CDC Y2T35X

Mission Generation Vehicular Equipment Maintenance Journeyman

Volume 3. Air Brake, Hydraulic, Heating and Air Conditioning, and Passenger Restraint Systems

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IN THIS THIRD volume of Career Development Course (CDC) Y2T35X, *Mission Generation Vehicular Equipment Maintenance Journeyman,* entitled *Air Brake, Hydraulic, Heating and Air Conditioning, and Passenger Restraint Systems*, you will learn about air brakes, hydraulics, heating, ventilation, and air conditioning (HVAC), and passenger restraint systems found on modern vehicles. Like the previous volume, these systems all play a role in vehicle safety and comfort. As a Vehicle Management Journeyman, your ability to understand and properly diagnose and repair these systems will be tested regularly.

Unit 1 will cover air systems and air brakes. It will begin with air systems typically found on heavier vehicles. Afterwards, it will discuss air-operated brakes, building upon what you learned about braking systems in the previous volume.

Unit 2 will introduce you to hydraulic systems such as those found on cranes, forklifts, and aircraft towing tractors.

Units 3 and 4 are derived from the textbook, *Modern Automotive Technology, 9th Edition,* written by James E. Duffy, and published in 2017 by The Goodheart-Willcox Company, Inc., Tinley Park, IL. For both units, the reading assignments and study questions (both review and Automotive Service Excellence [ASE]-type) have been carefully selected to increase your knowledge and comprehension of both subject matter and tasks required of journeymen within your career field. To assist you, the correct responses to the study questions are provided at the end of both units. The CDC writer and Air Force Career Development Academy (AFCDA) personnel have methodically researched and verified these responses to ensure their accuracy.

Unit 3 will teach you about HVAC systems. You will learn how these systems work and how they play a role not just in occupant comfort but also in vehicle safety.

Unit 4 will cover passenger restraints. This final unit of the volume will explain how restraint systems are designed and produced to protect vehicle occupants in the event of a collision.

A glossary is included for your use for Units 1 and 2 and the introduction of Unit 3. For all other terms, a glossary is also included in the textbook *Modern Automotive Technology, 9th Edition*, for your use. Further, if you encounter any measurement-related acronyms with which you are unfamiliar, please refer to Figures 6-1 and 6-3 on pages 90-91 in the textbook for an explanation.

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To get a response to your questions concerning subject matter in this course, or to point out technical errors in the text, unit review exercises, or course examination, call or write the author using the contact information provided in this volume.

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For Guard and Reserve personnel, this volume is valued at 20 hours and 5 points.

NOTE:

In this volume, the subject matter is divided into separate units. Although Units 1 and 2 have lessons that are self-contained, Units 3 and 4 each incorporate lessons derived from the textbook *Modern Automotive Technology, 9th Edition*. As a result, Units 1 and 2 have their own self-test questions, with the respective answers at the end of both units. Units 3 and 4 contain assigned reading from the textbook along with review questions. After reading the unit menu page and unit introduction, study the reading assignment, answer the indicated questions, and compare your answers with those given at the end of the unit. Then complete the unit review exercises.

Page

Please read the menu for Unit 1 and begin ➔

Unit 1. Air Systems

AIR BRAKES ARE COMMON on large vehicles. Unlike hydraulic brakes, an air brake system relies on air pressure to apply the brakes. The air brake system contains components that are unique to it as compared to the components used in a hydraulic brake system. In this unit, you will learn about air brake system component fundamentals and maintenance procedures. The unit will conclude with a discussion of the central tire inflation system, which operates in conjunction with the air system.

1–1. Air System and Brake Components

In this section, you will focus on the air supply portions of the air brake system, beginning with a lesson on the overall air supply system and follow up with a discussion on the air delivery valves. Once you have mastered this portion of the unit, you will be ready to cover how air brakes operate using the air supply.

401. Air supply system and delivery valves

The air supply system is the source of air pressure for the air brake system. The air supply system consists of the compressor, governor, reservoirs, different types of valves, and a low-pressure indicator. Additionally, some systems may include an air dryer.

Compressor

In an air brake system, the *air compressor's* function is to build the required air pressure and maintain it in the reservoirs. Actually, the air compressor construction is similar to a basic internal combustion engine.

Most air compressors are of the one- or two-cylinder, single-stage, reciprocating-piston design (fig. 1–1), and are rated by the amount of air volume measured in cubic feet per minute. The compressor is constructed from two major assemblies—the cylinder head and crankcase.

- The cylinder head, located on the upper portion of the crankcase, houses the discharge valving.
- The crankcase is a one-piece casting containing the cylinder block. The upper portion of the casting houses the cylinder bore(s) and inlet valving. The lower portion of the crankcase casting houses the crankshaft and main bearings. To meet the mounting and drive configurations required by different vehicles, different mounting flanges, end covers, and base adapters are bolted to the crankcase. Some compressors are belt-driven while others are gear-driven; the drive type depends on the application.

Most air compressors use oil from the vehicle engine for lubrication. This is a continuous flow from the engine to the compressor, and then returned to the engine. The oil feed is an external line from the engine lubrication system. An oil passage in the compressor crankshaft feeds pressurized oil to the connecting rod bearings and the main bearings.

The pressurized oil forced out around the crankshaft journals provides splash lubrication of other components in the crankcase. Oil returns to the engine through a line or mounting adapter; again, the method depends on compressor application.

Like lubrication, cooling the compressor also involves the engine cooling system, as well as airflow through the engine compartment. The compressor head incorporates a water jacket similar to that in the engine’s cylinder head. Coolant supply and return lines connect the engine coolant supply to the air compressor head water jacket. This flow helps cool the compressor. Cooling is also enhanced by a series of air fins around the air compressor. These fins transfer heat from the compressor to the ambient air.

The unloader piston and related components can be located above or below the inlet valve, depending on compressor model. The inlet valve operates like a check valve, and the unloader piston works in conjunction with the governor to control when compression can build up.

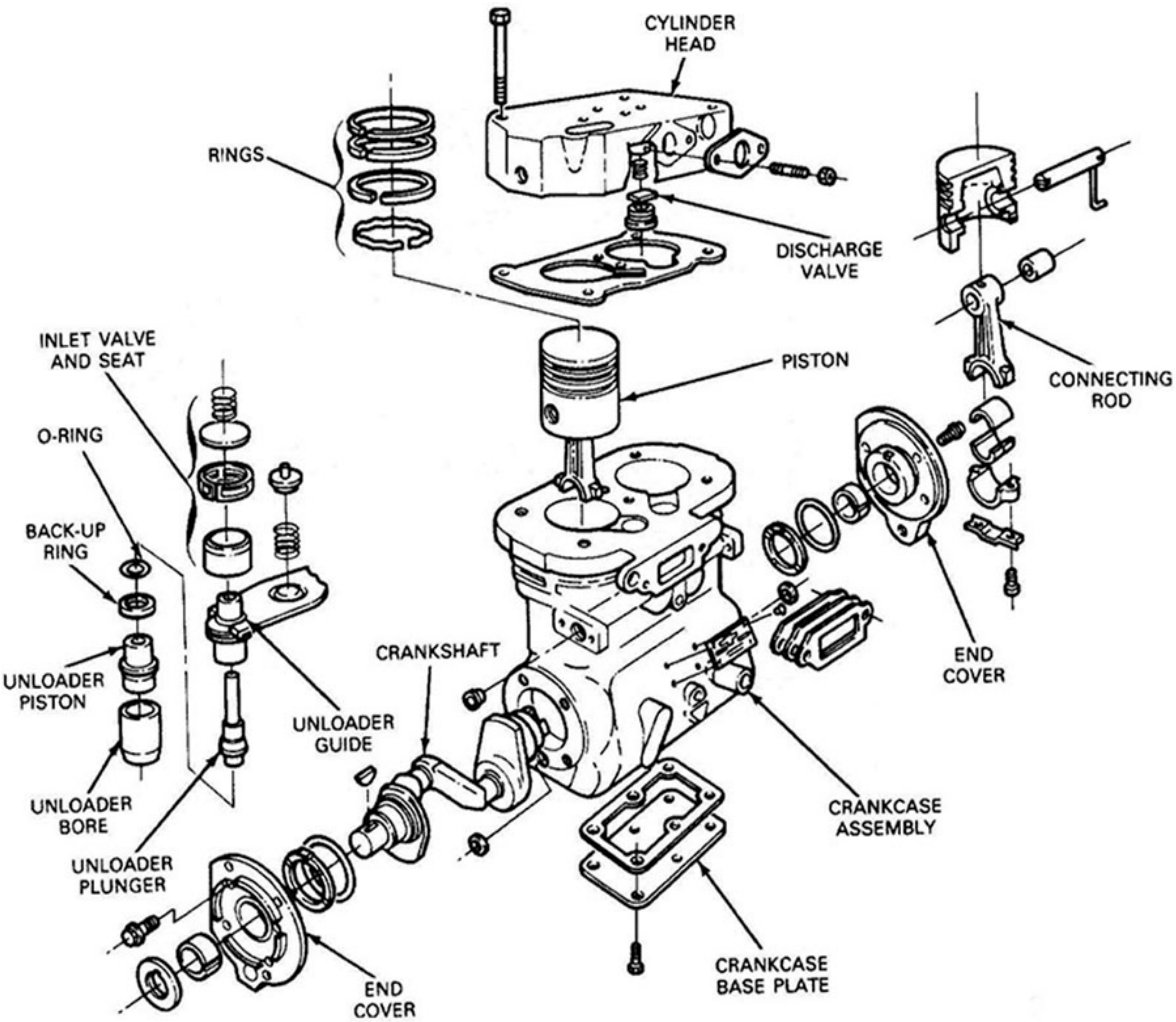


Figure 1–1. Air compressor breakdown.

The compressor operates while the engine is running; however, it compresses air only when the governor is not pressurizing the unloader piston. When not pressurized by the governor, the unloader piston is in the retracted position. Consequently, our discussion will begin with the unloader piston in the retracted position.

Retracted position

1. As the compressor piston moves downward, it creates a vacuum in the cylinder that opens the inlet valve and draws air in.
2. As the piston moves upward, it compresses the air just like in an internal combustion engine.
3. The inlet valve is seated, preventing air from escaping through the inlet port.
4. As the air compresses further, it overcomes the spring force of the discharge valve and allows the compressed air into the discharge line and on to the reservoir.
5. As the piston moves downward again, the discharge valve returns to its seat and the inlet valve opens to draw air into the cylinder.

The cycle begins again and repeats itself until air pressure builds up to the correct limits.

Predetermined governor cut-out and cut-in settings

When air pressure in the reservoir reaches the governor's predetermined cut-out setting, the governor opens and allows air pressure to the unloader piston in the compressor. As a result, the unloader piston is lifted, moving the compressor's air inlet valve off its seat. With the inlet valve off its seat, compression cannot occur in the cylinder; air is simply pumped back and forth in the cylinder cavity. The compressor does not build up any pressure during this stage.

As air departs the reservoir, air pressure in the brake system drops. When the air pressure in the reservoir drops to the governor cut-in setting, the governor closes and exhausts the air below the unloader piston. This allows the seating of the inlet valve, facilitating compression during the piston compression stroke. At this point, the compressor cycle is restarted.

Governor

Most governors are mounted directly to the air compressor's cylinder head. However, they can also be remotely mounted. Regardless of how a governor is mounted, it operates with the unloader to automatically control the air pressure in the air supply system. It keeps pressure between the desired, predetermined maximum and minimum settings. However, the compressor operates continuously while the engine runs; it is not compressing air all the time. The governor actuating the unloader piston controls the actual air compression. Compression stops or starts when the maximum or minimum reservoir pressures are reached. In most governors, air pressure acts on a piston (fig. 1–2) to overcome the pressure setting of a spring, which, in turn, controls the governor's inlet and exhaust valve, admitting air into or exhausting air out of the governor.

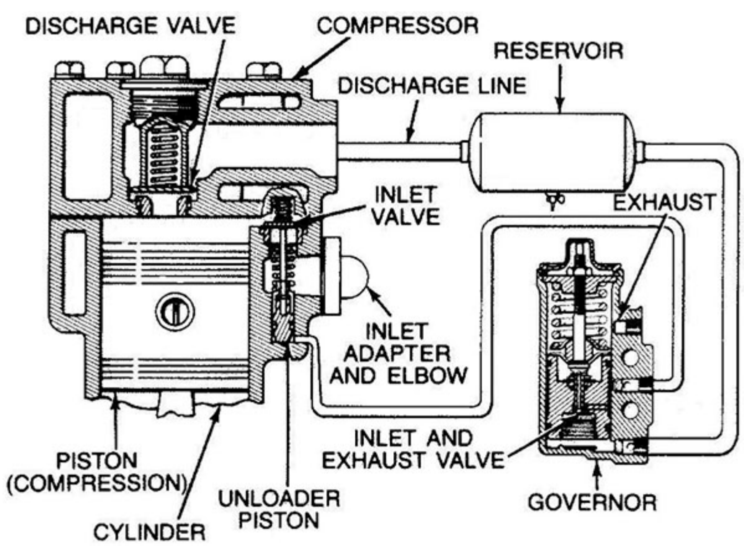


Figure 1–2. Governor assembly.

Reservoir air pressure enters the governor at one of its reservoir ports and acts on the area of the piston beneath the inlet and exhaust valves. As the air pressure builds up, the piston moves against the resistance of the pressure-setting spring. The piston, inlet and exhaust valve move up when the reservoir air pressure reaches the governor’s cut-out setting; the exhaust stem seats on the inlet and exhaust valve, and then the inlet passage opens. Reservoir air pressure then flows by the open inlet valve, through the passage in the piston and out the unloader port to the compressor unloading mechanism. This causes the unloader piston to move, preventing the compressor from building up compression as previously discussed.

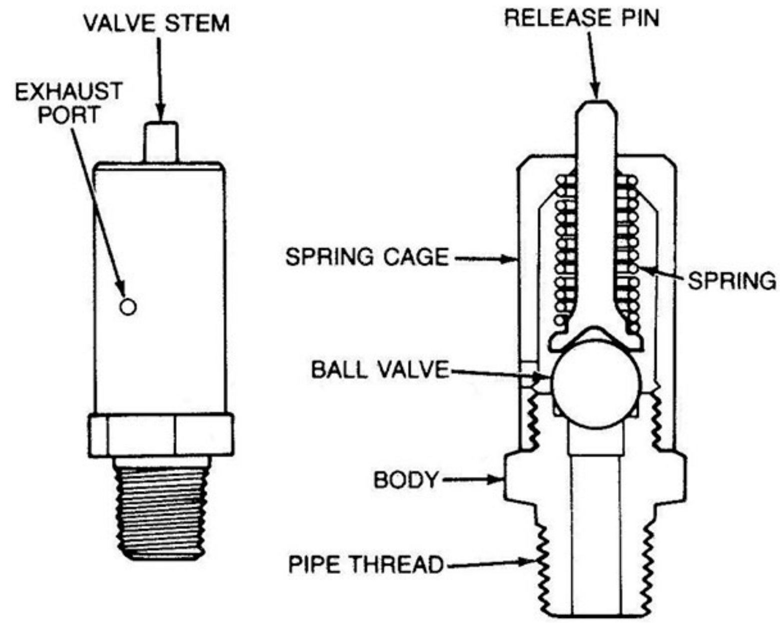
As the system reservoir air pressure drops to the governor’s cut-in setting, the force extended by the air pressure on the piston reduces so the pressure-setting spring moves the piston down. This causes the governor’s inlet valve to close and the exhaust valve to open. With the exhaust open, the air in the unloader line escapes back through the piston, through the exhaust stem, and out the exhaust port. With no pressure in the unloader line, the compressor again begins building air pressure.

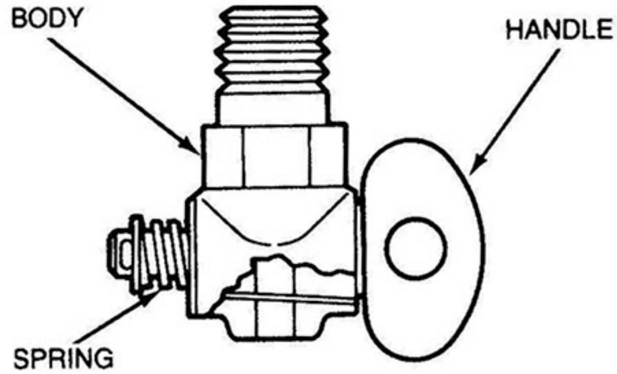
Reservoirs

The *reservoir* is a storage tank made of strong, heavy metal. It provides an adequate volume of compressed air for braking, meeting the design requirements of the system in which it is installed. It serves another function by cooling hot, compressed air and condensing water vapor. Most air brake systems contain three or more reservoirs, which are normally mounted along the vehicle’s frame rail and secured by a variety of clamps. The following table provides descriptions of the different reservoir types.

Reservoirs	
Type	**Description**
Supply reservoir	The supply reservoir connects to the output line of the air compressor. Sometimes referred to as the “wet tank,” more moisture develops within the supply reservoir than in any other reservoir due to the direct line connection to the compressor. The compressor’s output air is very hot and when the hot air is expose to the “cool” reservoir, condensation takes place. Manual and automatic drain valves drain off any moisture.
Primary and secondary reservoirs	The supply reservoir (wet tank) provides the primary and secondary reservoirs with air. • The primary reservoir is the air source for the rear brakes. • The secondary reservoir supplies air to the front brakes. Referred to as “dry tanks,” both reservoirs receive cooler, drier air than the supply reservoir, and less moisture condenses in them than in the supply reservoir. However, these reservoirs also contain a manual or automatic drain valve to drain off moisture because some water does collect in them.
Dual-compartment reservoir	Some vehicles have a dual-compartment reservoir that houses two separate reservoirs. When used, this reservoir houses the wet tank and one of the dry tanks. An integral check valve provides a one-way passage of air from the supply tank to the primary or secondary tank. The check valve protects the dry tank from losing its air if a leak develops in the wet tank.

The following table provides descriptions of the various components associated with air brake system reservoirs.

Reservoirs	
Type	**Description**
Safety valve	The safety valve (fig. 1–3) is located in the supply tank of an air brake system. While in some vehicles the safety valve may be located on the air dryer in the supply tank, the usual location is on the supply reservoir, also within the supply tank. The valve protects the air brake system against excessive air pressure buildup in case of governor or unloader failure. For example, it exhausts reservoir pressures to the atmosphere whenever this pressure rises above the valve's pressure setting. This setting on most safety valves is 150 pounds per square inch (psi). The safety valve is nonadjustable; as a result, its operation is based upon this preset pressure. When this occurs, the ball valve is forced off its seat, allowing the excessive pressure to vent through the exhaust port in the spring cage (shown on the right side of figure 1–3). After the pressure drops, the spring reseats the ball valve, sealing off reservoir pressure.  **Figure 1–3. Safety valve.**
Single check valves	External-type single check valves are also used in the air brake supply system. They protect the primary and secondary reservoir against an air loss in the compressor or supply reservoir and allow an emergency stop. The valve only permits airflow in one direction. The check valves are normally located on the primary and secondary reservoir, or they may be located in the supply line to these reservoirs. Even though their shape is a little different, the operation is still the same. A spring inside the valve keeps the valve closed, preventing air from escaping the primary or secondary reservoir if a leak occurs in the supply reservoir or its air lines. As previously mentioned, the dual-compartment type reservoir contains a single check valve that is internally located.
Drain valve	A drain valve is standard on air reservoirs that do not have automatic moisture ejectors. Drain valves have a brass body fitted with a tapered brass key (fig. 1–4). It is open when the handle is parallel to the body and closed when the handle is at right angles to the body. Drain valves, installed in the bottom of each reservoir, provide a convenient means of draining the condensation that normally collects in the bottom of the reservoirs. The tanks should be drained completely each day to remove any moisture.

Reservoirs	
Type	**Description**
	 **Figure 1–4. Drain valve.**
Dual-compartment reservoir	Some vehicles have a dual-compartment reservoir that houses two separate reservoirs. When used, this reservoir houses the wet tank and one of the dry tanks. An integral check valve provides a one-way passage of air from the supply tank to the primary or secondary tank. The check valve protects the dry tank from losing its air if a leak develops in the wet tank.

Automatic moisture ejector valve

Some vehicle reservoirs are equipped with an optional *automatic drain valve* that ejects moisture and contaminants from the reservoir to which it is connected. Figure 1–5 displays a cross-sectional view of a typical valve that operates automatically without assistance. Normally mounted at the bottom of the reservoir, the valve has a die-cast aluminum body and cover. For vehicles operating in subfreezing temperatures, the valve is also available with a heater and thermostat built into the cover. The thermostat on the heated model activates the heating element when the valve body reaches a temperature of approximately 45 degrees Fahrenheit (° F).

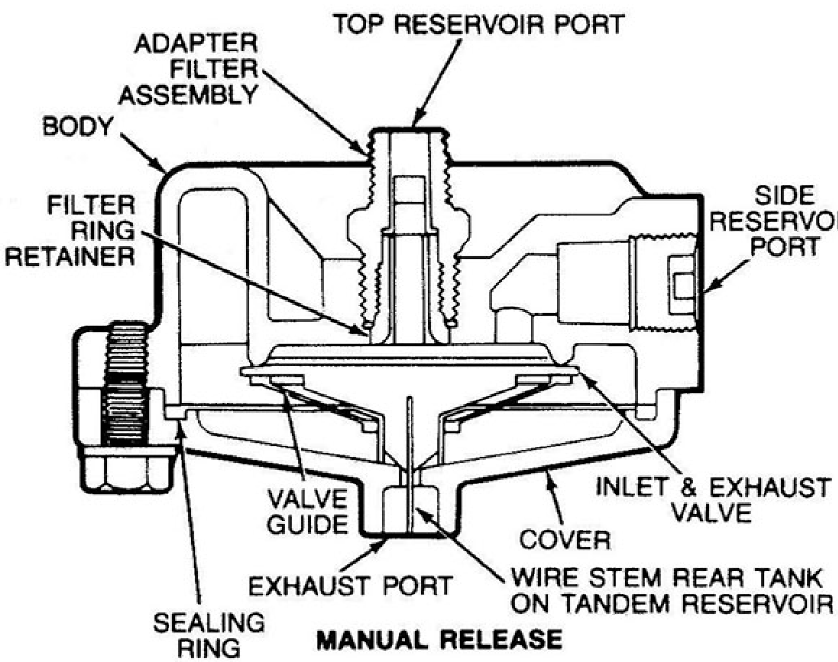


Figure 1–5. Automatic moisture ejector.

Without any air pressure in the system, the inlet and exhaust valves are closed. Upon charging the system, a slight pressure opens the inlet valve, which permits air pressure and contaminants to collect in the sump (not shown in the figure). The inlet valve remains open while pressure builds up in the system until it reaches maximum. The spring action of the valve guide in the sump cavity closes the inlet valve with the aid of air pressure in the sump cavity. The inlet valve and the exhaust valve are now closed. When the reservoir pressure drops approximately 2 psi, air pressure in the sump cavity opens the exhaust valve and allows ejection of moisture and contaminants from the sump cavity until pressure in the sump drops sufficiently to close the exhaust valve. How long the exhaust valve remains open depends on the sump pressure and the reservoir pressure drop that occurs each time air is used from the reservoir. The valve can be drained manually by pushing the wire in the exhaust port upward and holding it until draining is complete.

Alcohol system

The air brake system may have an optional *alcohol system* to prevent possible faults that may result from water present in the components. The alcohol system mixes alcohol vapors with the compressed air in order to prevent any moisture in the system from freezing during cold weather.

Alcohol System	
Parts	**Description**
Alcohol bottle	A simple alcohol system consists of an alcohol bottle connected to a line leading to the compressor's air intake. A partial vacuum exists at the alcohol bottle's connecting line while the compressor is building up air pressure. This partial vacuum causes alcohol vapors to be drawn out of the alcohol bottle and into the compressor's air intake.
Alcohol injection	Some vehicles use more complex alcohol injection systems. The injection system uses an alcohol injector in addition to an alcohol bottle. Mounted on the vehicle frame, the injector is connected in the air line between the air compressor discharge port and the supply reservoir. A control line from the governor's unloader port also connects to the alcohol injector. During the compressor's unloaded cycle, the governor sends air pressure to the injector. This air pressure forces the piston downward against the spring. The piston pushes the alcohol in the chamber against the valve. Afterwards, the valve is forced down against its spring, allowing alcohol to enter the air supply system through the discharge port. At the beginning of the air compressor's loaded cycle, the lack of air pressure to the governor port allows the spring pressure to push the piston to a position that allows the chamber to fill again with alcohol. The injector has a cam mechanism that allows the vehicle operator to turn the system on or off. When the cam is rotated so that ON is facing upwards, the injector works as previously described, allowing alcohol to enter the air supply system. If the cam is rotated and facing downward, the position of the piston will not allow any injection to occur.

Air dryer

An *air dryer* is another option available to reduce moisture and contamination in the air brake system. An air dryer provides clean, dry air to the components of the brake system, which can increase the life of the system and reduce maintenance costs. Daily manual draining of the reservoirs may be eliminated (certain applications only) if the air brake system is equipped with an air dryer. There are two basic types of air dryers—the desiccant type and the condensation type. The air dryer is normally mounted along the vehicle's frame or one of its cross members.

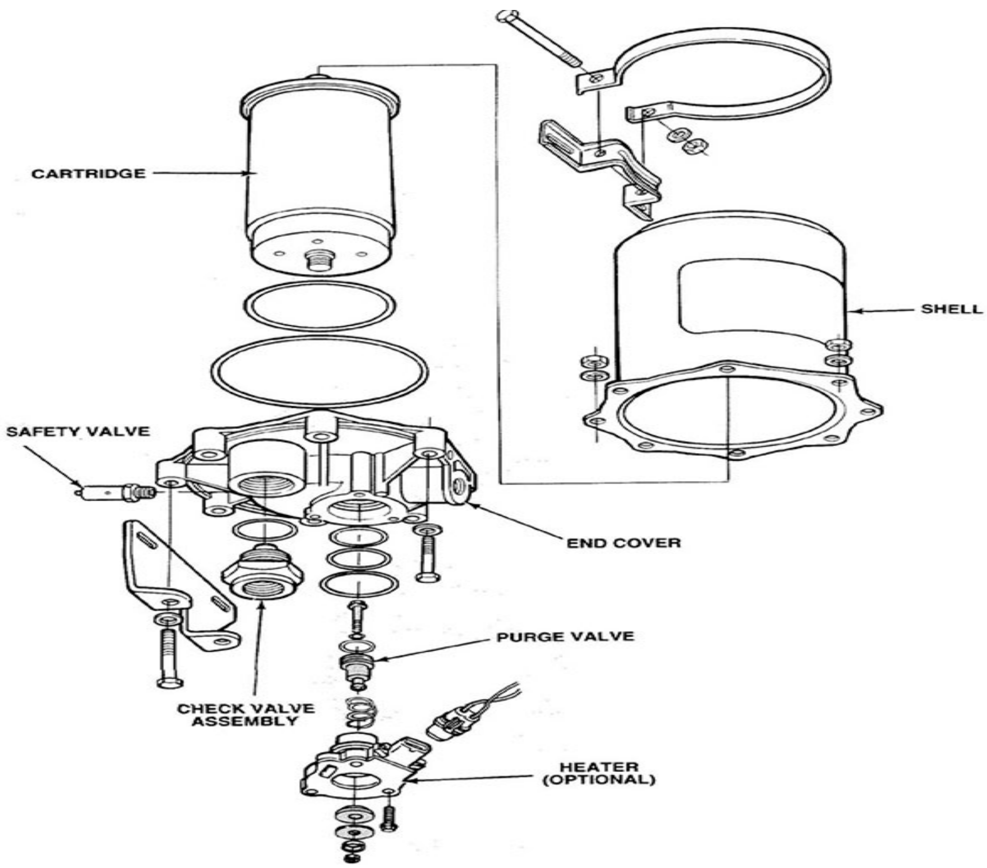


Figure 1–6. Desiccant air dryer.

Air Driers	
Types	**Description**
Desiccant	The dryer (fig. 1–6) is connected in the line between the air compressor's discharge port and the supply reservoir. An air line connects the governor's unloader port to the control port of the air dryer. The exhaust port releases air and moisture from underneath the dryer. The major parts include the following: • A housing (shell and end cover). • Desiccant cartridge. • Purge valve assembly. • Check valve assembly. The purge valve assembly may have an optional heater to prevent water in the end cover sump from freezing.
Condensation type	There are some similarities between the desiccant-type dryer and the condensation-type dryer. The condensation-type dryer is also connected in the line between the air compressor discharge port and the supply reservoir. An air line connects the governor unloader port to the control port of the air dryer. An exhaust port releases air and moisture underneath the dryer. Major parts include the following: • A housing (body and caps). • Deflector. • Filter. • Purge valve assembly. • Check valve assembly. The purge valve assembly may have an optional heater to prevent water in the bottom cap sump from freezing.

Air gauge

The purpose of the dash-mounted *air pressure gauge* is to register the amount of reservoir air pressure in the air system. The air pressure gauge may be either two separate gauges, or a single gauge with two indicators. They display air pressure for both the primary and secondary air systems. The indicator needles of a single air gauge are different colors:

- A green needle indicates the primary systems air pressure.
- A red or yellow needle indicates the secondary systems air pressure.

Low-pressure indicator switch

This switch is a safety device designed to give an automatic warning to the driver whenever the air pressure in the system is below 60 psi, the safe minimum for normal vehicle operation. The low-pressure indicator switch operates an electrical warning buzzer/chime or warning light, or both, which are audible and visible to the driver. Low-pressure indicator switches are located in both the primary and secondary air supply lines. When the air pressure is below 60 psi, the indicator switch electrical contacts remain closed by spring force until the pressure in the air system overcomes the spring tension. While these indicator contacts remain closed, the warning circuit is also closed or it is connected to ground (depending upon the circuit's design). The warning circuit then actuates the warning light, the chime, and/or the buzzer. The contacts open when the air pressure rises above the minimum setting.

Air delivery system valves

The air delivery system delivers air pressure from the air supply system’s reservoirs to the brake chambers. It controls the amount of air pressure delivered to the brake chambers, thus controlling the amount of braking during a stop. The primary valves used in the air delivery system include the foot valve, the relay valve, and the quick-release valve.

Foot valve

Used by the vehicle operator, the foot valve is commonly referred to as the brake valve or treadle valve. It meters air pressure delivery to the primary (rear) and secondary (front) air circuits, relative to the amount of force applied to the foot pedal. Two styles of the foot valve are discussed in the following tables and paragraphs.

