Section 2

The Components of an Air Brake System

Section One of this manual has explained that it is possible to gain a mechanical advantage through the use of levers and that air under pressure can be used to gain a mechanical advantage. Section Two will explain how air under pressure can be used to operate the air brakes of a vehicle.

Piping illustrations have been kept simple in order to be easily understood. The piping arrangements found on vehicles in actual use on the highway might differ somewhat from the illustrations in this manual.

The Components of an Air Brake System

A basic air brake system capable of stopping a vehicle has five main components:

1. A compressor to pump air with a governor to control it.
2. A reservoir or tank to store the compressed air.
3. A foot valve to regulate the flow of compressed air from the reservoir when it is needed for braking.
4. Brake chambers and slack adjusters to transfer the force exerted by the compressed air to mechanical linkages.
5. Brake linings and drums or rotors to create the friction required to stop the wheels.

It is necessary to understand how each of these components work before studying their functions in the air brake system.

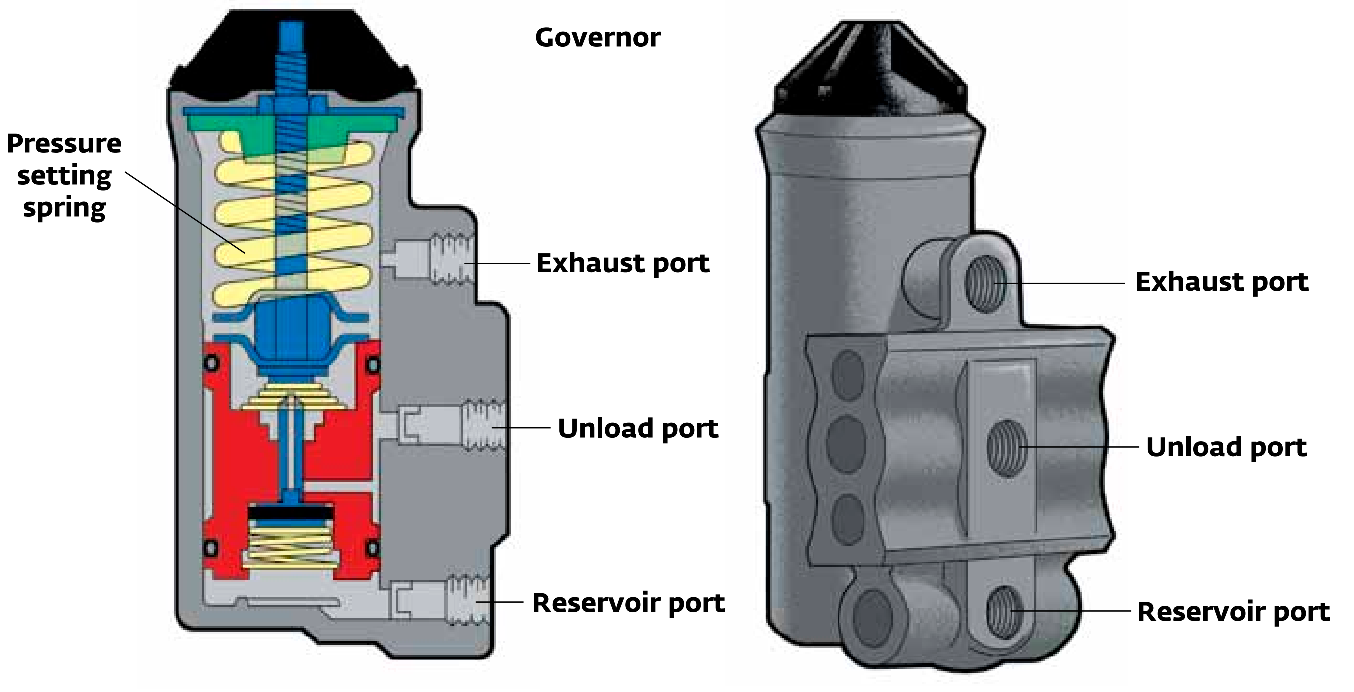
Compressor and Governor

Compressed air is used to transmit force in an air brake system. The source of the compressed air is a compressor (1). A compressor is designed to pump air into a reservoir which results in pressurized air.

The compressor is driven by the vehicle's engine, either by belts and pulleys or shafts and gears. In vehicles where the compressor is driven by belts, they should be checked regularly for cracks and tension. Also, check the compressor for broken mounting brackets or loose bolts.

The compressor is in constant drive with the engine. Whenever the engine is running, so is the compressor. When pressure in the system is adequate, anywhere from a low of 80 psi to a high of 135 psi it is not necessary for the compressor to pump air. A governor (2) controls the minimum and maximum air pressure in the system by controlling when the compressor pumps air. This is known as the "loading" or "unloading" stage. Most compressors have two cylinders similar to an engine's cylinders. When the system pressure reaches its maximum, which is between 115 and 135 psi, the governor places the compressor in the "unloading" stage.

The compressor must be able to build reservoir air pressure from 50 to 90 psi within three minutes. If unable to do so the compressor requires servicing. A compressor may not be able to build air pressure from 50 to 90 psi within three minutes if the air filter is plugged or if the belt was slipping, if these were not at fault the compressor could be faulty.



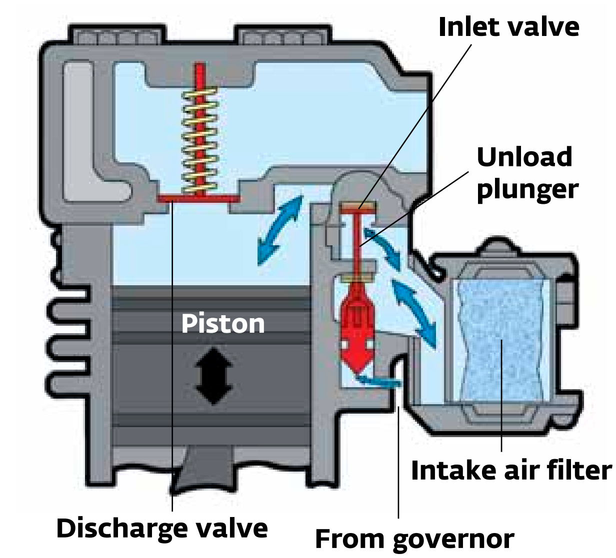
Placing the compressor in the unloading stage is done by directing air pressure to the inlet valves of the compressor, holding them open, allowing the air to be pumped back and forth between the two cylinders, instead of compressing the air. When the pressure in the system drops, the inlet valves close, returning the compressor to the "loading" stage. The governor must place the compressor in the "loading" stage at no lower than 80 psi. During the "unloading" stage, the compressor is able to cool.

