coolant may be inside the combustion chambers. If coolant is present on the oil dipstick, it may require a major engine rebuild or replacement.

Troubleshooting the steering system

In this lesson, we will cover some general steering system inspection and maintenance procedures. After prolonged use, steering system components can fail. It is very important that the steering system be kept in good working condition for safe vehicle operation. As a technician, it is your job to find and correct any steering system problems quickly and properly. The procedures in this lesson are general in nature and may not apply to every type of vehicle. Consult the specific vehicle service manual or technical order for exact procedures before attempting a steering system repair.

Inspect steering linkage components

Any looseness in a linkage component can cause a change in alignment, which will wear the tires prematurely. It can also cause the vehicle to wander (not drive in a straight line). Looseness usually shows up as too much “free-play” in the steering wheel. Free-play is when you can turn the steering wheel but the wheels do not respond. Generally, you should not be able to move the steering wheel more than one and one-half inches without causing movement of the front wheels. If the steering wheel rotates beyond this range, a serious steering problem exists. Most of the time, excessive free-play is caused by one of the following:

- Worn steering gearbox.
- Loose steering gearbox bolts.
- Worn ball sockets in a linkage component.
- Worn steering column universal joints or bearings.

Check for looseness in the steering while the vehicle is either on the ground or on a lift. If you find any faulty components, follow the repair or replacement procedures in the specific vehicle technical order.

Steering-stop check and adjustment

The following procedure is a common adjustment on the HMMWV. The steering stops are bolt and lock-nut assemblies located on the lower inside portion of the geared hub. The steering stops limit the outward steering motion of the front wheels. This happens when the head of the bolt makes contact with the control arm.

The steering-stop adjustment (fig. 4–39) consists of the following steps:

1. Draw a reference chalk line 30 ft. long. Mark this line “A.”
2. Position the vehicle so that the center of the left rear and left front tire is positioned directly on the reference line “A.”
3. Mark a second reference line at 34°. Mark this line as “B.” You’ll have to dig out your protractor from when you took geometry class.

4. Mark a third reference line at 36° and mark it as “C.”
5. Roll vehicle forward until center of left front tire is over the intersection of lines “A,” “B,” and “C.” When set, turn the steering wheel full left.
6. If the centerline of the front and rear of the left front tire is over the area between lines “B” and “C,” no adjustment is necessary.
7. If centerline of the front tire is not over the area between lines “B” and “C,” loosen the jamnut and turn the adjustment screw (1) all the way in.
8. Turn the steering wheel until the centerline of the front and rear of tire is over the area between lines “B” and “C.”
9. Loosen the bolt (capscrew) until the bolt head makes contact with the wheel stop on the lower control arm. Tighten the bolt with the jamnut.
10. Repeat adjustment procedure for the opposite side.

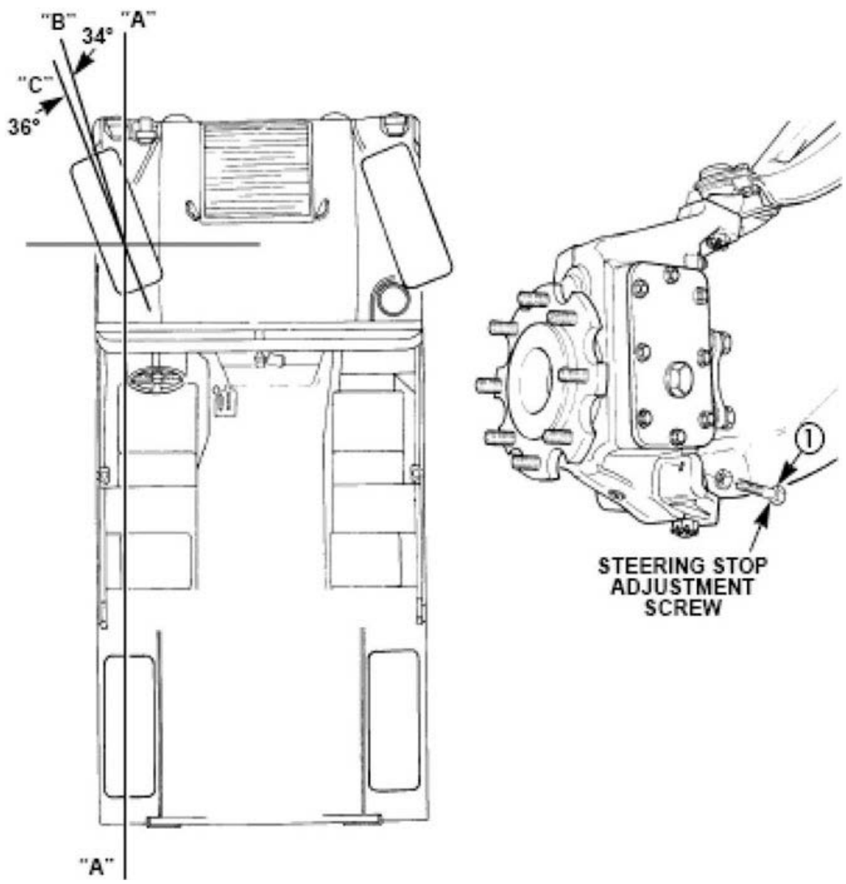


Figure 4–39. Steering-stop reference-line check and adjustment.

Troubleshooting the suspension system

When you work on a suspension system, follow basic troubleshooting and inspection rules. The following guidelines are general in nature. Remember, whenever you are working on a vehicle, always follow the exact troubleshooting and inspection procedures in the service manual or technical order for the specific vehicle you are working on.

The following information is intended to provide you with general inspection and replacement procedures that apply to suspension components. The following table discusses regular inspections on the suspension system.

Common M-series Suspension Problems	
Condition	**Problem Areas**
Noisy operation	Inspect leaf springs for breaks and damage. Replace if damaged. Check spring U-bolts and shackles for lack of lubrication, looseness, wear, or damage. Lubricate as necessary, tighten loose U-bolts and shackles, and replace worn or broken parts. Check rear-spring seat pads for wear. Replace spring seat pads if springs are rubbing against the spring seat bracket.
Continuous wandering or swaying (poor control)	Inspect leaf springs for breaks or damage. Replace if damaged. Check tires for wear. Inspect spring U-bolts and shackles. Check the steering system.
Vehicle sags	Inspect leaf springs for breaks or damage. Inspect spring U-bolts and shackles.
Harsh or rough ride	Inspect spring U-bolts and shackles. Test shock absorbers for resistance. Disconnect top end of shock absorber. Pull up and down to test resistance. If there is little or no resistance, the shock absorber is defective.

When replacing or repairing suspension system components, always follow the step-by-step procedures in the applicable technical order.

Troubleshooting the electrical system

We will discuss the operation of the STE/ICE when testing the M-series electrical system. This particular piece of test equipment can help you isolate malfunctions, anticipate failures, and make sure that proper repairs have been accomplished. Check your shop to see if this test equipment is available. If not, make sure you follow the testing procedures in the technical order.

Using the VTM

The VTM provides a method for the technician to test various vehicle electrical and mechanical components. Readings are either pass/fail indications or digital displays in units familiar to the technician (psi, rpm, volts, ohms, amps, etc.). The DCA is permanently mounted in the vehicle and provides accessibility to the most frequently needed test points. The use of the VTM through the DCA is referred to as DCA mode. The VTM interfaces with the vehicle directly with a transducer(s) from the TK. The use of the VTM through the TK is referred to as TK mode. The DCA and the TK can be used at the same time. This may be necessary when the DCA has a missing transducer. If a transducer is missing, a no-sensor indication (E002) is displayed when a measurement is made. If this happens, the TK mode can be used to make the measurement. The use of the VTM through the DCA and TK is referred to as the *combined mode*.

Additional tests can be done that involve manually probing and/or connecting transducers to appropriate test points. Operating power for the VTM is drawn from the vehicle batteries or some equivalent battery source. Power is routed to the VTM through the DCA connected to the battery. The STE/ICE general-purpose testing capabilities that may be applied to the vehicle are 0–1,000 psi, 0–45 volts, and 0–40K ohms resistance. The following control functions can be performed in conjunction with the special tests: interleave (displays rpm with next test), display minimum/ maximum values, and display peak-to-peak value.

The controls and readout display on the VTM are illustrated in figure 4–40. The following paragraphs describe how the controls are used, and how the readout display functions.

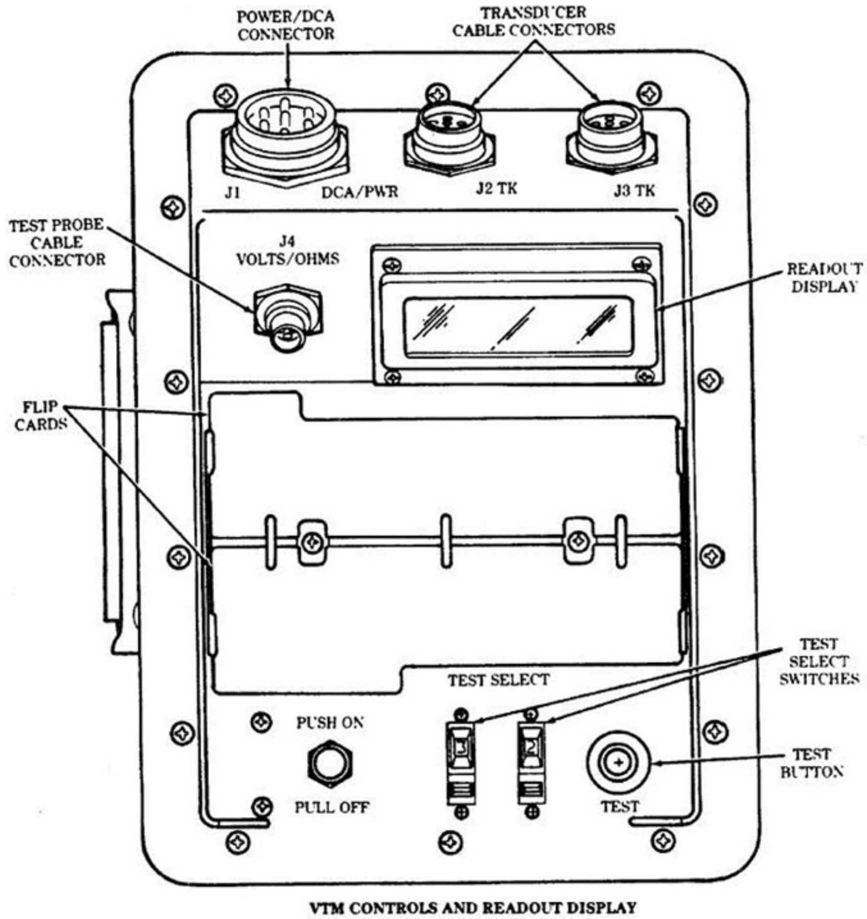


Figure 4–40. VTM controls and readout display.