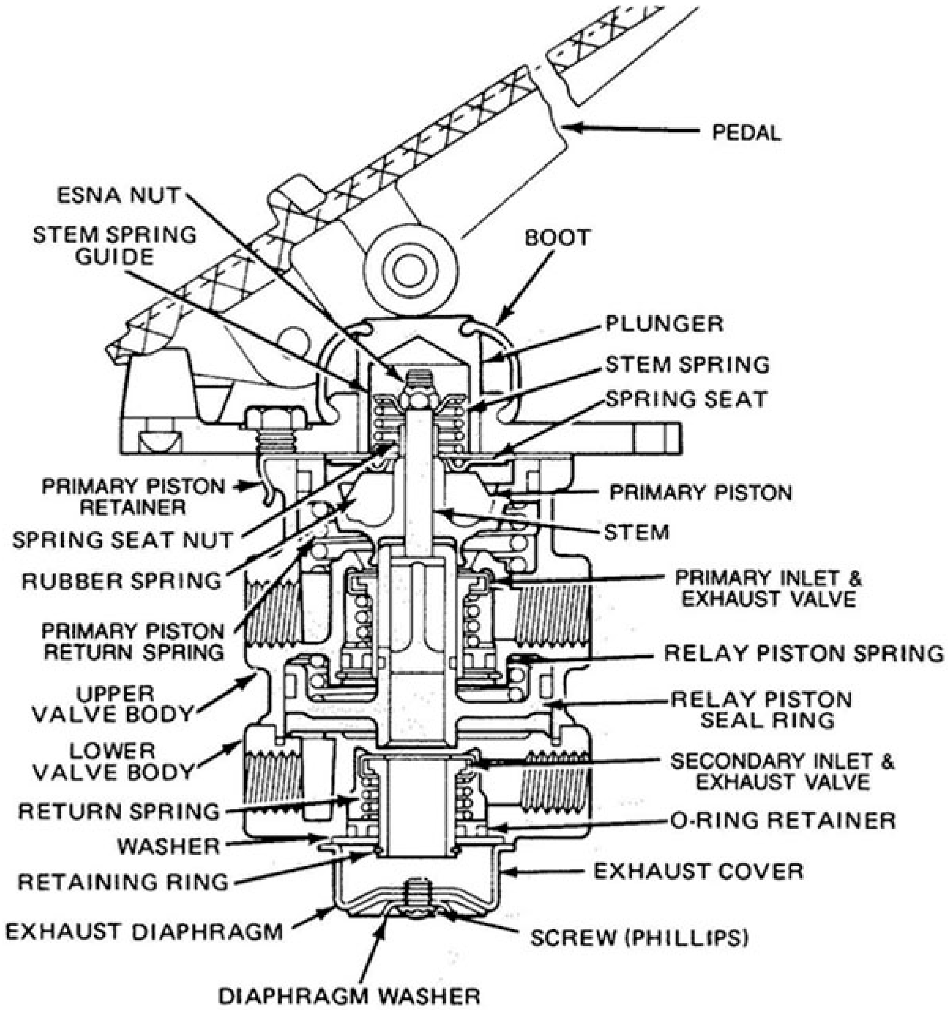


Figure 1–7. Cross-section of a foot valve.

Floor-mounted foot valve

This brake valve is a floor-mounted, treadle-operated valve with two separate supply and delivery circuits for service and emergency braking. The circuits in the valve (fig. 1–7) are identified as follows:

- The *primary circuit* is the portion of the valve between the spring seat, which contacts the plunger, and the relay piston.
- The *secondary circuit* is the portion between the relay piston and the exhaust cavity.

Both primary and secondary circuit portions of the brake valve use a common exhaust circuit. The following three tables provide the applying, balanced, and releasing operational phases of the valve in more detail.

Foot Valve Operational Phases	
Applying Phase	
Primary circuit portion	When the foot valve is pressed, the plunger exerts force on the spring seat, graduating spring, and primary piston. • The primary piston containing the exhaust valve seat closes the primary exhaust valve. • As the exhaust valve closes, the primary inlet valve moves off its seat, allowing primary air to flow out of the primary delivery port.

Foot Valve Operational Phases	
Applying Phase	
Secondary circuit portion	When the primary inlet valve is moved off its seat, the following occurs: • Air enters the relay piston cavity through the bleed passage. • The air pressure moves the relay piston, which contains the exhaust seat, and closes the secondary exhaust valve. • As the secondary exhaust valve closes, the secondary inlet valve moves off its seat, allowing the secondary air to flow out the secondary delivery port. A small volume of air is required to move the relay piston, action of the secondary circuit is almost simultaneous with the primary circuit.
Loss of air in secondary circuit portion	If air is lost in the secondary circuit, the primary circuit portion continues to function as described above.
Loss of air in the primary circuit	If air is lost in the primary circuit, the valve will operate as follows: • When the brake pedal is pressed and no air pressure is present in the primary circuit supply and delivery ports. • The primary piston mechanically moves the relay piston. • This allows the piston to close the secondary exhaust valve and open the secondary inlet valve, allowing air to flow out of the secondary delivery port. This action provides the vehicle with front braking capability.

Foot Valve Operational Phases	
Balanced Phase	
Primary circuit portion	When the primary delivery pressure acting on the piston equals the mechanical force of the brake pedal: • The primary piston moves and the primary inlet valve closes. • This stops airflow from the primary supply line through the valve. • The exhaust valve remains closed, preventing escape of air through the exhaust port.
Secondary circuit portion	When the air pressure on the secondary side of the relay piston approaches the same pressure delivered on the primary side of the relay piston: • The relay piston moves, closing the secondary inlet valve. • This action stops further flow of air from the supply line through the valve. • The exhaust remains closed as the secondary delivery pressure balances the primary delivery pressure.

Foot Valve Operational Phases	
Releasing Phase	
Primary circuit portion	With the brake pedal released: • Mechanical force is removed from the spring seat, graduating spring, and primary piston. • Air pressure and spring load move the primary piston, opening the primary exhaust valve. • This allows air pressure in the primary delivery line to exhaust out the exhaust port.
Secondary circuit portion	With the brake pedal released: • Air is exhausted from the primary circuit side of the relay piston. • Air pressure and spring load move the relay piston, opening the secondary exhaust valve. • This allows air pressure in the secondary delivery line to exhaust out the exhaust port.

Suspended foot valve

This brake valve is a suspended, pedal-operated valve with two separate supply and delivery circuits for service and emergency braking. The major difference between the previous valve and this brake valve is the way they are mounted. Figure 1–8 illustrates the way this type of brake valve is mounted. As you can see, the valve is secured to its own mounting plate. The mounting plate is usually bolted to the firewall. The operation of this valve is about the same as the floor-mounted foot valve previously discussed.

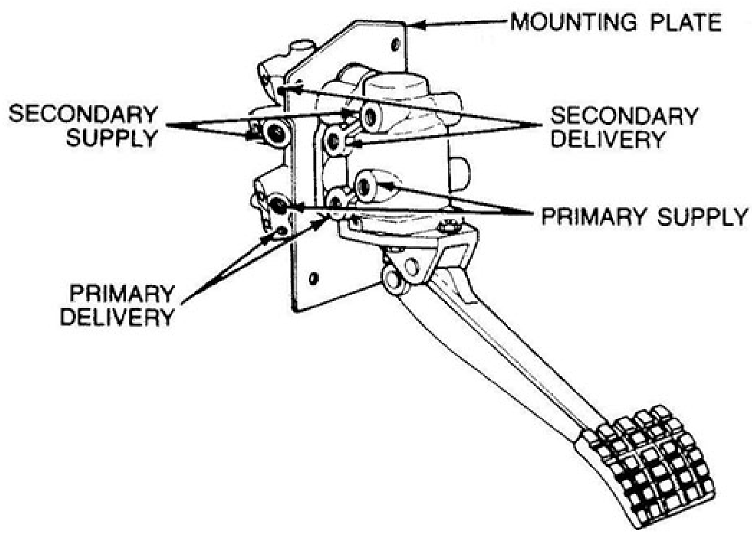


Figure 1–8. Suspended brake valve.

If you suspect a valve is not working correctly, perform an operational test. The test procedures are the same for both types of foot valves. Check the delivery pressure of both primary and secondary circuits using test gauges known to be accurate. For example:

1. Hook up the test gauges according to the service manual.
2. Press the pedal to several positions between fully released and fully applied positions.
3. Check the delivery pressure on the test gauges to see that it varies equally and proportionately with the movement of the brake pedal.
4. After a full application is released by releasing the pedal, the reading on the test gauges should promptly fall to 0 psi.

Relay valves

The *relay valve* in an air brake system functions as a relay station to speed up the application and release of the rear service brakes and parking brakes. There can be several relay valves on each vehicle depending on model. The valve normally mounts at the rear of the vehicle in proximity to the brake chamber it serves. The relay valve operates as a remote-controlled valve delivering or releasing air to the brake chamber in response to control air delivered to it from the foot valve or other source.

Figure 1–9 is a cross section view of a typical relay valve. Notice the three major valve ports of the valve: the service port, supply port, and delivery port.

- A line/hose connects the service port to the foot valve or other controlling source. Air pressure entering or leaving this port is what actually controls the valve.
- An air line connects the supply port to an air reservoir.
- An air line connects the delivery port to the brake chambers controlled by the valve.

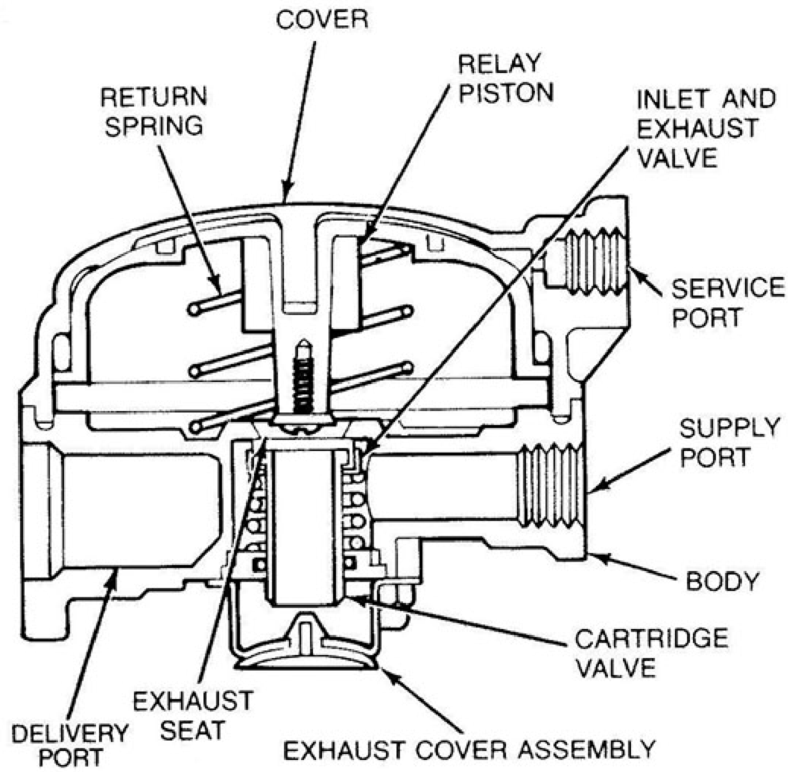


Figure 1–9. Relay valve.

Air pressure delivered to the service port enters the small cavity above the piston and moves the piston down. The exhaust seat moves down with the piston and seats on the inner or exhaust portion of the inlet/exhaust valve, sealing off the exhaust passage. At the same time, the outer or inlet portion of the inlet/exhaust valve moves off its seat, permitting supply air to flow from the reservoir, past the open inlet valve, and out the delivery port. When the service port releases air pressure, the cavity above the relay piston exhausts air pressure. The air pressure beneath the relay piston causes it to rise, moving the exhaust seat away from the exhaust valve, thereby opening the exhaust passage. With the exhaust passage open, the air pressure in the brake chambers discharges through the exhaust port, releasing the brakes.

Quick-release valve

The *quick-release valve* (fig. 1–10) provides several benefits to the air brake system. It is used to speed up exhausting air from a particular component/section of the brake system. It exhausts air from front or rear brake chambers and may be used in conjunction with a relay valve. The quick-release valve exhausts the air near the brake chambers, speeding up the release of the brakes so the air does not have to travel all the way back to its source. Additionally, this valve may be used in truck-tractors to release air in the service line to the trailer. Further, it is used in the parking brake system for releasing the air from the parking brake chamber so large quantities of air do not have to be exhausted in the cab.

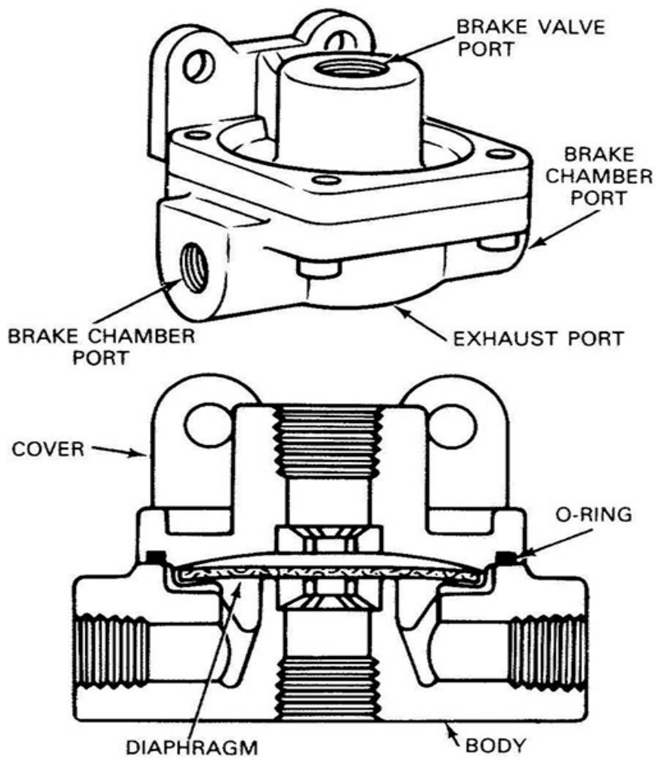


Figure 1–10. Quick-release valve.

The following table describes the operation and functional testing of the quick-release valve.

Quick-Release Valve	
Function	**Description**
Operation	Look at the operation of the quick-release valve when used in the service brake system. When a brake application is made, the following occurs: • Air pressure enters the brake valve port from the foot valve. • The diaphragm moves down and seals the exhaust port. • At the same time, air pressure forces the edges of the diaphragm down and air flows out from the brake chamber ports into the brake chambers. • When the driver releases the foot valve, air pressure above the quick release valve's diaphragm is released back through the foot valve's exhaust port. • Air pressure beneath the diaphragm forces the diaphragm to rise, opening the exhaust port and allowing air in the brake chambers to exhaust.
Functional test	To conduct a functional test, perform the following: • Apply and release the brakes. • Check to see that when the brakes release; air pressure quickly discharges through the exhaust port of the valve. Be sure the exhaust port is not restricted in any way.

Parking brake and tractor-trailer valves

Now, we will consider other valves in an air brake system with which you need to be familiar. These valves are part of the parking brake or trailer air systems.

Parking brake control valve

The parking brake control on the instrument panel actuates the parking brakes. Figure 1–11 shows a typical control valve. The air reservoir constantly supplies air pressure to the supply port. Pushing in the button actuates the valve, supplying air to the parking brake chambers, releasing the brakes. Pulling outward on the button applies the parking brakes. This action releases the air pressure from the parking brake chambers. When the brakes release, the air discharges through the parking brake control valve exhaust port, along with a quick-release valve, if used. The parking brake control valve is pressure-sensitive and automatically moves from the released position to the park position if the air pressure in the reservoirs falls below approximately 45 psi.

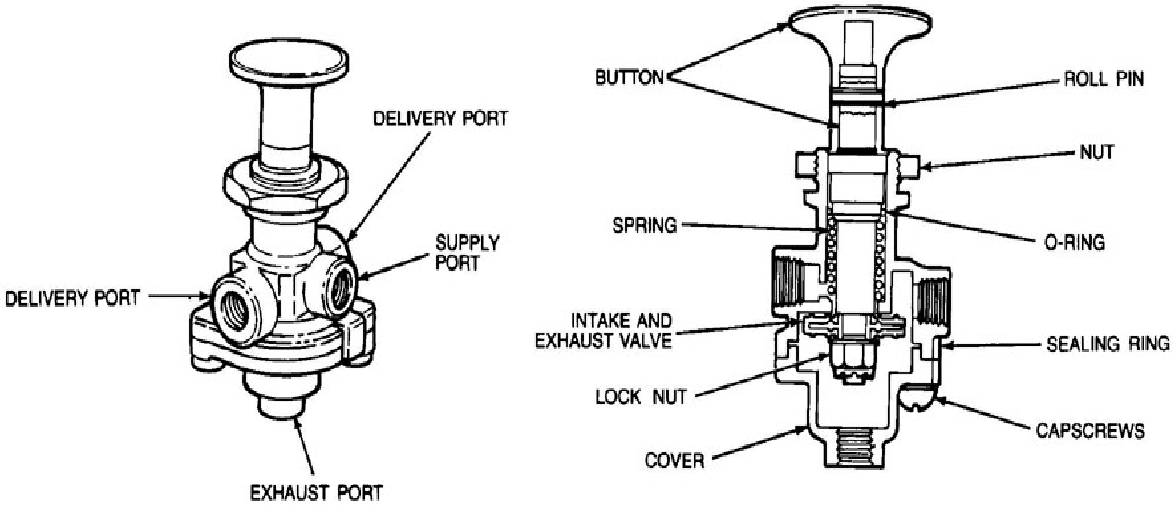


Figure 1–11. Parking brake control valve.

Trailer control valve

The trailer control valve (fig. 1–12) is similar in appearance to the parking brake control valve. It is a push-pull-type valve located in the instrument panel that controls trailer air supply and the trailer parking brakes. This valve is actually comprised of two control valves built into one unit.

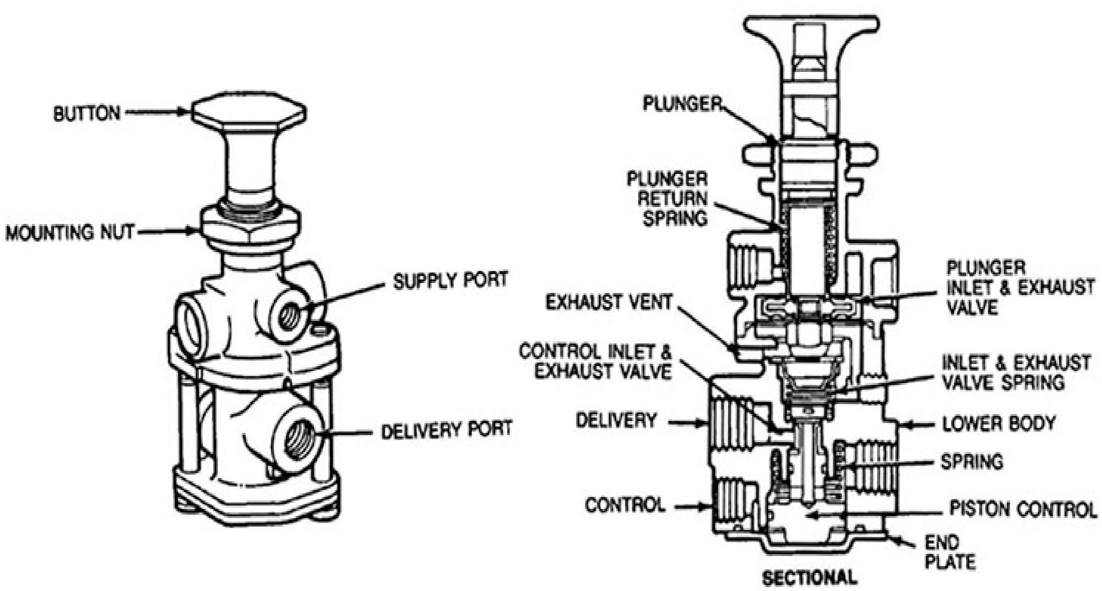


Figure 1–12. Trailer control valve.

Tractor protection valve

The air brake systems of tractors and trucks with trailer brake controls have a tractor protection valve (fig. 1–13), normally mounted behind the cab of the vehicle. Its primary function is to protect the truck/tractor air system if there is an air loss in the trailer air system. Air pressure from the truck/tractor must go through this valve before it reaches the trailer.

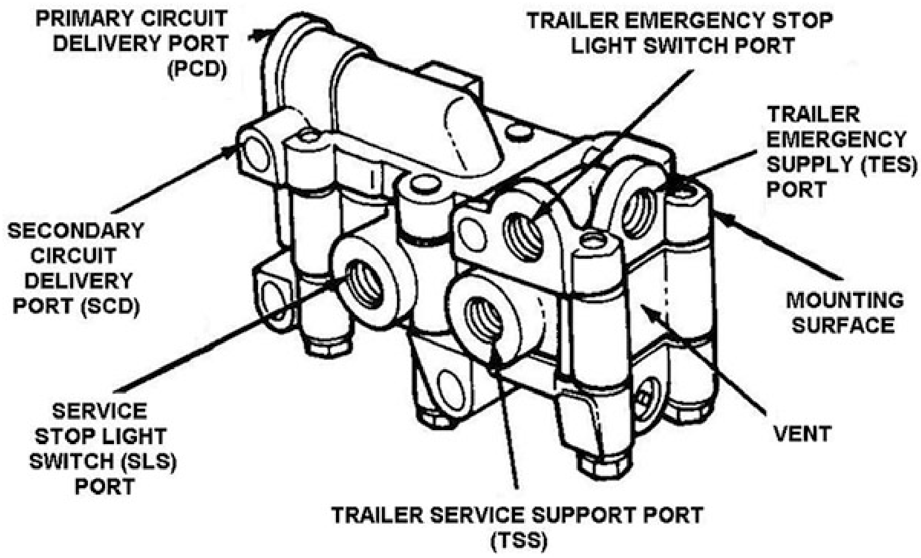


Figure 1–13. Tractor protection valve.

Trailer brake hand-control valve

The hand-control valve is usually mounted to the steering column or on the dash. This valve controls the application of trailer brakes independent of the truck/tractor brakes. Applying only the trailer brakes can be advantageous under certain conditions, such as slippery roads. The hand-control valve also helps the driver maneuver the vehicle when braking for emergencies. The hand-control valve is *not* intended as a parking brake control valve and you should not use it for that purpose. However, be aware that some trucks without trailer brake controls use a hand-control valve to apply the rear service brakes independent of the front brakes.

402. Air brake chambers and foundation brakes

Up until now, you have been learning about components associated with the buildup and transmittal of air pressure. Now, turn your attention to the components that utilize the effects of this air pressure in order to stop the vehicle—the brake system.

The brake chamber is a diaphragm-type actuator, which converts the energy of air pressure into mechanical force. Single brake chambers on the front axle are used for applying service brakes only. However, brake chambers on a rear axle can also be used to apply the parking brake in addition to the service brakes. These dual-purpose chambers, often called “spring” or “maxi” brake chambers are more complex than the simple, single-unit-type service brake chambers. You will cover both service and spring brake chambers within this lesson. .

Service brake chambers

Refer to figure 1–14, as you learn the construction and operation of a typical brake chamber used only for applying the service brakes. The diaphragm, push rod, and return spring are sandwiched between the body and cover. The body and cover (also known as the non-pressure plate and pressure plate) are secured together by a one-piece or two-piece clamp.

Different size brake chambers are identified by numbers, which specify the diaphragm's square area. For example, a type 30 brake chamber contains a diaphragm that has an area of 30 square inches; a type 24 brake chamber has a diaphragm whose area is 24 square inches, and so on. The diaphragm is usually made out of natural rubber and nylon.

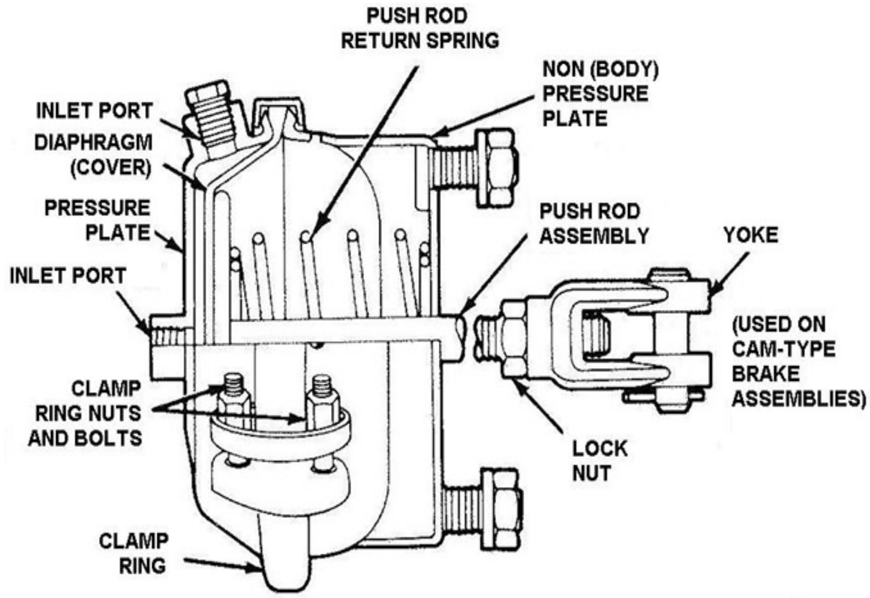


Figure 1–14. Typical service brake chamber.

The cover side of a brake chamber diaphragm is exposed to air pressure when the brakes are applied and the body side is exposed to atmospheric pressure. Controlled air pressure enters the brake chamber through the inlet port in the cover. The air pressure acts upon the diaphragm; in-turn, the diaphragm moves the push rod assembly forward. The forward motion of the push rod actuates the service brakes. The greater the air pressure admitted to the brake chamber, the greater the force applied to the push rod. When air pressure is exhausted from the brake chamber, the push rod return spring, in combination with the brake shoe return spring, returns the diaphragm and push rod to their original positions.

Parking brake chambers

The parking brake chambers, also known as the "spring brake," are additional brake chambers you need to know about. These chambers are located on the rear axle and are essentially two separate chambers combined into a double-diaphragm single unit. Each chamber has a unique function:

- The foot valve operates the service brake function; as with the service brake chamber, it is air-applied/spring-released.
- The parking brake control valve operates the parking brake function.

In contrast to the service brake chamber, the parking brake chamber is spring-applied/air-released.

- When air pressure is applied to the parking brake chamber, the power spring is compressed, causing the push rod to retract, which releases the brakes.
- When air pressure is exhausted from the parking brake chamber, the power spring expands, which extends the pushrod and causes the brake shoes to apply.

CAUTION: The power spring is very strong! Use extreme caution when servicing a brake chamber with a power spring.

The return spring in a service brake chamber is not as big or as strong as a power spring. There are several different models of “spring brakes.” The following paragraph and table describe their basic design and operation.

The service and spring (parking) brake assembly is found on many vehicles with S-cam brakes. In this system, the brake chamber assembly consists of two separate air chambers, each with its own diaphragm and push rod (fig. 1–15). The service brake chamber applies the brake by air pressure and releases it by spring pressure when air is exhausted. The parking or emergency brake is applied by spring pressure and is released by air pressure.

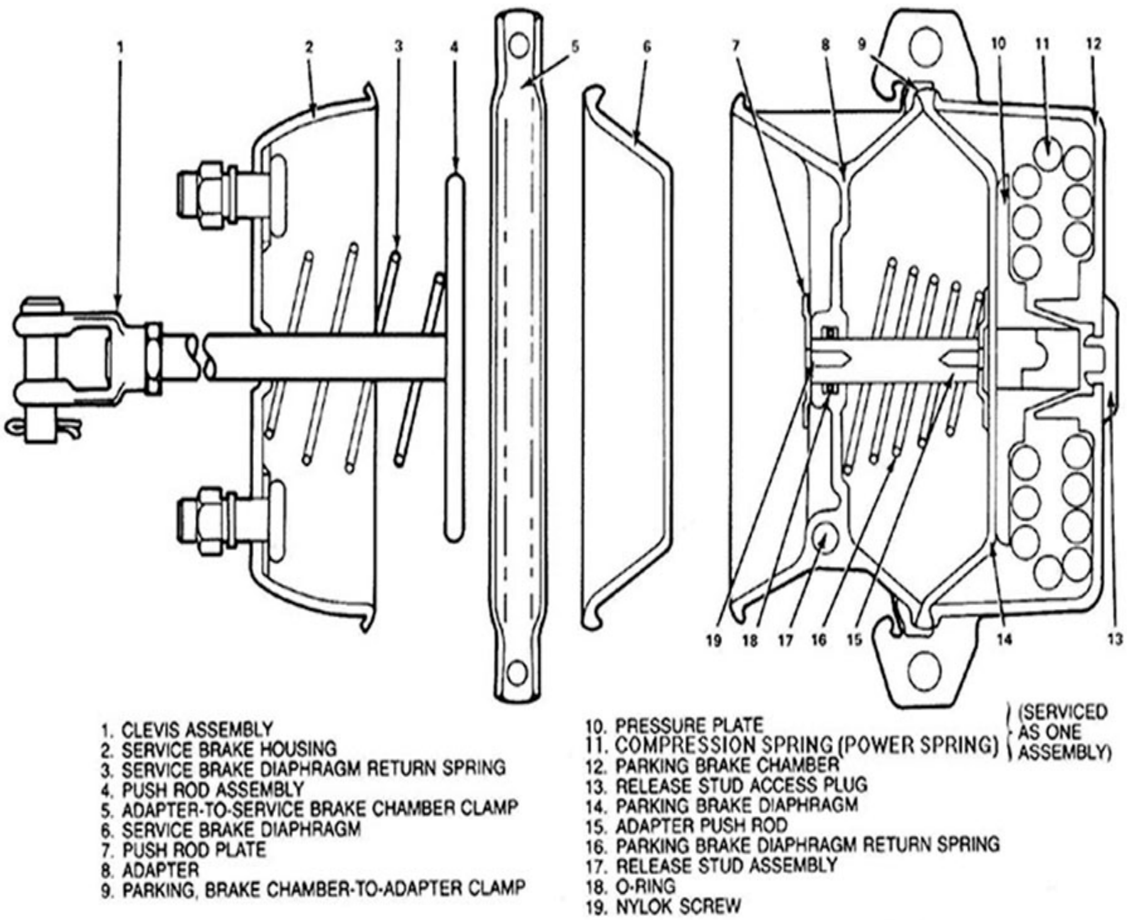


Figure 1–15. Parking brake chamber.

Parking Brake Chamber Operations	
Type	**Description**
Normal driving	The following occurs during normal driving (brakes released): • The brakes are held in the released position by the diaphragm return spring in the service brake chamber and the brake shoe return springs. • Air pressure in the parking brake chamber working against the diaphragm compresses the power spring. This holds the parking brake in the released position. The air pressure is applied by the parking brake control valve (fig. 1–16).