It is very important the air that enters the system be kept as clean as possible. The air must first pass through a filter to remove any dust particles. The air filter must be cleaned regularly. A dirty filter will restrict the flow of air into the compressor, reducing its efficiency. Some vehicles have the inlet port of the compressor connected to the intake manifold and receive air that has been filtered by the engine air cleaner.

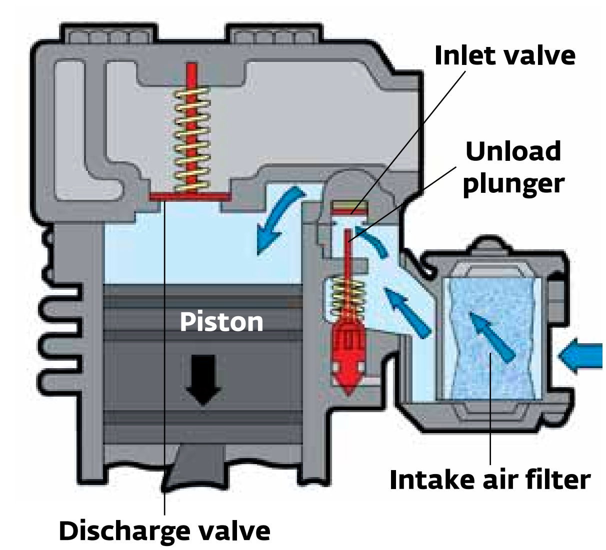
A piston type compressor operates on the same principle as the intake and compression strokes of an engine.

- Intake stroke: The downward stroke of the piston creates a vacuum within the cylinder which causes the inlet valve to open. This causes atmospheric air to flow past the inlet valve into the cylinder.

Compressor (Unloading stage)



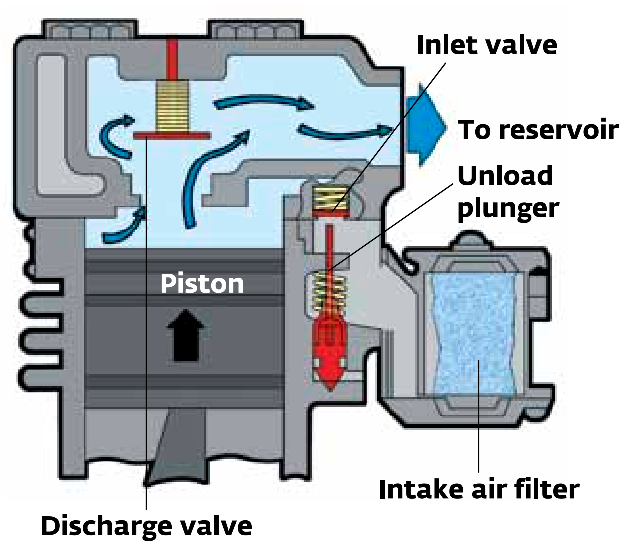
Compressor (Intake stroke)



Usually compressors are lubricated from the engine lubrication system, although some compressors are self–lubricating and require regular checks of the lubricant level.

- Compression stroke: The upward motion of the piston compresses the air in the cylinder. The rising pressure cannot escape past the inlet valve (which the compressed air has closed). As the piston nears the top of the stroke, the pressurized air is forced past the discharge valve and into the discharge line leading to the reservoir.

Compressor (Compression stroke)



Reservoirs

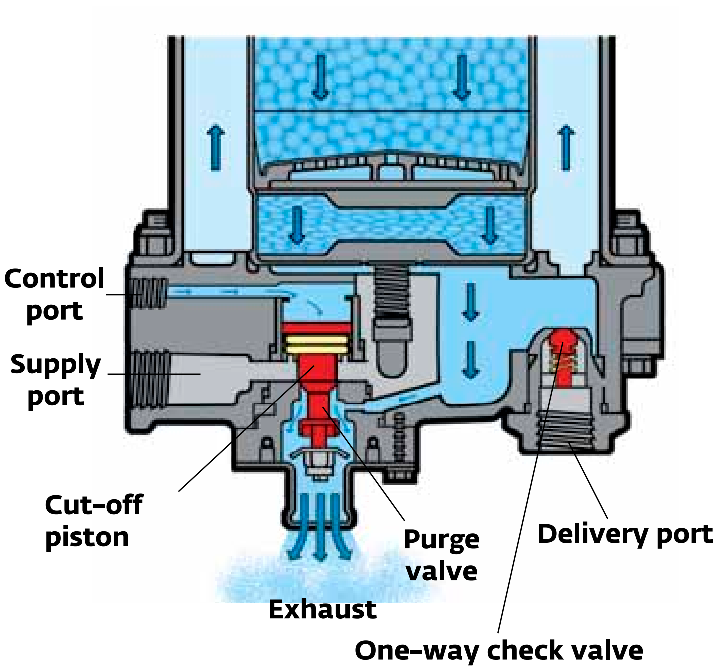
Reservoirs or tanks hold a supply of compressed air. The number and size of the reservoirs on a vehicle will depend on the number of brake chambers and their size, along with the parking brake configuration. Air brake vehicles are equipped with more than one reservoir. This gives the system a larger volume of main reservoir air. The first reservoir after the compressor is referred to as the supply or wet (5) reservoir. The other reservoirs are known as primary (8) and secondary (10) or dry (8)(10) reservoirs. When air is compressed, it becomes hot. The heated air cools in the reservoir, forming condensation. It is in this reservoir that most of the water is condensed from the incoming air. If oil leaks past the piston rings of the compressor and mixes with this moisture, it forms sludge, which accumulates in the bottom of the reservoir. If allowed to accumulate, this sludge (water and oil) would enter the braking system and could cause trouble with valves and other parts. In winter, water in the system may freeze, causing the malfunction of valves or brake chambers. Reservoirs are equipped with drain valves so that any moisture or sludge that may have accumulated can be drained. If you notice sludge when draining your system, have it inspected by a mechanic. To minimize the amount of water collection, all reservoirs must be drained daily. Under extreme conditions, reservoirs may have to be drained more than once a day. To drain the reservoirs always start with the wet reservoir on the tractor. Open the drain valve fully and allow all air pressure to escape, which will also exhaust the moisture collected in the reservoir.

