Figure 13-72. *Bruising is caused by fine particle contamination possibly from a bad seal or improper maintenance of bearing cleanliness. It leaves a less than smooth surface on the bearing cup.*

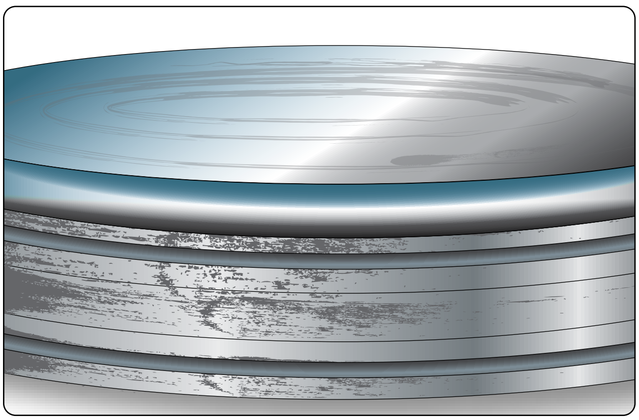

Figure 13-73. *Bearing cups should be tight in the wheel boss and should never rotate. The outside of a bearing cup that was spinning while installed in the wheel is shown.*

primer before insertion. Consult the wheel manufacturer's maintenance manual for specific instructions.

Bearing Handling & Lubrication

Handling of bearings is of the utmost importance. Contamination, moisture, and vibration, even while the bearing is in a static state, can ruin a bearing. Avoid conditions where these may affect bearings and be sure to install and torque bearings into place according manufacturer's instructions.

Proper lubrication is a partial deterrent to negative environmental impacts on a bearing. Use the lubricant recommended by the manufacturer. Use of a pressure bearing packing tool or adapter is also recommended as the best method to remove any contaminants from inside the bearing that may have remained after cleaning. *[Figure 13-74]*

Inspection of the Wheel Halves

A thorough visual inspection of each wheel half should be conducted for discrepancies specified in the wheel

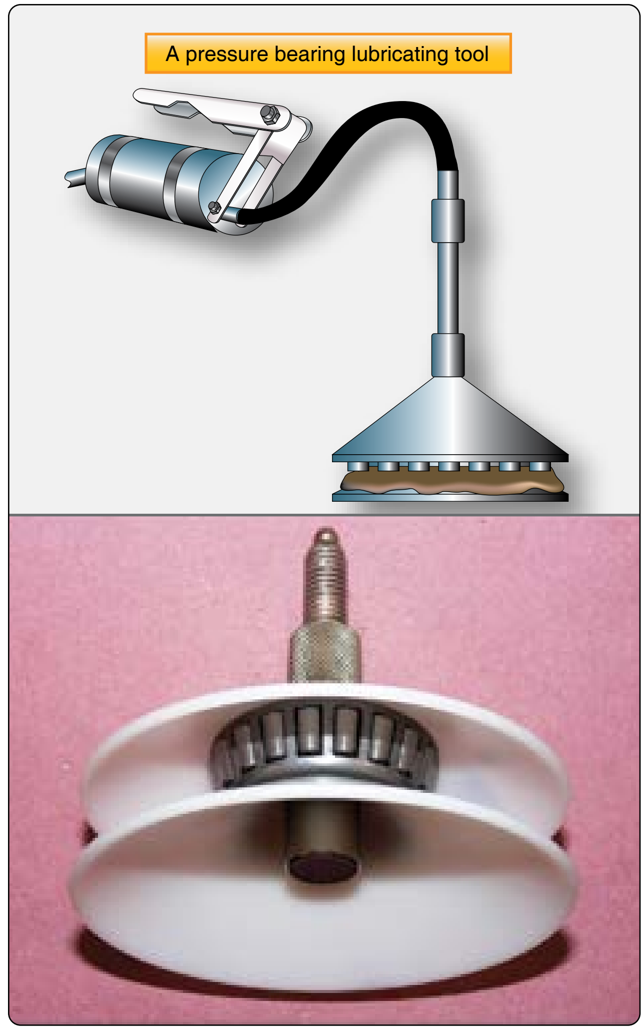

Figure 13-74. *A pressure bearing lubricating tool.*

manufacturer's maintenance data. Use of a magnifying glass is recommended. Corrosion is one of the most common problems encountered while inspecting wheels. Locations where moisture is trapped should be checked closely. It is possible to dress out some corrosion according to the manufacturer's instructions. An approved protective surface treatment and finish must be applied before returning the wheel to service. Corrosion beyond stated limits is cause for rejection of the wheel.

In addition to corrosion, cracks in certain areas of the wheel are particularly prevalent. One such area is the bead seat area. *[Figure 13-75]* The high stress of landing is transferred to the wheel by the tire in this contact area. Hard landings produce distortion or cracks that are very difficult to detect. This is a concern on all wheels and is most problematic in high-pressure, forged wheels. Dye penetrant inspection is generally ineffective when checking for cracks in the bead area. There is a tendency for cracks to close up tightly once the tire is dismounted, and the stress is removed from the metal. Eddy

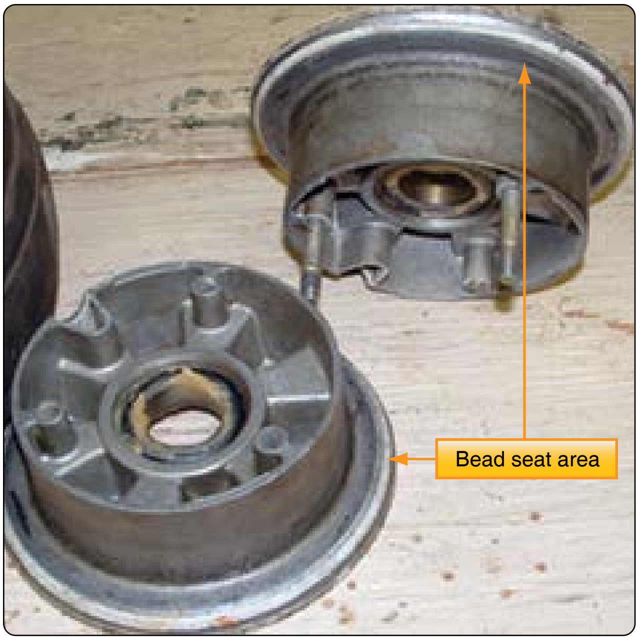

Figure 13-75. *The bead seat areas of a light aircraft wheel set. Eddy current testing for cracks in the bead seat area is common.*

current inspection of the bead seat area is required. Follow the wheel manufacturer's instruction when performing the eddy current check.

The wheel brake disc drive key area is another area in which cracks are common. The forces experienced when the keys drive the disc against the stopping force of the brakes are high. Generally, a dye penetrant test is sufficient to reveal cracks in this area. All drive keys should be secure with no movement possible. No corrosion is permitted in this area. *[Figure 13-76]*

Wheel Tie Bolt Inspection

Wheel half tie bolts are under great stress while in service and require inspection. The tie bolts stretch and change dimension usually at the threads and under the bolt head. These are areas where cracks are most common. Magnetic particle inspection can reveal these cracks. Follow the maintenance manual procedures for inspecting tie bolts.

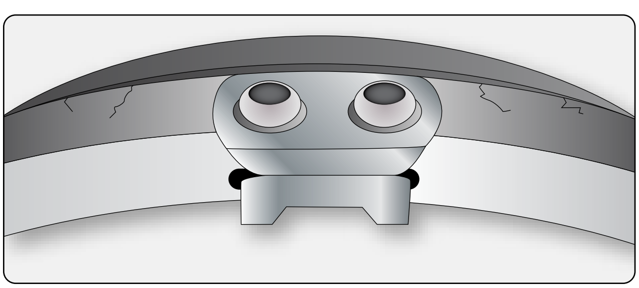

Figure 13-76. *Inspection for cracks in the wheel disc drive key area is performed with dye penetrant on many wheels.*

Key & Key Screw Inspection

On most aircraft inner wheel halves, keys are screwed or bolted to the wheel to drive the brake disc(s). The drive keys are subject to extreme forces when the brakes are applied. As mentioned, there should be no movement between the wheel and the keys. The bolts should be checked for security, and the area around the keys should be inspected for cracks. There is also a limitation on how worn the keys can be since too much wear allows excessive movement. The wheel manufacturer's maintenance instructions should be used to perform a complete inspection of this critical area.

Fusible Plug Inspection

Fusible plugs or thermal plugs must be inspected visually. These threaded plugs have a core that melts at a lower temperature than the outer part of the plug. This is to release air from the tire should the temperature rise to a dangerous level. A close inspection should reveal whether any core has experienced deformation that might be due to high temperature. If detected, all thermal plugs in the wheel should be replaced with new plugs. *[Figure 13-77]*

Balance Weights

The balance of an aircraft wheel assembly is important. When manufactured, each wheel set is statically balanced. Weights are added to accomplish this if needed. They are a permanent part of the wheel assembly and must be installed to use the wheel. The balance weights are bolted to the wheel halves and can be removed when cleaning and inspecting the wheel. They must be re-fastened in their original position. When a tire is mounted to a wheel, balancing of the wheel and tire assembly may require that additional weights be added. These are usually installed around the circumference of the outside of the wheel and should not be taken as substitutes for the factory wheel set balance weights. *[Figure 13-78]*

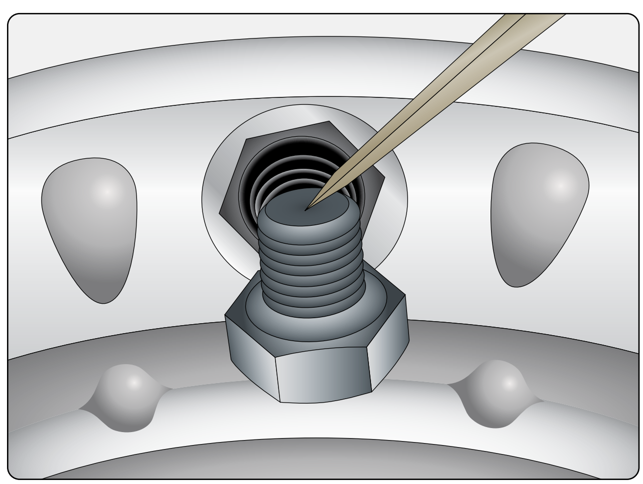

Figure 13-77. *Visually inspect the core of a thermal or fusible plug for deformation associated with heat exposure. Replace all of the plugs if any appear to have begun to deform.*

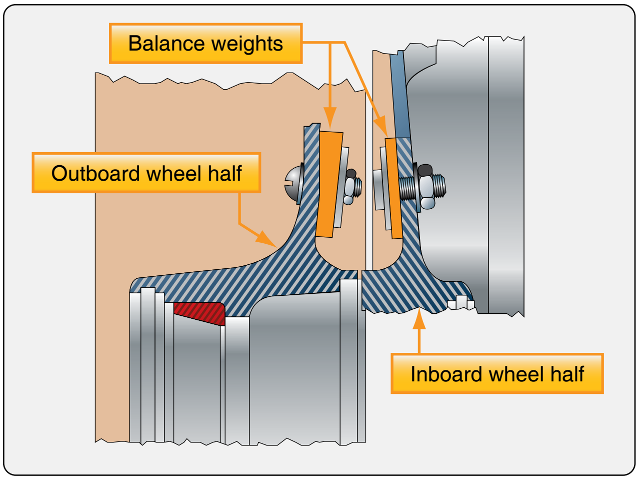

Figure 13-78. *Two piece aircraft wheels are statically balanced when manufactured and may include weights attached to each wheel half that must stay with the wheel during its entire serviceable life.*

Aircraft Brakes

Very early aircraft have no brake system to slow and stop the aircraft while it is on the ground. Instead, they rely on slow speeds, soft airfield surfaces, and the friction developed by the tail skid to reduce speed during ground operation. Brake systems designed for aircraft became common after World War I as the speed and complexity of aircraft increased, and the use of smooth, paved runway surfaces proliferated. All modern aircraft are equipped with brakes. Their proper functioning is relied upon for safe operation of the aircraft on the ground. The brakes slow the aircraft and stop it in a reasonable amount of time. They hold the aircraft stationary during engine run-up and, in many cases, steer the aircraft during taxi. On most aircraft, each of the main wheels is equipped with a brake unit. The nose wheel or tail wheel does not have a brake.

In the typical brake system, mechanical and/or hydraulic linkages to the rudder pedals allow the pilot to control the brakes. Pushing on the top of the right rudder pedal activates the brake on the right main wheel(s) and pushing on the top of the left rudder pedal operates the brake on the left main wheel(s). The basic operation of brakes involves converting the kinetic energy of motion into heat energy through the creation of friction. A great amount of heat is developed and forces on the brake system components are demanding. Proper adjustment, inspection, and maintenance of the brakes is essential for effective operation.

Types & Construction of Aircraft Brakes

Modern aircraft typically use disc brakes. The disc rotates with the turning wheel assembly while a stationary caliper resists the rotation by causing friction against the disc when the brakes are applied. The size, weight, and landing speed of the aircraft influence the design and complexity of the disc brake system. Single, dual, and multiple disc brakes are common types of brakes. Segmented rotor brakes are used on large aircraft. Expander tube brakes are found on older large aircraft. The use of carbon discs is increasing in the modern aviation fleet.

Single Disc Brakes

Small, light aircraft typically achieve effective braking using a single disc keyed or bolted to each wheel. As the wheel turns, so does the disc. Braking is accomplished by applying friction to both sides of the disc from a non-rotating caliper bolted to the landing gear axle flange. Pistons in the caliper housing under hydraulic pressure force wearable brake pads or linings against the disc when the brakes are applied. Hydraulic master cylinders connected to the rudder pedals supply the pressure when the upper halves of the rudder pedals are pressed.

Floating Disc Brakes

A floating disc brake is illustrated in *Figure 13-79*. A more detailed, exploded view of this type of brake is shown in *Figure 13-80*. The caliper straddles the disc. It has three cylinders bored through the housing, but on other brakes this number may vary. Each cylinder accepts an actuating piston assembly comprised mainly of a piston, a return spring, and an automatic adjusting pin. Each brake assembly has six brake linings or pucks. Three are located on the ends of the pistons, which are in the outboard side of the caliper. They are designed to move in and out with the pistons and apply pressure to the outboard side of the disc. Three more linings are located opposite of these pucks on the inboard side of the caliper. These linings are stationary.

The brake disc is keyed to the wheel. It is free to move laterally in the key slots. This is known as a floating disc. When the brakes are applied, the pistons move out from the outboard cylinders and their pucks contact the disc. The disc

Figure 13-79. *A single disc brake is a floating-disc, fixed caliper brake.*

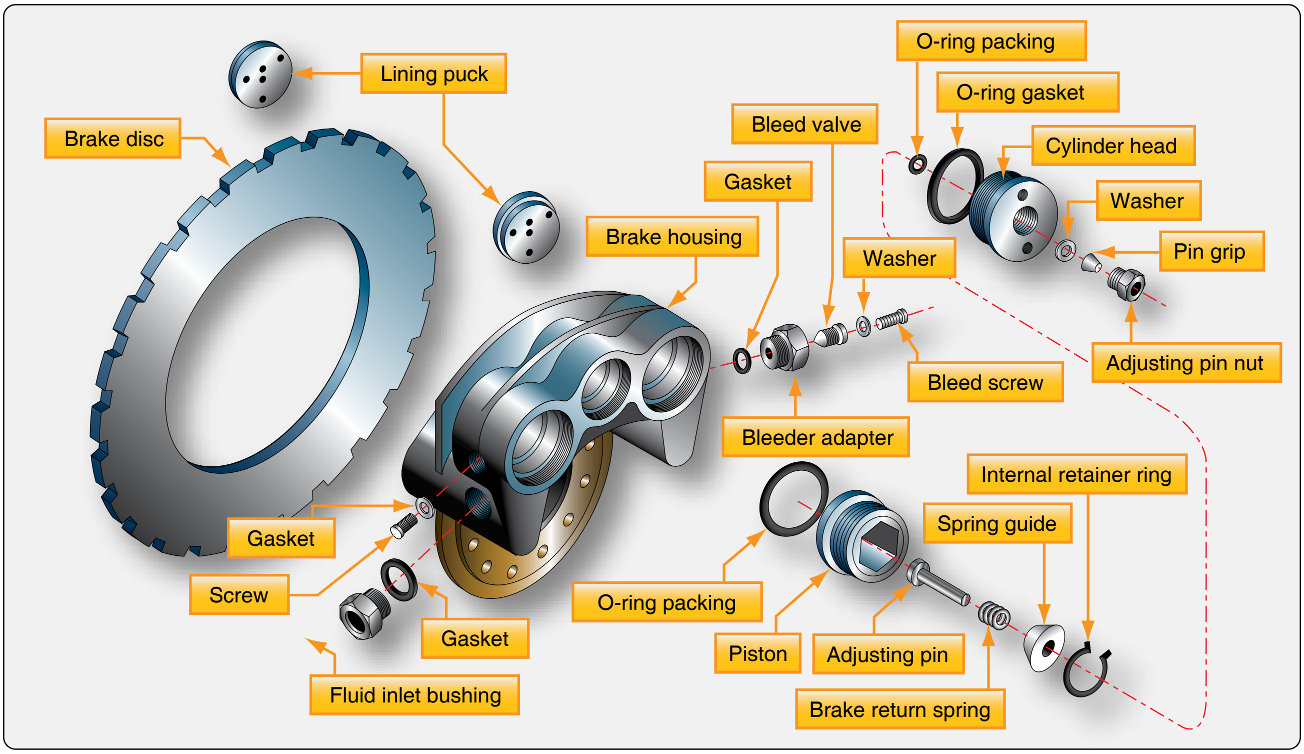

Figure 13-80. *An exploded view of a single-disc brake assembly found on a light aircraft.*

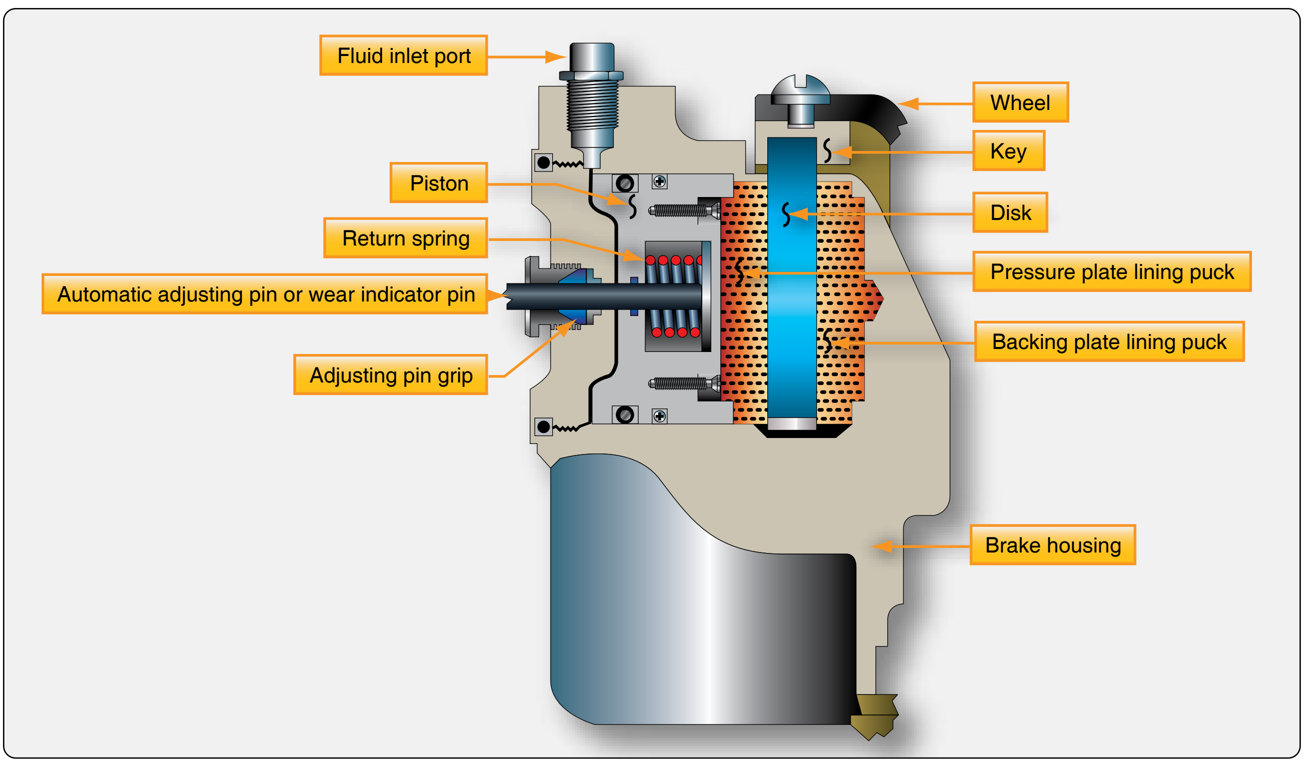

Figure 13-81. *A cross-sectional view of a Goodyear single-disc brake caliper illustrates the adjusting pin assembly that doubles as a wear indicator.*

slides slightly in the key slots until the inboard stationary pucks also contact the disc. The result is a fairly even amount of friction applied to each side of the disc and thus, the rotating motion is slowed.

When brake pressure is released, the return spring in each piston assembly forces the piston back away from the disc. The spring provides a preset clearance between each puck and the disc. The self-adjusting feature of the brake maintains the same clearance, regardless of the amount of wear on the brake pucks. The adjusting pin on the back of each piston moves with the piston through a frictional pin grip. When brake pressure is relieved, the force of the return spring is sufficient to move the piston back away from the brake disc, but not enough to move the adjusting pin held by the friction of the pin grip. The piston stops when it contacts the head of the adjusting pin. Thus, regardless of the amount of wear, the same travel of the piston is required to apply the brake. The stem of the pin protruding through the cylinder head serves as a wear indicator. The manufacturer's maintenance information states the minimum length of the pin that needs to be protruding for the brakes to be considered airworthy. *[Figure 13-81]*

The brake caliper has the necessary passages machined into it to facilitate hydraulic fluid movement and the application of pressure when the brakes are utilized. The caliper housing also contains a bleed port used by the technician to remove unwanted air from the system. Brake bleeding, as it is known, should be done in accordance with the manufacturer's maintenance instructions.

Fixed-Disc Brakes

Even pressure must be applied to both sides of the brake disc to generate the required friction and obtain consistent wear properties from the brake linings. The floating disc accomplishes this as described above. It can also be accomplished by bolting the disc rigidly to the wheel and allowing the brake caliper and linings to float laterally when pressure is applied. This is the design of a common fixed-disc brake used on light aircraft. The brake is manufactured by the Cleveland Brake Company and is shown in *Figure 13-82*. An exploded detail view of the same type of brake is shown in *Figure 13-83*.

The fixed-disc, floating-caliper design allows the brake caliper and linings to adjust position in relationship to the disc. Linings are riveted to the pressure plate and backplate. Two anchor bolts that pass through the pressure plate are secured to the cylinder assembly. The other ends of the bolts are free to slide in and out of bushings in the torque plate, which is bolted to the axle flange. The cylinder assembly is bolted to the backplate to secure the assembly around the disc. When pressure is applied, the caliper and linings center on the disc via the sliding action of the anchor bolts in the torque plate bushings. This provides equal pressure to both sides of the disc to slow its rotation.

A unique feature of the Cleveland brake is that the linings can be replaced without removing the wheel. Unbolting the cylinder assembly from the backplate allows the anchor bolts to slide out of the torque plate bushings. The entire caliper assembly is then free and provides access to all of the components.

Maintenance requirements on all single disc brake systems are similar to those on brake systems of any type. Regular inspection for any damage and for wear on the linings and discs is required. Replacement of parts worn beyond limits is always followed by an operational check. The check is performed while taxiing the aircraft. The braking action for each main wheel should be equal with equal application of pedal pressure. Pedals should be firm, not soft or spongy,

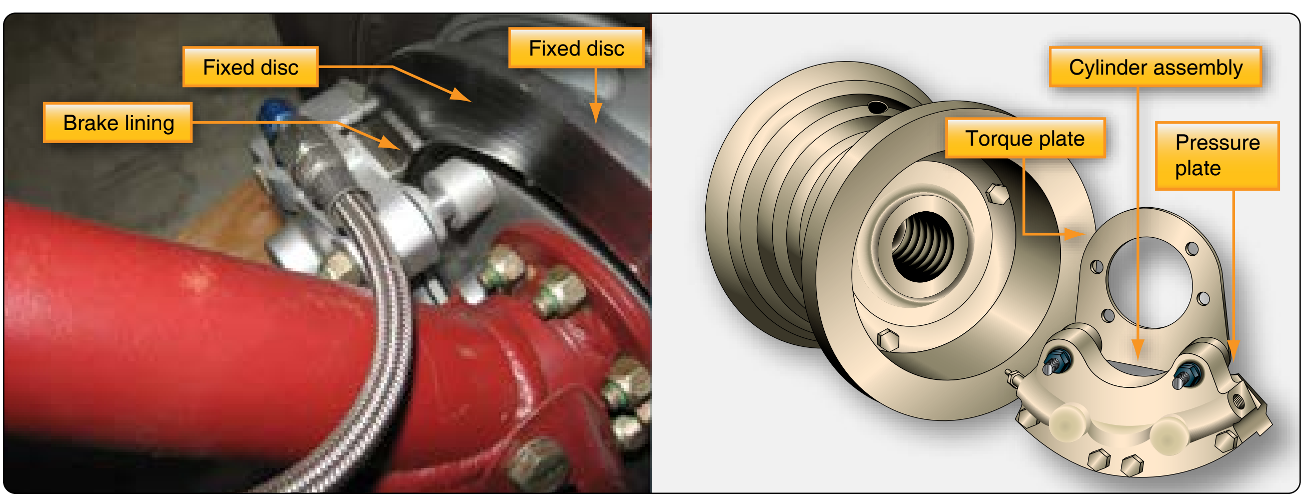

Figure 13-82. *A Cleveland brake on a light aircraft is a fixed-disc brake. It allows the brake caliper to move laterally on anchor bolts to deliver even pressure to each side of the brake disc.*

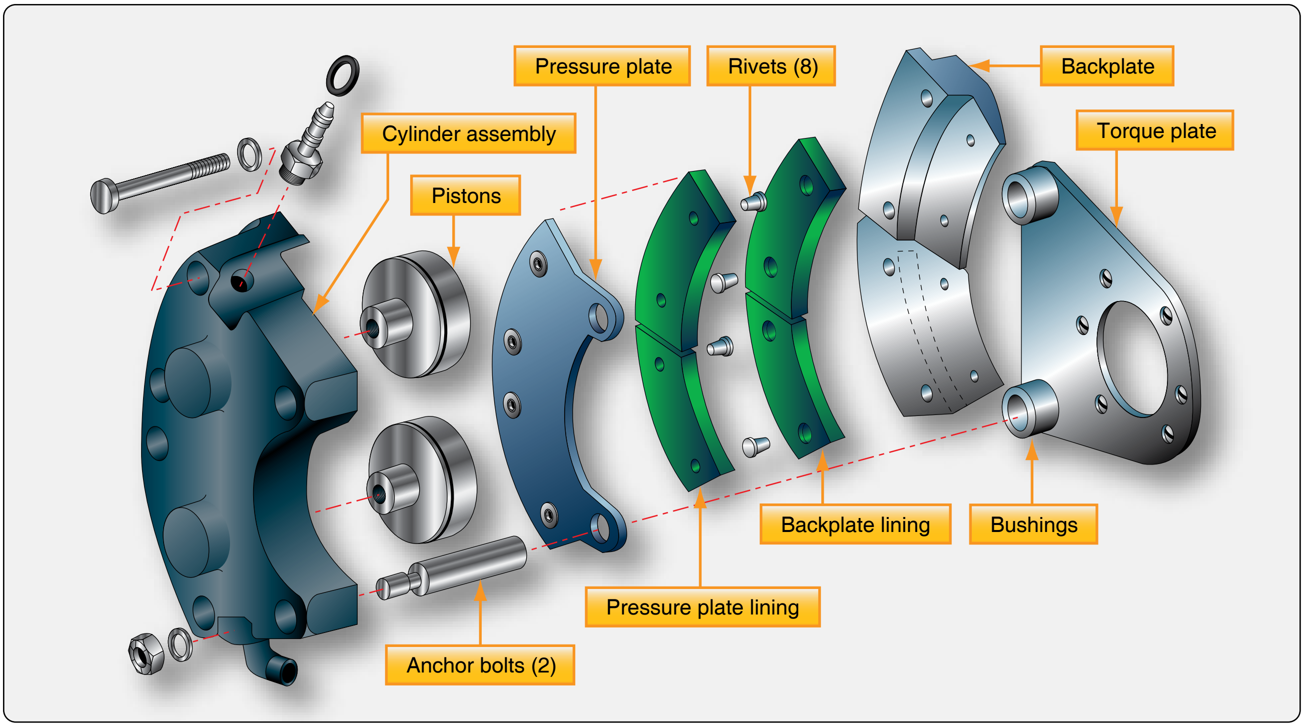

Figure 13-83. *An exploded view of a dual-piston Cleveland brake assembly.*

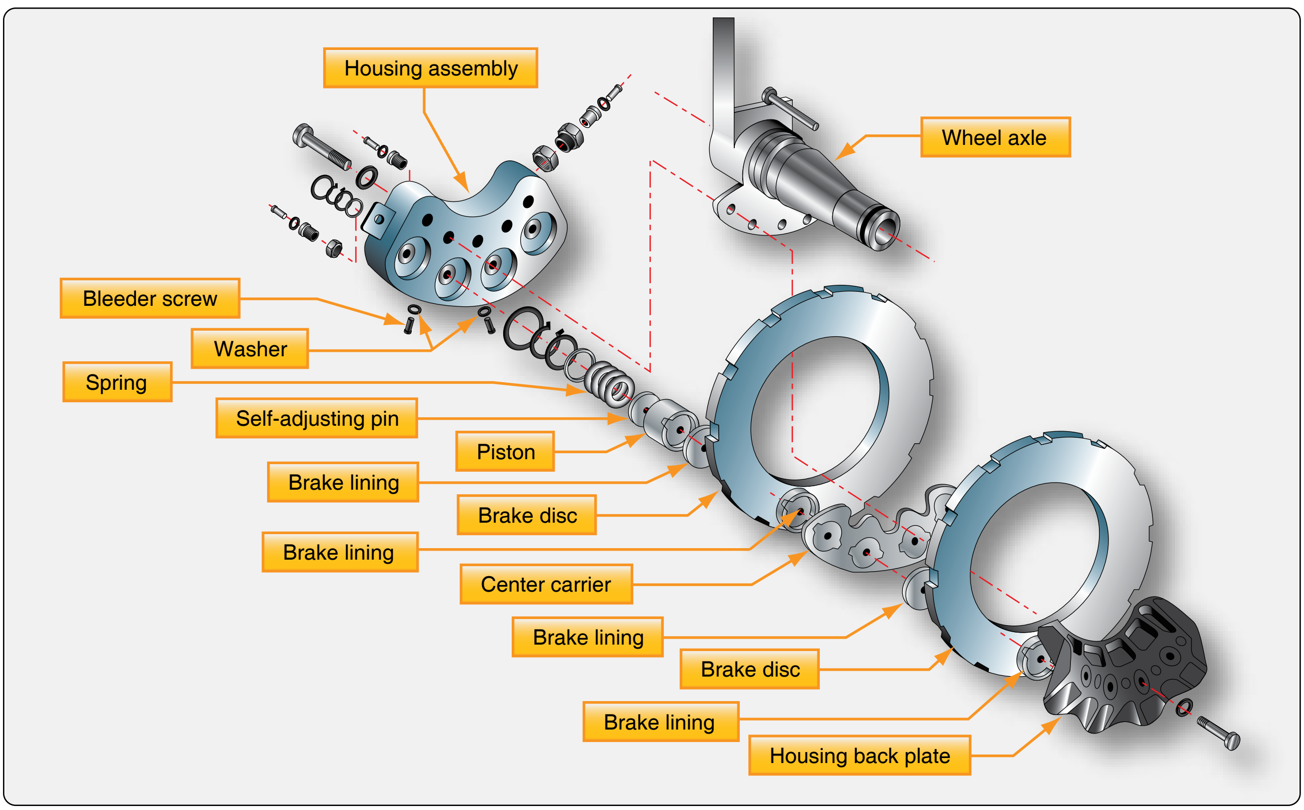

Figure 13-84. *A dual-disc brake is similar to a single-disc brake. It uses a center carrier to hold brake linings against each of the discs.*

when applied. When pedal pressure is released, the brakes should release without any evidence of drag.

Dual-Disc Brakes

Dual-disc brakes are used on aircraft where a single disc on each wheel does not supply sufficient braking friction. Two discs are keyed to the wheel instead of one. A center carrier is located between the two discs. It contains linings on each side that contact each of the discs when the brakes are applied. The caliper mounting bolts are long and mount through the center carrier, as well as the backplate which bolts to the housing assembly. *[Figure 13-84]*

Multiple-Disc Brakes

Large, heavy aircraft require the use of multiple-disc brakes. Multiple-disc brakes are heavy duty brakes designed for use with power brake control valves or power boost master cylinders, which is discussed later in this chapter. The brake assembly consists of an extended bearing carrier similar to a torque tube type unit that bolts to the axle flange. It supports the various brake parts, including an annular cylinder and piston, a series of steel discs alternating with copper or bronze-plated discs, a backplate, and a backplate retainer. The steel stators are keyed to the bearing carrier, and the copper or bronze plated rotors are keyed to the rotating wheel. Hydraulic pressure applied to the piston causes the entire stack of stators and rotors to be compressed. This creates enormous friction and heat and slows the rotation of the wheel. *[Figure 13-85]*

As with the single and dual-disc brakes, retracting springs return the piston into the housing chamber of the bearing carrier when hydraulic pressure is relieved. The hydraulic fluid exits the brake to the return line through an automatic adjuster. The adjuster traps a predetermined amount of fluid in the brakes that is just sufficient to provide the correct clearances between the rotors and stators. *[Figure 13-86]* Brake wear is typically measured with a wear gauge that is not part of the brake assembly. These types of brake are typically found on older transport category aircraft. The rotors and stators are relatively thin, only about ⅛-inch thick. They do not dissipate heat very well and have a tendency to warp.