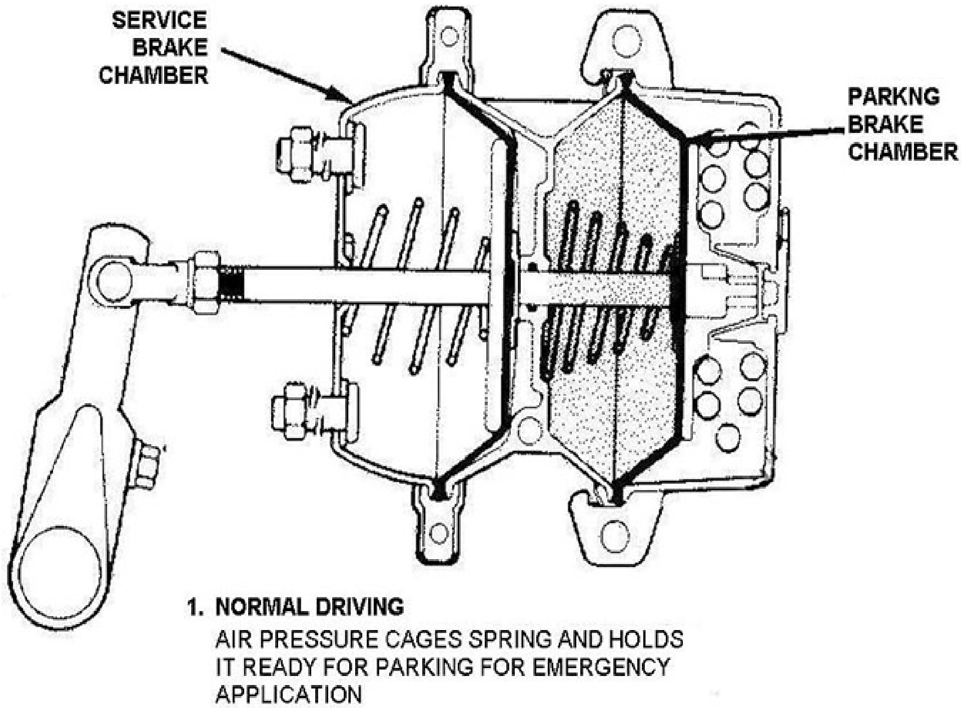
<table>
<tr><th colspan="2">Parking Brake Chamber Operations</th></tr>
<tr><th>Type</th><th>Description</th></tr>
<tr><td></td><td>


Figure 1–16. Chamber in normal position.
</td></tr>
<tr><td>Normal service brake operation</td><td>
In normal braking (service brake applied), air pressure from the foot valve/relay valve, works against the service brake diaphragm in the chamber, applies the brakes (fig. 1–17). Air pressure from the parking brake control valve holds the power spring compressed. The spring brake does not affect normal service brake operation.

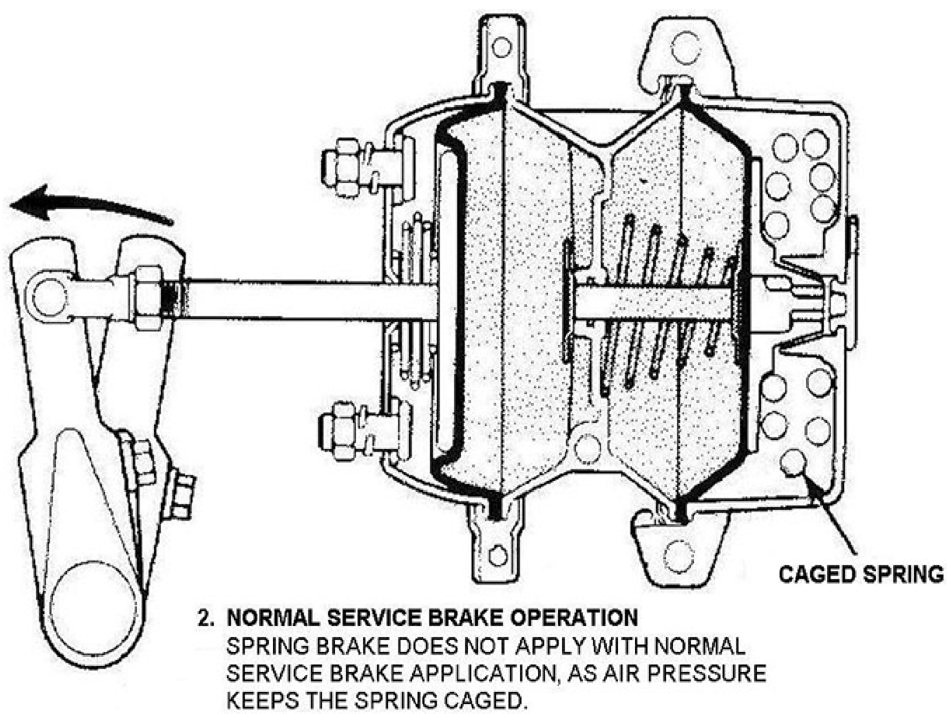
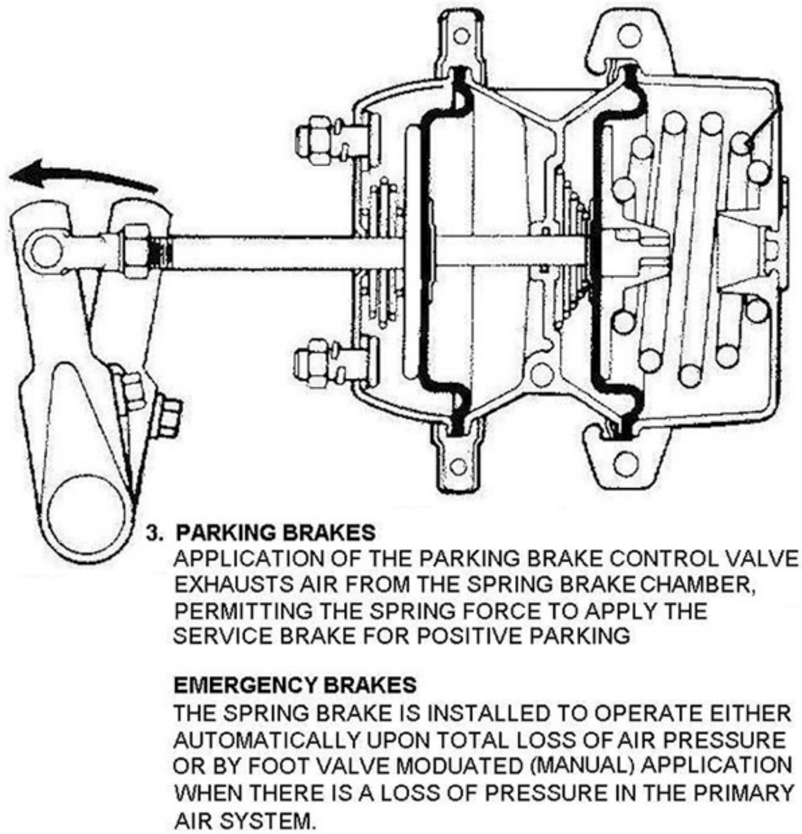


Figure 1–17. Brake chamber under normal operation.
</td></tr>
</table>

Parking Brake Chamber Operations	
Type	**Description**
Parking brake/ emergency brake operation	For parking, or to make an emergency brake application, the air pressure is exhausted from the spring brake chamber. This permits the power spring to expand, moving the spring brake push rod and the service brake push rod to apply the brake (fig. 1–18). In some setups, a loss of air pressure in the system results in total loss of air pressure in the spring brake chambers, resulting in the automatic application of the spring brake. Other setups may have a check valve in the parking brake system, which prevents the air from exhausting if a loss of air pressure occurs in the main system.  **Figure 1–18. Parking brake chamber operation.**
Manually caging the spring	The power spring can be mechanically caged in the event a vehicle, which cannot build air pressure, must be moved. A special release stud (spring caging tool) is furnished with the brake chamber assembly. The release stud engages in the power spring’s pressure plate, and its nut is tightened to compress (cage) the spring and release the brake. The procedure, called “caging the brake,” is also performed when service to the brake chamber is needed. **NOTE:** Follow the exact service manual instructions when caging the spring.

Foundation brakes

There are two basic styles of foundation brakes utilized in an air brake system—camshaft, or cam, and wedge. The cam-type is the most common.

Cam brakes

The cam-type brake is an air-operated, two-shoe brake. The front brakes use a one-piece shoe lining. The rear shoes each use a two-piece lining.

As the brake pedal is applied, air pressure is supplied to the brake chamber. The brake chamber's internal diaphragm pushes against the brake chamber push rod with a force proportional to the air pressure being applied to the chamber.

1. The push rod then pushes on the slack adjuster arm, which rotates the brake camshaft, also called a cam (fig. 1–19).
2. The cam rotation forces the brake shoes outward against the brake drum.
3. When the brake pedal is released, the return springs pull the shoes away from the drum. The chamber return spring moves the chamber to the released position.

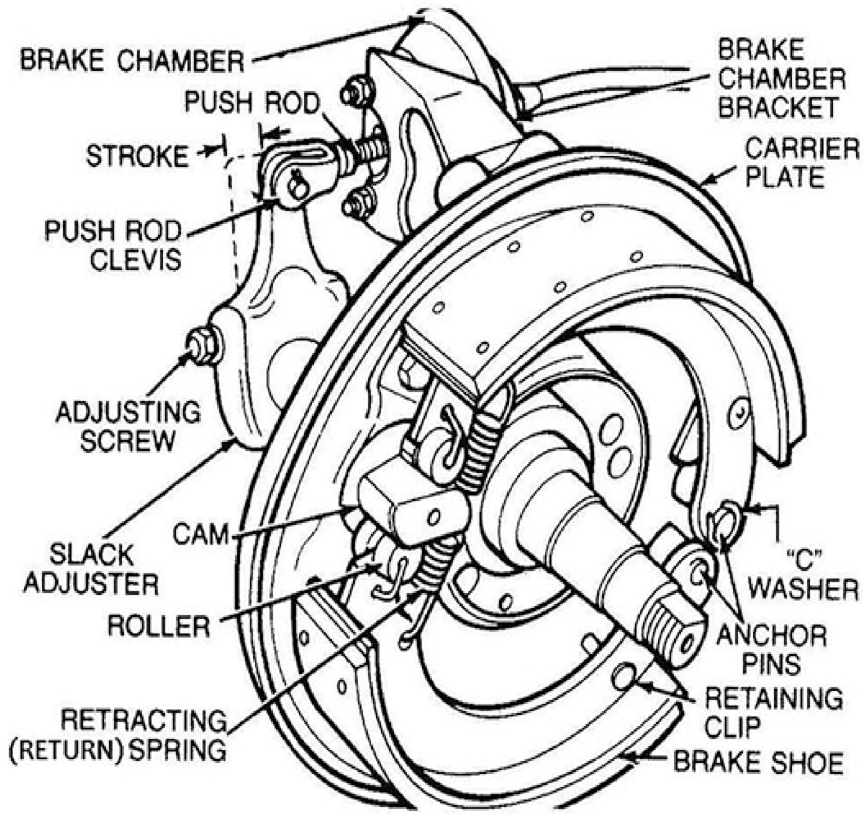
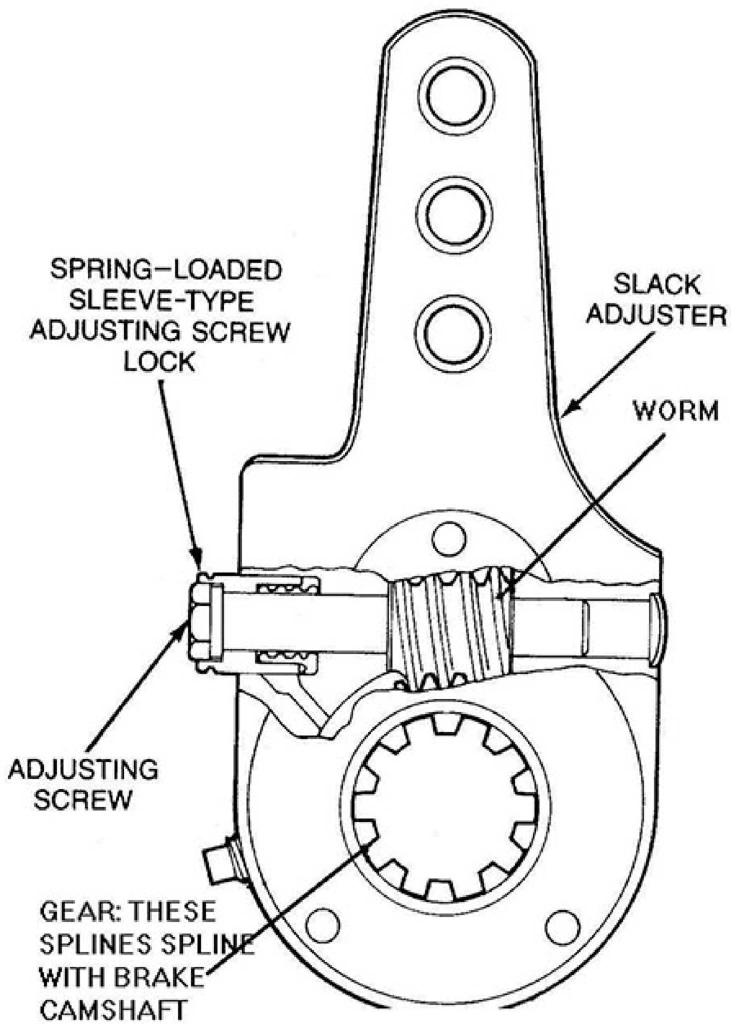
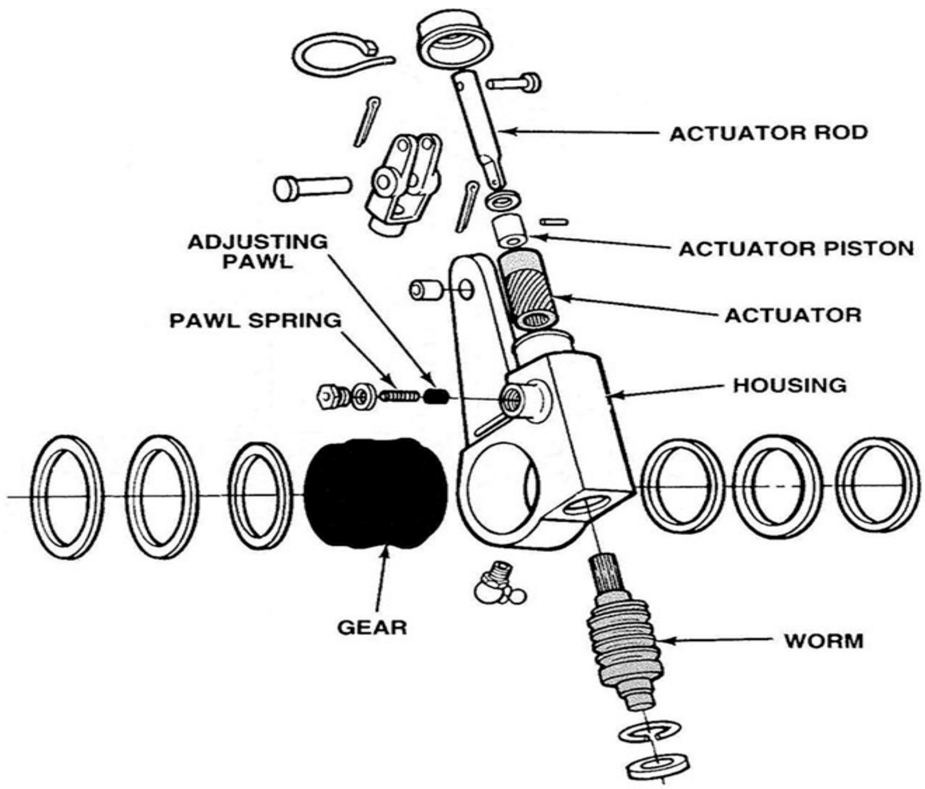


Figure 1–19. Cam brake and slack adjuster.

There are two cam head styles—a flat cam and an S-shaped cam. Both styles work the same way.

Cam Brake Slack Adjusters	
Type	**Description**
Manual	In a cam foundation brake, the link between the air system and the brake assembly is the slack adjuster. The arm of the slack adjuster is fastened to the push rod of the chamber with a clevis, and the slack adjuster is internally splined to the brake camshaft. Primarily, the slack adjuster is a lever, converting the force of the brake chamber into a torque that turns the brake camshaft and applies the brakes. The brake chamber's push rod pushes against the slack adjuster, which, in turn, rotates the camshaft. All slack adjusters utilize the worm-and-gear principle (fig. 1–20). A manual slack adjuster contains four basic components: • Housing. • Worm. • Gear. • Adjusting screw mechanism.

Cam Brake Slack Adjusters	
Type	**Description**
	The adjusting screw mechanism uses a positive-lock mechanism consisting of a spring-loaded lock sleeve, which engages the adjusting screw nut, preventing the adjusting screw from rotating. • Turning the adjusting screw nut on the end of the wormshaft rotates the wormshaft and worm. • The worm meshes with and rotates the slack adjuster worm gear, which is connected to the brake camshaft through splines. • The turning of the worm gear rotates the brake cam, spreading the brake shoes to compensate for lining wear. In this way, the slack adjuster provides an easy means of adjusting the brakes.  **Figure 1–20. Manual slack adjuster.**

Cam Brake Slack Adjusters	
Type	**Description**
Automatic	An automatic slack adjuster has a built-in mechanism that adjusts itself as the brake linings wear. Since there are several different manufacturers of automatic slack adjusters, the built-in mechanisms may look different; however, the operation is the same. An exploded view of a typical automatic slack adjuster can be seen in figure 1–21. It has a housing, worm, and gear, as well as the other components, which perform the self-adjusting function. The following occurs during brake application: • The movement of the clevis pulls the actuator rod and piston. • The worm prevents the actuator from rotating, so the adjusting pawl is pushed outward against spring force as the actuator moves. The following occurs during brake release: • The clevis pushes the actuator rod and piston, which pushes the actuator. • The teeth of a spring-loaded adjusting pawl mesh with the helical of the actuator, causing it to rotate as it is being pushed. • The worm (splined to the actuator) also rotates until the gear and camshaft are at the point of adjustment. • At this time, the actuator pushes the pawl outward against spring force. • As the actuator rod and piston continue to push the actuator, it ratchets past the pawl without rotating.  **Figure 1–21. Automatic slack adjuster.**

Wedge brakes

Wedge-operated brakes use a different method of expanding the brake shoes than cam-operated brakes. This type of brake assembly can be either hydraulic and/or air-actuated. Figure 1–22 shows an exploded view of a typical air-actuated wedge-type brake.

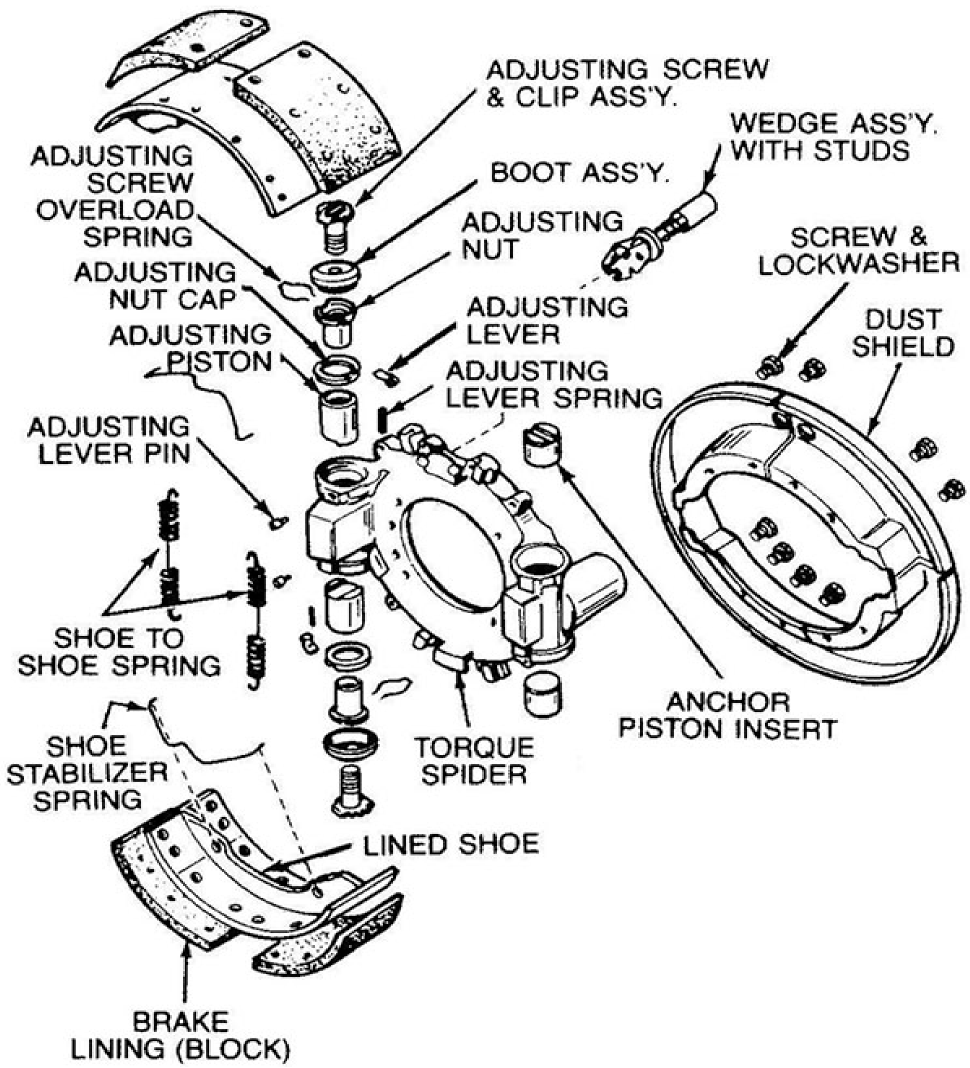


Figure 1–22. Wedge brake.

Brake shoe guide pads and brackets are machined as integral parts of the torque spider (refer to fig. 1–22). The actuator is also integrally machined into the spider. Depending on the design, there can be one or two actuators built into the torque spider. The design of the wedge-brake assembly can accommodate one or two brake chambers. The brake chamber can be a simple single chamber, or it can be a double chamber including a power spring for parking.

The function of the stationary anchor pistons is to support the frame of the brake shoe. The other actuator bore contains an adjusting piston and other related parts. These other parts make up the automatic adjustment mechanism for this particular design. Some designs have a manual adjuster instead of an automatic adjustment mechanism.

The wedge assembly is also located in the actuator bore adjacent to the adjusting pistons. The wedge assembly (fig. 1–23) is constructed of the wedge, roller cage, and return spring. The wedge is made of chrome-plated, hardened steel.

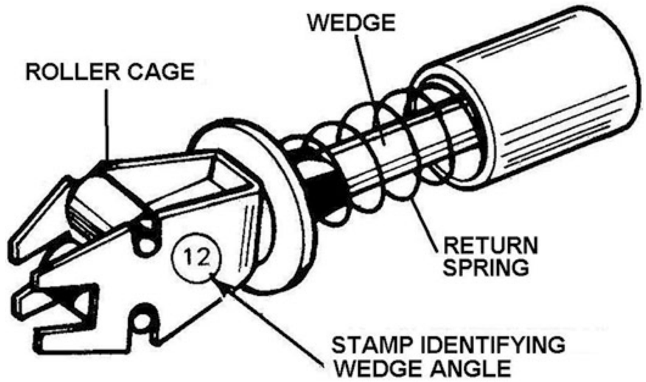


Figure 1–23. Wedge assembly.

The angle is stamped on the side of the wedge surface, which can be identified through a hole in the roller cage. Wedge angles need to be the same for each wedge assembly on a particular axle. Different wedge angles on the same axle can cause uneven braking. When the wedge is pushed into the cage, the rollers expand. Different wedge angles also change the amount of roller expansion.

During a brake application (fig. 1–24), the air brake chamber forces the wedge assembly between the two adjusting pistons, causing them to force the brake shoes against the drum. The roller expansion caused by the force of the wedge drives the brake shoes against the brake drum. When the foot valve is released, air pressure is exhausted from the brake chamber, allowing the wedge to move from between the pistons. This allows the pistons to move inward in the actuator bore, releasing the pressure of the brake shoes against the drum, thus releasing the brakes. The automatic adjustment mechanism compensates for lining wear by expanding as the brakes are applied and released. A manual adjuster mechanism requires periodic brake adjustments.

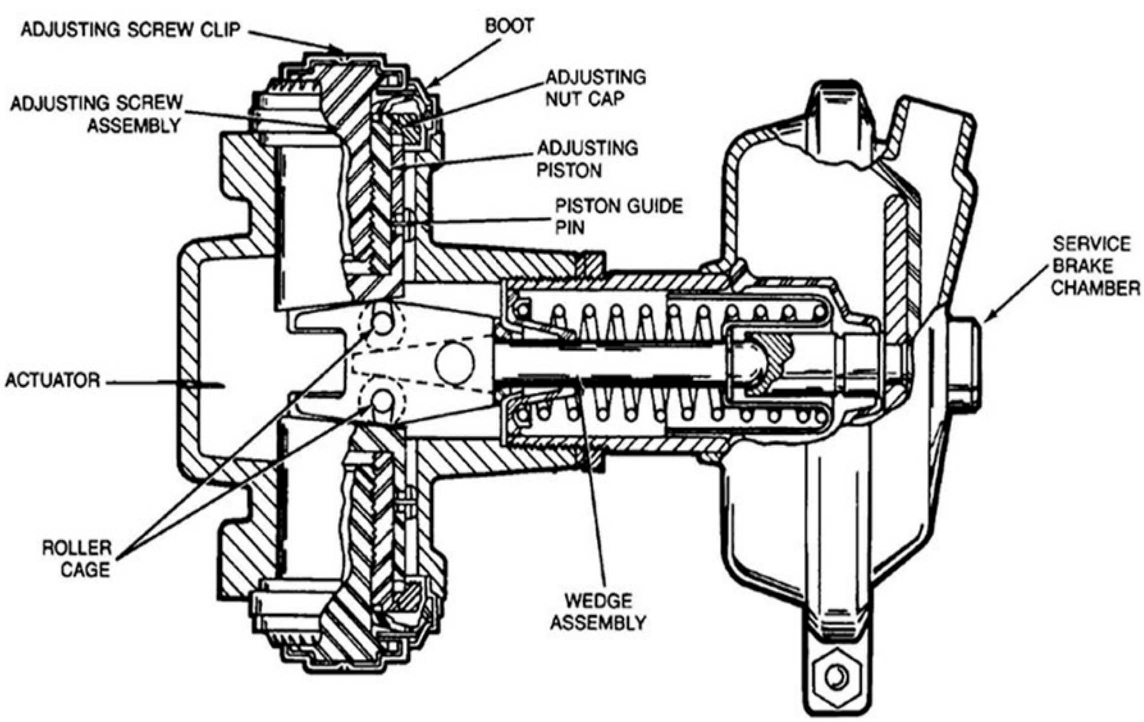


Figure 1–24. Cutaway of a wedge brake.

403. Servicing the air brake system components

In this lesson, we consider some general areas of inspecting, troubleshooting, and adjusting some of the air supply circuit components that you have learned thus far. 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.

<table>
<tr><th colspan="2">Component Inspection, Testing, and Repair</th></tr>
<tr><th colspan="2">Compressor</th></tr>
<tr><td>Inspection</td><td>There are several general checks, which apply to most compressors. It is important the compressor receives a clean supply of air.
The air strainer/filter must be kept clean and properly installed.
Check the compressor mounting to be sure it is tight.
Be sure the drive pulleys are in proper alignment and belt tension is properly adjusted.
The oil and coolant lines are another area to observe:
Make sure there are no leaks or routing problems.
Look at the coolant fins on the crankcase and make sure they are not clogged with dirt, grease, and so forth.
Operate the engine to see if the compressor builds up pressure according to specifications.
Check the unloader mechanism for proper operation according to the service manual.</td></tr>
<tr><td>Buildup test</td><td>This test measures the air compressor’s ability to build up air pressure:
Check the service manual for the specified maximum amount of time the test should take.
Bleed both the primary and secondary reservoirs down to 85 psi as measured with a test gauge.
Run the engine at the manufacturer’s specified revolutions per minute (rpm) until air pressure reaches 100 psi.
If the time taken to reach 100 psi exceeds specifications, further troubleshooting is necessary.</td></tr>
<tr><td>Excessive buildup and recovery time.</td><td>If the compressor is slow to build initial pressure, or to recover following heavy usage, you may suspect these items:
Dirty intake strainer/filter.
Restriction in the compressor inlet or discharge line.
Leaking or broken discharge valves.
Drive belt slipping.
Inlet valves worn or stuck open.
Excessive leakage in the air system.
Worn pistons, rings, and/or cylinders.
NOTE: Worn pistons, rings, or cylinders can cause excessive lubricating oil to be discharged from the compressor into the air system. Excessive oil in the supply reservoir is an indication of this problem. The compressor will most likely require overhaul or replacement. Follow the procedures outlined in the service manual.</td></tr>
<tr><td>Noisy compressor operation</td><td>A healthy air compressor should be relatively quiet during operation. The following items may cause the compressor to generate excessive noise.
Loose drive gear or pulley.
Worn drive coupling.
Worn bearings in the compressor.</td></tr>
</table>

Component Inspection, Testing, and Repair	
	• Worn pistons, rings, or cylinders. • Improper lubrication to the compressor. • Restrictions in the cylinder head or discharge line. **NOTE:** Follow service manual procedures to determine if the compressor requires overhaul or replacement.
Compressor fails to unload	If a compressor is not unloading when it reaches the predetermined cut-out setting, the following conditions may be at fault: • Defective or worn unloader pistons or bores. • Defective governor. • Unloader line from governor kinked, or the cavity beneath the unloader piston restricted.
Governor	
Operating test and adjustment	Start the engine and build up air pressure in the air brake system. • Check the air pressure at the time the governor cuts out (stopping the compression of air). • The governor should cut out at approximately 115–125 psi. While the engine is still running, make a series of brake applications to reduce system air pressure and observe at what pressure the governor cuts in the compressor (cut-in pressure). • The compressor should cut-in approximately 20–25 psi below the cut-out pressure. In most cases, you need to replace the governor if it does not operate as previously mentioned. However, some governors are adjustable. • The adjustment is made by rotating the adjusting screw until the desired governor-controlling pressures are reached. • Check the service manual for more details.
Safety Valve	
Operating test	Perform the following with air pressure in the system: • Pull up on the exposed end of the valve stem. • This action should remove the spring load from the ball valve. • Air should exhaust from the valve's exhaust port. • Release the stem and the airflow should stop. If the valve does not operate in this manner, it must be replaced.
Moisture Ejector	
Operating test	With the air system charged and pressure stabilized in the system, there should not be any leaks at the valve's exhaust port. Make several brake applications and note each time an application is made if an exhaust of air occurs at the exhaust port of the drain valve. • If no air comes out, push the wire stem. • If air still does not come out, the valve should be removed and cleaned.
Air Gauge	
Accuracy	The simplest way to check an air gauge for accuracy is to compare its readings with an accurate test gauge. Replace the dash gauge if it is inaccurate by more than 5 psi.

Low-Pressure Indicator Switch	
Test	If possible, determine the setting of the low-pressure indicator switch by referring to the label on the switch or by checking the service manual. Turn the ignition switch to the RUN position and reduce system air pressure while observing the exact air pressure at which the warning light/buzzer illuminates/sounds. • The warning light/buzzer should operate at approximately 60 psi. • If the warning light/buzzer does not operate within the correct pressures, the low-pressure indicator switch is probably at fault and should be replaced. If the warning device(s) does not work at all, accomplish the following: • Disconnect the wire at the low-pressure indicator switch, which leads to the warning device. • Ground the wire and see if the warning device works. o If it does, replace the low-pressure indicator switch. o If the warning device still does not work when you ground the wire, check the warning device and its wiring for faults.
Reservoir	
Inspection	Check the air brake reservoir tanks for punctures or other external damage. Ensure the tanks are free of corrosion and that the outside surface is painted. This will prevent the possibility of corrosion causing a failure. **NOTE:** Welding repairs should never be performed on reservoirs. If the reservoir is deemed unfit for use, it should be replaced.

