

**Figure 12-59.** Backup O-rings installed downstream.

### O-Ring Installation

When removing or installing O-rings, avoid using pointed or sharp-edged tools that might cause scratching or marring of hydraulic component surfaces or cause damage to the O-rings. Special tooling for the installation of O-rings is available. While using the seal removal and the installation tools, contact with cylinder walls, piston heads, and related precision components is not desirable.

After the removal of all O-rings, the parts that receive new O-rings have to be cleaned and inspected to make sure that they are free from all contamination. Each replacement O-ring should be removed from its sealed package and inspected for defects, such as blemishes, abrasions, cuts, or punctures. Although an O-ring may appear perfect at first glance, slight surface flaws may exist. These flaws are often capable of preventing satisfactory O-ring performance under the variable operating pressures of aircraft systems; therefore, O-rings should be rejected for flaws that affect their performance. Such flaws are difficult to detect, and

one aircraft manufacturer recommends using a four-power magnifying glass with adequate lighting to inspect each ring before it is installed. By rolling the ring on an inspection cone or dowel, the inner diameter surface can also be checked for small cracks, particles of foreign material, or other irregularities that cause leakage or shorten the life of the O-ring. The slight stretching of the ring when it is rolled inside out helps to reveal some defects not otherwise visible.

After inspection and prior to installation, immerse the O-ring in clean hydraulic fluid. During the installation, avoid rolling and twisting the O-ring to maneuver it into place. If possible, keep the position of the O-ring's mold line constant. When the O-ring installation requires spanning or inserting through sharply threaded areas, ridges, slots, and edges, use protective measures, such as O-ring entering sleeves, as shown in *Figure 12-60A*. After the O-ring is placed in the cavity provided, gently roll the O-ring with the fingers to remove any twist that might have occurred during installation. [*Figure 12-61*]

### Wipers

Wipers are used to clean and lubricate the exposed portions of piston shafts. They prevent dirt from entering the system and help protect the piston shaft against scoring. Wipers may be either metallic or felt. They are sometimes used together, a felt wiper installed behind a metallic wiper.

## Large Aircraft Hydraulic Systems

*Figure 12-62* provides an overview of hydraulic components in large aircraft.

### Boeing 737 Next Generation Hydraulic System

The Boeing 737 Next Generation has three 3,000 psi hydraulic systems: system A, system B, and standby. The standby system is used if system A and/or B pressure is lost. The hydraulic systems power the following aircraft systems:

- Flight controls.
- Leading edge flaps and slats.
- Trailing edge flaps.
- Landing gear.
- Wheel brakes.
- Nose wheel steering.
- Thrust reversers.
- Autopilots.

### Reservoirs

The system A, B, and standby reservoirs are located in the wheel well area. The reservoirs are pressurized by bleed air

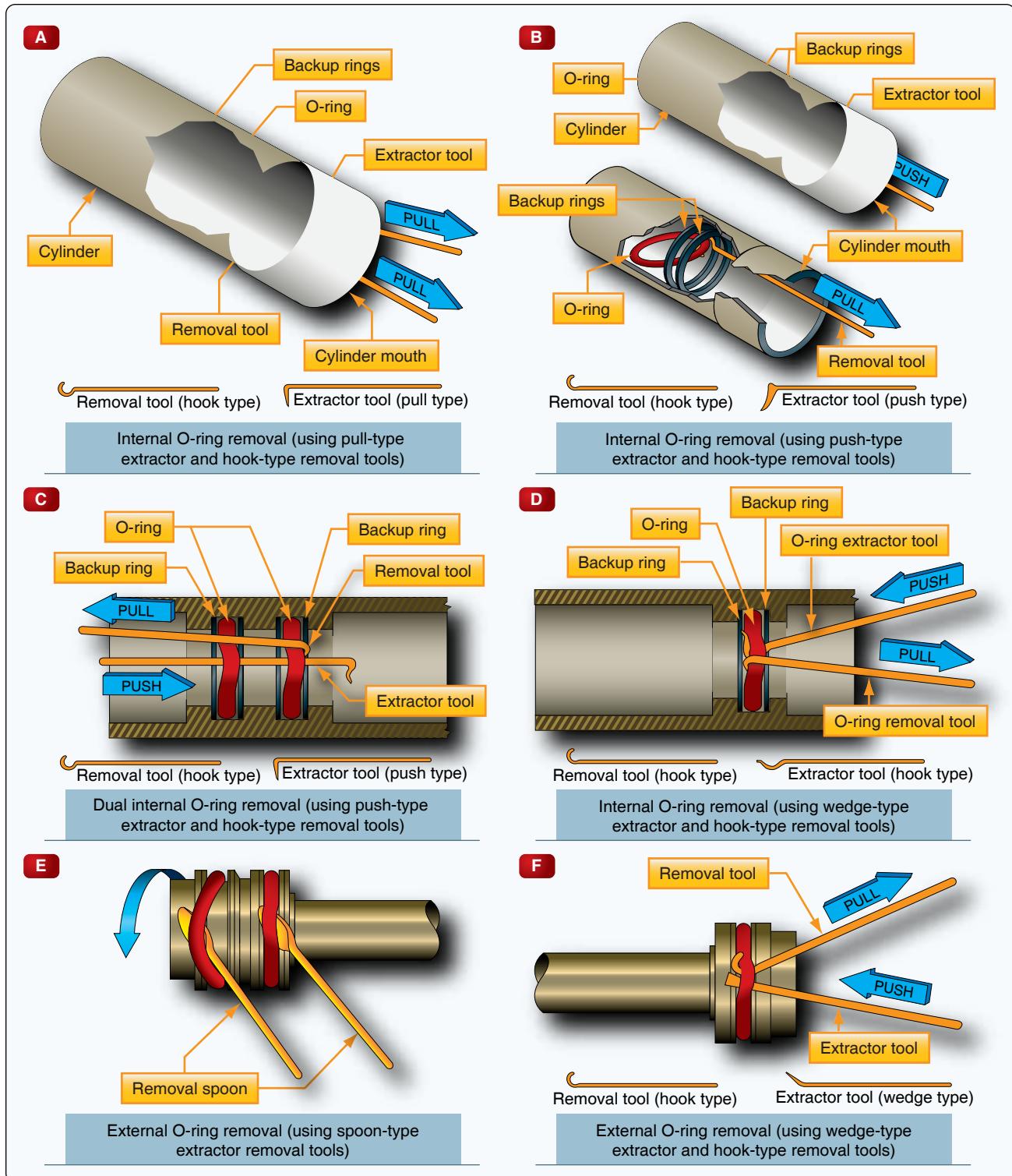
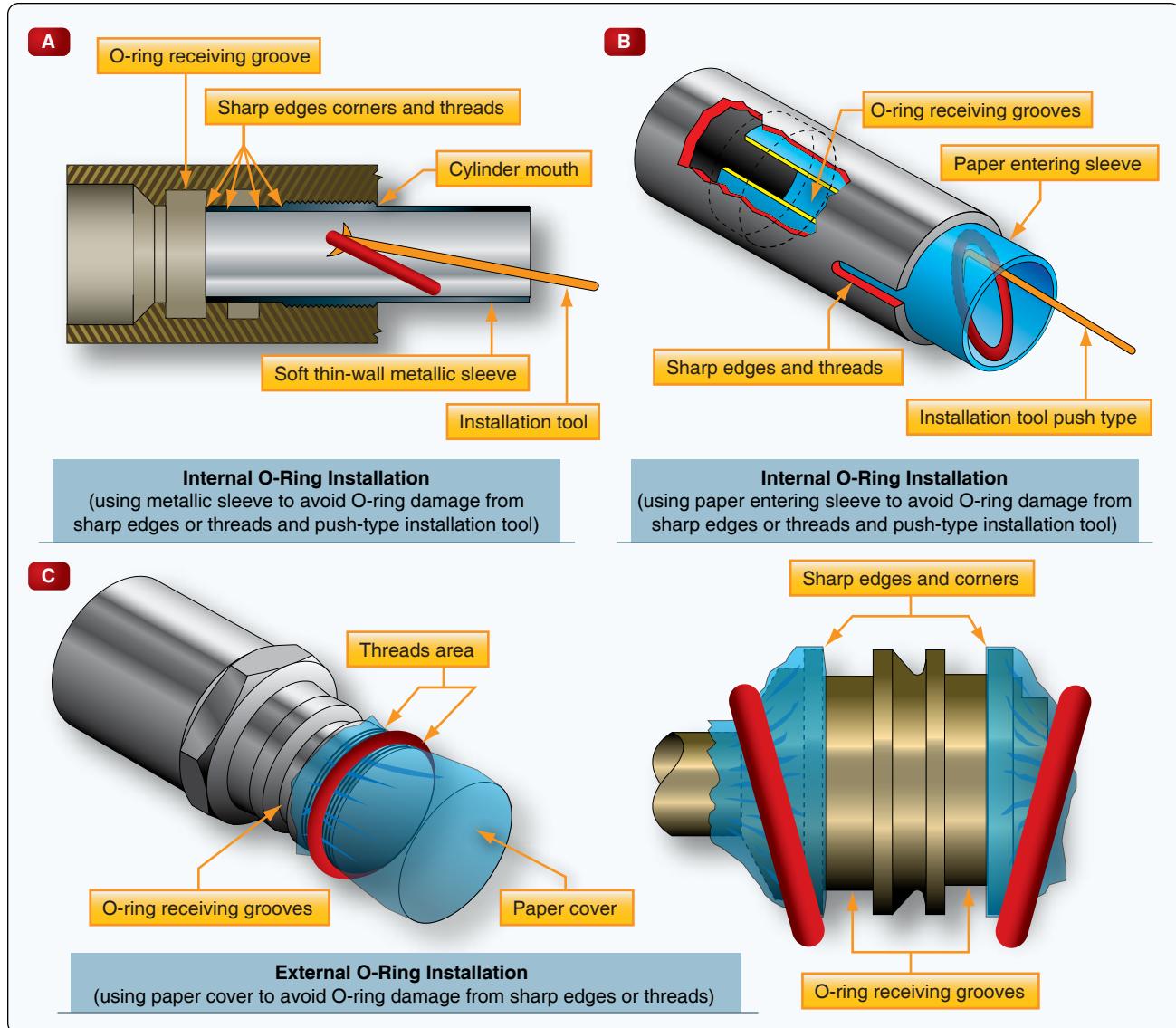


Figure 12-60. O-ring installation techniques.

through a pressurization module. The standby reservoir is connected to the system B reservoir for pressurization and servicing. The positive pressure in the reservoir ensures a positive flow of fluid to the pumps. The reservoirs have a standpipe that prevents the loss of all hydraulic fluid if a leak develops in the engine-driven pump or its related lines.

The engine-driven pump draws fluid through a standpipe in the reservoir and the AC motor pump draws fluid from the bottom of the reservoir. [Figure 12-63]



**Figure 12-61.** More O-ring installation techniques.

### Pumps

Refer to *Figure 12-64* for the following description. Both A and B hydraulic systems have an engine-driven pump (EDP) and an ACMP. The system A engine-driven pump is installed on the number 1 engine and the system B engine-driven pump is installed on the number 2 engine. The AC pumps are controlled by a switch on the flight deck. The hydraulic case drain fluid that lubricates and cools the pumps return to the reservoir through a heat exchanger. [*Figure 12-65*] The heat exchanger for the A system is installed in the main fuel tank No. 1, and the heat exchanger for the B system is installed in the main fuel tank No. 2. Minimum fuel for ground operation of electric motor-driven pumps is 1,675 pounds in the related main tank. Pressure switches, located in the EDP and ACMP pump output lines, send signals to illuminate the related LOW PRESSURE light if pump output

pressure is low. The related system pressure transmitter sends the combined pressure of the EDP and ACMP to the related hydraulic system pressure indicator.

### Filter Units

Filter modules are installed in the pressure, case drain, and return lines to clean the hydraulic fluid. Filters have a differential pressure indicator that pops out when the filter is dirty and needs to be replaced.

### Power Transfer Unit (PTU)

The purpose of the PTU is to supply the additional volume of hydraulic fluid needed to operate the autoslats and leading-edge flaps and slats at the normal rate when system B EDP malfunctions. The PTU unit consists of a hydraulic motor and hydraulic pump that are connected through a shaft. The

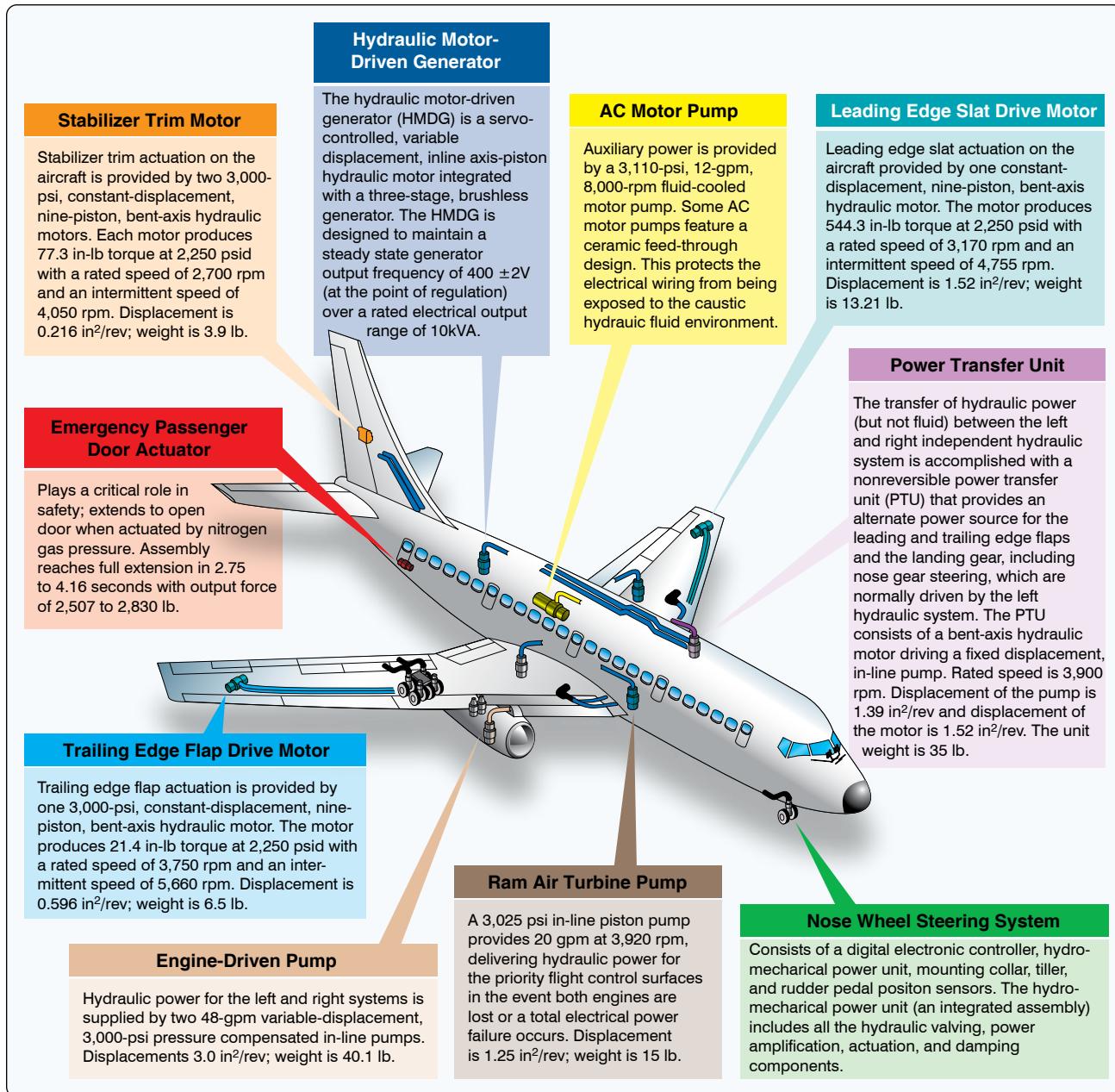


Figure 12-62. Large aircraft hydraulic systems.

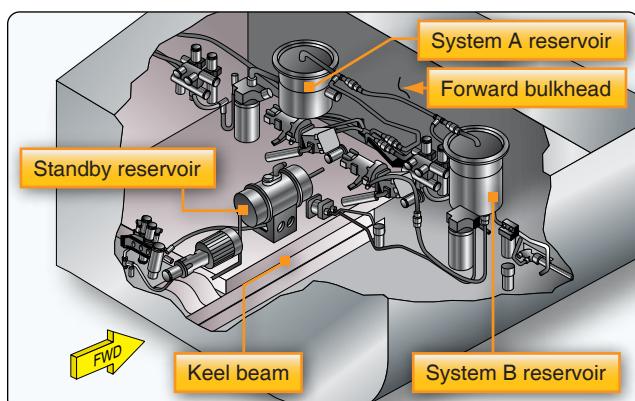
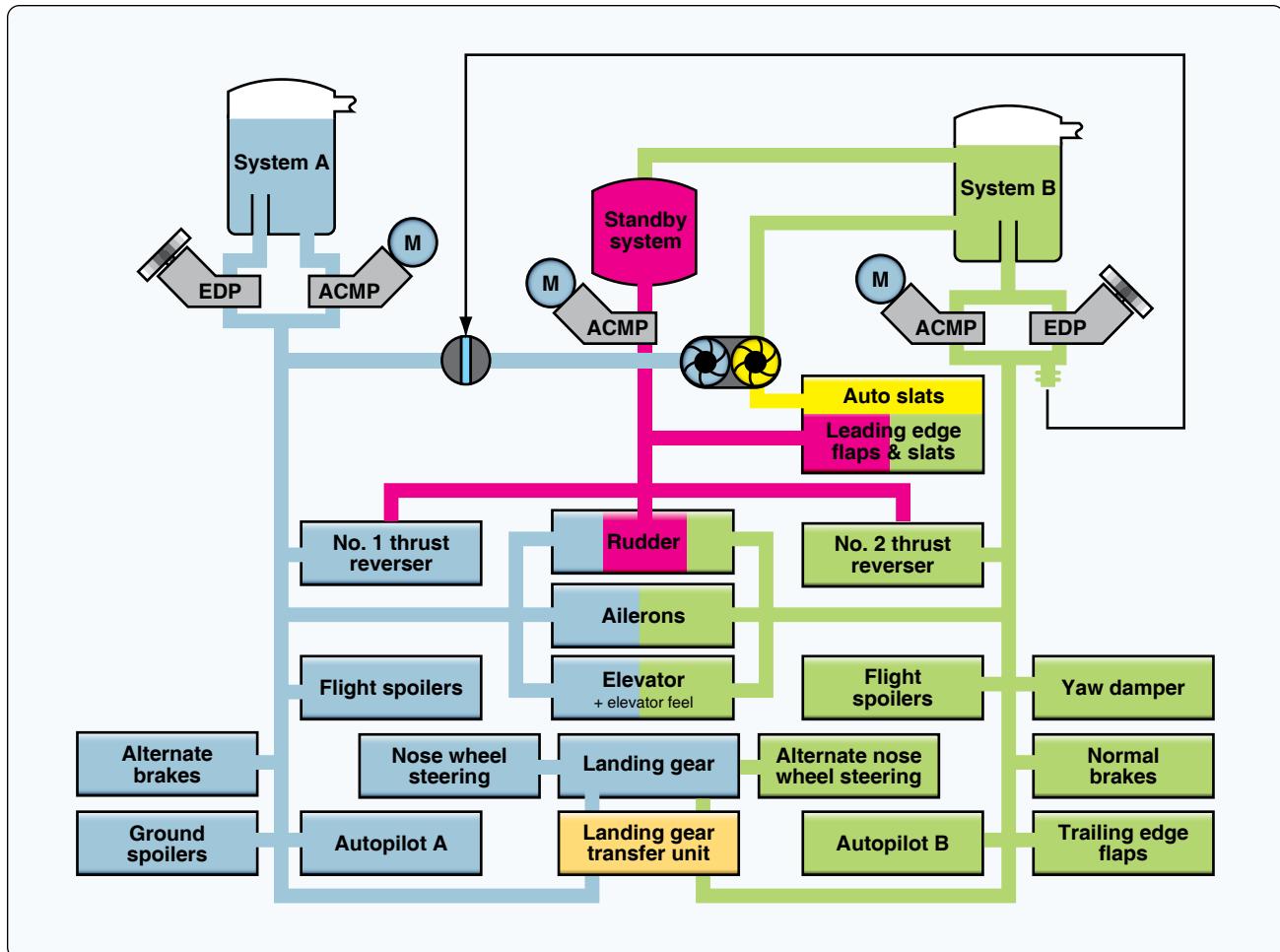


Figure 12-63. Hydraulic reservoirs on a Boeing 737.