Power switch

The power switch controls power to the VTM. It can operate from a 12- or 24-volt battery system. When the power switch is pushed in (PUSH ON), the VTM power is on. To shut the VTM off, pull out the power switch (PULL OFF). The power switch contains a 4-amp circuit breaker. The power switch will pop out automatically if something is wrong, which causes the VTM to use more power than it should. If the switch pops out, check your hookup carefully and retry.

TEST SELECT switches

The TEST SELECT switches are used to select the actual test to be performed. There are ten positions on each switch numbered 0–9. The number dialed into these switches is read by the VTM when you press the test button. Changing the TEST SELECT switch positions has no effect until the TEST button is pushed.

TEST button

Depressing and releasing the TEST button causes a test measurement to begin. Observe the measured value on the readout display. The reading will be in units normally used for the particular vehicle measurement. These units are listed on the flip cards. The TEST button must be pressed and immediately released. Depressing and holding the TEST button down initiates an offset test.

STE/ICE go-chain testing

We will discuss the "go-chain" test, which is located in the vehicle specific technical order. Another name for this test is the "go/no-go" test. System tests are laid out as a flow chart where a task is first accomplished, and then based on the outcome you either "go" to the next step or "stop" for further troubleshooting. We will briefly look at an example of the following two tests: the VTM connections and checkout (fig. 4–41) and the compression unbalance (fig.4–42).

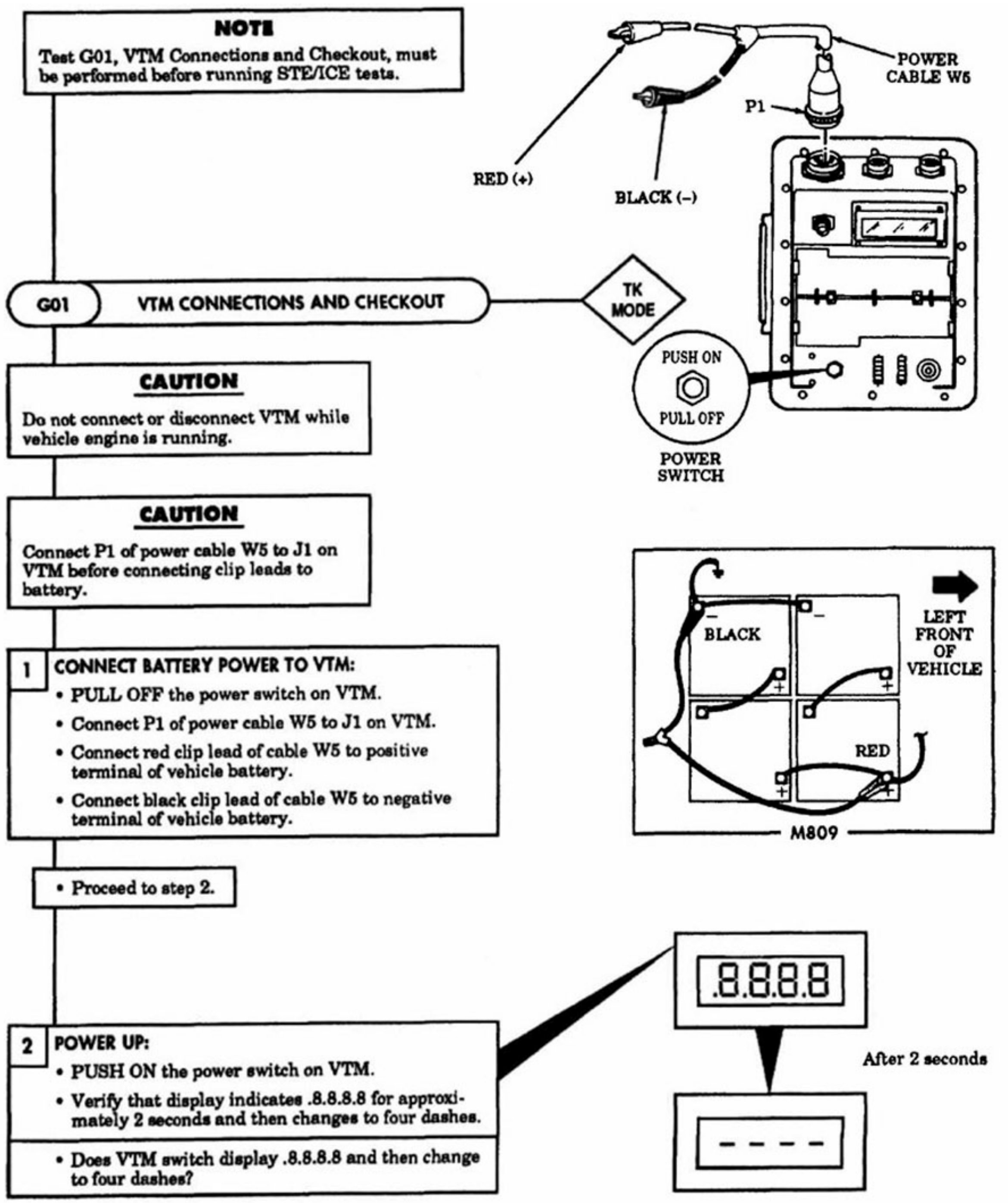


Figure 4–41. Example of VTM connections and checkout test.

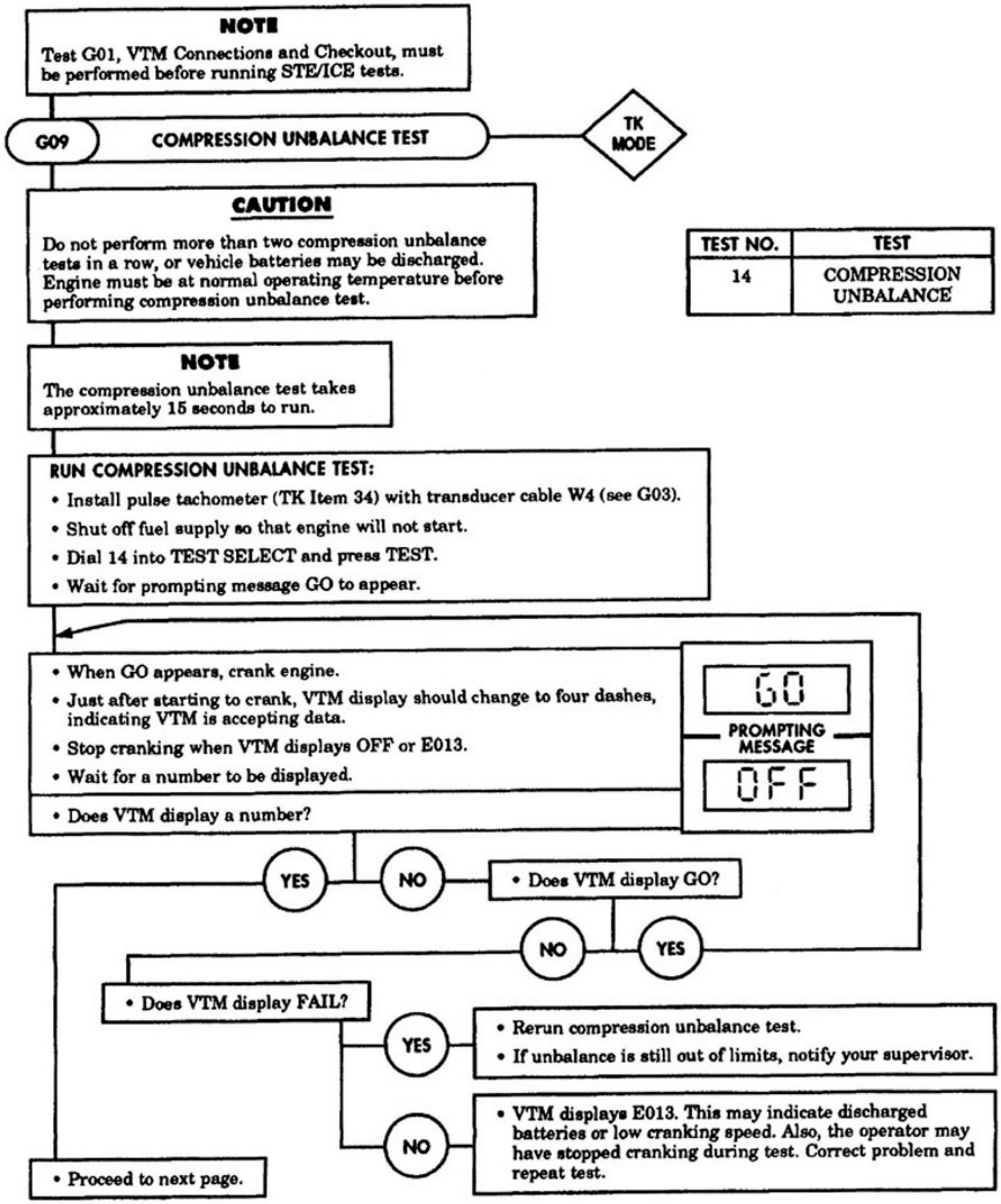


Figure 4–42. Example of compression unbalance test.

As you can see in figures 4–41 and 4–42, you progress through each step-by-step task in order to find the malfunction in the specific system you are checking. These types of tests are very thorough as long as you *do not skip any steps*. Additional information concerning system repair and component replacement is covered in the technical order.

Troubleshooting the compressed air system

Since we discussed the compressed air system in a previous lesson, this lesson will cover only a few troubleshooting basics. Before troubleshooting an air brake malfunction, completely drain all the reservoirs to ensure no moisture is in the system. You will find many problems in the system are caused by moisture buildup. The technical order will provide step-by-step procedures for troubleshooting air system malfunctions.

If you are troubleshooting an air system for “not building up pressure” and the low-pressure air buzzer is sounding continuously, follow these steps:

1. Direct an assistant to start the engine.
2. Check the air reservoir drain valve. Close valve if open. Tighten or replace if leaking.
3. Check the front and rear air gladhands (air brake connects). Close the gladhands if open. Tighten or replace if leaking continues. Also check the trailer gladhand connections.
4. Check the auxiliary air supply valve for leakage.
5. Check air lines for leaks or damage. Tighten loose fittings and replace damaged air lines, if necessary.
6. Check for a defective air compressor governor. With the engine running, check compressor outlet line for heat (high pressure). If outlet line is not warm to touch, continue testing. Carefully loosen the outlet line from the air compressor until air can be heard escaping.