Repairing air delivery valves

Over a vehicle's service life, air delivery valves can become dirty or sticky, preventing them from opening or closing easily. Accomplish the following when you come across this type of situation:

- Disassemble the suspected valves and give them a good cleaning.
- Consult the service manual to find out detailed procedures concerning disassembly, cleaning, and reassembly of the air brake valves.

Most valves are easy to disassemble. For example, the disassembly of a quick-release valve involves removing four bolts that hold the two housings together. In most cases, the valves and their components can be cleaned with a mild solvent. Emery cloth(s) can be used to remove any corrosion on the valve's components. It is a good trade practice to replace all the seals inside the valve whenever it is disassembled. You can order a repair kit for most air valves; each kit includes all the necessary seals and gaskets to repair the valve.

Service brake chamber maintenance

Common types of maintenance you will accomplish on service brake chambers includes removing and installing new chambers, diaphragm replacement, and chamber repair. The following table provides general procedures for servicing this type of brake chamber.

Service Brake Chamber Maintenance	
Action	**Description**
Removal and installation	Drain the air system before removing the brake chamber. Most brake chambers are secured to their mounting bracket with two bolts. Perform the following to remove the brake chamber: • Remove the mounting bolts. • Disconnect the air line. • Disconnect the push rod's clevis pin.

<table>
<tr><th colspan="2">Service Brake Chamber Maintenance</th></tr>
<tr><th>Action</th><th>Description</th></tr>
<tr><td></td><td>
NOTE: If you are going to replace a brake chamber, it is a good idea to replace both chambers on the same axle. Replacing both chambers ensures even braking across the axle.
If installing a new brake chamber, use a hacksaw to cut the push rod to the same length as the old chamber. Push rods of new brake chambers are usually longer than necessary.
Installation of the brake chamber is a reversal of the removal procedures.
Of course, you will need to follow-up the job with a slack adjustment. Be sure to consult the service manual for specific guidance.
</td></tr>
<tr><td>Diaphragm replacement</td><td>
Diaphragm replacement is the most common reason for disassembling a brake chamber. If you are installing a new diaphragm in one brake chamber, it is a good trade practice to install a new one in the opposite chamber to ensure even braking across the axle.
The service brake chamber can be disassembled by removing the clamp bolts.
Before removing the clamp bolts, it is a good idea to mark the position of the cover, body, and clamp so they can be reassembled in their original position.
You will need to relieve the tension of the return spring before loosening the clamp.
Pull the push rod outward to compress the spring, and relieve tension on the diaphragm and clamp ring.
Secure the rod in this position by clamping a vise or vise grip pliers on the push rod (fig. 1–25).

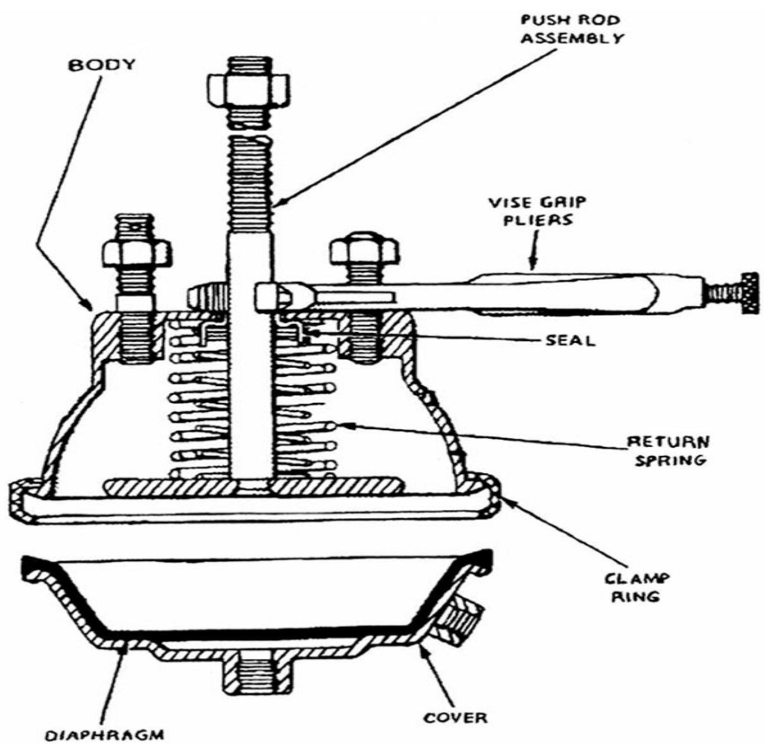
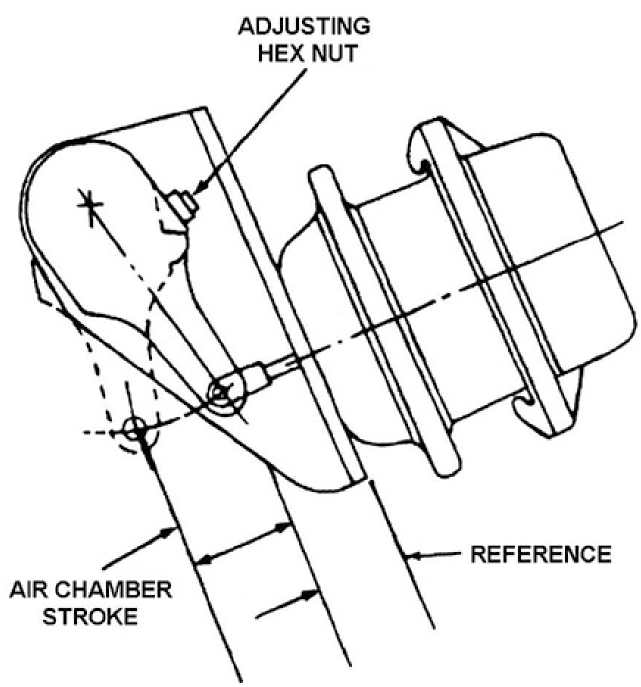


Figure 1–25. Vise grips to compress spring.
</td></tr>
<tr><td>Chamber repair</td><td>Remove the clamp and separate the cover and diaphragm from the rest of the unit. If more service is required other than diaphragm replacement, continue disassembly and repair the chamber following service manual procedures.</td></tr>
</table>

CAUTION: The preceding procedure is general in nature. For SAFETY reasons, it is imperative you follow the procedures in the service manual any time you are working on air brake chambers. This is especially true of brake chambers that contain a power spring used for a parking brake. The parking brake chamber must be caged first or it can come apart with great force, causing personal injury or damage to other resources.

Foundation brake maintenance

There are two basic maintenance operations you need to perform to ensure proper operation of cam-type brakes—slack adjustments and lubricating the camshaft.

Foundation Brake Maintenance	
Action	**Steps You Take**
Making a slack adjustment	Slack adjustment (also called brake adjustment) is critical for the correct operation of the vehicle during braking; all brake assemblies must be applied and released promptly with controlled timing. A properly aligned slack adjuster ensures the brake chamber's push rod travel results in a promptly applied and released brake. • Consult the service manual to determine the correct way to check the operation and adjustment of the slack adjuster. • Each manufacturer specifies the correct way to check the slack adjuster for proper operation/adjustment.
	For example, on some vehicles, you must inspect the length of the push rod stroke when the brakes are applied (fig. 1–26). Another method is to check the angle between the centerline of the push rod and the centerline of the slack adjuster when the brakes are applied and released (fig. 1–27). Perform the following if a slack adjustment is required: • Turn the adjusting nut on the slack adjuster until the correct angles or stroke lengths are obtained. • As always, follow step-by-step procedures in the service manual.  **Figure 1–26. Push rod length.**

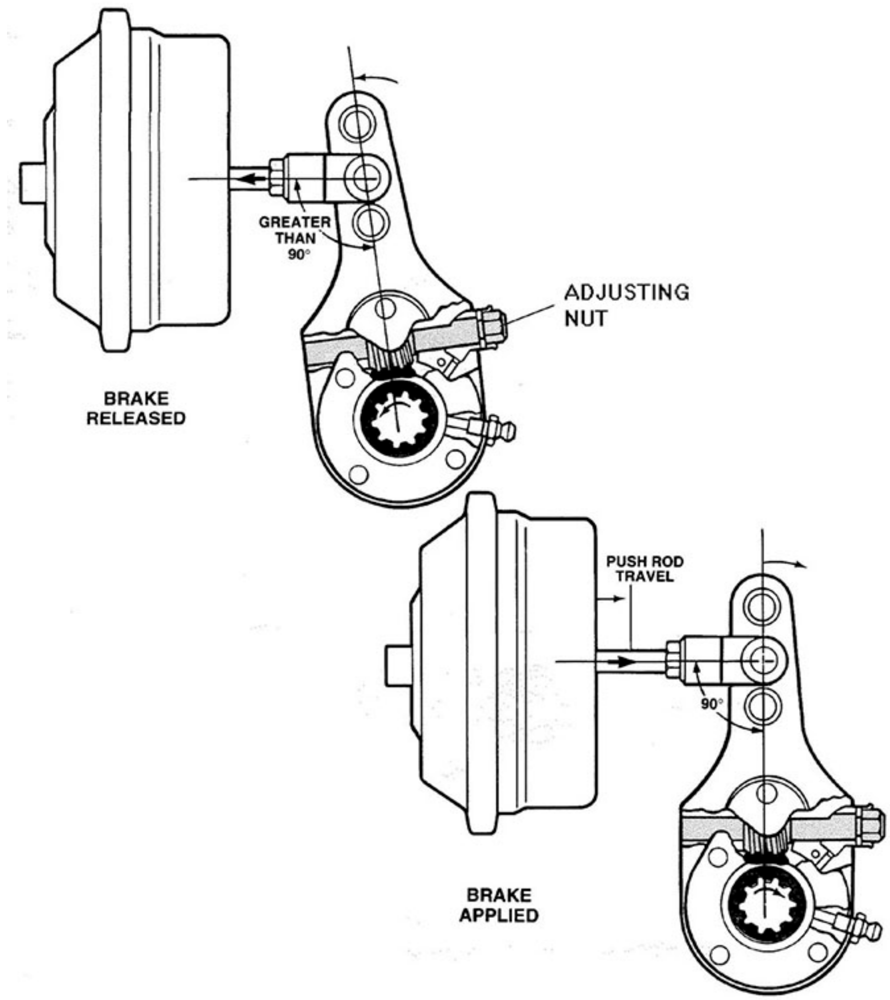
<table>
<tr><th colspan="2">Foundation Brake Maintenance</th></tr>
<tr><th>Action</th><th>Steps You Take</th></tr>
<tr><td></td><td>

Figure 1–27. Slack adjuster angles.</td></tr>
<tr><td>Lubricating the camshaft</td><td>During a preventive maintenance inspection, you must lubricate all grease fittings. The camshaft housing grease fitting requires special attention because it needs less grease than you would normally apply to other fittings.

A common problem is many technicians “over grease” this particular fitting. This happens because you cannot see the grease coming out anywhere when you pump into this fitting. Since you normally pump until you see grease coming out, this tends to “over grease” this particular fitting. To avoid this when applying grease to this fitting, only inject “one shot” or “one pump” of grease.

NOTE: Too much grease pumped into this fitting will force grease inside the brake drum through the cam opening. The resulting presence of grease inside the drum will eventually contaminate the brake linings and cause unsafe braking conditions.</td></tr>
</table>

Diagnosing antilock brakes

Antilock air brakes operate on the same principle as hydraulic antilock brake systems (ABS). Therefore, from this point forward we will refer to antilock brake systems as ABS. The ABS operates as a one-channel or two-channel systems. A one-channel system provides antilock braking to the rear axle(s).

A two-channel system provides antilock braking to both the front and rear axles. We will cover the two-channel system since it is used by several heavy-duty truck manufacturers and you will be more likely to encounter it.

Two-channel system

The major components of the two-channel system include the following:

- A control module.
- Two front-wheel-speed sensors.
- Two drive-axle wheel-speed sensors.
- A rear modulator/relay valve assembly.
- A front modulator valve.

NOTE: The major components of the one-channel system are the same as the two-channel system, except for the absence of front-wheel-speed sensors and front modulator valve.

Keep in mind that an ABS still uses a compressor, governor, and many of the air valves you learned about earlier in this unit.

Control module

The control module mounted on the rear modulator valve is the computer or “brain” that controls the ABS. An electronic device receives electrical input signals from several antilock system components. Based on these signals, the control module is programmed to send output signals to control other ABS components during aggressive braking. When aggressive braking is occurring, the control module uses the front and/or rear modulator to regulate air to the service-brake chambers in order to prevent wheel lockup.

The control module has self-test capabilities and a diagnostic display window for troubleshooting. The self-test and diagnostic circuitry of the module continuously checks the entire antilock system for proper operation. If a circuit or component problem is detected, one or more light emitting diodes (LED) in the diagnostic window illuminate and the dash-mounted antilock warning lamp is illuminated. The LEDs only show one fault at a time. After correcting the first fault (and clearing it with the reset function), if a second fault exists, it will be displayed.

The control module receives an alternating current voltage signal from each wheel-speed sensor. Based on the frequency of the voltage signal, the control module compares the speed of each wheel in the ABS system. When the brakes are applied, all the wheels begin to slow down. Since the rate of deceleration occurs faster during an aggressive or hard brake application, the control module is programmed to recognize normal and abnormal deceleration rates. For example, all wheels should decelerate at the same rate during braking; however, if one wheel decelerates faster than the others, it may lock up.
In this situation, the ABS takes control of the braking. When the control module senses one wheel is about to lock up, it commands the modulator on that axle to exhaust air from the service brakes. This reduces air brake pressure and prevents the wheel from locking up. The control module and modulator are able to apply and exhaust air the same way as if the driver were “pumping the brakes.” However, the modulator is able to “pump” the brakes directly on the axle requiring correction.

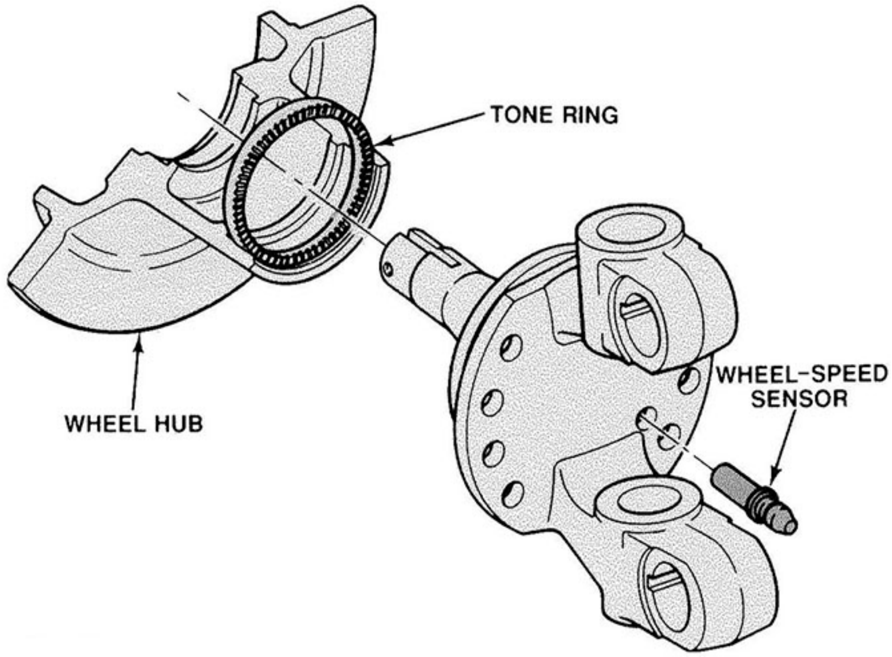


Figure 1–28. Wheel-speed sensor.

Front-wheel-speed sensors

Each sensor (fig. 1–28) is mounted into its own hole in the front spindle. The tip of the sensor is positioned to align with a tone ring, which has 100 teeth and is mounted on the wheel hub assembly. When the hub is installed on the axle, there is a small air gap between the tip of the sensor and the tone ring.

The magnet in the sensor generates a magnetic flux (magnetic lines of force), which is, in essence, a magnetic field. When the teeth of the tone ring align with the sensor, it moves within the magnetic field and concentrates the flux (magnetic lines of force) so it becomes stronger. This movement of flux induces a positive voltage in the sensor winding. Since the tone ring has 100 teeth, 100 alternating current cycles are generated each time the wheel makes one complete revolution.

Rear axle speed sensor

The rear axle wheel-speed sensors may differ slightly in design depending on axle manufacturer. Both rear sensors are “in-axle”-type sensors because they are mounted to the differential bearing adjuster. One advantage of having the sensors located inside the rear axle is they are protected from damage. They are not affected by wheel styles, rear wheel servicing, or bearing wear. The disadvantage of the sensor being located inside the rear axle is the differential must be disassembled to replace the sensor. The rear sensors operate in the same way as the front-wheel sensors.

Rear modulator/relay valve assembly

The purpose of the rear modulator/relay valve (fig. 1–29) is to modify driver-applied air pressure to the service brakes. A combination valve has the following three components:

1. A standard relay valve (like other air brake relay valves).
2. Two solenoids (one inlet and one exhaust), which rapidly apply and exhaust air during an ABS stop.

The following table describes the valve's three air connections.

Modulator/Relay Valve Assembly Connections		
Type	**Abbreviation**	**Origin/Destination**
Supply air pressure	SUP	From the reservoir
Delivery air	DEL	To the rear brake chambers
Control air pressure	CON	From the foot valve control

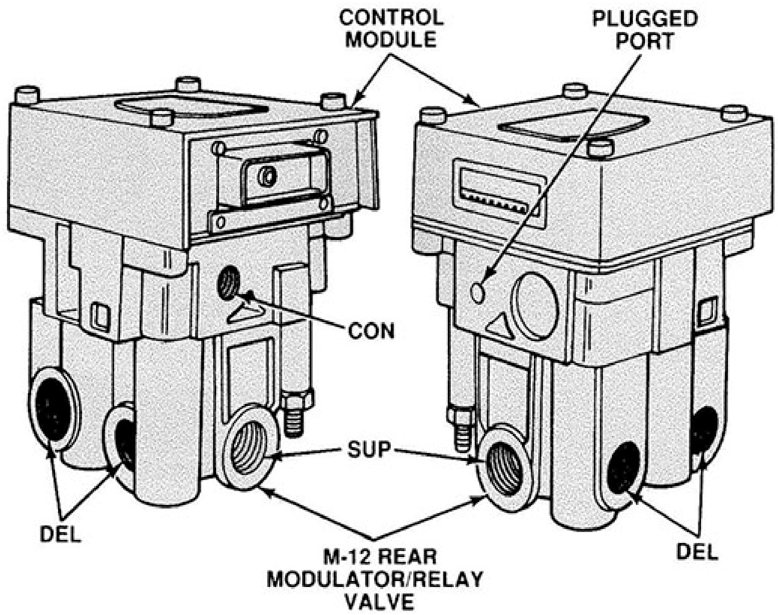


Figure 1–29. Rear modulator/relay valve.

As mentioned previously, the rear modulator has an exhaust solenoid and an inlet solenoid. The solenoids are inactive during normal braking. The rear modulator/relay valve acts like a typical relay valve in a standard air brake system during non-ABS stops.

During an ABS stop, the control module opens and closes the inlet and exhaust solenoids many times per second. The control module alternately activates and deactivates the solenoids as required to achieve controlled air pressure to the rear air brake chambers. This antilock activity of exhausting and reapplying the brakes occurs in a pulsating manner, which simulates "pumping the brakes."

Front modulator valve

The front modulator valve (fig. 1–30) is a high capacity, on/off air valve that has two electrical solenoids controlled by the control module. This valve controls air pressure to the front brake chambers during an antilock stop. It has one exhaust and one supply solenoid. The control module controls solenoid operation by supplying a "ground" to complete the circuit through the solenoid. The front modulator valve has the two air connections provided in the following table.

Modulator/Relay Valve Assembly Connections		
Type	**Abbreviation**	**Origin/Destination**
Supply air pressure	SUP	From the foot valve
Delivery air	DEL	To the front brake chambers

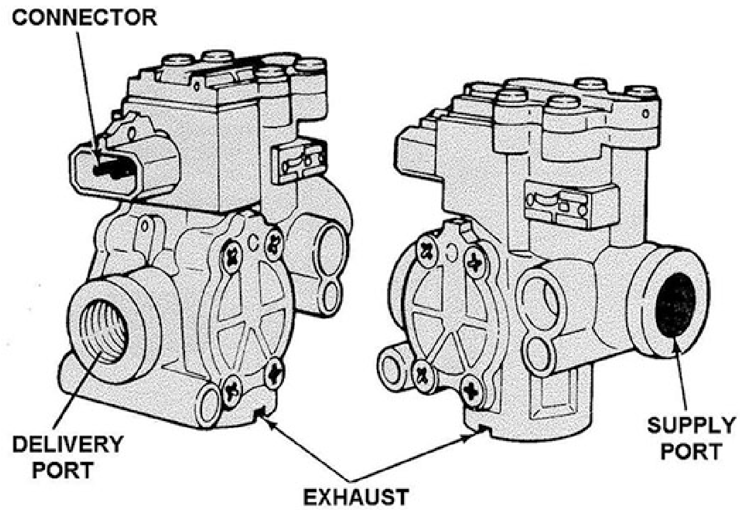


Figure 1–30. Front modulator valve.

The front modulator valve works similar to the rear modulator/relay valve. During a normal non-ABS stop, the solenoids in the front modulator valve are inactive, allowing air pressure to go through to the front brake chambers when the foot valve is depressed. If a front-wheel-sensor indicates a wheel is approaching lockup, the control module begins pulsing the solenoids in the front modulator valve. The pulsing solenoids in the front modulator valve exhaust and apply air to the front brake chambers very rapidly. This allows the front brake chambers to receive controlled amounts of air pressure so the wheels will not lock up.

Isolating antilock brake system malfunctions

The control module diagnostic display locates a specific problem; however, it is still necessary to confirm if the problem is in the component itself or in the wiring. When the LEDs indicate a fault, you can use troubleshooting charts in the service manual to lead you through a series of voltage and resistance checks. All voltage and resistance tests are performed by beginning where the module's wire harness half of the connector is located and moving away from the control module toward the antilock system component.

The simplicity of this system should be pointed out. There are no *fault codes* to interpret. The fault codes for most other ABS systems are interpreted by recording a series of flashes from the warning lamp or by reading them from a hand-held scanner. However, in this system, the control module illuminates the faulty component/circuit in the diagnostic window on the control module. Depending on which LEDs are illuminated, you simply follow the proper diagnostic charts to pinpoint the cause of the fault.

Antilock warning lamp

All troubleshooting begins by checking the operation of the amber ANTILOCK lamp on the dash. When the ignition switch is turned to the ON position, watch the ANTILOCK lamp on the dash. If the ANTILOCK warning lamp does not illuminate, follow the diagnostic chart in the service manual to find the fault in the lamp circuit.

Normally, when the ignition is in the ON position, the amber lamp blinks twice and then remains illuminated as the control module performs a self-test of the ABS system. The self-test is completed when vehicle speed exceeds 10 miles per hour (mph) and the lamp extinguishes. If the warning lamp *does not blink* when the ignition switch is turned ON, the control module has already detected a fault in the system.

In order for the control module to perform the self-test, the vehicle must be moving faster than 10 mph.

During the self-test, the control module checks all wheel-speed sensors for too much variation between their signals. If the control module senses too much variation in wheel-speed sensor signals after 15 seconds (front-to-rear, or left-to-right), the control module will “shut down” the antilock system and illuminate the ANTILOCK lamp. This condition could be caused by towing, operation (testing) on a dynamometer, or accelerating on an icy surface. When the control module receives uniform wheel-speed signals, the antilock function is reactivated and the amber ANTILOCK lamp is turned off.

Control module

As previously mentioned, the control module contains a diagnostic window that has a series of LEDs. A two-channel ABS control module diagnostic window contains nine such LEDs. The first five LEDs isolate a problem to a specific area of the vehicle, and the last four pinpoint the problem component or its wiring. When the control module senses a faulty condition, it illuminates the ANTILOCK warning lamp on the dash, as well as the appropriate LEDs in its diagnostic window. The faulty condition is stored in memory and is not cleared if the control module loses power. When power is restored, the LEDs remain illuminated until the problem is corrected.

After the fault is corrected, you clear the control module diagnostics by passing a small magnet over the RESET point in the diagnostic window. This action resets the diagnostic LEDs. If there are multiple faults, the LEDs for the second and other problems are displayed *only after the first fault has been repaired and the control module reset using a magnet*. No special tools are needed to interpret the LEDs. To give you a better understanding of this system, look at the function of each LED in the control module diagnostic window presented in the following table.

Control Module LEDs	
LED	***Except where noted, all LEDs are red.***
FRONT	For a faulty wheel-speed sensor (SENS), it illuminates with either RIGHT or LEFT LED and the SENS LED. If there is a problem in the front modulator (MOD), it illuminates the FRONT LED along with the MOD LED.
MID	This middle (MID) LED *is not used* and should only illuminate when a magnet is held next to the reset point on the diagnostic window.
REAR	For a faulty wheel-speed sensor, it illuminates with either the RIGHT or LEFT LED and the SENS LED. If there is a problem in the rear modulator valve, the REAR LED also illuminates with the MOD LED.
RIGHT	Illuminates with either the FRONT or REAR LED and SENS LED to indicate a problem. It *should not illuminate* when a MOD LED is on.
LEFT	It illuminates with either the FRONT or REAR LED and SENS LED. This LED *should not illuminate* when a MOD LED is illuminated.
MOD	Illuminates to indicate a permanent or intermittent open or short circuit in a modulator solenoid or its wiring. The MOD LED illuminates with either the FRONT or REAR LED.
SENS	Illuminates to indicate a failed wheel-speed sensor (SENS) or its wiring. The SENS LED illuminates with the FRONT or REAR LED, and either the RIGHT or LEFT LED.
ECU	Indicates that the control module has failed. It illuminates and STAYS ON for *all* control module failures *except low voltage*. If there is low voltage to the control module, the electronic control unit (ECU) LED remains illuminated until the voltage is within range. • For voltages less than 9 volts, its LED illuminates and indicates the control module is inoperative. • When the voltage exceeds 9 volts, the LED will go out automatically.

Control Module LEDs	
LED	***Except where noted, all LEDs are red.***
VOLT	This LED is GREEN. It illuminates and remains on during vehicle operation to indicate electrical power is reaching the control module. If power is below 10 volts or above 17 volts, this LED flashes until power is brought into range.

The RESET area is a magnetically-sensitive switch, located below the LEDs, used to reset the diagnostic system of the control module. Holding a magnet against the word “RESET” illuminates all LEDs, which remain illuminated until the magnet is removed. The magnet must be strong enough to lift a 3-ounce weight in order to activate the reset function.

Self-Test Questions

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

401. Air supply system and delivery valves

1. How many cylinders do most air compressors have?

2. Where do most air compressors get their lubricating oil?

3. What is the purpose of the air fins around the air compressor?

4. What position is the unloader piston in when it is not pressurized by the governor?

5. What happens to the governor when air pressure in the reservoir reaches the governor’s predetermined cut-out setting?

6. Where are most governors mounted?

7. What two components work together to control the amount of pressure in the air supply system?

8. What happens to air pressure in the unloader line when the governor’s exhaust valve opens, and what effect does this have on the air compressor?

9. How many reservoirs do most air brake systems contain?

10. Why is the supply reservoir often referred to as the “wet tank”?

11. Which reservoir supplies the front brakes with air?

12. What component on the supply reservoir protects the air brake system from excessive air pressure buildup in case of governor failure?

13. What component protects the dry tanks from an air loss in the supply reservoir?

14. How can you manually drain an automatic moisture ejector?

15. What optional system prevents any moisture in the air system from freezing during cold weather?

16. What are the two types of air dryers?

17. What color are the air pressure gauge indicator needles for the primary and secondary air systems?

18. At what system pressure does the low-pressure indicator switch actuate in order to alert the driver of low air pressure?

19. What are two common names for the foot valve?

20. When the foot valve is applied, what internal component closes the primary exhaust valve?

21. During the releasing phase of the foot valve, what type of forces cause the primary piston to move in order for air to exhaust out of the valve?

22. During an operational test, what should the gauge read after releasing the foot valve?

23. What is the function of the relay valve?

24. What are the three major valve ports of the relay valve?

25. What is the function of the quick-release valve?

26. When the driver releases the foot valve, through what component is the air pressure above the quick-release valve’s diaphragm released?

27. How is the parking brake control valve actuated in order to release the parking brake?

28. What will happen to the parking brake control valve if air pressure in the system falls below 45 psi?

29. Which valve protects the truck air system if there is an air loss in the trailer air system?

30. Which valve has the ability of applying the trailer brakes independently of the truck/tractor brakes?

402. Air brake chambers and foundation brakes

1. What component secures the brake chamber’s body and cover together?

2. Which side of the diaphragm is exposed to atmospheric pressure?

3. What is another name for a parking brake chamber?

4. In a double diaphragm chamber, what kind of force is used to apply and release the service brake chamber?

5. What kind of force is used to hold the power spring compressed for the parking brake?

6. What procedure would you need to perform to the power spring when servicing the brake chamber?

7. What is the most common type of foundation air brake?

8. What happens to the brake shoes when the brake camshaft rotates because of force applied to the slack adjuster?

9. What are the two styles of camshaft heads?

10. How is the manual slack adjuster connected to the brake camshaft?

11. What are the four basic components of a manual slack adjuster?

12. What component pushes the automatic self-adjuster’s actuator rod during brake release?

13. What is the function of the anchor pistons in a wedge-type brake?

14. Where is the wedge assembly located?

15. What will happen if you have different wedge angles located on the same axle?

403. Servicing the air brake system components

1. What is one of the first actions you should take before troubleshooting an air brake malfunction?

2. When performing an air compressor buildup test, what air pressure should the primary and secondary reservoirs be bled down to?

3. What problems can cause excessive oil to be discharged into the supply reservoir?

4. At what air pressure should the governor “cut-out”?

5. What action should you take if you find that the air pressure dash gauge is inaccurate by over 5 psi?

6. If you reduce air system pressure, when should the warning light/buzzer activate?

7. What can normally be used to clean air valves and their components?

8. What tool should you use to cut the push rod of a new replacement brake chamber to ensure it is the same length as the old chamber?

9. Why should you replace both service brake chamber diaphragms of one particular axle, even if only one diaphragm is defective?