Segmented Rotor-Disc Brakes

The large amount of heat generated while slowing the rotation of the wheels on large and high-performance aircraft is problematic. To better dissipate this heat, segmented rotor-disc brakes have been developed. Segmented rotor-disc brakes are multiple-disc brakes but of more modern design than the type discussed earlier. There are many variations. Most feature numerous elements that aid in the control

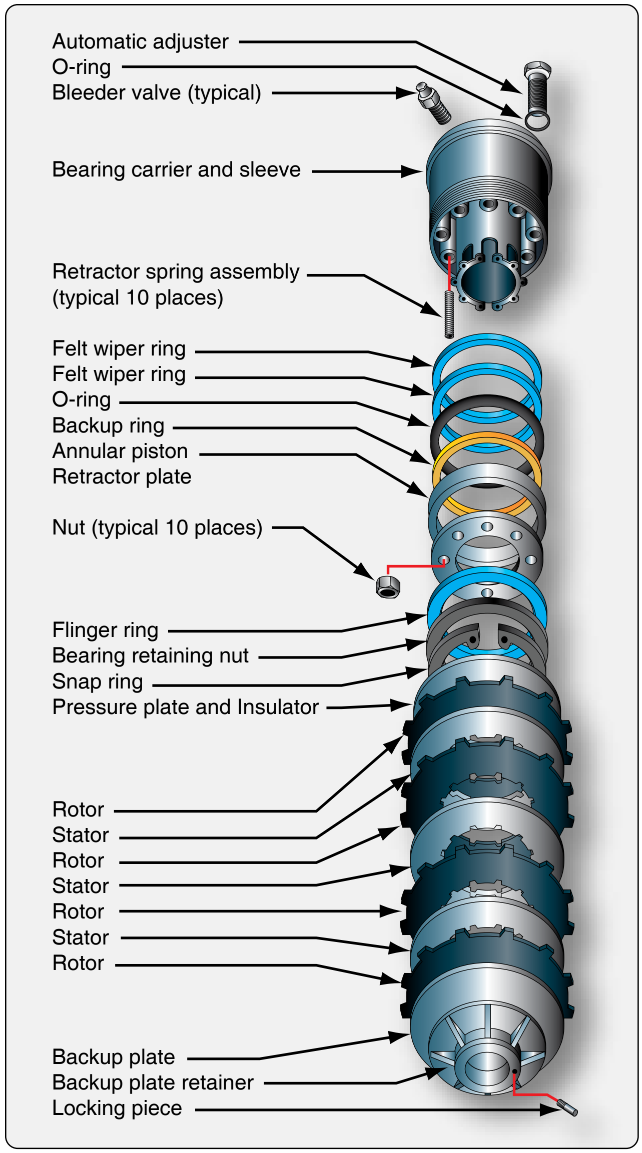

Figure 13-85. *A multiple disc brake with bearing carrier upon which the parts of the brake are assembled including an annular cylinder and piston assembly that apply pressure evenly to a stack of rotors and stators.*

and dissipation of heat. Segmented rotor-disc brakes are heavy-duty brakes especially adapted for use with the high pressure hydraulic systems of power brake systems. Braking is accomplished by means of several sets of stationary, high friction type brake linings that make contact with rotating segments. The rotors are constructed with slots or in sections with space between them, which helps dissipate heat and give the brake its name. Segmented rotor multiple-disc brakes are the standard brake used on high performance and air carrier aircraft. An exploded view of one type of segmented rotor brake assembly is shown in *Figure 13-87*.

The description of a segmented rotor brake is very similar to the multiple-disc type brake previously described. The brake

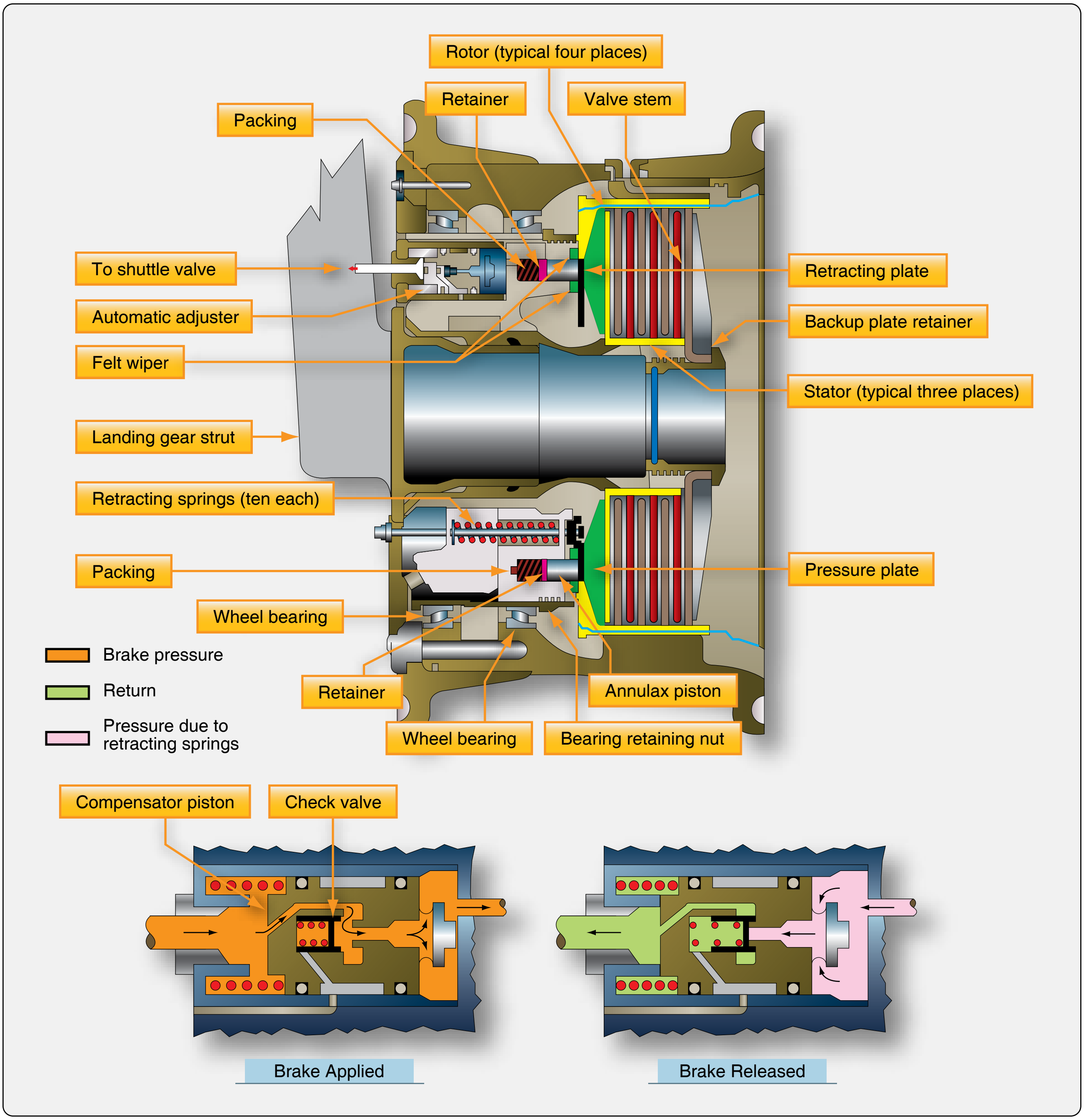

Figure 13-86. *A multiple-disc brake with details of the automatic adjuster.*

assembly consists of a carrier, a piston and piston cup seal, a pressure plate, an auxiliary stator plate, rotor segments, stator plates, automatic adjusters, and a backing plate.

The carrier assembly, or brake housing with torque tube, is the basic unit of the segmented rotor brake. It is the part that attaches to the landing gear shock strut flange upon which the other components of the brake are assembled. On some brakes, two grooves or cylinders are machined into the carrier to receive the piston cups and pistons. *[Figure 13-87]* Most segmented rotor-disc brakes have numerous individual cylinders machined into the brake housing into which fit the same number of actuating pistons. Often, these cylinders are supplied by two different hydraulic sources, alternating every other cylinder from a single source. If one source fails, the brake still operates sufficiently on the other. *[Figure 13-88]* External fittings in the carrier or brake housing admit the hydraulic fluid. A bleed port can also be found.

A pressure plate is a flat, circular, high-strength steel, non-rotating plate notched on the inside circumference to fit over the stator drive sleeves or torque tube spines. The brake

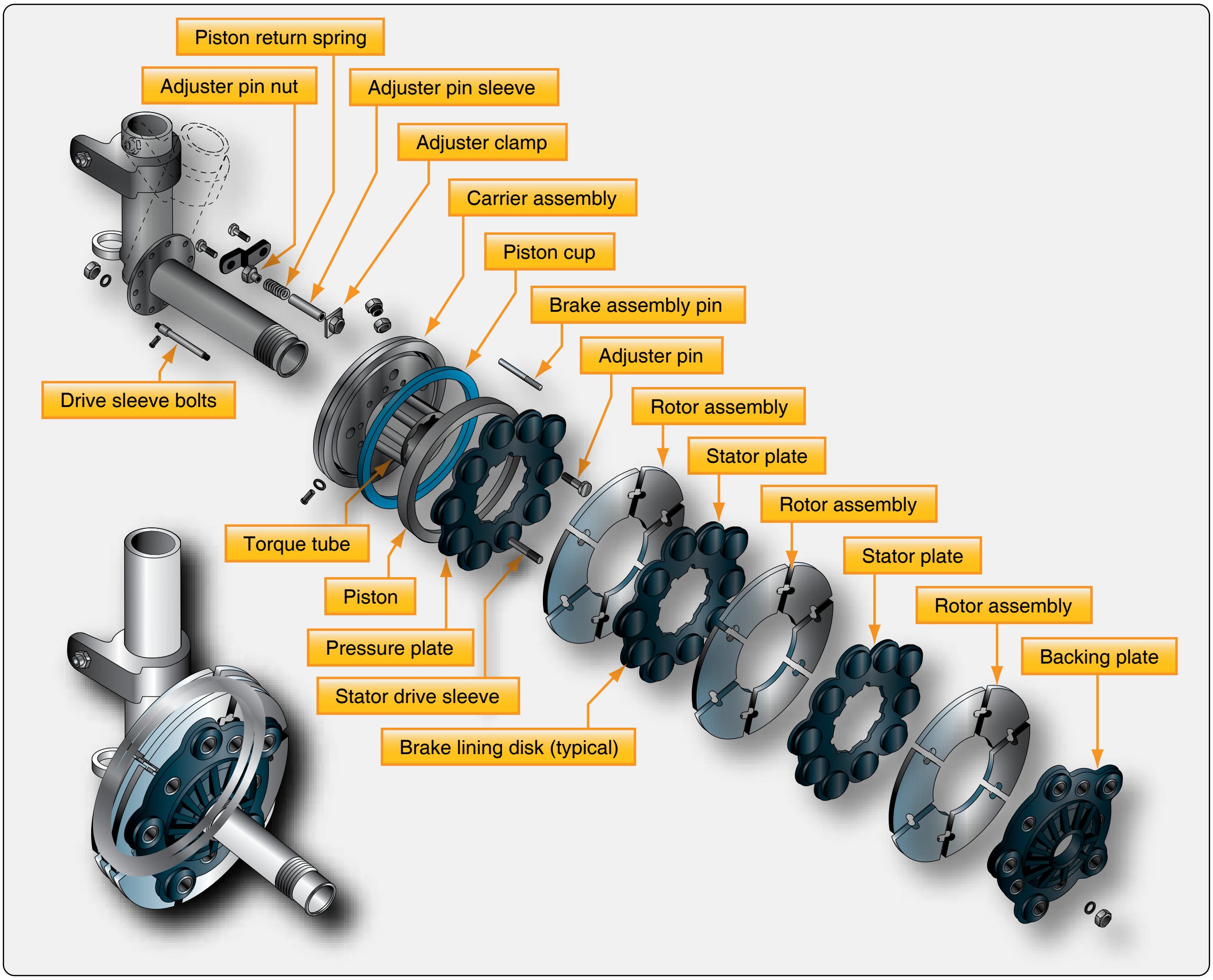

Figure 13-87. *Exploded and detail views of segmented rotor brakes.*

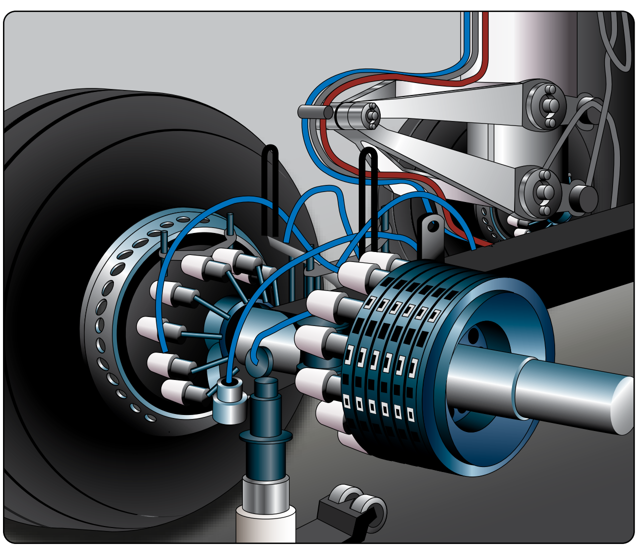

Figure 13-88. *Many modern segmented rotor disc brakes use a housing machined to fit numerous individual actuating pistons.*

actuating pistons contact the pressure plate. Typically, an insulator is used between the piston head and the pressure plate to impede heat conduction from the brake discs. The pressure plate transfers the motion of the pistons to the stack of rotors and stators that compress to slow the rotation of the wheels. On most designs, brake lining material attached directly to the pressure plate contacts the first rotor in the stack to transfer the motion of the piston(s). *[Figure 13-87]* An auxiliary stator plate with brake lining material on the side opposite the pressure plate can also be used.

Any number of alternating rotors and stators are sandwiched under hydraulic pressure against the backing plate of the brake assembly when the brakes are applied. The backing plate is a heavy steel plate bolted to the housing or torque tube at a fixed dimension from the carrier housing. In most cases, it has brake lining material attached to it and contacts the last rotor in the stack. *[Figure 13-87]*

Stators are flat plates notched on the internal circumference to be held stationary by the torque tube spines. They have wearable brake lining material riveted or adhered to each side to make contact with adjacent rotors. The liner is typically constructed of numerous isolated blocks. *[Figure 13-87]* The space between the liner blocks aids in the dissipation of heat. The composition of the lining materials vary. Steel is often used.

Rotors are slit or segmented discs that have notches or tangs in the external circumference that key to the rotating wheel. Slots or spaces between sections of the rotor create segments that allow heat to dissipate faster than it would if the rotor was solid. They also allow for expansion and prevent warping. *[Figure 13-87]* Rotors are usually steel to which a frictional surface is bonded to both sides. Typically, sintered metal is used in creating the rotor contact surface.

Segmented multiple-disc brakes use retraction spring assemblies with auto clearance adjusters to pull the backplate away from the rotor and stator stack when brake pressure is removed. This provides clearance so the wheel can turn unimpeded by contact friction between the brake parts but keeps the units in close proximity for rapid contact and braking when the brakes are applied. The number of retraction devices varies with brake design. *Figure 13-89* illustrates a brake assembly used on a Boeing 737 transport category aircraft. In the cutaway view, the number and locations of the auto adjustment retraction mechanisms can be seen. Details of the mechanisms are also shown.

Instead of using a pin grip assembly for auto adjustment, an adjuster pin, ball, and tube operate in the same manner. They move out when brake pressure is applied, but the ball in the tube limits the amount of the return to that equal to the brake lining wear. Two independent wear indicators are used on the brake illustrated. An indicator pin attached to the backplate protrudes through the carrier. The amount that it protrudes with the brakes applied is measured to ascertain if new linings are required.

Note: Other segmented multiple-disc brakes may use slightly different techniques for pressure plate retraction and wear indication. Consult the manufacturer's maintenance information to ensure wear indicators are read correctly.

Carbon Brakes

The segmented multiple-disc brake has given many years of reliable service to the aviation industry. It has evolved through time in an effort to make it lightweight and to dissipate the frictional heat of braking in a quick, safe manner. The latest iteration of the multiple-disc brake is the carbon-disc brake. It is currently found on high performance and air carrier aircraft. Carbon brakes are so named because carbon fiber materials are used to construct the brake rotors. *[Figure 13-90]*

Carbon brakes are approximately forty percent lighter than conventional brakes. On a large transport category aircraft, this alone can save several hundred pounds in aircraft weight. The carbon fiber discs are noticeably thicker than sintered steel rotors but are extremely light. They are able to withstand temperatures fifty percent higher than steel component brakes. The maximum designed operating temperature is limited by the ability of adjacent components to withstand the high temperature. Carbon brakes have been shown to withstand two to three times the heat of a steel brake in non-aircraft applications. Carbon rotors also dissipate heat faster than steel rotors. A carbon rotor maintains its strength and dimensions at high temperatures. Moreover, carbon brakes last twenty to fifty percent longer than steel brakes, which results in reduced maintenance.

The only impediment to carbon brakes being used on all aircraft is the high cost of manufacturing. The price is expected to lower as technology improves and greater numbers of aircraft operators enter the market.

Expander Tube Brakes

An expander tube brake is a different approach to braking that is used on aircraft of all sizes produced in the 1930s–1950s. It is a lightweight, low pressure brake bolted to the axle flange that fits inside an iron brake drum. A flat, fabric-reinforced neoprene tube is fitted around the circumference of a wheel-like torque flange. The exposed flat surface of the expander tube is lined with brake blocks similar to brake lining material. Two flat frames bolt to the sides of the torque flange. Tabs on the frames contain the tube and allow evenly spaced torque bars to be bolted in place across the tube between each brake block. These prevent circumferential movement of the tube on the flange. *[Figure 13-91]*

The expander tube is fitted with a metal nozzle on the inner surface. Hydraulic fluid under pressure is directed through this fitting into the inside of the tube when the brakes are applied. The tube expands outward, and the brake blocks make contact with the wheel drum causing friction that slows the wheel. As hydraulic pressure is increased, greater friction develops. Semi-elliptical springs located under the torque bars return the expander tube to a flat position around the flange when hydraulic pressure is removed. The clearance between the expander tube and the brake drum is adjustable by rotating an adjuster on some expander tube brakes. Consult the manufacturer's maintenance manual for the correct clearance setting. *Figure 13-92* gives an exploded view of an expander tube brake, detailing its components.

Expander tube brakes work well but have some drawbacks.

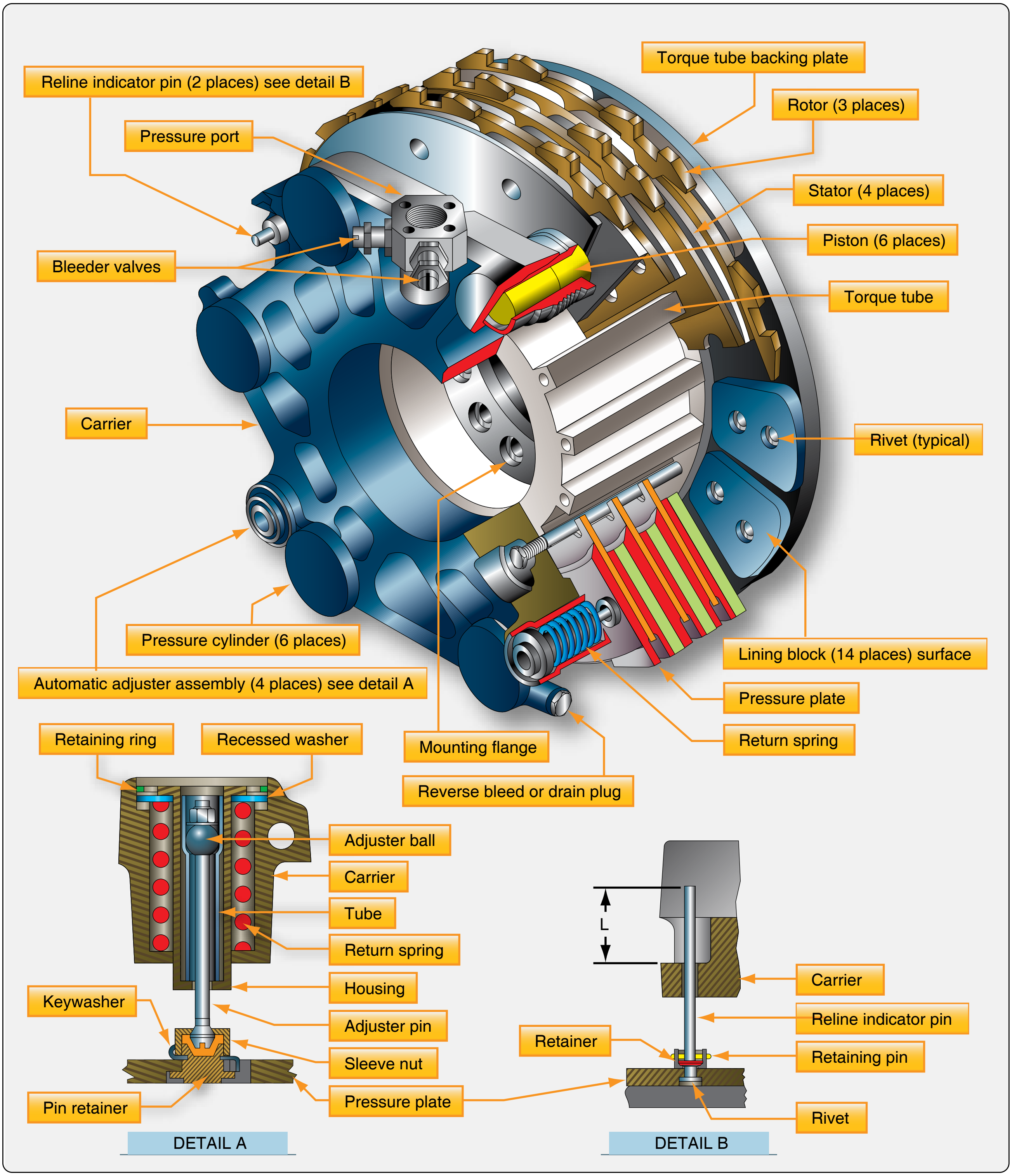

Figure 13-89. *The multiple-disc brake assembly and details from a Boeing 737.*

They tend to take a setback when cold. They also have a tendency to swell with temperature and leak. They may drag inside the drum if this occurs. Eventually, expander brakes were abandoned in favor of disc brake systems.

Brake Actuating Systems

The various brake assemblies, described in the previous section, all use hydraulic power to operate. Different means of delivering the required hydraulic fluid pressure to brake assemblies are discussed in this section. There are three basic actuating systems:

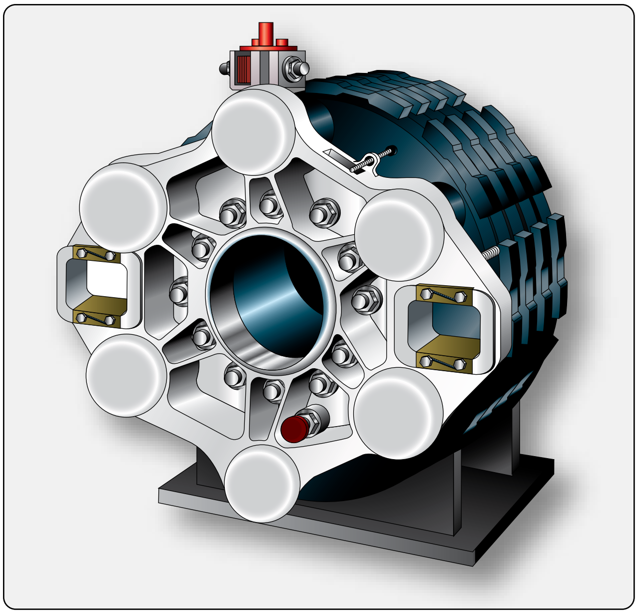

Figure 13-90. *A carbon brake for a Boeing 737.*

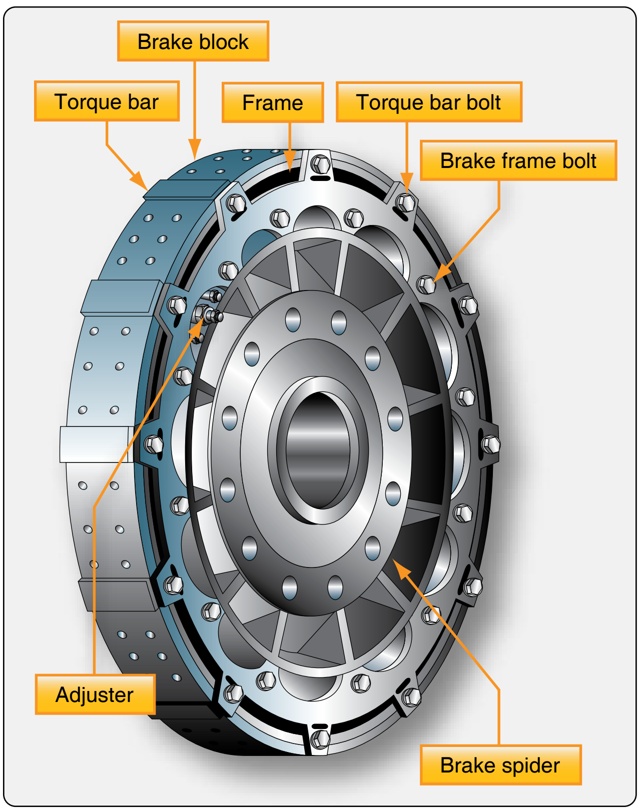

Figure 13-91. *An expander tube brake assembly.*

1. An independent system not part of the aircraft main hydraulic system;
2. A booster system that uses the aircraft hydraulic system intermittently when needed; and
3. A power brake system that only uses the aircraft main. hydraulic system(s) as a source of pressure.

Systems on different aircraft vary, but the general operation is similar to those described.

Independent Master Cylinders

In general, small, light aircraft and aircraft without hydraulic systems use independent braking systems. An independent brake system is not connected in any way to the aircraft hydraulic system. Master cylinders are used to develop the necessary hydraulic pressure to operate the brakes. This is similar to the brake system of an automobile.

In most brake actuating systems, the pilot pushes on the tops of the rudder pedals to apply the brakes. A master cylinder for each brake is mechanically connected to the corresponding rudder pedal (i.e., right main brake to the right rudder pedal, left main brake to the left rudder pedal). *[Figure 13-93]* When the pedal is depressed, a piston inside a sealed fluid-filled chamber in the master cylinder forces hydraulic fluid through a line to the piston(s) in the brake assembly. The brake piston(s) push the brake linings against the brake rotor to create the friction that slows the wheel rotation. Pressure is increased throughout the entire brake systems and against the rotor as the pedal is pushed harder.

Many master cylinders have built-in reservoirs for the brake hydraulic fluid. Others have a single remote reservoir that services both of the aircraft's two master cylinders. *[Figure 13-94]* A few light aircraft with nose wheel steering have only one master cylinder that actuates both main wheel brakes. This is possible because steering the aircraft during taxi does not require differential braking. Regardless of the set-up, it is the master cylinder that builds up the pressure required for braking.

A master cylinder used with a remote reservoir is illustrated in *Figure 13-95*. This particular model is a Goodyear master cylinder. The cylinder is always filled with air-free, contaminant-free hydraulic fluid as is the reservoir and the line that connects the two together. When the top of the rudder pedal is depressed, the piston arm is mechanically moved forward into the master cylinder. It pushes the piston against the fluid, which is forced through the line to the brake. When pedal pressure is released, the return springs in the brake assembly retract the brake pistons back into the brake housing. The hydraulic fluid behind the pistons is displaced and must return to the master cylinder. As it does, a return spring in the master cylinder move the piston, piston rod and rudder pedal back to the original position (brake off, pedal not depressed). The fluid behind the master cylinder piston flows back into the reservoir. The brake is ready to be applied again.

Hydraulic fluid expands as temperature increases. Trapped

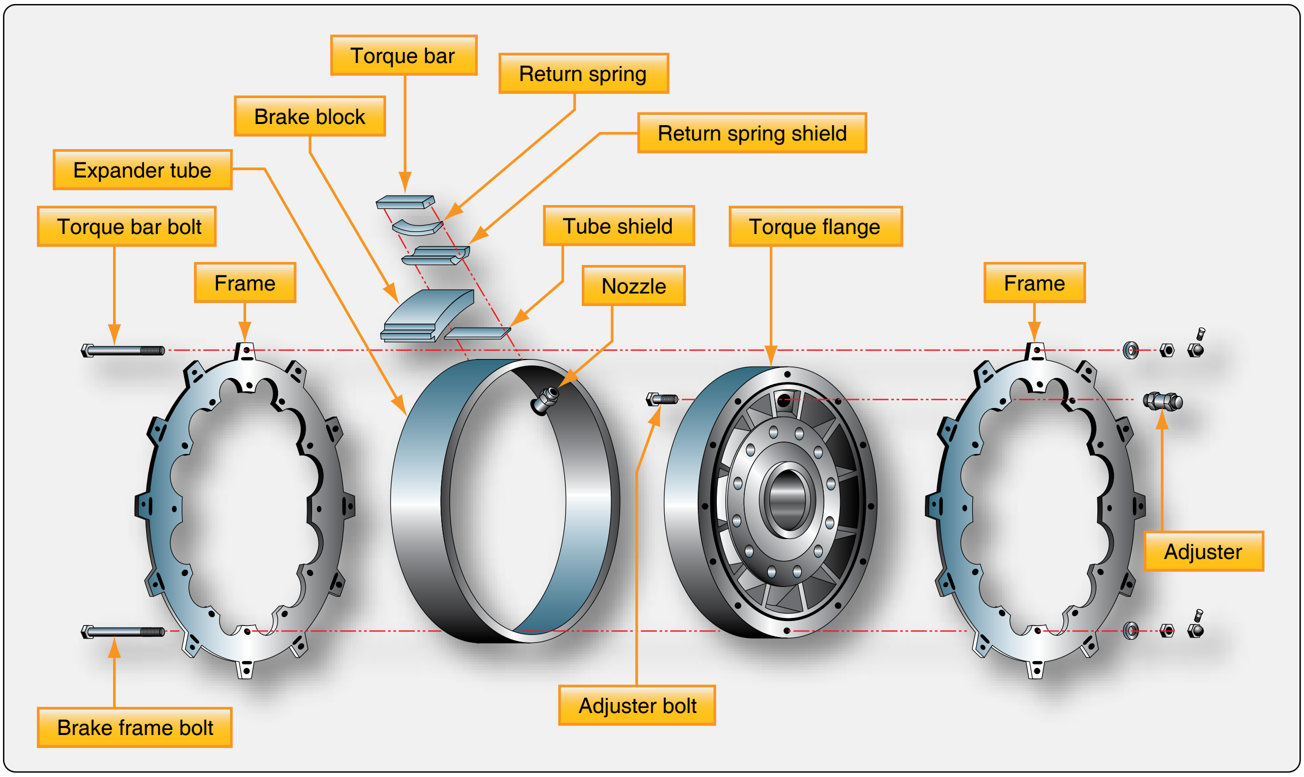

Figure 13-92. *An exploded view of an expander tube brake.*

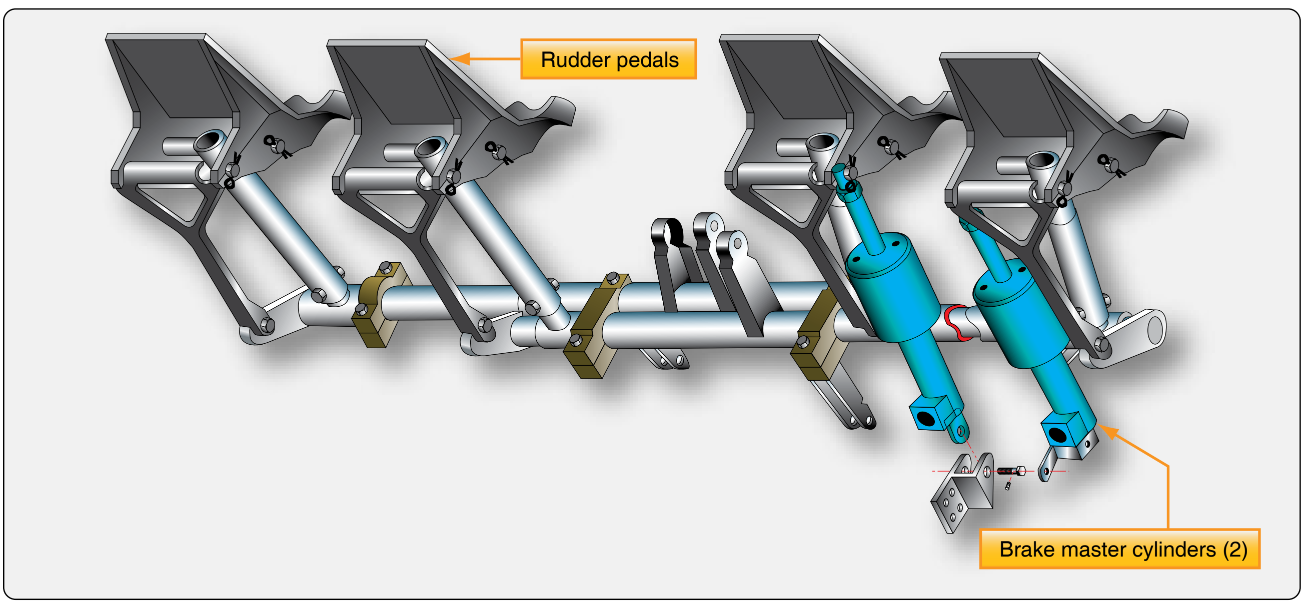

Figure 13-93. *Master cylinders on an independent brake system are directly connected to the rudder pedals or are connected through mechanical linkage.*

fluid can cause a brake to drag against the rotor(s). Leaks may also result. When the brakes are not applied, fluid must be allowed to expand safely without causing these issues. A compensating port is included in most master cylinders to facilitate this. In the master cylinder in *Figure 13-95*, this port is opened when the piston is fully retracted. Fluid in the brake system is allowed to expand into the reservoir, which has the capacity to accept the extra fluid volume. The typical reservoir is also vented to the atmosphere to provide positive pressure on the fluid.