Some reservoirs have more than one compartment and each compartment has its own drain valve, which must be drained individually. Briefly opening the valve just to allow some of the air to escape does not drain the moisture! It is not safe to assume that the wet reservoir, or the presence of an air dryer is reason to neglect the other reservoirs on the power unit, trailers or dollies. They should all be completely drained daily by opening the drain valve fully and allowing all of the air to escape. This should be done during the post–trip inspection at the end of the day. See post–trip Inspection later in this manual for more information.

Some reservoirs may be equipped with automatic reservoir drain valves (spitter valves). These valves will automatically exhaust moisture from the reservoir when required, although they should be checked daily and drained periodically to ensure the mechanism is functioning properly. Any loose or disconnected wires associated with the valve heaters should be repaired immediately.

Reservoir

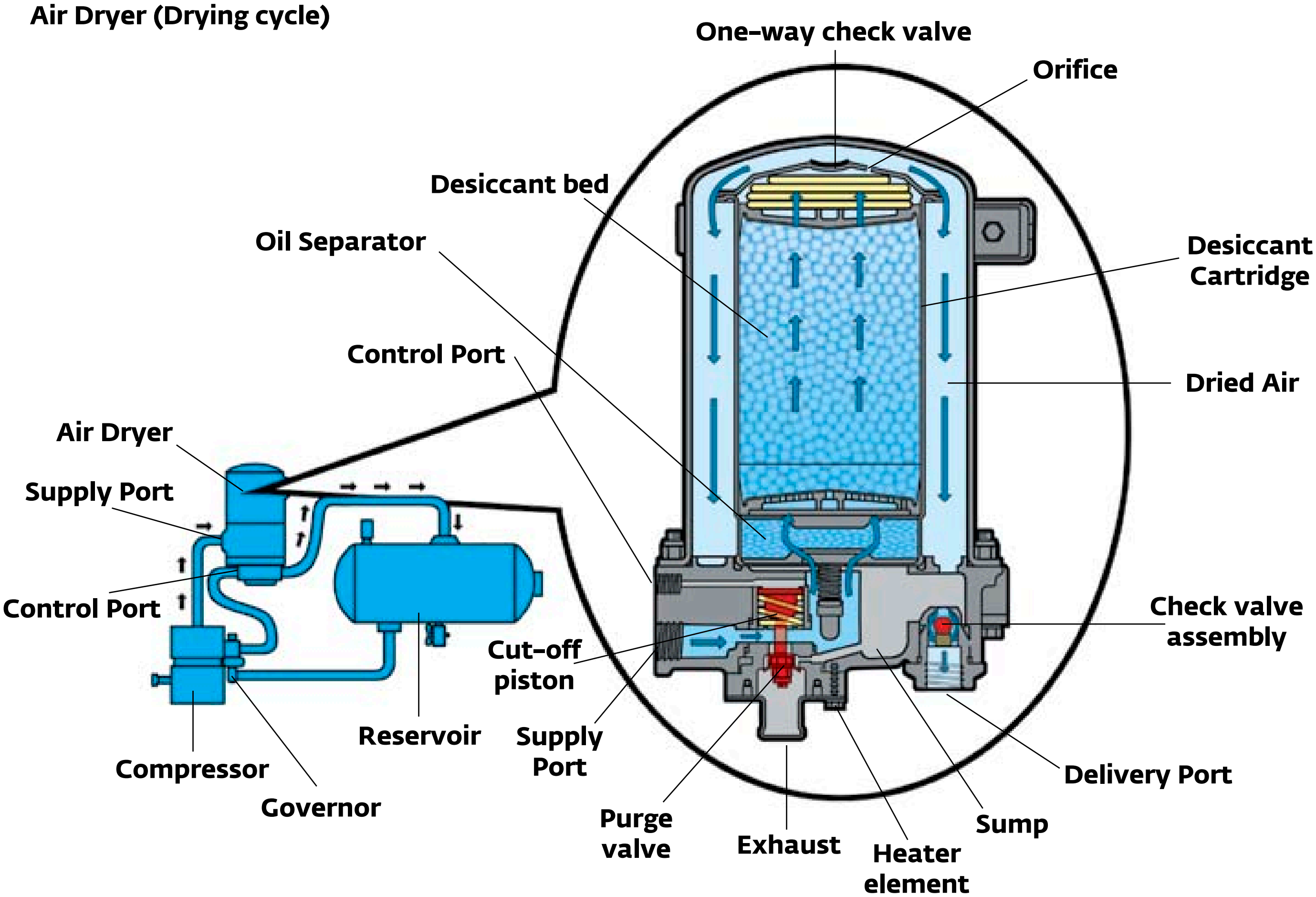
Air Dryer (Purge cycle)



Air Dryer

An air dryer (3) may be installed between the compressor and the wet reservoir to help remove moisture from the compressed air. It may be partially filled with a high moisture–absorbent desiccant and an oil filter, or it may be hollow with baffles designed to assist in separating the moisture from the air. Both types of air dryers use air pressure to purge or eject the accumulated contaminants from their desiccant bed. The purge valve has a heater element, which prevents the moisture from freezing in cold climate operation. The wiring connected to the heater should be inspected for loose or disconnected wires. They are also equipped with a safety valve.

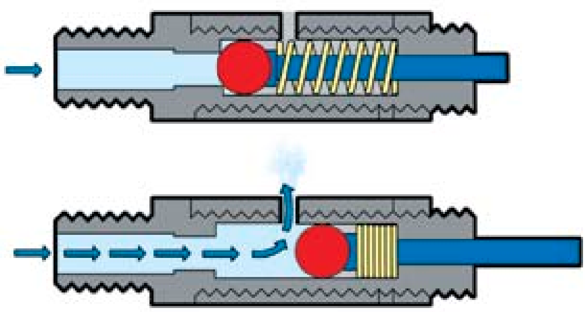
Air Dryer (Drying cycle)



Safety Valve

A safety valve (4) protects reservoirs from becoming over pressurized and bursting if the governor malfunctioned and did not place the compressor in the unloading stage. The valve consists of a spring–loaded ball that will allow air to exhaust from the reservoir into the atmosphere. The valve's pressure setting is determined by the force of the spring. A safety valve is normally set at 150 psi. If the pressure in the system rises to approximately 150 psi, the pressure would force the ball off its seat, allowing the pressure to exhaust through the exhaust port in the spring cage. When reservoir pressure is sufficiently reduced to approximately 135 psi, the spring will force the ball back onto its seat, sealing off the reservoir pressure. Not all safety valves have a manual release feature.