PTU uses system A pressure to drive a hydraulic motor. The hydraulic motor of the PTU unit is connected through a shaft with a hydraulic pump that can draw fluid from the system B reservoir. The PTU can only transfer power and cannot transfer fluid. The PTU operates automatically when all of the following conditions are met:

- System B EDP pressure drops below limits.
- Aircraft airborne.
- Flaps are less than 15° but not up.



**Figure 12-64. Boeing 737 hydraulic system (simplified).**

### Landing Gear Transfer Unit

The purpose of the landing gear transfer unit is to supply the volume of hydraulic fluid needed to raise the landing gear at the normal rate when system A EDP is lost. The system B EDP supplies the volume of hydraulic fluid needed to operate the landing gear transfer unit when all of the following conditions are met:

- Aircraft airborne.
- No. 1 engine rpm drops below a limit value.
- Landing gear lever is up.
- Either or both main landing gear not up and locked.

### Standby Hydraulic System

The standby hydraulic system is provided as a backup if system A and/or B pressure is lost. The standby system can be activated manually or automatically and uses a single electric ACMP to power:

- Thrust reversers.
- Rudder.

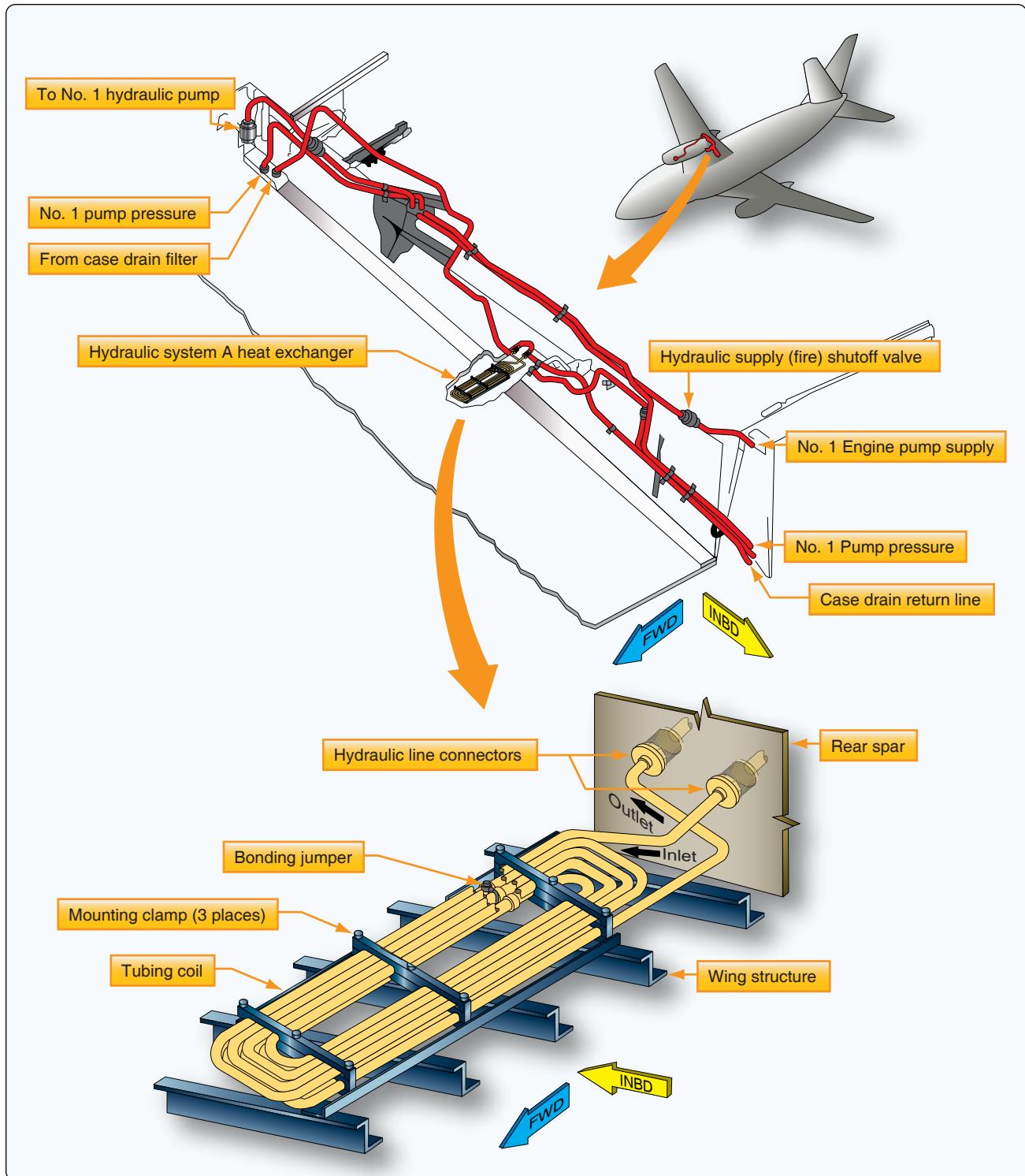
- Leading edge flaps and slats (extend only).
- Standby yaw damper.

### Indications

A master caution light illuminates if an overheat or low pressure is detected in the hydraulic system. An overheat light on the flight deck illuminates if an overheat is detected in either system A or B and a low-pressure light illuminates if a low pressure is detected in system A and B.

### Boeing 777 Hydraulic System

The Boeing 777 is equipped with three hydraulic systems. The left, center, and right systems deliver hydraulic fluid at a rated pressure of 3,000 psi (207 bar) to operate flight controls, flap systems, actuators, landing gear, and brakes. Primary hydraulic power for the left and right systems is provided by two EDPs and supplemented by two on-demand ACMPs. Primary hydraulic power for the center system is provided by two electric motor pumps (ACMP) and supplemented by two on-demand air turbine-driven pumps. The center system provides hydraulic power for the engine thrust reversers,

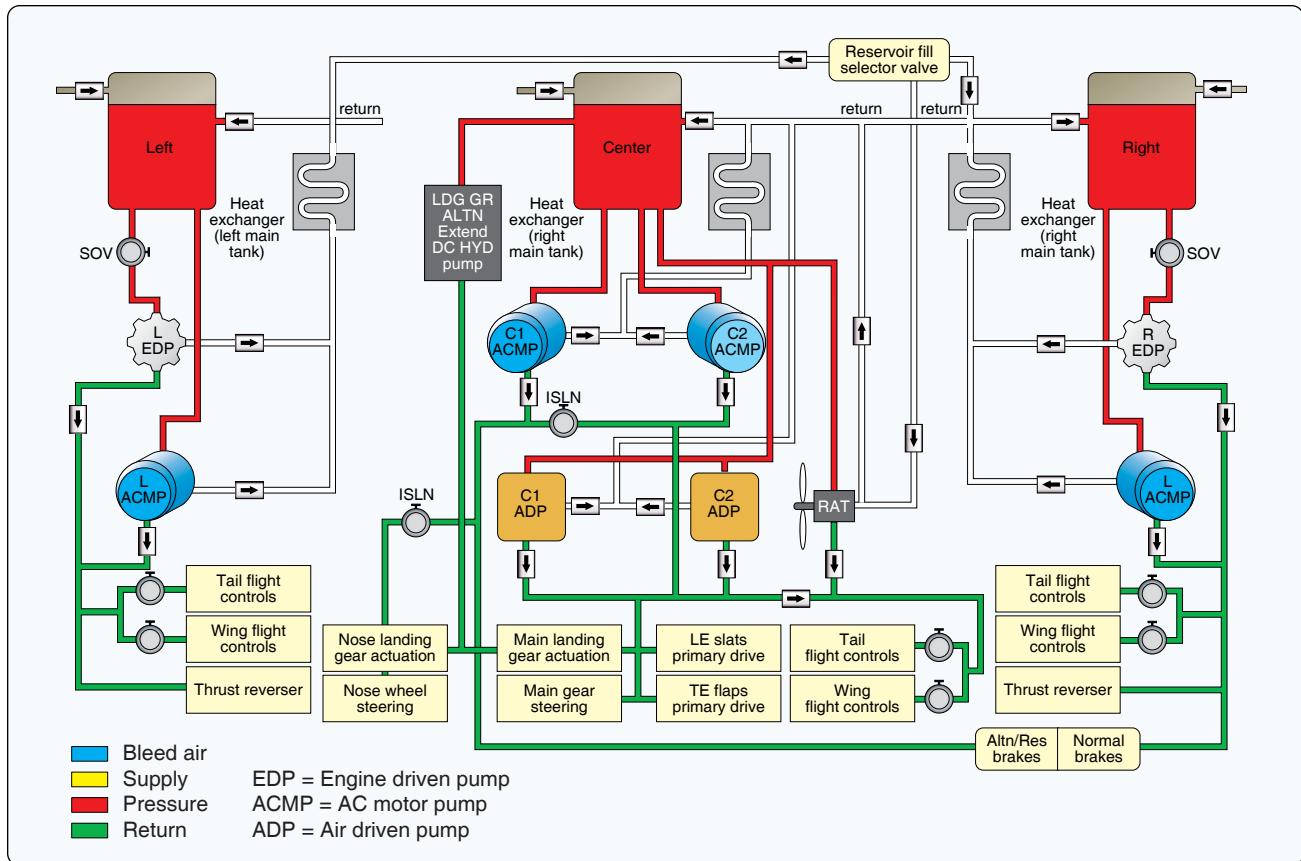


**Figure 12-65.** Boeing 737 hydraulic case drain fluid heat exchanger installed in the fuel tank.

primary flight controls, landing gear, and flaps/slats. Under emergency conditions, hydraulic power is generated by the ram air turbine (RAT), which is deployed automatically and drives a variable displacement inline pump. The RAT pump provides flow to the center system flight controls. [Figure 12-66]

#### **Left & Right System Description**

The left and right hydraulic systems are functionally the same. The left hydraulic system supplies pressurized hydraulic fluid to operate the left thrust reverser and the flight control systems. The right hydraulic system supplies pressurized



**Figure 12-66.** A Boeing 777 hydraulic system.

hydraulic fluid to operate the right thrust reverser, flight control systems, and the normal brake system. [Figure 12-67]

### Reservoir

The hydraulic system reservoirs of the left and right system contain the hydraulic fluid supply for the hydraulic pumps. The reservoir is pressurized by bleed air through a reservoir pressurization module. The EDP draws fluid through a standpipe. The ACMP draws fluid from the bottom of the reservoir. If the fluid level in the reservoir gets below the standpipe, the EDP cannot draw any fluid any longer, and the ACMP is the only source of hydraulic power. The reservoir can be serviced through a center servicing point in the fuselage of the aircraft. The reservoir has a sample valve for contamination testing purposes, a temperature transmitter for temperature indication on the flight deck, a pressure transducer for reservoir pressure, and a drain valve for reservoir draining.

### Pumps

The EDPs are the primary pumps for the left and right hydraulic systems. The EDPs get reservoir fluid through the EDP supply shutoff valves. The EDPs operates whenever the engines operate. A solenoid valve in each EDP controls the

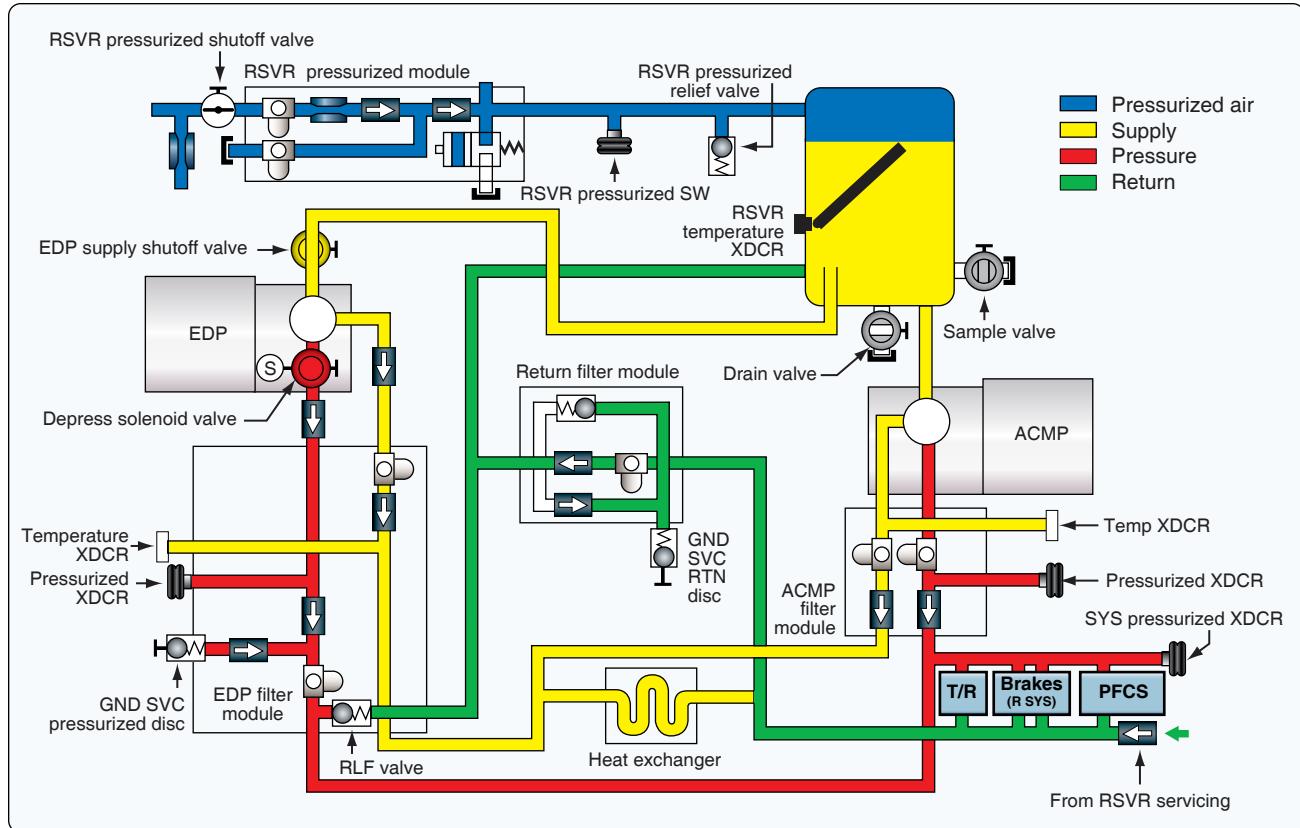
pressurization and depressurization of the pump. The pumps are variable displacement inline piston pumps consisting of a first stage impeller pump and a second stage piston pump. The impeller pump delivers fluid under pressure to the piston pump. The ACMPs are the demand pumps for the left and right hydraulic systems. The ACMPs normally operate only when there is high hydraulic system demand.

### Filter Module

Pressure and case drain filter modules clean the pressure flows and the case drain flows of the hydraulic pumps. A return filter module cleans the return flow of hydraulic fluid from the user systems. The module can be bypassed if the filter clogs, and a visible indicator pops to indicate a clogged filter. The heat exchanger, which is installed in the wing fuel tanks, cools the hydraulic fluid from ACMP and EDP case drain lines before the fluid goes back to the reservoir.

### Indication

The hydraulic system sensors send pressure, temperature, and quantity signals to the flight deck. A reservoir quantity transmitter and temperature transducer are installed on each of the reservoirs, and a hydraulic reservoir pressure switch is located on the pneumatic line between the reservoir



**Figure 12-67.** Right hydraulic system of a Boeing 777. A left system is similar.

pressurization module and the reservoir. The ACMP and EDP filter modules each have a pressure transducer to measure pump output pressure. A temperature transducer is installed in the case drain line of each filter module and measures pump case drain fluid temperature. A system pressure transducer measures hydraulic system pressure. A pressure relief valve on the EDP filter module protects the system against overpressurization. [Figure 12-67]

### Center Hydraulic System

The center hydraulic system supplies pressurized hydraulic fluid to operate these systems. [Figure 12-68]

- Nose landing gear actuation.
- Nose landing gear steering.
- Alternate brakes.
- Main landing gear actuation.
- Main landing gear steering.
- Trailing edge flaps.
- Leading edge slat.
- Flight controls.