The forward side of the piston head contains a seal that closes off the compensating port when the brakes are applied so that pressure can build. The seal is only effective in the forward

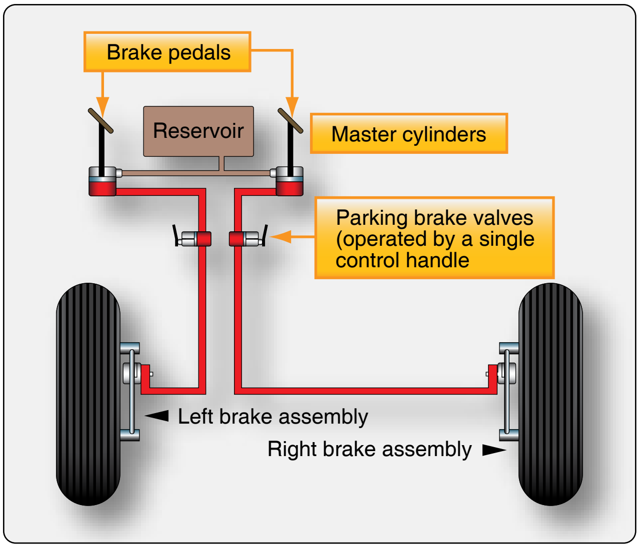

Figure 13-94. *A remote reservoir services both master cylinders on some independent braking systems.*

direction. When the piston is returning, or is fully retracted to the off position, fluid behind the piston is free to flow through piston head ports to replenish any fluid that may be lost downstream of the master cylinder. The aft end of the master cylinder contains a seal that prevents leakage at all times. A rubber boot fits over the piston rod and the aft end of the master cylinder to keep out dust.

A parking brake for this remote reservoir master cylinder brake system is a ratcheting mechanical device between the master cylinder and the rudder pedals. With the brakes applied, the ratchet is engaged by pulling the parking brake handle. To release the brakes, the rudder pedals are depressed further allowing the ratchet to disengage. With the parking brake set, any expansion of hydraulic fluid due to temperature is relieved by a spring in the mechanical linkage.

A common requirement of all braking systems is for there to be no air mixed in with the hydraulic fluid. Since air is compressible and hydraulic fluid essentially is not, any air under pressure when the brakes are applied causes spongy brakes. The pedals do not feel firm when pushed down due to the air compressing. Brake systems must be bled to remove all air from the system. Instructions for bleeding the brakes are in the manufacturer's maintenance information. Brake systems equipped with Goodyear master cylinders must be bled from the top down to ensure any air trapped behind the master cylinder piston is removed.

An alternative common arrangement of independent braking systems incorporates two master cylinders, each with its own integral fluid reservoir. Except for the reservoir location, the brake system is basically the same as just described. The master cylinders are mechanically linked to the rudder pedals as before. Depressing the top of a pedal causes the piston rod to push the piston into the cylinder forcing the fluid out to the brake assembly. The piston rod rides in a compensator sleeve and contains an O-ring that seals the rod to the piston when the rod is moved forward. This blocks the compensating ports. When released, a spring returns the piston to its original position which refills the reservoir as it returns. The rod end seal retracts away from the piston head allowing a free flow of fluid from the cylinder through the compensating ports in the piston to the reservoir. *[Figure 13-96]*

The parking brake mechanism is a ratcheting type that operates as described. A servicing port is supplied at the top of the master cylinder reservoir. Typically, a vented plug is installed in the port to provide positive pressure on the fluid.

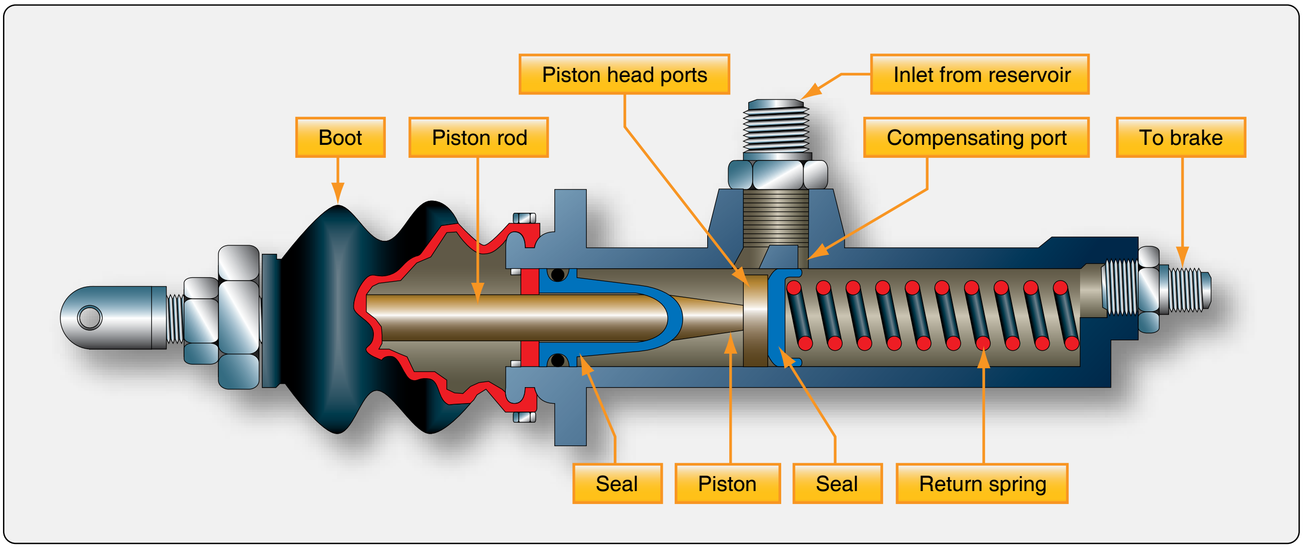

Figure 13-95. *A Goodyear brake master cylinder from an independent braking system with a remote reservoir.*

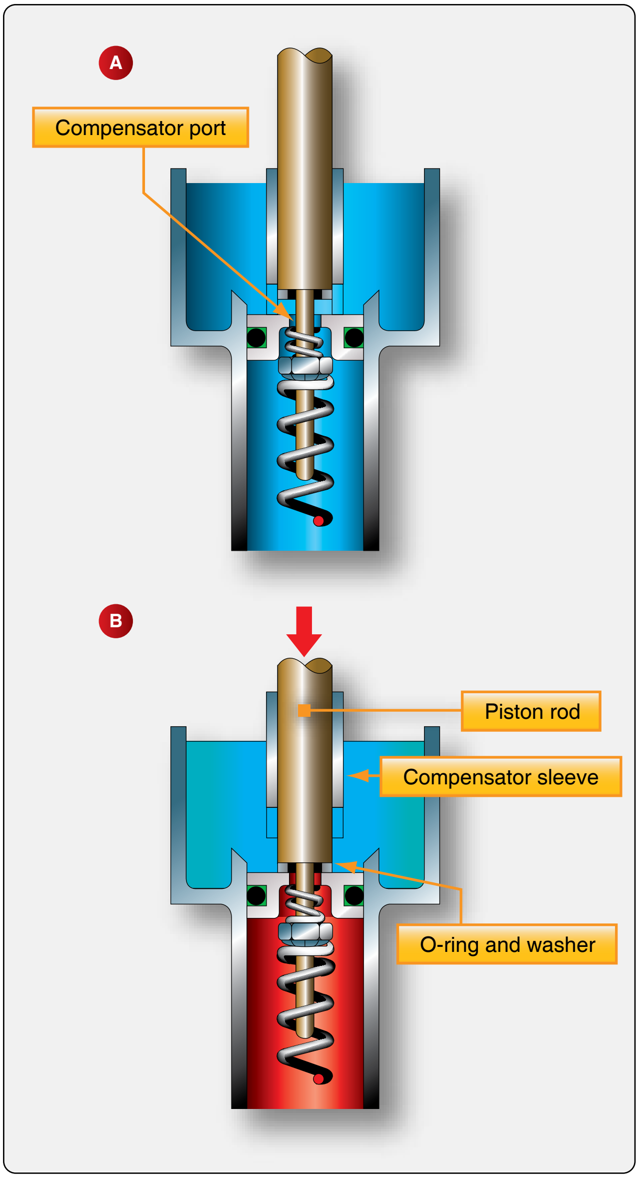

Figure 13-96. *A common master cylinder with built-in reservoir is shown. Illustration A depicts the master cylinder when the brakes are off. The compensating port is open to allow fluid to expand into the reservoir should temperature increase. In B, the brakes are applied. The piston rod-end seal covers the compensating port as it contacts the piston head.*

Boosted Brakes

In an independent braking system, the pressure applied to the brakes is only as great as the foot pressure applied to the top of the rudder pedal. Boosted brake actuating systems augment the force developed by the pilot with hydraulic system pressure when needed. The boost is only during heavy braking. It results in greater pressure applied to the brakes than the pilot alone can provide. Boosted brakes are used on medium and larger aircraft that do not require a full power brake actuating system.

A boosted brake master cylinder for each brake is mechanically attached to the rudder pedals. However, the boosted brake master cylinder operates differently. *[Figure 13-97]*

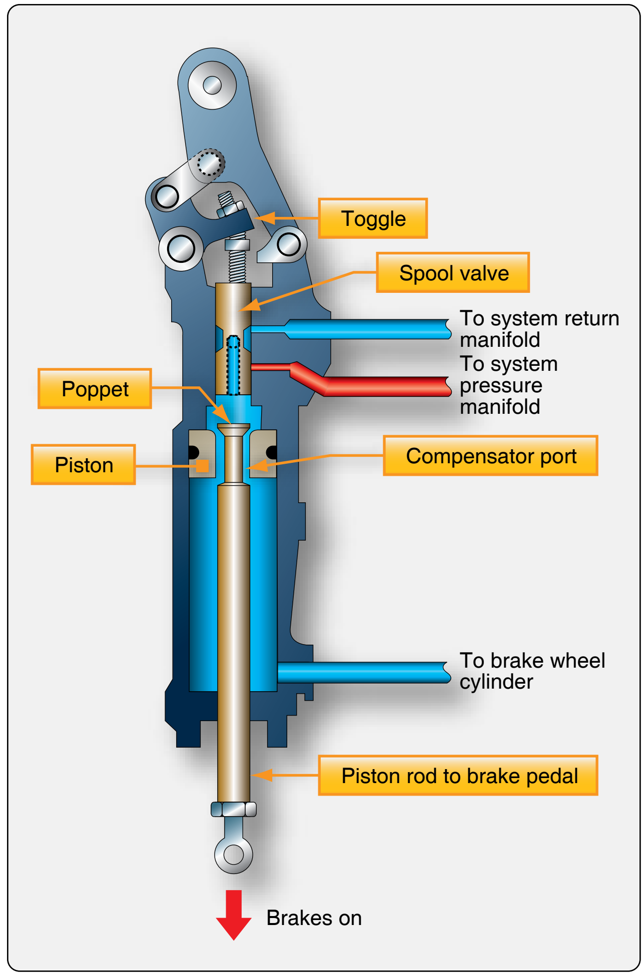

Figure 13-97. *A master cylinder for a boosted brake system augments foot pedal pressure with aircraft system hydraulic pressure during heavy braking.*

When the brakes are applied, the pressure from the pilot's foot through the mechanical linkage moves the master cylinder piston in the direction to force fluid to the brakes. The initial movement closes the compensator poppet used to provide thermal expansion relief when the brakes are not applied. As the pilot pushes harder on the pedal, a spring-loaded toggle moves a spool valve in the cylinder. Aircraft hydraulic system pressure flows through the valve to the back side of the piston. Pressure is increased, as is the force developed to apply the brakes.

When the pedal is released, the piston rod travels in the opposite direction, and the piston returns to the piston stop. The compensating poppet reopens. The toggle is withdrawn from the spool via linkages, and fluid pushes the spool back to expose the system return manifold port. System hydraulic fluid used to boost brake pressure returns through the port.

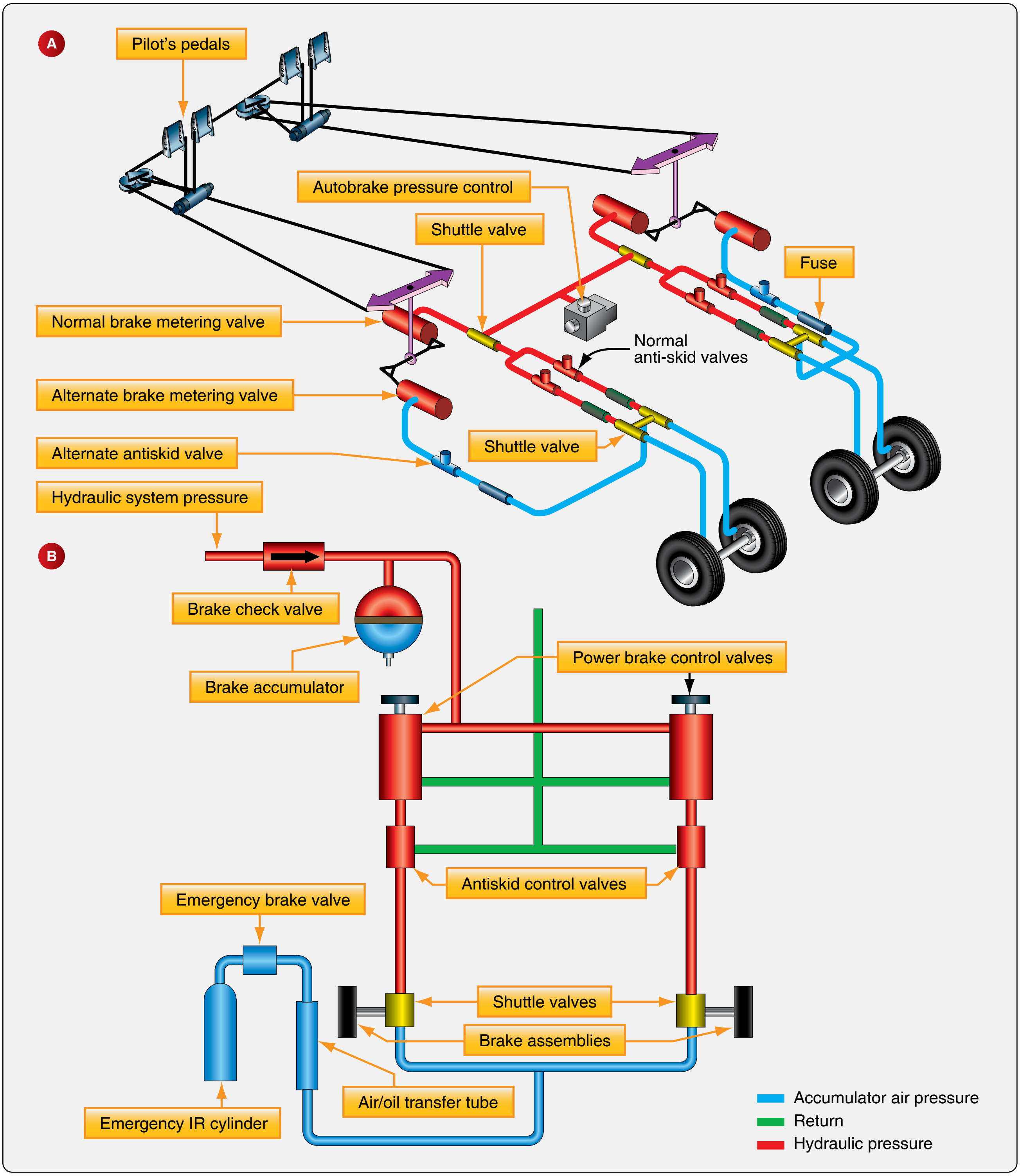

Figure 13-98. *The orientation of components in a basic power brake system is shown in A. The general layout of an airliner power brake system is shown in B.*

Power Brakes

Large and high-performance aircraft are equipped with power brakes to slow, stop, and hold the aircraft. Power brake actuating systems use the aircraft hydraulic system as the source of power to apply the brakes. The pilot presses on the top of the rudder pedal for braking as with the other actuating systems. The volume and pressure of hydraulic fluid required cannot be produced by a master cylinder. Instead, a power brake control valve or brake metering valve receives the brake pedal input either directly or through linkages.

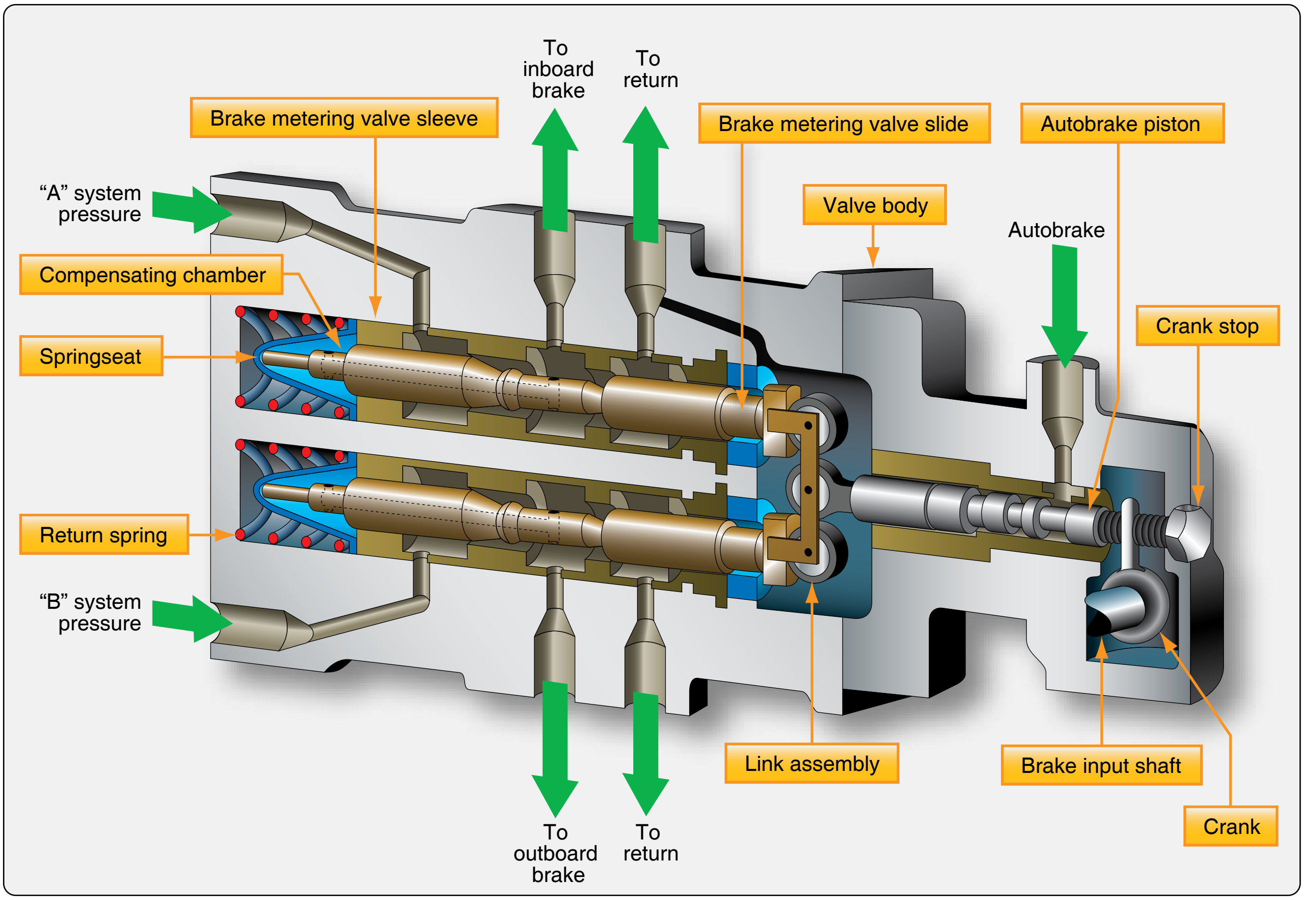

Figure 13-99. *A brake metering valve from a Boeing 737. A machined slide or spool moves laterally to admit the correct amount of hydraulic system fluid to the brakes. The pressure developed is in proportion to the amount the rudder/brake pedal is depressed and the amount the slide is displaced. The slide/spool also simultaneously controls the return of fluid to the hydraulic system return manifold when brake pressure is released.*

The valve meters hydraulic fluid to the corresponding brake assembly in direct relation to the pressure applied to the pedal.

Many power brake system designs are in use. Most are similar to the simplified system illustrated in *Figure 13-98A*. Power brake systems are constructed to facilitate graduated brake pressure control, brake pedal feel, and the necessary redundancy required in case of hydraulic system failure. Large aircraft brake systems integrate anti-skid detection and correction devices. These are necessary because wheel skid is difficult to detect on the flight deck without sensors. However, a skid can be quickly controlled automatically through pressure control of the hydraulic fluid to the brakes. Hydraulic fuses are also commonly found in power brake systems. The hostile environment around the landing gear increases the potential for a line to break or sever, a fitting to fail, or other hydraulic system malfunctions to occur where hydraulic fluid is lost en route to the brake assemblies. A fuse stops any excessive flow of fluid when detected by closing to retain the remaining fluid in the hydraulic system. Shuttle valves are used to direct flow from optional sources of fluid, such as in redundant systems or during the use of an emergency brake power source. An airliner power brake system is illustrated in *Figure 13-98B*.

Brake Control Valve/Brake Metering Valve

The key element in a power brake system is the brake control valve, sometimes called a brake metering valve. It responds to brake pedal input by directing aircraft system hydraulic fluid to the brakes. As pressure is increased on the brake pedal, more fluid is directed to the brake causing a higher pressure and greater braking action.

A brake metering valve from a Boeing 737 is illustrated in *Figure 13-99*. The system in which it is installed is diagramed in *Figure 13-100*. Two sources of hydraulic pressure provide redundancy in this brake system. A brake input shaft, connected to the rudder/brake pedal through mechanical linkages, provides the position input to the metering valve. As in most brake control valves, the brake input shaft moves a tapered spool or slide in the valve so that it allows hydraulic system pressure to flow to the brakes. At the same time, the slide covers and uncovers access to the hydraulic system return port as required.

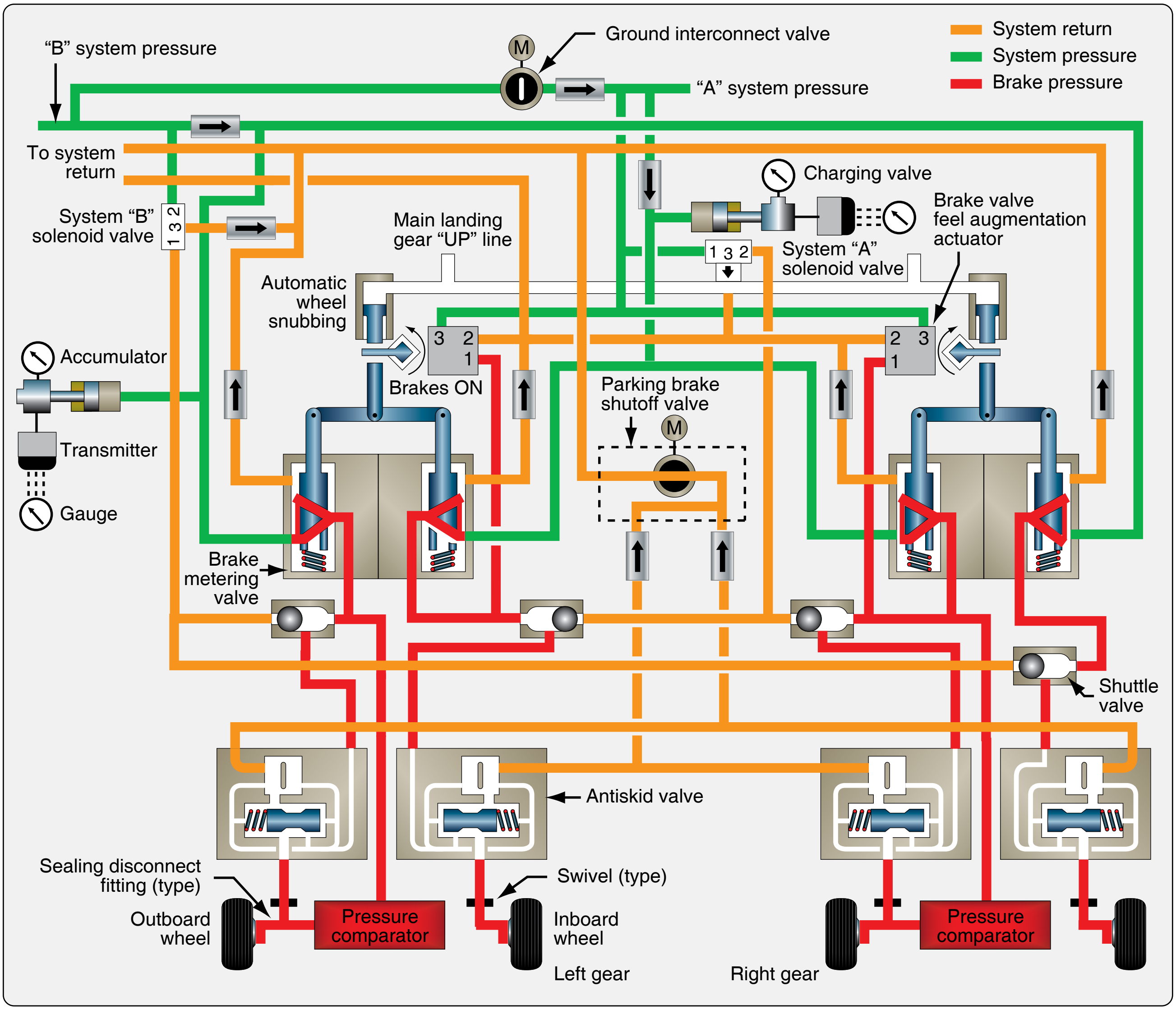

Figure 13-100. *The power brake system on a Boeing 737.*

When the rudder/brake pedal is depressed, the slide in the metering valve moves to the left. *[Figure 13-99]* It covers the return port so pressure can build in the brake system. The hydraulic supply pressure chamber is connected to the brake system pressure chamber by the movement of the slide, which due to its taper, unblocks the passage between these two. As the pedal is depressed further, the valve slide moves farther to the left. This enables more fluid to flow to the brakes due to the narrowing shape of the slide. Brake pressure increases with the additional fluid. A passage in the slide directs brake pressure fluid into a compensating chamber at the end of the slide. This acts on the end of the slide creating a return force that counters the initial slide movement and gives feel to the brake pedal. As a result, the pressure and return ports are closed and pressure proportional to the foot pressure on the pedal is held on the brakes. When the pedal is released, a return spring and compensating chamber pressure drive the slide to the right into its original position (return port open, supply pressure chamber and brake pressure chambers blocked from each other).

The metering valve operates as described simultaneously for the inboard and the outboard brakes. *[Figure 13-99]* The design of the link assembly is such that a single side of the metering valve can operate even if the other fails. Most brake control valves and metering valves function in a similar manner, although many are single units that supply only one brake assembly.

The auto brake, referenced in the metering valve diagram, is connected into the landing gear retraction hydraulic line. Pressurized fluid enters this port and drives the slide slightly to the left to apply the brakes automatically after takeoff. This stops the wheels from rotating when retracted into the wheel wells. Auto brake pressure is withheld from this port when the landing gear is fully stowed since the retraction system is depressurized.

The majority of the rudder/brake pedal feel is supplied by the brake control or brake metering valve in a power brake system. Many aircraft refine the feel of the pedal with an additional feel unit. The brake valve feel augmentation unit, in the above system, uses a series of internal springs and pistons of various sizes to create a force on the brake input shaft movement. This provides feel back through the mechanical linkages consistent with the amount of rudder/brake pedal applied. The request for light braking with slight pedal depression results in a light feel to the pedal and a harder resistance feel when the pedals are pushed harder during heavy braking. *[Figure 13-101]*

Emergency Brake Systems

As can be seen in *Figure 13-100,* the brake metering valves not only receive hydraulic pressure from two separate hydraulic systems, they also feed two separate brake assemblies. Each main wheel assembly has two wheels. The inboard wheel brake and the outboard wheel brake, located in their respective wheel rims, are independent from each other. In case of hydraulic system failure or brake failure, each is independently supplied to adequately slow and stop the aircraft without the other. More complicated aircraft may involve another hydraulic system for back-up or use a similar alternation of sources and brake assemblies to maintain braking in case of hydraulic system or brake failure.

Note: In the segmented rotor brake section above, a brake assembly was described that had alternating pistons supplied by independent hydraulic sources. This is another method of redundancy particularly suitable on, but not limited to, single main wheel aircraft.

In addition to supply system redundancy, the brake accumulator is also an emergency source of power for the brakes in many power brake systems. The accumulator is pre-charged with air or nitrogen on one side of its internal diaphragm. Enough hydraulic fluid is contained on the other side of the diaphragm to operate the brakes in case of an emergency. It is forced out of the accumulator into the brakes through the system lines under enough stored pressure to slow the aircraft. Typically, the accumulator is located upstream of the brake control/metering valve to capitalize on the control given by the valve. *[Figure 13-102]*

Some simpler power brake systems may use an emergency source of brake power that is delivered directly to the brake assemblies and bypasses the remainder of the brake system completely. A shuttle valve immediately upstream of the brake units shifts to accept this source when pressure is lost from the primary supply sources. Compressed air or nitrogen is sometimes used. A pre-charged fluid source can also be used as an alternate hydraulic source.

Parking Brake

The parking brake system function is a combined operation. The brakes are applied with the rudder pedals and a ratcheting system holds them in place when the parking

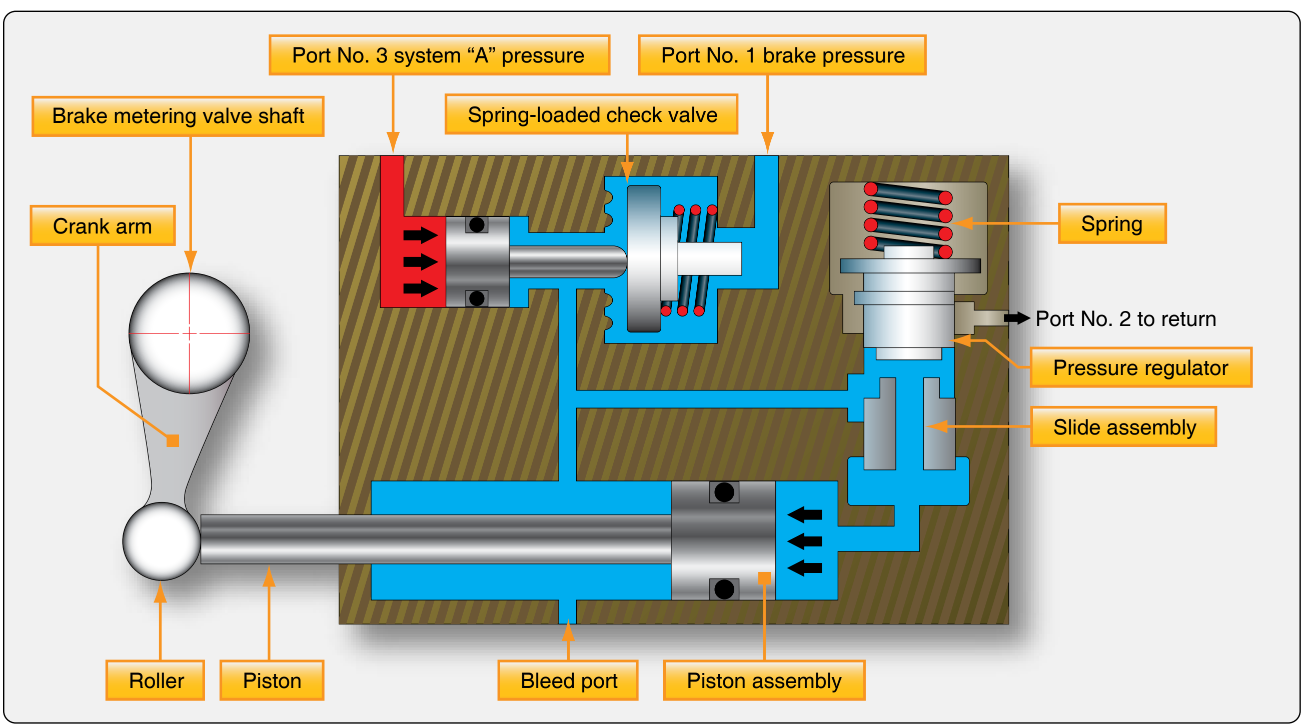

Figure 13-101. *The power brake system on a Boeing 737.*

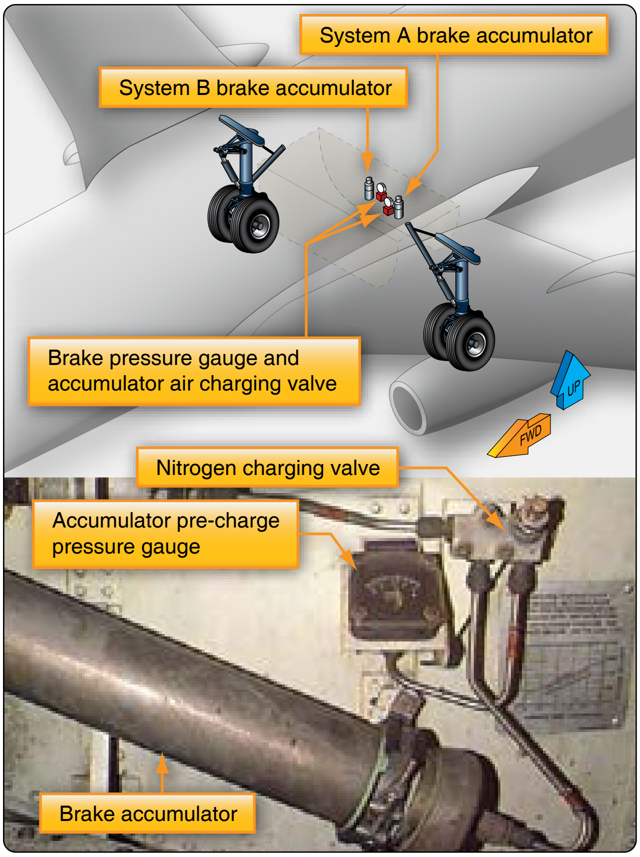

Figure 13-102. *Emergency brake hydraulic fluid accumulators are precharged with nitrogen to deliver brake fluid to the brakes in the event normal and alternate hydraulic sources fail.*

Figure 13-103. *The parking brake lever on a Boeing 737 center pedestal throttle quadrant.*

brake lever on the flight deck is pulled. *[Figure 13-103]* At the same time, a shut-off valve is closed in the common return line from the brakes to the hydraulic system. This traps the fluid in the brakes holding the rotors stationary. Depressing the pedals further releases the pedal ratchet and opens the return line valve.