10. What might be the result if you disassemble a parking brake chamber without first caging the power spring?

11. What are the two basic ways of checking slack adjustments?

12. How much grease should be applied to the camshaft grease fitting during a preventive maintenance inspection?

13. What are the major components of the two-channel system?

14. Where is the control module mounted?

15. How many faults can be indicated by the LED display at any one time?

16. What component is programmed to recognize normal and abnormal deceleration rates of the wheels?

17. How many teeth does the tone ring have?

18. What is a disadvantage of having the rear wheel-speed sensors located inside the rear axle?

19. How many solenoids are located in the rear modulator valve?

20. What is the function of the front modulator valve?

21. How do you interpret ABS fault codes?

22. What component’s operation should you check first when troubleshooting the antilock system?

23. What vehicle speed is required for the control module to complete the self-test?

24. How many LEDs are located in the two-channel ABS control module diagnostic window?

25. Which LEDs in the diagnostic window isolate a problem to a specific area of the vehicle?

26. What is the purpose of the last four LEDs in the diagnostic window?

27. How can you clear the control module diagnostics and reset the diagnostic LEDs?

28. Which LEDs would be illuminated to indicate a problem in the rear modulator valve?

1–2. Central Tire Inflation System

The central tire inflation system (CTIS) allows the operator to manually select a tire pressure suitable to the terrain being traveled. The system incorporates an electronic controller unit and air regulating system that provides and maintains the correct air pressure to all tires at the same time. The air pressure is provided by the air supply system discussed in the previous section. The controller governs the manifold, which automatically directs compressed air to inflate the tires, or signals the deflation port to deflate the tires according to the operator-selected terrain setting.

The A/S32P–23 crash-fire-rescue trucks and the refurbished 2.5-ton (M–35) and 5-ton (M–1083) vehicles are equipped with CTIS. The CTIS on firefighting and M-series vehicles operates on the same principal, but with different components. This section deals with three areas unique to this system. In the first lesson, we will look at the components that make up a common CTIS (fig. 1–31) and then turn our attention to its operation. Within the second lesson, we will focus our attention on troubleshooting malfunctions and repairing the system. It is always vital that you refer to the technical order for the vehicle you are working. The components described in the following lesson are from a P–23 crash-fire-rescue truck.

404. Central tire inflation system components and operation

This lesson covers the CTIS components and its different modes of operation. Additionally, you will learn procedures used to select the tire pressure required for the type of operation or conditions encountered while the vehicles are operated on the highway, cross-country, in mud/snow/sand, and during emergencies.

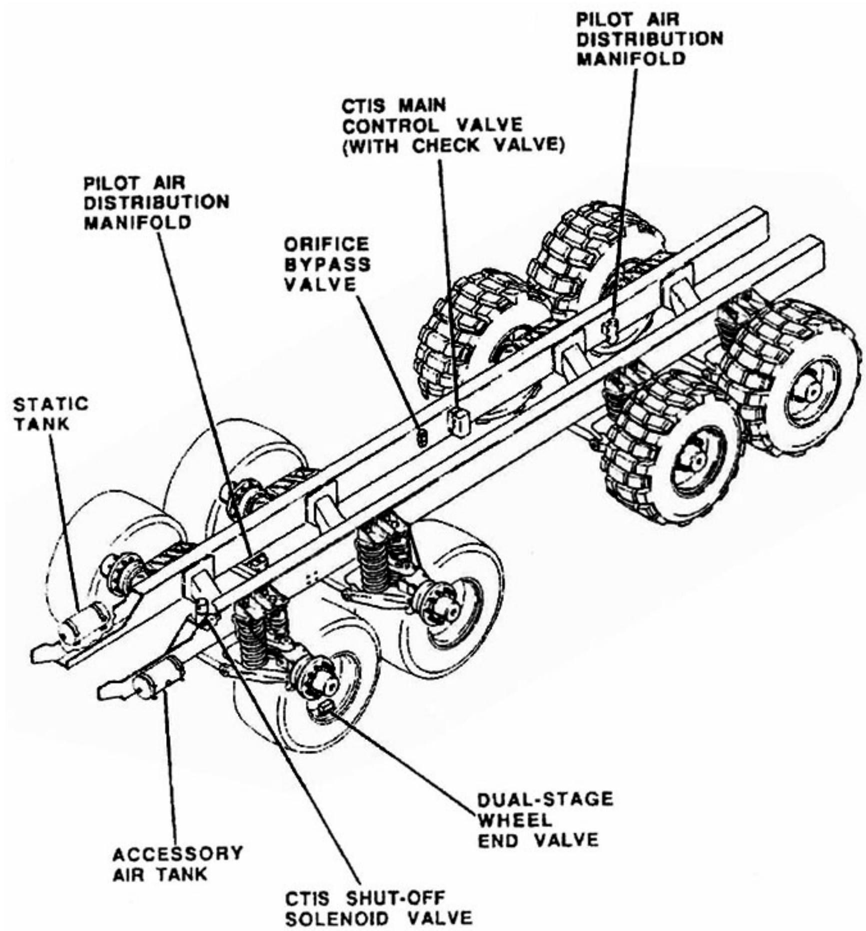


Figure 1–31. Central tire inflation system components.

Components

The following table explains each CTIS component.

Component	Explanation
CTIS controller (microprocessor)	The controller is equipped with an erasable and programmable memory chip containing the parameters required to monitor and adjust tire pressure in response to operator- or sensor-initiated inputs. The onboard computer controls the system. The controller panel is shown in figure 1–32.

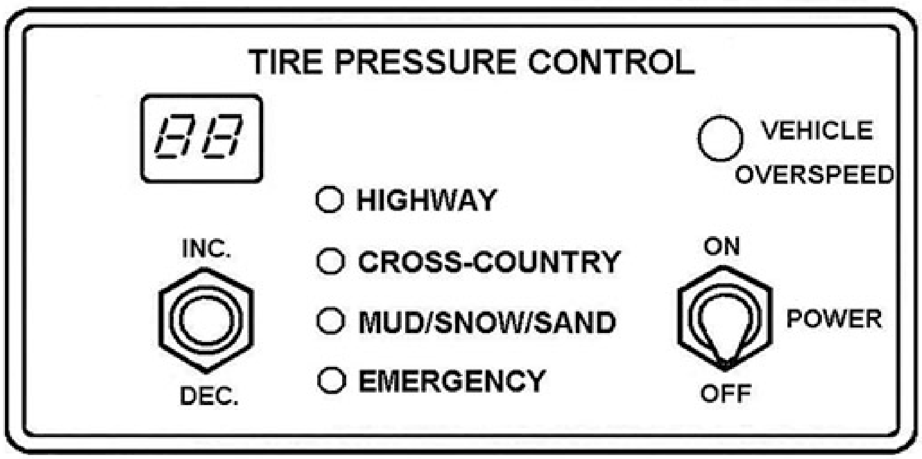
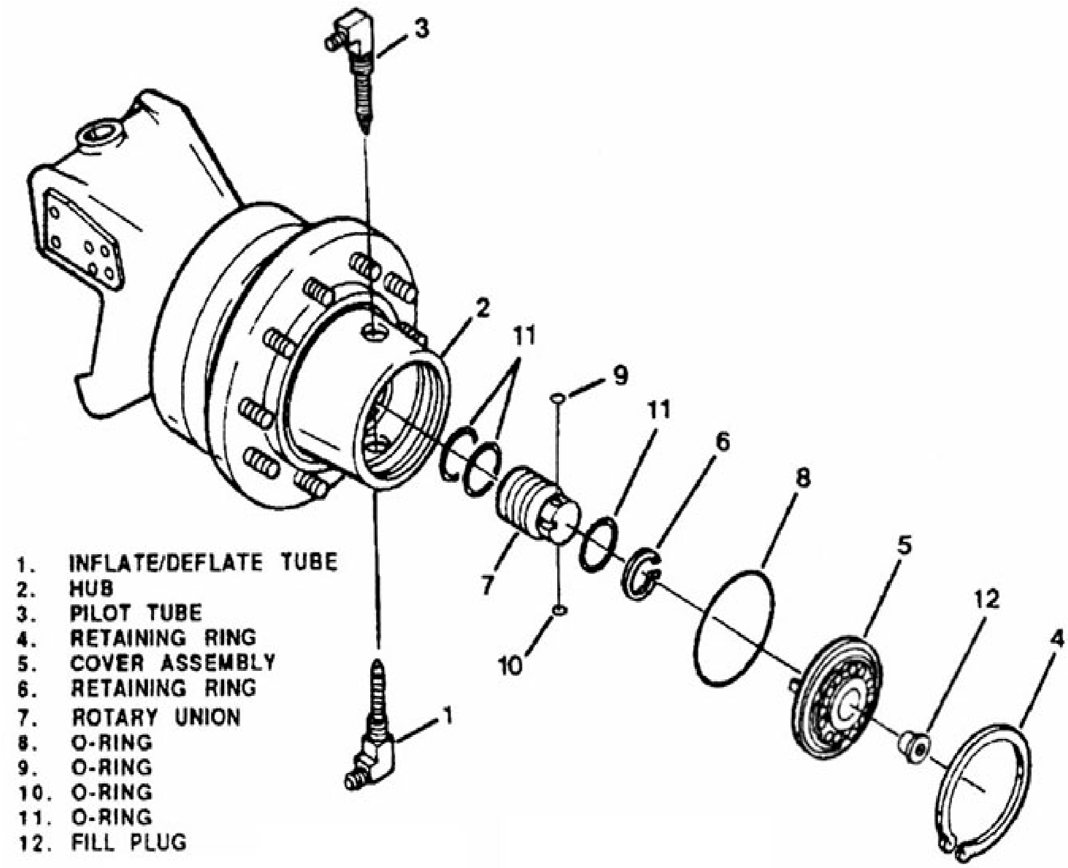


Figure 1–32. Central tire inflation system controller panel.

Speed sensor	This is an electromagnetic sensor installed on the transmission output drive. It is designed to monitor vehicle speed and input this information to the controller. Other sensors include two transmission speed sensors and a turbine speed sensor.
Accessory air tank	This tank stores pressurized air for use by the CTIS and vehicle accessories (fan clutch, roof turret, bumper turret differential lock-up, etc.). It is equipped with a manual drain valve.
Static air tank	Serves as a holding tank for air supplied to the tires. Since static tank and tire pressures are equal, the static tank is the source for monitoring actual tire pressure. This tank is equipped with a manual drain valve and should be drained daily.
Main control valve	The main control valve consists of four air control solenoids, a pressure regulator, a double check valve, and two air controlled piston assemblies. The main control valve reacts to the output signals of the controller and/or the operator adjustments of the INCREASE/DECREASE control to add or release air from the tires.
Pilot air distribution manifold	This manifold directs air to the pilot section of each dual-stage wheel end valve. Two manifolds are provided.
Rotary union	The rotary union is mounted in the wheel hub (fig. 1–33). It is designed to allow airflow to and from the rotating wheel. Air pressure is contained within the union by an extremely close tolerance and finish carbon face seal.

Component	Explanation
 **Figure 1–33. Rotary union.**	
Dual-stage wheel end valve	Figure 1–34 shows an exploded view of the dual-stage wheel end valve. It is mounted on the lock ring of each wheel. It has a pilot-operated valve that controls air flow to and from the tire. The valve has three positions. In the first position, the valve prevents air flow in or out of the tire. In the second position, it allows inflation/deflation to occur. In the third position, it allows rapid exhaust of air directly from the valve.

<table>
<tr><th>Component</th><th>Explanation</th></tr>
<tr><td colspan="2">

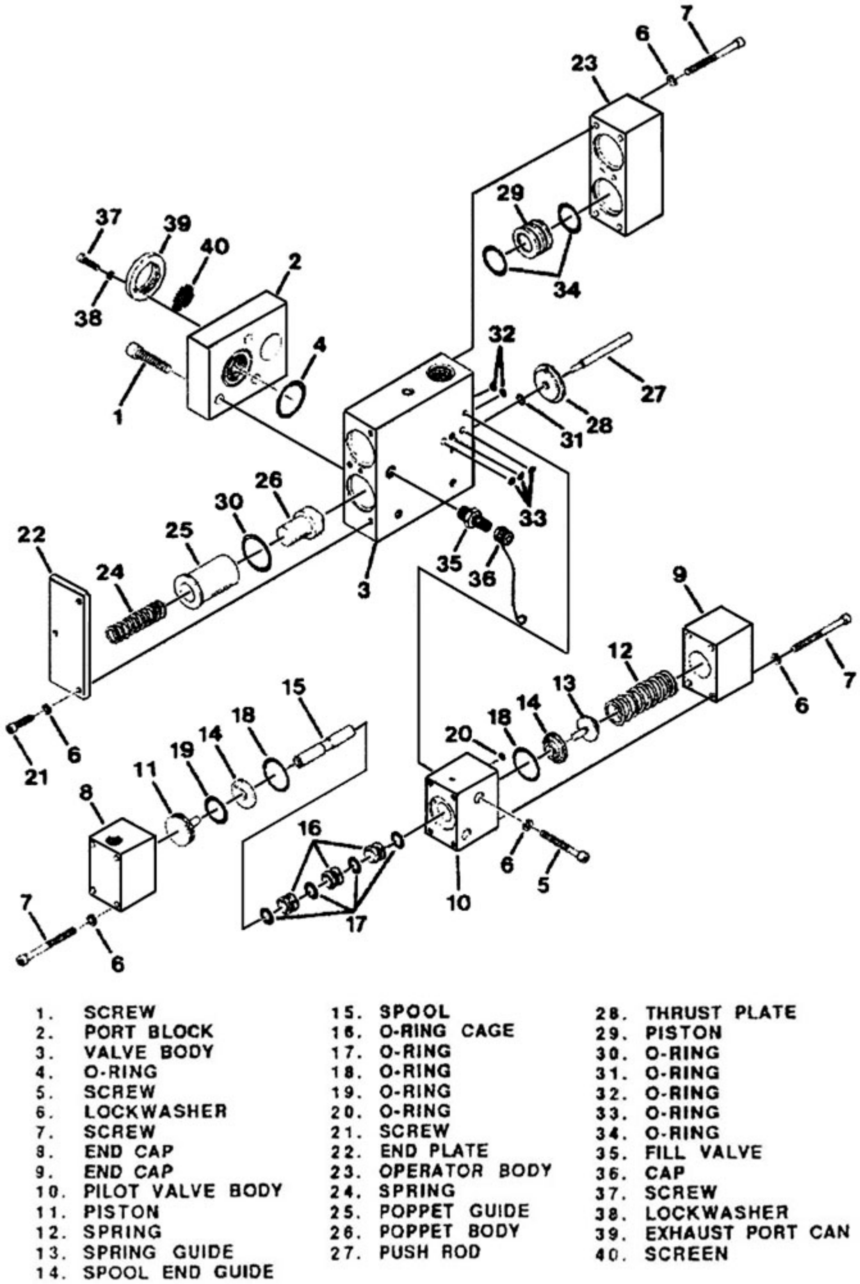


Figure 1–34. Wheel end valve.

</td></tr>
<tr><td>Orifice bypass valve</td><td>The orifice bypass valve is a pilot-operated valve that opens during rapid deflation to permit venting to the atmosphere. Rapid deflation would not be possible if the air is routed directly through the orifice fitting.</td></tr>
<tr><td>CTIS shutoff solenoid valve</td><td>This pilot-operated valve opens only when the CTIS is energized.</td></tr>
<tr><td>Check valve</td><td>The check valve is located at the main control valve. It permits air to flow to the CTIS, but prevents reverse flow.</td></tr>
<tr><td>CTIS low-pressure switch</td><td>This switch is set at 80 psi and is located at the right-hand air tank. If system air pressure drops below 80 psi, the low-pressure switch will shut down the CTIS. This will ensure there is adequate air pressure for the brake system.</td></tr>
</table>

Operation

The CTIS is essentially a solenoid-operating system. The schematic, shown in figure 1–35, shows each solenoid (labeled) to help you identify them and see how they work together as a unit.

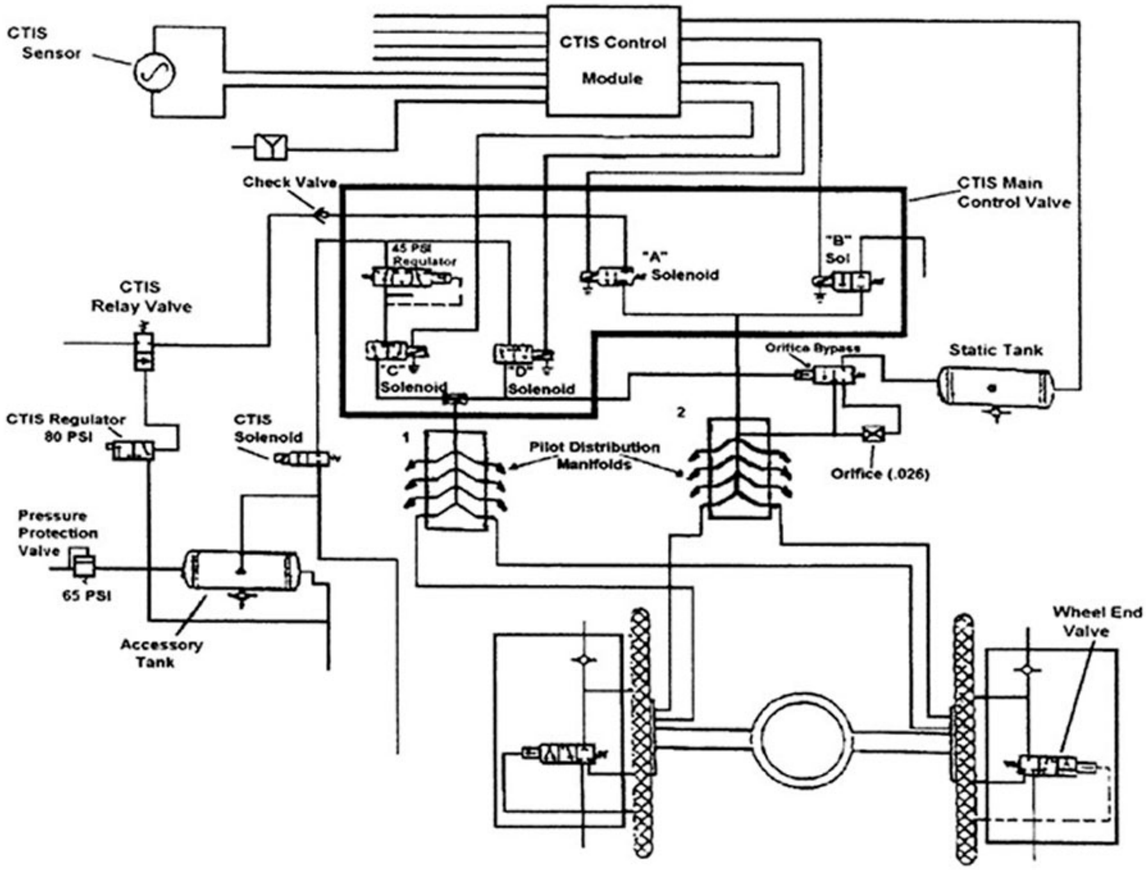


Figure 1–35. Central tire inflation system schematic.

An ON/OFF button on the controller activates and deactivates the CTIS. In the event the unit is not deactivated before engine shutdown, it will automatically activate when the engine is started again. When the power switch is in the ON position, the CTIS senses vehicle speed and will automatically increase tire pressure to the next higher setting when the vehicle speed is too great for the current setting.

The operator can set controller terrain switches for different terrain conditions—emergency, sand/mud/snow, cross-country, and highway. When the operator selects the terrain switch for a desired pressure setting, the air system inflates/deflates and maintains all tires to the appropriate tire pressure corresponding to a recommended vehicle speed. No additional operator inputs are required provided the operator does not experience over-speed conditions.

If the CTIS suffers complete failure, the operator is able to access a manual wheel valve at each wheel and inflate each tire from an external air source. If tire pressure falls below 10 psi, CTIS will not inflate the tire. The CTIS should be deactivated during operation in extreme cold, which is below 0° F. Extremely cold temperatures can cause the air seals located at each wheel to fail.

Automatic inflation

If the operator exceeds the recommended vehicle speed in the emergency, mud/snow/sand, or cross-country modes, the VEHICLE OVERSPEED indicator will illuminate continuously. This in turn alerts the operator of the overspeed condition.

The purpose is to signal the operator to decrease vehicle speed or select a higher tire pressure on the controller due to the conditions. If the operator fails to slow down or select a higher tire pressure in approximately one minute, the system will automatically increase air pressure to the next higher tire pressure setting.

Manual inflation

In manual inflation with the engine started and the power switch in the ON position, the current pressure setting (in psi) will appear on the controller panel and the corresponding terrain condition indicator will illuminate. To adjust the tire pressure manually for new terrain conditions, use the INCREASE/DECREASE switch to adjust the tire pressure as applicable; release the switch when set. The tire pressure indicator displays the actual tire pressure and the terrain indicator will change to reflect the new setting.

Monitor mode

The monitor mode used during both manual and automatic inflation. When the CTIS switch is in the ON position, the system ONLY MONITORS the tire pressures, neither inflating nor deflating the tires. Additionally, the CTIS solenoid energizes, sending air to the regulator valve (set at 45 psi) inside the CTIS main control valve. The "C" solenoid energizes, sending first stage air pilot pressure (45 psi) to the wheel end valve (WEV) to reposition the internal spool valve. This action sends tire air pressure to the pilot air distribution manifold (PDM) 1. The air goes through the orifice bypass to the CTIS tank. All eight tires are now joined as one through the PDM 2 and the CTIS tank, providing one reading to the controller at the dash. If the vehicle is in motion, it will adjust the tire pressure automatically to the selected setting on the controller.

Inflate mode

With the CTIS turned ON, the operator selects a higher setting to inflate the tires by pressing the INCREASE/DECREASE switch to the desired setting. In this mode, the "C" solenoid remains energized, keeping the WEV in the same position as in the monitor mode. This action also energizes the "A" solenoid, sending air to the PDM 2 to inflate the tires through the rotary union in the wheel hub, and to the CTIS tank. The air passes through the orifice bypass valve and orifice, so the tires and the CTIS tank fill at the same rate. Once pressure is established, the system will go into "auto" inflate. This means, if the tire pressure drops below 3 psi of the programmed setting, it will reinflate the tires to the proper setting. During inflation, a light will blink next to the desired setting.

Deflate mode

In the deflate mode, the operator can lower the tire pressure by pressing the INCREASE/DECREASE switch to the desired setting. Just like in the inflate mode, the "C" solenoid remains energized. At this time, the "B" solenoid energizes and both the tires and the CTIS tank are vented outside the main control valve underneath the vehicle. Air in the CTIS tank passes through the orifice bypass valve and orifice allowing the tires and tank to deflate evenly. Once the desired pressure is achieved, the system goes to "auto" deflate if the pressure is over 3 psi of the programmed setting (expansion from heat while driving), or if the deflate requested by the operator is less than 20 seconds. During deflation, the light will blink next to the desired setting.

Mass deflate

Mass deflate is a timed operation controlled by the CTIS controller. To initiate mass deflate, the operator selects a lower setting (i.e., highway to mud/snow/sand). At this time, the "C" solenoid de-energizes and the "D" solenoid energizes. This sends full system air pressure (second-stage 130 psi) to the WEV, repositioning it to open tire pressure to the exhaust port at the WEV itself. At the same time, the system air pressure (secondary-stage 130 psi) is sent to the orifice bypass valve to reposition it to allow the CTIS tank to exhaust more rapidly by bypassing the orifice.

Once the timed portion is completed, the “D” solenoid de-energizes, the “C” solenoid re-energizes, and the “A” solenoid energizes for three seconds to reposition the WEV to the center position. After the tires deflate, the system may go into normal deflate to balance the tire pressure.

405. Diagnosing and servicing the central tire inflation system

Before performing any diagnosis, servicing, or component replacement procedures on the CTIS, refer to the appropriate technical order for instructions. It will normally provide you with a troubleshooting chart, along with both electrical and air circuit schematics for diagnosing and servicing the system. Always ensure you diagnose the system properly. Replacing the wrong component may have an adverse effect on your shop’s vehicle mission capable rates.

Inspecting and isolating central tire inflation system malfunctions

The best way to begin any CTIS diagnosis is to refer to the troubleshooting chart in the technical order, which will provide a list of common malfunctions that may occur during normal operations. The chart can become a handy tool to help you quickly isolate problems. However, keep in mind that the chart may not list every conceivable CTIS malfunction.

Typically, most of your CTIS diagnoses will consist of trying to locate air leaks in the system, which can sometimes be a time-consuming task. The following table lists problems, possible causes, and corrective actions.

CTIS Troubleshooting Chart		
Problem	**Possible Causes**	**Corrective Action**
Inoperative CTIS	Power switch turned OFF.	Turn power switch ON.
	System air pressure below 80 psi.	Increase system air pressure.
	Electrical problem.	Check CTIS circuit.
	Faulty controller.	Replace controller.
Frequent automatic cycling in the INFLATE mode	Leak in tire.	Repair tire.
	Leak in air system or defective valve.	Check air system or valve.
	Dual-stage WEV sticking.	Disassemble and clean valve. Replace O-rings, if necessary.

A troubleshooting flow chart, as shown in figure 1–36, can also guide you with CTIS diagnosis. It provides step-by-step test procedures and required outcomes. Flow charts can be found in the applicable vehicle technical order.

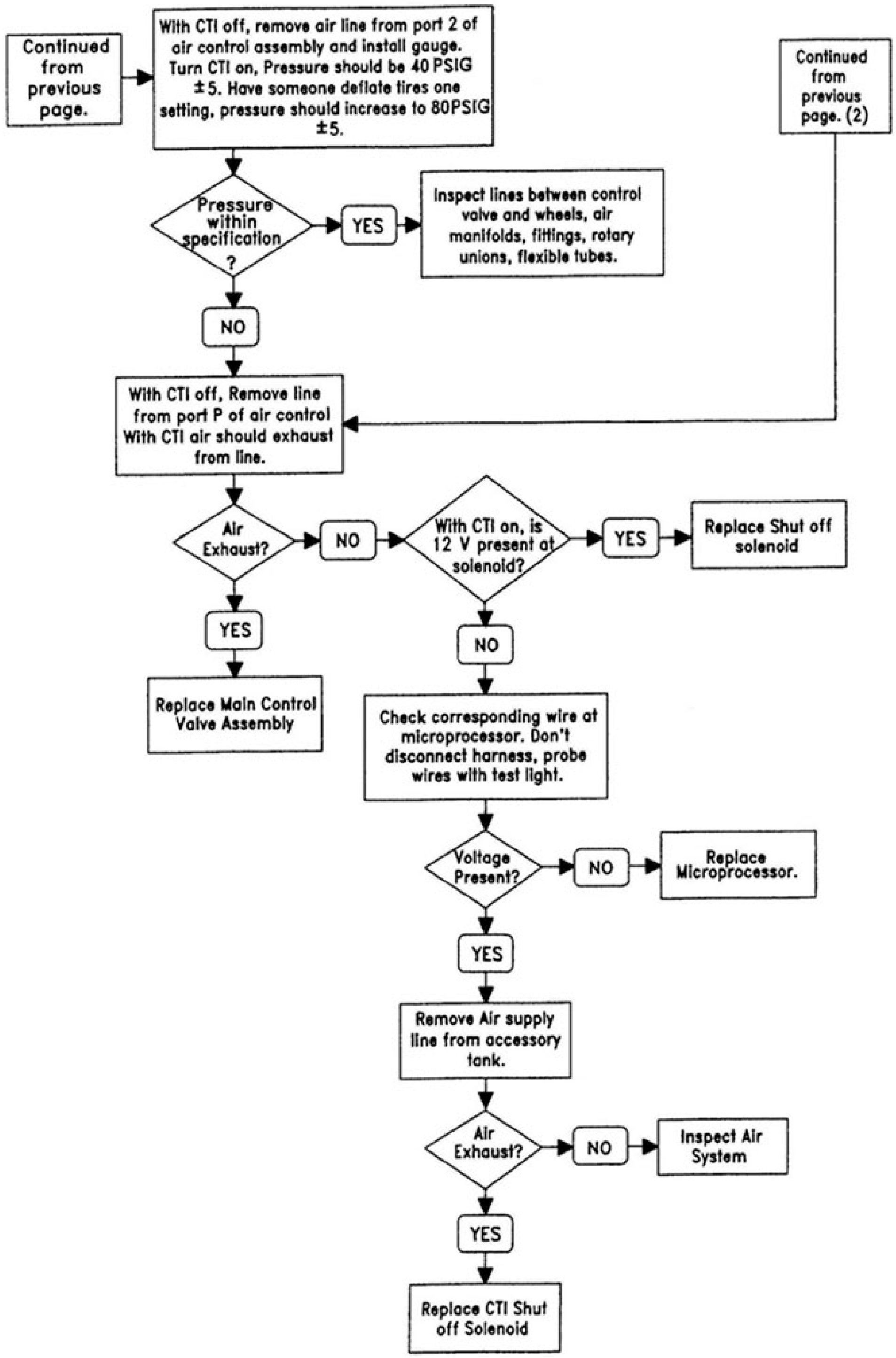


Figure 1–36. Example of central tire inflation system flow chart.

Basic operational check

A failure of the CTIS to function properly may be due to a malfunction in the controller, a faulty solenoid, defective valve, or an air leak in the system. If the controller readout indicates frequent automatic cycling in the INFLATE mode, the system is losing air pressure.

Perform the basic operating checks presented in the following table before replacing components:

Basic Operating Checks	
Step	**Actions**
1.	Inspect the tires for punctures or other damage, and inspect for damaged air lines or loose connections.
2.	Cycle the CTIS in both INFLATE and DEFLATE modes to determine if the system is operating properly. If not operating properly, check the electrical inputs and outputs.
3.	Check for proper functioning of the main control valve solenoids by cycling the CTIS and ensuring proper valve actuation. An audible “click” should be heard when the solenoid properly energizes or de-energizes.
4,	Coat the valve fittings with a soap and water solution and repeat step 1. If you observe bubbles at the valve(s), tighten or replace the leaky valve(s).

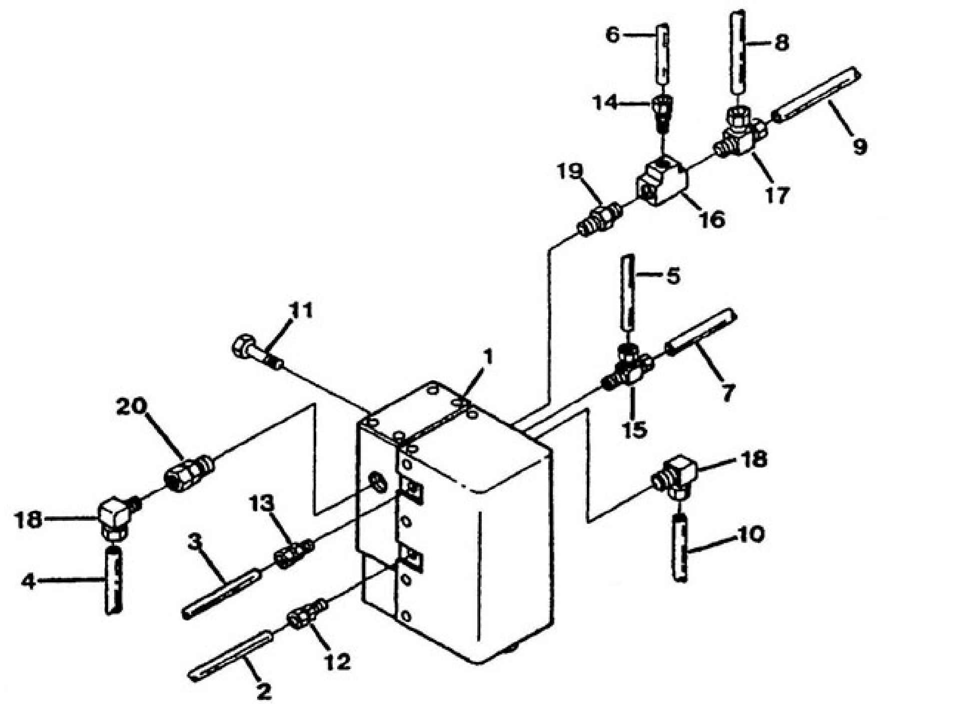
Removing and replacing central tire inflation system components

This portion of the lesson describes basic component removal and replacement. As mentioned previously, take time to properly diagnose the system and determine the specific component to replace. This will ensure the vehicle is not out-of-service for an unwarranted amount of time.