> **CAUTION:** Loosen the outlet line on the air compressor very slowly. Stop the procedure and retighten the fitting the moment air begins to escape. Injury to personnel may result if the output line is accidentally disconnected from a compressor that is operating.

7. Check the governor for proper adjustment and adjust as needed. If the adjustment does not solve the problem, replace the governor and retest the air compressor. If the compressor is still not functioning, a compressor rebuild or replacement may be needed.

Troubleshooting the hydraulic system

Use standard hydraulic troubleshooting techniques previously studied. Always reference the appropriate technical order, and most importantly be safe. The following are general troubleshooting steps to remember when troubleshooting the hydraulic system on the M936/A1/A2 wrecker.

If the hydraulic system does not operate:

1. Check hydraulic oil reservoir for proper fluid level. Fill oil reservoir if necessary.
2. Verify PTO is engaged correctly; if it is not, correctly engage the PTO.
3. Check all hydraulic lines for damage and leaks. Tighten loose fittings. If hoses are leaking or damaged, repair or replace as required.
4. Check reservoir drain plug and valve for leaks. Tighten if necessary.

Drive train component maintenance

The drive train components on the HMMWV are subject to heavy wear due to their unique purpose and capability. The most common drive train component you will service on the HMMWV is the halfshaft(s). The constant velocity (CV) joints can fail under heavy use and the CV boots are subject to wear as well. Additionally, if the brake rotor needs to be removed, the halfshaft must first be separated from the differential output flange. Always follow the procedures outlined in the technical order when servicing the drive train components.

Removal of the halfshaft involves the following steps:

1. Remove the tire, access plug, and washer from the geared hub.
2. Remove the halfshaft retaining bolt (capscrew) and lock washer from the halfshaft and geared hub (refer back to fig. 4–6).
3. Remove six bolts, lock washers, and halfshaft from the rotor and differential output flange.

NOTE: Perform steps 4 and 5 for rear halfshafts only.

4. Remove cotter pin, washer, and clevis pin from parking brake clevis and lever.
5. Remove retaining ring and disconnect cable from caliper cable bracket.

Continue brake rotor service, CV boot replacement, geared hub repair, or complete halfshaft replacement as per technical order specifications.

Replacement of the halfshaft involves the following steps:

1. Install halfshaft into the geared hub.
2. Apply approved sealing compound to halfshaft retaining bolt. Tighten the halfshaft retaining bolt and torque to 37 ft. lbs.
3. Reinstall washer and access plug into geared hub and tighten to 8–13 ft. lbs.
4. Apply approved sealing compound to the six bolts. Install halfshaft to rotor and output flange. Tighten the bolts to 48 ft. lbs.
5. On rear halfshafts, install the parking brake cable bracket with the retaining ring. Ensure the lever is in contact with the caliper bracket stop. Damage to equipment and poor performance will result if not aligned properly. Also, check the alignment of the clevis and clevis pin in the lever to prevent damage to equipment and poor performance.
6. Install parking brake clevis to lever with clevis pin, washer, and cotter pin. Check position of the lever and ensure it is in contact with the cable bracket stop.
7. If lever is not in contact with the caliper cable bracket stop, adjust the rear parking brake following technical order procedures.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

023. High-mobility multipurpose-wheeled vehicle

1. What is the HMMWV designed for?

2. What are the M998 and M1038 models used for?

3. What are the M966 and M1036 models used for?

4. The HMMWV engine is identical on all models except those equipped with a deep-water fording kit, which adds what components to the engine?

5. How is the HMMWV coolant pump driven?

6. Which component directs hydraulic fluid to activate the fan clutch?

7. What does the HMMWV transfer case provide?

8. What is the purpose of the halfshafts on the HMMWV?

9. What component serves as the front-wheel steering spindle?

10. What type of suspension system does the HMMWV have?

11. What provides gear reduction, increasing torque to the wheel and tire assembly?

12. What suspension system component supports the weight of the vehicle and allows suspension travel to vary depending on terrain and vehicle loading?

13. What type of common headlight switch is used on M-series vehicles?

14. What is the purpose of the blackout lamp and markers?

15. What does it mean if you see two red “cat eye” blackout markers on each side of the vehicle in front of you during night convoy operations?

16. What does the rotary switch provide?

17. What generating system circuit provides a ground circuit to the alternator?

18. What circuit connects the batteries to the starter and to the protective control box through circuit 81A?

19. At what component is the junction point for the battery positive lead (circuit 6A) and the vehicle electrical feed wire (circuit 81A)?

20. What is the purpose of the runflat tire and wheel assembly?

21. What special test can be performed with the STE/ICE system?

22. How is the VTM powered?

024. 2½-ton M-series

1. Which 2½-ton M-series model truck is not suited for maneuvering in limited spaces? Why?

2. Which engine component allows unrestricted oil flow if the oil cooler and filter are plugged?

3. When used in conjunction with the transmission, the transfer case provides how many forward and reverse gears?

4. What type of fuel injector system is used in the M35 engine?

5. What are the M35 main cooling system components?

6. What is the purpose of the M35 throttle control located in the cab?

7. What provides the operator with the current tire pressure and maximum speed for the selected terrain setting?

8. At what psi will the M35 low-air pressure indicator light illuminate?

9. What are the two STE/ICE-R operating modes?

025. 5-ton M-series

1. What is a rear bogie?

2. What major component of the 5-ton M-series permits the vehicle to be towed by another or tied down for transporting?

3. List the electrical subsystems of the 5-ton M-series electrical system.

4. What are the most common components that provide hydraulic power on the 5-ton M-series?

5. What is the purpose of the control valve in the front winch of the 5-ton M-series?

6. What is the main difference between the front and rear winches on the 5-ton medium wrecker?

7. Which rear winch component controls the hydraulic pressure to engage the winch clutch for high- and low-mode selection?

8. How many lbs. is the 5-ton medium wrecker capable of lifting?

9. What major component used for raising and lowering the wrecker boom engages and disengages the transfer case PTO?

10. What major component used for raising and lowering the wrecker boom eliminates twisting of the hydraulic lines connecting the reservoir to the stationary pump?

11. What major component used for raising and lowering the wrecker boom directs hydraulic oil from the hydraulic pump to the boom lift cylinder for lifting?

12. What major component used for raising and lowering the wrecker crane cable and hook guides the hoist cable through the boom?

13. What major component used for extending and retracting the wrecker boom permits smooth extension and retraction of the boom?

14. What major component used for swinging the wrecker crane left and right is driven by the swing motor through a ring gear?

026. Isolating and repairing M-series vehicle malfunctions

1. If the engine air cleaner indicator window reflects red, what does it mean?

2. You notice white exhaust smoke during engine cranking, what is your next step?

3. What are some causes of excessive steering wheel “free-play” on an M-series vehicle?

4. What is the purpose of the “steering stop” on the HMMWV?

5. What is the first step when performing a “steering-stop” adjustment?

6. What should you look for when troubleshooting a sagging vehicle?

7. What control functions can be performed in conjunction with the special tests when using the VTM?

8. How do you initiate a measurement test with the STE/ICE?

9. When STE/ICE “go-chain” testing, what is one important thing to remember?

10. Why can’t you remove the output line from an operating compressor during testing?

11. What is the first thing you check if the hydraulic system does not operate?

12. Before removing an HMMWV brake rotor, what component must be removed first?

13. What is the first step when removing a halfshaft on an HMMWV?

14. When installing the HMMWV rear halfshafts, what may result if the parking brake lever is not aligned properly with the caliper bracket stop?

4–2. Mine Resistant Ambush Protected

The MRAP series of vehicles were developed for one purpose: protect our military men and women from the enemy. The enemy likes to use explosive devices to harm our troops. The threat comes from improvised explosive devices (IED), rocket propelled grenades (RPG), mines, small-arms fire, and other types of weapons. MRAP vehicles are produced by a variety of companies and each company offers different versions. They are differentiated by category (CAT). There are three CATs of MRAP: CAT I, CAT II, and CAT III. The Air Force is using CAT I and CAT II MRAP vehicles. In this CDC, we will cover the International Military and Government (IMG) Limited Liability Company (LLC) MaxxPro CAT I MRAP.

NOTE: The following lessons were built from technical data available on a specific MRAP revision at the time of CDC production. Expect variations in the MRAPs as options or improvements are added and variants are designed throughout the production run. Always use the most current technical order specific to the model of MRAP you are maintaining.

027. MRAP fundamentals

The IMG MaxxPro (fig. 4–43) can carry up to six personnel. It is a four-wheel–drive vehicle with a curb weight of 21K–32K lbs. and a gross vehicle weight (GVW) of 31K–52K lbs. This small MRAP is designed for small unit missions in urban or confined areas. Missions performed by this CAT I MRAP include the following:

- Reconnaissance.
- Mounted patrols.
- Convoy security.
- Casualty evacuation.
- Troop or cargo transport.
- Communications/command and control.

The vehicle can operate in most weather and terrain conditions. It can ford water up to 36 in. deep and climb or descend grades up to 60 percent.

The major systems of the vehicle include the cab, mechanical system, electrical system, air system, suspension, steering, and winch. We will also cover the fire suppression and HVAC and life support system (LSS) systems.

Figure 4–43. MaxxPro.

Mechanical system

The majority of the mechanical (drive train) system on the MaxxPro consists of commercial off-the-shelf components. This allows for ease of maintenance and parts procurement as well as reliability and longevity. We will discuss the engine, transmission, transfer case, axles, suspension, steering, air system, and brakes as well as the wheel and tire assemblies.

Engine

The MaxxPro is powered by an International DT 530, in-line six-cylinder computer-controlled diesel engine capable of running on diesel or JP-8 fuel. The engine produces 330 hp and 950 ft. lbs. of torque. Maximum engine speed is governed at 2,200 rpm. The engine uses a conventional cooling system consisting of a radiator, fill reservoir, and surge tank as well as a full flow oiling system.

Fuel injection is accomplished using hydraulically actuated, electronically controlled unit injectors (HEUI). The high-pressure engine oil used to actuate the injectors is supplied by a high-pressure oil pump, lines, and a high-pressure oil manifold. A low-pressure fuel pump supplies fuel to the injectors through a fuel rail in the cylinder head. The engine has an air inlet preheater located in the intake for cold weather starting.

Exhaust brake

The MaxxPro is equipped with an exhaust brake system. Using the exhaust brake allows the operator to slow the vehicle or maintain a constant speed when descending steep road grades. This reduces the need to use the service brakes in these conditions where prolonged use of the service brakes could cause brake failure. The exhaust brake should not be used in rain or other slippery conditions. Doing so may cause skidding and possible loss of control.