Brake Deboosters

Some aircraft brake assemblies that operate on aircraft hydraulic system pressure are not designed for such high pressure. They provide effective braking through a power brake system but require less than maximum hydraulic system pressure. To supply the lower pressure, a brake debooster cylinder is installed downstream of the control valve and anti-skid valve. *[Figure 13-104]* The debooster reduces some pressure from the control valve to within the working range of the brake assembly.

Brake deboosters are simple devices that use the application of force over different sized pistons to reduce pressure. *[Figure 13-105]* Their operation can be understood through the application of the following equation:

Pressure = Force/Area

High-pressure hydraulic system input pressure acts on the small end of a piston. This develops a force proportional to the area of the piston head. The other end of the piston is larger and housed in a separate cylinder. The force from the smaller piston head is transferred to the larger area of the other end of the piston. The amount of pressure conveyed by the larger end of the piston is reduced due to the greater area over which the force is spread. The volume of output fluid increases since a larger piston and cylinder are used. The reduced pressure is delivered to the brake assembly.

The spring in the debooster aids in returning the piston to the ready position. If fluid is lost downstream of the deboost cylinder, the piston travels further down into the cylinder when the brakes are applied. The pin unseats the ball and allows fluid into the lower cylinder to replace what was lost. Once replenished, the piston rises up in the cylinder due to pressure build-up. The ball reseats as the piston travels above the pin and normal braking resumes. This function is not meant to permit leaks in the brake assemblies. Any leak discovered must be repaired by the technician.

A lockout debooster functions as a debooster and a hydraulic fuse. If fluid is not encountered as the piston moves down in the cylinder, the flow of fluid to the brakes is stopped. This prevents the loss of all system hydraulic fluid should a rupture downstream of the debooster occur. Lockout deboosters have a handle to reset the device after it closes as a fuse. If not reset, no braking action is possible.

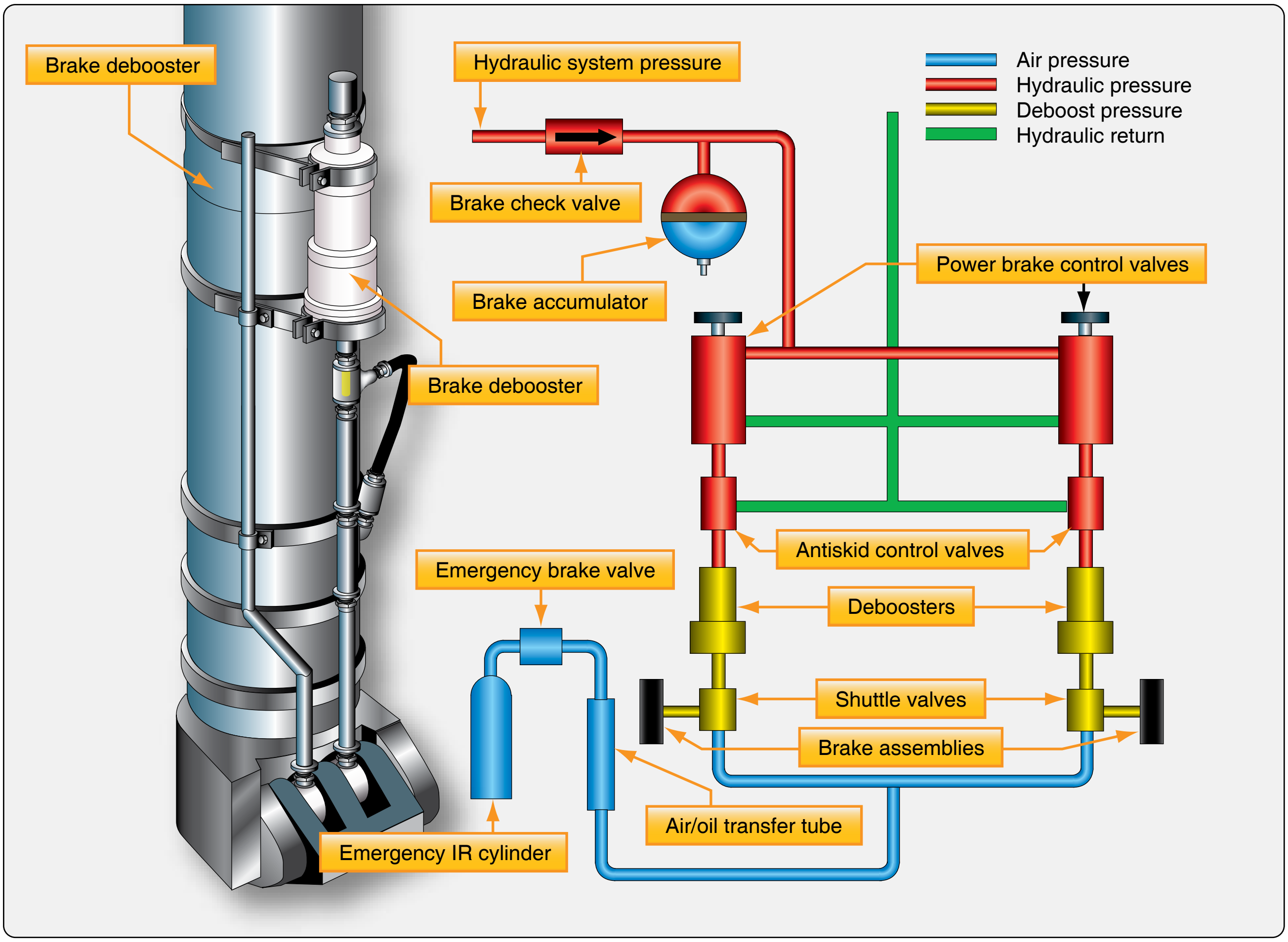

Figure 13-104. *The location of a brake debooster cylinder on a landing gear strut and the debooster's position in relation to other components of a power brake system.*

Anti-Skid

Large aircraft with power brakes require anti-skid systems. It is not possible to immediately ascertain in the flight deck when a wheel stops rotating and begins to skid, especially in aircraft with multiple-wheel main landing gear assemblies. A skid not corrected can quickly lead to a tire blowout, possible damage to the aircraft, and control of the aircraft may be lost.

System Operation

The anti-skid system not only detects wheel skid, it also detects when wheel skid is imminent. It automatically relieves pressure to the brake pistons of the wheel in question by momentarily connecting the pressurized brake fluid area to the hydraulic system return line. This allows the wheel to rotate and avoid a skid. Lower pressure is then maintained to the brake at a level that slows the wheel without causing it to skid.

Maximum braking efficiency exists when the wheels are decelerating at a maximum rate but are not skidding. If a wheel decelerates too fast, it is an indication that the brakes are about to lock and cause a skid. To ensure that this does not happen, each wheel is monitored for a deceleration rate faster than a preset rate. When excessive deceleration is detected, hydraulic pressure is reduced to the brake on that wheel. To operate the anti-skid system, flight deck switches must be placed in the ON position. *[Figure 13-106]* After the aircraft touches down, the pilot applies and holds full pressure to the rudder brake pedals. The anti-skid system then functions automatically until the speed of the aircraft has dropped to approximately 20 mph. The system returns to manual braking mode for slow taxi and ground maneuvering.

There are various designs of anti-skid systems. Most contain three main types of components: wheel speed sensors, anti-skid control valves, and a control unit. These units work together without human interference. Some anti-skid systems provide complete automatic braking. The pilot needs only to turn on the auto brake system, and the anti-skid components slow the aircraft without pedal input. *[Figure 13-106]* Ground safety switches are wired into the circuitry for anti-skid and auto brake systems. Wheel speed sensors are located on each wheel equipped with a brake assembly. Each brake also has its own anti-skid control valve. Typically, a single control box contains the anti-skid comparative circuitry for all of the brakes on the aircraft. *[Figure 13-107]*

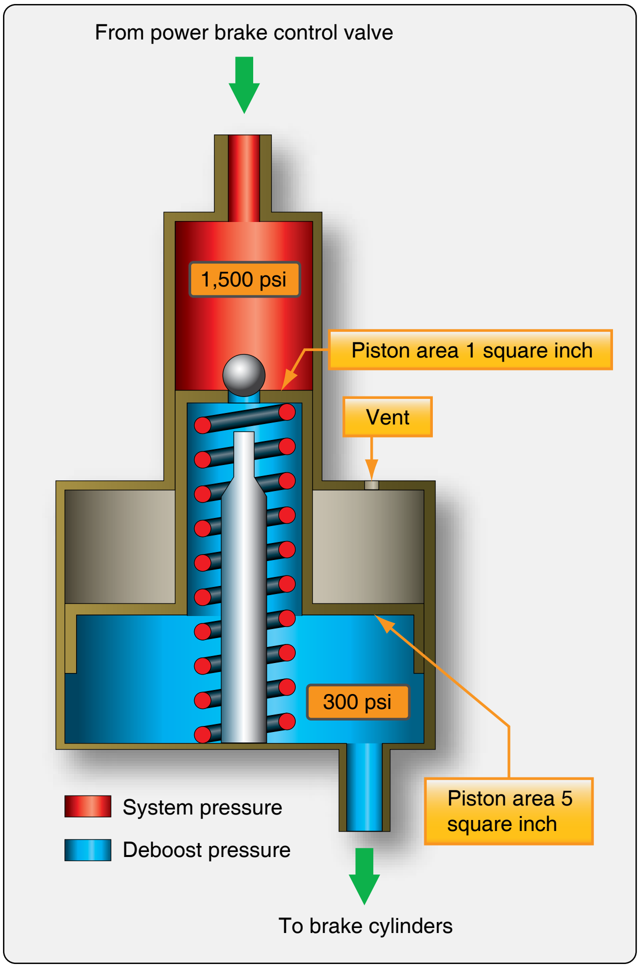

Figure 13-105. *Brake deboosters.*

Wheel Speed Sensors

Wheel speed sensors are transducers. They may be alternating current (AC) or direct current (DC). The typical AC wheel speed sensor has a stator mounted in the wheel axle. A coil around it is connected to a controlled DC source so that when energized, the stator becomes an electromagnet. A rotor that turns inside the stator is connected to the rotating wheel hub assembly through a drive coupling so that it rotates at the speed of the wheel. Lobes on the rotor and stator cause the distance between the two components to constantly change during rotation. This alters the magnetic coupling or reluctance between the rotor and stator. As the electromagnetic field changes, a variable frequency AC is induced in the stator coil. The frequency is directly proportional to the speed of rotation of the wheel. The AC signal is fed to the control unit for processing. A DC wheel speed sensor is similar, except that a DC is produced the magnitude of which is directly proportional to wheel speed. *[Figure 13-108]*

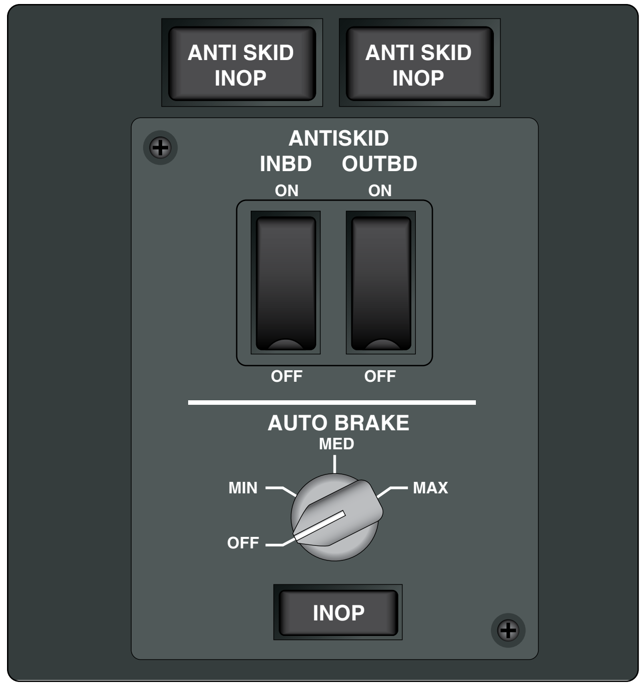

Figure 13-106. *Anti-skid switches in the flight deck.*

Control Units

The control unit can be regarded as the brain of the anti-skid system. It receives signals from each of the wheel sensors. Comparative circuits are used to determine if any of the signals indicate a skid is imminent or occurring on a particular wheel. If so, a signal is sent to the control valve of the wheel to relieve hydraulic pressure to that brake which prevents or relieves the skid. The control unit may or may not have external test switches and status indicating lights. It is common for it to be located in the avionics bay of the aircraft. *[Figure 13-109]*

The Boeing anti-skid control valve block diagram in *Figure 13-110* gives further detail on the functions of an anti-skid control unit. Other aircraft may have different logic

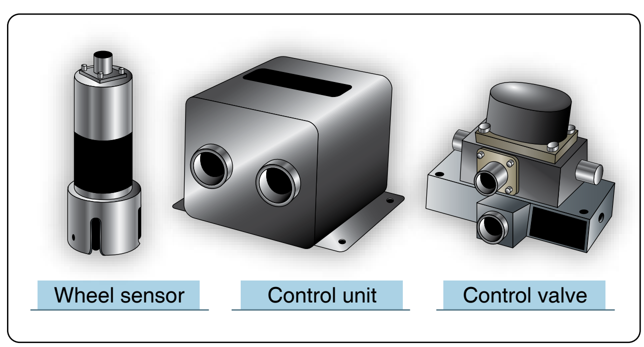

Figure 13-107. *A wheel sensor (left), a control unit (center), and a control valve (right) are components of an anti-skid system. A sensor is located on each wheel equipped with a brake assembly. An anti-skid control valve for each brake assembly is controlled from a single central control unit.*

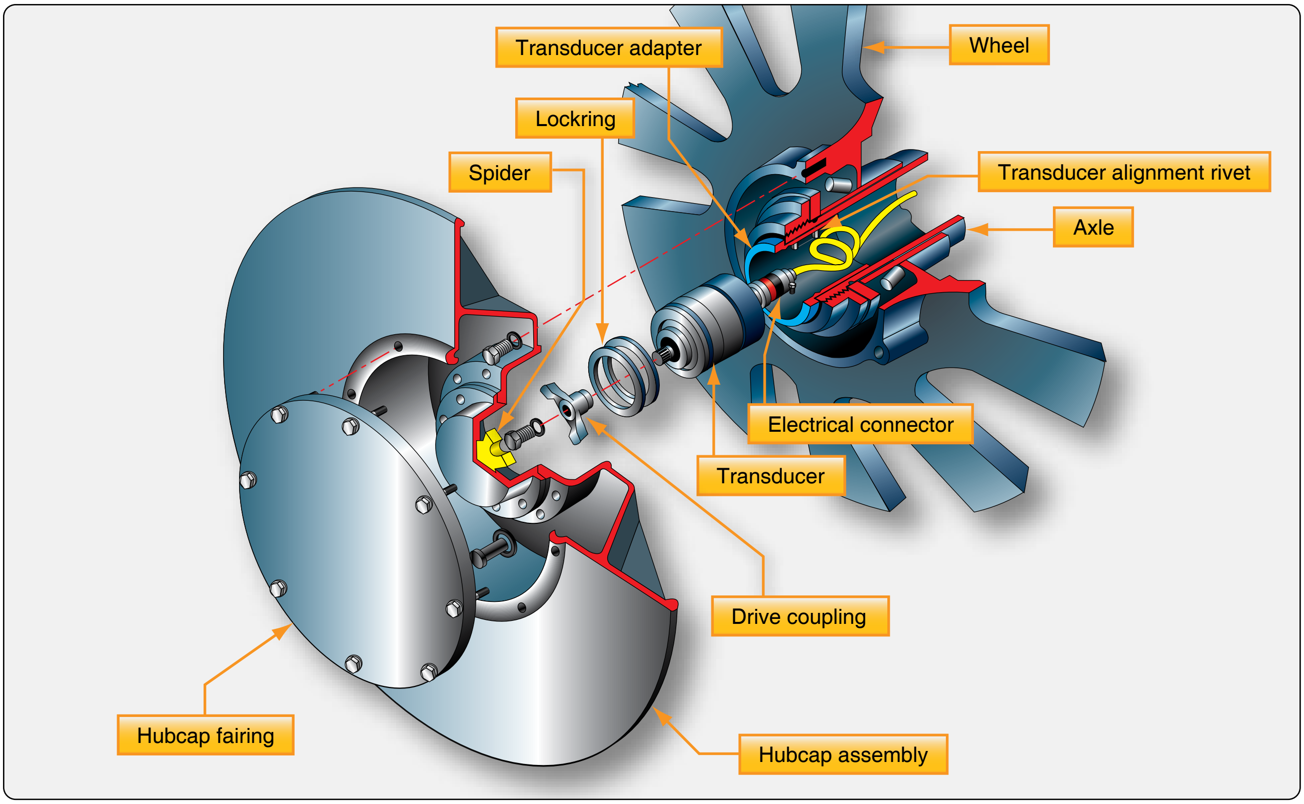

Figure 13-108. *The stator of an anti-skid wheel sensor is mounted in the axle, and the rotor is coupled to the wheel hub spider that rotates with the wheel.*

Figure 13-109. *A rack mounted anti-skid control unit from an airliner.*

to achieve similar end results. DC systems do not require an input converter since DC is received from the wheel sensors, and the control unit circuitry operates primarily with DC. Only the functions on one circuit card for one-wheel brake assembly are shown in *Figure 13-110*. Each wheel has its own identical circuitry card to facilitate simultaneous operation. All cards are housed in a single control unit that Boeing calls a control shield.

The converter shown changes the AC frequency received from the wheel sensor into DC voltage that is proportional to wheel speed. The output is used in a velocity reference loop that contains deceleration and velocity reference circuits. The converter also supplies input for the spoiler system and the locked wheel system, which is discussed at the end of this section. A velocity reference loop output voltage is produced, which represents the instantaneous velocity of the aircraft. This is compared to converter output in the velocity comparator. This comparison of voltages is essentially the comparison of the aircraft speed to wheel speed. The output from the velocity comparator is a positive or negative error voltage corresponding to whether the wheel speed is too fast or too slow for optimum braking efficiency for a given aircraft speed.

The error output voltage from the comparator feeds the pressure bias modulator circuit. This is a memory circuit that establishes a threshold where the pressure to the brakes provides optimum braking. The error voltage causes the modulator to either increase or decrease the pressure to the brakes in attempt to hold the modulator threshold. It produces a voltage output that is sent to the summing amplifier to do this. A lead output from the comparator anticipates when the tire is about to skid with a voltage that decreases the pressure to the brake. It sends this voltage to the summing amplifier as well. A transient control output from the comparator designed for rapid pressure dump when a sudden skid has occurred also

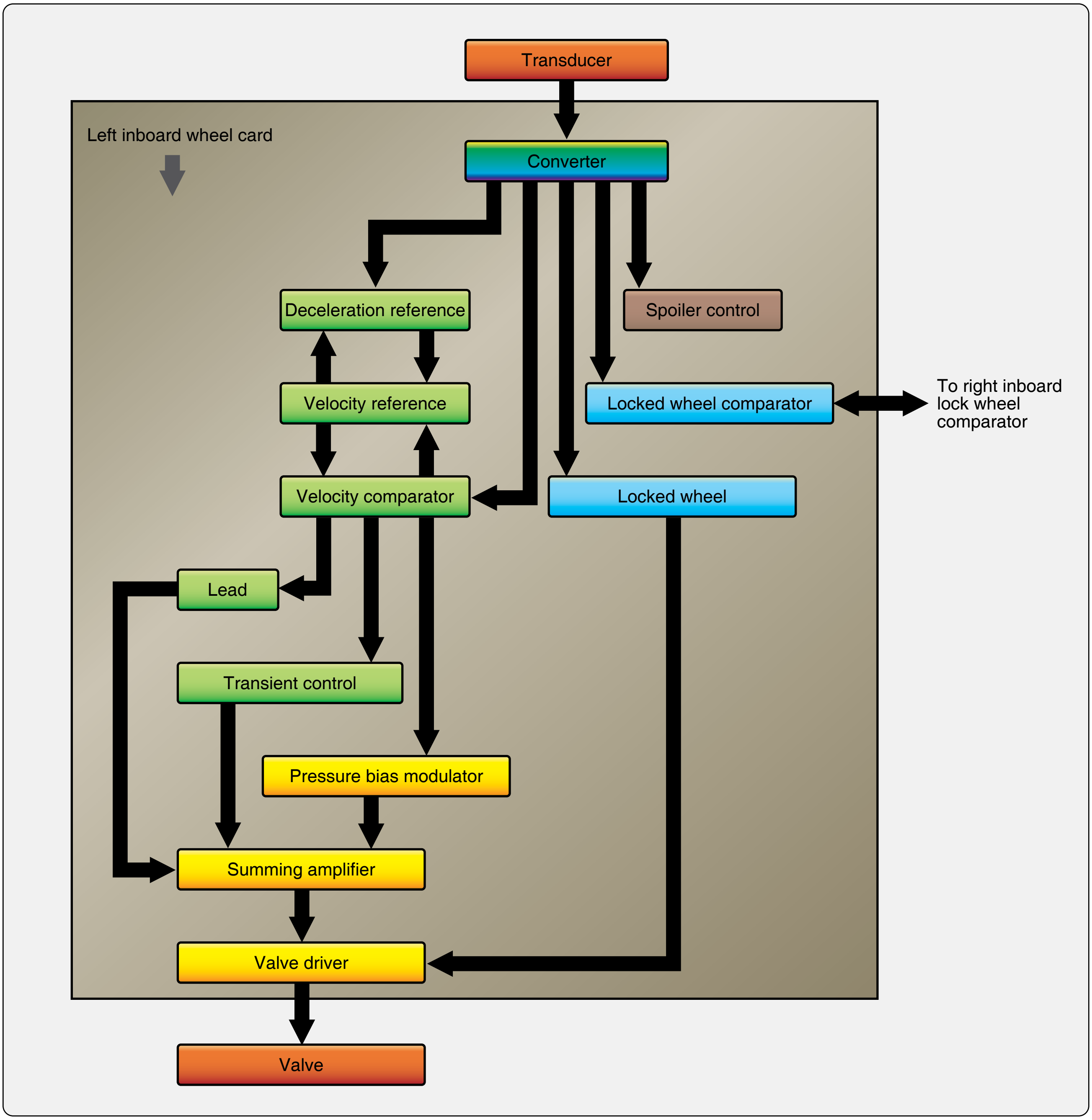

Figure 13-110. *A Boeing 737 anti-skid control unit internal block diagram.*

sends voltage to the summing amp. As the name suggests, the input voltages to the amplifier are summed, and a composite voltage is sent to the valve driver. The driver prepares the current required to be sent to the control valve to adjust the position of the valve. Brake pressure increases, decreases, or holds steady depending on this value.

Anti-Skid Control Valves

Anti-skid control valves are fast-acting, electrically controlled hydraulic valves that respond to the input from the anti-skid control unit. There is one control valve for each brake assembly. A torque motor uses the input from the valve driver to adjust the position of a flapper between two nozzles. By moving the flapper closer to one nozzle or the other, pressures are developed in the second stage of the valve. These pressures act on a spool that is positioned to build or reduce pressure to the brake by opening and blocking fluid ports. *[Figure 13-111]*

As pressure is adjusted to the brakes, deceleration slows to within the range that provides the most effective braking without skidding. The wheel sensor signal adjusts to the

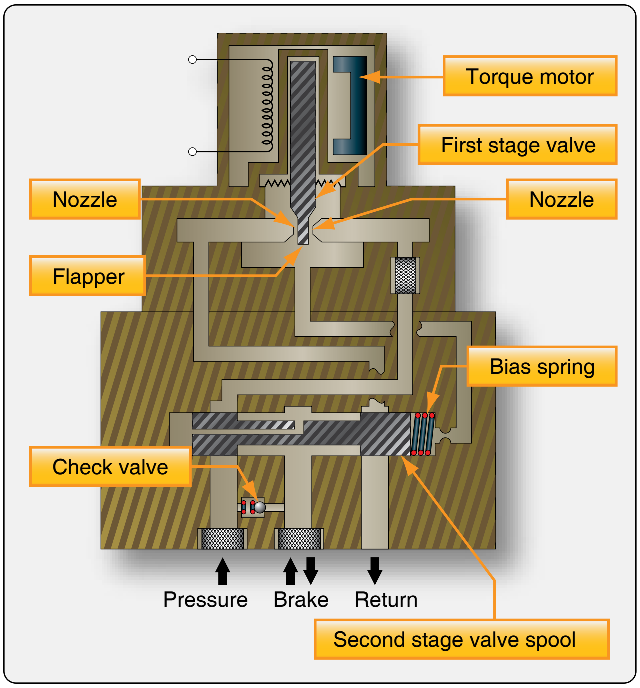

Figure 13-111. *An anti-skid control valve uses a torque motor controlled flapper in the first stage of the valve to adjust pressure on a spool in the second stage of the valve to build or relieve pressure to the brake.*

wheel speed, and the control unit processes the change. Output is altered to the control valve. The control valve flapper position is adjusted and steady braking resumes without correction until needed. Anti-skid control valves are typically located in the main wheel for close access to hydraulic pressure and return manifolds, as well as the brake assemblies. *[Figure 13-112]* Systematically, they are positioned downstream of the power brake control valves but upstream of debooster cylinders if the aircraft is so equipped as was shown in *Figure 13-104*.

Touchdown & Lock Wheel Protection

It is essential that the brakes are not applied when the aircraft contacts the runway upon landing. This could cause immediate tire blowout. A touchdown protection mode is built into most aircraft anti-skid systems to prevent this. It typically functions in conjunction with the wheel speed sensor and the air/ground safety switch on the landing gear strut (squat switch). Until the aircraft has weight on wheels, the detector circuitry signals the anti-skid control valve to open the passage between the brakes and the hydraulic system return, thus preventing pressure build-up and application of the brakes. Once the squat switch is open, the anti-skid control unit sends a signal to the control valve to close and permit brake pressure build-up. As a back-up and when the aircraft is on the ground with the strut not compressed enough to open the squat switch, a minimum wheel speed sensor signal can override and allow braking. Wheels are

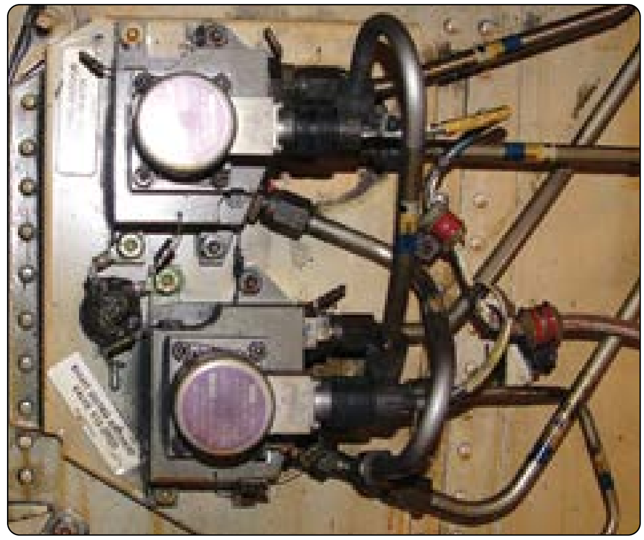

Figure 13-112. *Two anti-skid control valves with associated plumbing and wiring.*

often grouped with one relying on the squat switch and the other on wheel speed sensor output to ensure braking when the aircraft is on the ground, but not before then.

Locked wheel protection recognizes if a wheel is not rotating. When this occurs, the anti-skid control valve is signaled to fully open. Some aircraft anti-skid control logic, such as the Boeing 737 shown in *Figure 13-111*, expands the locked wheel function. Comparator circuitry is used to relieve pressure when one wheel of a paired group of wheels rotates 25 percent slower than the other. Inboard and outboard pairs are used because if one of the pair is rotating at a certain speed, so should the other. If it is not, a skid is beginning or has occurred.

On takeoff, the anti-skid system receives input through a switch located on the gear selector that shuts off the anti-skid system. This allows the brakes to be applied as retraction occurs so that no wheel rotation exists while the gear is stowed.

Auto Brakes

Aircraft equipped with auto brakes typically bypass the brake control valves or brake metering valves and use a separate auto brake control valve to provide this function. In addition to the redundancy provided, auto brakes rely on the anti-skid system to adjust pressure to the brakes if required due to an impending skid. *Figure 13-113* shows a simplified diagram of the Boeing 757 brake system with the auto brake valve in relation to the main metering valve and anti-skid valves in this eight-main wheel system.

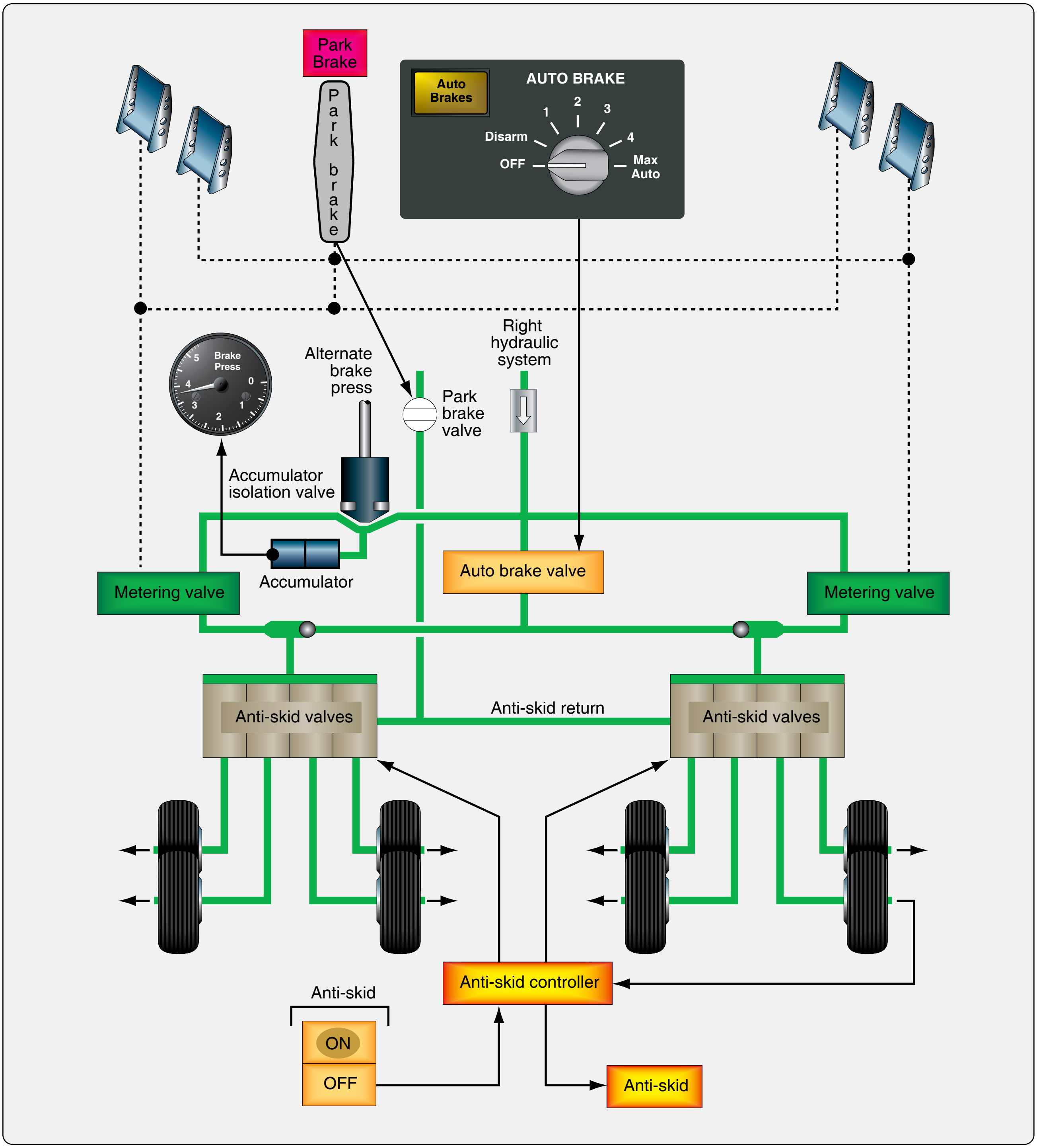

Figure 13-113. *The Boeing 757 normal brake system with auto brake and anti-skid.*

Anti-Skid System Tests

It is important to know the status of the anti-skid system prior to attempting to use it during a landing or aborted takeoff. Ground tests and in-flight tests are used. Built-in test circuits and control features allow testing of the system components and provide warnings should a particular component or part of the system become inoperative. An inoperative anti-skid system can be shut off without affecting normal brake operation.