NOTE: Always wear safety glasses when servicing the CTIS. The sudden release of air pressure can disperse dirt or other contaminants with sufficient force and cause an injury. It is critical to understand this, as you must drain the air system prior to disconnecting any CTIS air line.

The following table lists basic component removal and replacement procedures for the main control and orifice bypass valves. Keep in mind, it is important to follow the technical order procedures for any CTIS components requiring replacement.

CTIS Component Removal and Replacement	
Component	**Action**
Main control valve	An exploded view of the manual control valve is shown in figure 1–37. Perform the following to remove the main control valve: • Drain the accessory and static air tanks and set the controller power switch to OFF. • Disconnect the electrical plug from the receptacle on the bottom of main control valve (1). • Tag and disconnect the air lines (2 through 10) from the fittings on the valve (1). • Reach through the access opening in the right-hand frame rail (just forward of number 3 axle) and remove three screws (11) securing the main control valve (1) to the frame rail. • Remove the main control valve assembly. • Installation is a reverse of the removal procedures. Pressurize the system and check for air leaks after installation.

<table>
<tr><th colspan="2">CTIS Component Removal and Replacement</th></tr>
<tr><th>Component</th><th>Action</th></tr>
<tr><td colspan="2">


1. MAIN CONTROL VALVE
2. AIR LINE FROM CTIS SOLENOID VALVE
3. AIR LINE FROM CTIS ORIFICE BYPASS VALVE TO PORT "3"
4. AIR LINE FROM TWO-WAY RELAY VALVE
5. AIR LINE TO AXLE 2 DROP EAR ELBOW
6. AIR LINE FROM CTI ORIFICE BYPASS VALVE TO PORT "T"
7. AIR LINE TO AXLE 3 AND 4 MANIFOLD DROP EAR ELBOW
8. AIR LINE TO AXLE 1 AND 2 MANIFOLD
9. AIR LINE TO AXLE 3 AND 4 MANIFOLD
10. AIR LINE, MAIN CONTROL EXHAUST
11. SCREW
12. CONNECTOR
13. CONNECTOR
14. CONNECTOR
15. TEE
16. TEE
17. TEE
18. ELBOW
19. NIPPLE
20. CHECK VALVE

Figure 1–37. Manual control valve.
</td></tr>
<tr><td>Orifice bypass valve and orifice</td><td>
Figure 1–38 displays an exploded view of the orifice bypass valve and orifice.

Perform the following to remove the orifice bypass valve and orifice:

- Drain the accessory and static air tanks and set controller the power switch to OFF.
- Tag and disconnect the air lines (2 through 5) from the fittings on the bypass valve (1) and orifice (6).
- Remove two screws (7) and washers (8) securing the bypass valve (1) to the right-hand frame rail (just forward of the main control valve).
- Remove the bypass valve and orifice assembly.
- Installation is a reverse of the removal procedures. Pressurize the system and check for air leaks after installation.
</td></tr>
</table>

CTIS Component Removal and Replacement	
Component	Action

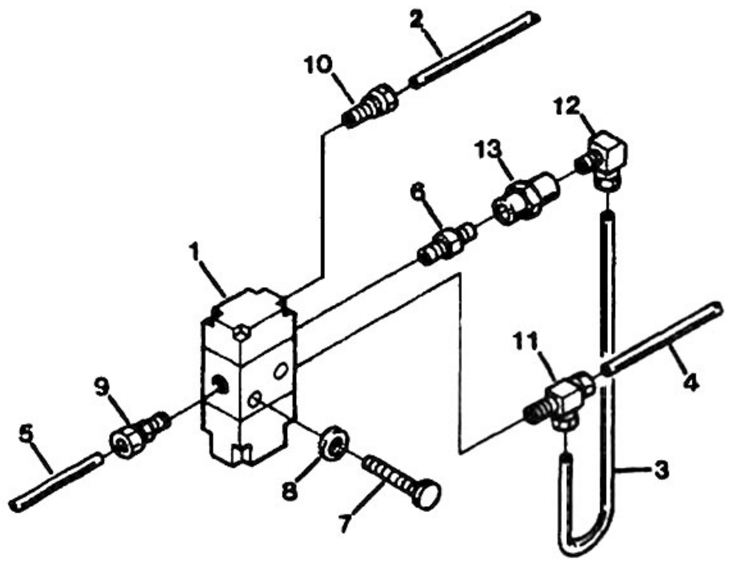


Figure 1–38. Orifice bypass valve and orifice.

Self-Test Questions

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

404. Central tire inflation system components and operation

1. What monitors and adjusts the tire pressure?

2. How many speed sensors are there on the P–23 CTIS? Where are they located?

3. Which tank stores the pressurized air for the CTIS and vehicle accessories?

4. What does the static tank do?

5. To which signals or adjustments does the main control valve react?

6. Where is the rotary union mounted and what is its purpose?

7. How many positions does the wheel end valve have and what happens in each position?

8. What is the importance of the orifice bypass valve?

9. What happens when the operator selects the terrain switch?

10. Why should the CTIS be deactivated during extreme cold temperatures?

11. During an overspeed condition, what happens if the operator fails to slow down or select a higher tire pressure setting?

12. When is the CTIS in the monitor mode?

13. What timed operation is controlled by the CTIS controller?

405. Diagnosing and servicing the central tire inflation system

1. Where can you find a common list of CTIS malfunctions that may occur during normal operations?

2. List the possible causes of an inoperative CTIS?

3. What should you do if the dual-stage WEV is sticking?

4. When checking the proper function of the main control valve solenoids, how do you know the solenoid is engaging or disengaging correctly?

5. What should you do prior to removing any CTIS air line?

6. Where is the location of the orifice bypass valve in relation to the main control valve?

Answers to Self-Test Questions

401

1. One or two.
2. Vehicle engine.
3. Enhance cooling by transferring heat from the compressor to the ambient air.
4. Retracted position.
5. The governor opens and allows air pressure to the unloader piston, causing the unloader piston to be lifted, moving the compressor’s air inlet valve off its seat.
6. Directly to the air compressor’s cylinder head.
7. Governor and unloader.
8. Air in the exhaust line escapes; the compressor builds air pressure.
9. Three or more.
10. More moisture is developed within it than any other reservoir in the system.
11. Secondary reservoir.
12. Safety valve.
13. Single check valve.
14. By pushing the wire in the exhaust port upward and holding it until draining is complete.
15. Alcohol system.
16. Desiccant and condensation.
17. The primary air needle is green; the secondary air needle is red or yellow.
18. Below 60 psi.
19. Brake valve or treadle valve.
20. Primary piston.
21. Air pressure and spring load.
22. It should promptly fall to 0 psi.
23. Speed up the application and release of the rear brakes and parking brakes.
24. Service, supply, and delivery ports.
25. Speed up exhausting air from a particular component/section of the brake system.
26. The foot valve’s exhaust port.
27. By pushing in the button.
28. It will automatically move from the released position to the park position.
29. Tractor protection valve.
30. Hand-control valve.

402

1. One-piece or two-piece clamp.
2. Body side.
3. Spring brake.

4. Air-applied/spring-released.
5. Air pressure.
6. “Caging” the spring.
7. Cam type.
8. They are forced against the drum.
9. Flat cam and S-shaped cam.
10. Internally splined.
11. Body, worm, gear, and adjusting screw mechanism.
12. Clevis.
13. To support the frame of the brake shoe.
14. In the actuator bore adjacent to the adjusting pistons.
15. Uneven braking.

403

1. Drain all the reservoirs to ensure no moisture is in the system.
2. Eighty-five psi.
3. Worn pistons, rings, or cylinders.
4. Approximately 115–125 psi.
5. Replace the dash gauge.
6. Approximately 60 psi.
7. Mild solvent; emery cloth can be used to remove any corrosion.
8. Hacksaw.
9. To ensure even braking across an axle.
10. The chamber could come apart with great force, causing personal injury or damage to other resources.
11. Checking the length of the push rod stroke when the brakes are applied, check the angle between the centerline of the push rod and the centerline of the slack adjuster when the brakes are applied and released.
12. One shot or one pump of grease.
13. Control module, two front-wheel-speed sensors, two drive-axle wheel-speed sensors, rear modulator/relay valve assembly, and front modulator valve.
14. On the rear modulator valve.
15. One.
16. Control module.
17. One hundred.
18. The rear axle must be disassembled to replace the sensor.
19. Two.
20. Controls air pressure to the front brake chambers during an antilock stop.
21. Recording a series of flashes from the warning lamp or using a hand-held scanner.
22. The amber ANTILOCK lamp on the dash.
23. An excess of 10 mph.
24. Nine.
25. The first five.
26. Pinpoint the problem component or its wiring.
27. By passing a small magnet over the RESET point in the diagnostic window.
28. REAR and MOD LEDs.

404

1. CTIS controller (microprocessor).
2. Four. One electromagnet sensor installed on the transmission output drive for the CTIS, two transmission speed sensors and one turbine speed sensor.
3. Accessory air tank.
4. Serves as a holding tank for the air supplied to the tires.
5. The output signals of the controller and/or operator adjustments of the INCREASE/DECREASE control to add or release air from the tires.
6. In the wheel hub; it is designed to allow airflow to and from the rotating wheel.
7. Three. In the first position, the valve prevents air flow in or out of the tire. In the second position, it allows inflation/deflation to occur. In the third position, it allows rapid exhaust of air directly from the valve.
8. Rapid deflation would not be possible if the air is routed directly through the orifice fitting.
9. The air system inflates/deflates and maintains all tires to the appropriate tire pressure corresponding to the recommended vehicle speed.
10. The cold temperatures can cause the air seals to fail.
11. After one minute, the system will automatically increase air pressure to the next higher tire pressure setting.
12. When the CTIS switch is in the ON position.
13. Mass deflate.

405

1. Technical order troubleshooting chart.
2. Power switch turned OFF, system air pressure below 80 psi, an electrical problem, or a faulty controller.
3. Disassemble and clean valve. Replace O-rings, if necessary.
4. An audible “click” will be heard.
5. Drain the air system.
6. Right-hand frame rail (just forward of the main control valve).

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. (401) Most air compressors are lubricated by using oil
   a. splash from the pistons.
   b. from the vehicle engine.
   c. splash from the rocker arms.
   d. from the vehicle transmission.

2. (401) Which air compressor component, when lifted, moves the inlet valve off its seat to prevent the compressor from building up more air pressure?
   a. Piston.
   b. Camshaft.
   c. Unloader piston.
   d. Discharge valve.

3. (401) Which air system reservoir is connected to the output line of the air compressor?
   a. Supply.
   b. Dry tank.
   c. Secondary.
   d. Quick buildup.

4. (401) Which air brake system component protects against excessive air pressure buildup in the event of governor failure?
   a. Check valve in the secondary line.
   b. Safety valve in the secondary tank.
   c. Check valve in the primary line.
   d. Safety valve in the supply tank.

5. (401) The air system's automatic moisture ejector valve is *manually* drained by
   a. turning the handle clockwise.
   b. turning the handle counterclockwise.
   c. pulling the diaphragm spring outward.
   d. pushing the wire in the exhaust port upward.

6. (401) In an air brake system, alcohol vapors from the alcohol bottle enter the system at the
   a. compressor's air exhaust.
   b. compressor's air intake.
   c. supply reservoir.
   d. governor port.

7. (401) On an air gauge with both primary and secondary indicator needles, the *primary* system indicator needle is
   a. yellow.
   b. black.
   c. green.
   d. red.

8. (401) The *main* difference between a floor-mounted foot valve and a suspended-type foot valve is the
   a. way they are mounted.
   b. primary air delivery routing.
   c. secondary air delivery routing.
   d. suspended-type control valve is operated by hand.

9. (401) What air brake component is connected to the relay valve's supply port by an air line?
   a. Reservoir.
   b. Safety valve.
   c. Brake chamber.
   d. Foot-control valve.

10. (401) The function of the quick-release valve on the air brake system is to
    a. speed up the exhaust of air from a particular component.
    b. speed up the application of air to a particular component.
    c. protect the secondary system in case of an air loss in the primary system.
    d. protect the primary system in case of an air loss in the secondary system.

11. (401) In order to release the parking brakes, the parking brake-control valve is actuated by
    a. pushing up the lever to supply air to the parking brake chambers.
    b. pushing in the button to supply air to the parking brake chambers.
    c. pulling down the lever to remove air from the parking brake chambers.
    d. pulling outward the button to remove air from the parking brake chambers.

12. (401) What valve protects the truck/tractor air system if there is an air loss in the trailer air system?
    a. Check valve.
    b. Safety valve.
    c. Quick-release valve.
    d. Tractor protection valve.

13. (402) A typical brake chamber's body and cover are held together by
    a. a clamp.
    b. a clevis.
    c. nuts and bolts.
    d. studs and nuts.

14. (402) A type 30 chamber indicates the
    a. outside diameter of the brake chamber is 30 centimeters.
    b. outside diameter of the diaphragm is 30 centimeters.
    c. diaphragm has an area of 30 square inches.
    d. diaphragm has an area of 30 cubic inches.

15. (402) On a vehicle equipped with a parking brake chamber, the parking brake is
    a. spring-applied.
    b. cable-applied.
    c. lever-applied.
    d. air-applied.

16. (402) Under normal driving operation, how is the parking brake held in the released position?
    a. Cam and S-lever.
    b. Air pressure in the parking brake chamber.
    c. Spring pressure in the service brake chamber.
    d. Spring pressure in the parking brake chamber.

17. (402) To service the basic parking brake chamber, you must *manually* cage the power spring by
    a. installing a C-clamp around the body and cover.
    b. installing a guide pin through the pushrod.
    c. using a special release stud.
    d. using large vise grips.

18. (402) On the automatic slack adjuster, what component pushes the actuator rod and piston during brake release?
    a. Clevis.
    b. Hex roller.
    c. Return spring.
    d. Torque spider.

19. (403) At approximately what pressure in pounds per square inch (psi) should the air system's low air pressure warning light/buzzer activate?
    a. 60 psi.
    b. 70 psi.
    c. 80 psi.
    d. 90 psi.

20. (403) Valves and their components can be cleaned with a mild solvent, and corrosion on the valves components can be removed with
    a. crocus cloth.
    b. emery cloth.
    c. wire wheel.
    d. sand paper.

21. (403) Why should you replace both brake chambers on the same axle?
    a. Ensures even braking.
    b. Increases braking effort.
    c. Prevents incorrect slack adjustment.
    d. Provides the correct air pressure setting.

22. (403) The *correct* way to check slack adjuster operation and adjustment is to inspect the
    a. length of the diaphragm when the brakes are applied.
    b. length of the push rod stroke when the brakes are applied.
    c. angle between the slack adjuster and the camshaft when the brakes are applied.
    d. angle between the slack adjuster and the camshaft when the brakes are *not* applied.

23. (403) Why must you be careful when greasing the foundation brake camshaft housing?
    a. Grease can contaminate the brake chamber diaphragm.
    b. The housing requires special high-temperature grease.
    c. Too much grease can contaminate the brake linings.
    d. Too little grease will cause brake lining wear.

24. (403) What antilock brake system (ABS) component regulates air to the service brake chambers to prevent wheel lockup during aggressive braking?
    a. Control module.
    b. Wheel speed sensor.
    c. Quick-service valve.
    d. Front and/or rear modulator.

25. (403) Where is the front tone ring mounted on an antilock brake system (ABS)?
    a. Spindle.
    b. Wheel hub.
    c. Backing plate.
    d. Wheel cylinder.

26. (403) What is a major disadvantage when it comes to replacing the rear axle wheel-speed sensor on an antilock brake system (ABS)?
    a. Control module re-calibration.
    b. Re-lining the rear brakes.
    c. Differential disassembly.
    d. Wheel hub disassembly.

27. (403) Interpreting fault codes from an antilock brake system (ABS) is accomplished by using a hand-held scanner or by
    a. recording a series of warning lamp flashes.
    b. cycling the ignition switch ON and OFF several times.
    c. turning ignition switch ON and stepping on the accelerator pedal.
    d. driving the vehicle and stopping abruptly to activate the ABS diagnostics.

28. (403) How many diagnostic light emitting diodes (LED) are located in the diagnostic window of a two-channel air brake antilock brake system (ABS) control module?
    a. 4.
    b. 9.
    c. 12.
    d. 15.

29. (403) On an antilock air brake system (ABS), the control module diagnostics are cleared by
    a. disconnecting the control module’s connector.
    b. disconnecting the rear axle speed sensor connector.
    c. pushing the RESET button on the diagnostic window.
    d. passing a small magnet over the RESET point in the diagnostic window.

30. (404) The pressurized air used by the central tire inflation system (CTIS) is stored in the
    a. quick buildup air tank.
    b. right-hand air tank.
    c. accessory air tank.
    d. static air tank.

31. (404) What allows for rapid deflation in the central tire inflation system (CTIS)?
    a. Pilot air distribution manifold 1.
    b. Pilot air distribution manifold 2.
    c. Orifice bypass valve.
    d. Orifice valve.

32. (404) What component shuts down the central tire inflation system (CTIS) if air pressure drops below 80 psi?
    a. Pressure regulator.
    b. Air pressure reservoir.
    c. CTIS low-pressure switch.
    d. Low-pressure indicator switch.

33. (404) What terrain condition is *not* a setting on the central tire inflation system (CTIS) controller?
    a. Swamp.
    b. Emergency.
    c. Cross-country.
    d. Sand/mud/snow.

34. (404) What is the timed operation controlled by the central tire inflation system (CTIS) controller?
    a. Fault code diagnostics.
    b. Engine shutdown.
    c. Automatic inflate.
    d. Mass deflate.

35. (405) The failure of the central tire inflation system (CTIS) to function properly is caused by the following conditions *except*
    a. air system leaks.
    b. malfunctioning controller.
    c. defective valve or faulty solenoid.
    d. terrain switch set for wrong driving conditions.

36. (405) Before disconnecting any central tire inflation system (CTIS) air line, what should you do *first*?
    a. Drain the air system.
    b. Remove the bypass valve.
    c. Cage the park brake chambers.
    d. Disable the governor assembly.

Please read the unit menu for unit 2 and continue ➔

Unit 2. Hydraulic Systems

HYDRAULICS IS THE SCIENCE of transmitting force and/or motion through the medium of a confined liquid. The Air Force uses many hydraulically operated types of equipment and vehicles. Your ability to understand and maintain hydraulic systems is important to the mission. This unit covers basic hydraulic fundamentals and maintenance procedures. Most of the hydraulic systems you will encounter use hydraulic pressure to move components.

You will begin by learning the fundamental principles of hydraulic systems. Afterwards, you will learn how to inspect and maintain a hydraulic system, before learning to isolate malfunctions and replace components.

406. Hydraulic system fundamentals

The basic principles of hydraulics include the following principles of fluids:

- Possess no shape of their own and take on the shape of their surroundings.
- Practically incompressible.
- Transmit applied pressure in all directions.
- Provide great increases in work force.

Hydraulic open and closed center systems

In regards to the open and closed center hydraulic systems, “center” refers to the neutral position of the control valve. The *open system* has fluid constantly flowing, at low pressure, through the control valve back to the fluid reservoir. Consequently, it can be redirected when necessary by operating the control valve.

In the *closed system*, fluid stops at the control valve and maintains a constant regulated pressure. This type of system supplies fully pressurized fluid on demand.

Hydraulic system fluid

Hydraulic fluids make up a very large class of materials used in machines and equipment to transfer pressure from one point to another. This includes vehicle automatic transmissions, brakes, and power steering systems. Additionally, hydraulic fluids are used in tractors and farm equipment, forklifts, bulldozers, and other construction equipment. The following are three of the many types of hydraulic fluids:

1. Mineral oil.
2. Organophosphate ester.
3. Polyalphaolefin.

Some hydraulic fluids have a bland, oily smell, while others have no smell. Mineral oil and polyalphaolefin hydraulic fluids are mixtures that have oil in them and will burn. Oil-in-water hydraulic fluids (a special type of mineral oil hydraulic fluid) do *not* burn because they contain water. Organophosphate ester hydraulic fluids are mostly made without oil and will only burn if a flame is directly applied to them; as a result, they are not flammable by themselves. This quality makes organophosphate ester hydraulic fluids ideal for use in aircraft cargo loaders and other places where fires are very undesirable.

Mineral oil hydraulic fluids are produced from crude oil, while organophosphate ester and polyalphaolefin hydraulic fluids are manufactured. All hydraulic fluids contain many ingredients that reduce wear, make the fluid flow better, and make it thinner when it is cold.

The main purpose of hydraulic fluid is to transfer power from the pump to the actuators, but it must also perform many other tasks that are critical to a well-designed system. These tasks include the following:

1. The oil must have good *lubricity* or be “slippery” so that the friction will be as low as possible in order to keep metal-to-metal wearing at a minimum.
2. The *viscosity* or “thickness” must be in the proper range at the operating temperature so that unwanted leakage is at a minimum and still allows the oil to lubricate the close-fitting parts in the system.
3. The oil must be compatible with the seals used in the system.
4. There should be additives in the oil to slow down the effects of rust, oxidation (oxygen in the air combining with the oil to form sludge), foaming, and water settling to the bottom of the reservoir.
5. The oil must be able to pour or flow at the lowest expected temperature so that the oil can reach or get into the pump.
6. The oil should contain extreme-pressure (EP) additives to prevent the fluid from breaking down.

There are many different types of hydraulic fluid available. You must check your service manual or technical order and verify what type of fluid is used in your system. Mixing or using the incorrect fluid can cause malfunctions or premature wear of system components.

Hydraulic system cleanliness

System cleanliness is a major problem in hydraulic systems. A system not cleaned or maintained properly can create many types of hazards. Fluids in a pressure system must pass through many small passages that can be easily restricted or completely closed by small particles of foreign material. Extreme care must be exercised to maintain system cleanliness during the assembly, installation, and testing of these systems.

Pressure and flow

Pressure is responsible for pushing or exerting a force or torque. *Flow* is responsible for making something move, causing motion. Squeezing or pushing on a confined fluid creates pressure only if there is a resistance to flow. If you do not have resistance, the system will never create pressure.

Flow is the movement of the hydraulic fluid caused by a difference in pressure at two points. Flow is then broken down in two parts. *Velocity* is the average speed of the fluid past a given point. *Flow rate* is the measure of how much volume of the liquid passes a point in a given time.

Fluid power

The term *fluid power* refers to energy that is transmitted from a fluid under pressure. Fluid power force comes from the principle that pressure applied to a confined fluid is transferred uniformly and undiminished to every portion of the fluid and to the walls of the container that holds the fluid. A surface such as a cylinder piston moves because the difference in force across the piston is larger than the total load, plus frictional forces. The resulting net force can then accelerate the load proportionately to the ratio of the force divided by the mass. In other words, the piston moves because one side of the piston has high pressure while the other side has lower pressure. The piston moves from the high force to the low force; commonly referred to as “the path of least resistance.”

Fluid power is used in a diverse range of applications from mobile construction and aerospace equipment to powering industrial machinery. It offers several advantages over other types of force (electric and pneumatic).

In fluid power systems, a single source of fluid pressure (pump) can control many fluid power devices. The power source (pump or motor) can be located where space is not critical. The hydraulic pump generates much of the size and weight of the fluid power system; the individual actuators can be small and produce a great amount of force or pressure without needing excess weight and space.

In addition, hydraulic systems are often quieter and generate less heat than electric actuators. Fluid power actuators can also be used in hazardous environments where electric sparks must be avoided. Hydraulic power offers many advantages over electric motors, especially for systems that require high-speed linear travel, moving or holding heavy loads, or very smooth position or pressure control. Compared to other types, hydraulic actuators are smaller and produce four times the power of an electrical or pneumatic system equivalent.

In applications such as presses where a constant holding pressure or torque must be applied, hydraulic actuators have a big advantage because no energy is used while they are not moving. However, an electric motor draws a large amount of current to maintain torque even while stopped. Most electric motors will overheat and fail under these conditions. Hydraulic cylinders are very smooth and efficient for linear movement, which means the movement is in one direction in a straight line.

Hydraulic pumps

Hydraulic pumps supply the oil under pressure that is required to move the system's cylinder pistons, converting mechanical power to fluid power (fig. 2–1).

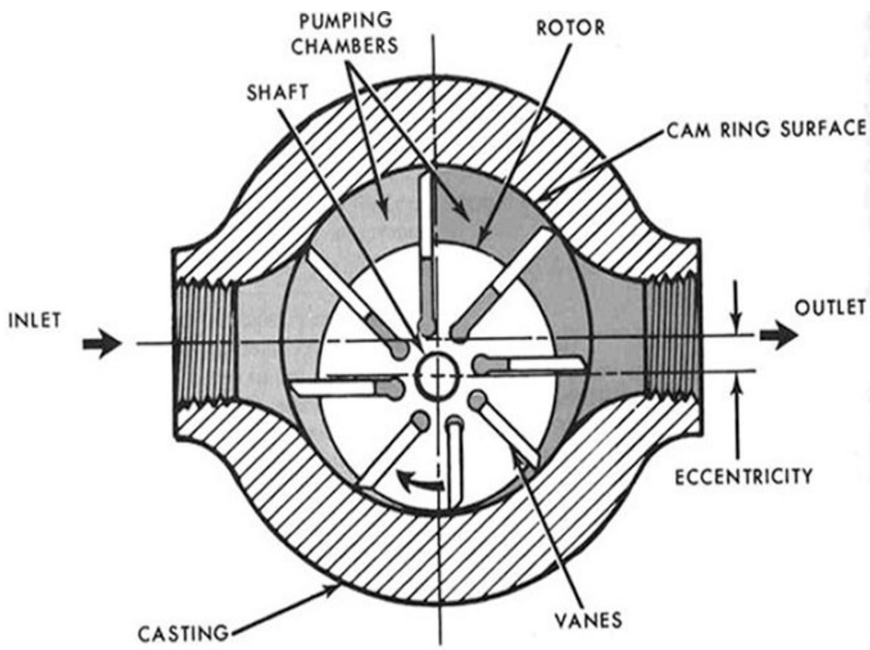


Figure 2–1. Hydraulic pump.

Some systems use a single pump, while others incorporate a tandem or through-drive "piggyback" pump setup.

- The tandem pump setup has one shaft (input) that operates two separate pump assemblies in the same housing, connected and operating as dual pumps; this facilitates separate hydraulic systems to function.

- The piggyback pump setup consists of two or more separate pumps bolted together with a common shaft running through all the pumps. One pump, for instance, could supply flow to a vehicle's steering system, while the other pump supplies flow to the main hydraulic system.

You must make sure that the proper hydraulic pump is used on the system you are servicing. Check the service manual to determine what type of pump and its specifications for fluid output and pressure ratings.

If the inlet is sealed from the outlet, the pump delivers fluid anytime the inlet is kept supplied and the pump is driven. This type of pump is classified as a *positive delivery* or *positive displacement*, and it requires a relief valve to protect it from pressure overloads.

If the inlet and outlet are connected hydraulically so that the fluid can recirculate in the pump when pressure builds up, the pump is *nonpositive displacement*.

Some common types of pumps are reciprocating, vane type, double pump, gear type, lobe, and piston type. You must check the service manual for the pump you are working with to determine the type of pump you are troubleshooting. The service manual also gives you specifications on the pump's input and output, gallons per minute (GPM), the flow measurement, and psi.

Hydraulic cylinders

Hydraulic cylinders are classified as *single acting* or *double acting*. A single-acting cylinder has only one port and hydraulically operates in one direction. A double-acting cylinder has two ports and hydraulically operates in both directions. Additionally, some cylinders may have "stages."

Hydraulic cylinders may have numerous rams that extend from a single-cylinder housing. When one ram is extended, a second ram (smaller in diameter and located inside the first ram) extends. This provides the capability to extend the travel distance and functional ability of the cylinder. This type of cylinder may be labeled as one-, two-, or three-stage, indicating how many ram extensions are integrated into the cylinder.

The cylinder (fig. 2–2) converts fluid power to linear movement. Just as the right size of a hydraulic pump is critical, so are correctly sized cylinders. Increasing the size of a cylinder increases the required fluid flow; in turn, this requires that the system use larger valves and pumps.

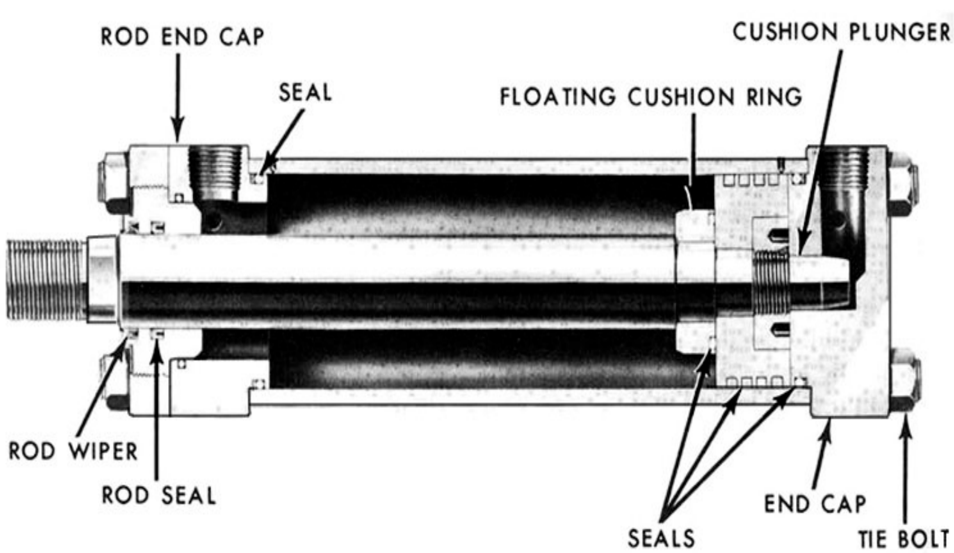


Figure 2–2. Hydraulic cylinder.

Hydraulic motors

A hydraulic motor is simply a pump that is being pushed instead of doing the pushing. Oil is pumped into one port causing the shaft to turn. The same hydraulic chambers carry the oil to the other port and discharge it to return to the tank or the pump inlet. The principal ratings of a motor are hydraulic displacement, torque, and pressure.

Displacement

Displacement tells how much flow is required for a specified drive speed. In other words, it is the amount of oil pumped into the motor to turn it one revolution.

Torque and pressure ratings

Torque and pressure ratings tell us how much load the motor can handle. Torque is a turning or twisting effort commonly referred to as “rotary thrust.”