Safety Valve



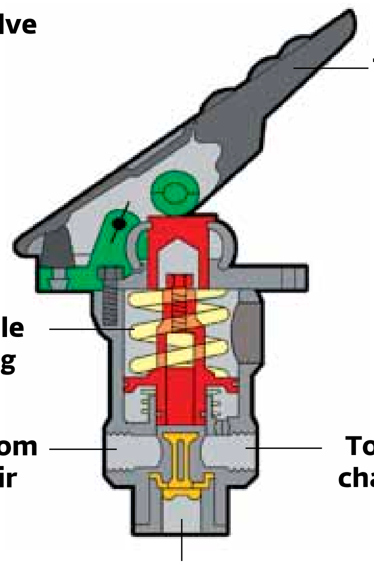
Air pressure greater than 150 psi

If the safety valve has to relieve pressure, the governor or compressor requires adjustment, service or repair. This should be done by a qualified mechanic.

Foot Valve

The foot–operated valve (31) is the means of applying air to operate the brakes. The distance the treadle of the foot valve is depressed by the driver determines the air pressure that will be applied, but the maximum application will not exceed the pressure in the reservoir. Releasing the foot valve treadle releases the brakes.

Foot Valve

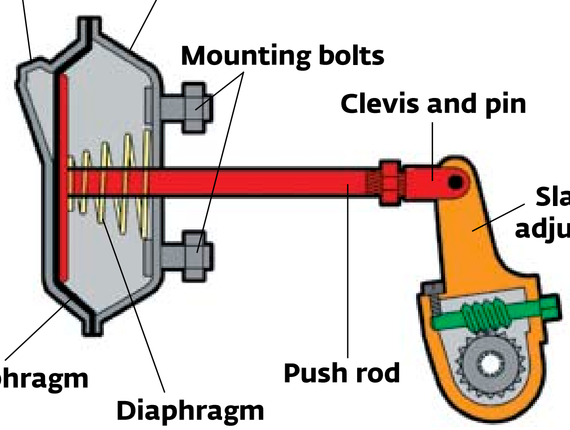


When the driver applies the brakes, depressing the treadle part way, the foot valve will automatically maintain the application air pressure without the driver having to adjust the pressure of his foot on the treadle.

Releasing the treadle allows the application air to be released through the exhaust ports into the atmosphere. Air treadles are spring loaded, producing a different "feel" from hydraulic brake applications.

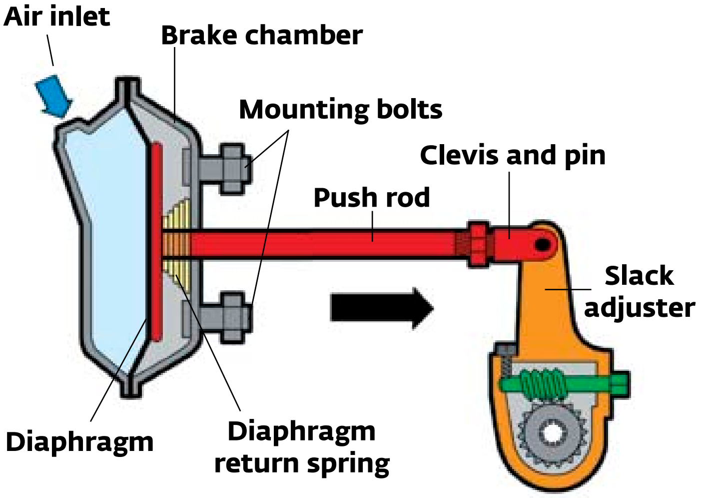
Brake Chambers, Slack Adjusters and Brake Lining

Brake Chamber and Slack Adjuster (Brakes off)



A brake chamber (11) (14) (32) is a circular container divided in the middle by a flexible diaphragm. Air pressure pushing against the diaphragm causes it to move away from the pressure, forcing the push rod outward against the slack adjuster. The force exerted by this motion depends on air pressure and diaphragm size. If a leak occurs in the diaphragm, air is allowed to escape, reducing the effectiveness of the brake chamber. If the diaphragm is completely ruptured, brakes become ineffective.

Brake Chamber and Slack Adjuster (Brakes on)



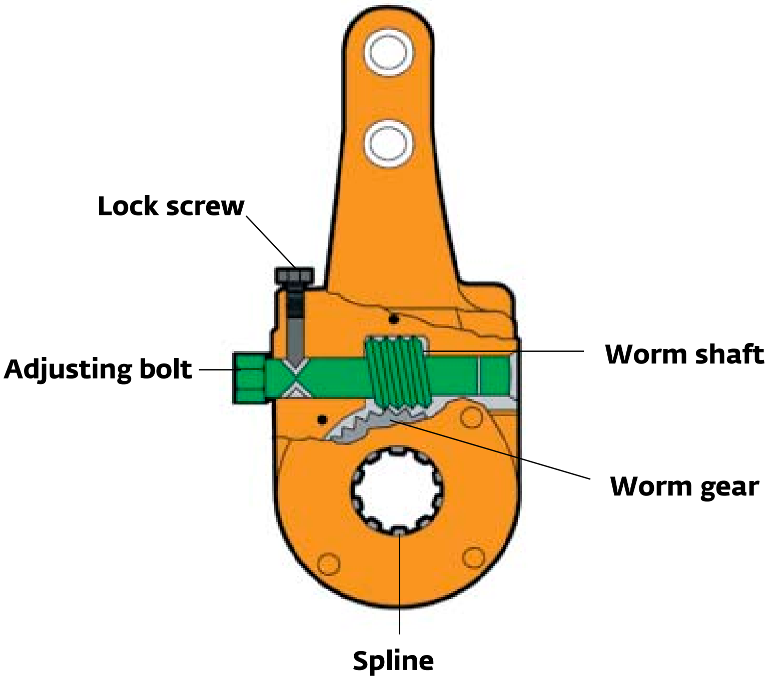
Front brake chambers (32) are usually smaller than those in the rear because front axles carry less weight. A brake chamber is usually mounted on the axle, near the wheel that is to be equipped for braking. Air pressure is fed through an inlet port. The air pushes against the diaphragm and the push rod. The push rod is connected by a clevis and pin to a crank arm–type lever called a "slack adjuster". This converts the pushing motion of the push rod from the brake chamber to a twisting motion of the brake camshaft and S–cams. When the air is exhausted, the return spring in the brake chamber returns the diaphragm and push rod to the released position.

As indicated by its name, the slack adjuster adjusts the "slack" or free play in the linkage between the push rod and the brake shoes. This slack occurs as the brake linings wear. If the slack adjusters are not adjusted within the limitations, effective braking is reduced and brake lag time is increased. If too much slack develops, the diaphragm will eventually "bottom" in the brake chamber, and the brakes will not be effective.