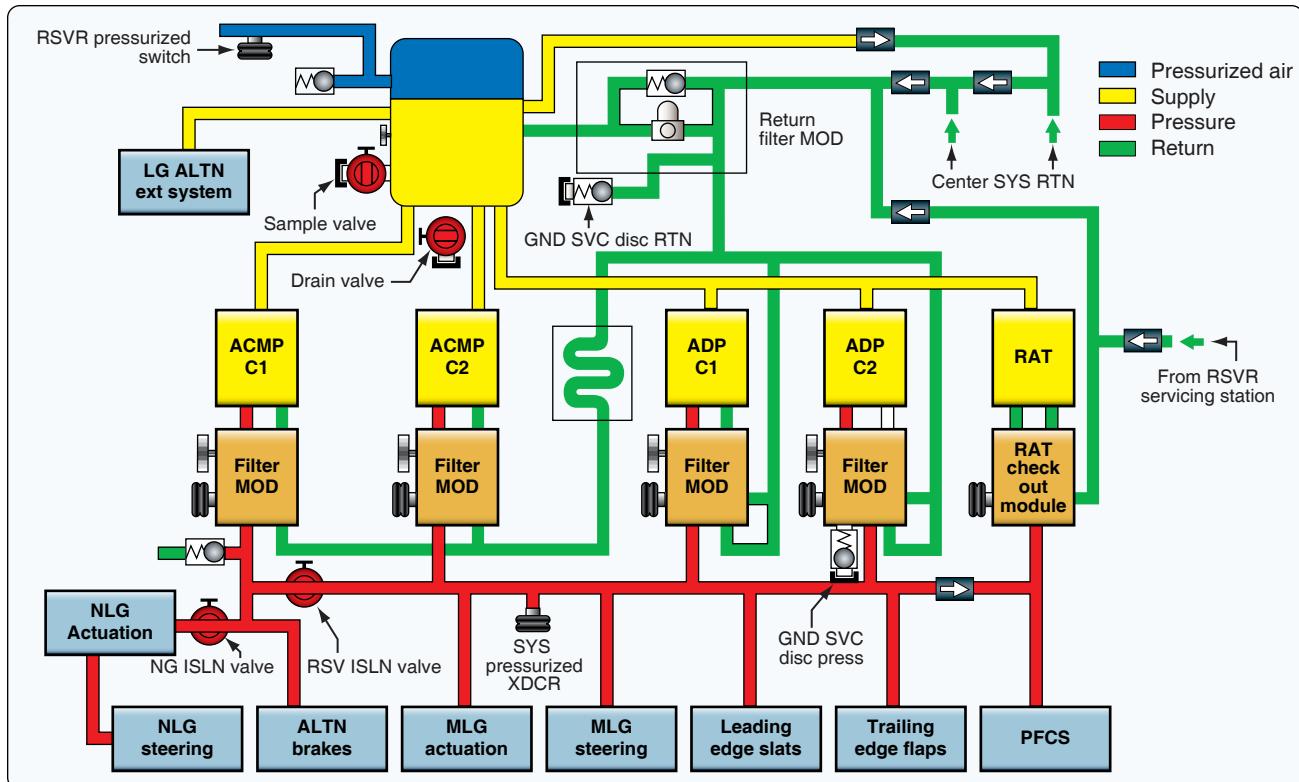
### Reservoir

The hydraulic system reservoir of the center system contains the hydraulic fluid supply for the hydraulic pumps. The reservoir is pressurized by bleed air through a reservoir pressurization module. The reservoir supplies fluid to the ADPs, the RAT, and one of the ACMPs through a standpipe. The other ACMP gets fluid from the bottom of the reservoir. The reservoir also supplies hydraulic fluid to the landing gear alternate extension system.

The ACMPs are the primary pumps in the center hydraulic system and are normally turned on. The ADPs are the demand pumps in the center system. They normally operate only when the center system needs more hydraulic flow capacity. The RAT system supplies an emergency source of hydraulic power to the center hydraulic system flight controls. A reservoir quantity transmitter and temperature transducer are installed on the reservoir. A hydraulic reservoir pressure switch is installed on the pneumatic line between the reservoir and the reservoir pressurization module.

### Filter

Filter modules clean the pressure and case drain output of the hydraulic pumps. A return filter module cleans the return flow of hydraulic fluid from the user systems. The module



**Figure 12-68.** Center hydraulic system.

can be bypassed. The heat exchanger cools the hydraulic fluid from the ACMP case drains before the fluid goes back to the reservoir. ADP case drain fluid does not go through the heat exchangers.

The ACMP and ADP filter modules each have a pressure transducer to measure pump output pressure. A temperature transducer in each filter module measures the pump case drain temperature. A system pressure transducer measures hydraulic system pressure.

Pressure relief valves in each ADP filter module prevent system overpressurization. A pressure relief valve near ACMP C1 supplies overpressure protection for the center hydraulic isolation system (CHIS).

#### Center Hydraulic Isolation System (CHIS)

The CHIS supplies engine burst protection and a reserve brakes and steering function. CHIS operation is fully automatic. Relays control the electric motors in the reserve and nose gear isolation valves. When the CHIS system is operational, it prevents hydraulic operation of the leading-edge slats.

ACMP C1 gets hydraulic fluid from the bottom of the center system reservoir. All other hydraulic pumps in the center system get fluid through a standpipe in the reservoir. This

gives ACMP C1 a 1.2-gallon (4.5 liter) reserve supply of hydraulic fluid.

The reserve and nose gear isolation valves are normally open. Both valves close if the quantity in the center system reservoir is low (less than 0.40) and the airspeed is more than 60 knots for more than one second. When CHIS is active, this divides the center hydraulic system into different parts. The NLG actuation and steering and the leading-edge slat hydraulic lines are isolated from center system pressure. The output of ACMP C1 goes only to the alternate brake system.

The output of the other center hydraulic system pumps goes to the trailing edge flaps, the MLG actuation and steering, and the flight controls. If there is a leak in the NLG actuation and steering or LE slat lines, there is no further loss of hydraulic fluid. The alternate brakes, the trailing edge flaps, the MLG actuation and steering, and the PFCS continue to operate normally.

If there is a leak in the trailing edge flaps, the MLG actuation and steering, or the flight control lines, the reservoir loses fluid down to the standpipe level (0.00 indication). This causes a loss of these systems, but the alternate brake system continues to get hydraulic power from ACMP C1. If there is a leak in the lines between ACMP C1 and the alternate brake system, all center hydraulic system fluid is lost.

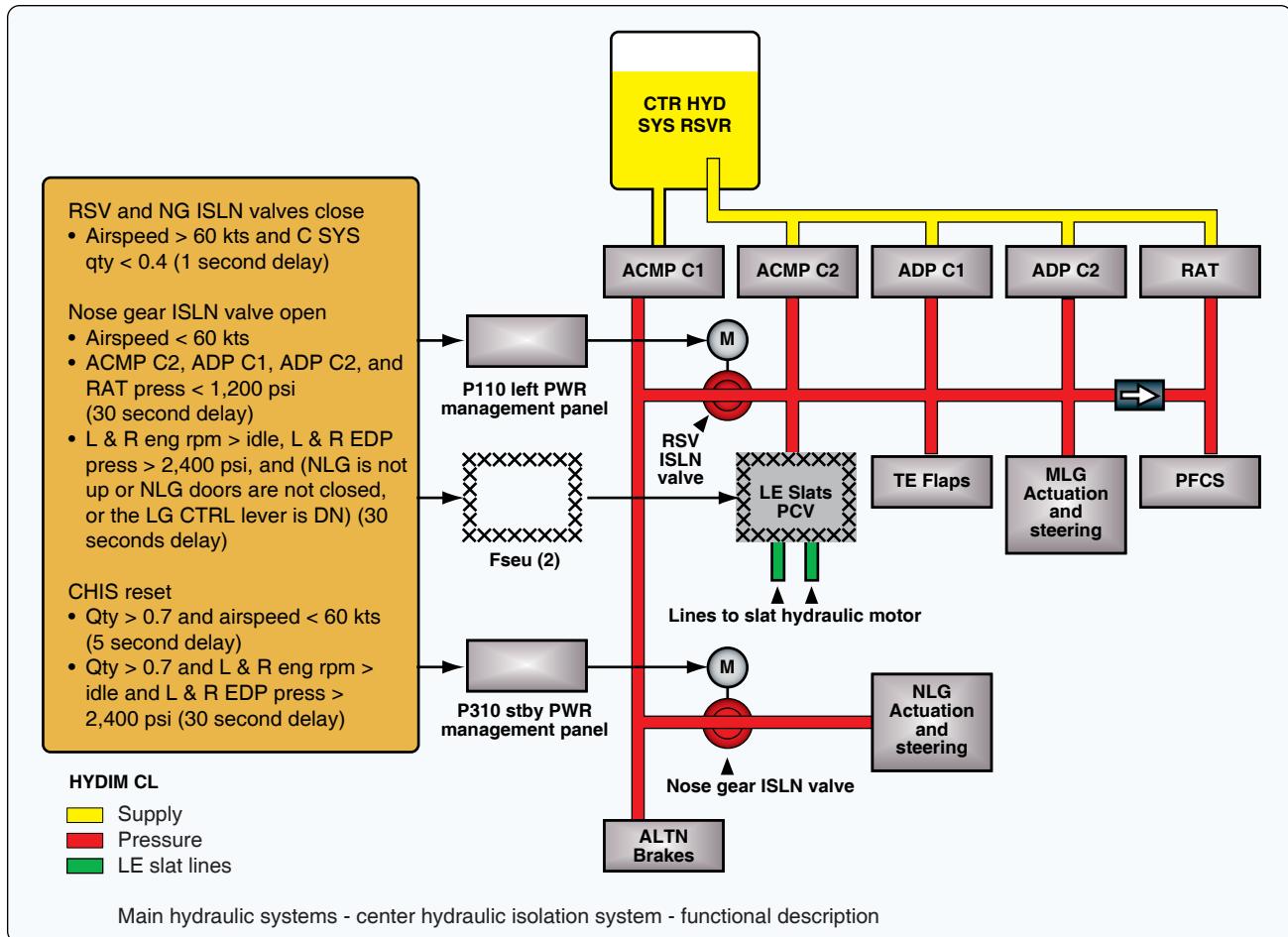


Figure 12-69. Center hydraulic isolation system.

#### Nose Gear Isolation Valve

The nose gear isolation valve opens for any of these conditions:

- Airspeed is less than 60 knots.
- Pump pressures for ACMP C2, ADP C1, ADP C2, and the RAT is less than 1,200 psi for 30 seconds.
- Left and right engine rpm is above idle, left and right EDP pressure is more than 2,400 psi, and the NLG is not up, the NLG doors are not closed, or the landing gear lever is not up for 30 seconds.

The first condition permits the flight crew to operate the NLG steering when airspeed is less than 60 knots (decreased rudder control authority during taxi). The second condition permits operation of the NLG actuation and steering if the hydraulic leak is in the part of the center hydraulic system isolated by the reserve isolation valve. The third condition permits operation of the NLG actuation and steering if there has not been an engine burst and the other hydraulic systems are pressurized. The nose gear isolation valve opens when pressure is necessary at the NLG. If the NLG is not fully

retracted or the NLG doors are not closed, the nose gear isolation valve opens to let the NLG complete the retraction. When the landing gear lever is moved to the down position, the nose gear isolation valve opens to let the NLG extend with center system pressure.

#### Central Hydraulic System Reset

Both valves open again automatically when the center system quantity is more than 0.70 and airspeed is less than 60 knots for 5 seconds. Both valves also reset when the center system quantity is more than 0.70 and both engines and both engine-driven pumps operate normally for 30 seconds. [Figure 12-69]

## Aircraft Pneumatic Systems

Some aircraft manufacturers have equipped their aircraft with a high pressure pneumatic system (3,000 psi) in the past. The last aircraft to utilize this type of system was the Fokker F27. Such systems operate a great deal like hydraulic systems, except they employ air instead of a liquid for transmitting power. Pneumatic systems are sometimes used for:

- Brakes.
- Opening and closing doors.
- Driving hydraulic pumps, alternators, starters, water injection pumps, etc.
- Operating emergency devices.

Both pneumatic and hydraulic systems are similar units and use confined fluids. The word confined means trapped or completely enclosed. The word fluid implies such liquids as water, oil, or anything that flows. Since both liquids and gases flow, they are considered as fluids; however, there is a great deal of difference in the characteristics of the two. Liquids are practically incompressible; a quart of water still occupies about a quart of space regardless of how hard it is compressed. But gases are highly compressible; a quart of air can be compressed into a thimbleful of space. In spite of this difference, gases and liquids are both fluids and can be confined and made to transmit power. The type of unit used to provide pressurized air for pneumatic systems is determined by the system's air pressure requirements.

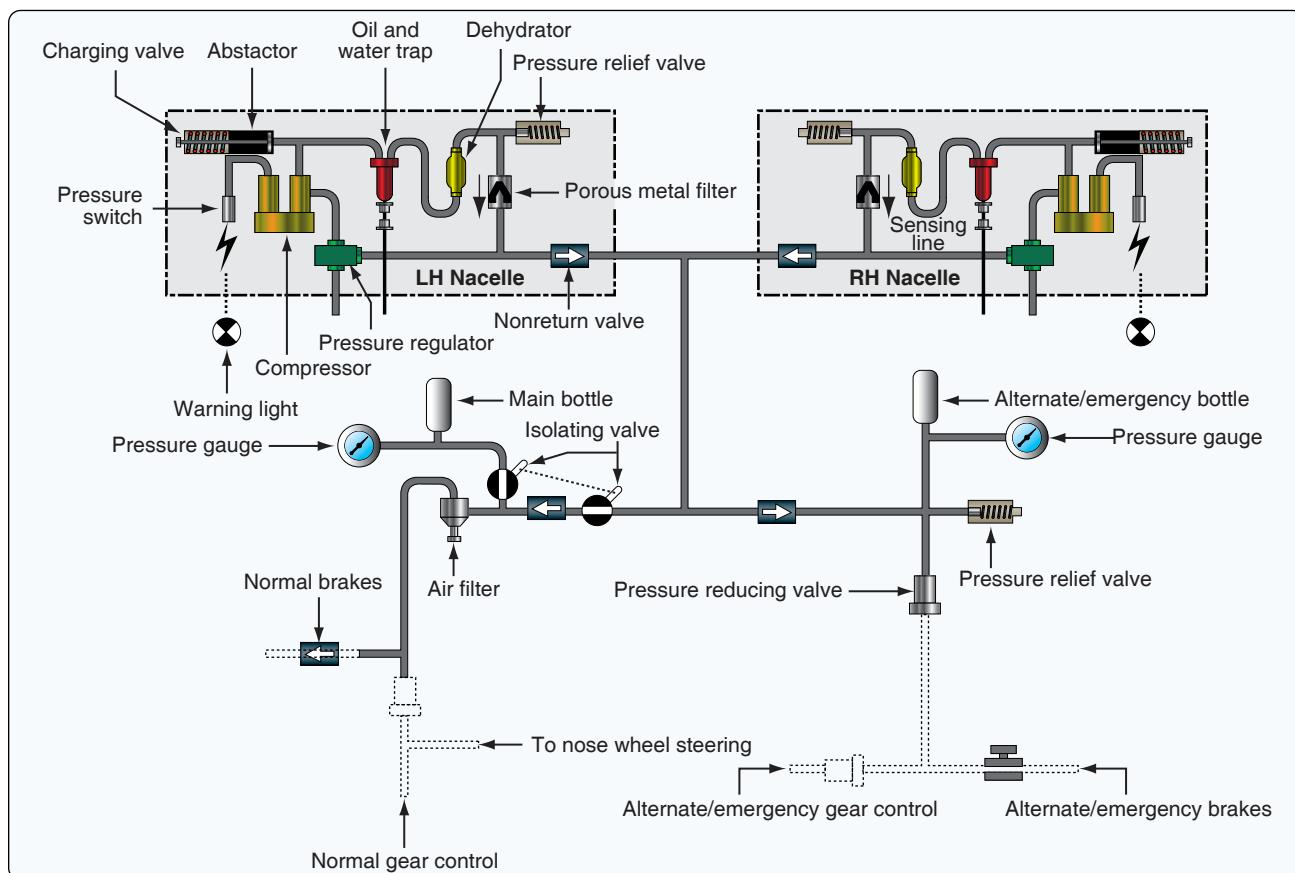
## High-Pressure Systems

For high-pressure systems, air is usually stored in metal bottles at pressures ranging from 1,000 to 3,000 psi,

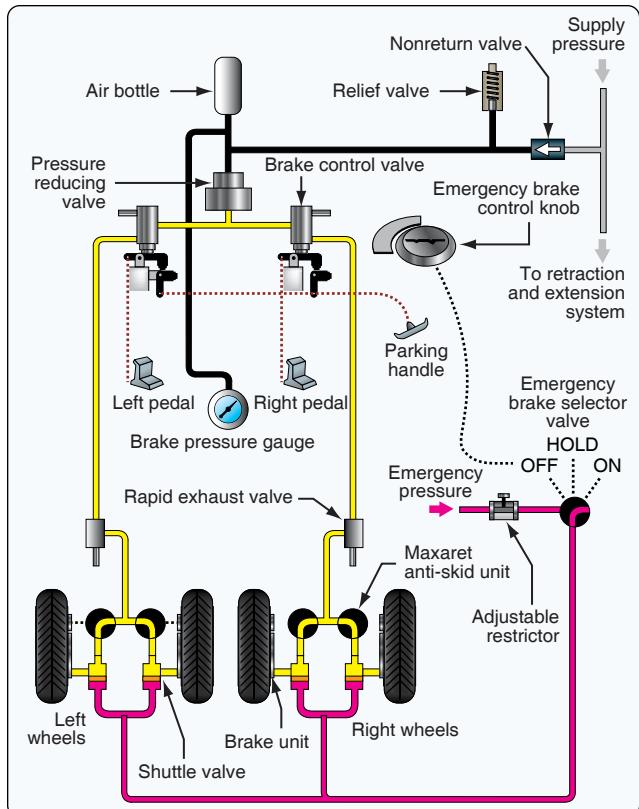
depending on the particular system. [Figure 12-70] This type of air bottle has two valves, one of which is a charging valve. A ground-operated compressor can be connected to this valve to add air to the bottle. The other valve is a control valve. It acts as a shutoff valve, keeping air trapped inside the bottle until the system is operated. Although the high-pressure storage cylinder is light in weight, it has a definite disadvantage. Since the system cannot be recharged during flight, operation is limited by the small supply of bottled air. Such an arrangement cannot be used for the continuous operation of a system. Instead, the supply of bottled air is reserved for emergency operation of such systems as the landing gear or brakes. The usefulness of this type of system is increased, however, if other air-pressurizing units are added to the aircraft. [Figure 12-71]

### Pneumatic System Components

Pneumatic systems are often compared to hydraulic systems, but such comparisons can only hold true in general terms. Pneumatic systems do not utilize reservoirs, hand pumps, accumulators, regulators, or engine-driven or electrically driven power pumps for building normal pressure. But similarities do exist in some components.