CAUTION: The service brakes should always be used as the primary vehicle braking system. The exhaust brake should never be considered a substitute for the vehicle’s service brakes. The exhaust brake cannot bring the vehicle to a complete stop. Only the service brakes can bring the vehicle to a complete stop. Using the exhaust brakes in place of the service brakes may result in death or injury to personnel or damage to equipment.

Diesel heater

The vehicle is equipped with an auxiliary diesel heater (fig.4–44) to assist during cold weather starting by heating the engine coolant to 149–176°F. Warm air is also provided for the interior of the vehicle. Once the engine is started, it uses the engine coolant to heat the engine block and provide heat to the interior of the vehicle. The auxiliary diesel heater is controlled by switches on the control panel of the HVAC and LSS system.

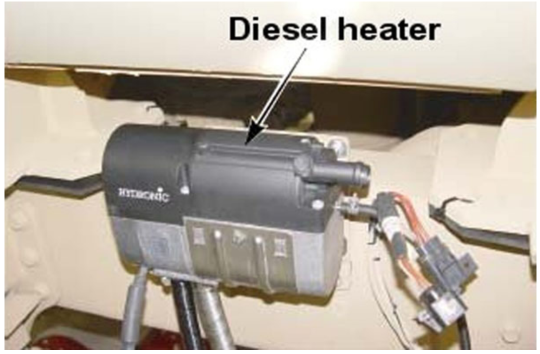


Figure 4–44. Auxiliary diesel heater.

Transmission

The engine drives an Allison 3000SP electronically controlled, automatic transmission. The transmission provides five forward and one reverse gear. The transmission uses an oil cooler attached to the radiator to help keep the transmission fluid cool under adverse conditions. The transmission control is a push-button–type, which allows the operator to choose reverse, neutral, or drive as well as change the drive range by using up and down arrow keys.

Transfer case

The transmission drives a two-speed transfer case equipped with an internal oil pump and external oil cooler. The transfer case is *not synchronized.* This means that the operator must stop the vehicle completely to change from rear-wheel drive to four-wheel drive or when changing between HI and LOW range. Failure to stop the vehicle can result in severe transfer case damage. The transfer case also has a neutral position that can be used when towing the vehicle. The transfer case mode and range is selected using rocker switches located on the instrument panel between the driver and passenger seats. The transfer case is shifted by air cylinders built into the assembly.

Axles and suspension

The MaxxPro utilizes heavy-duty, full-floating, commercial truck axles. The front axle has an 18K lb. capacity while the rear axle has a 23K lb. capacity. They attach to the vehicle frame through the use of a conventional leaf spring suspension.

Steering

Steering is accomplished using a cross-steer linkage system. The power steering pump provides hydraulic power to an integral power-steering gearbox. The left-steering gearbox houses the control valve for the power steering. The left gearbox control valve also sends hydraulic fluid to a second “slave” gearbox on the right side of the truck (fig. 4–45).

When the power steering is functioning properly, both gearboxes move in unison. Two power-steering gearboxes provide for ease of steering as the steering system on this vehicle requires significant force to move. A pitman arm from each gearbox transmits movement through drag links to the upper steering arm on both spindles (steering knuckles). A second steering arm on each spindle connects to a tie rod, which, in turn, connects the spindles together. This ensures the wheels turn together and maintains steering alignment.

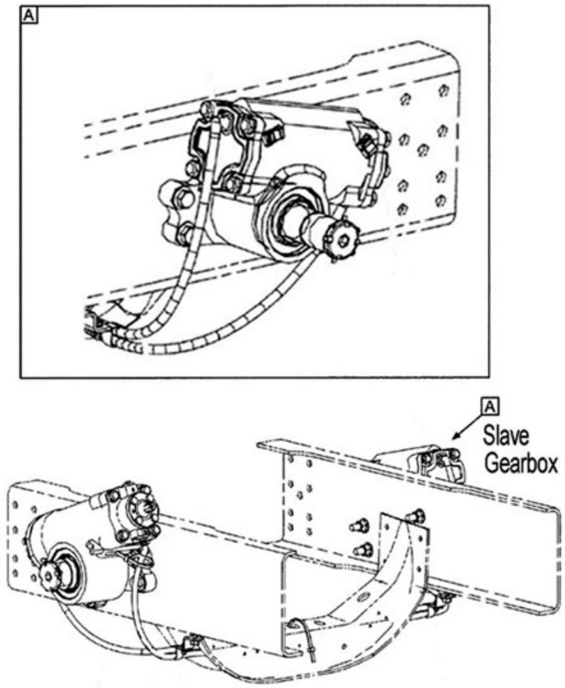


Figure 4–45. Dual-steering gearboxes.

Air and brake systems

The air system provides air for the service brakes, air assistance for the vehicle doors, and shifting of the transfer case. Opening and closing of the vehicle's doors is assisted by pneumatic (air) cylinders mounted inside each of the side doors. The air system components include the following:

- Air dryer.
- Governor.
- Associated valves and lines.
- Engine driven air compressor.
- Primary and secondary supply tanks.
- External air connection—used to inflate tires or run small air tools.

The vehicle uses a standard air brake system. The front brakes are disk-type brakes that use service brake chambers to actuate the calipers. The rear brakes are the drum type and are equipped with spring-applied parking brakes. There are gladhands on the front and rear of the vehicle. They can be used to supply air to a trailer or another MRAP that is being flat towed.

The MaxxPro is equipped with an ABS, which helps improve braking when excessive wheel slippage or wheel lock-up is detected. The ABS system will take over and apply or relieve extra pressure to the wheel or wheels that need it. When activated, you will feel a fast pulsation on the brake pedal. This is normal; the ABS system is taking over and stopping the vehicle or slowing it down.

As with other ABS systems, apply steady pressure to the brake pedal; *do not pump the brakes*. The ABS system is integral to the service brakes. The ABS components include an ECM, wheel-speed sensors, control valves, and an indicator light. If the ABS light stays illuminated or flashes during vehicle operation, a malfunction has been detected.

Wheel and tire assemblies

All MRAPS are required to have runflat capability. You definitely would not want to stop to change a flat tire in a combat situation. The wheel assembly consists of a two-piece bolt-together rim, an

O-ring to seal the two halves together, and a runflat (fig. 4–46). The whole assembly is like a larger version of an HMMWV wheel and tire assembly. The runflat capability allows the vehicle to operate at speeds of up to 35 mph for up to 30 miles.

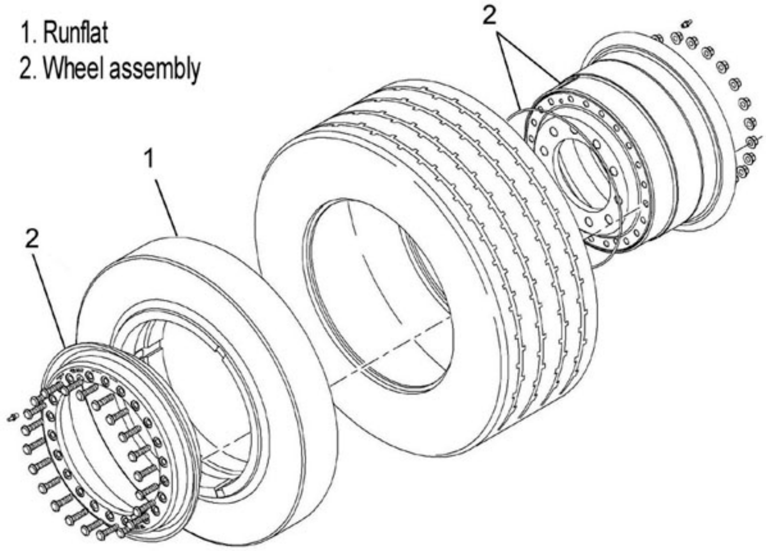


Figure 4–46. Wheel assembly with runflat.

Electrical system

The MRAPS electrical system is powered by a 24-volt alternator, which runs the vehicle while the engine is operating and it charges the four 12-volt batteries. The batteries are connected in series-parallel and are located under the right-hand passenger front side of vehicle. These batteries provide 12- or 24-volt power.

A battery disconnect system, controlled by a switch on the dash, protects the batteries from being drained if accessories were left on. There is a standard NATO slave receptacle, in the right front storage box, for jump-starting disabled vehicles. The vehicle is also equipped with a power inverter box (fig. 4–47), which provides 110 VAC at receptacles in the right rear-stowage box and in the cab. There are also several 12-volt receptacles located in the cab.

Figure 4–47. Inverter.

Just like other M-series vehicles, this vehicle has both conventional and blackout lighting systems. The conventional and blackout lighting systems are controlled by the newer style push-button light switch. There is also a remote-control spotlight mounted on the vehicle roof as well as an infrared (IR) light located on the front bumper for use with night vision.

HVAC, LSS, and fire suppression system

The purpose of the HVAC, LSS, and fire suppression system (FSS) is to protect the vehicle's occupants from heat; cold; nuclear, biological, chemical (NBC) threats; and fire.

HVAC and LSS

The HVAC and LSS regulate the fresh and recirculated air within the cabin. It provides protection from outside extreme hot or cold temperatures. Fresh air (FA) is received into the vehicle's cabin through an inlet located on the vehicle's roof. The pretreated air then moves through an evaporator and a heater, where FA is mixed with recycled air (RA). A blower injects the treated air into the cabin. In a wartime configuration, the system provides protection from NBC agents through the use of special filters. The filters do not decontaminate or neutralize contamination; they only collect and contain it.

The HVAC unit is inside the vehicle, on the cab's right-side wall, behind the front passenger seat. The NBC filter is accessed externally. Vehicle occupants can control the HVAC system functions with a mode selection panel, located directly behind the front seats (fig. 4–48). Controls consist of a group of switches. The HVAC system operates in the following modes:

- DRY**—**this is the defrost mode. When using this mode, open the handle above the driver to direct air to the window. Use the temperature level to adjust heat setting.
- HEAT**—**this setting provides maximum heat to the cab area.
- OFF**—**turns off FA and recirculating air in the cab area.
- VENT**—**only FA received from the outside enters the cab through the NBC filter (if installed). You cannot adjust the fan speed.
- COOL**—**FA and RA are mixed and cooled to provide air conditioning.

There are also controls for temperature level and fan speed.

Figure 4–48. HVAC/LSS control panel.

The LSS, integrated within the vehicle's HVAC system, provides a safe and comfortable indoor air supply for cabin occupants. The LSS is activated by a toggle switch on the HVAC control panel. The LSS unit has the following functions:

- Ventilation.
- NBC protection.
- Space air-conditioning.
- Dust and particulate removal.
- Cabin pressurization with fresh air.