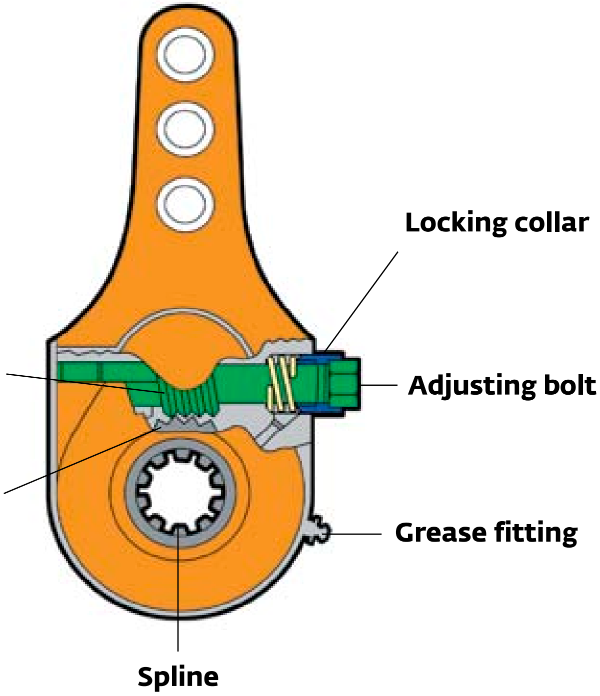
Illustrated below are two common types of manual slack adjusters, showing the worm adjusting gear.

Manual Slack Adjusters

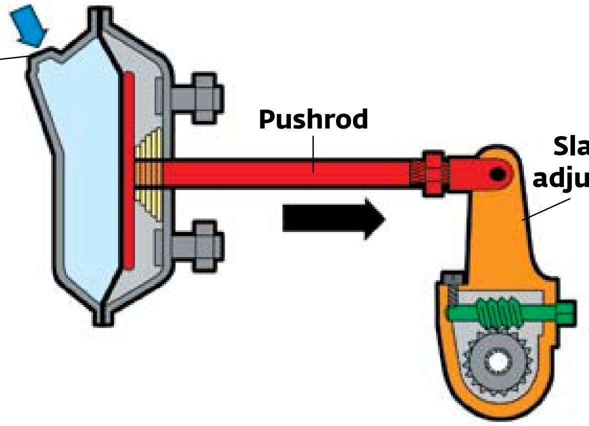
Ball Indent Slack Adjuster



Positive Lock Slack Adjuster



Brake Chamber and Slack Adjuster (Brakes on)



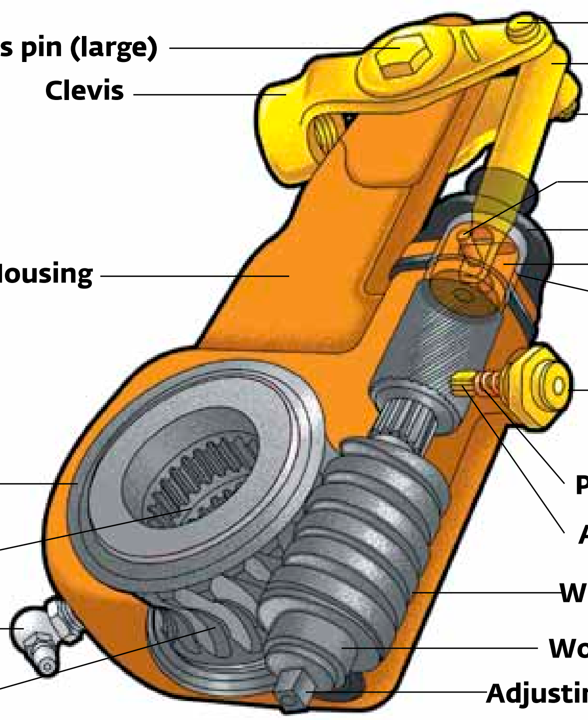
On manual slack adjusters, the adjusting worm bolt is turned until the brake linings touch the drums and then backed off, normally ¼ to ½ a turn. A locking device, which may be a spring loaded collar over the head of the adjusting bolt, must be depressed when the wrench is slipped over the bolt head. This is known as a positive lock slack adjuster.

Or they could use a spring–loaded internal check ball to lock the adjustment, and it must be removed to make any adjustment. This is known as a ball indent slack adjuster. The more often the driver checks the "slack", the less the probability of brake failure. Vehicles rarely "lose" their brakes because of air loss; it is usually because they are out of adjustment.

It is the driver's responsibility to ensure that brakes are adjusted correctly. A simple service brake application at low speed to check brake adjustment is not adequate. Braking at highway speed causes brake drum expansion due to heat, which in turn requires greater push rod travel to maintain the same braking force. If a brake is out of adjustment there would not be enough reserve stroke of the push rod travel to compensate for drum expansion. This would cause a brake fade and would greatly extend stopping distance. If travelling down a hill, this could cause complete brake loss.

Note: Detailed brake adjustment procedures are outlined in Section 8.