Ground Test

Ground tests vary slightly from aircraft to aircraft. Consult the manufacturer's maintenance manual for test procedures specific to the aircraft in question.

Much of the anti-skid system testing originates from testing circuits in the anti-skid control unit. Built-in test circuits continuously monitor the anti-skid system and provide warning if a failure occurs. An operational test can be performed before flight. The anti-skid control switch and/or test switch is used in conjunction with system indicator light(s) to determine system integrity. A test is first done with the aircraft at rest and then in an electrically simulated anti-skid braking condition. Some anti-skid control units contain system and component testing switches and lights for use by the technician. This accomplishes the same operational verification but allows an additional degree of troubleshooting. Test sets are available for anti-skid systems that produce electric signals that simulate speed outputs of the wheel transducer, deceleration rates, and flight/ground parameters.

In-Flight Test

In-flight testing of the anti-skid system is desirable and part of the pre-landing checklist so that the pilot is aware of system capability before landing. As with ground testing, a combination of switch positions and indicator lights are used according to information in the aircraft operations manual.

Anti-Skid System Maintenance

Anti-skid components require little maintenance. Troubleshooting anti-skid system faults is either performed via test circuitry or can be accomplished through isolation of the fault to one of the three main operating components of the system. Anti-skid components are normally not repaired in the field. They are sent to the manufacturer or a certified repair station when work is required. Reports of anti-skid system malfunction are sometimes malfunctions of the brake system or brake assemblies. Ensure brake assemblies are bled and functioning normally without leaks before attempting to isolate problems in the anti-skid system.

Wheel Speed Sensor

Wheel speed sensors must be securely and correctly mounted in the axle. The means of keeping contamination out of the sensor, such as sealant or a hub cap, should be in place and in good condition. The wiring to the sensor is subject to harsh conditions and should be inspected for integrity and security. It should be repaired or replaced if damaged in accordance with the manufacturer's instructions. Accessing the wheel speed sensor and spinning it by hand or other recommended device to ensure brakes apply and release via the anti-skid system is common practice.

Control Valve

Anti-skid control valve and hydraulic system filters should be cleaned or replaced at the prescribed intervals. Follow all manufacturer's instructions when performing this maintenance. Wiring to the valve must be secure, and there should be no fluid leaks.

Control Unit

Control units should be securely mounted. Test switches and indicators, if any, should be in place and functioning. It is essential that wiring to the control unit is secure. A wide variety of control units are in use. Follow the manufacturer's instructions at all times when inspecting or attempting to perform maintenance on these units.

Brake Inspection & Service

Brake inspection and service is important to keep these critical aircraft components fully functional at all times. There are many different brake systems on aircraft. Brake system maintenance is performed both while the brakes are installed on the aircraft and when the brakes are removed. The manufacturer's instructions must always be followed to ensure proper maintenance.

On Aircraft Servicing

Inspection and servicing of aircraft brakes while installed on the aircraft is required. The entire brake system must be inspected in accordance with manufacturer's instructions. Some common inspection items include: brake lining wear, air in the brake system, fluid quantity level, leaks, and proper bolt torque.

Lining Wear

Brake lining material is made to wear as it causes friction during application of the brakes. This wear must be monitored to ensure it is not worn beyond limits and sufficient lining is available for effective braking. The aircraft manufacturer gives specifications for lining wear in its maintenance information. The amount of wear can be checked while the brakes are installed on the aircraft.

Many brake assemblies contain a built-in wear indicator pin. Typically, the exposed pin length decreases as the linings wear, and a minimum length is used to indicate the linings must be replaced. Caution must be used as different assemblies may vary in how the pin measured. On the Goodyear brake described above, the wear pin is measured where it protrudes through the nut of the automatic adjuster on the back side of the piston cylinder. *[Figure 13-114]* The Boeing brake illustrated in *Figure 13-89* measures the length of the pin from the back of the pressure plate when the brakes are applied (dimension L). The manufacturer's maintenance information must be consulted to ensure brake wear pin indicators on different aircraft are read correctly.

On many other brake assemblies, lining wear is not measured via a wear pin. The distance between the disc and a portion of the brake housing when the brakes are applied is sometimes used. As the linings wear, this distance increases. The manufacturer specified at what distance the linings should be changed. *[Figure 13-115]*

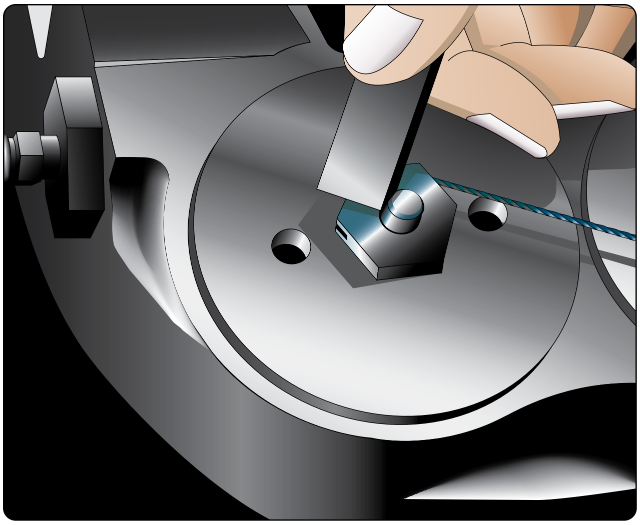

Figure 13-114. *Brake lining wear on a Goodyear brake is ascertained by measuring the wear pin of the automatic adjuster.*

On Cleveland brakes, lining wear can be measured directly, since part of the lining is usually exposed. The diameter of a number 40 twist drill is approximately equal to the minimum lining thickness allowed. *[Figure 13-116]*

Multiple disc brakes typically are checked for lining wear by applying the brakes and measuring the distance between the back of the pressure plate and the brake housing. *[Figure 13-117]* Regardless of the method particular to each brake, regular monitoring and measurement of brake wear ensures linings are replaced as they become unserviceable. Linings worn beyond limits usually require the brake assembly to be removed for replacement.

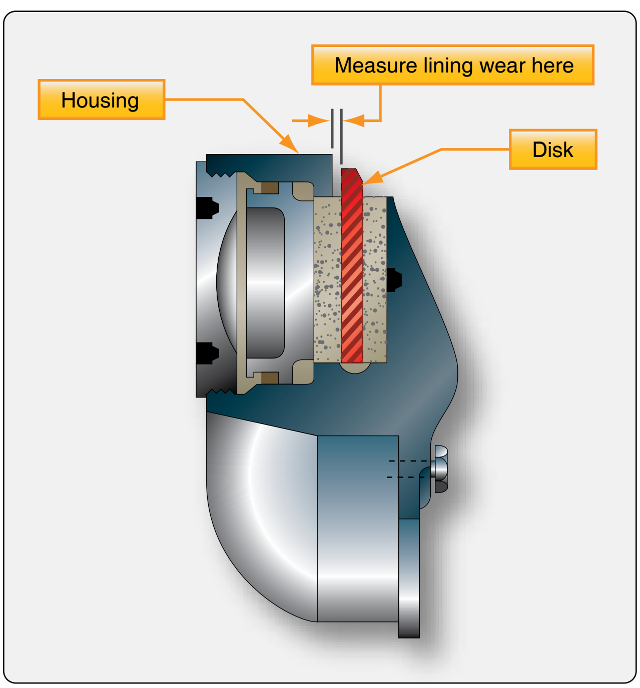

Figure 13-115. *The distance between the brake disc and the brake housing measured with the brakes applied is a means for determining brake lining wear on some brakes.*

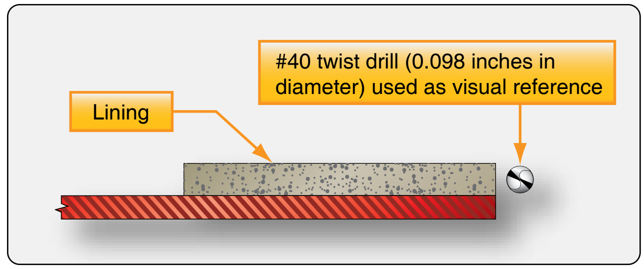

Figure 13-116. *A #40 twist drill laid next to the brake lining indicates when the lining needs to be changed on a Cleveland brake.*

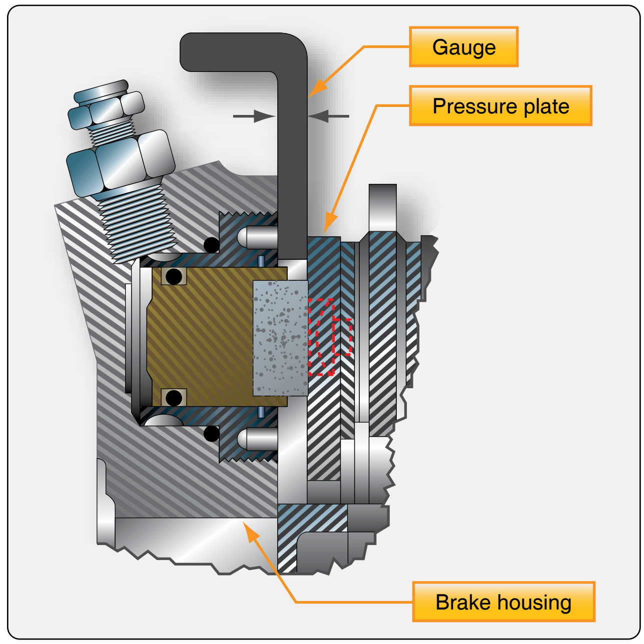

Figure 13-117. *The distance between the brake housing and the pressure plate indicates lining wear on some multiple disc brakes.*

Air in the Brake System

The presence of air in the brake system fluid causes the brake pedal to feel spongy. The air can be removed by bleeding to restore firm brake pedal feel. Brake systems must be bled according to manufacturers' instructions. The method used is matched to the type of brake system. Brakes are bled by one of two methods: top down, gravity bleeding or bottom up pressure bleeding. Brakes are bled when the pedals feel spongy or whenever the brake system has been opened.

Bleeding Master Cylinder Brake Systems

Brake systems with master cylinders may be bled by gravity or pressure bleeding methods. Follow the instructions in the aircraft maintenance manual. To pressure bleed a brake system from the bottom up, a pressure pot is used. *[Figure 13-118]* This is a portable tank that contains a supply of brake fluid under pressure. When dispersing fluid from the tank, pure air-free fluid is forced from near the bottom of the tank by the air pressure above it. The outlet hose that attaches the bleed port on the brake assembly contains a shut-off valve. Note that a similar source of pure, pressurized fluid can be substituted for a pressure tank, such as a hand-pump type unit found in some hangars.

The typical pressure bleed is accomplished as illustrated in *Figure 13-119*. The hose from the pressure tank is attached to the bleed port on the brake assembly. A clear hose is attached to the vent port on the aircraft brake fluid reservoir or on the master cylinder if it incorporates the reservoir. The other end of this hose is placed in a collection container with a supply of clean brake fluid covering the end of the hose. The brake assembly bleed port is opened. The valve on the pressure tank hose is then opened allowing pure, air-free fluid to enter the brake system. Fluid containing trapped air is expelled through the hose attached to the vent port of the reservoir. The clear hose is monitored for air bubbles. When they cease to exist, the bleed port and pressure tank shutoff are closed, and the pressure tank hose is removed. The hose at the reservoir is also removed. Fluid quantity may need to be adjusted to assure the reservoir is not over filled. Note that it is absolutely necessary that the proper fluid be used to service any brake system including when bleeding air from the brake lines.

Brakes with master cylinders may also be gravity bled from the top down. This is a process similar to that used on automobiles. *[Figure 13-120]* Additional fluid is supplied to the aircraft brake reservoir so that the quantity does not exhaust while bleeding, which would cause the reintroduction of more air into the system. A clear hose is connected to the

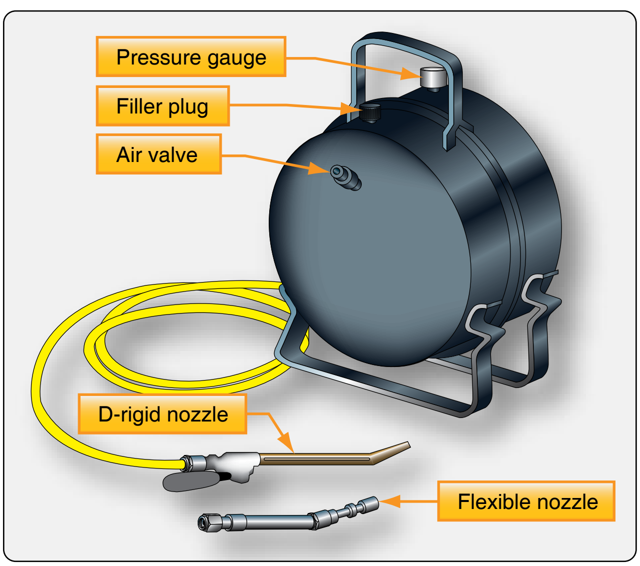

Figure 13-118. *A typical brake bleeder pot or tank contains pure brake fluid under pressure. It pushes the fluid through the brake system to displace any air that may be present.*

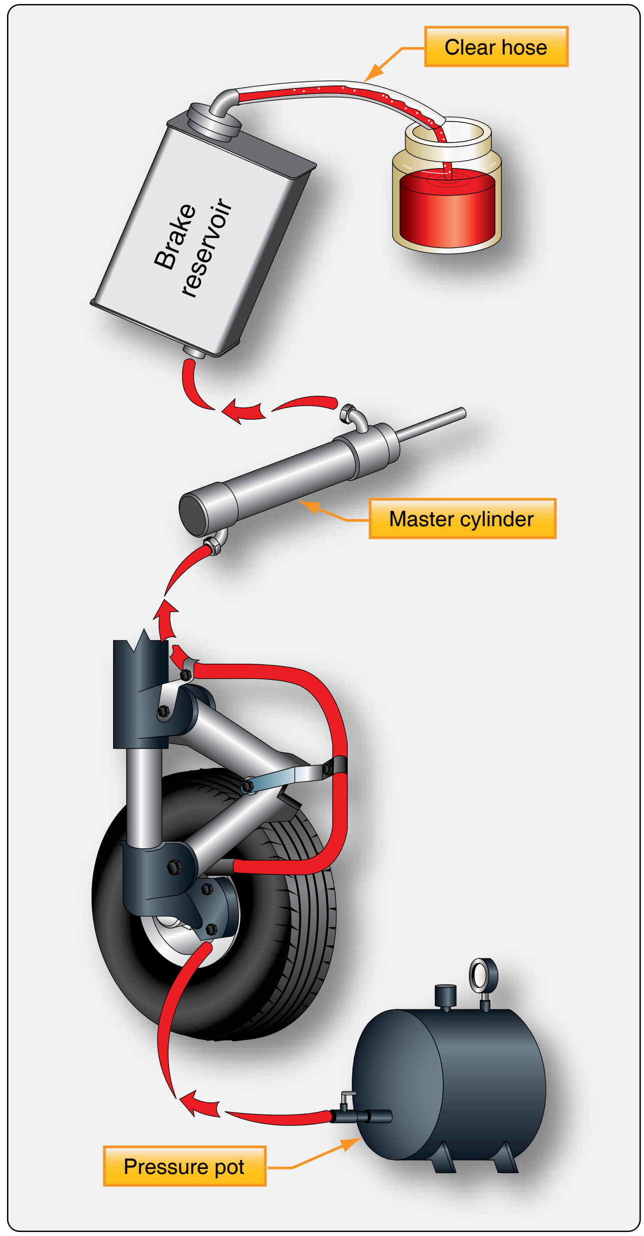

Figure 13-119. *Arrangement for bottom-up pressure bleeding of aircraft brakes. Fluid is pushed through the system until no air bubbles are visible in the hose at the top.*

bleed port on the brake assembly. The other end is submersed in clean fluid in a container large enough to capture fluid expelled during the bleeding process. Depress the brake pedal and open the brake assembly bleed port. The piston in the master cylinder travels all the way to the end of the cylinder forcing air fluid mixture out of the bleed hose and into the container. With the pedal still depressed, close the bleed port. Pump the brake pedal to introduce more fluid from the reservoir ahead of the piston in the master cylinder. Hold the pedal down and open the bleed port on the brake assembly. More fluid and air is expelled through the hose into the container. Repeat this process until the fluid exiting the brake through the hose

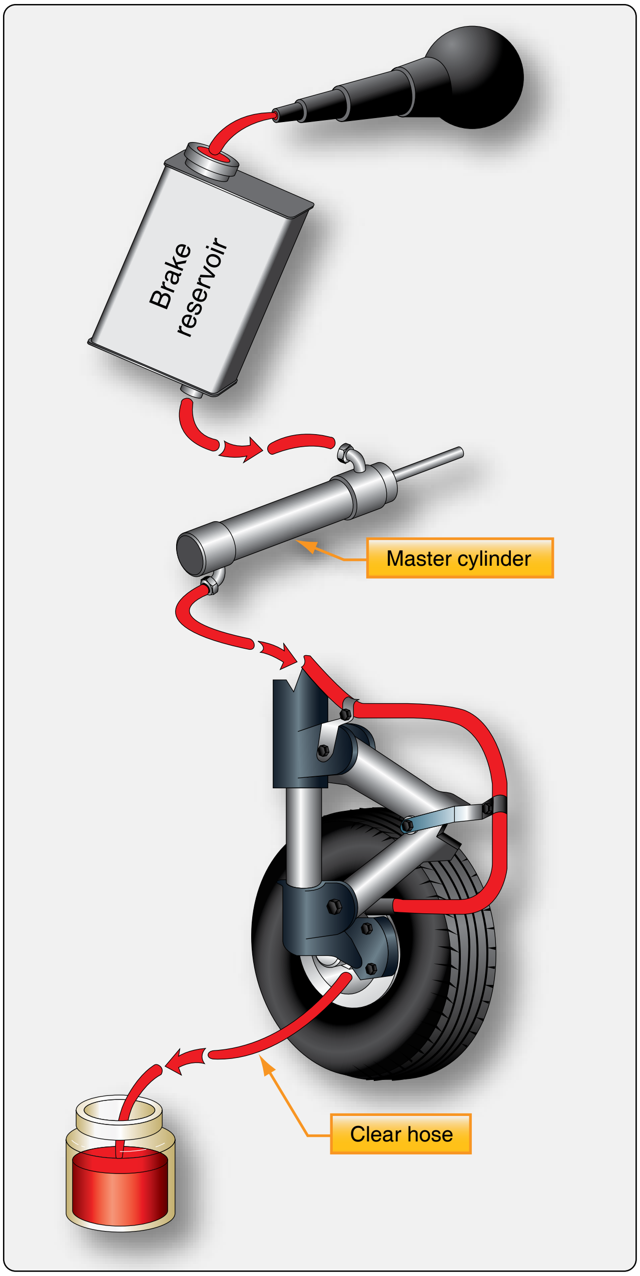

Figure 13-120. *Arrangement for top down or gravity bleeding of aircraft brakes.*

no longer contains any air. Tighten the bleed port fitting and ensure the reservoir is filled to the proper level.

Whenever bleeding the brakes, ensure that reservoirs and bleed tanks remain full during the process. Use only clean, specified fluid. Always check the brakes for proper operation, any leaks when bleeding is complete, and assure that the fluid quantity level is correct.

Bleeding Power Brake Systems

Top down brake bleeding is used in power brake systems. Power brakes are supplied with fluid from the aircraft hydraulic system. The hydraulic system should operate without air in the fluid as should the brake system. Therefore, bottom up pressure bleeding is not an option for power brakes. The trapped air in the brake system would be forced into the main hydraulic system, which is not acceptable.

Many aircraft with power brake systems accept the connection of an auxiliary hydraulic mule that can be used to establish pressure in the system for bleeding. Regardless, the aircraft system must be pressurized to bleed power brake systems. Attach a clear hose to the brake bleed port fitting on the brake assembly and immerse the other end of the hose in a container of clean hydraulic fluid. With the bleeder valve open, carefully apply the brake to allow aircraft hydraulic fluid to enter the brake system. The fluid expels the fluid contaminated with air out of the bleed hose into the container. When air is no longer visible in the hose, close the bleed valve and restore the hydraulic system to normal operation configuration.

Power brake systems on different aircraft contain many variations and a wide array of components that may affect the proper bleeding technique to be followed. Consult the manufacturer's maintenance information for the correct bleeding procedure for each aircraft. Be sure to bleed auxiliary and emergency brake systems when bleeding the normal brake system to ensure proper operation when needed.

Fluid Quantity & Type

As mentioned, it is imperative that the correct hydraulic fluid is used in each brake system. Seals in the brake system are designed for a particular hydraulic fluid. Deterioration and failure occurs when they are exposed to other fluids. Mineral-based fluid, such as MIL-H-5606 (red oil), should never be mixed with phosphate-ester based synthetic hydraulic fluid, such as Skydrol®. Contaminated brake/hydraulic systems must have all of the fluid evacuated and all seals replaced before the aircraft is released for flight.

Fluid quantity is also important. The technician is responsible for determining the method used to ascertain when the brake and hydraulic systems are fully serviced and for the maintenance of the fluid at this level. Consult the manufacturer's specifications for this information.

Inspection for Leaks

Aircraft brake systems should maintain all fluid inside lines and components and should not leak. Any evidence of a leak must be investigated for its cause. It is possible that the leak is a precursor to more significant damage that can be repaired, thus avoiding an incident or accident. *[Figure 13-121]*

Many leaks are found at brake system fittings. While this type of leak may be fixed by tightening an obviously loose connection, the technician is cautioned against over-tightening fittings. Removal of hydraulic pressure from the brake system followed by disconnection and inspection of the connectors is recommended. Over-tightening of fitting can cause damage and make the leak worse. MS flareless fitting are particularly sensitive to over-tightening. Replace all fittings suspected of damage. Once any leak is repaired, the brake system must be re-pressurized and tested for function as well as to ensure the leak no longer exists. Occasionally, a brake housing may seep fluid through the housing body. Consult the manufacturer's maintenance manual for limits and remove any brake assembly that seeps excessively.

Proper Bolt Torque

The stress experience by the landing gear and brake system requires that all bolts are properly torqued. Bolts used to attach the brakes to the strut typically have the required torque specified in the manufacturer's maintenance manual. Check for torque specifications that may exist for any landing gear and brake bolts, and ensure they are properly tightened. Whenever applying torque to a bolt on an aircraft, use of a calibrated torque wrench is required.

Off Aircraft Brake Servicing & Maintenance

Certain servicing and maintenance of an aircraft brake assembly is performed while it has been removed from the aircraft. A close inspection of the assembly and its many parts should be performed at this time. Some of the inspection items on a typical assembly follow.

Bolt & Threaded Connections

All bolts and threaded connections are inspected. They should be in good condition without signs of wear. Self-locking nuts should still retain their locking feature. The hardware should be what is specified in the brake manufacturer's parts manual. Many aircraft brake bolts, for example, are not standard hardware and may be of closer tolerance or made of a different material. The demands of the high stress environment in which the brakes perform may cause brake failure if improper substitute hardware is used. Be sure to check the condition of all threads and O-ring seating areas machined into the housing. The fittings threaded into the housing must also be checked for condition.

Figure 13-121. *The cause of all aircraft brake leaks must be investigated, repaired, and tested before releasing the aircraft for flight.*

Discs

Brake discs must be inspected for condition. Both rotating and stationary discs in a multiple disc brake can wear. Uneven wear can be an indication that the automatic adjusters may not be pulling the pressure plate back far enough to relieve all pressure on the disc stack.

Stationary discs are inspected for cracks. Cracks usually extend from the relief slots, if so equipped. On multiple disc brakes, the slots that key the disc to the torque tube must also be inspected for wear and widening. The discs should engage the torque tube without binding. The maximum width of the slots is given in the maintenance manual. Cracks or excessive key slot wear are grounds for rejection. Brake wear pads or linings must also be inspected for wear while the brake assembly is removed from the aircraft. Signs of uneven wear should be investigated, and the problem corrected. The pads may be replaced if worn beyond limits as long as the stationary disc upon which they mount passes inspection. Follow the manufacturer's procedures for inspections and for pad replacement.

Rotating discs must be similarly inspected. The general condition of the disc must be observed. Glazing can occur when a disc or part of a disc is overheated. It causes brake squeal and chatter. It is possible to resurface a glazed disc if the manufacturer allows it. Rotating discs must also be inspected in the drive key slot or drive tang area for wear and deformation. Little damage is allowed before replacement is required.

The pressure plate and back plate on multiple disc brakes must be inspected for freedom of movement, cracks, general condition, and warping. New linings may be riveted to the plates if the old linings are worn and the condition of the plate is good. Note that replacing brake pads and linings by riveting may require specific tools and technique as described in the maintenance manual to ensure secure attachment. Minor warping can be straightened on some brake assemblies.

Automatic Adjuster Pins

A malfunctioning automatic adjuster assembly can cause the brakes to drag on the rotating disc(s) by not fully releasing and pulling the lining away from the disc. This can lead to excessive, uneven lining wear and disc glazing. The return pin must be straight with no surface damage so it can pass through the grip without binding. Damage under the head can weaken the pin and cause failure. Magnetic inspection is sometimes used to inspect for cracks.

The components of the grip and tube assembly must be in good condition. Clean and inspect in accordance with the manufacturer's maintenance instructions. The grip must move with the force specified and must move through its full range of travel.

Torque Tube

A sound torque tube is necessary to hold the brake assembly stable on the landing gear. General visual inspection should be made for wear, burrs, and scratches. Magnetic particle inspection is used to check for cracks. The key areas should be checked for dimension and wear. All limits of damage are referenced in the manufacturer's maintenance data. The torque tube should be replaced if a limit is exceeded.

Brake Housing & Piston Condition

The brake housing must be inspected thoroughly. Scratches, gouges, corrosion, or other blemishes may be dressed out and the surface treated to prevent corrosion. Minimal material should be removed when doing so. Most important is that there are no cracks in the housing. Fluorescent dye penetrant is typically used to inspect for cracks. If a crack is found, the housing must be replaced. The cylinder area(s) of the housing must be dimensionally checked for wear. Limits are specified in the manufacturer's maintenance manual.

The brake pistons that fit into the cylinders in the housing must also be checked for corrosion, scratches, burrs, etc. Pistons are also dimensionally checked for wear limits specified in the maintenance data. Some pistons have insulators on the bottom. They should not be cracked and should be of a minimal thickness. A file can be used to smooth out minor irregularities.

Seal Condition

Brake seals are very important. Without properly functioning seals, brake operation will be compromised, or the brakes will fail. Over time, heat and pressure mold a seal into the seal groove and harden the material. Eventually, resilience is reduced and the seal leaks. New seals should be used to replace all seals in the brake assembly. Acquire seals by part number in a sealed package from a reputable supplier to avoid bogus seals and ensure the correct seals for the brake assembly in question. Check to ensure the new seals have not exceeded their shelf life, which is typically three years from the cure date.

Many brakes use back-up rings in the seal groove to support the O-ring seals and reduce the tendency of the seal to extrude into the space which it is meant to seal. These are often made of Teflon® or similar material. Back-up seals are installed on the side of the O-ring away from the fluid pressure. *[Figure 13-122]* They are often reusable.

Replacement of Brake Linings

In general aviation, replacement of brake linings is commonly done in the hangar. The general procedure used on two common brake assemblies is given. Follow the actual manufacturer's instruction when replacing brake linings on any aircraft brake assembly.

Goodyear Brakes

To replace the linings on a Goodyear single disc brake assembly, the aircraft must be jacked and supported. Detach the anti-rattle clips that help center the disc in the wheel before removing the wheel from the axle. The disc remains between the inner and outer lining when the wheel is removed. Extract the disc to provide access to the old lining pucks. These can be removed from the cavities in the housing and replaced with new pucks. Ensure the smooth braking surface of the puck contacts the disc. Reinsert the disc between the linings. Reinstall the wheel and anti-rattle clips. Tighten the axle nut in accordance with the manufacturer's instructions. Secure it with a cotter pin and lower the aircraft from the jack. *[Figure 13-123]*

Cleveland Brakes

The popular Cleveland brake uniquely features the ability to change the brake linings without jacking the aircraft or removing the wheel. On these assemblies, the torque plate is bolted to the strut while the remainder of the brake is assembled on the anchor bolts. The disc rides between the pressure plate and back plate. Linings are riveted to both plates. By unbolting the cylinder housing from the backplate,

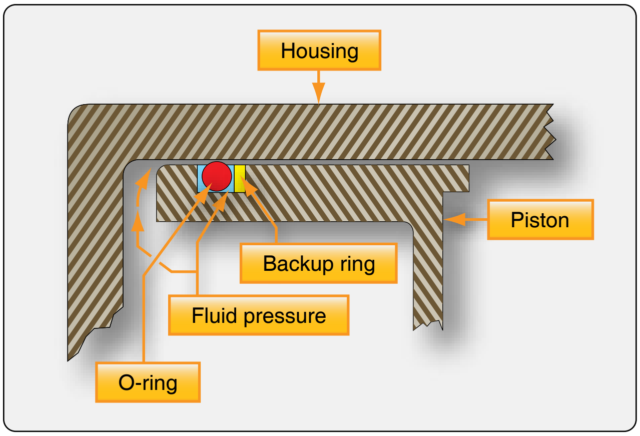

Figure 13-122. *Back-up rings are used to keep O-rings from extruding into the space between the piston and the cylinder. They are positioned on the side of the O-ring away from the fluid pressure.*

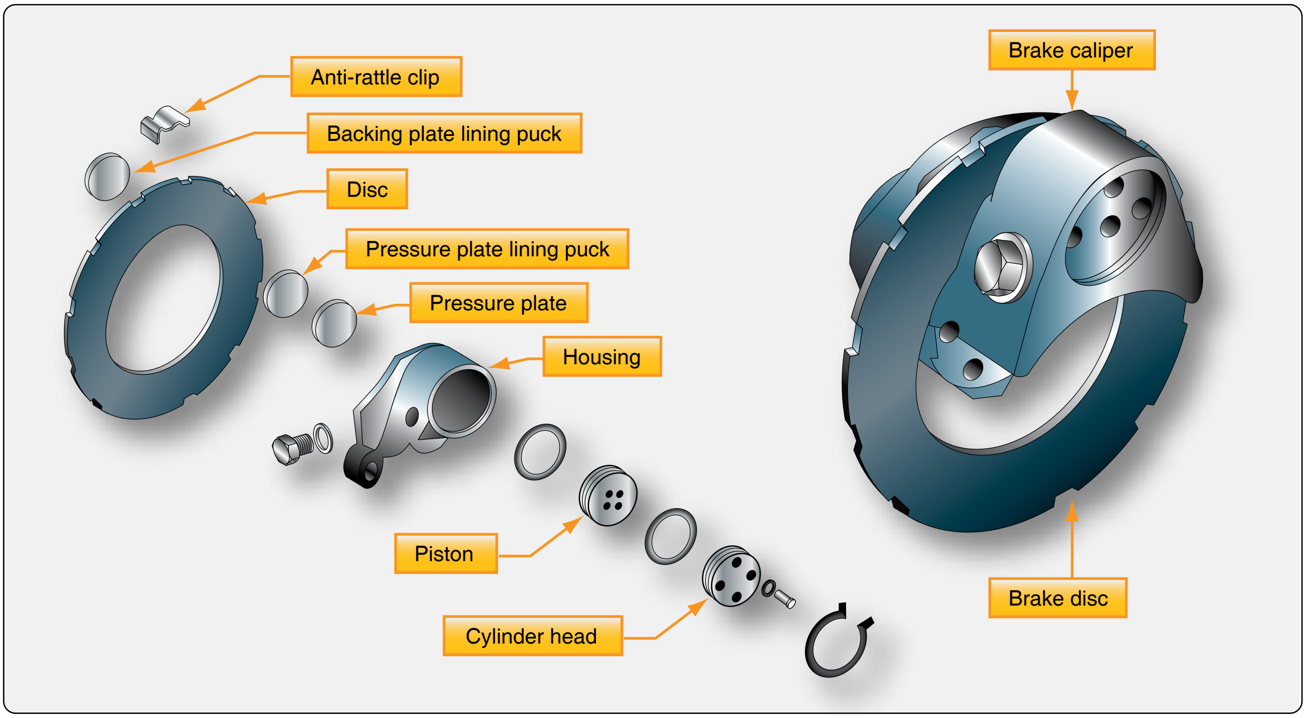

Figure 13-123. *Goodyear brake lining replacement requires that the wheel be removed from the axle to access the brake assembly. The lining pucks slip into recesses in the brake housing.*

the backplate is freed to drop away from the torque plate. The remainder of the assembly is pulled away, and the pressure plate slides off of the torque bolts. *[Figure 13-124]*

The rivets that hold the linings on the pressure plate and back plate are removed with a knockout punch. After a thorough inspection, new linings are riveted to the pressure plate and backplate using a rivet clinching tool *[Figure 13-125]* Kits are sold that supply everything needed to perform the operation. The brake is reassembled in the reverse order. Be certain to include any shims if required. The bolts holding the backplate to the cylinder assembly must be torqued according to manufacturer specifications and safetied. The manufacturer's data also provides a burn in procedure. The aircraft is taxied at a specified speed, and the brakes are smoothly applied. After a cooling period, the process is repeated, thus preparing the linings for service.