**Figure 12-70.** High-pressure pneumatic system.



**Figure 12-71.** Pneumatic brake system.

#### Air Compressors

On some aircraft, permanently installed air compressors have been added to recharge air bottles whenever pressure is used for operating a unit. Several types of compressors are used for this purpose. Some have two stages of compression, while others have three, depending on the maximum desired operating pressure.

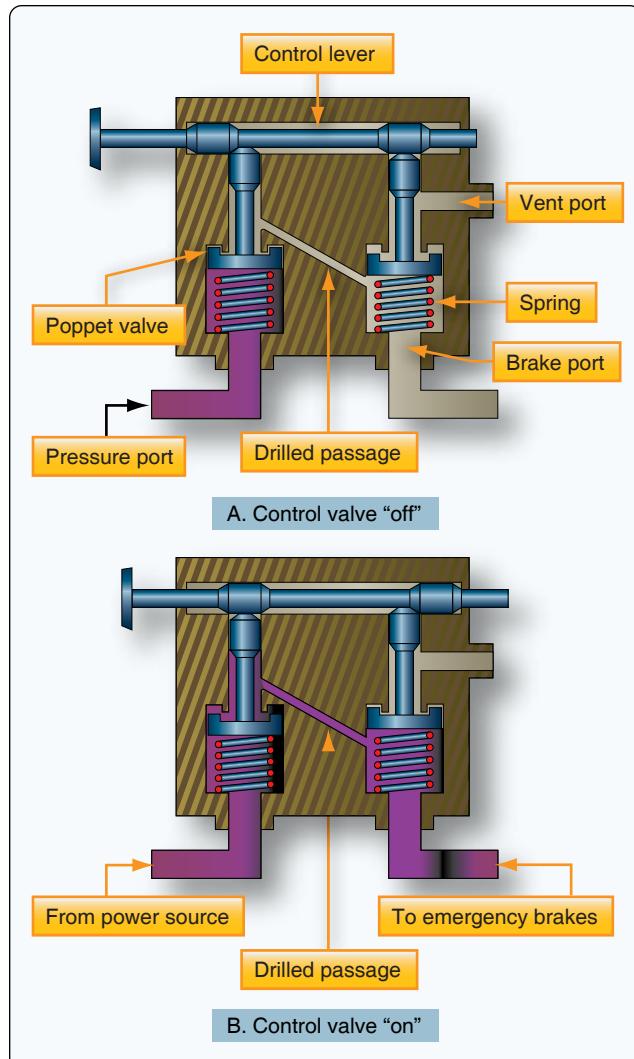
#### Relief Valves

Relief valves are used in pneumatic systems to prevent damage. They act as pressure limiting units and prevent excessive pressures from bursting lines and blowing out seals.

#### Control Valves

Control valves are also a necessary part of a typical pneumatic system. *Figure 12-72* illustrates how a valve is used to control emergency air brakes. The control valve consists of a three-port housing, two poppet valves, and a control lever with two lobes.

In *Figure 12-72A*, the control valve is shown in the off position. A spring holds the left poppet closed so that compressed air entering the pressure port cannot flow to the brakes. In *Figure 12-72B*, the control valve has been placed in the on position. One lobe of the lever holds the left poppet open, and a spring closes the right poppet. Compressed air



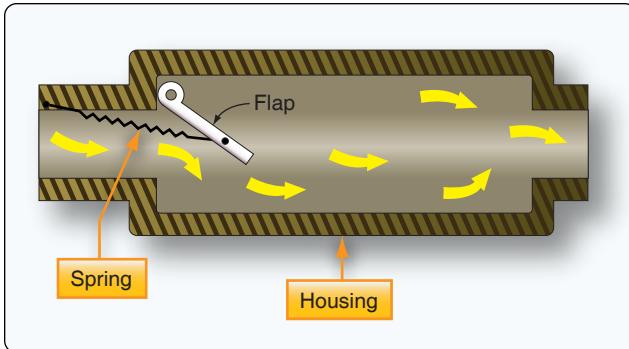
**Figure 12-72.** Pneumatic control valve.

now flows around the opened left poppet, through a drilled passage, and into a chamber below the right poppet. Since the right poppet is closed, the high-pressure air flows out of the brake port and into the brake line to apply the brakes.

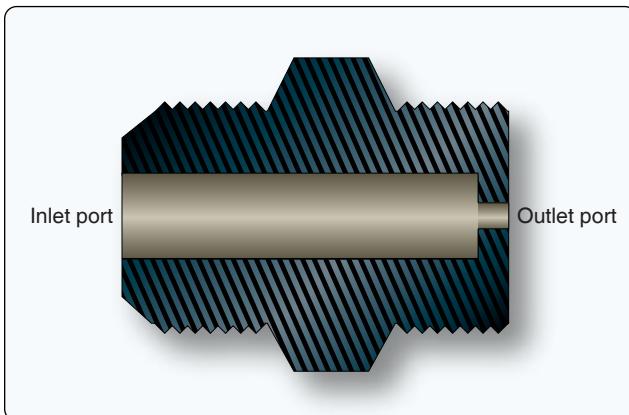
To release the brakes, the control valve is returned to the off position. [*Figure 12-72A*] The left poppet now closes, stopping the flow of high-pressure air to the brakes. At the same time, the right poppet is opened, allowing compressed air in the brake line to exhaust through the vent port and into the atmosphere.

#### Check Valves

Check valves are used in both hydraulic and pneumatic systems. *Figure 12-73* illustrates a flap-type pneumatic check valve. Air enters the left port of the check valve, compresses a light spring, forcing the check valve open and allowing air to flow out of the right port. But if air enters from the right, air pressure closes the valve, preventing a flow of air out of



**Figure 12-73.** Flap-type pneumatic check valve.



**Figure 12-74.** Pneumatic orifice valve.

the left port. Thus, a pneumatic check valve is a one-direction flow control valve.

#### Restrictors

Restrictors are a type of control valve used in pneumatic systems. *Figure 12-74* illustrates an orifice-type restrictor with a large inlet port and a small outlet port. The small outlet port reduces the rate of airflow and the speed of operation of an actuating unit.

#### Variable Restrictor

Another type of speed-regulating unit is the variable restrictor. *[Figure 12-75]* It contains an adjustable needle valve, which has threads around the top and a point on the lower end. Depending on the direction turned, the needle valve moves the sharp point either into or out of a small opening to decrease or increase the size of the opening. Since air entering the inlet port must pass through this opening before reaching the outlet port, this adjustment also determines the rate of airflow through the restrictor.

#### Filters

Pneumatic systems are protected against dirt by means of various types of filters. A micronic filter consists of a housing

with two ports, a replaceable cartridge, and a relief valve. Normally, air enters the inlet, circulates around the cellulose cartridge, and flows to the center of the cartridge and out the outlet port. If the cartridge becomes clogged with dirt, pressure forces the relief valve open and allows unfiltered air to flow out the outlet port.

A screen-type filter is similar to the micron filter but contains a permanent wire screen instead of a replaceable cartridge. In the screen filter, a handle extends through the top of the housing and can be used to clean the screen by rotating it against metal scrapers.

#### Desiccant/Moisture Separator

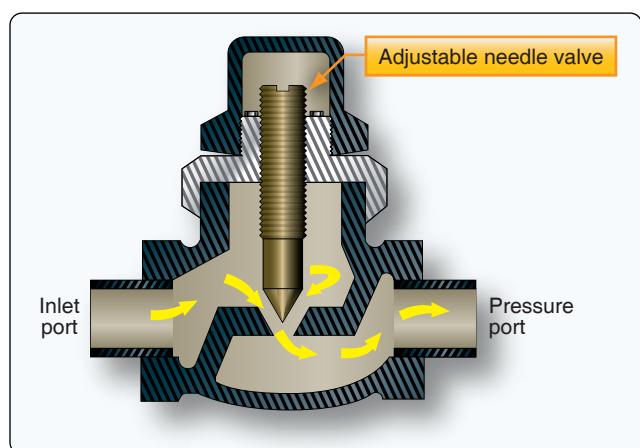
The moisture separator in a pneumatic system is always located downstream of the compressor. Its purpose is to remove any moisture caused by the compressor. A complete moisture separator consists of a reservoir, a pressure switch, a dump valve, and a check valve. It may also include a regulator and a relief valve. The dump valve is energized and deenergized by the pressure switch. When deenergized, it completely purges the separator reservoir and lines up to the compressor. The check valve protects the system against pressure loss during the dumping cycle and prevents reverse flow through the separator.

#### Chemical Drier

Chemical driers are incorporated at various locations in a pneumatic system. Their purpose is to absorb any moisture that may collect in the lines and other parts of the system. Each drier contains a cartridge that should be blue in color. If otherwise noted, the cartridge is to be considered contaminated with moisture and should be replaced.

#### Emergency Backup Systems

Many aircraft use a high-pressure pneumatic back-up source of power to extend the landing gear or actuate the brakes,



**Figure 12-75.** Variable pneumatic restrictor.

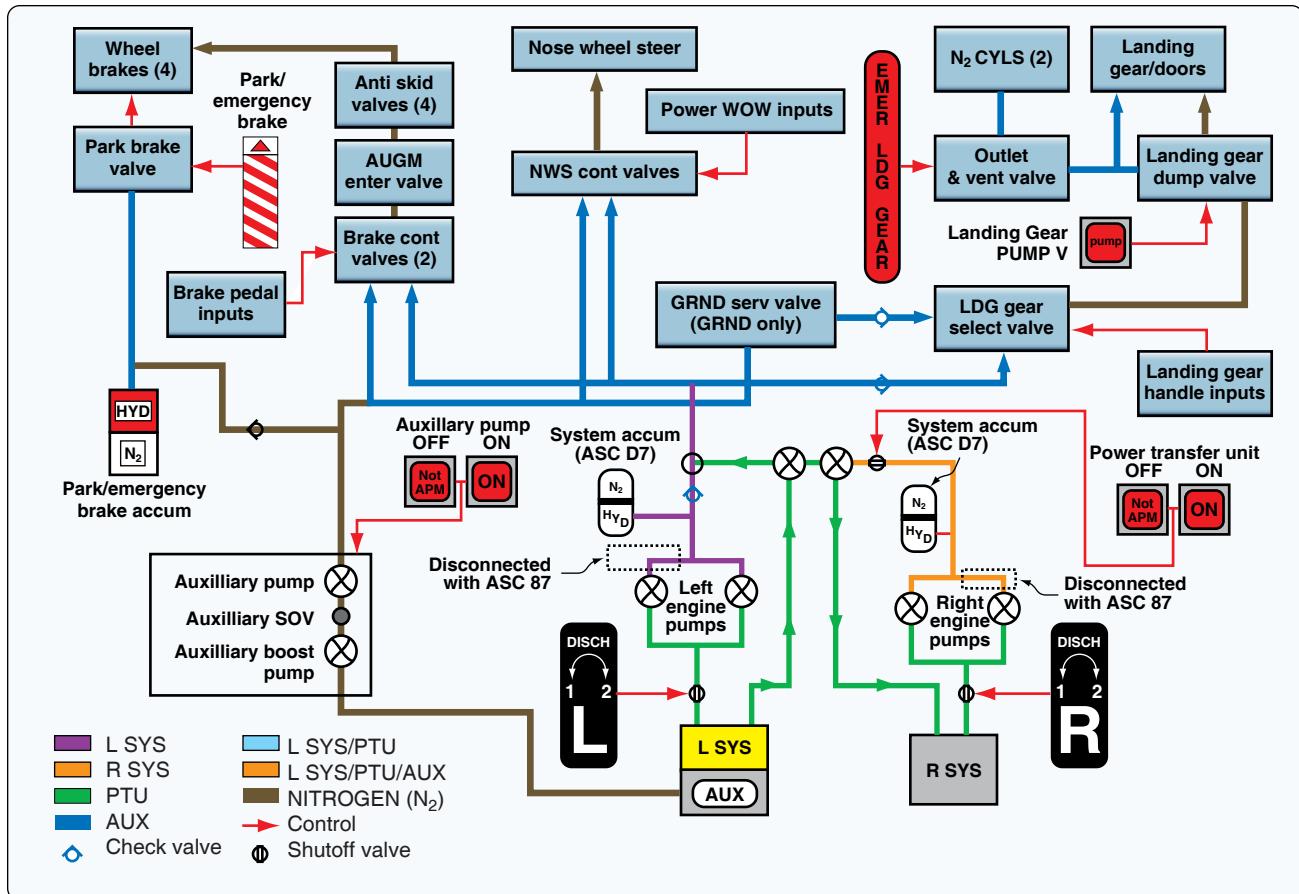


Figure 12-76. Pneumatic emergency landing gear extension system.

if the main hydraulic braking system fails. The nitrogen is not directly used to actuate the landing gear actuators or brake units but, instead, it applies the pressurized nitrogen to move hydraulic fluid to the actuator. This process is called pneumdraulics. The following paragraph discusses the components and operation of an emergency pneumatic landing gear extension system used on a business jet. [Figure 12-76]

#### Nitrogen Bottles

Nitrogen used for emergency landing gear extension is stored in two bottles, one bottle located on each side of the nose wheel well. Nitrogen from the bottles is released by actuation of an outlet valve. Once depleted, the bottles must be recharged by maintenance personnel. Fully serviced pressure is approximately 3,100 psi at 70 °F/21 °C, enough for only one extension of the landing gear.

#### Gear Emergency Extension Cable & Handle

The outlet valve is connected to a cable and handle assembly. The handle is located on the side of the copilot's console and is labeled EMER LDG GEAR. Pulling the handle fully upward opens the outlet valve, releasing compressed nitrogen into the landing gear extension system. Pushing the handle

fully downward closes the outlet valve and allows any nitrogen present in the emergency landing gear extension system to be vented overboard. The venting process takes approximately 30 seconds.

#### Dump Valve

As compressed nitrogen is released to the landing gear selector/dump valve during emergency extension, the pneumdraulic pressure actuates the dump valve portion of the landing gear selector/dump valve to isolate the landing gear system from the remainder of hydraulic system. When activated, a blue DUMP legend is illuminated on the LDG GR DUMP V switch, located on the flight deck overhead panel. A dump valve reset switch is used to reset the dump valve after the system has been used and serviced.

#### Emergency Extension Sequence:

1. Landing gear handle is placed in the DOWN position.
2. Red light in the landing gear control handle is illuminated.
3. EMER LDG GEAR handle is pulled fully outward.
4. Compressed nitrogen is released to the landing gear

- selector/dump valve.
5. Pneudraulic pressure actuates the dump valve portion of the landing gear selector/dump valve.
  6. Blue DUMP legend is illuminated on the LDG GR DUMP switch.
  7. Landing gear system is isolated from the remainder of hydraulic system.
  8. Pneudraulic pressure is routed to the OPEN side of the landing gear door actuators, the UNLOCK side of the landing gear uplock actuators, and the EXTEND side of the main landing gear sidebrace actuators and nose landing gear extend/retract actuator.
  9. Landing gear doors open.
  10. Uplock actuators unlock.
  11. Landing gear extends down and locks.
  12. Three green DOWN AND LOCKED lights on the landing gear control panel are illuminated.
  13. Landing gear doors remain open.

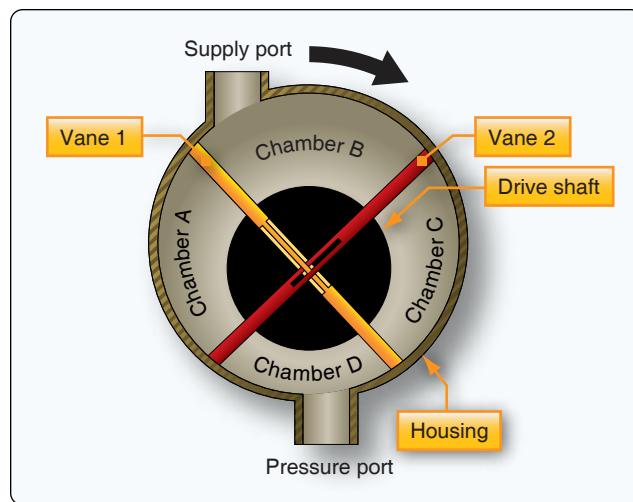
### Medium-Pressure Systems

A medium-pressure pneumatic system (50–150 psi) usually does not include an air bottle. Instead, it generally draws air from the compressor section of a turbine engine. This process is often called bleed air and is used to provide pneumatic power for engine starts, engine deicing, wing deicing, and in some cases, it provides hydraulic power to the aircraft systems (if the hydraulic system is equipped with an air-driven hydraulic pump). Engine bleed air is also used to pressurize the reservoirs of the hydraulic system. Bleed air systems are discussed in more detail in the powerplant handbook.

### Low-Pressure Systems

Many aircraft equipped with reciprocating engines obtain a supply of low-pressure air from vane-type pumps. These pumps are driven by electric motors or by the aircraft engine. *Figure 12-77* shows a schematic view of one of these pumps, which consists of a housing with two ports, a drive shaft, and two vanes. The drive shaft and the vanes contain slots, so the vanes can slide back and forth through the drive shaft. The shaft is eccentrically mounted in the housing, causing the vanes to form four different sizes of chambers (A, B, C, and D). In the position shown, B is the largest chamber and is connected to the supply port. As depicted in *Figure 12-77*, outside air can enter chamber B of the pump. When the pump begins to operate, the drive shaft rotates and changes positions of the vanes and sizes of the chambers. Vane No. 1 then moves to the right, separating chamber B from the supply port. Chamber B now contains trapped air.

As the shaft continues to turn, chamber B moves downward



**Figure 12-77.** Schematic of vane-type air pump.

and becomes increasingly smaller, gradually compressing its air. Near the bottom of the pump, chamber B connects to the pressure port and sends compressed air into the pressure line. Then chamber B moves upward again becoming increasingly larger in area. At the supply port, it receives another supply of air. There are four such chambers in this pump and each goes through this same cycle of operation. Thus, the pump delivers to the pneumatic system a continuous supply of compressed air from 1 to 10 psi. Low-pressure systems are used for wing deicing boot systems.

### Pneumatic Power System Maintenance

Maintenance of the pneumatic power system consists of servicing, troubleshooting, removal, and installation of components, and operational testing.

The air compressor's lubricating oil level should be checked daily in accordance with the applicable manufacturer's instructions. The oil level is indicated by means of a sight gauge or dipstick. When refilling the compressor oil tank, the oil (type specified in the applicable instructions manual) is added until the specified level. After the oil is added, ensure that the filler plug is torqued, and safety wire is properly installed.

The pneumatic system should be purged periodically to remove the contamination, moisture, or oil from the components and lines. Purging the system is accomplished by pressurizing it and removing the plumbing from various components throughout the system. Removal of the pressurized lines causes a high rate of airflow through the system, causing foreign matter to be exhausted from the system. If an excessive amount of foreign matter, particularly oil, is exhausted from any one system, the lines and components should be removed and cleaned or replaced.