Automatic Slack Adjuster

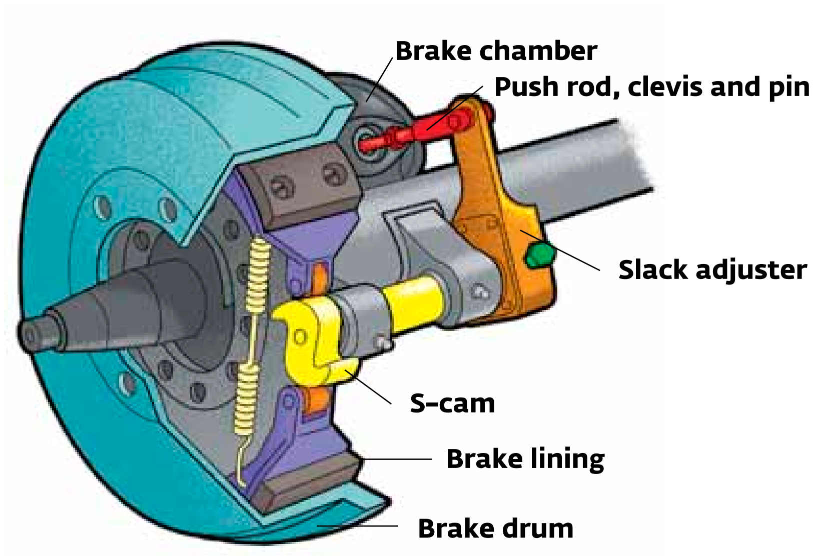


Some systems have automatic slack adjusters that adjust automatically to compensate for brake lining wear, usually maintaining the correct clearance between the brake lining and drum. Automatic slack adjusters must be checked regularly to ensure that correct adjustment is being maintained. There are various makes and models of automatic slack adjusters in use. Primarily, they are either stroke–sensing or clearance–sensing. A stroke–sensing adjuster will adjust the slack when it senses the set stroke is exceeded. A clearance–sensing adjuster will adjust when the proper clearance between the brake drum and brake shoe is not maintained. Some automatic slack adjusters have the ability to back–off or increase the slack when it has over adjusted the brake. If a vehicle is equipped with automatic slack adjusters, it should not be taken for granted that the brakes will always be in adjustment. The system is not foolproof. A number of factors could result in the automatic slack adjuster not maintaining proper slack. There could be improper installation, inadequate maintenance, deformed brackets, worn cam bushings, bent push rods. Even poor visual inspection can result in problems unrelated to adjuster function. When conducting a pre–trip or post–trip air brake inspection, look for worn or damaged components. Automatic slack adjusters can malfunction and not keep the brake in adjustment, especially when it has been in service for a long period of time. The two most common problems are excessive premature wear and internal contamination. As an automatic slack adjuster ages in service, the components wear that sense when an adjustment is required. The result is more stroke is required for the lining to contact the brake drum, and if not checked the brake could be out of adjustment. If even a small amount of water is sucked into an automatic slack adjuster mechanism it can cause corrosion or, in winter, it can freeze the internal sensing components and inhibit or prevent adjustment. Also, under certain conditions, an automatic slack adjuster that does not have the ability to back–off or increase slack, may over adjust a brake causing it to drag. For example this could take place when a tractor–trailer is negotiating a long, curving downgrade. The driver should "snub" the brakes, which is repeatedly applying the brakes moderately to maintain safe control of the vehicle. However it would not take long in this severe braking condition for one or more of the brake drums to over heat and expand. The over heating will physically increase the brake drums diameter, and in extreme and prolonged conditions will lead to longer push–rod strokes to achieve the braking force required. The automatic slack adjuster interprets this as a need for adjustment and will take up slack. When the brake drum cools down and returns to normal size the brakes are over adjusted and dragging. At that time the driver should stop and check the brakes for adjustment. A number of full brake applications above 90 psi per day are required to keep the automatic slack adjusters in adjustment (see Section 8 for more information).

Because automatic slack adjusters are not foolproof, it is important the operator of a vehicle equipped with automatic slack adjusters be able to manually adjust them. For information on manually adjusting the automatic slack adjusters on your vehicle consult the manufacturer.

Illustrated is a common type of brake assembly used on truck rear axles and trailer axles. A front axle assembly has the brake chamber and slack adjuster mounted on the backing–plate because of the steering action.

Brake Assembly



Brake lining material is attached to the shoes. The material used depends on the braking requirements of the vehicle. Brake lining must give uniform output of brake effort with minimum fade at high temperatures.

Fading or reduction in braking effort occurs when the heated drums expand away from the brake linings. The brake linings also lose their effectiveness with overheating.

The twisting action of the brake cam shaft and S–cam forces the brake shoes and linings against the drums. The brake linings generate heat from friction with the brake drum surface.

The thickness of the drums determines the amount of heat they are able to absorb and dissipate into the atmosphere. Drums worn thin will build up heat too quickly. Dangerously undependable brake performance will result from distorted drums, weak return springs, improper lining, poor adjustment, or grease or dirt on the lining. Drums must never be machined or worn beyond the manufacturer's specification.

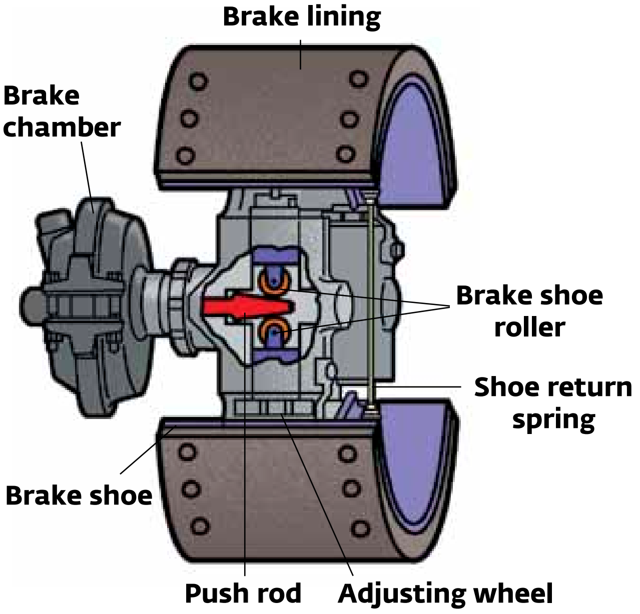
Wedge Brakes

This is another example of a brake assembly used on some air brake–equipped vehicles. The action of the brake chamber push rod forces a wedge–shaped push rod between the brake shoe rollers. This forces the brake shoe lining against the brake drum.

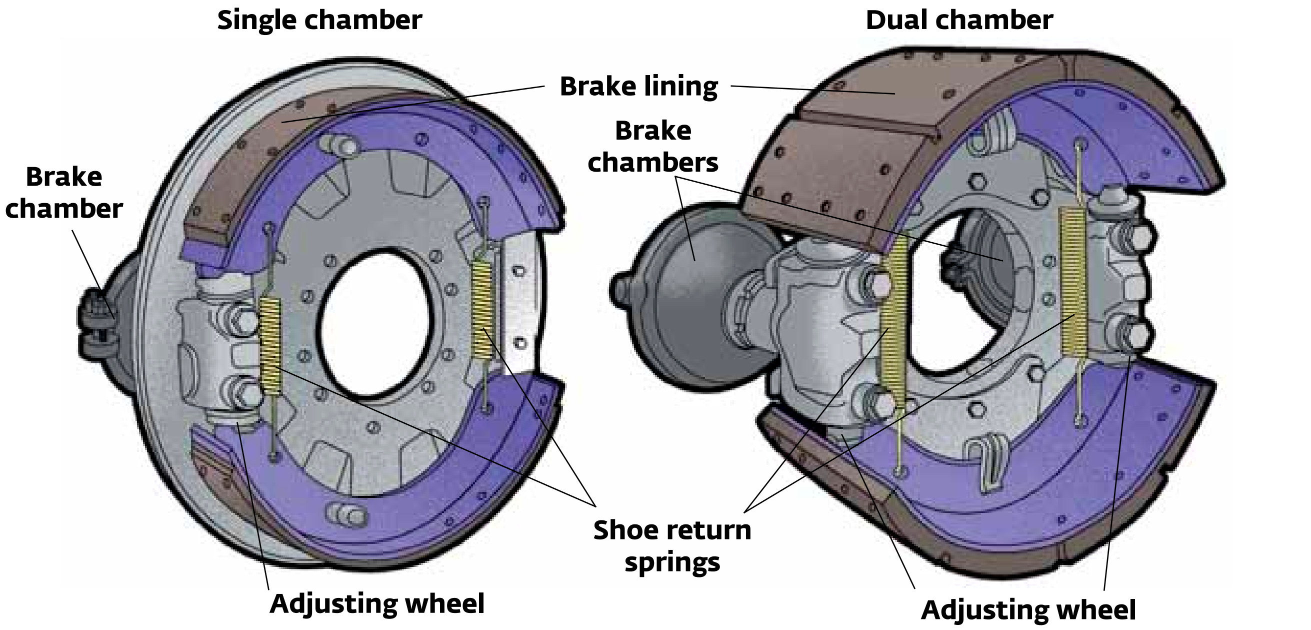
The vehicle may be equipped with a single or dual chambers on each wheel, depending on the vehicle's size and style.