Brake Malfunctions & Damage

Aircraft brakes operate under extreme stress and varied conditions. They are susceptible to malfunction and damage. A few common brake problems are discussed in this section.

Overheating

While aircraft brakes slow the aircraft by changing kinetic energy into heat energy, overheating of the brakes is not desirable. Excessive heat can damage and distort brake parts weakening them to the point of failure. Protocol for brake usage is designed to prevent overheating. When a brake shows signs of overheating, it must be removed from the aircraft and inspected for damage. When an aircraft is involved in an aborted takeoff, the brakes must be removed and inspected to ensure they withstood this high level of use.

The typical post-overheat brake inspection involves removal of the brake from the aircraft and disassembly of the brakes. All of the seals must be replaced. The brake housing must be checked for cracks, warping, and hardness per the maintenance manual. Any weakness or loss of heat treatment could cause the brake to fail under high-pressure braking. The brake discs must also be inspected. They must not be warped, and the surface treatment must not be damaged or transferred to an adjacent disc. Once reassembled, the brake should be bench tested for leaks and pressure tested for operation before being installed on the aircraft.

Dragging

Brake drag is a condition caused by the linings not retracting from the brake disc when the brakes are no longer being applied. It can be caused by several different factors. Brakes that drag are essentially partially on at all times. This can cause excessive lining wear and overheating leading to damage to the disc(s).

A brake may drag when the return mechanism is not functioning properly. This could be due to a weak return spring, the return pin slipping in the auto adjuster pin grip,

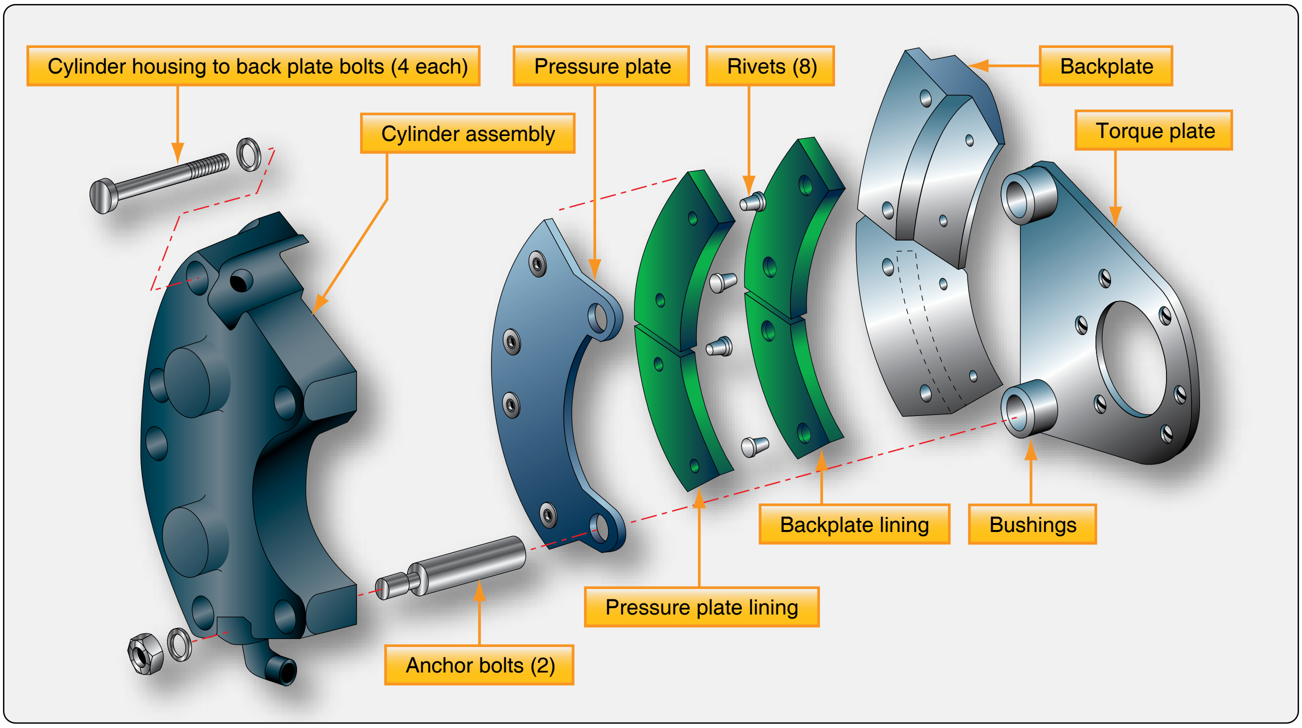

Figure 13-124. *A Cleveland brake disassembles once the four bolts holding the cylinder to the backplate are removed while the aircraft wheel remains in place. The pressure plate slides off the anchor bolts and linings can be replaced by riveting on the pressure plate and back plate.*

Figure 13-125. *Rivet setting tool is used to install brake linings on Cleveland brake pressure plates and back plates.*

or similar malfunction. Inspect the auto adjuster(s) and return units on the brake when dragging is reported. An overheated brake that has warped the disc also causes brake drag. Remove the brake and perform a complete inspection as discussed in the previous section. Air in the brake fluid line can also cause brake drag. Heat causes the air to expand, which pushes the brake linings against the disc prematurely. If no damage has been caused when reported, bleed the brakes to remove the air from the system to eliminate the drag.

At all times, the technician should perform inspections to ensure the proper parts are used in the brake assembly. Improper parts, especially in the retraction/adjuster assemblies, can cause the brakes to drag.

Chattering or Squealing

Brakes may chatter or squeal when the linings do not ride smoothly and evenly along the disc. A warped disc(s) in a multiple brake disc stack produces a condition wherein the brake is actually applied and removed many times per minute. This causes chattering and, at high frequency, it causes squealing. Any misalignment of the disc stack out of parallel causes the same phenomenon. Discs that have been overheated may have damage to the surface layer of the disc. Some of this mix may be transferred to the adjacent disc resulting in uneven disc surfaces that also leads to chatter or squeal. In addition to the noise produced by brake chattering and squealing, vibration is caused that may lead to further damage of the brake and the landing gear system. The technician must investigate all reports of brake chattering and squealing.

Aircraft Tires & Tubes

Aircraft tires may be tube-type or tubeless. They support the weight of the aircraft while it is on the ground and provide the necessary traction for braking and stopping. The tires also help absorb the shock of landing and cushion the roughness of takeoff, rollout, and taxi operations. Aircraft tires must be carefully maintained to perform as required. They accept a variety of static and dynamic stresses and must do so dependably in a wide range of operating conditions.

Tire Classification

Aircraft tires are classified in various ways including by: type, ply rating, whether they are tube-type or tubeless, and whether they are bias ply tires or radials. Identifying a tire by its dimensions is also used. Each of these classifications is discussed as follows.

Types

A common classification of aircraft tires is by type as classified by the United States Tire and Rim Association. While there are nine types of tires, only Types I, III, VII, and VIII, also known as a Three-Part Nomenclature tires, are still in production.

Type I tires are manufactured, but their design is no longer active. They are used on fixed gear aircraft and are designated only by their nominal overall diameter in inches. These are smooth profile tires that are obsolete for use in the modern aviation fleet. They may be found on older aircraft.

Type III tires are common general aviation tires. They are typically used on light aircraft with landing speeds of 160 miles per hour (mph) or less. Type III tires are relatively low-pressure tires that have small rim diameters when compared to the overall width of the tire. They are designed to cushion and provide flotation from a relatively large footprint. Type III tires are designated with a two-number system. The first number is the nominal section width of the tire, and the second number is the diameter of the rim the tire is designed to mount upon. *[Figure 13-126]*

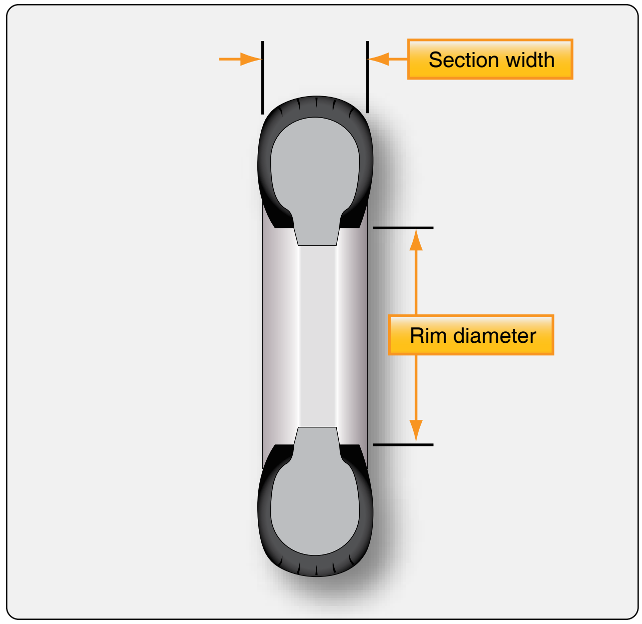

Figure 13-126. *Type III aircraft tires are identified via a two-number system with a (-) separating the numbers. The first number is the tire section width in inches. The second number is the rim diameter in inches. For example: 6.00 – 6 is a Cessna 172 tire that is 6.00 inches wide and fits on a rim that has a diameter of 6 inches.*

Type VII tires are high performance tires found on jet aircraft. They are inflated to high-pressure and have exceptional high load carrying capability. The section width of Type VII tires is typically narrower than Type III tires. Identification of Type VII aircraft tires involves a two-number system. An X is used between the two numbers. The first number designates the nominal overall diameter of the tire. The second number designates the section width. *[Figure 13-127]*

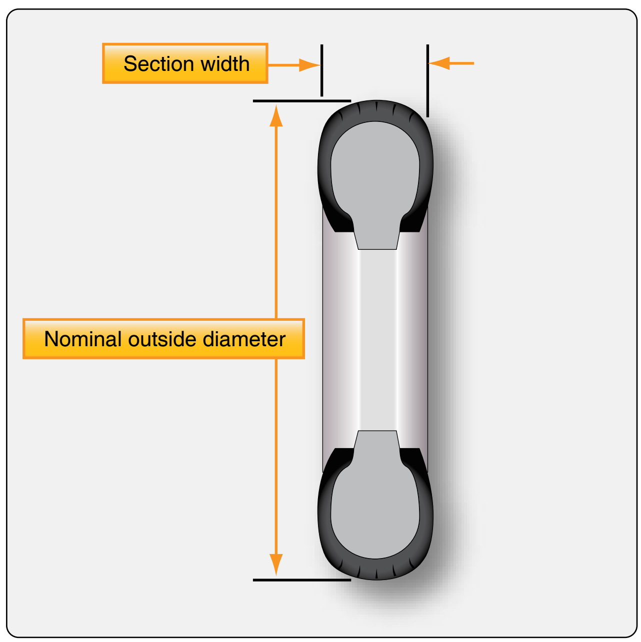

Figure 13-127. *A Type VII aircraft tire is identified by its two-number designation. The first number represents the tire's overall diameter in inches and the second number represents the section width in inches. Type VII designators separate the first and second number an "X." For example: 26 X 6.6 identifies a tire that is 26 inches in diameter with a 6.6-inch nominal width.*

Type VIII aircraft tires are also known as three-part nomenclature tires. *[Figure 13-128]* They are inflated to very high-pressure and are used on high-performance jet aircraft. The typical Type VIII tire has relatively low profile and is capable of operating at very high speeds and very high loads. It is the most modern design of all tire types. The three-part nomenclature is a combination of Type III and Type VII nomenclature where the overall tire diameter, section

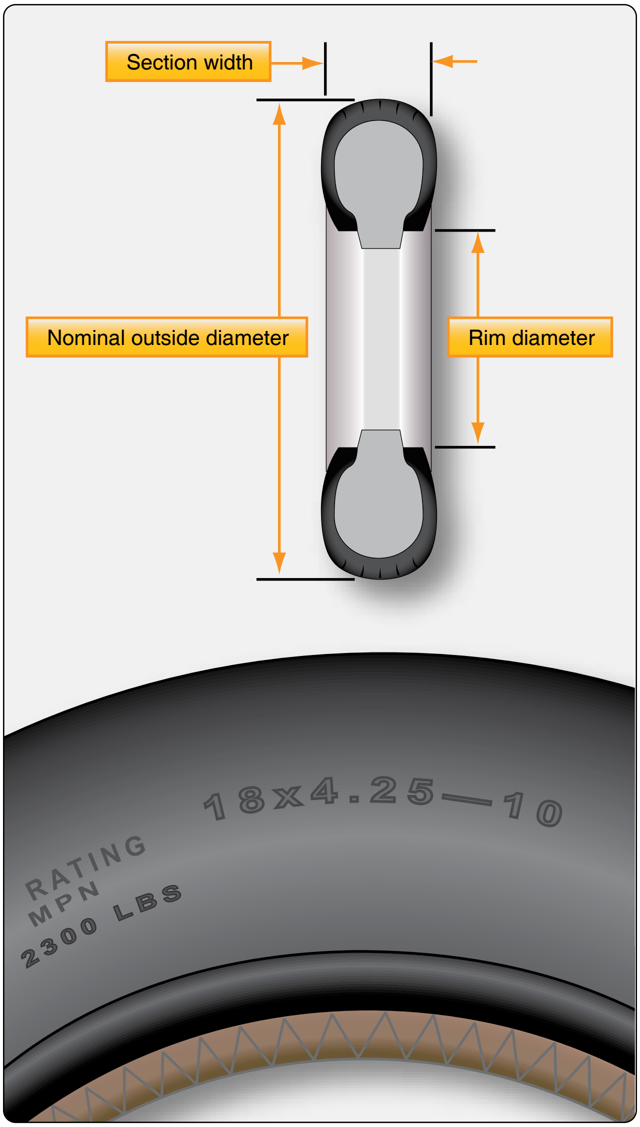

Figure 13-128. *A Type VIII or three-part nomenclature tire is identified by 3 parameters: overall diameter, section width, and rim diameter. They are arranged in that order with the first two separated by an "X" and the second two separated by a "–." For example: 18 X 4.25—10 designates a tire that is 18 inches in diameter with a 4.25-inch section width to be mounted on a 10-inch wheel rim.*

width, and rim diameter are used to identify the tire. The X and "–" symbols are used in the same respective positions in the designator.

When three-part nomenclature is used on a Type VIII tire, dimensions may be represented in inches or in millimeters. Bias tires follow the designation nomenclature and radial tires replace the "–" with the letter R. For example, 30 X 8.8 R 15 designates a Type VIII radial aircraft tire with a 30-inch tire diameter, an 8.8-inch section width to be mounted on a 15-inch wheel rim.

A few special designators may also be found for aircraft tires. When a B appears before the identifier, the tire has a wheel rim to section width ratio of 60 to 70 percent with a bead taper of 15 degrees. When an H appears before the identifier, the tire has a 60 to 70 percent wheel rim to section width ratio but a bead taper of only 5 degrees.

Ply Rating

Tire plies are reinforcing layers of fabric encased in rubber that are laid into the tire to provide strength. In early tires, the number of plies used was directly related to the load the tire could carry. Nowadays, refinements to tire construction techniques and the use of modern materials to build up aircraft tires makes the exact number of plies somewhat irrelevant when determining the strength of a tire. However, a ply rating is used to convey the relative strength of an aircraft tire. A tire with a high ply rating is a tire with high strength able to carry heavy loads regardless of the actual number of plies used in its construction.

Tube-Type or Tubeless

As stated, aircraft tires can be tube-type or tubeless. This is often used as a means of tire classification. Tires that are made to be used without a tube inserted inside have an inner liner specifically designed to hold air. Tube-type tires do not contain this inner liner since the tube holds the air from leaking out of the tire. Tires that are meant to be used without a tube have the word tubeless on the sidewall. If this designation is absent, the tire requires a tube. Consult the aircraft manufacturer's maintenance information for any allowable tire damage and the use of a tube in a tubeless tire.

Bias Ply or Radial

Another means of classifying an aircraft tire is by the direction of the plies used in construction of the tire, either bias or radial. Traditional aircraft tires are bias ply tires. The plies are wrapped to form the tire and give it strength. The angle of the plies in relation to the direction of rotation of the tire varies between 30° and 60°. In this manner, the plies have the bias of the fabric from which they are constructed facing the direction of rotation and across the tire. Hence, they are called bias tires. The result is flexibility as the sidewall can flex with the fabric plies laid on the bias. *[Figure 13-129]*

Some modern aircraft tires are radial tires. The plies in radial tires are laid at a 90° angle to the direction of rotation of the tire. This configuration puts the non-stretchable fiber of the plies perpendicular to the sidewall and direction of rotation. This creates strength in the tire allowing it to carry high loads with less deformation. *[Figure 13-130]*

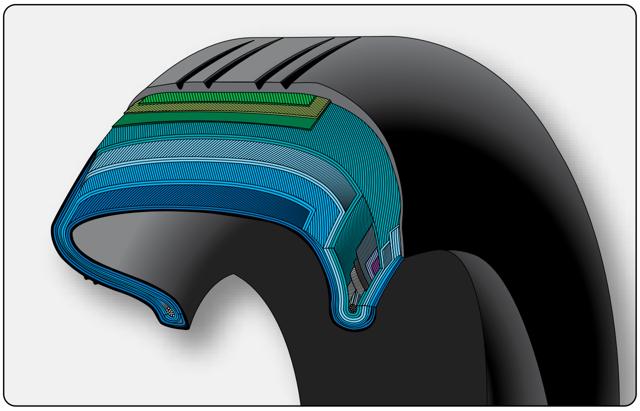

Figure 13-129. *A bias ply tire has the fabric bias oriented with and across the direction of rotation and the sidewall. Since fabric can stretch on the bias, the tire is flexible, and can absorb loads. Strength is obtained by adding plies.*

Tire Construction

An aircraft tire is constructed for the purpose it serves. Unlike an automobile or truck tire, it does not have to carry a load for a long period of continuous operation. However, an aircraft tire must absorb the high impact loads of landing and be able to operate at high speeds even if only for a short time. The deflection built into an aircraft tire is more than twice that of an automobile tire. This enables it to handle the forces during landings without being damaged. Only tires designed for an aircraft as specified by the manufacturer should be used.

It is useful to the understanding of tire construction to identify the various components of a tire and the functions contributed to the overall characteristics of a tire. Refer to *Figure 13-131* for tire nomenclature used in this discussion.

Bead

The tire bead is an important part of an aircraft tire. It anchors the tire carcass and provides a dimensioned, firm mounting surface for the tire on the wheel rim. Tire beads are strong.

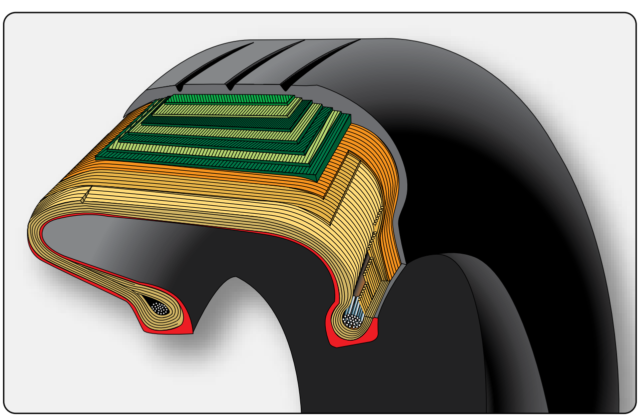

Figure 13-130. *A radial tire has the fiber strands of the ply fabric oriented with and at 90° to the direction of rotation and the tire sidewall. This restricts flexibility directionally and the flexibility of the sidewall while it strengthens the tire to carry heavy loads.*

They are typically made from high-strength carbon steel wire bundles encased in rubber. One, two, or three bead bundles may be found on each side of the tire depending on its size and the load it is designed to handle. Radial tires have a single bead bundle on each side of the tire. The bead transfers the impact loads and deflection forces to the wheel rim. The bead toe is closest to the tire centerline and the bead heel fit against the flange of the wheel rim.

An apex strip is additional rubber formed around the bead to give a contour for anchoring the ply turn-ups. Layers of fabric and rubber called flippers are placed around the beads to insulate the carcass from the beads and improve tire durability. Chafers are also used in this area. Chafer strips made of fabric or rubber are laid over the outer carcass plies after the plies are wrapped around the beads. The chafers protect the carcass from damage during mounting and demounting of the tire. They also help reduce the effects of wear and chafing between the wheel rim and the tire bead especially during dynamic operations.

Carcass Plies

Carcass plies, or casing plies as they are sometimes called, are used to form the tire. Each ply consists of fabric, usually nylon, sandwiched between two layers of rubber. The plies are applied in layers to give the tire strength and form the carcass body of the tire. The ends of each ply are anchored by wrapping them around the bead on both sides of the tire to form the ply turn-ups. As mentioned, the angle of the fiber in the ply is manipulated to create a bias tire or radial tire as desired. Typically, radial tires require fewer plies than bias tires.

Once the plies are in place, bias tires and radial tires each have their own type of protective layers on top of the plies but under the tread of the running surface of the tire. On bias tires, these single or multiple layers of nylon and rubbers are called tread reinforcing plies. On radial tires, an undertread and a protector ply do the same job. These additional plies stabilize and strengthen the crown area of the tire. They reduce tread distortion under load and increase stability of the tire at high speeds. The reinforcing plies and protector plies also help resist puncture and cutting while protecting the carcass body of the tire.

Tread

The tread is the crown area of the tire designed to come in contact with the ground. It is a rubber compound formulated to resist wear, abrasion, cutting, and cracking. It also is made to resist heat build-up. Most modern aircraft tire tread is formed with circumferential grooves that create tire ribs. The grooves provide cooling and help channel water from under the tire in wet conditions to increase adhesion to the ground surface.

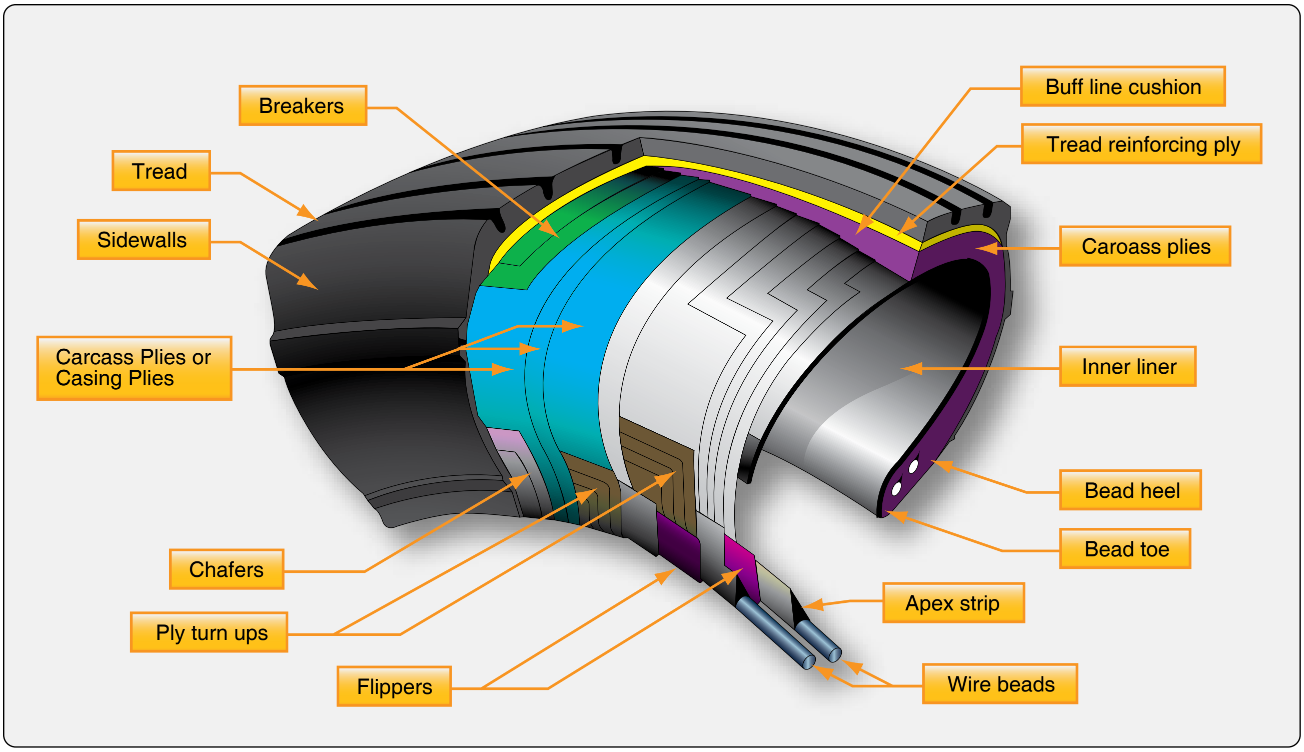

Figure 13-131. *Construction nomenclature of an aircraft tire.*

Tires designed for aircraft frequently operated from unpaved surfaces may have some type of cross-tread pattern. Older aircraft without brakes or brakes designed only to aid in taxi may not have any grooves in the tread. An all-weather tread may be found on some aircraft tires. This tread has typical circumferential ribs in the center of the tire with a diamond patterned cross tread at the edge of the tire. [*Figure 13-132*]

The tread is designed to stabilize the aircraft on the operating surface and wears with use. Many aircraft tires are designed with protective undertread layers as described above. Extra tread reinforcement is sometimes accomplished with breakers. These are layers of nylon cord fabric under the tread that strengthen the tread while protecting the carcass plies. Tires with reinforced tread are often designed to be re-treaded and used again once the tread has worn beyond limits. Consult the tire manufacturer's data for acceptable tread wear and re-tread capability for a particular tire.

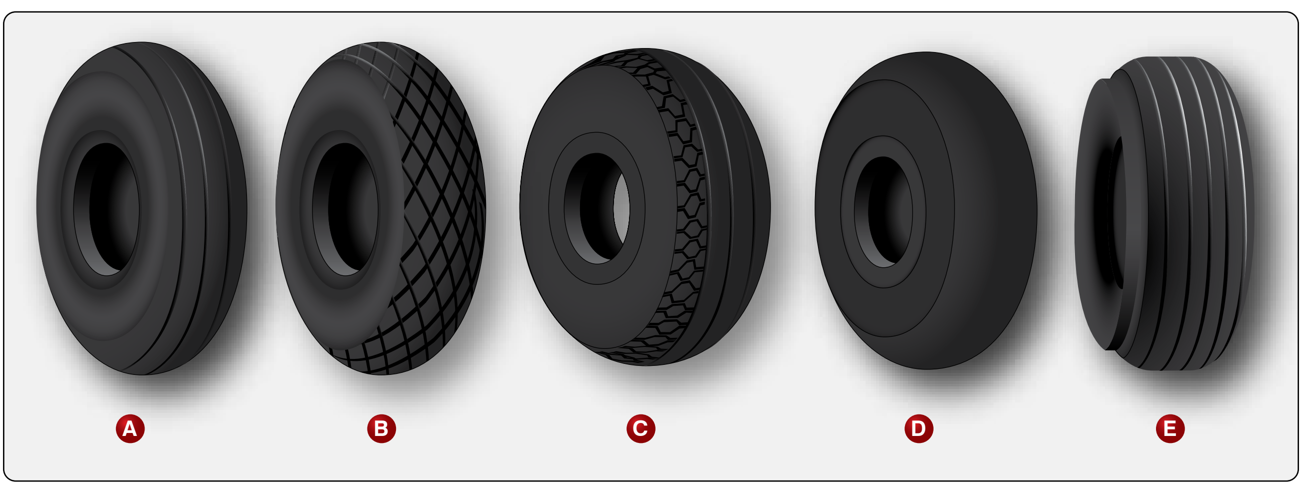

Figure 13-132. *Aircraft tire treads are designed for different uses. A is a rib tread designed for use on paved surfaces. It is the most common aircraft tire tread design. B is a diamond tread designed for unpaved runways. C is an all weather tread that combines a ribbed center tread with a diamond tread pattern of the edges. D is a smooth tread tire found on older, slow aircraft without brakes designed for stopping. E is a chine tire used on the nose gear of aircraft with fuselage mounted jet engines to deflect runway water away from the engine intake(s).*

Figure 13-133. *A sidewall vent marked by a colored dot must be kept free from obstruction to allow trapped air or nitrogen to escape from the carcass plies of the tire.*

Sidewall

The sidewall of an aircraft tire is a layer of rubber designed to protect the carcass plies. It may contain compounds designed to resist the negative effects of ozone on the tire. It also is the area where information about the tire is contained. The tire sidewall imparts little strength to the cord body. Its main function is protection.

The inner sidewall of a tire is covered by the tire inner liner. A tube-type tire has a thin rubber liner adhered to the inner surface to prevent the tube from chafing on the carcass plies. Tubeless tires are lined with a thicker, less permeable rubber. This replaces the tube and contains the nitrogen or inflation air within the tire and keeps from seeping through the carcass plies.

The inner liner does not contain 100 percent of the inflation gas. Small amounts of nitrogen or air seep through the liner into the carcass plies. This seepage is released through vent holes in the lower outer sidewall of the tires. These are typically marked with a green or white dot of paint and must be kept unobstructed. Gas trapped in the plies could expand with temperature changes and cause separation of the plies, thus weakening the tire leading to tire failure. Tube-type tires also have seepage holes in the sidewall to allow air trapped between the tube and the tire to escape. *[Figure 13-133]*

Chine

Some tire sidewalls are mounded to form a chine. A chine is a special built-in deflector used on nose wheels of certain aircraft, usually those with fuselage mounted engines. The chine diverts runway water to the side and away from the intake of the engines. *[Figure 13-132E]* Tires with a chine on both sidewalls are produced for aircraft with a single nose wheel.

Tire Inspection on the Aircraft

Tire condition is inspected while mounted on the aircraft on a regular basis. Inflation pressure, tread wear and condition, and sidewall condition are continuously monitored to ensure proper tire performance.

Inflation

To perform as designed, an aircraft tire must be properly inflated. The aircraft manufacturer's maintenance data must be used to ascertain the correct inflation pressure for a tire on a particular aircraft. Do not inflate to a pressure displayed on the sidewall of the tire or by how the tire looks. Tire pressure is checked while under load and is measured with the weight of the aircraft on the wheels. Loaded versus unloaded pressure readings can vary as much as 4 percent. Tire pressure measured with the aircraft on jacks or when the tire is not installed is lower due to the larger volume of the inflation gas space inside of the tire. On a tire designed to be inflated to 160 psi, this can result in a 6.4 psi error. A calibrated pressure gauge should always be used to measure inflation pressure. Digital and dial-type pressure gauges are more consistently accurate and preferred. *[Figure 13-134]*

Aircraft tires disperse the energy from landing, rollout, taxi, and takeoff in the form of heat. As the tire flexes, heat builds and is transferred to the atmosphere, as well as to the wheel rim through the tire bead. Heat from braking also heats the tire externally. A limited amount of heat is able to be handled by any tire beyond which structural damage occurs.

An improperly inflated aircraft tire can sustain internal damage that is not readily visible and that can lead to tire failure. Tire failure upon landing is always dangerous. An aircraft tire is designed to flex and absorb the shock of landing. Temperature rises as a result. However, an underinflated tire may flex beyond design limits of the tire. This causes excessive heat build-up that weakens the carcass construction. To ensure tire temperature is maintained within limits, tire pressure must be checked and maintained within the proper range on a daily basis or before each flight if the aircraft is only flown periodically. Important reasons for maintaining proper tire pressure are to prolong tire life and prevent tire damage.