Upon completion of pneumatic system purging and after

reconnecting all the system components, the system air bottles should be drained to exhaust any moisture or impurities that may have accumulated there.

After draining the air bottles, service the system with nitrogen or clean, dry compressed air. The system should then be given a thorough operational check and an inspection for leaks and security.

# Chapter 13

# Aircraft Landing Gear Systems

## Landing Gear Types

Aircraft landing gear supports the entire weight of an aircraft during landing and ground operations. They are attached to primary structural members of the aircraft. The type of gear depends on the aircraft design and its intended use. Most landing gear have wheels to facilitate operation to and from hard surfaces, such as airport runways. Other gear feature skids for this purpose, such as those found on helicopters, balloon gondolas, and in the tail area of some tail dragger aircraft. Aircraft that operate to and from frozen lakes and snowy areas may be equipped with landing gear that have skis. Aircraft that operate to and from the surface of water have pontoon-type landing gear. Regardless of the type of landing gear utilized, shock absorbing equipment, brakes, retraction mechanisms, controls, warning devices, cowling, fairings, and structural members necessary to attach the gear to the aircraft are considered parts of the landing gear system. [Figure 13-1]

Numerous configurations of landing gear types can be found. Additionally, combinations of two types of gear are common. Amphibious aircraft are designed with gear that allow landings to be made on water or dry land. The gear features pontoons for water landing with extendable wheels for landings on hard surfaces. A similar system is used to allow the use of skis and wheels on aircraft that operate on both slippery, frozen surfaces and dry runways. Typically, the skis are retractable to allow use of the wheels when needed. Figure 13-2 illustrates this type of landing gear.

**Note:** References to auxiliary landing gear refer to the nose gear, tail gear, or outrigger-type gear on any particular aircraft. Main landing gear are the two or more large gear located close to the aircraft's center of gravity.



Figure 13-1. Basic landing gear types include those with wheels (a), skids (b), skis (c), and floats or pontoons (d).



**Figure 13-2.** An amphibious aircraft with retractable wheels (left) and an aircraft with retractable skis (right).



**Figure 13-3.** Tail wheel configuration landing gear on a DC-3 (left) and a STOL Maule MX-7-235 Super Rocket.

### Landing Gear Arrangement

Three basic arrangements of landing gear are used: tail wheel-type landing gear (also known as conventional gear), tandem landing gear, and tricycle-type landing gear.

#### Tail Wheel-Type Landing Gear

Tail wheel-type landing gear is also known as conventional gear because many early aircraft use this type of arrangement. The main gear are located forward of the center of gravity, causing the tail to require support from a third wheel assembly. A few early aircraft designs use a skid rather than a tail wheel. This helps slow the aircraft upon landing and provides directional stability. The resulting angle of the aircraft fuselage, when fitted with conventional gear, allows the use of a long propeller that compensates for older, underpowered engine design. The increased clearance of the forward fuselage offered by tail wheel-type landing gear is also advantageous when operating in and out of non-paved runways. Today, aircraft are manufactured with conventional gear for this reason and for the weight savings accompanying the relatively light tail wheel assembly. [Figure 13-3]

The proliferation of hard surface runways has rendered the tail skid obsolete in favor of the tail wheel. Directional control is maintained through differential braking until the speed of the aircraft enables control with the rudder. A steerable tail wheel, connected by cables to the rudder or rudder pedals, is also a common design. Springs are incorporated for dampening. [Figure 13-4]

#### Tandem Landing Gear

Few aircraft are designed with tandem landing gear. As the name implies, this type of landing gear has the main gear and tail gear aligned on the longitudinal axis of the aircraft. Sailplanes commonly use tandem gear, although many only have one actual gear forward on the fuselage with a skid under the tail. A few military bombers, such as the B-47 and the B-52, have tandem gear, as does the U2 spy plane. The VTOL Harrier has tandem gear but uses small outrigger gear under the wings for support. Generally, placing the gear only under the fuselage facilitates the use of very flexible wings. [Figure 13-5]



**Figure 13-4.** The steerable tail wheel of a Pitts Special.



**Figure 13-5.** Tandem landing gear along the longitudinal axis of the aircraft permits the use of flexible wings on sailplanes (left) and select military aircraft like the B-52 (center). The VTOL Harrier (right) has tandem gear with outrigger-type gear.



**Figure 13-6.** Tricycle-type landing gear with dual main wheels on a Learjet (left) and a Cessna 172, also with tricycle gear (right).

### Tricycle-Type Landing Gear

The most commonly used landing gear arrangement is the tricycle-type landing gear. It is comprised of main gear and nose gear. [Figure 13-6]

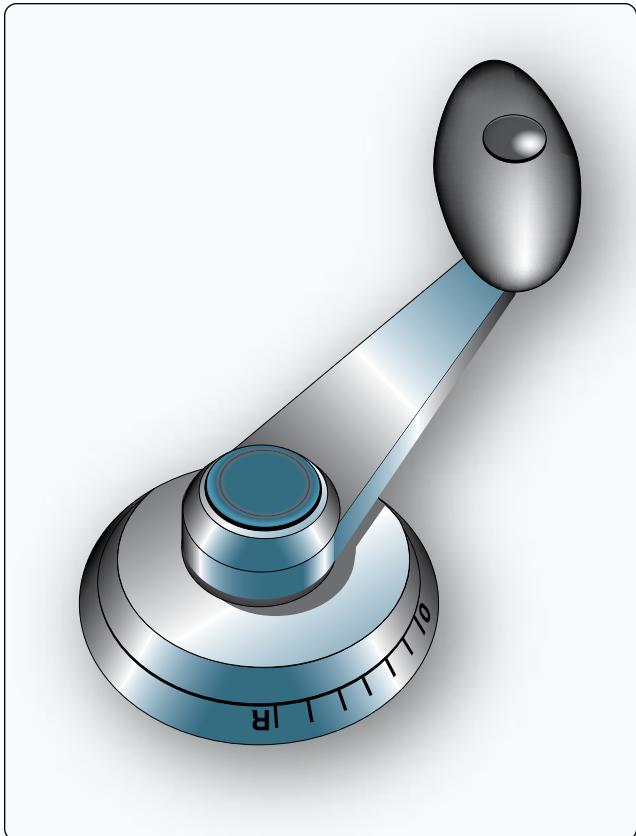
Tricycle-type landing gear is used on large and small aircraft with the following benefits:

1. Allows more forceful application of the brakes without nosing over when braking, which enables higher landing speeds.
2. Provides better visibility from the flight deck,

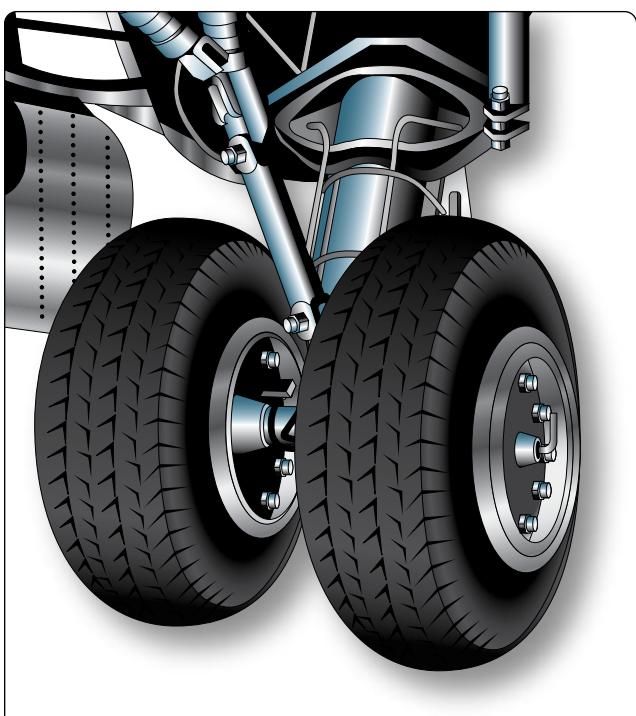
especially during landing and ground maneuvering.

3. Prevents ground-looping of the aircraft. Since the aircraft center of gravity is forward of the main gear, forces acting on the center of gravity tend to keep the aircraft moving forward rather than looping, such as with a tail wheel-type landing gear.

The nose gear of a few aircraft with tricycle-type landing gear is not controllable. It simply casters as steering is accomplished with differential braking during taxi. However, nearly all aircraft have steerable nose gear. On light aircraft,



**Figure 13-7.** A nose wheel steering tiller located on the flight deck.



**Figure 13-8.** Dual main gear of a tricycle-type landing gear.



**Figure 13-9.** Triple bogie main landing gear assembly on a Boeing 777.

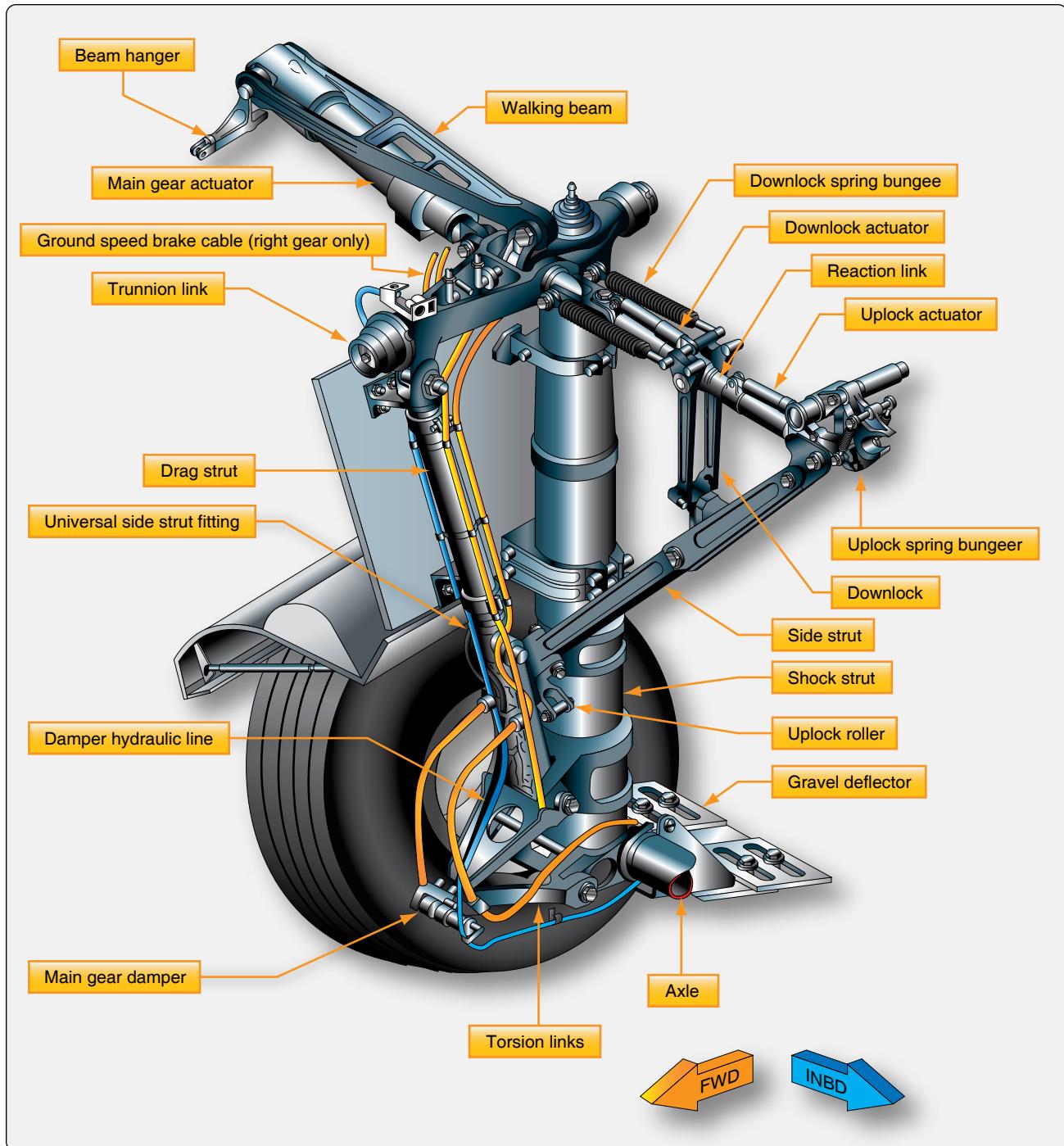
the nose gear is directed through mechanical linkage to the rudder pedals. Heavy aircraft typically utilize hydraulic power to steer the nose gear. Control is achieved through an independent tiller in the flight deck. [Figure 13-7]

The main gear on a tricycle-type landing gear arrangement is attached to reinforced wing structure or fuselage structure. The number and location of wheels on the main gear vary. Many main gear have two or more wheels. [Figure 13-8] Multiple wheels spread the weight of the aircraft over a larger area. They also provide a safety margin should one tire fail. Heavy aircraft may use four or more wheel assemblies on each main gear. When more than two wheels are attached to a landing gear strut, the attaching mechanism is known as a bogie. The number of wheels included in the bogie is a function of the gross design weight of the aircraft and the surface type on which the loaded aircraft is required to land. *Figure 13-9* illustrates the triple bogie main gear of a Boeing 777.

The tricycle-type landing gear arrangement consists of many parts and assemblies. These include air/oil shock struts, gear alignment units, support units, retraction and safety devices, steering systems, wheel and brake assemblies, etc. A main landing gear of a transport category aircraft is illustrated in *Figure 13-10* with many of the parts identified as an introduction to landing gear nomenclature.

#### Fixed & Retractable Landing Gear

Further classification of aircraft landing gear can be made into two categories: fixed and retractable. Many small, single-engine light aircraft have fixed landing gear, as do a few light twins. This means the gear is attached to the airframe and remains exposed to the slipstream as the aircraft is flown. As discussed in Chapter 2 of this handbook, as the speed of



**Figure 13-10.** Nomenclature of a main landing gear bogie truck.

an aircraft increases, so does parasite drag. Mechanisms to retract and stow the landing gear to eliminate parasite drag add weight to the aircraft. On slow aircraft, the penalty of this added weight is not overcome by the reduction of drag, so fixed gear is used. As the speed of the aircraft increases, the drag caused by the landing gear becomes greater and a means to retract the gear to eliminate parasite drag is required, despite the weight of the mechanism.

A great deal of the parasite drag caused by light aircraft landing gear can be reduced by building gear as aerodynamically as possible and by adding fairings or wheel pants to streamline the airflow past the protruding assemblies. A small, smooth profile to the oncoming wind greatly reduces landing gear parasite drag. *Figure 13-11* illustrates a Cessna aircraft landing gear used on many of the manufacturer's light planes.



**Figure 13-11.** Wheel fairings, or pants, and low profile struts reduce parasite drag on fixed gear aircraft.

The thin cross section of the spring steel struts combine with the fairings over the wheel and brake assemblies to raise performance of the fixed landing gear by keeping parasite drag to a minimum.

Retractable landing gear stow in fuselage or wing compartments while in flight. Once in these wheel wells, gear are out of the slipstream and do not cause parasite drag. Most retractable gear have a close-fitting panel attached to them that fairs with the aircraft skin when the gear is fully retracted. [Figure 13-12] Other aircraft have separate doors that open, allowing the gear to enter or leave, and then close again.

**Note:** The parasite drag caused by extended landing gear can be used by the pilot to slow the aircraft. The extension and retraction of most landing gear is usually accomplished with hydraulics. Landing gear retraction systems are discussed later in this chapter.



**Figure 13-13.** Non-shock absorbing struts made from steel, aluminum, or composite material transfer the impact forces of landing to the airframe at a non-damaging rate.

### Shock Absorbing & Non-Shock Absorbing Landing Gear

In addition to supporting the aircraft for taxi, the forces of impact on an aircraft during landing must be controlled by the landing gear. This is done in two ways: 1) the shock energy is altered and transferred throughout the airframe at a different rate and time than the single strong pulse of impact, and 2) the shock is absorbed by converting the energy into heat energy.

#### Leaf-Type Spring Gear

Many aircraft utilize flexible spring steel, aluminum, or composite struts that receive the impact of landing and return it to the airframe to dissipate at a rate that is not harmful. The gear flexes initially and forces are transferred as it returns to its original position. [Figure 13-13] The most common example of this type of non-shock absorbing landing gear are the thousands of single-engine Cessna aircraft that use it. Landing gear struts of this type made from composite materials are lighter in weight with greater flexibility and do not corrode.



**Figure 13-12.** The retractable gear of a Boeing 737 fair into recesses in the fuselage. Panels attached to the landing gear provide smooth airflow over the struts. The wheel assemblies mate with seals to provide aerodynamic flow without doors.



**Figure 13-14.** Rigid steel landing gear is used on many early aircraft.

### Rigid

Before the development of curved spring steel landing struts, many early aircraft were designed with rigid, welded steel landing gear struts. Shock load transfer to the airframe is direct with this design. Use of pneumatic tires aids in softening the impact loads. [Figure 13-14] Modern aircraft that use skid-type landing gear make use of rigid landing gear with no significant ill effects. Rotorcraft, for example, typically experience low impact landings that are able to be directly absorbed by the airframe through the rigid gear (skids).

### Bungee Cord

The use of bungee cords on non-shock absorbing landing gear is common. The geometry of the gear allows the strut assembly to flex upon landing impact. Bungee cords are positioned between the rigid airframe structure and the flexing gear assembly to take up the loads and return them to the airframe at a non-damaging rate. The bungees are made

of many individual small strands of elastic rubber that must be inspected for condition. Solid, donut-type rubber cushions are also used on some aircraft landing gear. [Figure 13-15]

### Shock Struts

True shock absorption occurs when the shock energy of landing impact is converted into heat energy, as in a shock strut landing gear. This is the most common method of landing shock dissipation in aviation. It is used on aircraft of all sizes. Shock struts are self-contained hydraulic units that support an aircraft while on the ground and protect the structure during landing. They must be inspected and serviced regularly to ensure proper operation.