These brakes may be equipped with a self–adjusting mechanism or with a manual "star wheel" adjuster. The star wheel adjustment is made with the vehicle jacked up, to insure that the brake linings do not drag. Manual adjustment of wedge brakes is usually done by a qualified mechanic.

Wedge Brake – Single Chamber



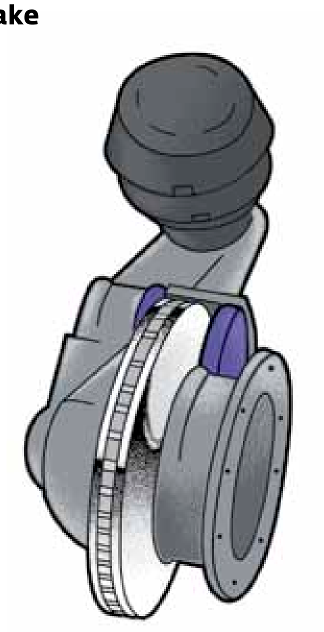
Wedge Brakes



Disc Brakes

The air–activated heavy truck disc brake is similar in principle to that used on passenger vehicles. Air pressure acts on a brake chamber and slack adjuster, activating the brakes. Instead of the cam or wedge used in conventional heavy truck drum brakes, a "power screw" is used. A power screw works like a C–clamp, so that the lining pads exert equal force to both sides of the disc or rotor. Some types of disc brakes have a built–in automatic adjuster. Disc brakes that require manual adjustment have adjustment specifications that differ from conventional S–cam braking systems. Always check the manufacturer's specifications before adjusting. Disc brake assemblies may have a spring parking brake unit attached to the service brake chamber.

Disc Brake



Air–Over–Hydraulic Brake Systems

Air–over–hydraulic brake systems were developed for medium weight vehicles because:

- diesel engines do not have a source for vacuum boosting unless they are equipped with a vacuum pump.
- medium weight vehicles do not require a full air brake system.
- it gives the option of pulling an air brake equipped trailer.

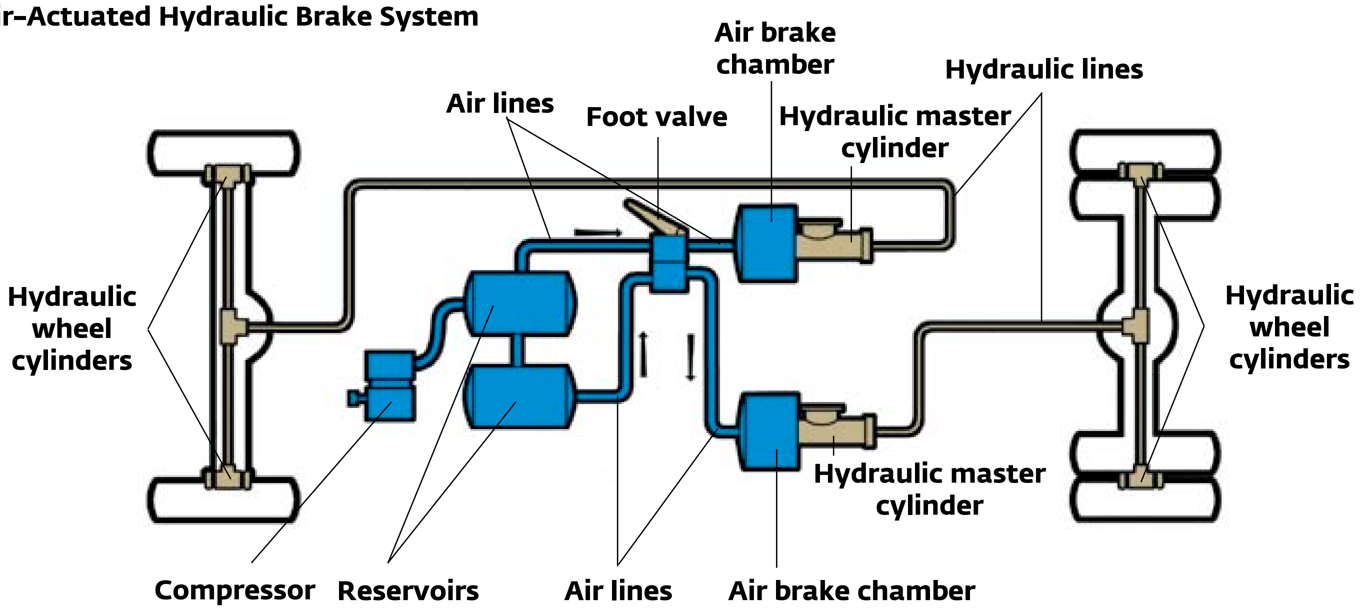
These systems combine the best features of an air and hydraulic brake system. They use hydraulic brakes at each wheel with their reliable self adjusters and limited maintenance. On these systems the air is used to either actuate the hydraulic brakes or boost the hydraulic brake pressure as explained in the following.