Reservoir

A reservoir is used to store the oil to meet system demands. The reservoir may have an air vent, allowing gravity and atmospheric pressure to force oil into the pump when the pump piston retracts. Other systems may not use a vent; instead, they pressurize the hydraulic system in order to function. A hydraulic reservoir also has some type of gauge, sight glass, or dipstick to allow checking of the fluid level. It is vital that the hydraulic fluid remain at the proper level. Low fluid can cause cavitation, excessive heat, and premature wear of hydraulic components.

CAUTION: *Always* read the service manual before opening the filler cap on a pressurized system. Releasing hydraulic fluid that is under pressure can cause serious injury.

Accumulator

Accumulators are energy storage devices with some type of reservoir to maintain specific oil pressure or system pressure. Accumulators serve the following two important functions:

1. Store energy so that the pumps do not have to be sized for peak loads.
2. Keep the system pressure relatively constant if sized correctly.

Hydraulic gauges, switches, relief valves, and sensors

Hydraulic pressure and temperature gauges may often be found in the cab or somewhere in-line with the hydraulic system. These gauges aid the operator by identifying operating pressures and temperatures of the hydraulic fluid and system. Sometimes there is a safety shutdown system incorporated with these gauges to ensure that the hydraulic system stays within its operating parameters.

Hydraulic pressure switches, relief valves, and sensors monitor the hydraulic system. Depending on the hydraulic pressure required by components, a pressure switch or a relief valve can signal the system to increase or decrease pressure as needed. A sensor can detect flow or hydraulic fluid temperature and warn the operator via gauges and warning buzzers or lights when there is a malfunction.

CAUTION: *Always* read the service manual before adjusting or servicing a gauge or sensor. Hydraulic system residual pressure may be present even after turning off the vehicle.

Hydraulic tubing

Tubing can be divided into two general groups, depending upon whether it is made with or without seams. It can be further divided into pipe, mechanical tubing, pressure tubing, and stainless steel tubing.

These types of tubing are described in the following table.

Tubing Types	
Type	**Description**
Pipe	*Pipe* is tubing made to certain standards. Pipe has a fixed wall thickness as designated and is referred to as standard, extra heavy (extra strong), and double extra heavy.
Mechanical	*Mechanical tubing* is designed and manufactured with mechanical uses in mind. Tolerances are closer than for other common classes of tubing. Do *not* use mechanical tubing in pressure piping systems; use pressure tubing.
Pressure	*Pressure tubing* differs from mechanical tubing in several respects. It is first pressure tested to ensure it meets requirements. Second, the dimensional tolerances are less restrictive. Finally, most pressure tubes are fully annealed (allow for flexibility) since many applications involve working or bending of the tube.
Stainless Steel	*Stainless steel tubing* can be of either the mechanical type or the pressure type and is available in a great variety of alloys.

CAUTION: Pressure tubing is for pressure systems only. Mechanical tubing should *never* be used in pressure systems; it is not rated for pressure applications, and has the potential to burst when subjected to working forces.

Solid piping, rather than hose, is often used between the valve and the cylinder since hoses contract and change shape; any change of area affects the fluid flow. Keep pipes as short and straight as possible, as pressure drops occur in bends. Place the valves on the cylinders as close as possible to the cylinders in order to keep the volume of oil between the valve and cylinder as small as possible. This helps maintain efficient system operation.

Use fittings that are fabricated or forged steel, *not cast*. They may be threaded or flanged for use with piping, or they may be flanged or of a compression type for use with the tubing. Compression fittings may or may not be flared; if flared, they may be classified as either *single flare* or *double flare*.

Hydraulic hose

Flex rubber hose and hose assemblies are conveniently classified as low, medium, or high pressure, depending on the type of construction. Low-pressure flex hose is constructed with single cotton-braid reinforcement and an inner and outer tube of synthetic rubber. Medium-pressure hose is constructed with single wire-braid reinforcement. High-pressure hoses have multiple wire-braid reinforcement.

Most hydraulic hoses are fabricated in a series of three layers (fig. 2–3). The material used for the inner layer is a type of synthetic rubber compatible with the fluid used in the system. Middle layers are for reinforcement; they are either fabric or rubber for low-pressure hose; wire braid is used in place of fabric braid for higher-pressure hoses. The pressure of the system determines if the hose used has one or two wire braids. The outer layer of the hose is a protective cover.

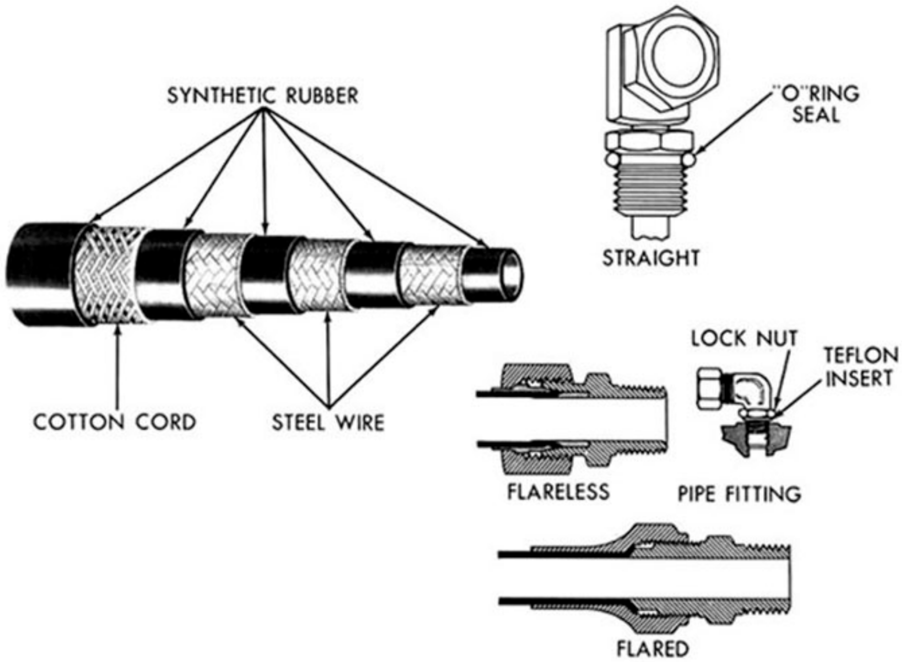


Figure 2–3. Hydraulic hose.

Press-on or screw-on fittings are often used for flex-hose assemblies. Make sure that the pressure rating of that fitting and line is not exceeded when using a press-on fitting. These fittings often have no additional holding clamp to secure them. Follow the recommended type and use for all hydraulic hose fittings.

Inlet lines should be as short and with as large an inside diameter as possible. This allows enough fluid to enter the pump. Make sure that all the lines are tight because any air entering the system can damage the pump and hydraulic system.

Pressure lines should always use piping, if possible. If a solid pipe is not applicable, ensure that the fittings are able to withstand the hydraulic system's pressure.

When installing a hose, allow enough slack to avoid kinking, but keep the hose tight enough so that the hose allows some movement with pressure surges.

CAUTION: Hydraulic fluid under pressure can cause extreme damage. Deteriorated hydraulic hoses are a main source for hydraulic leaks and system failure.

Wear proper personal protective equipment (PPE) when performing any maintenance or servicing of a hydraulic system. At a minimum, use rubber gloves and safety goggles. Hydraulic fluid may cause irritation to your skin. Check with the manufacturer's safety data sheet (SDS) for further precautions and specifications on the fluid you are using.

Valves

A valve that uses most of its range is generally easier to control, so choose the response time and flow rates that match the application. Most valves are called "zero overlap" because there is no "dead zone" between active control ranges (ranges that increase or decrease fluid pressure). Valves with overlap may be advantageous for manually controlled systems but *not* for high-performance, high-precision position/pressure systems.

Some common names for valves are the pressure control, flow control, and directional valves. All of these valves have a particular function and must be checked and adjusted according to manufacturer settings. Always check the service manual or technical order when determining the type and settings needed.

Hydraulic System Valves	
Type	**Description**
Pressure Control	Pressure control valves limit, control, or regulate pressure in the system. A relief valve limits the amount of pressure developed in the circuit. Other types of pressure control valves are brake, sequence, pressure-reducing, and backpressure or counterbalance valves.
Flow Control	Flow control valves regulate flow to control actuator speed. In other words, they control how fast or slow the actuator will operate. Reducing flow slows down the actuator, while increasing flow speeds up the actuator.
Directional	Directional control valves cause passages to open and close, directing oil into the desired passages. Check valves are commonly called one-way valves because they permit flow path in only one direction. A reversing valve is a four-way valve because it has four flow paths.

407. Inspecting and maintaining the hydraulic system

In the previous lesson, you learned hydraulic system fundamentals. A comprehensive knowledge of this information is extremely important when maintaining the system. In this lesson, you will learn about component inspection and maintenance of filters and strainers, hydraulic reservoir magnetic plugs, pump operation, hydraulic cylinders, and valves. In the last part of the lesson, we will cover information on manufacturing hydraulic lines, checking hydraulic leaks, and schematics. Always follow safety procedures when working with hydraulic systems.

CAUTION: Failure to identify pressure system components may cause accidental operation of equipment beyond its design capabilities and can result in equipment failure and personnel injury.

Wear the proper PPE before performing any maintenance on a hydraulic system (i.e., safety glasses, rubber gloves).

Inspect hydraulic system components

Now let us begin with the basic procedures for inspecting hydraulic system components. Refer to the appropriate service manual or technical order for proper inspection and maintenance procedures.

Strainers and filters

A strainer is a device for removing large contaminants from a fluid. A filter is a device for removing finer (smaller) contaminants from a fluid (fig. 2–4). The easiest way to remember the difference is that a strainer is a coarse filter, and a filter is a device whose primary function is the retention, by some porous medium, of insoluble (incapable of being dissolved) contaminants from a fluid.

Strainers are usually constructed of fine mesh-wire screens or of screening elements consisting of specially processed wire of varying thickness wrapped around metal frames. Strainers are located in the system before the filter. Service these filters and strainers periodically to keep the hydraulic system operational and the fluid clean.

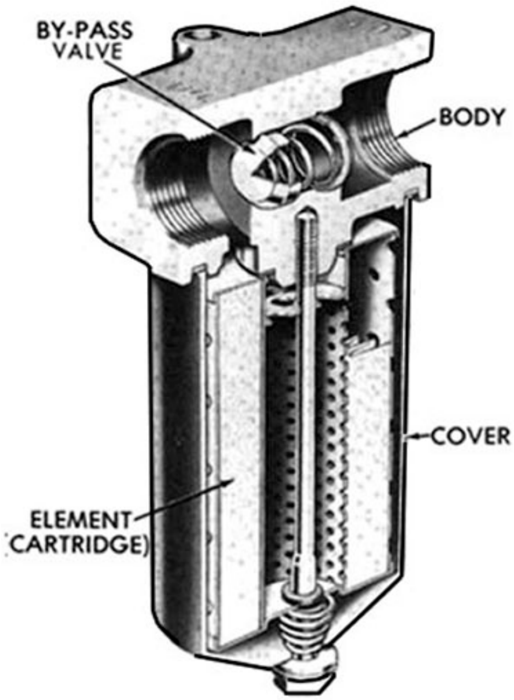


Figure 2–4. Filter assembly.

Filters can be further classified as mechanical and absorbent (inactive) filters.

Mechanical filters

Mechanical filters contain closely woven metal screens or discs. They generally remove only coarse, insoluble particles.

Absorbent (inactive) filters

Absorbent (inactive) filters have material such as cotton, wood pulp, yarn, cloth, or resin-impregnated paper. They remove much smaller particles, and some remove water and water-soluble contaminants.

Hydraulic oil reservoir magnetic plugs

Magnetic plugs are useful for removing iron or steel particles from the oil. They are installed inside the hydraulic oil reservoir where they attract metal particles that have gotten into the fluid. Cleaning the magnetic plugs on a regular basis keeps the hydraulic system clean. During *normal pump operation*, you may find small bits of metal (grindings) on this magnet. However, finding large metal shavings or pieces of metal indicates a serious internal problem that warrants further investigation.

Pump operation

Check the system pressure regularly to ensure that you are not exceeding the pump and system capability. The following table provides descriptions for pump troubles:

Pump Troubles	
Type	**Description**
Cavitation	This condition occurs when the available fluid does not fill the existing space. This often occurs in a pump inlet when the supply of oil is not sufficient to keep the oil at the inlet filled. As a result, bubbles implode when exposed to system pressure, which can cause serious damage to the pump and hydraulic system.
No Pressure	Pumps do not create pressure; they create flow.

Slow Operation	A worn pump or partial leakage of the oil in the system can result in slow operation.
No Delivery	Often a pump needs to be primed (fluid added into pump before operating) for proper start-up.
Noise	If you hear any unusual noise, you need to shut down the pump immediately. One noise you might hear is from cavitation, which is often identified as a rumbling noise that sounds like marbles rolling around in the pump.

Hydraulic cylinders

Common checks on the cylinder include the barrel or tube, piston and rod (ram), and end caps. By looking the entire cylinder over for signs of leakage, you may obtain clues about seals that require replacement. Seals and wipers are installed in the rod end cap to keep the rod clean and to prevent external leakage around the rod. These seals come in many varieties, making it imperative that you check the service manual or technical order before disassembling a cylinder. An improper tool or improper sequence for removing and reassembling these seals can cause additional damage to the cylinder assembly.

The barrel should be checked for any visible damage such as dents, ballooning, or signs of machine interference. Once the cylinder is disassembled, it should also be checked for internal scoring or other damage, which may result from side loading of the cylinder. The piston should be clean, smooth, and unmarked. The faces, where the seals seat, should be undamaged. Check the steel piston rod to make sure there is no pitting or bending of the rod. These shafts are usually hard-chrome plated to resist pitting and scoring. *Never* use a pipe wrench or other tool on this rod because you can damage the shaft and cause the cylinder to leak.

NOTE: Lubricate seals and O-rings before installing them into a cylinder assembly or on the piston. This is a vital step to ensure the piston assembly initially moves freely. Sometimes you might even have to heat the seals (by immersing in hot oil) before installing to allow the seals to give (stretch) a small amount.

Valves

Valves come in a variety of operational and functional types. With a relief valve, first check the system's hydraulic pressure to ensure that proper relief is given at the valve's predetermined setting. If you suspect a relief valve is at fault, remove the valve and check it for dirt and debris that may be clogging the internal ports. Reinstall the valve and, if it is an adjustable relief valve, check the service manual for adjustment procedures.

CAUTION: Read the service manual or technical order before removing any valves. Some hydraulic systems maintain residual hydraulic pressure even when the engine is not running.

If a hydraulic system has multiple valves mounted in its valve bank, its purpose is to support multiple valve functions (fig. 2–5). In this case, a central fluid supply can be used as a source for all of the valves to function. Additional ports direct fluid flow out of the valve bank according to which valve assembly is operating. If you suspect malfunctioning of the valve bank, check all the passages and valves for contamination. You must check the service manual or technical manual for the flow passages and pressure passages within the valve bank. Often there are springs, seals, and plungers within the valve bank that can be very easily lost or not put in correctly when you reassemble the bank.

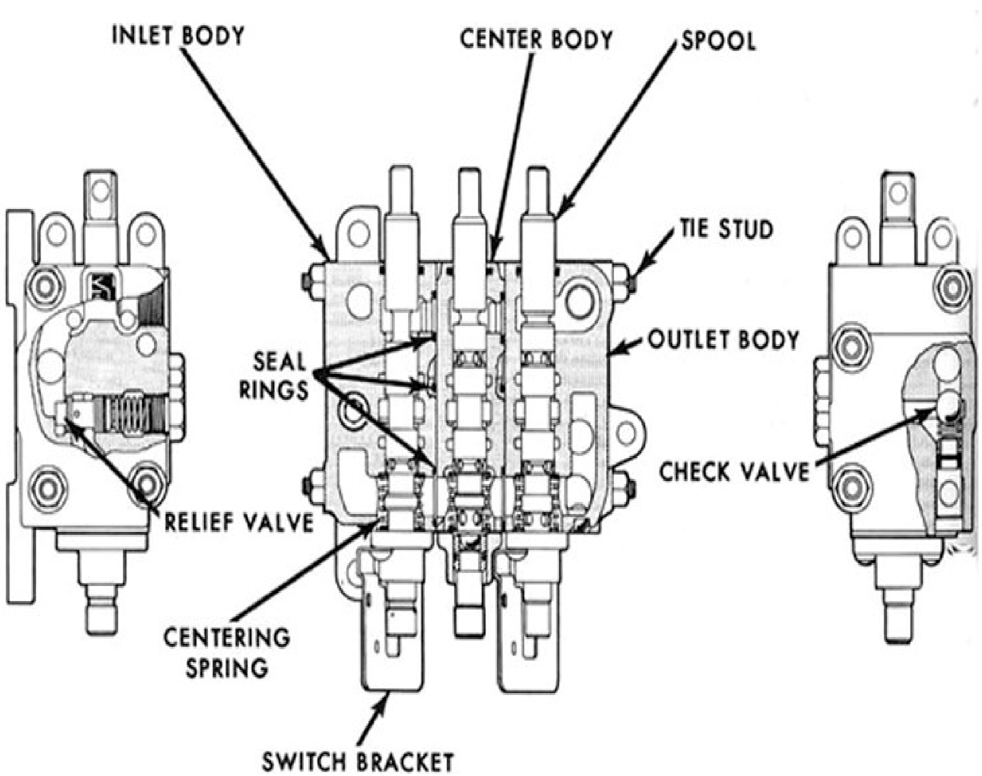


Figure 2–5. Hydraulic valve bank.

Manufacturing hydraulic hoses

Check hydraulic flex (rubber) hoses for cracking, leaks, blistering, flatness, and the general age of the hoses. All of these signs could indicate that the hose needs to be replaced.

Check metal lines and piping for scoring, abnormally bent or creased tubing, surface rust, and cracking. Check the service manual or technical order when determining what, if any, tolerances are acceptable. There are special flaring tools and kits available for solid hydraulic lines if you need to replace or repair a line. Of course, you can always replace the part with one that a manufacturer has already made. However, there may be times where you need to manufacture a line to return a vehicle to service more quickly. Additionally, if your shop has a stock of bulk supplies (hoses and fittings), it is more cost-effective to manufacture your own rather than purchase a replacement hose. Check with your shop to see what type of equipment and supplies are available.

Various machine types assist in hydraulic flex hose manufacturing. Most machines have a crimping tool that hold the hydraulic hose and then spin or clamp the fitting in place. Each hydraulic hose and fitting has an identifying number or mark to dictate the hose type (water, oil, fuel) and the type of fitting that matches up with that hose. Hose size is determined by its inside diameter.

CAUTION: Putting the wrong size fitting on a hydraulic hose or using the wrong hose size can be very dangerous and could injure personnel or damage intended equipment.

Always check the service manual or technical order for the equipment you are using and use only the recommended hoses and fittings for that application. Wear the proper PPE.

To manufacture a flex hose with a reusable-type (screw-on) fitting, first determine the new hose assembly length by matching it up with the old hose. Be sure to account for the hose length hidden inside the fittings. Next, place the hose in a vice and cut it off square with a fine-tooth bladed hacksaw or an abrasive cutoff wheel with the slow gradual feed.

Afterwards, strip the hose in accordance with the procedure provided in the following table:

How to Strip a Hydraulic Hose	
Step	**Action**
1	Locate and mark off the cutting point of the cover to be stripped, using the fitting to be attached as a guide.
2	Cut around the hose through the outer cover at the cutting mark. Be sure the cut is down to the wire braid all the way around.
3	Slit the outer cover lengthwise from the cutting mark to the end of the hose. Grip the raised flap firmly with pliers and twist off the cover.
4	Clean the exposed end with a wire scratch brush or wire wheel until the wire braid is free of all exposed rubber particles left from removal of the outer cover. Be careful and ensure that the wire braid does not fray when brushed.

To assemble the fitting and hose correctly, perform the following:

1. Place the socket in the vise or machine and screw the hose into the socket counterclockwise until the hose bottoms.
2. Screw the nipple into the hose using a wrench.

Replacing a hydraulic hose with the incorrect size can affect fluid flow fluid and the hydraulic system may not operate correctly. Remember this simple rule: if you are unsure of what equipment and materials to use, simply check the service manual or technical order.

Drip, steady stream, wet, and seepage are common terms that apply when troubleshooting hydraulic system malfunctions. You must check the manufacturer's service manual to determine each condition. A drip for one hydraulic pump may be defined as one or two drops of hydraulic fluid in one minute. Another manufacturer may define a drip to be one drop in five minutes.

A hydraulic hose that has a wet or seeping outer layer may require replacing; however, it may be possible to continue using this hose if the manufacturer considers this a safe and serviceable condition. This is why it is vital that you check with the manufacturer's service manual for specifications. A hydraulic leak, if not kept in check, can damage equipment and may even be a safety hazard.

Interpret hydraulic schematics and diagrams

As with electrical schematics, it is important to understand the basic operation of hydraulic systems as well as how to follow their schematic diagrams. A hydraulic schematic is a line drawing composed of symbols that indicate the types of components the hydraulic circuit contains and how they are interconnected. As a result, it is essentially a "road map" of the specific hydraulic system, making it invaluable when troubleshooting malfunctions. Figure 2–6 is a sample of a hydraulic schematic.

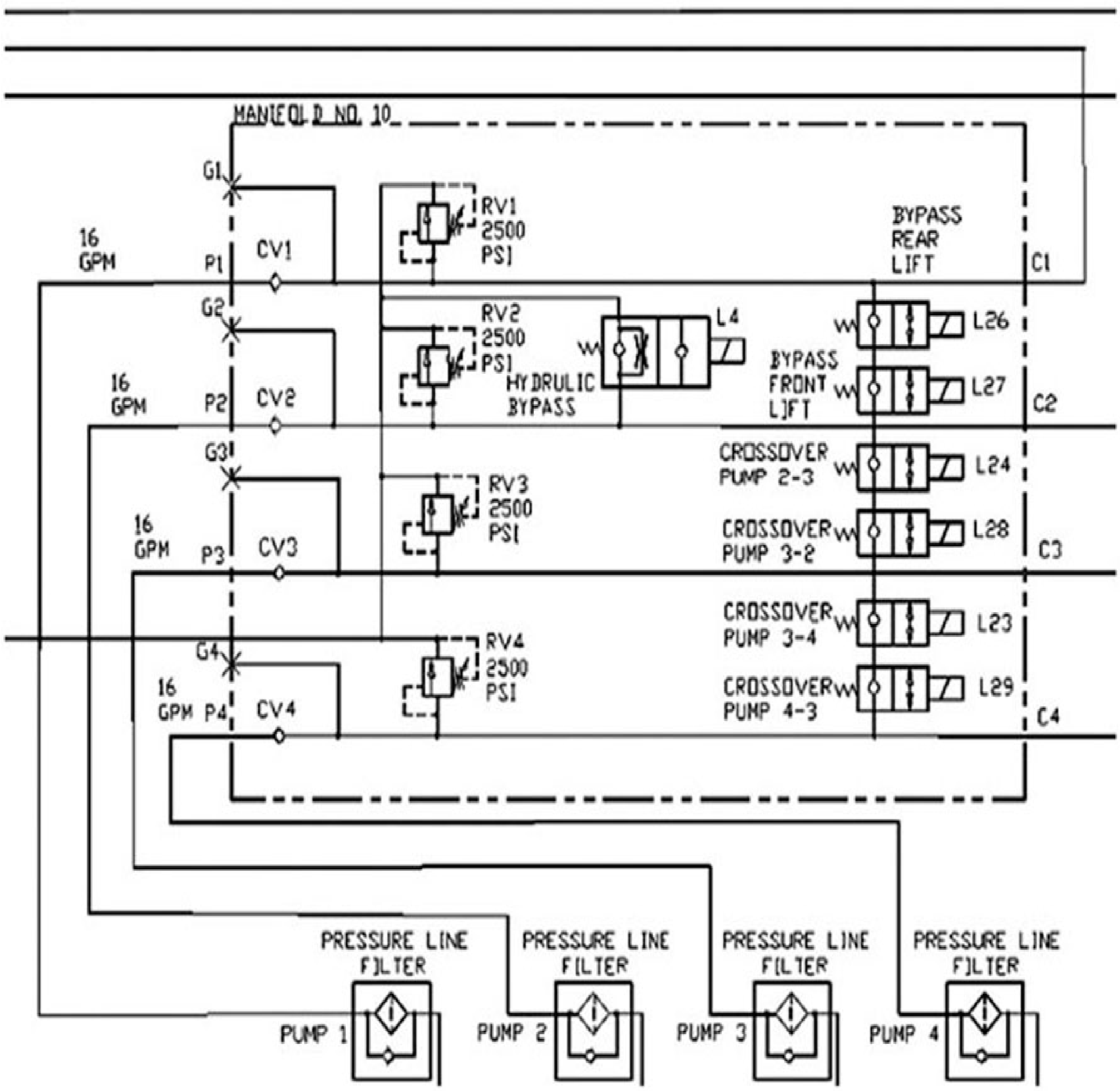


Figure 2–6. Partial hydraulic schematic.

If a schematic is not available, you must trace the hydraulic circuit and identify the components in order to isolate possible causes of the problem. This can be a time-consuming process, depending on the complexity of the system. Additionally, without knowing the function or purpose of a component within a hydraulic system, it can be difficult to eliminate it as a possible cause of the problem.

Typically, hydraulic schematics contain a legend to help clarify circuits and components during troubleshooting. Figure 2–7 is a sample of a hydraulic legend.

Before troubleshooting hydraulic malfunctions, be sure to study the manufacturer's schematic. Always refer to your service manual or technical order for a complete set of schematics and the legend to explain component information.

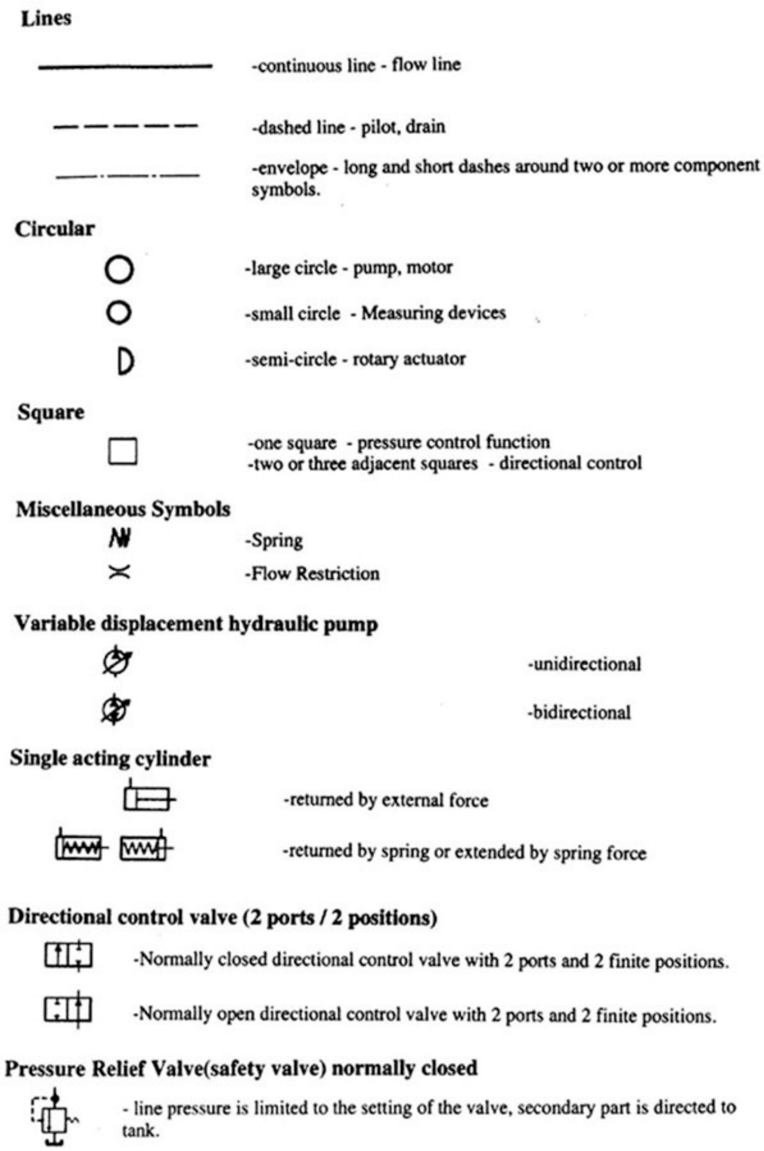


Figure 2–7. Sample of hydraulic legend.

408. Isolating hydraulic malfunctions and component replacement

In previous lessons, you learned about the fundamentals and maintenance of the hydraulic system as well as the manufacturing of hydraulic hoses. We now turn our attention to isolating malfunctions and replacing hydraulic components.

When you begin to troubleshoot a vehicle that has an inoperable hydraulic system, first ensure the following requirements by performing a visual inspection:

- The hydraulic tank is filled to the proper operating level.
- The tank shut-off valve is in the open position.
- All lines and hoses are free of kinks or bends.
- There are no visible hydraulic leaks.

Once you have completed the visual inspection that has not revealed any obvious problems, it is time to perform troubleshooting. This process helps you determine what component is causing the malfunction. You will need to check the various components, starting with the hydraulic pump itself.

Hydraulic pump

If you suspect that the pump is at fault, the following are two things you need to identify first:

1. It is a single or tandem pump (discussed earlier).
2. The pump is driven by a set of belts, internally splined shaft, or by a drive shaft attached to the harmonic balancer.

If the pump is belt driven, make sure the belts are properly adjusted to the correct tension before condemning the pump as faulty. Follow the service manual or technical order procedures for proper belt adjustment. If you over tighten the belts, you can cause premature failure of the pump bearings. Some symptoms of loose belts include the following:

- Erratic pump operation (i.e., jerky hydraulic operation).
- Slow or no hydraulic system functions.
- Audible squealing noise (i.e., belts slipping).

If the pump is driven by a drive shaft connected to the harmonic balancer, visually check to see if the drive shaft is securely mounted. If a splined shaft drives the pump internally, you may have to remove the pump to see if the shaft is broken or if the splines are stripped. Once you have completed these steps, you can start testing the hydraulic pump to see if it is working properly.

Start by locating the proper pressure port where you can hook up a pressure gauge to see if the pump is generating pressure. You can locate the correct pressure ports by referring to the appropriate service manual or technical order, checking the troubleshooting guide, and the hydraulic schematic. Once you locate the correct hydraulic port, attach the pressure gauge and operate the system. Next, write down the pressure gauge reading and compare it to the service manual or technical order specifications. If the pump pressure is not within tolerance, check the pressure relief valve. If the relief valve is good, then the pump is faulty and needs to either be rebuilt or replaced.

NOTE: When using a pressure gauge on the hydraulic system, ensure it is rated to *handle maximum system pressure* on the system you are testing, and that it is an oil-filled gauge.

CAUTION: You MUST ALWAYS *relieve hydraulic system pressure* prior to connecting a pressure gauge or loosening a hydraulic line. Hydraulic fluid can pierce the skin and cause severe injury or even death. Always wear proper PPE during these procedures.

Consider the possibility that after making the preceding checks, you have determined the pump is faulty and must be replaced. You must then identify where the pump sits in relation to the reservoir. In the event the pump is below the reservoir, the following table covers your next actions.