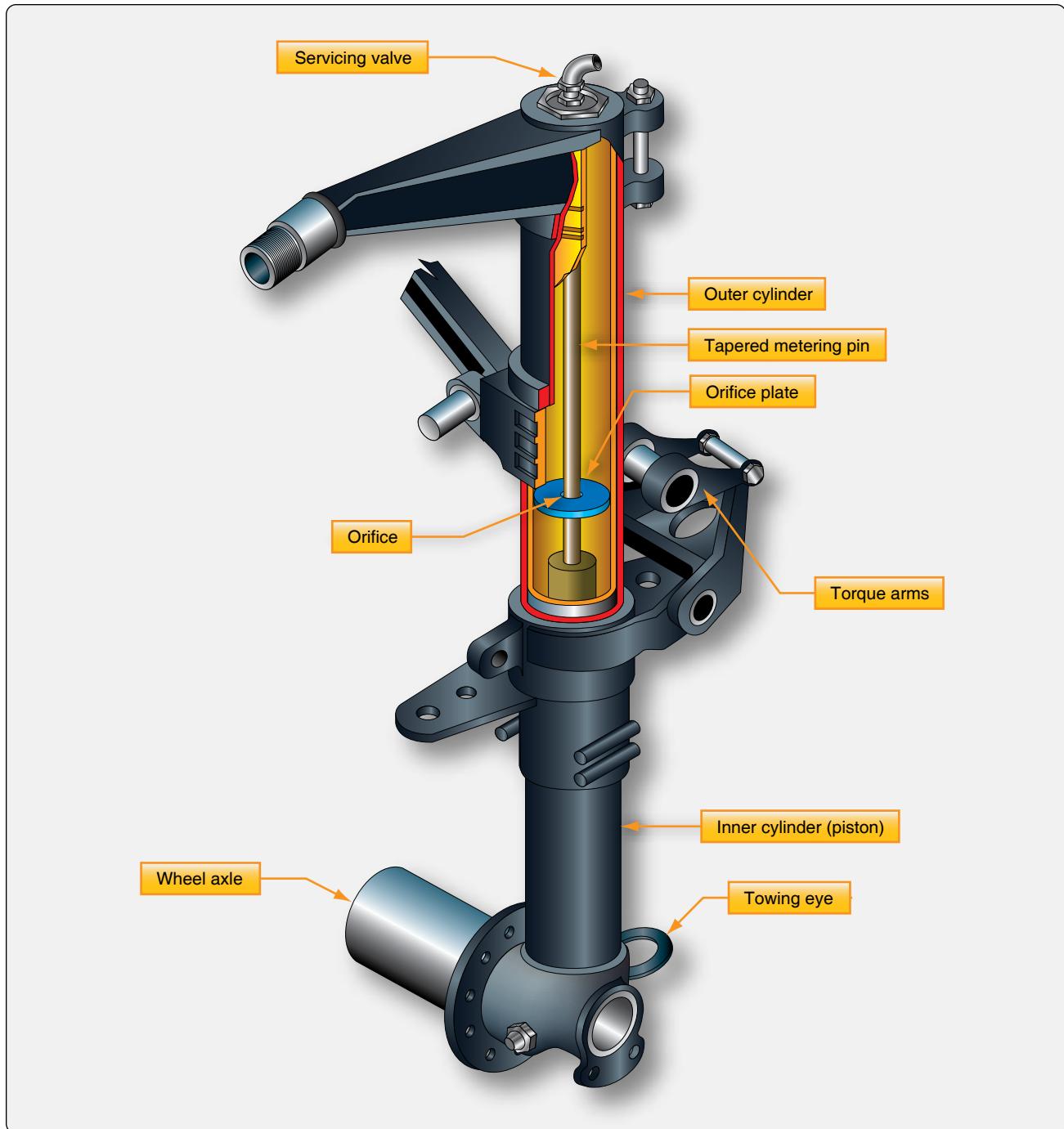
There are many different designs of shock struts, but most operate in a similar manner. The following discussion is general in nature. For information on the construction, operation, and servicing of a specific aircraft shock, consult the manufacturer's maintenance instructions.

A typical pneumatic/hydraulic shock strut uses compressed air or nitrogen combined with hydraulic fluid to absorb and dissipate shock loads. It is sometimes referred to as an air/oil or oleo strut. A shock strut is constructed of two telescoping cylinders or tubes that are closed on the external ends. The upper cylinder is fixed to the aircraft and does not move. The lower cylinder is called the piston and is free to slide in and out of the upper cylinder. Two chambers are formed. The lower chamber is always filled with hydraulic fluid and the upper chamber is filled with compressed air or nitrogen. An orifice located between the two cylinders provides a passage for the fluid from the bottom chamber to enter the top cylinder chamber when the strut is compressed. [Figure 13-16]

Most shock struts employ a metering pin similar to that shown in Figure 13-16 for controlling the rate of fluid flow



**Figure 13-15.** Piper Cub bungee cord landing gear transfer landing loads to the airframe (left and center). Rubber, donut-type shock transfer is used on some Mooney aircraft (right).

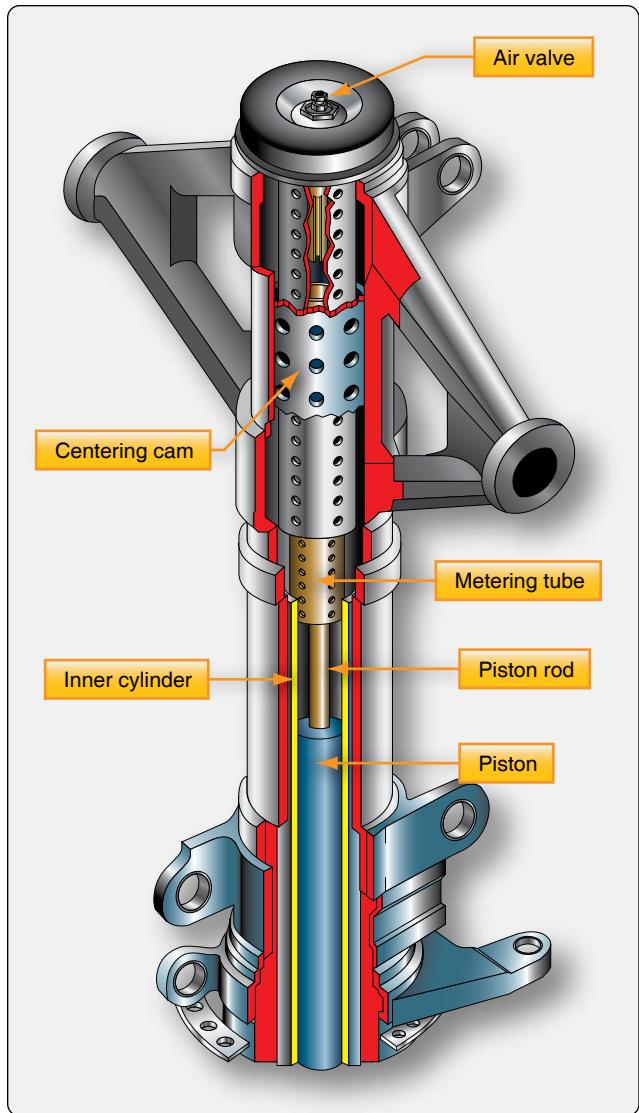


**Figure 13-16.** A landing gear shock strut with a metering pin to control the flow of hydraulic fluid from the lower chamber to the upper chamber during compression.

from the lower chamber into the upper chamber. During the compression stroke, the rate of fluid flow is not constant. It is automatically controlled by the taper of the metering pin in the orifice. When a narrow portion of the pin is in the orifice, more fluid can pass to the upper chamber. As the diameter of the portion of the metering pin in the orifice increases, less fluid passes. Pressure build-up caused by strut compression and the hydraulic fluid being forced through the metered

orifice causes heat. This heat is converted impact energy. It is dissipated through the structure of the strut.

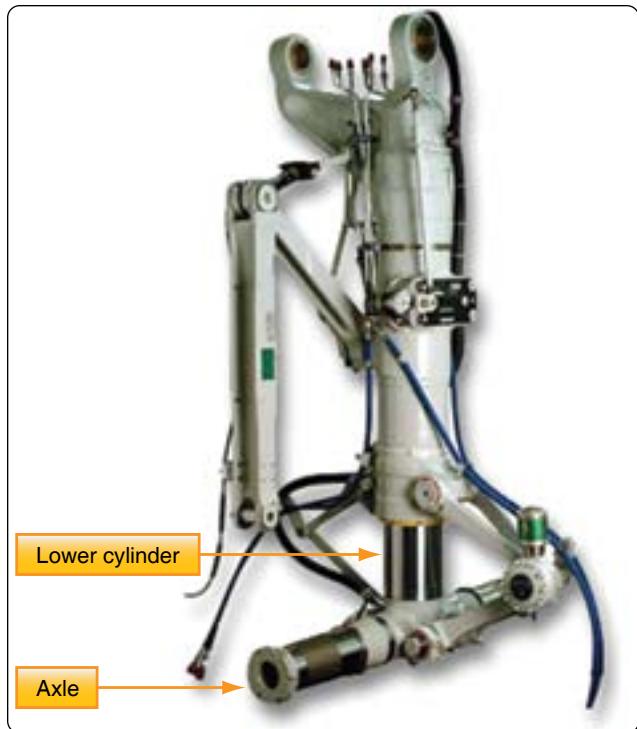
On some types of shock struts, a metering tube is used. The operational concept is the same as that in shock struts with metering pins, except the holes in the metering tube control the flow of fluid from the bottom chamber to the top chamber during compression. [Figure 13-17]



**Figure 13-17.** Some landing gear shock struts use an internal metering tube rather than a metering pin to control the flow of fluid from the bottom cylinder to the top cylinder.

Upon lift off or rebound from compression, the shock strut tends to extend rapidly. This could result in a sharp impact at the end of the stroke and damage to the strut. It is typical for shock struts to be equipped with a damping or snubbing device to prevent this. A recoil valve on the piston or a recoil tube restricts the flow of fluid during the extension stroke, which slows the motion and prevents damaging impact forces.

Most shock struts are equipped with an axle as part of the lower cylinder to provide installation of the aircraft wheels. Shock struts without an integral axle have provisions on the end of the lower cylinder for installation of the axle assembly. Suitable connections are provided on all shock strut upper cylinders to attach the strut to the airframe. [Figure 13-18]



**Figure 13-18.** Axles machined out of the same material as the landing gear lower cylinder.

The upper cylinder of a shock strut typically contains a valve fitting assembly. It is located at or near the top of the cylinder. The valve provides a means of filling the strut with hydraulic fluid and inflating it with air or nitrogen as specified by the manufacturer. A packing gland is employed to seal the sliding joint between the upper and lower telescoping cylinders. It is installed in the open end of the outer cylinder. A packing gland wiper ring is also installed in a groove in the lower bearing or gland nut on most shock struts. It is designed to keep the sliding surface of the piston from carrying dirt, mud, ice, and snow into the packing gland and upper cylinder. Regular cleaning of the exposed portion of the strut piston helps the wiper do its job and decreases the possibility of damage to the packing gland, which could cause the strut to leak.

To keep the piston and wheels aligned, most shock struts are equipped with torque links or torque arms. One end of the links is attached to the fixed upper cylinder. The other end is attached to the lower cylinder (piston), so it cannot rotate. This keeps the wheels aligned. The links also retain the piston in the end of the upper cylinder when the strut is extended, such as after takeoff. [Figure 13-19]

Nose gear shock struts are provided with a locating cam assembly to keep the gear aligned. A cam protrusion is attached to the lower cylinder, and a mating lower cam recess is attached to the upper cylinder. These cams line up

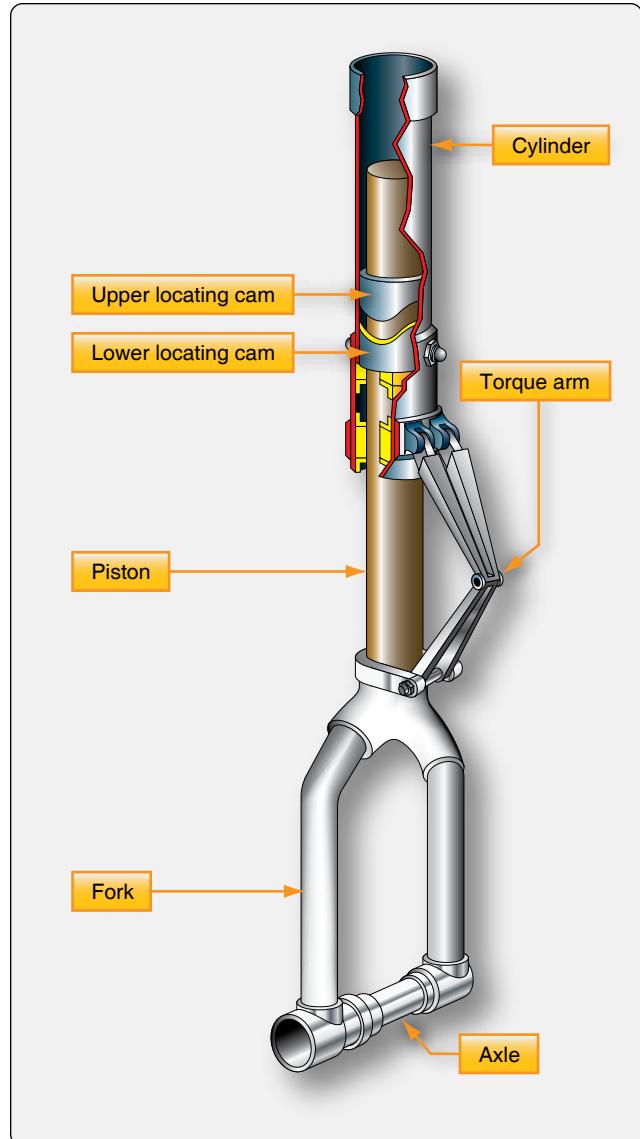


**Figure 13-19.** Torque links align the landing gear and retain the piston in the upper cylinder when the strut is extended.

the wheel and axle assembly in the straight-ahead position when the shock strut is fully extended. This allows the nose wheel to enter the wheel well when the nose gear is retracted and prevents structural damage to the aircraft. It also aligns the wheels with the longitudinal axis of the aircraft prior to landing when the strut is fully extended. [Figure 13-20] Many nose gear shock struts also have attachments for the installation of an external shimmy damper. [Figure 13-21]

Nose gear struts are often equipped with a locking or disconnect pin to enable quick turning of the aircraft while towing or positioning the aircraft when on the ramp or in a hangar. Disengagement of this pin allows the wheel fork spindle on some aircraft to rotate 360°, thus enabling the aircraft to be turned in a tight radius. At no time should the nose wheel of any aircraft be rotated beyond limit lines marked on the airframe.

Nose and main gear shock struts on many aircraft are also equipped with jacking points and towing lugs. Jacks should always be placed under the prescribed points. When towing lugs are provided, the towing bar should be attached only to these lugs. [Figure 13-22]



**Figure 13-20.** An upper locating cam mates into a lower cam recess when the nose landing gear shock strut is extended before landing and before the gear is retracted into the wheel well.

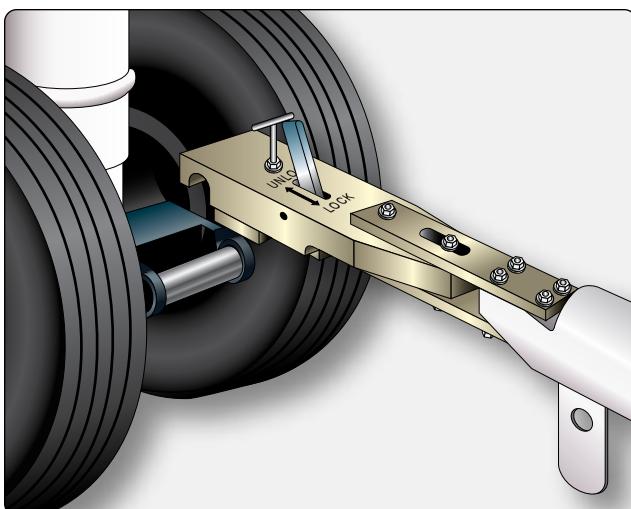
Shock struts contain an instruction plate that gives directions for filling the strut with fluid and for inflating the strut. The instruction plate is usually attached near filler inlet and air valve assembly. It specifies the correct type of hydraulic fluid to use in the strut and the pressure to which the strut should be inflated. It is of utmost importance to become familiar with these instructions prior to filling a shock strut with hydraulic fluid or inflating it with air or nitrogen.

### Shock Strut Operation

Figure 13-23 illustrates the inner construction of a shock strut. Arrows show the movement of the fluid during compression and extension of the strut. The compression stroke of the shock strut begins as the aircraft wheels touch the ground. As

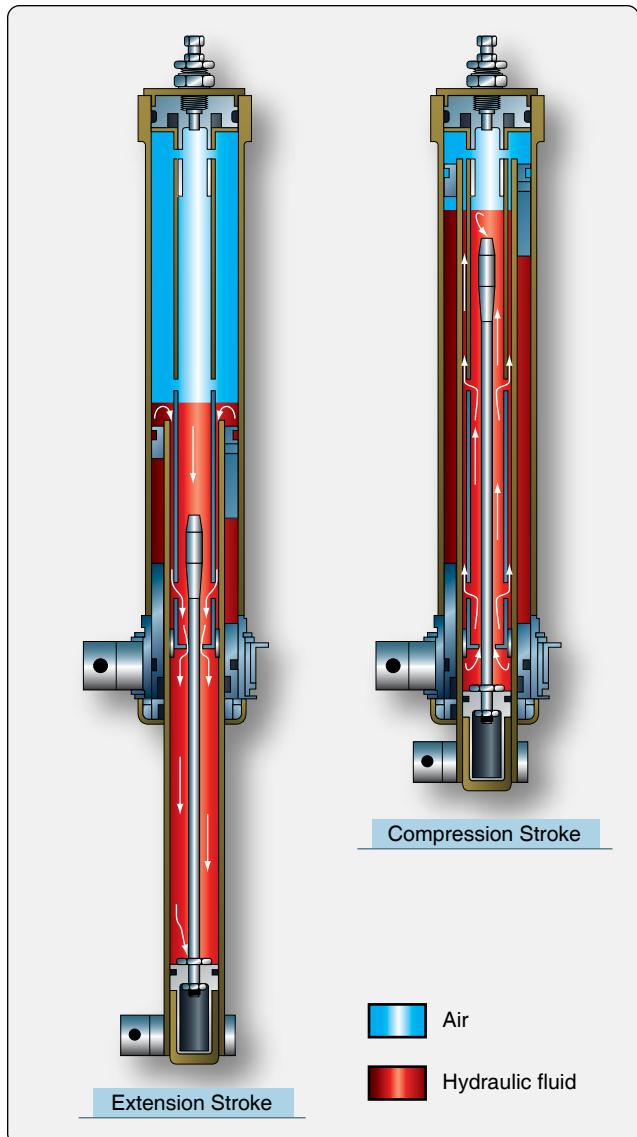


**Figure 13-21.** A shimmy damper helps control oscillations of the nose gear.



**Figure 13-22.** A towing lug on a landing gear is the designed means for attaching a tow bar.

the center of mass of the aircraft moves downward, the strut compresses, and the lower cylinder or piston is forced upward into the upper cylinder. The metering pin is therefore moved up through the orifice. The taper of the pin controls the rate of fluid flow from the bottom cylinder to the top cylinder at all points during the compression stroke. In this manner, the greatest amount of heat is dissipated through the walls of the strut. At the end of the downward stroke, the compressed air in the upper cylinder is further compressed which limits the compression stroke of the strut with minimal impact. During taxi operations, the air in the tires and the strut combine to smooth out bumps.