Air–Actuated Hydraulic Brake System

(Air Brake Endorsement Required)

An air–actuated system usually has the same components of a standard air supply system including a warning buzzer and light, compressor, governor, wet and dry reservoirs, and a foot valve that could be a single or dual type. These components are found usually in the same places as on a full air brake system. Also there are one or two air actuated hydraulic pressure converters depending on if the system is a single or a dual system. This system consists of an air chamber or cylinder attached to a hydraulic master cylinder. When the foot valve is depressed, the air pressure actuates the pushrod from the air unit that pushes against the master cylinder piston, producing hydraulic pressure directed through tubing to the wheel cylinders actuating the front and rear axle service brakes.

Air–Actuated Hydraulic Brake System



It is essential that the operator of such a vehicle have knowledge of air pressure build up time, governor loading and unloading pressure, warning device operation, and how to drain air reservoirs properly (see Section Nine; Pre–Trip Air Brake Inspection).

If an air–actuated hydraulic brake system was to lose its air supply, the vehicle would have no service brakes. Only the parking brake would be operating as it is mechanical and requires no air pressure to operate.

Each vehicle manufacturer may have different parking brake applications, either automatically when air pressure is reduced in the reservoir, or mechanically by a brake on the rear of the transmission, or with the rear brake system. Since hydraulic brake systems actuated by air pressure are regarded as an air brake system, your driver's licence must have an air brake endorsement for you to operate vehicles equipped with air–activated hydraulic brakes.

As there are many different systems in use, refer to the operator's manual.

Air–Boost Hydraulic Brake System

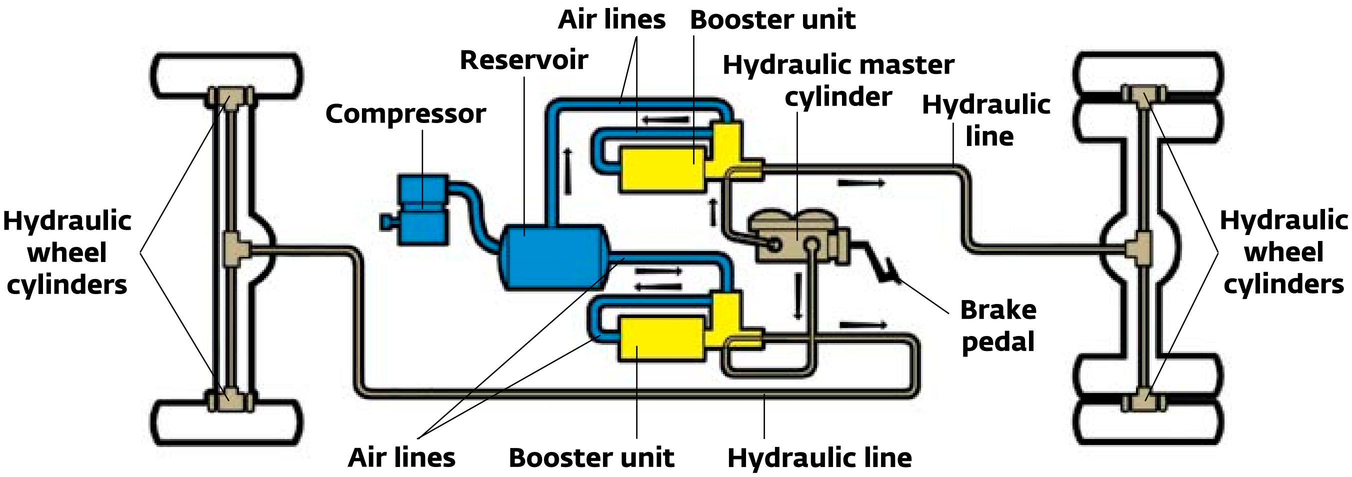
(Air Brake Endorsement not Required)

An air–boost hydraulic brake system uses air pressure to assist brake force. This is similar to vacuum–assisted brakes on most passenger vehicles. An air–boost system usually has the same components of a standard air supply system including a compressor, governor, wet and dry reservoirs. These components are found usually in the same places as on a full air brake system.
The brake pedal linkage operates a hydraulic master cylinder that sends hydraulic pressure to the booster unit. Initially, at low pressure the hydraulic fluid passes through the booster and begins to pressurize the wheel cylinders moving the brake shoes out to the drums. These booster units are similar in operation to "Hypower" or "Hydrovac" vacuum boosters found on most light and medium weight vehicles, but air pressure is used to intensify the hydraulic pressure generated by the master cylinder rather than vacuum. Built into the booster unit is a hydraulically operated air control valve.

This is where air from the reservoir is directed. As the pressure from the master cylinder increases, the air control section in the booster will open and begin to deliver air pressure to the rear of the air cylinder. The air cylinder pushrod transfers pressure on a piston in the hydraulic section of the booster, increasing the hydraulic pressure at the wheel cylinders.

The driver has full control of the braking force as the air control section modulates the boost pressure in proportion to the master cylinder pressure. If the vehicle was to lose all of the air pressure the brake system would lose the air assist boost, however the hydraulic system would continue to work but at reduced effectiveness. An air brake endorsement on a driver's licence is not required to operate a vehicle with this brake system. Consult the operator's manual for the vehicle you drive for maintenance requirements.

Air-Boost Hydraulic Brake System



Section Summary Questions

1. What are the five basic components of an air brake system?
2. At what pressure should the governor cause the compressor to return to its "loading" stage?
3. At what pressure will the governor place the compressor in the "unloading" stage?
4. How is a plugged air filter likely to affect the air compressor?
5. What causes moisture to form in the air brake system?
6. When is the compressor able to accomplish most of its cooling?
7. How are most compressors lubricated?
8. How often should the reservoirs be drained?
9. Is it necessary to allow all the pressure to escape from the reservoir in order to remove the moisture and sludge which may have accumulated?
10. What is the maximum pressure available for a full brake application at any given time?
11. What will result if the brake drums are worn thin or turned too far?
12. If the governor valve failed to "unload" the compressor, what would protect the reservoirs from becoming over pressurized and bursting?
13. What is the purpose of having more than one reservoir?
14. What are two functions of the slack adjusters?
15. Does the amount of slack in the brake linkages have any effect on the braking efficiency of the vehicle?
16. What is the advantage of keeping the brake chamber push rod travel adjusted within limitations?
17. What is the most common cause of loss of effective braking in an air brake system?
18. Do automatic slack adjusters on S–cam brakes require checking?
19. Can the adjustment on air–operated disc brakes differ from S–cam brakes?
20. What occurs when drum brakes become overheated?
21. What causes brake fade?
22. What is the main function of the foot valve?
23. Why does the "feel" of an air–operated foot valve differ from a hydraulic brake pedal?
24. On what principle does a disc brake operate?
25. What type of air–over–hydraulic brake system requires the operator to hold an air brake endorsement?