Tire pressure should be measured at ambient temperature. Fluctuations of ambient temperature greatly affect tire pressure and complicate maintenance of pressure within the allowable range for safe operation. Tire pressure typically changes 1 percent for every 5 °F of temperature change. When aircraft are flown from one environment to another, ambient temperature differences can be vast. Maintenance personnel must ensure that tire pressure is adjusted accordingly. For

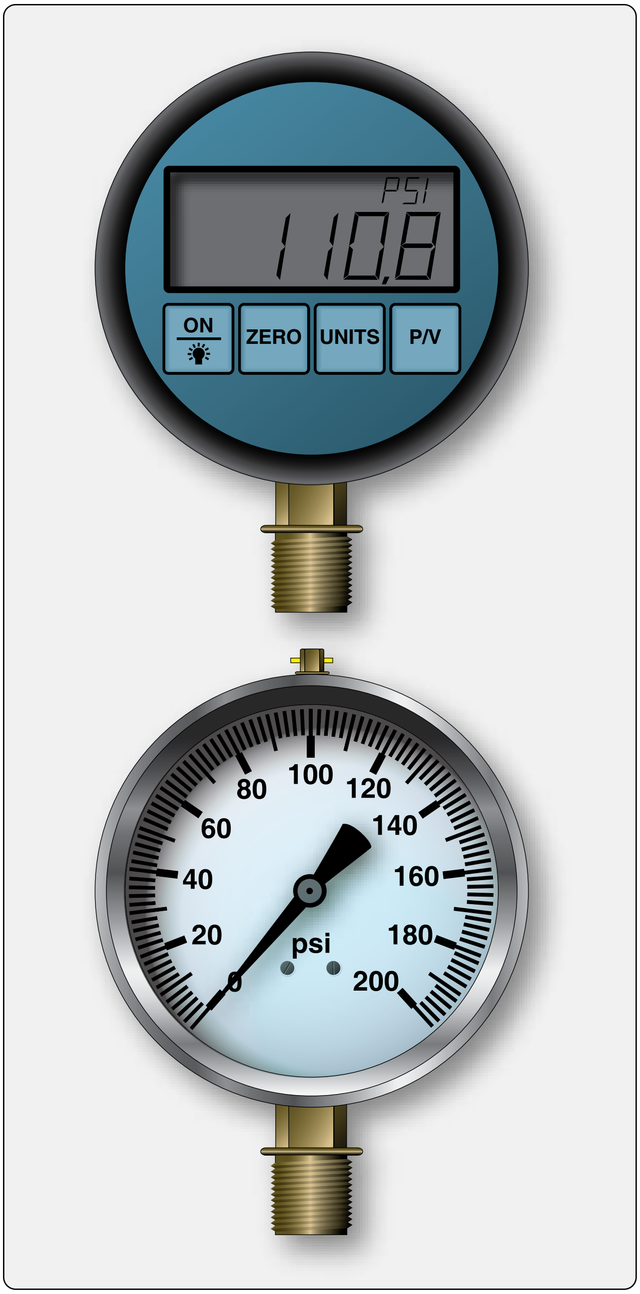

Figure 13-134. *A calibrated bourdon tube dial-type pressure gauge or a digital pressure gauge is recommended for checking tire pressure.*

example, an aircraft with the correct tire pressure departing Phoenix, Arizona where the ambient temperature is 100 °F arrives in Vail, Colorado where the temperature is 50 °F. The 50° difference in ambient temperature results in a 10 percent reduction in tire pressure. Therefore, the aircraft could land with underinflated tires that may be damaged due to over-temperature from flexing beyond design limits as described above. An increase in tire pressure before takeoff in Phoenix, Arizona prevents this problem as long as the tires are not inflated beyond the allowable limit provided in the maintenance data.

When checking tire pressure, allow 3 hours to elapse after a typical landing to ensure the tire has cooled to ambient temperature. The correct tire pressure for each ambient temperature is typically provided by the manufacturer on a table or graph.

In addition to overheating, under inflated aircraft tires wear unevenly, which leads to premature tire replacement. They may also creep or slip on the wheel rim when under stress or when the brakes are applied. Severely under inflated tires can pinch the sidewall between the rim and the runway causing sidewall and rim damage. Damage to the bead and lower sidewall area are also likely. This type of abuse like any over flexing damages the integrity of the tire and it must be replaced. In dual-wheel setups, a severely underinflated tire affects both tires and both should be replaced.

Over inflation of aircraft tires is another undesirable condition. While carcass damage due to overheating does not result, adherence to the landing surface is reduced. Over a long period of time, over inflation leads to premature tread wear. Therefore, over inflation reduces the number of cycles in service before the tire must be replaced. It makes the tire more susceptible to bruises, cutting, shock damage, and blowout. *[Figure 13-135]*

Tread Condition

Condition of an aircraft tire tread is able to be determined while the tire is inflated and mounted on the aircraft. The following is a discussion of some of the tread conditions and damage that the technician may encounter while inspecting tires.

Tread Depth & Wear Pattern

Evenly worn tread is a sign of proper tire maintenance. Uneven tread wear has a cause that should be investigated and corrected. Follow all manufacturer instructions specific to the aircraft when determining the extent and serviceability of a worn tire. In the absence of this information, remove any tire that has been worn to the bottom of a tread groove along more than ⅛ of the circumference of the tire. If either the protector ply on a radial tire or the reinforcing ply on a bias tire is exposed for more than ⅛ of the tire circumference, the tire should also be removed. A properly maintained evenly worn tire usually reaches its wear limits at the centerline of the tire. *[Figure 13-136]*

Asymmetrical tread wear may be caused by the wheels being out of alignment. Follow the manufacturer's instructions while checking caster, camber, toe-in, and toe-out to correct this situation. Occasionally, asymmetrical tire wear is a result of landing gear geometry that cannot, or is not, required to be corrected. It may also be caused by regular taxiing on a single

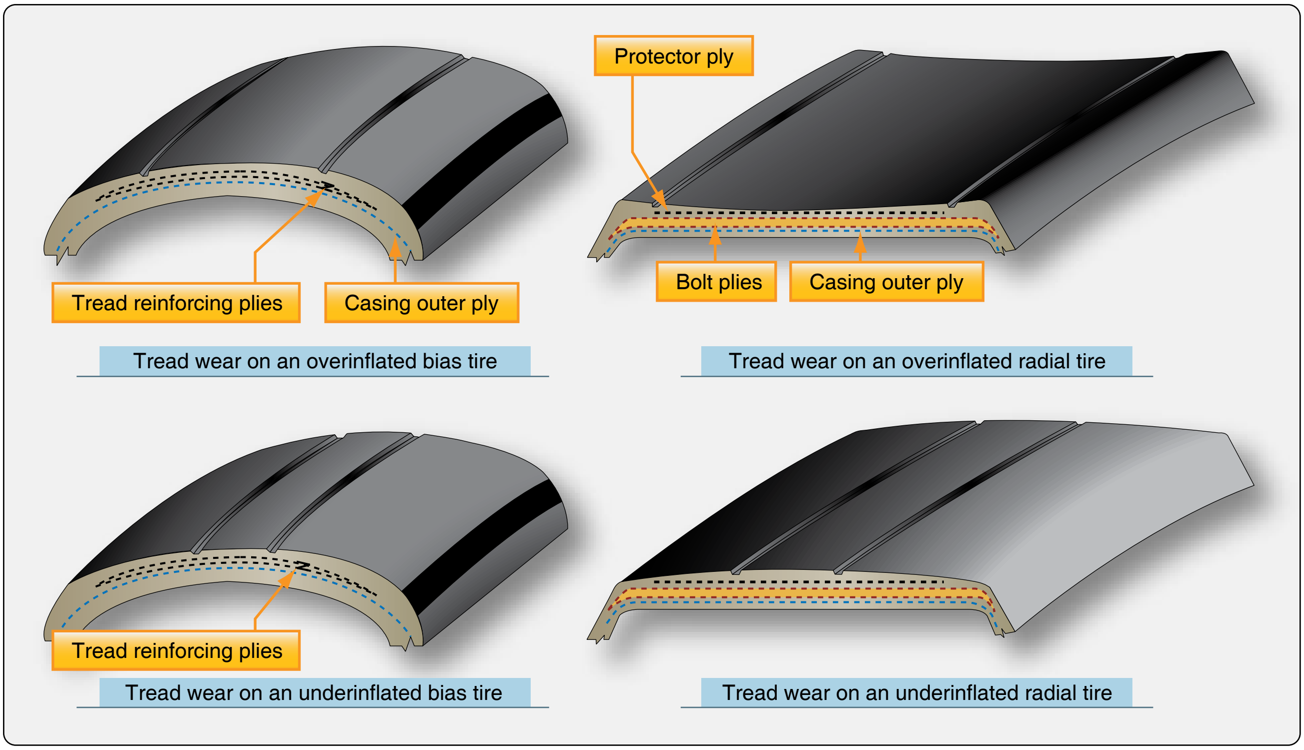

Figure 13-135. *Tires that are overinflated lack adherence to the runway and develop excess tread wear in the center of the tread. Tires that are underinflated develop excess tread wear on the tire shoulders. Overheating resulting in internal carcass damage and potential failure are possible from flexing the tire beyond design limits.*

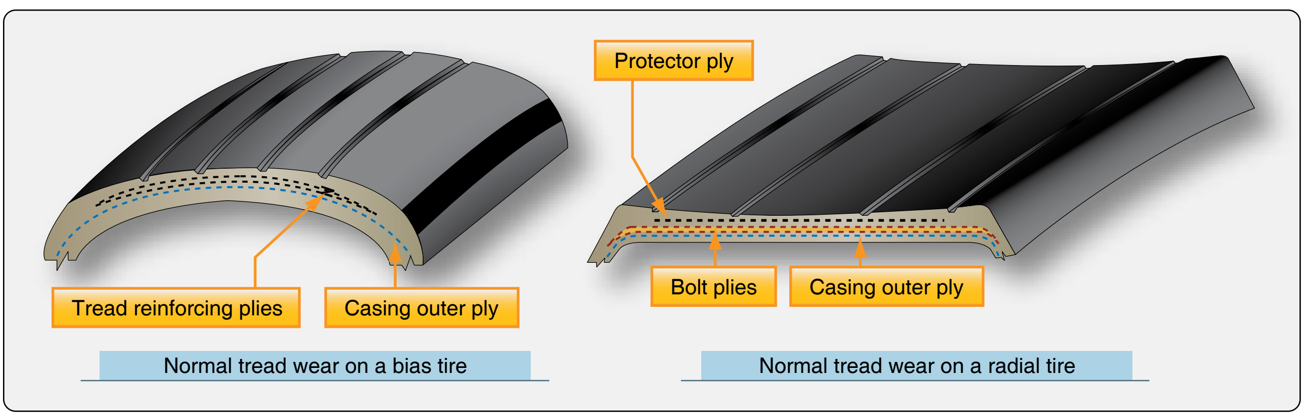

Figure 13-136. *Normal tire wear.*

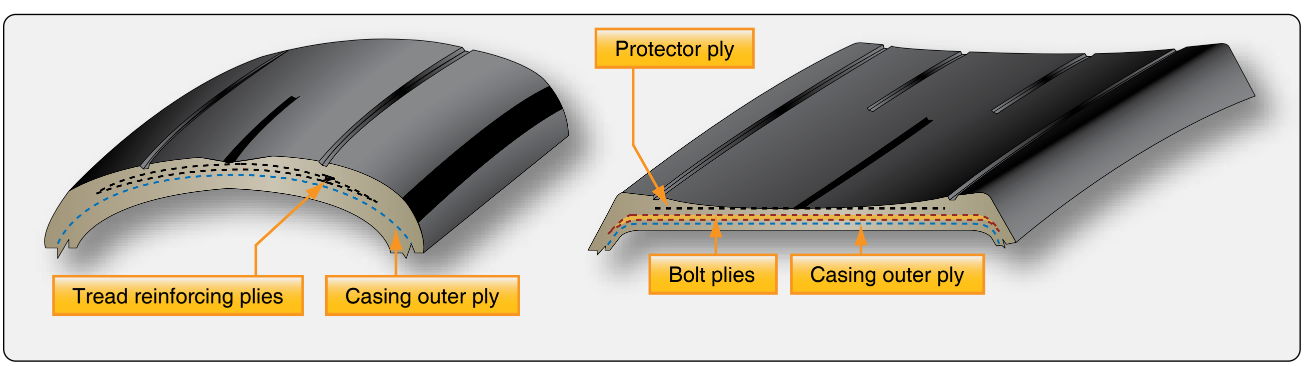

Figure 13-137. *Tread wear on a bias ply tire (left) and a radial tire (right) show wear beyond limits of serviceability but still eligible to be retreaded.*

Figure 13-138. *Marking of damaged area to enable closer inspection.*

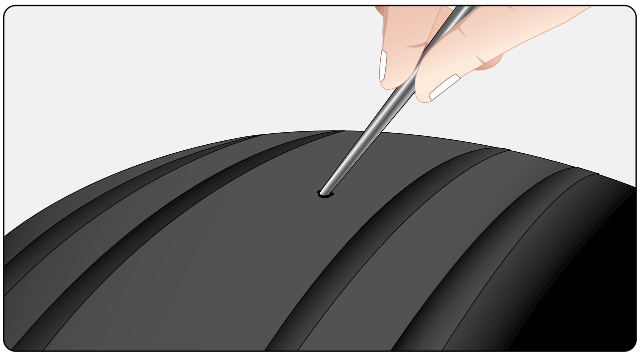

Figure 13-139. *Deflate a tire before removing or probing any area where a foreign object is lodged.*

engine or high-speed cornering while taxiing. It is acceptable to remove the tire from the wheel rim, turn it around, and remount it to even up tread wear if the tire passes all other criterion of inspection for serviceability.

Removal of a tire before it is worn beyond limits to be eligible for retreading is cost effective and good maintenance practice. Considerable traction is lost when tire tread is severely worn and must also be considered when inspecting a tire for condition. *[Figure 13-137]* Consult airframe manufacturer and tire manufacturer specifications for wear and retread limitations.

Tread Damage

In addition to tread wear, an aircraft tire should be inspected for damage. Cuts, bruises, bulges, imbedded foreign objects, chipping, and other damage must be within limits to continue the tire in service. Some acceptable methods of dealing with this type of damage are described below. All damage, suspected damage, and areas with leaks should be marked with chalk, a wax marker, paint stick, or other device before the tire is deflated or removed. Often, it is impossible to relocate these areas once the tire is deflated. Tires removed

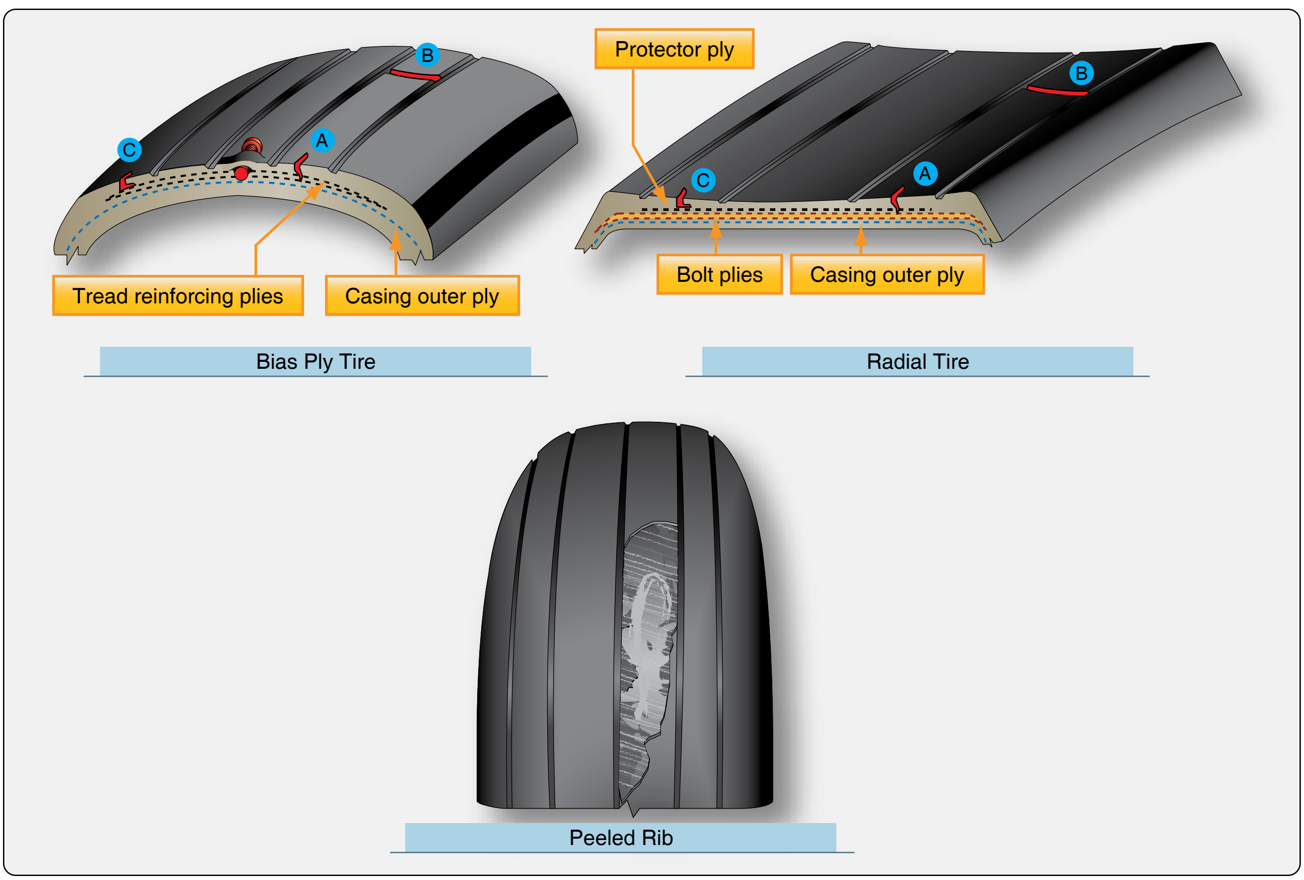

Figure 13-140. *Remove an aircraft tire from service when the depth of a cut exposes the casing outer plies of a bias ply tire or the outer belt layer of a radial tire (A); a tread rib has been severed across the entire width (B); or, when undercutting occurs at the base of any cut (C). These conditions may lead to a peeled rib.*

for retread should be marked in damaged areas to enable closer inspection of the extent of the damage before the new tread is installed. *[Figure 13-138]*

Foreign objects imbedded in a tire's tread are of concern and should be removed when not imbedded beyond the tread. Objects of questionable depth should only be removed after the tire has been deflated. A blunt awl or appropriately sized screwdriver can be used to pry the object from the tread. Care must be exercised to not enlarge the damaged area with the removal tool. *[Figure 13-139]* Once removed, assess the remaining damage to determine if the tire is serviceable. A round hole caused by a foreign object is acceptable only if it is ⅜-inch or less in diameter. Embedded objects that penetrate or expose the casing cord body of a bias ply tire or the tread belt layer of a radial tire cause the tire to become unairworthy and it must be removed from service.

Cuts and tread undercutting can also render a tire unairworthy. A cut that extends across a tread rib is cause for tire removal. These can sometimes lead to a section of the rib to peel off the tire. *[Figure 13-140]* Consult the aircraft maintenance manual, airline operations manual, or other technical documents applicable to the aircraft tire in question.

A flat spot on a tire is the result of the tire skidding on the runway surface while not rotating. This typically occurs when the brakes lock on while the aircraft is moving. If the flat spot damage does not expose the reinforcing ply of a bias tire or the protector ply of a radial tire, it may remain in service. However, if the flat spot causes vibration, the tire must be removed. Landing with a brake applied can often cause a severe flat spot that exposes the tire under tread. It can also cause a blowout. The tire must be replaced in either case. *[Figure 13-141]*

A bulge or separation of the tread from the tire carcass is cause for immediate removal and replacement of the tire. Mark the

Figure 13-141. *Landing with the brake on causes a tire flat spot that exposes the under tread and requires replacement of the tire.*

area before deflation as it could easily become undetectable without air in the tire. *[Figure 13-142]*

Operation on a grooved runway can cause an aircraft tire tread to develop shallow chevron shaped cuts. These cuts are allowed for continued service, unless chunks or cuts into the fabric of the tire result. Deep chevrons that cause a chunk of the tread to be removed should not expose more than 1 square inch of the reinforcing or protector ply. Consult the applicable inspection parameters to determine the allowable extent of chevron cutting. *[Figure 13-143]*

Tread chipping and chunking sometimes occurs at the edge of the tread rib. Small amounts of rubber lost in this way are permissible. Exposure of more than 1 square inch of the reinforcing or protector ply is cause for removal of the tire. *[Figure 13-144]*

Cracking in a tread groove of an aircraft tire is generally not acceptable if more than ¼-inch of the reinforcing or protector ply is exposed. Groove cracks can lead to undercutting of

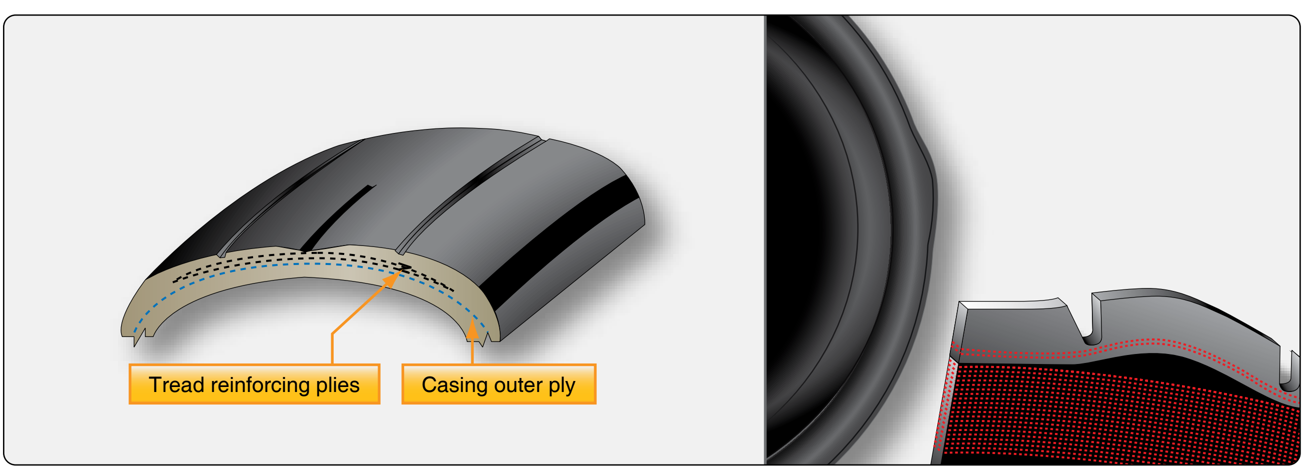

Figure 13-142. *Bulges and tread separation are cause for removal of a tire from service.*

Figure 13-143. *Chevron cuts in a tire are caused by operation on grooved runway surfaces. Shallow chevron cuts are permitted on aircraft tires.*

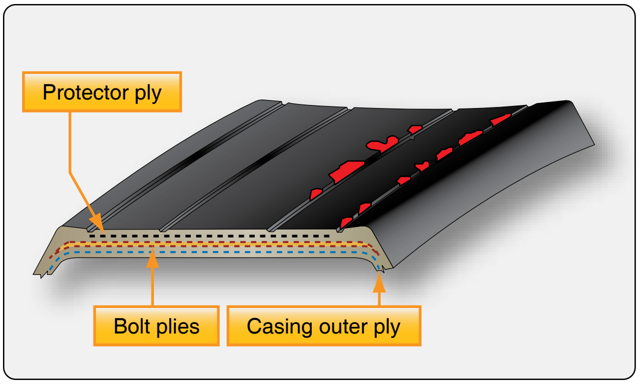

Figure 13-144. *Tread chipping and chunking of a tire requires that the tire be removed from service if more than 1 square inch of the reinforcing ply or protector ply is exposed.*

the tread, which eventually can cause the entire tread to be thrown from the tire. *[Figure 13-145]*

Oil, hydraulic fluid, solvents, and other hydrocarbon substances contaminate tire rubber, soften it, and make it spongy. A contaminated tire must be removed from service. If any volatile fluids come in contact with the tire, it is best to wash the tire or area of the tire with denatured alcohol followed by soap and water. Protect tires from contact with potentially harmful fluids by covering tires during maintenance in the landing gear area.

Tires are also subject to degradation from ozone and weather. Tires on aircraft parked outside for long periods of times can be covered for protection from the elements. *[Figure 13-146]*

Sidewall Condition

The primary function of the sidewall of an aircraft tire is protection of the tire carcass. If the sidewall cords are exposed due to a cut, gouge, snag, or other injury, the tire must be replaced. Mark the area of concern before removal of the tire. Damage to the sidewall that does not reach the cords is typically acceptable for service. Circumferential cracks or slits in the sidewall are unacceptable. A bulge in a tire sidewall indicates possible delamination of the sidewall carcass plies. The tire must immediately be removed from service.

Weather and ozone can cause cracking and checking of the sidewall. If this extends to the sidewall cords, the tire must be removed from service. Otherwise, sidewall checking as show in *Figure 13-147* does not affect the performance of the tire and it may remain in service.

Tire Removal

Removal of any tire and wheel assembly should be accomplished following all aircraft manufacturer's instructions for the procedure. Safety procedures are designed for the protection of the technician and the maintenance of aircraft parts in serviceable condition. Follow all safety

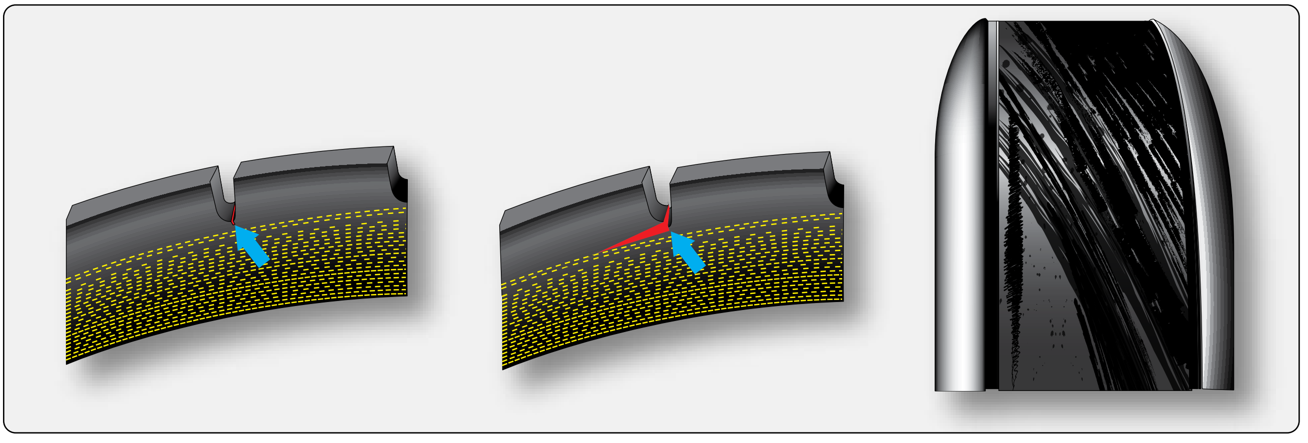

Figure 13-145. *A thrown tread can result from a groove crack or tread undercutting and must be removed from service.*

Figure 13-146. *Cover tires to protect from harmful chemicals and from the elements when parked outside for long periods of time.*

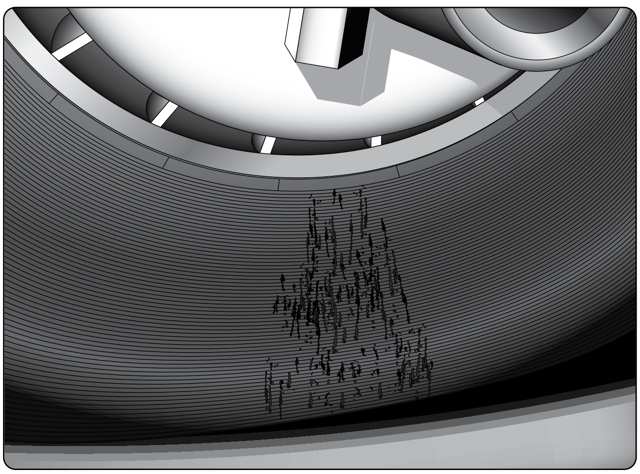

Figure 13-147. *Cracking and checking in the sidewall of a tire is acceptable for service as long as it does not extend to or expose the sidewall carcass plies.*

procedures to prevent personal injury and damage to aircraft parts and assemblies.

An aircraft tire and wheel assembly, especially a high-pressure assembly that has been damaged or overheated, should be treated as though it may explode. Never approach such a tire while its temperature is still elevated above ambient temperature. Once cooled, approach a damaged tire and wheel assembly from an oblique angle advancing toward the shoulder of the tire. *[Figure 13-148]*

Deflate all unserviceable and damaged tires before removal from the aircraft. Use a valve core/deflation tool to deflate the tire. Stand to the side—away from the projectile path of the valve core. A dislodged valve core propelled by internal tire

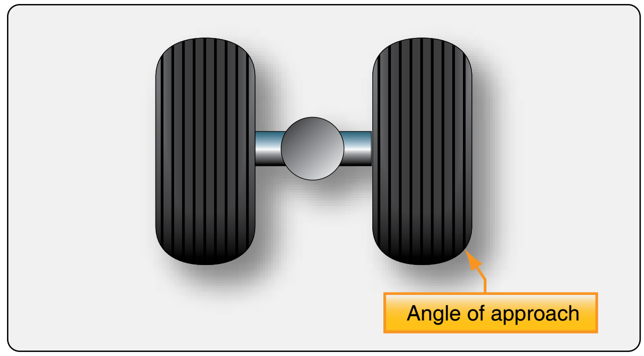

Figure 13-148. *To avoid potential injury, approach a tire/wheel assembly that has damage or has been overheated at an angle toward the tire shoulder only after it has cooled to ambient temperature.*

pressure can cause serious human injury. When completely deflated, remove the valve core. *[Figure 13-149]* A tire and wheel assembly in airworthy condition may be removed to access other components for maintenance without deflating the tire. This is common practice, such as when accessing the brake when the wheel assembly is immediately reinstalled.

For tracking purposes, ensure damaged areas of a tire are marked before deflation. Record all known information about an unserviceable tire and attach it to the tire for use by the retread repair station.

Once removed from the aircraft, a tire must be separated from the wheel rim upon which it is mounted. Proper equipment and technique should be followed to avoid damage to the tire and wheel. The wheel manufacturer's maintenance information is the primary source for dismounting guidelines.

The bead area of the tire sits firmly against the rim shoulder and must be broken free. Always use proper bead breaking equipment for this purpose. Never pry a tire from a wheel rim as damage to the wheel is inevitable. The wheel tie bolts must remain installed and fully tightened when the bead is broken from the rim to prevent damage to the wheel half mating surfaces.

Figure 13-149. *The tire valve core should be removed after the tire is completely deflated and before the tire and wheel assembly is removed from the aircraft.*

When the bead breaking press contact surface is applied to the tire, it should be as close to the wheel as possible without touching it during the entire application of pressure. Tires and rims of different sizes require contact pads suitable for the tire. Hand presses and hydraulic presses are available. Apply the pressure and hold it to allow the bead to move on the rim. Gradually progress around the rim until the tire bead is broken free. Ring-type bead breakers apply pressure around the circumference of the entire sidewall so rotation is not required. *[Figure 13-150]* Once the bead is broken free, the wheel halves may be disassembled. *[Figure 13-151]*

Radial tires have only one bead bundle on each side of the tire. The sidewall is more flexible in this area than a bias ply tire. The proper tooling should be used, and pressure should be applied slowly to avoid heavy distortion of the sidewall. Lubrication may be applied and allowed to soak into the tire-wheel interface. Only soapy tire solutions should be used. Never apply a hydrocarbon-based lubricant to an aircraft tire as this contaminates the rubber compound used to construct the tire. Beads on tube-type and tubeless tires are broken free in a similar manner.

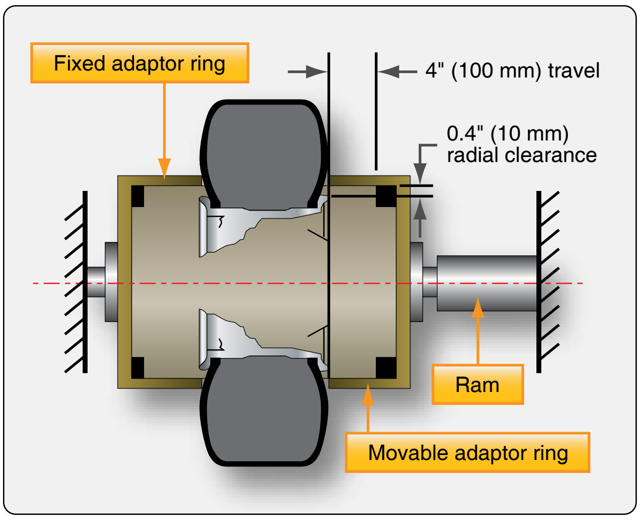

Figure 13-150. *A ring adapter applies pressure around the entire circumference of the lower sidewall of the tire to break the bead free from the wheel rim. The diameter of the adapter must be correct for the tire and the travel limited so as to not injure the tire.*

Tire Inspection Off of the Aircraft

Once a tire has been removed from the wheel rim, it should be inspected for condition. It may be possible to retread the tire at an approved repair station and return it to service. A sequential inspection procedure helps ensure no parts of the tire are overlooked. Mark and record the extent of all damage. Advisory Circular (AC) 43-13-1 gives general guidelines for tire inspection and repair. Tires must only be repaired by those with the experience and equipment to do so. Most tire repairs are accomplished at a certified tire repair facility.

When inspecting a tire removed from the aircraft, pay special attention to the bead area since it must provide an air tight seal to the wheel rim and transfer forces from the tire to the rim. Inspect the bead area closely as it is where the heat is concentrated during tire operation. Surface damage to the chafer is acceptable and can be repaired when the tire is retreaded. Other damage in the bead area is usually cause for rejection. Damage to the turn-ups, ply separation at the bead, or a kinked bead are examples of bead area damage that warrant the tire be discarded. The bead area of the tire may sustain damage or have an altered appearance or texture on a tire that has been overheated. Consult a certified tire repair station or re-tread facility when in doubt about the condition observed. The wheel rim must also be inspected for damage. An effective seal without slippage, especially on tubeless tires, is dependent on the condition and integrity of the wheel in the bead seat area.