**Figure 13-23.** Fluid flow during shock strut operation is controlled by the taper of the metering pin in the shock strut orifice.

Insufficient fluid, or air in the strut, cause the compression stroke to not be properly limited. The strut could bottom out, resulting in impact forces to be transferred directly to the airframe through the metallic structure of the strut. In a properly serviced strut, the extension stroke of the shock strut operation occurs at the end of the compression stroke. Energy stored in the compressed air in the upper cylinder causes the aircraft to start moving upward in relation to the ground and lower strut cylinder as the strut tries to rebound to its normal position. Fluid is forced back down into the lower cylinder through restrictions and snubbing orifices. The snubbing of fluid flow during the extension stroke dampens the strut rebound and reduces oscillation caused by the spring action of the compressed air. A sleeve, spacer, or bumper ring incorporated into the strut limits the extension stroke.

Efficient operation of the shock struts requires that proper fluid and air pressure be maintained. To check the fluid level, most struts need to be deflated and compressed into the fully compressed position. Deflating a shock strut can be a dangerous operation. The technician must be thoroughly familiar with the operation of the high-pressure service valve found at the top of the strut's upper cylinder. Refer to the manufacturer's instructions for proper deflating technique of the strut in question and follow all necessary safety precautions.

Two common types of high pressure strut servicing valves are illustrated in *Figure 13-24*. The AN6287-1 valve in *Figure 13-24A* has a valve core assembly and is rated to 3,000 pounds per square inch (psi). However, the core itself is only rated to 2,000 psi. The MS28889-1 valve in *Figure 13-24B* has no valve core. It is rated to 5,000 psi. The swivel nut on the AN6287-1 valve is smaller than the valve body hex. The MS28889-1 swivel nut is the same size as the valve body hex. The swivel nuts on both valves engage threads on an internal stem that loosens or draws tight the valve stem to a metal seat.

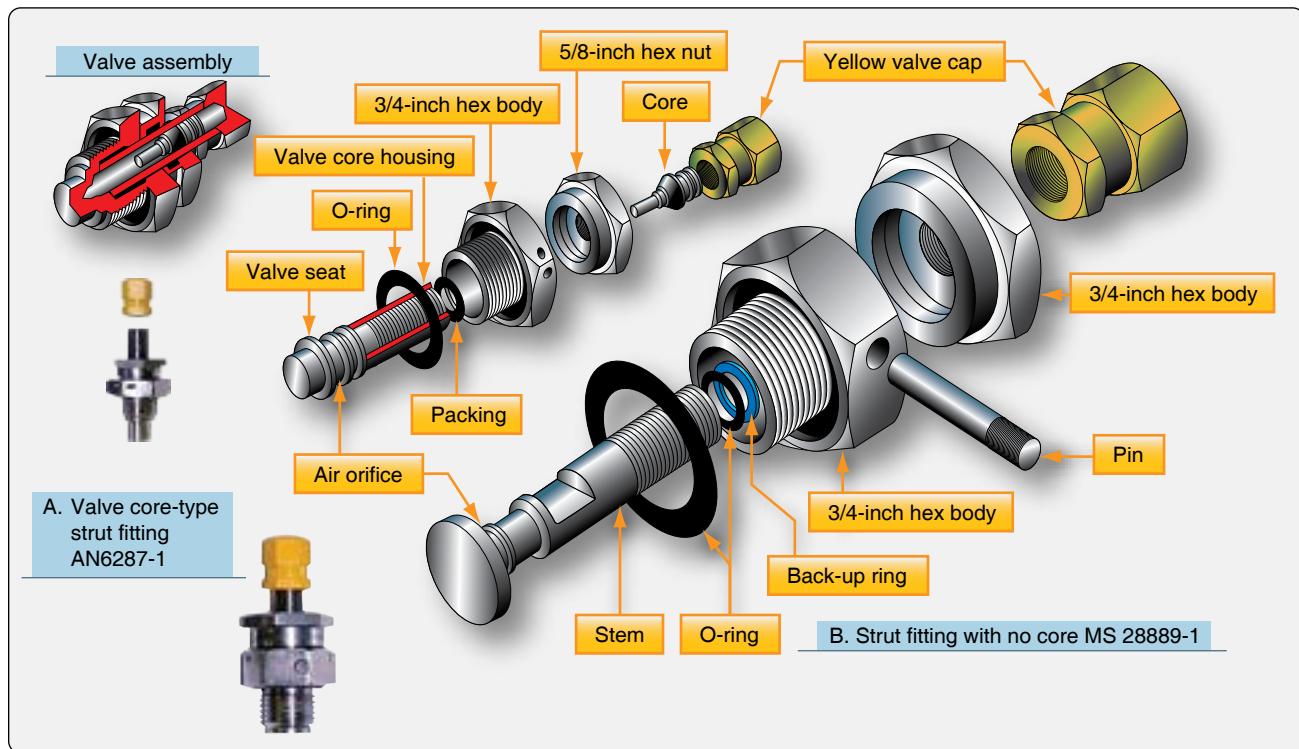
### Servicing Shock Struts

The following procedures are typical of those used in deflating a shock strut, servicing it with hydraulic fluid, and re-inflating the strut.

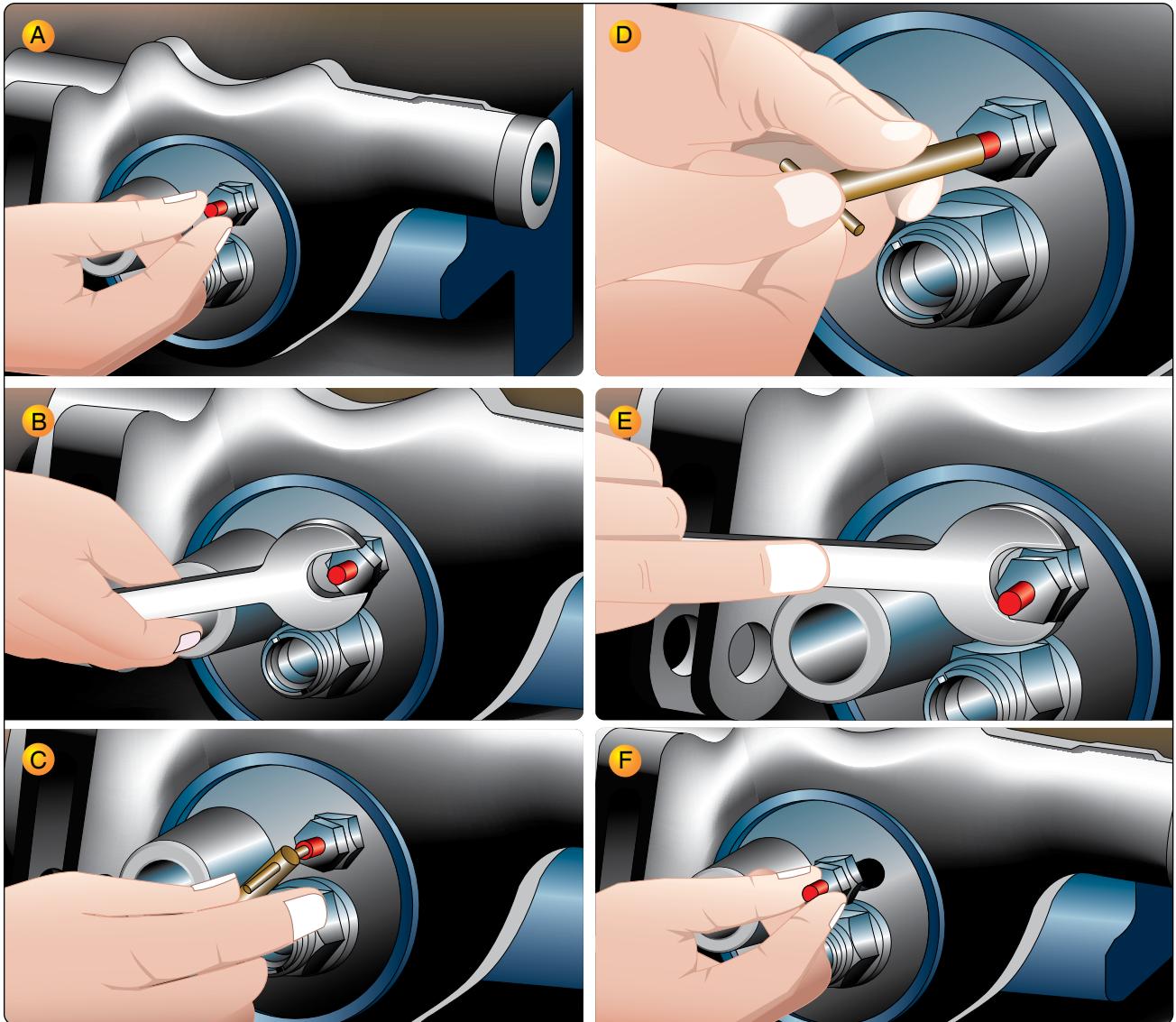
1. Position the aircraft so that the shock struts are in the

normal ground operating position. Make certain that personnel, work stands, and other obstacles are clear of the aircraft. If the maintenance procedures require, securely jack the aircraft.

2. Remove the cap from the air servicing valve. [*Figure 13-25A*]
3. Check the swivel nut for tightness.
4. If the servicing valve is equipped with a valve core, depress it to release any air pressure that may be trapped under the core in the valve body. [*Figure 13-25B*] Always be positioned to the side of the trajectory of any valve core in case it releases. Propelled by strut air pressure, serious injury could result.
5. Loosen the swivel nut. For a valve with a valve core (AN6287-1), rotate the swivel nut one turn (counter clockwise). Using a tool designed for the purpose, depress the valve core to release all of the air in the strut. For a valve without a valve core (MS28889), rotate the swivel nut sufficiently to allow the air to escape.
6. When all air has escaped from the strut, it should be compressed completely. Aircraft on jacks may need to have the lower strut jacked with an exerciser jack to achieve full compression of the strut. [*Figure 13-26*]
7. Remove the valve core of an AN6287 valve [*Figure 13-25D*] using a valve core removal tool.



**Figure 13-24.** Valve core-type (A) and core-free valve fittings (B) are used to service landing gear shock struts.

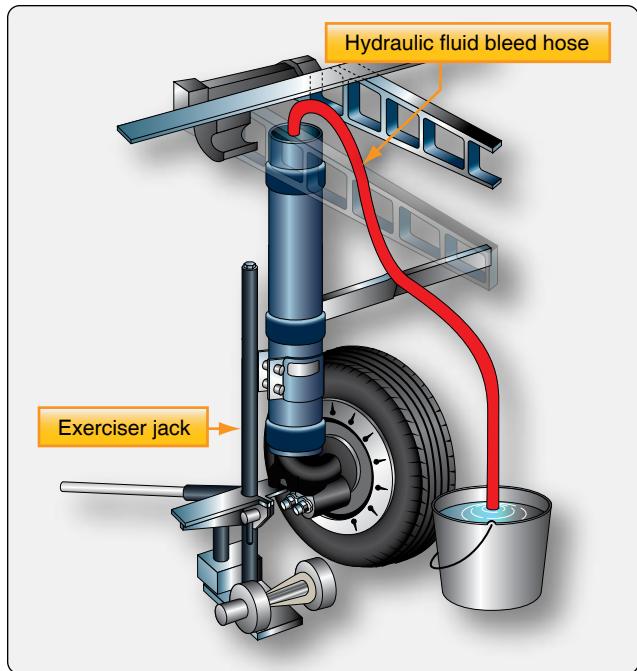


**Figure 13-25.** Steps in servicing a landing gear shock strut include releasing the air from the strut and removing the service valve from the top of the strut to permit the introduction of hydraulic fluid. Note that the strut is illustrated horizontally. On an actual aircraft installation, the strut is serviced in the vertical position (landing gear down).

- [Figure 13-27] Then, remove the entire service valve by unscrewing the valve body from the strut. [Figure 13-25E]
8. Fill the strut with hydraulic fluid to the level of the service valve port with the approved hydraulic fluid.
  9. Re-install the air service valve assembly using a new O-ring packing. Torque according to applicable manufacturer's specifications. If an AN2687-1 valve, install a new valve core.
  10. Inflate the strut. A threaded fitting from a controlled source of high pressure air or nitrogen should be screwed onto the servicing valve. Control the flow with the service valve swivel nut. The correct amount

of inflation is measured in psi on some struts. Other manufacturers specify struts to be inflated until extension of the lower strut is a certain measurement. Follow manufacturer's instructions. Shock struts should always be inflated slowly to avoid excess heating and over inflation.

11. Once inflated, tighten the swivel nut and torque as specified.
12. Remove the fill hose fitting and finger tighten the valve cap of the valve.



**Figure 13-26.** Air trapped in shock strut hydraulic fluid is bled by exercising the strut through its full range of motion while the end of an air-tight bleed hose is submerged in a container of hydraulic fluid.



**Figure 13-27.** This valve tool features internal and external thread chasers, a notched valve core removal/installation tool, and a tapered end for depressing a valve core or clearing debris.

### Bleeding Shock Struts

It may be necessary to bleed a shock strut during the service operation or when air becomes trapped in the hydraulic fluid inside the strut. This can be caused by low hydraulic fluid quantity in the strut. Bleeding is normally done with the aircraft on jacks to facilitate repeated extension and

compression of the strut to expel the entrapped air. An example procedure for bleeding the shock strut follows.

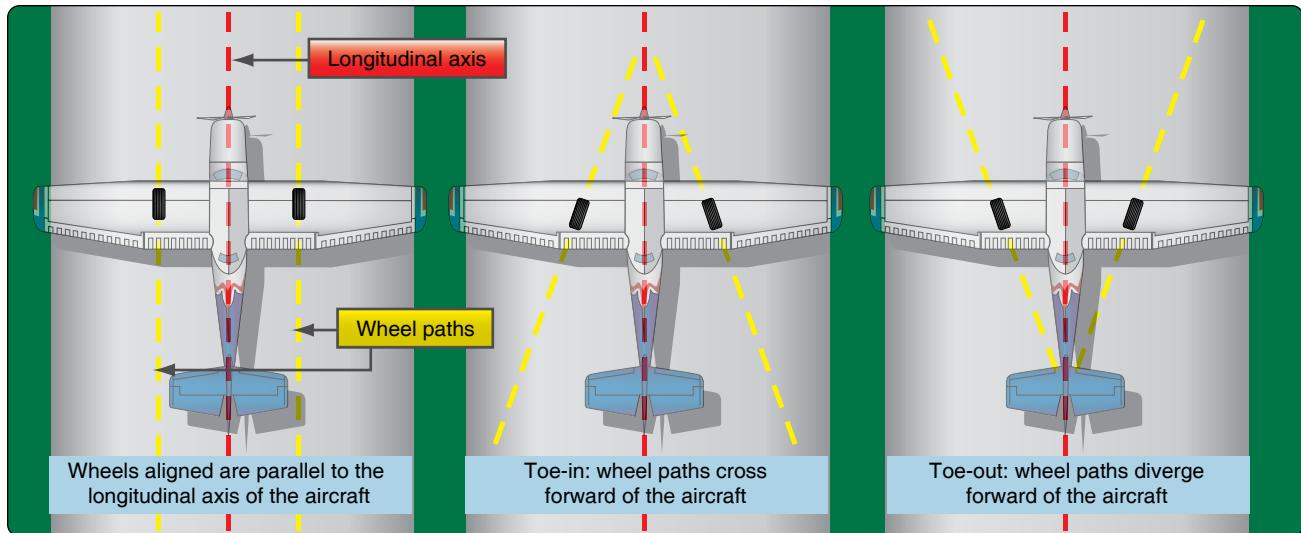
1. Construct and attach a bleed hose containing a fitting suitable for making an airtight connection at the shock strut service valve port. Ensure a long enough hose to reach the ground while the aircraft is on jacks.
2. Jack the aircraft until the shock struts are fully extended.
3. Release any air pressure in the shock strut.
4. Remove the air service valve assembly.
5. Fill the strut to the level of the service port with approved hydraulic fluid.
6. Attach the bleed hose to the service port and insert the free end of the hose into a container of clean hydraulic fluid. The hose end must remain below the surface of the fluid.
7. Place an exerciser jack or other suitable jack under the shock strut jacking point. Compress and extend the strut fully by raising and lowering the jack. Continue this process until all air bubbles cease to form in the container of hydraulic fluid. Compress the strut slowly and allow it to extend by its own weight. Ensure that the hydraulic fluid is still at the appropriate level before moving on to the next step.
8. Remove the exerciser jack. Lower the aircraft and remove all other jacks.
9. Remove the bleed hose assembly and fitting from the service port of the strut.
10. Install the air service valve, torque, and inflate the shock strut to the manufacturer's specifications.

### Landing Gear Alignment, Support, & Retraction

Retractable landing gear consist of several components that enable it to function. Typically, these are the torque links, trunnion and bracket arrangements, drag strut linkages, electrical and hydraulic gear retraction devices, as well as locking, sensing, and indicating components. Additionally, nose gear have steering mechanisms attached to the gear.

#### Alignment

As previously mentioned, a torque arm or torque links assembly keeps the lower strut cylinder from rotating out of alignment with the longitudinal axis of the aircraft. In some strut assemblies, it is the sole means of retaining the piston in the upper strut cylinder. The link ends are attached to the fixed upper cylinder and the moving lower cylinder with a hinge pin in the center to allow the strut to extend and compress.



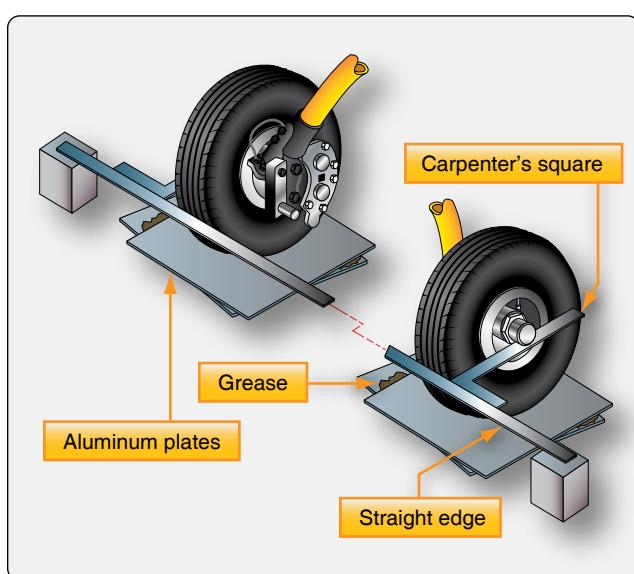
**Figure 13-28.** Wheel alignment on an aircraft.