The overpressure in the cab created by the LSS system prevents outside contaminates from entering the cab through small leaks in door seals or other areas of the cab. The overpressure causes clean air in the cab to be forced out through any leaks, in turn keeping contaminates out. A pressure gauge on the dash allows personnel to monitor the pressure in the vehicle and will indicate if a significant leak is present.

FSS

The FSS utilizes a dry chemical to extinguish fires. It is designed to fight fires both inside and outside of the vehicle. The MaxxPro's FSS is actually comprised of two separate FSS systems: Kidde Automatic Fire Extinguisher System (AFES) and Firetrace Manual Fire Suppression System. The Kidde AFES protects the engine and interior, while the Firetrace protects the tires and fuel tank (fig. 4–49).

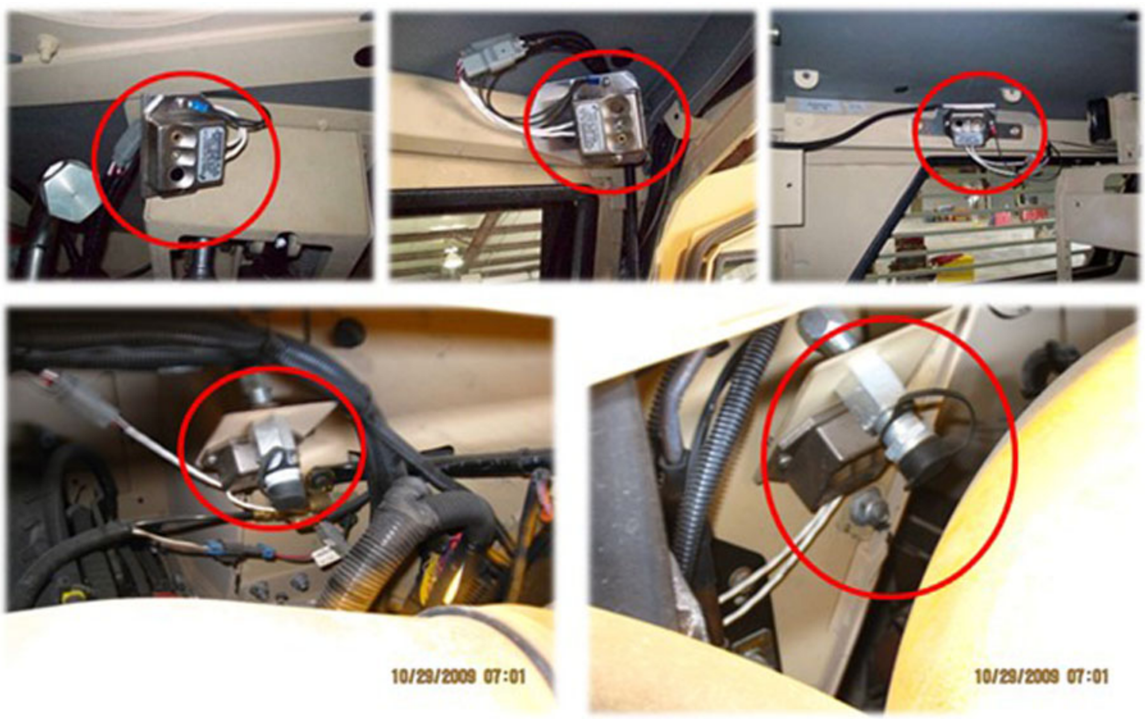


Figure 4–49. Kidde optical fire sensors.

The Kidde system can detect a fire situation by using five optical fire sensors mounted throughout the vehicle. Three sensors are mounted within the crew subsystem and two located in the engine subsystem. Each of these sensors detect two forms of IR light, short and long wavelength.

The engine and interior fire sensors will automatically operate the FSS when fire is detected. For reference during inspection and maintenance, the wire loom (a plastic sleeve that protects the wiring) that is connected to each sensor provides labels that number each sensor. This number represents its position in the circuit. For example, sensor 1 comes first, then sensor 2, followed by sensor 3, which is the end of line (EOL) sensor for the interior circuit. There are no optical sensors used for the tires and fuel tank subsystem because the Firetrace system must be manually activated using a toggle switch.

The FSS control panel (fig. 4–50) has indicator lights and manual switches for each system, a dimmer, and a power indicator lamp. When a fire is present in one of the protected areas (engine, interior, tires, or fuel tank) the operator can manually activate the needed system by lifting up the switch cover and flipping the toggle switch up. Remember, the tire and fuel tank subsystem can only be activated manually. Each protected area has its own separate FSS bottle(s). The bottles for each area are located in or near that area. For example, the bottles for the interior are located behind the HVAC/LSS control panel and at the rear of the cab. The FSS operates on 24-volt power and uses a battery backup located under the driver seat. The backup provides up to 10 minutes of reserve power to activate the AFES when needed.

CAUTION: Prior to servicing the FSS, ensure the master battery disconnect switch is OFF and the FSS battery backup connector is removed from the battery backup box. Failure to comply may result in accidental discharging of system and injury to personnel.

Figure 4–50. FSS control panel.

Vehicle body and armor

The MaxxPro provides protection for the crew from blast, shock, fragments, and affects explosive blasts. The “V” shaped hull and other design features provide protection even when an explosive device is detonated under any wheel or directly under the crew compartment. The vehicle armor helps protect the crew against anti-tank mines, small-arms fire, IEDs, and overhead airburst. Additional crew protection is provided by the four-point restrain system and shock-absorbing seats.

Cab

The base cab is constructed of metal-composite materials made of ceramic armor. External armor modules, called “catcher” plates (fig. 4–51), equipped with internal high-performance liners are attached externally to the base armor. The panels are bolted together and sealed. The catcher plates are removable and can be replaced if damaged.

Figure 4–51. Catcher plates.

Another layer of armor that may be used is called “effector” assemblies (fig. 4–52). They are supplemental armor assemblies that attach to brackets that hold the effector plates several inches from the vehicle body. The armored windows, made from multiple layers of ballistic glass and laminate, are bolted on and do not open.

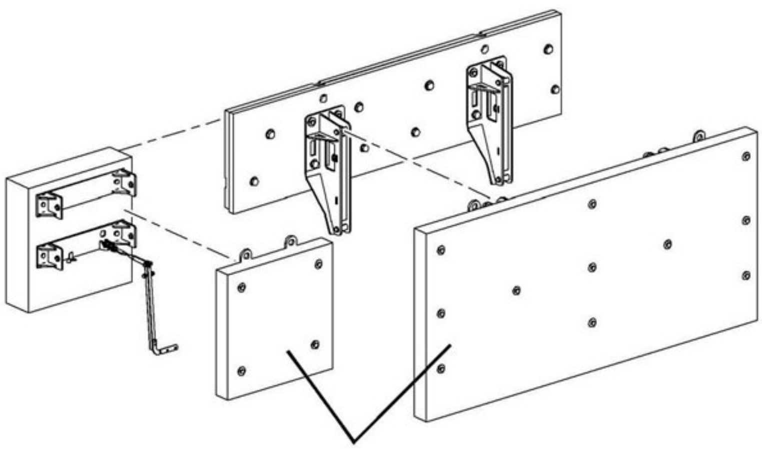


Figure 4–52. Effector assemblies.

Doors and hatches

The MaxxPro has several doors and hatches to provide entry and exit from the vehicle during normal and egress conditions. There are two forward doors: one for the driver and front passenger, as well as a rear door for crew or cargo. Located on the roof are two hatches: one is the gunner’s hatch and the other is strictly used for escaping the vehicle in an emergency. There are also six gun ports, three on each side of the vehicle.

Forward doors

As mentioned above, there are two forward doors. One is for the driver and the other for the vehicle commander. Because the doors are very heavy, opening and closing the doors is assisted by air cylinders located in each door. When you push open or pull close on the door handle linkage, it actuates an air valve. The valve sends air pressure to the cylinders that push or pull on a linkage assembly to assist in door operation. The doors are also equipped with a combat lock. The purpose of the combat lock is to secure the door from the inside to keep the enemy out and keep the door closed during an explosion, rollover, and so forth.

The combat lock consists of a lever, linkages, and locking plates. When the combat locks are engaged, the locking plates rotate into position effectively locking the door to the cab. The combat lock can be opened from the outside of the vehicle in the case an emergency evacuation is necessary. A small shaft protruding from the door connects to the linkage inside the cab. The shaft can be rotated by inserting a screwdriver into a hole in the shaft and rotating the shaft counter-clockwise.

Rear door

The MaxxPro has one large rear door, hinged at the bottom, which opens like a ramp. The ramp is equipped with stairs allowing for easy entry and exit by personnel. The rear door is opened and closed hydraulically but can be opened manually in an emergency. The door hydraulics can be operated electrically using toggle switches located on the center dash panel or on the hydraulic pump cover at the rear of the cab (fig. 4–53).

Figure 4–53. Rear-door hydraulic pump assembly.

The hydraulic system operates one cylinder, which provides the power to lower and raise the rear door. The rear door hydraulics may also be operated manually. To operate the ramp using the hydraulic pump located in the crew compartment, push the round plunger in and turn the plunger clockwise, insert the handle into the pump, and move the handle up and down to lower the ramp. To raise the ramp, turn the round plunger counter-clockwise and push the plunger out, insert the handle into the pump, and move the handle up and down to raise the ramp.

To operate the ramp manually, remove the safety pin from the lower connection point of the main cylinder. Using the pump handle, place it in the hole on the center bar and rotate the center bar to unlock the ramp. Remove the pin in the lower connection point of the main hydraulic cylinder to allow the ramp to fall open.

CAUTION: Ensure the area behind the rear door is clear prior to lowering it, especially when doing so manually. Anyone struck by the falling door may incur serious injury or be killed. DO NOT operate the door while the vehicle is in motion, and stay clear of pinch and crush points during door operation.

Hatches

As mentioned earlier, the vehicle has two hatches, one for the gunner and an escape hatch. The gunner's hatch is located in the roof just behind the driver. The hatch slides open and closed and is operated manually. To open the hatch, it must be unlocked and slid rearward until it locks in the open position. It must also be unlocked prior to being closed. The locking open feature prevents the gunner from being injured by the hatch sliding closed.

CAUTION: Ensure that the gunner's hatch is in the locked position before moving the vehicle. The gunner's sliding hatch can only be opened or closed when the vehicle is stationary and on a level surface. DO NOT attempt to open or close the hatch when the vehicle is in motion. Keep arms and hands clear of the gunner's hatch when closing it. Failure to comply may result in serious injury or death.