Overheating of a tire weakens it even though the damage might not be obvious. Any time a tire is involved in an aborted

Figure 13-151. *An electrohydraulic tire bead breaker (left) used on large tires and a manual tire bead breaker (right) used on small tires.*

takeoff, severe braking, or the thermal plug in the wheel has melted to deflate the tire before explosion, the tire must be removed. On a dual installation, both tires must be removed. Even if only one tire shows obvious damage or deflates, the loads experienced by the mate are excessive. Internal damage such as ply separation, is likely. The history of having been through an overheat event is all that is required for the tire to be discarded.

Damaged or suspected damaged areas of the tire should be re-inspected while the tire is off the aircraft. Cuts can be probed to check for depth and extent of damage below the tread. In general, damage that does not exceed 40 percent of the tire plies can be repaired when the tire is retreaded. Small punctures with a diameter on the tire inner surface of less than ⅛-inch and a diameter on the outer surface of less than ¼-inch can also be repaired and retreaded. A bulge caused by ply separation is reason to discard a tire. However, a bulge caused by tread separation from the tire carcass may be repairable during retread. Exposed sidewall cord or sidewall cord damage is unacceptable, and the tire cannot be repaired or retreaded. Consult the tire manufacturer or certified retreader for clarification on damage to a tire.

Tire Repair & Retreading

The technician should follow airframe and tire manufacturer instructions to determine if a tire is repairable. Many example guidelines have also been given in this section. Nearly all tire repairs must be made at a certified tire repair facility equipped to perform the approved repair. Bead damage, ply separation, and sidewall cord exposure all require that the tire be scrapped. Inner liner condition on tubeless tires is also critical. Replacing the tube in a tube-type tire is performed by the technician as are mounting and balancing all types of aircraft tires.

Aircraft tires are very expensive. They are also extremely durable. The effective cost of a tire over its life can be reduced by having the tread replaced while the carcass is still sound, and injuries are within repairable limits. Federal Aviation Administration (FAA) certified tire retread repair stations, often the original equipment manufacturer (OEM), do this work. The technician inspects a tire to pre-qualify it for retread so that the cost of shipping it to the retread repair facility is not incurred if there is no chance to retread the tire. The tire retreader inspects and tests every tire to a level beyond the capability of the hangar or line technician. Shearography, an optical nondestructive testing method that provides detailed information about the internal integrity of the tire, is used by tire retread repair facilities to ensure a tire carcass is suitable for continued service.

Tires that are retreaded are marked as such. They are not compromised in strength and give the performance of a new tire. No limits are established for the number of times a tire can be retreaded. This is based on the structural integrity of the tire carcass. A well maintained main gear tire may be able to be retreaded a handful of times before fatigue renders the carcass un-airworthy. Some nose tires can be retread nearly a dozen times.

Tire Storage

An aircraft tire can be damaged if stored improperly. A tire should always be stored vertically so that it is resting on its treaded surface. Horizontal stacking of tires is not recommended. Storage of tires on a tire rack with a minimum 3–4-inch flat resting surface for the tread is ideal and avoids tire distortion.

If horizontal stacking of tires is necessary, it should only be done for a short time. The weight of the upper tires on the lower tires cause distortion possibly making it difficult for the bead to seat when mounting tubeless tires. A bulging tread also stresses rib grooves and opens the rubber to ozone attack in this area. *[Figure 13-152]* Never stack aircraft tires horizontally for more than 6 months. Stack no higher than four tires if the tire is less than 40-inches in diameter and no higher than three tires if greater than 40-inches in diameter. The environment in which an aircraft tire is stored is critical. The ideal location in which to store an aircraft tire is cool, dry, and dark, free from air currents and dirt.

An aircraft tire contains natural rubber compounds that are prone to degradation from chemicals and sunlight. Ozone (O_3) and oxygen (O_2) cause degradation of tire compounds. Tires should be stored away from strong air currents that continually present a supply of one or both of these gases. Fluorescent lights, mercury vapor lights, electric motors, battery chargers, electric welding equipment, electric generators, and similar shop equipment produce ozone and should not be operated near aircraft tires. Mounted inflated

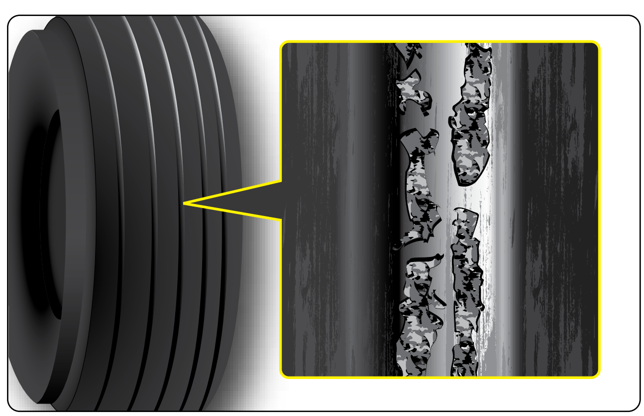

Figure 13-152. *Ozone cracking in a tire tread groove is facilitated by horizontal stacking.*

tires can be stored with up to 25 percent less pressure than operating pressure to reduce vulnerability from ozone attacks. Sodium vapor lighting is acceptable. Storage of an aircraft tire in the dark is preferred to minimize degradation from ultraviolet (UV) light. If this is not possible, wrap the tire in dark polyethylene or paper to form an ozone barrier and to minimize exposure to UV light.

Common hydrocarbon chemicals, such as fuels, oils, and solvents, should not contact a tire. Avoid rolling tires through spills on the hangar or shop floor and be sure to clean any tire immediately if contaminated. Dry the tire and store all tires in a dry place away from any moisture, which has a deteriorating effect on the rubber compounds. Moisture with foreign elements may further damage the rubber and fabric of a tire. Dirty areas must be avoided.

Tires are made to operate in a wide range of temperatures. However, storage should be at cool temperatures to minimize degradation. A general range for safe aircraft tire storage is between 32 °F and 104 °F. Temperatures below this are acceptable but higher temperatures must be avoided.

Aircraft Tubes

Many aircraft tires accept a tube inside to contain the inflation air. Tube-type tires are handled and stored in similar fashion as tubeless tires. A number of issues concerning the tubes themselves must be addressed.

Tube Construction & Selection

Aircraft tire tubes are made of a natural rubber compound. They contain the inflation air with minimal leakage. Unreinforced and special reinforced heavy-duty tubes are available. The heavy-duty tubes have nylon reinforcing fabric layered into the rubber to provide strength to resist chafing and to protect against heat such as during braking.

Tubes come in a wide range of sizes. Only the tube specified for the applicable tire size must be used. Tubes that are too small stress the tube construction.

Tube Storage & Inspection

An aircraft tire tube should be kept in the original carton until put into service to avoid deterioration through exposure to environmental elements. If the original carton is not available, the tube can be wrapped in several layers of paper to protect it. Alternately, for short time periods only, a tube may be stored in the correct size tire it is made for while inflated just enough to round out the tube. Application of talc to the inside of the tire and outside of the tube prevents sticking. Remove the tube and inspect it and the tire before permanently mounting the assembly. Regardless of storage method, always store aircraft tubes in a cool, dry, dark place away from ozone producing equipment and moving air.

When handling and storing aircraft tire tubes, creases are to be avoided. These weaken the rubber and eventually cause tube failure. Creases and wrinkles also tend to be chafe points for the tube when mounted inside the tire. Never hang a tube over a nail or peg for storage.

An aircraft tube must be inspected for leaks and damage that may eventually cause a leak or failure. To check for leaks, remove the tube from the tire. Inflate the tube just enough to have it take shape but not stretch. Immerse a small tube in a container of water and look for the source of air bubbles. A large tube may require that water be applied over the tube. Again, look for the source of bubbles. The valve core should also be wetted to inspect it for leaks.

There is no mandatory age limit for an aircraft tire tube. It should be elastic without cracks or creases in order to be consider serviceable. The valve area is prone to damage and should be inspected thoroughly. Bend the valve to ensure there are no cracks at the base where it is bonded to the tire or in the area where it passes through the hole in the wheel rim. Inspect the valve core to ensure it is tight and that it does not leak.

If an area of a tube experiences chafing to the point where the rubber is thinned, the tube should be discarded. The inside diameter of the tube should be inspected to ensure it has not been worn by contact with the toe of the tire bead. Tubes that have taken an unnatural set should be discarded. *[Figure 13-153]*

Tire Inspection

It is important to inspect the inside of a tube-type tire before installing a tube for service. Any protrusions or rough areas should be cause for concern, as these tend to abrade the tube and may cause early failure. Follow the tire, tube, and aircraft manufacturer's inspection criterion when inspecting aircraft tires and tubes.

Tire Mounting

A licensed technician is often called upon to mount an aircraft tire onto the wheel rim in preparation for service. In the case of a tube-type tire, the tube must also be mounted. The following section presents general procedures for these operations using tube-type and tubeless tires. Be sure to have the proper equipment and training to perform the work according to manufacturer's instructions.

Tubeless Tires

Aircraft tire and wheel assemblies are subject to enormous stress while in service. Proper mounting ensures tires perform to

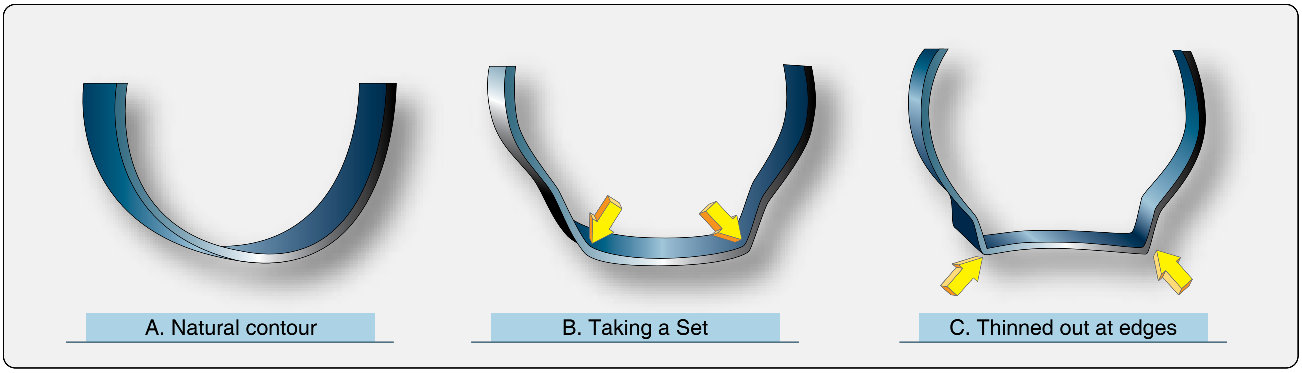

Figure 13-153. *During inspection, an aircraft tire tube should retain its natural contour. Tubes with thinned areas or that have taken a set should be discarded and replaced.*

the limits of their design. Consult and follow all manufacturer's service information including bolt torques, lubrication and balancing requirements, and inflation procedures.

As mentioned, a wheel assembly that is to have a tire mounted upon it must be thoroughly inspected to ensure it is serviceable. Pay close attention to the bead seat area, which should be smooth and free from defects. The wheel half mating surface should be in good condition. The O-ring should be lubricated and in good condition to ensure it seals the wheel for the entire life of the tire. Follow the manufacturer's instructions when inspecting wheels and the tips provided earlier in this chapter. *[Figure 13-154]*

A final inspection of the tire to be mounted should be made. Most important is to check that the tire is specified for the aircraft application. It should say tubeless on the sidewall. The part number, size, ply rating, speed rating, and technical standard order (TSO) number should also be on the sidewall and be approved for the aircraft installation. Visually check the tire for damage from shipping and handling. There should

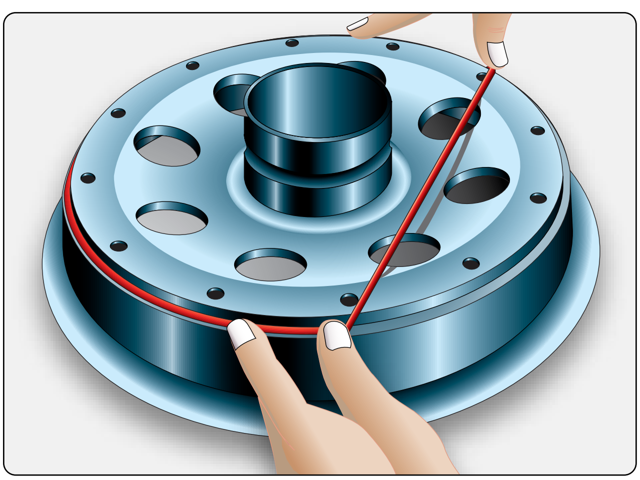

Figure 13-154. *The wheel half O-ring for a tubeless tire wheel assembly must be in good condition and lubricated to seal for the entire life of the tire. The mating surfaces of the wheel halves must also be in good condition.*

be no permanent deformation of the tire. It should pass all inspections for cuts and other damage discussed in the previous sections of this chapter. Clean the tire bead area with a clean shop towel and soap and water or denatured alcohol. Inspect the inside of the tire for condition. There should be no debris inside the tire.

Tire beads are sometimes lubricated when mounted on aluminum wheels. Follow the manufacturer's instructions and use only the non-hydrocarbon lubricant specified. Never lubricate any tire bead with grease. Do not use lubricants with magnesium alloy wheels. Most radial tires are mounted without lubricant. The airframe manufacturer may specify lubrication for a radial tire in a few cases.

When the wheel halves and tires are ready to be mounted, thought must be given to tire orientation and the balance marks on the wheel halves and tire. Typically, the tire serial number is mounted to the outboard side of the assembly. The marks indicating the light portion of each wheel half should be opposite each other. The mark indicating the heavy spot of the wheel assembly should be mounted aligned with the light spot on the tire, which is indicated by a red mark. If the wheel lacks a mark indicating the heavy spot, align the red spot on the tire (the light point) with the valve fitting location on the wheel. A properly balanced tire and wheel assembly improves the overall performance of the tire. It promotes smooth operation free from vibration, which results in uniform tread wear and extended tire life.

When assembling the wheel halves, follow manufacturer's instructions for tie bolt tightening sequences and torque specification. Anti-seize lubricants and wet-torque values are common on wheel assemblies. Use a calibrated hand torque wrench. Never use an impact wrench on an aircraft tire assembly.

For the initial inflation of an aircraft tire and wheel assembly, the tire must be placed in a tire inflation safety cage and treated as though it may explode due to wheel or tire failure. The inflation hose should be attached to the tire valve stem, and inflation pressure should be regulated from a safe distance away. A minimum of 30 feet is recommended. Air or nitrogen should be introduced gradually as specified. Dry nitrogen keeps the introduction of water into the tire to a minimum, which helps prevent corrosion. Observe the tire seating progress on the wheel rim while it inflates. Depressurize the tire before approaching it to investigate any observed issue. *[Figure 13-155]*

Aircraft tires are typically inflated to their full specified operating pressure. Then, they are allowed to remain with no load applied for 12-hours. During this time, the tire stretches, and tire pressure decreases. A 5-10 percent reduction is normal. Upon bringing the tire up to full pressure again, less than 5 percent loss per day of pressure is allowable. More should be investigated.

Tube-Type Tires

Wheel and tire inspection should precede the mounting of any tire, including tube-type tires. The tube to be installed must also pass inspection and must be the correct size for the tire and tire must be specified for the aircraft. Tire talc is commonly used when installing tube-type tires to ensure easy mounting and free movement between the tube and tire as they inflate. *[Figure 13-156]* The technician should lightly talc the inside of the tire and the outside of the tube. Some tubes come from the factory with a light talc coating over the outside of the tube. Inflate the tube so that it just takes shape with minimal pressure. Install the tube inside the tire. Tubes are typically produced with a mark at the heavy spot

Figure 13-156. *Tire talc is used on the inside of tube-type tires and the outside of aircraft tubes. This prevents binding and allows the tube to expand without stress into place within the tire.*

of the tube. In the absence of this balance mark, it is assumed that the valve is located at the heaviest part of the tube. For proper balance, align the heavy part of the tube with the red mark on the tire (the light spot on the tire). *[Figure 13-157]*

Once wheel balance is marked and the tube balance mark and the tire balance mark are all positioned correctly, install the outboard wheel half so the valve stem of the tube passes through the valve stem opening. *[Figure 13-158]* Mate the inboard wheel half to it, being careful not to pinch the tube between the wheel rims. Install the tie bolts, tighten, and

Figure 13-155. *Modern tire inflation cages have been tested to withstand catastrophic failure of a tire and wheel assembly during inflation. All newly mounted tires should be inflated in such a cage.*

Figure 13-157. *When assembling a tube into a tire, the heavy balance mark on the tube is aligned with the light balance mark on the tire.*

Figure 13-158. *Mounting a tube type tire with the tube valve stem positioned to pass through the outboard wheel half.*

torque as specified. Inflate the assembly in a tire inflation cage.

The inflation procedure for a tube-type tire differs slightly from that of a tubeless tire. The assembly is slowly brought up.to full operating pressure. Then, it is completely deflated. Re-inflate the tire/tube assembly a second time to the specified operating pressure and allow it to remain with no load for 12-hours. This allows any wrinkles in the tube to smooth out, helps prevent the tube from being trapped under a bead, and generally evens how the tube lays within the tire to avoid any stretched areas and thinning of the tube. The holding time allows air trapped between the tube and the tire to work its way out of the assembly, typically through the tire sidewall or around the valves stem.

Tire Balancing

Once an aircraft tire is mounted, inflated, and accepted for service, it can be balanced to improve performance. Vibration is the main result of an imbalanced tire and wheel assembly. Nose wheels tend to create the greatest disturbance in the cabin when imbalanced.

Static balance is all that is required for most aircraft tires and wheels. A balance stand typically accepts the assembly on cones. The wheel is free to rotate. The heavy side moves to the bottom. *[Figure 13-159]* Temporary weights are added to eliminate the wheel from rotating and dropping the heavy side down. Once balanced, permanent weights are installed. Many aircraft wheels have provisions for securing the permanent weight to the wheel. Weights with adhesive designed to be glued to the wheel rim are also in use. Occasionally, a weight in the form of a patch glued to the inside of the tire is required. Follow all manufacturer's instructions and use only the weights specified for the wheel assembly. *[Figure 13-160]*

Some aviation facilities offer dynamic balancing of aircraft tire and wheel assemblies. While this is rarely specified by manufacturers, a well-balanced tire and wheel assembly helps provide shimmy free operation and reduces wear on brake and landing gear components, such as torque links.

Operation & Handling Tips

Aircraft tires experience longer life if operated in a manner to conserve wear and minimize damage. The most important factor impinging on tire performance and wear, as well as resistance to damage is proper inflation. Always inflate tires to the specified level before flight for maximum performance and minimal damage. An improperly inflated tire has increased potential to fail upon landing due to the high

Figure 13-159. *A typical aircraft tire and wheel balancing stand.*

Figure 13-160. *A tire balancing patch (left), adhesive wheel weights (center), and a bolted wheel weight (right) are all used to balance aircraft tire and wheel assemblies per the manufacturer's instructions.*

impact loads experienced. The following sections include other suggestions that can extend the life and the investment made in aircraft tires.

Taxiing

Needless tire damage and excessive wear can be prevented by proper handling of the aircraft during taxi. Most of the gross weight of an aircraft is on the main landing gear wheels. Aircraft tires are designed and inflated to absorb the shock of landing by deflection of the sidewalls two to three times as much as that found on an automobile tire. While this enables the tire to handle heavy loads, it also causes more working of the tread and produces scuffing action along the outer edges of the tread that results in more rapid wear. It also leaves the tire more prone to damage as the tread compound opens during this flexing.

An aircraft tire that strikes a chuck hole, a stone, or some other foreign object is more likely to sustain a cut, snag, or bruise than an automobile tire due to its more flexible nature. There is also increased risk for internal tire injury when a tire leaves the paved surface of the taxi way. These incidents should be avoided. Dual or multiple wheel main gear should be operated so that all tires remain on the paved surface so the weight of the aircraft is evenly distributed between the tires. When backing an aircraft on a ramp for parking, care should be taken to stop the aircraft before the main wheels roll off of the paved surface.

Taxiing for long distances or at high speeds increase the temperature of aircraft tires. This makes them more susceptible to wear and damage. Short taxi distances at moderate speeds are recommended. Caution should also be used to prevent riding the brakes while taxiing, which adds unnecessary heat to the tires.

Braking & Pivoting

Heavy use of aircraft brakes introduces heat into the tires. Sharp radius turns do the same and increase tread abrasion and side loads on the tire. Plan ahead to allow the aircraft to slow without heavy braking and make large radius turns to avoid these conditions. Objects under a tire are ground into the tread during a pivot. Since many aircraft are primarily maneuvered on the ground via differential braking, efforts should be made to always keep the inside wheel moving during a turn rather than pivoting the aircraft with a locked brake around a fixed main wheel tire.

Landing Field & Hangar Floor Condition

One of the main contributions made to the welfare of aircraft tires is good upkeep of airport runway and taxiway surfaces, as well as all ramp areas and hangar floors. While the technician has little input into runway and taxiway surface upkeep, known defects in the paved surfaces can be avoided and rough surfaces can be negotiated at slower than normal speeds to minimize tire damage. Ramps and hangar floors should be kept free of all foreign objects that may cause tire damage. This requires continuous diligence on the part of all aviation personnel. Do not ignore foreign object damage (FOD). When discovered, action must be taken to remove it. While FOD to engines and propellers gains significant attention, much damage to tires is avoidable if ramp areas and hangar floors are kept clean.

Takeoffs & Landings

Aircraft tires are under severe strain during takeoff and landing. Under normal conditions, with proper control and maintenance of the tires, they are able to withstand these stresses and perform as designed.

Most tire failures occur during takeoff which can be extremely dangerous. Tire damage on takeoff is often the result of running over some foreign object. Thorough preflight inspection of the tires and wheels, as well as maintenance of hangar and ramp surfaces free of foreign objects, are keys to prevention of takeoff tire failure. A flat spot caused on the way to the runway may lead to tire failure during takeoff. Heavy braking during aborted takeoffs is also a common cause of takeoff tire failure. *[Figure 13-161]*

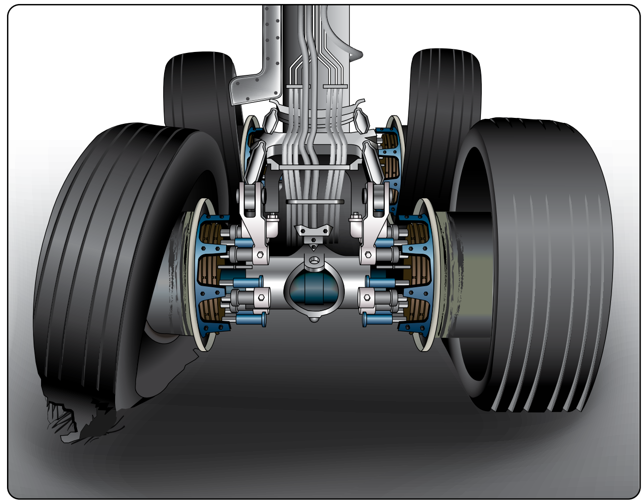

Figure 13-161. *Heavy braking during an aborted takeoff caused these tires to fail.*

Tire failure upon landing can have several causes. Landing with the brakes on is one. This is mitigated on aircraft with anti-skid systems but can occur on other aircraft. Other errors in judgment, such as landing too far down the runway and having to apply the brakes heavily, can cause overheating or skidding. This can lead to flat-spotting the tires or blow out.

Hydroplaning

Skidding on a wet, icy, or dry runway is accompanied by the threat of tire failure due to heat build-up and rapid tire wear damage. Hydroplaning on a wet runway may be overlooked as a damaging condition for a tire. Water building up in front of the tire provides a surface for the tire to run on and contact with the runway surface is lost. This is known as dynamic hydroplaning. Steering ability and braking action is also lost. A skid results if the brakes are applied and held.

Viscous hydroplaning occurs on runways with a thin film of water that mixes with contaminants to cause an extremely slick condition. This can also happen on a very smooth runway surface. A tire with a locked brake during viscous hydroplaning can form an area of reverted rubber or skid burn in the tread. While the tire may continue in service if the damage is not too severe, it can be cause for removal if the reinforcing tread or protector ply is penetrated. The same damage can occur while skidding on ice.

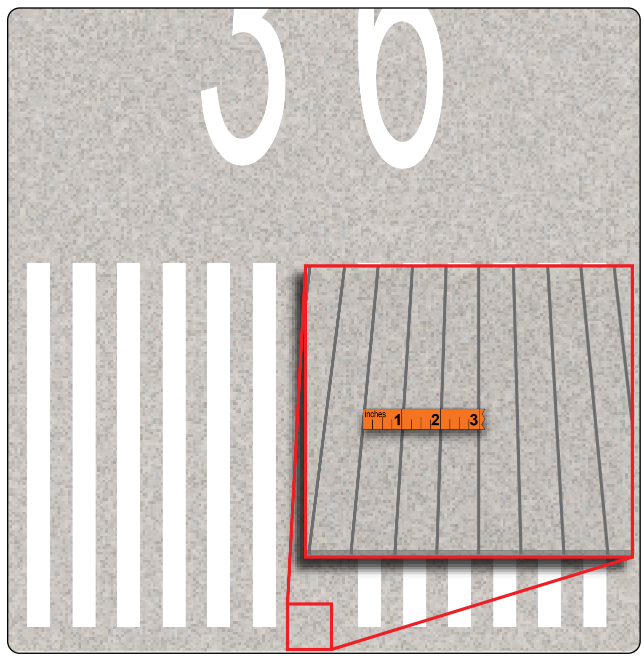

Figure 13-162. *Crosscut runway surfaces drain water rapidly but increase tire wear.*

Modern runways are designed to drain water rapidly and provide good traction for tires in wet conditions. A compromise exists in that crosscut runways and textured runway surfaces cause tires to wear at a greater rate than a smooth runway. *[Figure 13-162]* A smooth landing is of great benefit to any tire. For the most part, aircraft tire handling and care is the responsibility of the pilot; however, the technician benefits from knowing the causes of tire failure and communicating this knowledge to the flight crew so that operating procedures can be modified to avoid those causes.

Chapter 14
Aircraft Fuel Systems

Basic Fuel System Requirements

All powered aircraft require fuel on board to operate the engine(s). A fuel system consisting of storage tanks, pumps, filters, valves, fuel lines, metering devices, and monitoring devices is designed and certified under strict Title 14 of the Code of Federal Regulations (14 CFR) guidelines. Each system must provide an uninterrupted flow of contaminant-free fuel regardless of the aircraft's attitude. Since fuel load can be a significant portion of the aircraft's weight, a sufficiently strong airframe must be designed. Varying fuel loads and shifts in weight during maneuvers must not negatively affect control of the aircraft in flight.

Figure 14-1. *Aircraft fuel systems must deliver fuel during any maneuver for which the aircraft is certified.*

Each Federal Aviation Administration (FAA) certified aircraft is designed and constructed under regulations applicable to that type of aircraft. The certification airworthiness standards are found in 14 CFR as follows:

- 14 CFR part 23—Airworthiness Standards: Normal Category Airplanes
- 14 CFR part 25—Airworthiness Standards: Transport Category Airplanes
- 14 CFR part 27—Airworthiness Standards: Normal Category Rotorcraft
- 14 CFR part 29—Airworthiness Standards: Transport Category Rotorcraft
- 14 CFR part 31—Airworthiness Standards: Manned Free Balloons

Additional information is found in 14 CFR part 33. It addresses airworthiness standards for engines and pertains mainly to engine fuel filter and intake requirements.

Title 14 of the CFR, part 23, Airworthiness Standards: Normal Category Airplanes, section 23.2430, Fuel Systems, is summarized below. Airworthiness standards specified for air carrier and helicopter certification are similar. Although the technician is rarely involved with designing fuel systems, a review of these criteria gives insight into how an aircraft fuel system operates.

Each fuel system must be constructed and arranged to ensure fuel flow at a rate and pressure established for proper engine and auxiliary power unit (APU) functioning under each likely operating condition. This includes any maneuver for which certification is requested and during which the engine or APU may be in operation. *[Figure 14-1]* Each fuel system must be arranged so that no fuel pump can draw fuel from more than one tank at a time. There must also be a means to prevent the introduction of air into the system.

Each fuel system for a turbine engine powered airplane must meet applicable fuel venting requirements. 14 CFR part 34 outlines requirements that fall under the jurisdiction of the Environmental Protection Agency (EPA). A turbine engine fuel system must be capable of sustained operation throughout its flow and pressure range even though the fuel has some water in it. The standard is that the engine continues to run using fuel initially saturated with water at 80 °F having 0.75 cubic centimeters (cm) of free water per gallon added to it and then cooled to the most critical condition for icing likely to be encountered in operation.

Fuel System Independence

Each fuel system must be designed and arranged to provide independence between multiple fuel storage and supply systems so that failure of any one component in one system will not result in loss of fuel storage or supply of another system.

Fuel System Lightning Protection

The fuel system must be designed and arranged to prevent the ignition of the fuel within the system by direct lightning strikes or swept lightning strokes to areas where such occurrences are highly probable, or by corona or streamering at fuel vent outlets. A corona is a luminous discharge that occurs as a result of an electrical potential difference

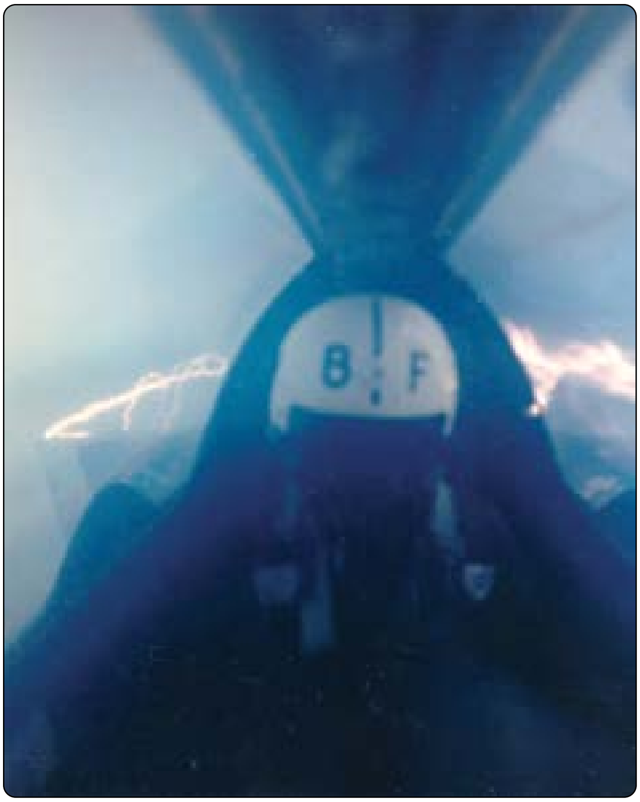

Figure 14-2. *Lightning streamering at the wingtips of a jet fighter.*

between the aircraft and the surrounding area. Streamering is a branch-like ionized path that occurs in the presence of a direct stroke or under conditions when lightning strikes are imminent. *[Figure 14-2]*

Fuel Flow

The ability of the fuel system to provide the fuel necessary to ensure each powerplant and auxiliary power unit functions properly in all likely operating conditions. It must also prevent hazardous contamination of the fuel supplied to each powerplant and auxiliary power unit.

The fuel system must provide the flightcrew with a means to determine the total useable fuel available and provide uninterrupted supply of that fuel when the system is correctly operated, accounting for likely fuel fluctuations. It should also provide a means to safely remove or isolate the fuel stored in the system from the airplane and be designed to retain fuel under all likely operating conditions and minimize hazards to the occupants during any survivable emergency landing. For level 4 airplanes, failure due to overload of the landing system must be taken into account

Fuel Storage System

Each fuel tank must be able to withstand, without failure, the loads under likely operating conditions. Each tank must be isolated from personnel compartments and protected from hazards due to unintended temperature influences. The fuel storage system must provide fuel for at least one-half hour of operation at maximum continuous power or thrust and be capable of jettisoning fuel safely if required for landing. *[Figure 14-3]* Fuel jettisoning systems are also referred to as fuel dump systems. *[Figure 14-4]* A fuel dump system is a system installed in most large aircraft that allows the flight crew to jettison, or dump, fuel to lower the gross weight of the aircraft to its allowable landing weight. Boost pumps in the fuel tanks move the fuel from the tank into a fuel manifold. From the fuel manifold, it flows away from the aircraft through dump chutes in each wing tip. The fuel jettison system must be so designed and constructed that it is free from fire hazards.

Aircraft fuel tanks must be designed to prevent significant loss of stored fuel from any vent system due to fuel transfer between fuel storage or supply systems, or under likely operating conditions.

Figure 14-3. *Fuel being jettisoned free of the airframe on a transport category aircraft.*

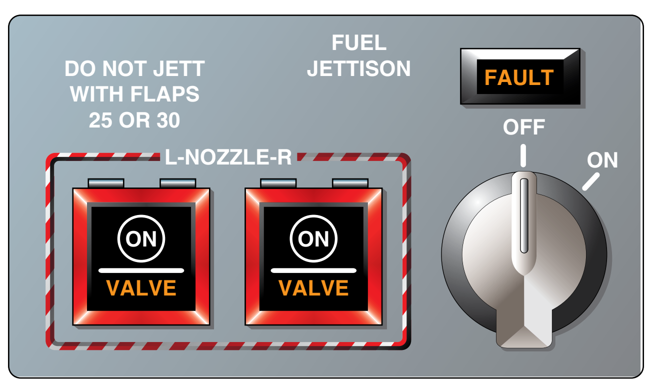

Figure 14-4. *The fuel jettison panel on a Boeing 767.*