Replacing a Pump Below the Reservoir	
Step	**Action**
1	Relieve any hydraulic pressure.
2	Shut off the in-line ball valve. This will help reduce the amount of fluid loss when removing the inlet line/hose from the pump. If there is not an in-line ball valve, you may have to open the top of the reservoir and install a rubber stopper in the line that feeds the hydraulic pump, if applicable.
3	Put a drain pan under the pump area to catch the fluid that you will lose.
4	Disconnect the pump inlet line/hose from the pump and cap the line or hose.

Replacing a Pump Below the Reservoir	
Step	**Action**
	This will help reduce contaminants from getting into the system.
5	Disconnect the outlet line/hose and install another cap.
6	Follow the service manual or technical order for the steps in removing the hydraulic pump from its location.

Just reverse the procedures for when installing the new pump. *REMEMBER to remove the rubber stopper or open the in-line ball valve before operating the pump.* Once you have completed these steps start the vehicle and let it idle for a few minutes and listen for any abnormal noises, this will remove air from the system and ensure proper operation.

Pressure relief valve

If you suspect the pressure relief valve is faulty, testing it is very simple. Connect a pressure gauge into the proper pressure port. Start the engine and check the pressure reading. Compare this reading to the technical order or manufacturer's specifications. If the relief valve is adjustable, follow the sequence listed in the service manual or applicable technical order and adjust the relief valve to the manufacturer's specified rating. If the valve is *not adjustable*, you will have to replace it.

Hydraulic cylinder

If a cylinder is thought to be at fault, you can isolate it from the hydraulic system and test it independently. For example, you can hook up a port-a-power and actuate the cylinder while it is still in place. If the cylinder operates, then it is good; consequently, the next thing to consider is control of the fluid flow to the cylinder. However, if the *cylinder does not work*, it could mean that the internal seals are leaking past the piston end of the ram; if so, you will want to pull it. At this point, you are faced with deciding whether to rebuild or replace it. Given today's tight budgets, you must choose the most cost effective method.

While removing a cylinder from its location, ensure the structure is properly supported. Additionally, be careful that the cylinder itself it supported when you remove the retaining pins or bolts. Dropping a cylinder can seriously damage it, other components around it, and, more importantly, you can injure yourself. Once you have the cylinder removed, cap the hydraulic lines and plug the cylinder ports. Capping the lines keeps dirt and debris from getting into the system. After the cylinder is repaired, it is time to put it back in place.

NOTE: When you get a cylinder back from rebuild or obtain a new one, it is in what we call the dry state—there is no fluid on either side of the piston.

Putting the cylinder back in place means that you just reverse the order in which you took the cylinder out of position. After you have the cylinder installed, you must bleed the air out of the cylinder before returning the vehicle to service. You can bleed the air using either of the following methods:

1. Once the cylinder is back in place and the hydraulic lines are attached, operate the respective system. Deadhead the cylinder for a few seconds and then deadhead the cylinder in the opposite direction in order to push the air out of the cylinder.
2. Another way is to fill the cylinder with the proper hydraulic fluid before putting it back in its original position and attaching the hydraulic lines. This helps reduce the amount of time needed to bleed the air out of the cylinder.

Directional control valve

These valves are operated one of two ways—mechanically or electronically. Most valves are electronically operated; however, it can vary widely depending on their use. If the control valve operates electronically, it has a solenoid that either pulls or pushes the valve open. If believe the solenoid is at fault, there are a few things you can do to verify whether it is operating:

- Check the solenoid for resistance (measured in Ohms). If the resistance measurement is too high, or if there is no resistance value, simply replace the solenoid.
- Determine if 12 volts is at the proper solenoid location.
- Conduct a manual override to check to identify if the fault is an electrical or a hydraulic problem. Many hydraulic valves have a built-in override system that is either a push-button- or locking-type valve. Manually overriding the system helps identify the nature of the malfunction.

If the solenoid is good and you still feel that the valve is the problem, pull the valve before you decide to replace it. Once pulled, visually inspect it to see if there is a piece of debris that is keeping it from functioning properly. Also, check its operation while it is out of the system. Put the solenoid back on the valve as if it was in the system, apply 12 volts to the solenoid, and watch to see if the valve moves and operates. If it does not operate properly, replace it.

Self-Test Questions

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

406. Hydraulic system fundamentals

1. Of the open and closed center hydraulic systems, which one supplies fully pressurized fluid on demand?

2. What is meant by “pressure” in a hydraulic system?

3. What is meant by “flow” in a hydraulic system?

4. What is the principle of fluid power?

5. What is an advantage of hydraulic actuators over electrical motors?

6. How can you identify a nonpositive displacement pump?

7. What is meant by hydraulic displacement?

8. What are two important functions of an accumulator?

9. How is a “low-pressure” flex hose generally constructed?

10. What types of fittings are commonly used on flex-hose assemblies?

11. What is the purpose of a pressure control valve?

12. What is the difference between a check valve and a reversing valve?

407. Inspecting and maintaining the hydraulic system

1. What is the difference between a strainer and filter?

2. Where are magnetic plugs installed to aid in removing metal particles from the hydraulic fluid?

3. When cleaning magnetic plugs, what would indicate a serious problem and warrant further investigation?

4. What are some common checks to perform on a hydraulic cylinder?

5. What component allows you to operate more than one valve function or house multiple valves?

6. What indicates the need to replace hydraulic hoses?

7. What can happen if an incorrectly sized hydraulic hose is used?

8. What is the definition of a hydraulic schematic?

408. Isolating hydraulic malfunctions and component replacement

1. What items must be visually inspected to ensure they meet requirements prior to diagnosing the hydraulic system?

2. What are the three ways hydraulic pumps are driven?

3. What items will assist you with locating the proper test ports?

4. Due to possible injury or death, what precautions should you take before connecting a pressure gauge or loosening any hydraulic line?

5. If a cylinder actuates after hooking up a port-a-power to it, does it need to be rebuilt or replaced? Why?

Answers to Self-Test Questions

406

1. Closed center system.
2. Pushing or exerting a force or torque.
3. Making something move, causing motion.
4. Pressure applied to a confined fluid is transferred uniformly and undiminished to every portion of the fluid and to the walls of the container that holds the fluid.
5. Hydraulic actuators use no energy while not moving; however, even while stopped, an electrical motor draws a large amount of current to maintain torque.
6. The inlet and outlet are connected hydraulically so that the fluid can recirculate.
7. How much flow is required for a specified drive speed; the amount of oil pumped into the motor to turn it one revolution.
8. (1) Store energy so that pumps do not have to be sized for peak loads.
   (2) Keep the system pressure relatively constant.
9. With single cotton-braid reinforcement, and an inner and outer tube of synthetic rubber.
10. Press-on or screw-on fittings.
11. To limit, control, or regulate pressure in the system.
12. A check valve permits only one flow path, while a reversing valve has four flow paths.

407

1. A strainer removes large contaminants and a filter removes finer (smaller) contaminants from a fluid.
2. Within the hydraulic oil reservoir.
3. Finding large metal shavings or pieces of metal.
4. The barrel or tube, piston and rod (ram), and end caps. Check the steel piston rod to make sure there is no pitting or bending of the rod.

5. Valve bank.
6. Cracking, leaks, blistering, flatness, and the general age of the hoses.
7. This can affect fluid flow, and the system may not operate correctly.
8. A line drawing composed of symbols that indicate the types of components the hydraulic circuit contains and how they are interconnected.

408

1. (1) The hydraulic tank is filled to the proper operating level.
   (2) The tank shut-off valve is in the open position.
   (3) All lines and hoses are free of kinks or bends.
   (4) There are no visible leaks.
2. Set of belts, internally by a splined shaft, or by a shaft attached to the harmonic balancer.
3. The appropriate service manual or technical order, the troubleshooting guide, and hydraulic schematic.
4. Relieve hydraulic system pressure and wear proper PPE.
5. It does not need replacing because it is operating; as a result, the next thing to consider is the fluid flow to the cylinder.

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 AFCDA.

37. (406) What is meant by the *flow rate* in a hydraulic system?
    a. Quantity of fluid viscosity detected at a certain point.
    b. Volume quantity of the liquid as it passes a point.
    c. Average speed of the fluid past a pint.
    d. Pressure exerted under resistance.

38. (406) The term *fluid power* refers to
    a. energy that is transmitted via a fluid under pressure.
    b. energy that is transmitted via a fluid's viscosity.
    c. speed generated by hydraulic fluid.
    d. fluid flow torque.

39. (406) What is meant by a *dual* or *tandem* hydraulic pump?
    a. Two pumps connected together individually operating separate systems (two input shafts).
    b. Two pumps connected together individually operating separate systems (one input shaft).
    c. A single hydraulic pump that operates multiple hydraulic functions.
    d. A single hydraulic pump that operates one hydraulic function.

40. (406) What type of pump has the inlet side sealed from the outlet side and delivers fluid anytime?
    a. Nonpositive displacement.
    b. Proactive displacement.
    c. Negative displacement.
    d. Positive displacement.

41. (406) A hydraulic motor is a pump that
    a. pulls fluid only.
    b. pushes fluid only.
    c. is being *pulled* instead of doing the pulling.
    d. is being *pushed* instead of doing the pushing.

42. (406) What is the purpose of an accumulator?
    a. Store hydraulic fluid for the pump to use.
    b. Store hydraulic fluid for a hydraulic motor to use.
    c. Store energy and keep system pressure relatively constant.
    d. Increase and maintain system pressure at the *maximum* pounds per square inch (psi).

43. (406) If you say a valve assembly is "zero overlap," then you mean
    a. the distance that the valve piston travels.
    b. there is no dead zone between active control ranges.
    c. the amount of play (excess space) inside the valve cavity.
    d. there is no change in fluid direction when the valve is moved.

44. (407) Which device is used for removing larger contaminants from a fluid?
    a. Magnetic plug.
    b. Skimmer.
    c. Strainer.
    d. Filter.

45. (407) A filter that contains closely woven metal screens or discs is classified as
    a. free flowing.
    b. mechanical.
    c. osmotic.
    d. porous.

46. (407) In order to remove metal particles from hydraulic fluid, magnetic plugs are installed in the hydraulic oil
    a. strainer.
    b. cylinder.
    c. reservoir.
    d. return line.

47. (407) When the available fluid does *not* fill the existing space, it causes
    a. cavitation.
    b. capillary vibration.
    c. low-pressure shutoff.
    d. excessive system pressure.

48. (407) To resist pitting and scoring, hydraulic cylinder shafts usually coated with hard
    a. copper plate.
    b. chrome plate.
    c. nickel cadmium.
    d. aluminum oxide.

49. (407) What is the *first* step for checking a pressure relief valve?
    a. Turn adjusting screw *all the way out* to relieve pressure.
    b. Turn adjusting screw *all the way in* to relieve pressure.
    c. Check the valve’s internal ports for dirt and debris.
    d. Check system pressure to ensure proper relief.

50. (407) A hydraulic valve bank is designed to support
    a. storing of hydraulic fluid for pump operation.
    b. cleaning and recirculating of hydraulic fluid.
    c. multiple valve functions.
    d. a single valve function.

51. (407) The following conditions are signs that a hydraulic hose needs to be replaced *except*
    a. leaking.
    b. cracking.
    c. flatness and blistering.
    d. low reservoir fluid level.

52. (407) If a schematic is unavailable, you can isolate hydraulic system problems by
    a. replacing each component until the problem is found.
    b. running the system at high-speed and listening.
    c. overfilling the reservoir and looking for leaks.
    d. tracing the hydraulic circuit.

53. (408) When conducting a visual inspection on the hydraulic system, what component should you ensure is in the *open* position?
    a. Hydraulic return valve.
    b. Reservoir drain valve.
    c. Filter bypass valve.
    d. Tank shut-off valve.

54. (408) Your *final step* after completing an inspection of all lines and hoses is to look for
    a. visible air leaks.
    b. improper tire wear.
    c. visible hydraulic leaks.
    d. rust on the cylinder rams.

55. (408) An audible squeal noise occurring while operating the hydraulic system is a symptom of
    a. loose belts.
    b. missing belts.
    c. belts too tight.
    d. properly adjusted belts.

56. (408) What do you compare readings to after taking pressure readings of the hydraulic pump?
    a. Same pressure readings from another same style of vehicle.
    b. Service manual or technical order specifications.
    c. Pressure readings from another hydraulic system.
    d. Pressure readings taken by another technician.

57. (408) What is the *second step* in removing the hydraulic pump?
    a. Loosen the pump inlet hose/line.
    b. Disconnect the pump outlet line.
    c. Shut off the in-line ball valve.
    d. Cap all hydraulic lines.

58. (408) Once you have installed the hydraulic cylinder and connected all lines, what is your *next step*?
    a. Bleed the air out of the cylinder.
    b. Test under max rated load.
    c. Ensure there are no leaks.
    d. Add hydraulic fluid.

59. (408) How many volts should be measured at the solenoid?
    a. 6 volts.
    b. 10 volts.
    c. 12 volts.
    d. 24 volts.

60. (408) When you test a valve assembly by applying 12 volts to the solenoid, what are you looking for?
    a. Heating of the solenoid.
    b. Valve movement and operation.
    c. Solenoid movement or operation.
    d. Jumping of the valve and solenoid.

Please read the unit menu for unit 3 and continue ➔

Student Notes

Unit 3. Heating, Ventilation, and Air Conditioning Systems

HEATING AND AIR CONDITIONING (A/C) systems provide operators and passengers with comfort, but they can also play a critical role in safe vehicle operation. In this unit, we will cover the basic operation, diagnosis, and repair procedures concerning heating and A/C systems.

While most vehicles are equipped with both heating and air conditioning systems, some may only have a heating system. Understanding how each of these systems operate and how to maintain them properly is important to accomplishing the Air Force mission.

409. Heating and air conditioning fundamentals

We will begin by learning the fundamentals of heating and A/C. This lesson includes principles and cycles of refrigeration, the function and construction of a typical heating and A/C system, its operation, and safety precautions. Please refer to *Modern Automotive Technology, 9th Edition* and the following table for the assigned reading and questions.

Assigned Material		
Task	**Material**	**Pages**
Read	Chapter 83: Heating and Air Conditioning Fundamentals	1673–1693
Answer	Review Questions: 1, 4, 5, 7, 9, 10, 11, 12, 13, 15, 17, 18	1694–1695
Answer	ASE-Type Questions: 1, 4, 6, 7, 8, 10, 11, 12, 14	1695–1696

410. Heating and air conditioning diagnosis, service, and repair

Now that we have established your foundational knowledge, this lesson will teach you to troubleshoot, diagnose, and properly service heating and A/C systems, along with their related components. Please refer to *Modern Automotive Technology, 9th Edition* and the following table for the assigned reading and questions.

Assigned Material		
Task	**Material**	**Pages**
Read	Chapter 84: Heating and Air Conditioning Diagnosis, Service, and Repair	1697–1719
Answer	Review Questions: 1, 2, 4, 6, 9, 10	1720
Answer	ASE-Type Questions: 1, 2, 3, 6, 8, 10, 13, 15	1720–1721

Answers to Textbook Questions

409

Chapter 83 Review Questions

1. Vapor, liquid, and solid.
4. Btu stands for British thermal unit. It is the unit of measurement for heat transfer from one object to another.
5. Condensation, vaporization.

7. (1) Refrigerant—Refrigerant is a substance, usually R–134a, which carries heat through the system to lower the air temperature in the vehicle.
   (2) Compressor—The compressor is an engine-driven or electric pump that pressurizes refrigerant and forces it through the system.
   (3) Condenser—The condenser causes refrigerant to change from a gaseous state to a liquid state, causing it to give off its stored heat.
   (4) Flow-control device— A flow-control device, usually an expansion valve or tube, causes refrigerant pressure and temperature to drop, cooling the evaporator.
   (5) Evaporator—An evaporator uses the cooling action of vaporizing refrigerant to cool the air inside the vehicle.
   (6) Receiver-drier or accumulator—A receiver-drier or accumulator removes moisture from and stores refrigerant.
   (7) Blower—The blower is a fan that forces air through the evaporator and into the passenger compartment.
   (8) Thermostatic switch—Thermostatic switch shuts the compressor off when the evaporator temperature nears freezing.
9. (1) The high side (discharge side) of an A/C system consists of the parts between the output of the compressor and the flow-control restriction.
   (2) The low side (suction side) of an A/C system consists of the parts between the flow-control restriction and the inlet of the compressor.
10. It uses a magnetic clutch.
11. Crank, axial, radial, rotary vane, scroll.
12. Refrigerant oil.
13. By cycling the compressor on and off.
15. To allow refrigerant installation and removal, as well as pressure gauge tests of the A/C system.
17. Heater core.
18. (1) An electric switch may operate (usually through relays) the blower motor, the compressor clutch, and other electric components.
    (2) Mechanical levers and cables can operate air doors (air flaps) over the heater core, evaporator, and ducts.
    (3) A vacuum switch can operate vacuum motors (vacuum diaphragms) that open and close the air doors.
    (4) An electronic control unit (computer) and sensors can operate the heating and air conditioning systems automatically.

Chapter 83 ASE-Type Questions

1. (B) B only.
4. (A) A only.
6. (B) B only.
7. (A) A only.
8. (A) A only.
10. (C) Both A and B.
11. (A) A only.
12. (A) A only.
14. (B) B only.

410

Chapter 84 Review Questions

1. (1) Loose or missing compressor drive belt.
   (2) Inoperative compressor clutch.
   (3) Disconnected or damaged wiring or vacuum hoses.

(4) Refrigerant leaks (wetness) around lines or fittings.
(5) Blockage (leaves, mud) in the condenser fins.
(6) Inoperative air control doors.

2. It will let you know if refrigerant is moving through the system.
4. (1) Refrigerant may cause frostbite. By placing a rag over the fitting prior to loosening the connection, the technician can help to prevent skin contact to avoid frostbite.
   (2) Always wear safety glasses due to the possibility of refrigerant spraying into the eyes and causing blindness.
   (3) Keep refrigerants away from excessive heat due to pressure increases in refrigerant containers when temperature rises. Heat could cause the tank to explode.
   (4) Keep refrigerant away from an open flame. If refrigerant is burned, it turns into phosgene gas, which is a highly toxic poison.
   (5) Never discharge refrigerant into the air as it will cause environmental damage. Further, any vapor discharge in a confined space may possibly cause suffocation.
6. Service.
9. It does not use a flame, which burns refrigerants, sometimes releasing very toxic phosgene gas.
10. Releasing refrigerant is unlawful and damaging to the environment.

Chapter 84 ASE-Type Questions

1. (C) Both A and B.
2. (A) A only.
3. (C) Both A and B.
6. (A) A only.
8. (C) Both A and B.
10. (B) B only.
13. (B) B only.
15. (C) Both A and B.

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 AFCDA.

61. (409) You can lower the boiling (vaporizing) point of a closed container of liquid by
    a. going to the lowest possible sea level and heating the container.
    b. placing a partial pressure over the container.
    c. decreasing the pressure over the container.
    d. placing a vacuum over the container.

62. (409) Refrigerant–12 (R–12) was phased out because it was
    a. too expensive to produce.
    b. dangerous to technicians.
    c. less efficient than R–134a.
    d. dangerous to the environment.

63. (409) The air conditioning system cools the passenger compartment when the blower
    a. forces air through the condenser.
    b. forces air through the evaporator.
    c. compresses and circulates the refrigerant.
    d. disperses refrigerant into the passenger compartment.

64. (409) Which of the following is *not* a function of an air conditioning system?
    a. Cools air.
    b. Cleans air.
    c. Circulates air.
    d. Humidifies air.

65. (409) What state is the refrigerant in when it *leaves* the evaporator?
    a. High-pressure gas/vapor.
    b. Low-pressure gas/vapor.
    c. High-pressure liquid.
    d. Low-pressure liquid.

66. (409) What kind of force locks the air conditioning compressor's clutch plate and pulley together when the compressor clutch is energized?
    a. Centrifugal.
    b. Magnetic.
    c. Spring.
    d. Static.

67. (409) Air conditioning refrigerant hoses are designed to withstand compressor pressures, measured in pounds per square inch (psi), as high as
    a. 50 psi.
    b. 125 psi.
    c. 250 psi.
    d. 1000 psi.

68. (409) Where is the condenser located and what is its function?
    a. Inside the heater case; transfer heat from the refrigerant to outside air.
    b. In front of the radiator; transfer heat from the refrigerant to outside air.
    c. Under the dash; transfer heat from the passenger compartment to the refrigerant.
    d. In front of the radiator; transfer heat from the passenger compartment to the refrigerant.

69. (409) If a vehicle has a sight glass, where is it normally located if it is not on the receiver-drier?
    a. On the compressor.
    b. In a refrigerant line.
    c. On the accumulator.
    d. Behind the glove box.

70. (409) What component of an air conditioning system prevents liquid refrigerant from entering the compressor?
    a. Reed valve.
    b. Orifice tube.
    c. Accumulator.
    d. Receiver-drier.

71. (409) The compressor cycling switch cycles the compressor to maintain the correct temperature of the
    a. condenser fins.
    b. receiver-drier.
    c. evaporator.
    d. condenser.

72. (409) The expansion valve controls
    a. when the compressor turns on.
    b. when the compressor turns off.
    c. how much refrigerant enters the evaporator.
    d. how much pressure is exerted on the refrigerant.

73. (409) A passenger compartment electrically-charged air filter can trap particles as small as
    a. 2 microns.
    b. 5 microns.
    c. 15 microns.
    d. 50 microns.

74. (410) On a vehicle equipped with a sight glass, what condition is indicated if the air conditioning (A/C) system does *not* cool and bubbles appear in the sight glass?
    a. A desiccant bag is broken.
    b. Refrigerant is low and air is in the system.
    c. The system is overcharged with refrigerant.
    d. The system is completely out of refrigerant.

75. (410) If refrigerant contacts your skin, it can cause severe
    a. frostbite.
    b. cracking.
    c. irritation.
    d. chemical burns.

76. (410) What external factor can affect readings when testing an air conditioning (A/C) system using a pressure or manifold gauge assembly?
    a. Outside temperature.
    b. Engine temperature.
    c. Humidity.
    d. Altitude.

77. (410) When connecting R134a quick-disconnect fittings, in what position should the thumb screws be?
    a. Low side turned out; high side turned in.
    b. Low side turned in; high side turned out.
    c. Both turned all the way out.
    d. Both turned all the way in.

78. (410) When conducting an air conditioning (A/C) performance test, if the system is functioning correctly, the dash vent temperature reading in degrees Fahrenheit (° F) should be approximately
    a. 30–45 ° F.
    b. 38–60 ° F.
    c. 42–57 ° F.
    d. 45–65 ° F.

79. (410) What type of detector causes air conditioning (A/C) leaks to show up as a bright color spot?
    a. Internally charged.
    b. Electronic.
    c. Bubble.
    d. Torch.

80. (410) One of the most common sources of air conditioning (A/C) system leaks are
    a. damaged O-rings.
    b. cracked condensers.
    c. aging refrigerant lines.
    d. loose refrigerant line fittings.

81. (410) Which of the following does *not* indicate air conditioning (A/C) compressor problems?
    a. High inlet pressure.
    b. A loud rattling noise.
    c. Low discharge pressure.
    d. A click when the compressor engages.

82. (410) When evacuating an air conditioning (A/C) system, approximately how many inches of mercury (in. Hg) at sea level should you pressure gauge display while operating the vacuum pump?
    a. 5–10.
    b. 13–14.
    c. 26–28.
    d. 34–40.

83. (410) When checking coolant flow through the heater core, how can you tell if the system has a blockage or is clogged?
    a. Coolant is dripping out of the condensation drain tube.
    b. Both heater hoses are about the same temperature.
    c. The blower motor will not operate at any speed.
    d. One heater hose is hot and the other is cool.

Please read the unit menu for unit 4 and continue ➔

Unit 4. Restraint Systems

A PROPERLY FUNCTIONING RESTRAINT SYSTEM will save lives in an accident. As you maintain the Air Force fleet, restraint systems you service will protect your fellow Airmen. Therefore, it is of critical importance for you to learn how these systems are designed to function together, and how to keep them operational.

In this section, you will begin by learning about restraint system technology. Then, you will go on to learn about restraint system service.

411. Restraint system technology

This lesson will introduce you to several different technologies employed to protect passengers in modern vehicles. Please refer to *Modern Automotive Technology*, *9th Edition* and the following table for the assigned reading and questions.

Assigned Material		
Task	**Material**	**Pages**
Read	Chapter 85: Restraint System Technology	1725–1738
Answer	Review Questions: 1, 2, 4, 6, 8, 9, 10	1738
Answer	ASE-Type Questions: 1, 5, 7, 8	1739

412. Restraint system service

For your final lesson in this volume, you will learn how to service modern restraint systems. The skills you learn in this lesson are not only important for the safety of your fellow Airmen, but also your own as you work in the shop. Please refer to *Modern Automotive Technology*, *9th Edition* and the following table for the assigned reading and questions.

Assigned Material		
Task	**Material**	**Pages**
Read	Chapter 86: Restraint System Service	1741–1749
Answer	Review Questions: 2, 3, 4, 5, 6, 7, 8, 10	1749
Answer	ASE-Type Questions: 1, 2, 5	1750

Answers to Textbook Questions

411

Chapter 85 Review Questions

1. Restraint system.
2. They are areas located at the front and rear of the body-frame assemblies and designed to collapse during a severe impact. As the crush zones collapse, they absorb some of the collision forces rather than transferring them to the passenger compartment.
4. (1) Impact sensors.

(2) Air bag module.
(3) Air bag controller.
(4) Clock spring.
(5) Dash warning lamp.

6. It consists of a nylon bag and an igniter-inflator unit enclosed in a metal and plastic housing.
8. It uses a small explosive charge and a pressurized gas cartridge to inflate the air bag.
9. Deceleration.
10. Accelerometer.

Chapter 85 ASE-Type Questions

1. (D) Neither A nor B.
5. (C) Both A and B.
7. (B) B only.
8. (C) Both A and B.

412

Chapter 86 Review Questions

2. To inspect a seat belt for damage, pull the belt all the way out of its retractor. Inspect the belt fabric, or webbing, for cuts, pulled threads, broken thread loops, color fading, and fabric deterioration. Look for twisted webbing, which could make the belt stick in its retractor or guide plates. If necessary, untwist the belt so it moves freely in and out of the retractor and guides. Fit the two ends of the seat belt buckle together. Listen for a solid click. After connecting the two ends, try to pull the buckle apart by pulling sharply on the belt. The two ends must not disengage. Make sure the belt buckle will release with normal finger pressure. Inspect the belt anchors for problems (bent, cracked, loose, etc.). Replace the seat belt assembly if problems are found.
3. Any two:
   (1) Sharp edges on sheet metal body parts and on tools can damage seat belts. Even small cuts can weaken the belt webbing, causing it to snap during a collision.
   (2) Never attempt to straighten any portion of the belt buckle, latch plate, or anchor plate. If bent, the components should be replaced.
   (3) Inspect seat belt anchors for bending, cracking, or looseness. When replacing anchors, use the correct grade case-hardened bolts.
   (4) Use a torque wrench to tighten all seat belt anchor bolts to factory specifications.
4. Simply pull out on the belt quickly. It should lock, and you should not be able to extend the belt further. Pulling slowly should allow free lengthening of the belt out of the retractor.
5. Drive the vehicle on an open road or empty parking lot at approximately 10 mph and then hit the brakes hard. The belt should lock up as the vehicle comes to a stop.
6. All sources of electricity for the igniter module must be disconnected from the air bag module. Disarming procedures will vary by manufacturer.
7. 30.
8. By connecting a voltage source to the air bag module wires to “fire” the air bag.
10. The air bag will not deploy during a frontal impact.

Chapter 86 ASE-Type Questions

1. (D) Neither A nor B.
2. (A) A only.
5. (C) Both A and B.

Complete the unit review exercises.

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 AFCDA.

84. (411) Which of the following tests is used to analyze how well a vehicle’s body-frame structure and restraint systems will protect the occupants?
    a. Crush zone test.
    b. Dummy test.
    c. Crash test.
    d. Beam test.

85. (411) What type of restraint is an air bag?
    a. Active.
    b. Passive.
    c. Collapsible.
    d. Retractable.

86. (411) Which response *best* describes the amount of time it takes for an air bag to inflate after an impact sensor has detected a collision?
    a. 1 to 2 seconds.
    b. 10 milliseconds.
    c. One-half second.
    d. One-twentieth of a second.

87. (411) The largest air bag in a dual air bag system is the
    a. passenger-side air bag.
    b. driver’s-side air bag.
    c. side-impact air bag.
    d. rear seat air bag.

88. (411) Each of the following types of air bags are found in vehicles *except*
    a. side-impact air bags.
    b. side curtain air bags.
    c. inflatable seat belts.
    d. overhead air bags.

89. (411) How fast in miles per hour (mph) can an air bag travel during deployment?
    a. 100 mph.
    b. 150 mph.
    c. 200 mph.
    d. 300 mph.

90. (411) Front impact air bag sensors are *often* located in the
    a. trunk.
    b. doors.
    c. passenger area.
    d. engine compartment.

91. (411) Which of the following is *not* an air bag sensor?
    a. Proximity sensor.
    b. Coil spring sensor.
    c. Accelerometer sensor.
    d. Arming or safing sensor.

92. (412) During a seat belt inspection, you should check the webbing for all of the following *except*
    a. cuts.
    b. twisting.
    c. color fading.
    d. excessive moisture.

93. (412) When servicing a seat belt, what should you do if you find a bent buckle?
    a. Replace the seat belt assembly.
    b. Straighten the buckle using heat.
    c. Measure the angle of the bend and compare it to specifications.
    d. Straighten the buckle with vice grips and tighten the anchor bolts with a torque wrench.

94. (412) What is the *recommended* procedure for disarming the air bag system?
    a. Short the air bag sensor to ground to release the stored energy from the capacitor.
    b. Specified by the manufacturer; refer to the service manual.
    c. Pull the ignition fuse from the fuse block.
    d. Disconnect the air bag fusible link.

95. (412) What is the *minimum* amount of time you should allow an air bag to cool before handling it after deployment?
    a. 5 minutes.
    b. 10 minutes.
    c. 15 minutes.
    d. 30 minutes.

96. (412) After air bag deployment, which of the following should *not* be done?
    a. Place tape over air bag vent holes.
    b. Vacuum the passenger compartment.
    c. Wear a respirator, goggles, and rubber gloves.
    d. Force excess powder out of the air bag using hand pressure.

97. (412) When carrying a live (undeployed) air bag module, how should you aim the trim cover?
    a. Away from your body.
    b. Toward your body.
    c. Toward the floor.
    d. Upward.

98. (412) After deployment from a collision, what air bag sensors should be replaced?
    a. All sensors.
    b. Crash sensors only.
    c. None; they need to be reset.
    d. Only those triggered in the collision.

Glossary

Abbreviations and Acronyms

° F	degrees Fahrenheit
A/C	air conditioning
ABS	antilock brake system
CON	control air pressure
CTIS	central tire inflation system
DEL	delivery air
ECU	electronic control unit
EP	extreme-pressure
GPM	gallons per minute
LED	light emitting diode
MID	middle
MOD	modulator
mph	miles per hour
PDM	pilot air distribution manifold
PPE	personal protective equipment
psi	pounds per square inch
rpm	revolutions per minute
SDS	safety data sheet
SENS	sensor
SUP	supply air pressure
WEV	wheel end valve

Student Notes

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