The emergency hatch is located in the roof at the rear of the vehicle. This hatch allows for escape in the event of a rollover when the other doors are inoperable. The hatch is opened manually and held closed by a latch.

CAUTION: The vehicle must not be operated with the emergency hatch open. Use caution when opening or closing the hatch; it is heavy and can cause serious injuries.

Additional armor components

Although the armor on the MaxxPro is centered around the cab, there are other protected areas that help the vehicle's survivability. These armor components help protect critical vehicle systems, such as the drive train, fuel tank, and batteries. The engine is protected by an armor plate assembly on each side and an armored grill in the front. The battery box and fuel tank are both protected by armored enclosures. The belly armor plate is large and helps protect the fuel tank, battery box, air tanks, as well as the transmission and transfer case. These additional armor components along with the main cab provide excellent protection to the vehicle and its occupants.

028. MRAP maintenance

Next, we will discuss some basic MRAP maintenance procedures. We will begin with electrical maintenance, followed by LSS and HVAC maintenance. Then, we'll discuss inspecting the FSS, and finish with a discussion of body armor removal and installation.

Electrical maintenance

The electrical system is capable of running self-diagnostics via the electrical system controller (ESC), which alerts the operator by illuminating the check electrical system light on the electronic gauge cluster (EGC) and storing DTC. These codes are viewable through the EGC. Now we will discuss how to access and read these codes to assist in troubleshooting the electrical system.

To place the EGC in diagnostic mode, turn the ignition switch to the ON or ACCESSORY position, then press the cruise control ON and RESUME switches simultaneously. If there aren't any faults, the EGC will display NO FAULTS. If there are faults present, the EGC will display the number of faults followed by the codes. Look at figure 4–54 for an example of how the DTC is displayed and read. The code will be displayed for 10 seconds, before automatically scrolling to the next entry and continuing to cycle. You can also manually cycle through the codes using the SELECT/RESET button on the cluster.

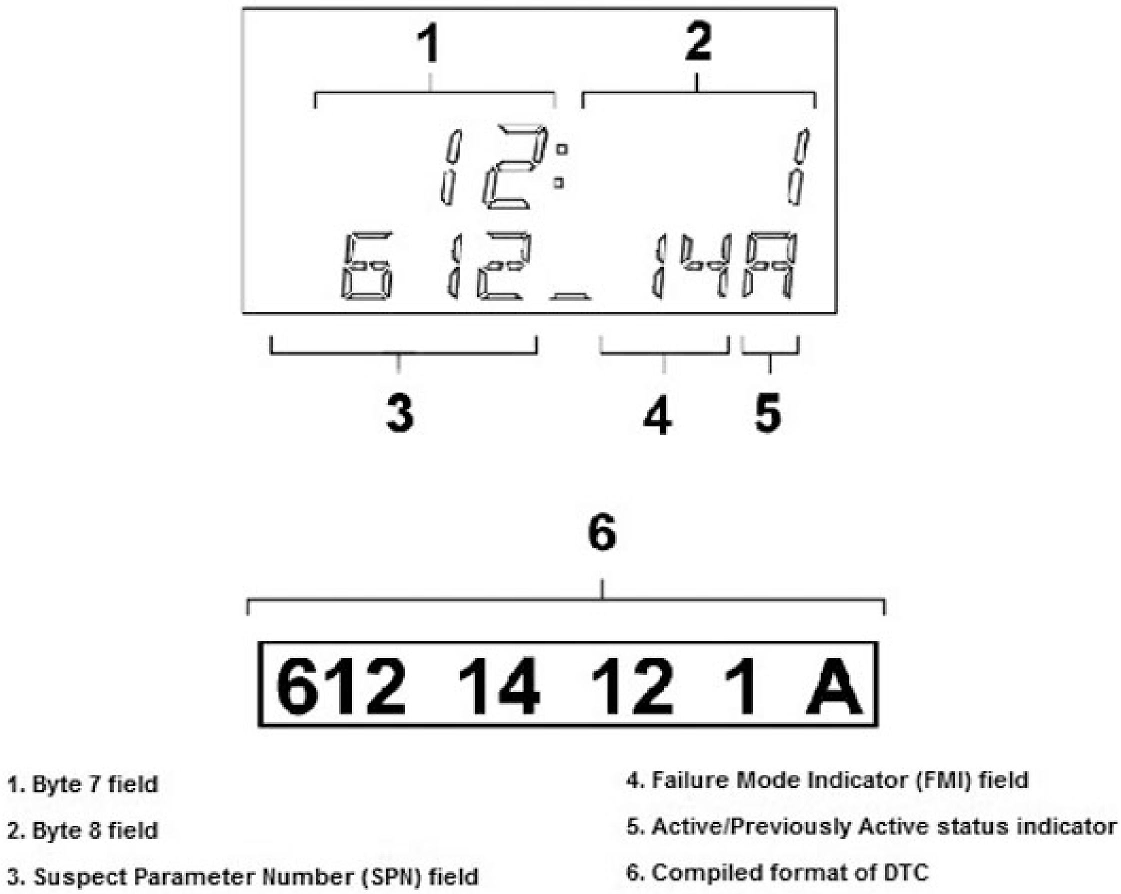


Figure 4–54. Electrical system DTC display.

Record the code in the following format: (SPN) (FMI) (Byte 7) (Byte 8), and compare it with the DTC listing in the appropriate technical order.

DTCs will end with an “A” if the code is active, meaning the feature is turned on and the fault is still detected. If the feature is turned off or the fault is not detected, the code will be considered previously active and will end with a “P.”

While in the diagnostic mode, P diagnostic trouble codes may be cleared by turning the left turn signal ON and pressing the cruise control ON and SET switches simultaneously.

To exit the diagnostics, cycle the ignition switch or release the parking brake.

NOTE: This diagnostic procedure will also initiate diagnostic flash codes for the engine controller and hydraulic ABS controller. However, these codes will not be affected by the clearing procedure.

LSS and HVAC maintenance

In order to troubleshoot the LSS and HVAC systems, it’s best to begin with a thorough function check to identify all symptoms associated with the malfunction. To do this, begin by checking the air conditioning.

COOL mode check

The following procedures are performed to complete the COOL mode check.

1. Connect an AC recovery/recharging unit. The valves on the tank and control panel should be CLOSED, with the high- and low-side hose valves near the service ports OPEN. This allows you to use the gauges to monitor pressures on the AC recovery/recharging unit during the operational check.
2. Place an AC thermometer in the forward side of the HVAC box near the RA temperature sensor.
3. Turn the main power switch on and start the engine.
4. Turn the LSS switch to the ON position.
5. Turn the mode control knob to the COOL position.
6. Turn the RA blower speed control knob to the MAX position.
7. Turn the temperature control knob to the coldest position.
8. Close all doors and hatches to seal the cabin.
9. Check for the following conditions:
    - Engine speed increases to 1,300 rpm (+/-800 rpm) within 10 seconds.
    - RA blower is running at maximum speed.
    - FA blower is on. (It may be necessary to reduce RA speed to the minimum position so you can hear the FA blower operating.)
    - AC compressor clutch engages.
    - All four condenser fans should turn on and off as a group to regulate AC pressure between 174 (+/–29) and 232 (+/–25.4) psi.
    - Cabin pressure between 0.8–2.8 inches water column (WC), as measured on the dash gauge.
    - Difference between outside air and thermometer is around 30°F after 30 minutes of run time (unless cabin temperature drops below 67°F).

HEAT mode check

Next, check the heater system by following these procedures:

1. Turn the mode control knob to the HEAT position.
2. Turn the temperature control knob to the warmest position.
3. Wait five minutes for system to stabilize.
4. Check for the following conditions:
    - Cabin temperature begins to rise.
    - AC compressor is off.
    - Condenser fans are off.
    - Engine returns to normal idle speed.

DRY mode check

Now, check the defrosting function by completing the following steps:

1. Turn the mode control knob to the DRY position.
2. Wait five minutes for the system to stabilize.
3. Check for the following conditions:
    - Engine speed increases to 1,300 rpm (+/–800) within 10 seconds.

- AC compressor clutch engages.
- All four condenser fans should turn on and off as a group to regulate AC pressure between 174 (+/–29) and 232 (+/–25.4) psi.
- Three-way valve opens or closes to regulate cabin temperature, depending on the temperature control knob position. Vary the temperature control knob position to verify HVAC output air temperature changes.

VENT mode check

Finally, check the vent function using these procedures:

1. Turn the mode control knob to the VENT position.
2. Wait five minutes for the system to stabilize.
3. Check for the following conditions:
   - AC compressor is off.
   - Condenser fans are off.
   - Engine returns to normal idle speed.
   - HVAC output air temperature is near outside air temperature.

This completes the operational check. Record any deviations from the listed conditions and cross-reference them with the appropriate technical order.

FSS inspection

All MRAPs are equipped with an FSS. Although they all differ, once you understand the MaxxPro's FSS inspection procedures, you can easily apply them to other MRAPs in the future. The MaxxPro AFES is critical to safe vehicle operation. Therefore, the vehicle maintenance technician must perform preventative maintenance checks during scheduled or unscheduled inspections.

WARNING: Prior to servicing the FSS, make sure the master battery disconnect switch is OFF and remove the FSS battery backup connector from battery backup box. Failure to comply may result in discharging of system and injury to personnel.

Preparations for testing

In order to test the Kidde AFES, obtain the correct test set (fig. 4–55). It consists of five valve simulators, a source simulator, and appropriate cables.

Figure 4–55. AFES test set.

Follow these steps to prepare for the test:

Step 1. Connect the valve simulators to all AFES valve cables. To minimize the chance of discharging the extinguishers, use the first on last off rule. Always connect valve simulators to all extinguisher valve harness connectors prior to connecting the source simulator to vehicle power. Disconnect the power to the source simulator before removing valve simulators and connecting the harness connectors to the extinguisher valves.

Step 2. Connect the power cable J1 (grey cable in fig. 4–55) to the source simulator. Clip the power leads to 24 VDC at the positive and negative vehicle battery posts. The cable’s positive is red and negative is black. Turn the vehicle master power switch ON. Verify that crew and engine TROUBLE LEDs are OFF after four seconds.

Step 3. Verify the source simulator has power. Press the TEST switch and watch, observing that it illuminates for approximately four seconds.

Step 4. Test the trouble detection function of the AFES by disconnecting the EOL sensor (highest number) wiring harness. Disconnecting the EOL sensor in the crew subsystem should make the crew TROUBLE LED blink. Disconnecting the EOL sensor in the engine subsystem should make the engine TROUBLE LED blink. Reconnect both EOL sensors and verify that both TROUBLE LEDs are off.

Step 5. Test the trouble detection function of the AFES by disconnecting the valve simulators one at a time. Disconnecting each crew valve simulator should make the crew TROUBLE LED turn on solid, and reconnecting it should make it turn off. Disconnecting each engine valve simulator should make the engine TROUBLE LED turn on solid, and reconnecting it should make it turn off.

FSS functional test

The purpose of this test is to ensure each of the fire sensors are able to detect and react to the sight of an IR light source, without accidently discharging the dry chemical agents during the test. There are three functional tests to perform: dual, near, and far. The source simulator and fire sensor being tested must be at approximately the same temperature**.**

NOTE: Wait at least 10 seconds between each functional test to ensure valid results.

Dual test

Step 1. Place the source simulator switch in the DUAL position.

Step 2. Place the source simulator in front of any crew fire sensor with the source simulator windows pointing into the sensor windows. Be sure to maintain correct alignment throughout the test period.

Step 3. Press and release the TEST push-button switch and note that the amber indicator is ON. Hold the source simulator in place until the indicator turns OFF (about four seconds).

Step 4. Be sure that all crew valve simulators activate during this test. The simulator will beep and the LED light will illuminate when activated. It may be necessary to have multiple personnel or repeat the test to confirm. (**NOTE:** It is necessary to confirm all crew valve simulators activate for only one crew sensor.) The crew TROUBLE LED on the FSS controller should remain OFF.

Step 5. The LED in the middle of the fire sensor being tested should begin flashing. This LED indicates which sensor has detected a fire situation.

Step 6. Disconnect the AFES sensor power for about four seconds, then reconnect the AFES sensor power. When the AFES sensor is disconnected, the LED light on the FSS controller should blink.

Near test

Step 1. Place the source simulator switch in the NEAR position.

Step 2. Place the source simulator in front of the same crew fire sensor with the source simulator windows pointing in the sensor windows. Be sure to maintain correct alignment throughout the test period.

Step 3. Press and release the TEST push-button switch and note that the amber indicator is ON. Hold the source simulator in place until the indicator turns OFF.

Step 4. No valve simulator should activate during this test.

Step 5. If a valve simulator activates, this fire sensor is not functioning properly and may give false alarms. Replace and retest this sensor if a valve simulator activates.

Far test

Step 1. Place the source simulator switch in the FAR position.

Step 2. Place the source simulator in front of the same crew fire sensor with the source simulator windows pointing in the sensor windows. Be sure to maintain correct alignment throughout the test period.

Step 3. Press and release the TEST push-button switch and note that the amber indicator is ON. Hold the source simulator in place until the indicator turns OFF.

Step 4. No valve simulator should activate during this test.

Step 5. If a valve simulator activates, this fire sensor is not functioning properly and may give false alarms. Replace and retest this sensor if a valve simulator activates.

Repeat all tests at the remaining crew and engine fire sensors associated with the AFES. Use the AFES test summary (fig. 4–56) to assist in completing all recommended tests.

TEST	RESPONSE
Test all Crew Sensors	
Dual	• All crew Valve Simulators alarm • Sensor LED blinks
Far	No Valve Simulator alarm
Near	No Valve Simulator alarm
Maintenance Shutdown	AFES ON LED OFF
Power up	Crew sensor and CE LEDs in normal operation
Test all Engine Sensors	
Dual	• Engine 1 Valve Simulator alarms except for manual-only engine system • Engine FIRE LED ON for ~ 1 second • Engine TROUBLE LED double blinks except for manual-only engine system (OFF for manual) • Sensor LED blinking
Far	No Valve Simulator alarm
Near	No Valve Simulator alarm
Maintenance Shutdown	AFES ON LED OFF
Power up with RESET	Engine sensor and CE LEDs in normal operation
Crew MANUAL DISCHARGE	• All crew Valve Simulators alarm • AFES ON LED: 9 sec. ON, 1 sec. OFF
Maintenance Shutdown	AFES ON LED OFF
Power up with RESET	CE LEDs in normal operation
Engine MANUAL DISCHARGE	• **Manual-only:** engine Valve Simulator alarms • **Auto/Manual (1 extinguisher):** engine Valve Simulator alarms immediately and/or after 5 seconds • **Auto/Manual (2 extinguishers):** Engine 2 Valve Simulator alarms immediately and Engine 1 Valve Simulator alarms after 5 seconds • Engine TROUBLE LED double blinks • AFES ON LED: 9 sec. ON, 1 sec. OFF
Maintenance Shutdown	AFES ON LED OFF
Power up with RESET	CE LEDs in normal operation

Figure 4–56. AFES test summary appendix.

Body armor removal and installation

The body armor that makes an MRAP so effective in protecting our brothers and sisters outside the wire also makes it significantly more dangerous and difficult to work on when it comes into the shop for maintenance. While we can't cover all aspects of removing and installing armor, here we will provide a few basic guidelines and things for you to bear in mind when you are tasked to do so.

First, body armor is heavy. While this may seem obvious, even small pieces of armor can be deceivingly heavy. For example, the battery box armor weighs 120–150 lbs., and the plates protecting the sides of the engine weigh 100–120 lbs. each. As a result, it's always best to ask for some help when removing armor components. Additionally, it's a good idea to leave at least one bolt in place during removal. Before removing this bolt, support the weight of the armor to keep it from falling and causing injury or damage.

Our second point works hand in hand with our first: use your technical order. The technical order is your best reference to identify unique requirements or concerns when removing a piece of armor. For instance, when removing the belly pan on a MaxxPro, the technical order identifies a special tool to be used and the need for a total of five personnel (one mechanic, four crewmembers) to complete the job. Armed with this information, you can gather the necessary equipment and enlist the help to safely complete the job. Lastly, the technical order provides the proper torque specs and identifies any single-use hardware that must be replaced when reinstalling body armor. This helps to ensure the armor performs its job correctly if the truck is hit.

Our third and final piece of advice is not to be afraid to remove the armor when the job warrants it. The armor was designed to protect the crew first and critical components of the truck second. Ease of repairs was a much lower priority. Spending a few extra minutes removing the recommended components can save you both time and frustration and will enable you to perform higher quality maintenance on the MRAP.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

027. MRAP fundamentals

1. What do the majority of MaxxPro CAT I MRAP drive train components consist of? Explain the benefit of using these components.

2. What does the MaxxPro exhaust brake allow the operator to do?

3. Why must the MaxxPro be completely stopped before changing the transfer case mode or range?

4. What type of suspension does the MaxxPro use?

5. Why are two steering gearboxes used on the MaxxPro?

6. How would you know if there is a malfunction in the ABS?

7. How far and at what maximum speed can the MaxxPro be driven on the runflat?

8. In wartime configuration, how does the HVAC and LSS system protect against NBC agents?

9. How does the LSS prevent contaminates from entering the vehicle cab?

10. What areas of the MaxxPro are protected by the FSS?

11. Which two MaxxPro fire sensors will automatically operate the FSS when fire is detected?

12. What MRAP armor panels attach externally to the base armor?

13. What assists in the opening and closing of the MRAP forward cab doors?

14. How is the MRAP rear door ramp opened and closed?

15. What MRAP armor component protects the fuel tank, battery box, air tanks, transmission, and transfer case?

028. MRAP maintenance

1. What gives the MaxxPro MRAP electrical system the capability of running self-diagnostics? How is the operator alerted when a problem is detected?

2. How can you manually cycle through MaxxPro MRAP electrical system trouble codes while in diagnostic mode?

3. What is indicated by an “A” in a MaxxPro MRAP electrical system trouble code? What is indicated by a “P?”

4. Why do you begin troubleshooting a MaxxPro MRAP's LSS and HVAC system with a thorough function check?

5. When function checking the MaxxPro MRAP's COOL mode, how much difference in temperature (outside air and thermometer) should be observed after 30 minutes of run time?

6. What should the MRAP's engine speed be when performing a functional check on the MaxxPro MRAP's HEAT mode?

7. What two things must be done prior to servicing the MaxxPro MRAP's FSS to avoid system discharge and injury to personnel?

8. When testing the MaxxPro MRAP's FSS, how do you verify that the source simulator has power?

9. What is the purpose of the FSS functional test on the MaxxPro MRAP?

10. How long should you wait between tests to ensure valid results when performing the MaxxPro MRAP FSS functional test?

11. What MaxxPro MRAP's FSS valve simulator actuates during the "Far test"?

12. Approximately how many lbs. does the MaxxPro MRAP's battery box armor weigh?

13. Why is knowing the proper torque specs and what hardware is single-use important when installing a MaxxPro MRAP's body armor?

Answers to Self-Test Questions

023

1. A tactical vehicle, for use over all types of roads, as well as cross-country terrain in all weather conditions.
2. Transport cargo and troops.
3. Transport, mount, and provide a platform for operating the TOW missile launcher system.

4. Specially sealed dipstick, dipstick tube, vented crankcase depression regulator valve, and a manual throttle control.
5. By belt.
6. Hydraulic control valve.
7. Three drive ranges of constant four-wheel drive.
8. Transfer torque to the wheels from the differential through the geared hub.
9. Geared hubs.
10. An independent coil spring-type system.
11. The geared hub.
12. The coil spring.
13. Three-lever light switch.
14. Night convoy operations.
15. You are at the correct distance from the vehicle in front of you.
16. Battery power to the starter solenoid and to the neutral start switch through circuit 14.
17. Circuit 3.
18. Circuit 6A.
19. Starter solenoid.
20. Allows the vehicle to still be driven under emergency conditions with one or more flat tires.
21. Compression balance test and starting system evaluations.
22. Vehicle batteries or an equivalent power source.

024

1. The M36A3. Because of the longer wheel base.
2. Bypass valves.
3. Eight forward and two reverse.
4. Plunger and barrel.
5. Radiator, charged air cooler, water pump, surge tank, thermostat, fan, and fan actuator.
6. To set the desired engine rpm without maintaining pressure on the accelerator pedal.
7. LCD.
8. 60 psi or below.
9. Normal and reprogramming.

025

1. Suspension system comprised of both rear axles, upper- and lower-torque rods, springs, and seats that support the rear vehicle weight.
2. Lifting shackles.
3. Battery, starting, ether, generating, directional signal, heating operation, indicator, gauge and warning, and trailer and semi-trailer connection.
4. Front winch, rear winch (wrecker), and wrecker crane.
5. It is a four-port valve that receives pressurized oil from the hydraulic pump and directs it to the winch motor.
6. The rear winch has two torque selections.
7. Torque control valve.
8. 20,000 lbs.
9. Transfer case PTO control.
10. Swivel valve.
11. Boom control valve.
12. Sheaves.

13. Rollers.
14. Turntable assembly.

026

1. Air cleaner or element has obstruction.
2. Prime the fuel system to remove any trapped air.
3. Worn ball sockets in a linkage component, worn steering gearbox, worn steering column universal joints or bearings, or loose steering gearbox bolts.
4. To limit the outward steering motion of the front wheels.
5. Draw a reference chalk line 30 ft. long. Mark the line “A.”
6. Inspect leaf springs for breaks or damage, as well as the spring U-bolts and shackles.
7. Interleave, display minimum/maximum values, and peak-to-peak value.
8. Depress and release the TEST switch.
9. The tests are very thorough as long as you do not skip any steps.
10. Injury to personnel may result.
11. Check hydraulic oil reservoir for proper fluid level.
12. Halfshaft must first be separated from the differential output flange.
13. Remove the tire, access plug, and washer from the geared hub.
14. Damage to equipment or poor performance.

027

1. Commercial off-the-shelf components. Ease of maintenance and parts procurement, reliability, and longevity.
2. Slow the vehicle or maintain a constant speed when descending steep road grades.
3. The transfer case is not synchronized; failure to stop can result in severe transfer case damage.
4. Conventional leaf spring.
5. Ease of steering.
6. ABS light stays on or flashes during vehicle operation.
7. 30 miles at 35 mph.
8. Through the use of special filters.
9. Creating an overpressure in the cab.
10. Engine, interior, tires, and fuel tank.
11. Engine and interior.
12. Catcher plates.
13. Air cylinders located in each door.
14. Hydraulically.
15. Belly armor plate.

028

1. The ESC makes it possible; it alerts the operator by illuminating the check electrical system light on the EGC and stores the DTCs.
2. By using the SELECT/RESET button on the cluster.
3. DTCs will end with an “A” if the code is active, meaning that “feature” is turned on and the fault is still detected. If that feature is turned off or the fault is not detected, the code will be considered previously active and will end with a “P.”
4. It’s best to begin with a thorough function check to identify all symptoms associated with the malfunction.
5. Should be around 30°F after 30 minutes of run time (unless cabin temperature drops below 67°F).
6. Normal idle speed.

7. Make sure the master battery disconnect switch is OFF and remove the FSS battery backup connector from battery backup box.
8. Press the TEST switch and watch, observing that it illuminates for approximately four seconds.
9. Ensure each of the fire sensors are able to detect and react to the sight of an IR light source, without accidently discharging the dry chemical agents during the test.
10. At least 10 seconds.
11. No valve simulator should activate during this test.
12. 120–150.
13. Helps to ensure the armor performs its job correctly if the truck is hit.

Complete the unit review exercises.

79. (023) These high-mobility multipurpose-wheeled vehicle (HMMWV) drive train components transfer torque from the differentials to the geared hubs.
    a. Halfshafts.
    b. Transfer case.
    c. Propeller shafts.
    d. Recirculating ball gearbox.

80. (023) This high-mobility multipurpose-wheeled vehicle (HMMWV) suspension system component provides a gear reduction to increase torque to the wheel and tire assembly.
    a. Ball joints.
    b. Geared hub.
    c. Shock absorbers.
    d. Upper control arm.

81. (023) Which circuit provides a ground circuit for the high-mobility multipurpose-wheeled vehicle (HMMWV) alternator?
    a. 3.
    b. 5.
    c. 29.
    d. 568.

82. (024) How many forward and reverse gears are available when using the 2½-ton M-series transmission in conjunction with its transfer case?
    a. Eight forward and one reverse.
    b. Eight forward and two reverse.
    c. Six forward and one reverse.
    d. Six forward and two reverse.

83. (024) How do you unlock the 2½-ton M-series throttle control setting?
    a. Rotate throttle control handle clockwise or counter clockwise.
    b. Rotate throttle control handle clockwise only.
    c. Step on the accelerator pedal.
    d. Step on the brake pedal.

84. (025) Which 5-ton M-series front winch component engages the winch drum gear to the winch motor drive gear?
    a. Clutch lever.
    b. Winch control switch.
    c. Hydraulic control valve.
    d. Power take-off (PTO) control switch.

85. (025) The major components that guide the hoist cable through the boom are the
    a. pads.
    b. rollers.
    c. sheaves.
    d. sprockets.

86. (025) The major components that provide smooth extension and retraction of the boom are the
    a. pads.
    b. rollers.
    c. sheaves.
    d. sprockets.

87. (026) You notice white exhaust smoke when cranking an M-series vehicle. You prime the fuel system, but white smoke is still seen. You should
    a. re-prime the fuel system.
    b. inspect the fuel filter for clogs.
    c. check the air cleaner indicator.
    d. check for coolant inside the engine.

88. (026) When loosening the 2½ or 5 ton M-series truck air compressor outlet line to check the governor operation, you hear the sound of air escaping. Which is your next step?
    a. Remove the outlet line.
    b. Drain the air reservoirs.
    c. Re-tighten the outlet line fitting.
    d. Check auxiliary air supply valve for leakage.

89. (026) This component must be removed first before the high-mobility multipurpose-wheeled vehicle (HMMWV) brake rotor can be replaced?
    a. Halfshaft.
    b. Geared hub.
    c. Propeller shaft.
    d. Park brake cable.

90. (027) How many personnel can the MaxxPro mine-resistant ambush-protected (MRAP) vehicle carry?
    a. 4.
    b. 6.
    c. 8.
    d. 10.

91. (027) The MaxxPro mine-resistant ambush-protected (MRAP) vehicle must be stopped prior to changing from rear wheel to four wheel drive because the transfer case is
    a. synchronized.
    b. not synchronized.
    c. manually shifted.
    d. electrically shifted.

92. (027) What area(s) on the MaxxPro mine-resistant ambush-protected (MRAP) vehicle, which are protected by the fire suppression system (FSS), can only be operated manually?
    a. Tires only.
    b. Fuel tank and tires.
    c. Engine and interior.
    d. Interior, engine, fuel tank, and tires.

93. (027) This MaxxPro mine-resistant ambush-protected (MRAP) vehicle component is made of ceramic armor.
    a. Base cab.
    b. Spall liners.
    c. Catcher plates.
    d. Effector assemblies.

94. (027) Which MaxxPro mine-resistant ambush-protected (MRAP) vehicle external armor modules that are equipped with internal high-performance liners attach externally to the base armor?
    a. Base cab.
    b. Spall liners.
    c. Catcher plates.
    d. Effector assemblies.

95. (027) This MaxxPro mine-resistant ambush-protected (MRAP) vehicle armor component is attached to brackets and is held several inches away from the vehicle body.
    a. Base cab.
    b. Spall liners.
    c. Catcher plates.
    d. Effector assemblies.

96. (027) What assists the operator in opening and closing the MaxxPro mine-resistant ambush-protected (MRAP) vehicle forward doors?
    a. Air cylinders.
    b. Heavy springs.
    c. Hydraulic cylinders.
    d. Electrical solenoids.

97. (027) This system opens and closes the MaxxPro mine-resistant ambush-protected (MRAP) vehicle rear door.
    a. Air.
    b. Spring.
    c. Hydraulic.
    d. Electrical.

98. (028) What should the engine speed (revolutions per minute) be during the MaxxPro mine-resistant ambush-protected (MRAP) vehicle COOL mode check while performing the life support and heating, ventilation, and air conditioning systems function check?
    a. 1,100.
    b. 1,300.
    c. 1,700.
    d. 2,100.

99. (028) This air conditioner compressor clutch response should be observed during the MaxxPro mine- resistant ambush-protected (MRAP) vehicle DRY mode check of the life support and heating, ventilation, and air conditioning systems function check.
    a. Engaged.
    b. Not engaged.
    c. Cycle on and off.
    d. Engage for two minute cycles.

100. (028) How many pounds do the armor plates on the sides of the MaxxPro mine-resistant ambush-protected (MRAP) vehicle engine weigh?
    a. 65–80.
    b. 80–100.
    c. 100–120.
    d. 120–150.

Glossary of Abbreviations and Acronyms

°	degree
A	active
A2B	anti-two-block
ABS	anti-lock braking system
AC	air conditioning
ACS	Advanced Control System
AF	Air Force
AFES	Automatic Fire Extinguisher System
AFI	Air Force instruction
APECS	A Proportional Engine Control System
BICS	Bobcat Interlock Control System
BTU	British thermal unit
C	clutch
CAD	cadmium
CAN	controller area network
CAT	category
CB	circuit breaker
CDC	career development course
CR	circuit relay
CTIS	central tire inflation system
CV	constant velocity
DC	direct current
DCA	diagnostic connector assembly
DTC	diagnostic trouble code
ECM	electronic/engine control module
ECU	electronic control unit
EDM	electronic data monitor
EGC	electronic gauge cluster
EGR	exhaust gas recirculation
EOL	end of line
ERR	engine run relay
ESC	electrical system controller

E-Stop	emergency stop
F	Fahrenheit
FA	fresh air
FEDS	Fluid Efficient Delivery System
FOD	foreign object damage
FSS	Fire Suppression System
ft.	foot
gpm	gallons per minute
GVW	gross vehicle weight
HEUI	hydraulically actuated, electronically controlled unit injector
HL	hydraulic low
HMMWV	high-mobility multipurpose-wheeled vehicle
hp	horsepower
HVAC	heating, ventilation, and air conditioning
IED	improvised explosive device
IMG	International Military and Government
in.	inch
IR	infrared
JP	jet propulsion
lb.	pound
LCD	liquid crystal display
LED	light emitting diode
LLC	limited liability company
LSS	Life Support System
mph	miles per hour
MRAP	mine-resistant ambush-protected
M-series	military-series
NATO	North Atlantic Treaty Organization
NBC	nuclear biological chemical
P	previously active
psi	pounds per square inch
PTO	power take-off
PWM	pulse width modulated

RA	recycled air
RCI	rated capacity indicator
RPG	rocket propelled grenade
rpm	revolutions per minute
RTD	remote temperature detector
RV	relief valve
SAE	society of automotive engineers
SIG	signal
SJC	selectable joystick controls
STE/ICE	simplified test equipment for internal combustion engines
STE/ICE-R	simplified test equipment for internal combustion engines, reprogrammable
TD	time delay
TK	transducer kit
TO	technical order
TOW	tube-launched, optically tracked, wired-guarded
TYMCO	The Young Manufacturing Company
USAF	United States Air Force
VAC	volts alternating current
VDB	valve driver board
VDC	volts direct current
VTM	vehicle test meter
WC	water column

Student Notes

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