Alignment of the wheels of an aircraft is also a consideration. Normally, this is set by the manufacturer and only requires occasional attention such as after a hard landing. The aircraft's main wheels must be inspected and adjusted, if necessary, to maintain the proper toe-in or toe-out and the correct camber. Toe-in and toe-out refer to the path a main wheel would take in relation to the airframe longitudinal axis or centerline if the wheel was free to roll forward. Three possibilities exist. The wheel would roll either: 1) parallel to the longitudinal axis (aligned); 2) converge on the longitudinal axis (toe-in); or 3) veer away from the longitudinal axis (toe-out). [Figure 13-28]

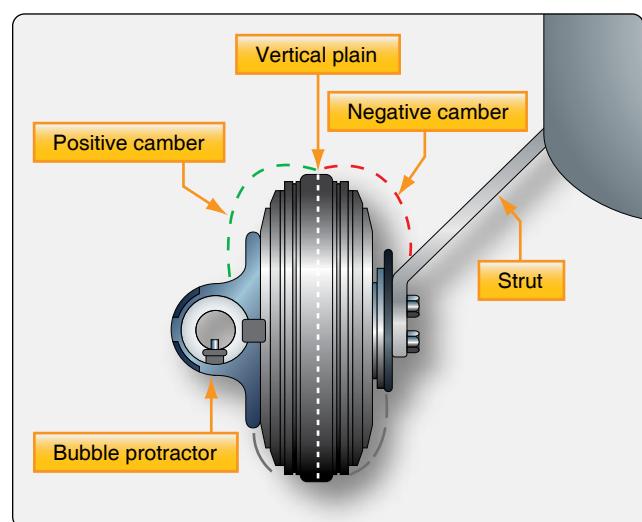
The manufacturer's maintenance instructions give the

procedure for checking and adjusting toe-in or toe-out. A general procedure for checking alignment on a light aircraft follows. To ensure that the landing gear settle properly for a toe-in/toe-out test, especially on spring steel strut aircraft, two aluminum plates separated with grease are put under each wheel. Gently rock the aircraft on the plates to cause the gear to find the at rest position preferred for alignment checks.

A straight edge is held across the front of the main wheel tires just below axle height. A carpenter's square placed against the straight edge creates a perpendicular that is parallel to the longitudinal axis of the aircraft. Slide the square against the wheel assembly to see if the forward and aft sections of the tire touch the square. A gap in front indicates the wheel is toed-in. A gap in the rear indicates the wheel is toed-out. [Figure 13-29]



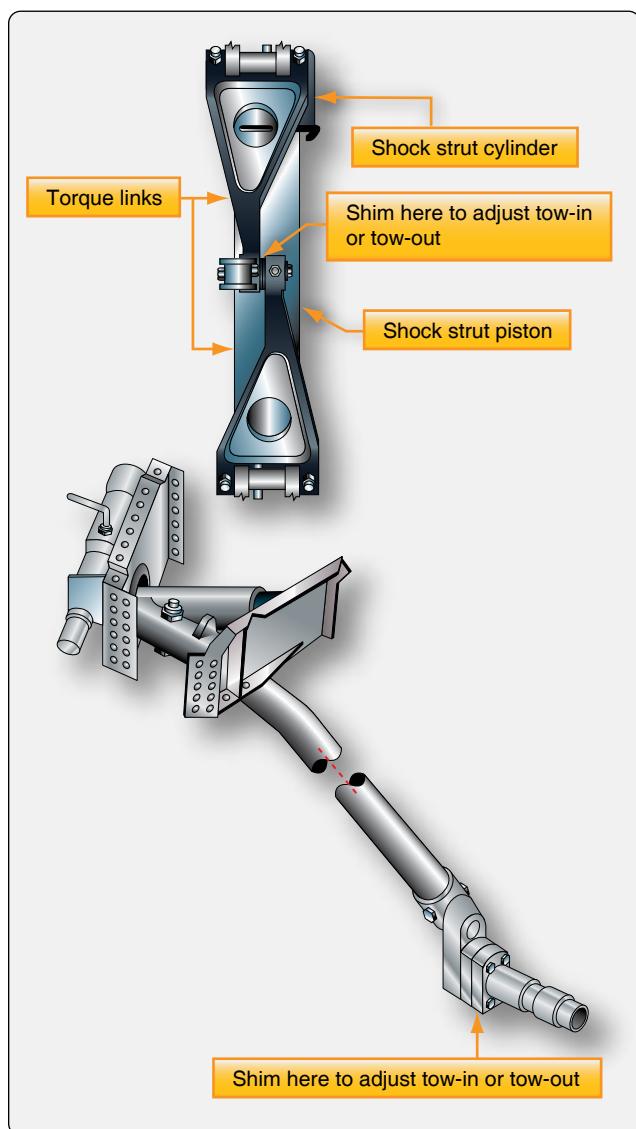
**Figure 13-29.** Finding toe-in and toe-out on a light aircraft with spring steel struts.



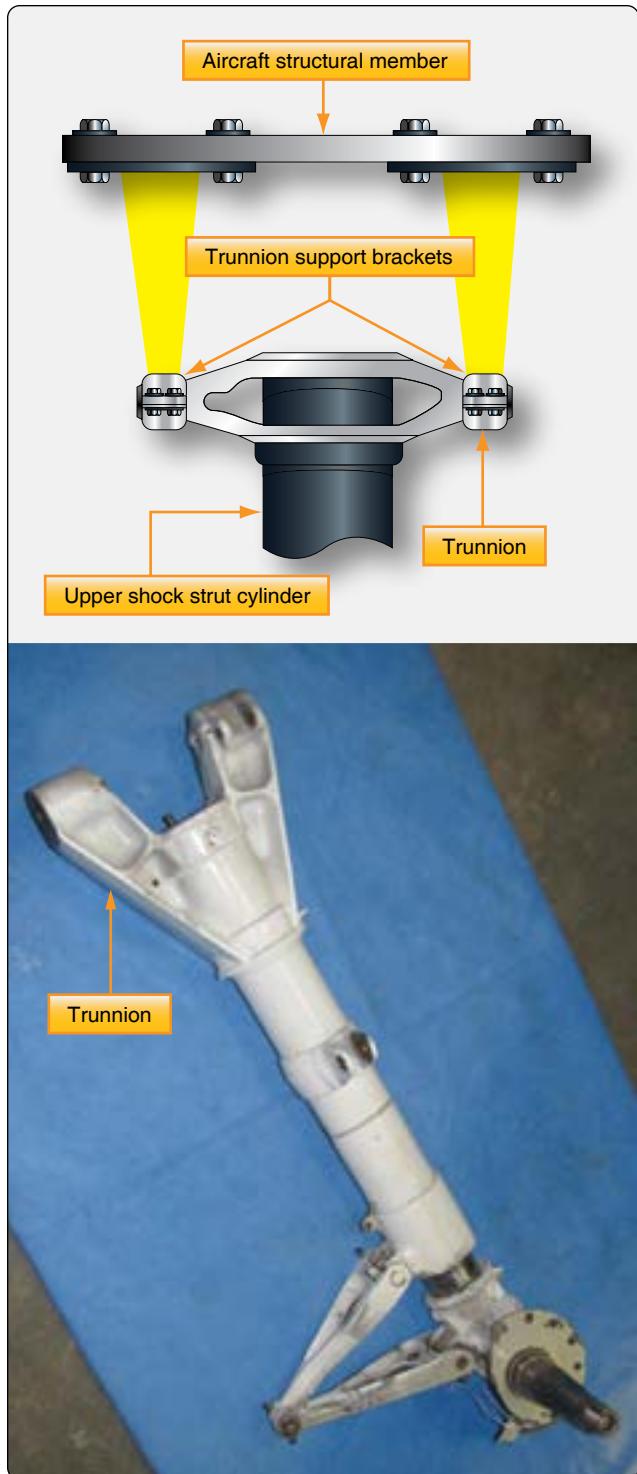
**Figure 13-30.** Camber of a wheel is the amount the wheel is tilted out of the vertical plain. It can be measured with a bubble protractor.

Camber is the alignment of a main wheel in the vertical plain. It can be checked with a bubble protractor held against the wheel assembly. The wheel camber is said to be positive if the top of the wheel tilts outward from vertical. Camber is negative if the top of the wheel tilts inward. [Figure 13-30]

Adjustments can be made to correct small amounts of wheel misalignment. On aircraft with spring steel gear, tapered shims can be added or removed between the bolt-on wheel axle and the axle mounting flange on the strut. Aircraft equipped with air/oil struts typically use shims between the two arms of the torque links as a means of aligning toe-in and toe-out. [Figure 13-31] Follow all manufacturer's instructions.



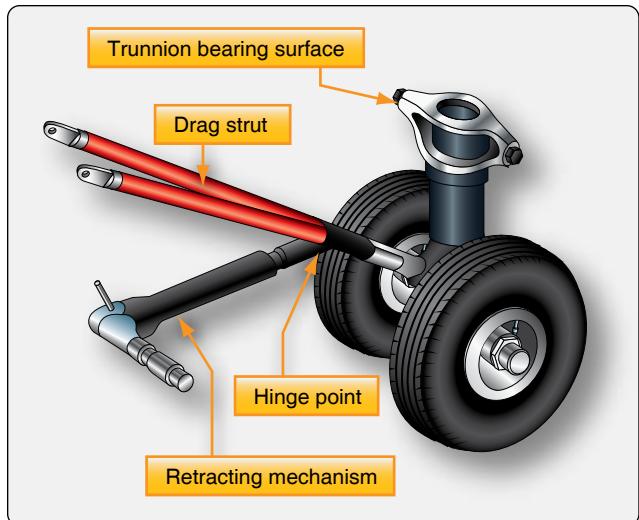
**Figure 13-31.** Toe-in and toe-out adjustments on small aircraft with spring steel landing gear are made with shims behind the axle assembly. On shock strut aircraft, the shims are placed where the torque links couple.



**Figure 13-32.** The trunnion is a fixed structural support that is part of or attached to the upper strut cylinder of a landing gear strut. It contains bearing surfaces so the gear can retract.

### Support

Aircraft landing gear are attached to the wing spars or other structural members, many of which are designed for the specific purpose of supporting the landing gear. Retractable gear must be engineered in such a way as to provide strong



**Figure 13-33.** A hinged drag strut holds the trunnion and gear firm for landing and ground operation. It folds at the hinge to allow the gear to retract.

attachment to the aircraft and still be able to move into a recess or well when stowed. A trunnion arrangement is typical. The trunnion is a fixed structural extension of the upper strut cylinder with bearing surfaces that allow the entire gear assembly to move. It is attached to aircraft structure in such a way that the gear can pivot from the vertical position required for landing and taxi to the stowed position used during flight. [Figure 13-32]

While in the vertical gear down position, the trunnion is free to swing or pivot. Alone, it cannot support the aircraft without collapsing. A drag brace is used to restrain against the pivot action built into the trunnion attachment. The upper end of the two-piece drag brace is attached to the aircraft structure and the lower end to the strut. A hinge near the middle of the brace allows the brace to fold and permits the gear to retract. For ground operation, the drag brace is straightened over

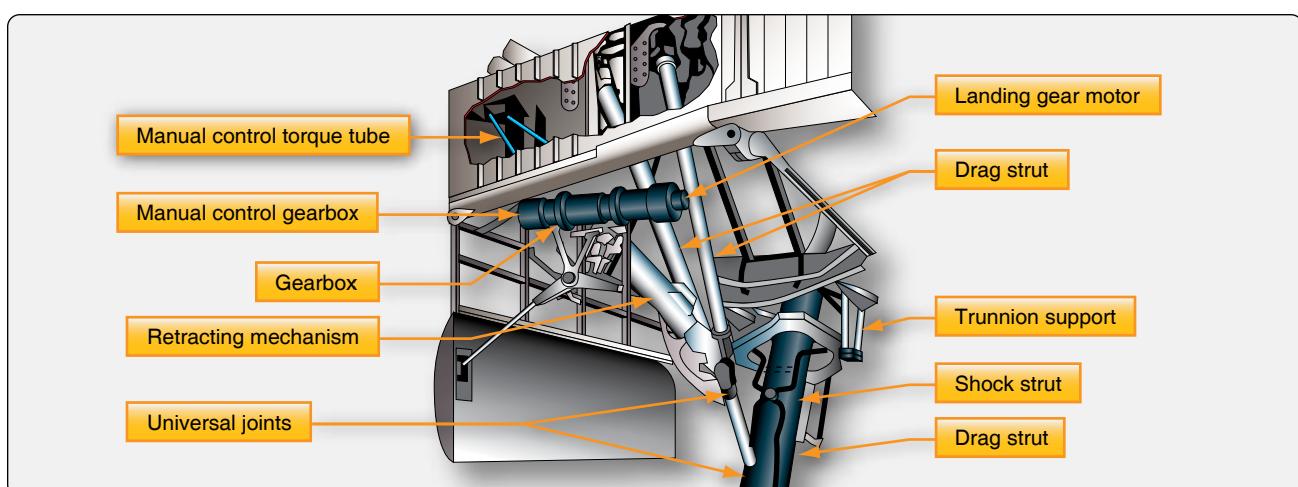
center to a stop and locked into position so the gear remains rigid. [Figure 13-33] The function of a drag brace on some aircraft is performed by the hydraulic cylinder used to raise and lower the gear. Cylinder internal hydraulic locks replace the over-center action of the drag brace for support during ground maneuvers.

### Small Aircraft Retraction Systems

As the speed of a light aircraft increases, there reaches a point where the parasite drag created by the landing gear in the wind is greater than the induced drag caused by the added weight of a retractable landing gear system. Thus, many light aircraft have retractable landing gear. There are many unique designs. The simplest contains a lever in the flight deck mechanically linked to the gear. Through mechanical advantage, the pilot extends and retracts the landing gear by operating the lever. Use of a roller chain, sprockets, and a hand crank to decrease the required force is common.

Electrically operated landing gear systems are also found on light aircraft. An all-electric system uses an electric motor and gear reduction to move the gear. The rotary motion of the motor is converted to linear motion to actuate the gear. This is possible only with the relatively lightweight gear found on smaller aircraft. An all-electric gear retraction system is illustrated in Figure 13-34.

A more common use of electricity in gear retraction systems is that of an electric/hydraulic system found in many Cessna and Piper aircraft. This is also known as a power pack system. A small lightweight hydraulic power pack contains several components required in a hydraulic system. These include the reservoir, a reversible electric motor-driven hydraulic pump, a filter, high-and-low pressure control valves, a thermal relief valve, and a shuttle valve. Some power packs incorporate an emergency hand pump. A hydraulic actuator for each gear is

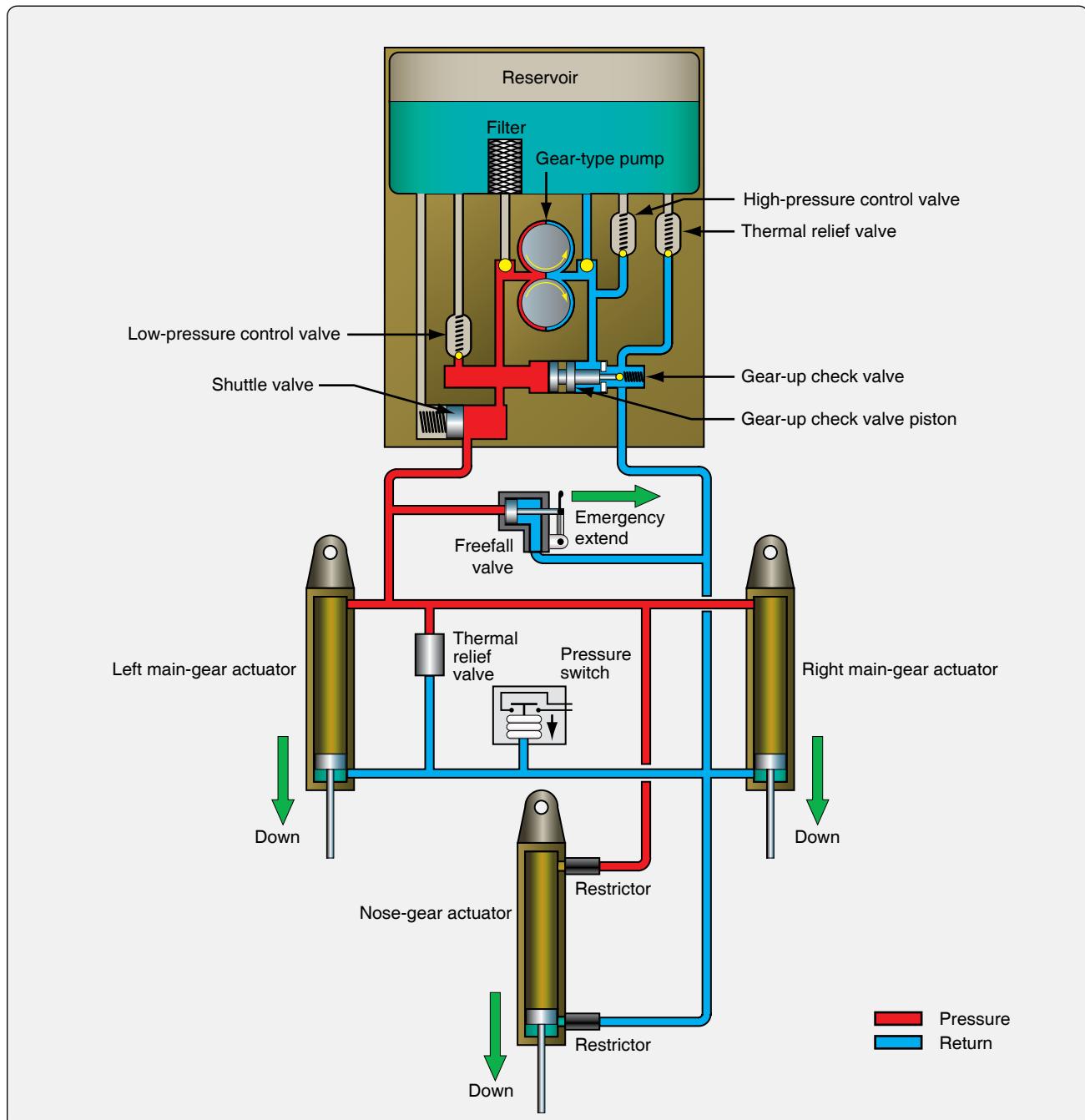


**Figure 13-34.** A geared electric motor landing gear retraction system.

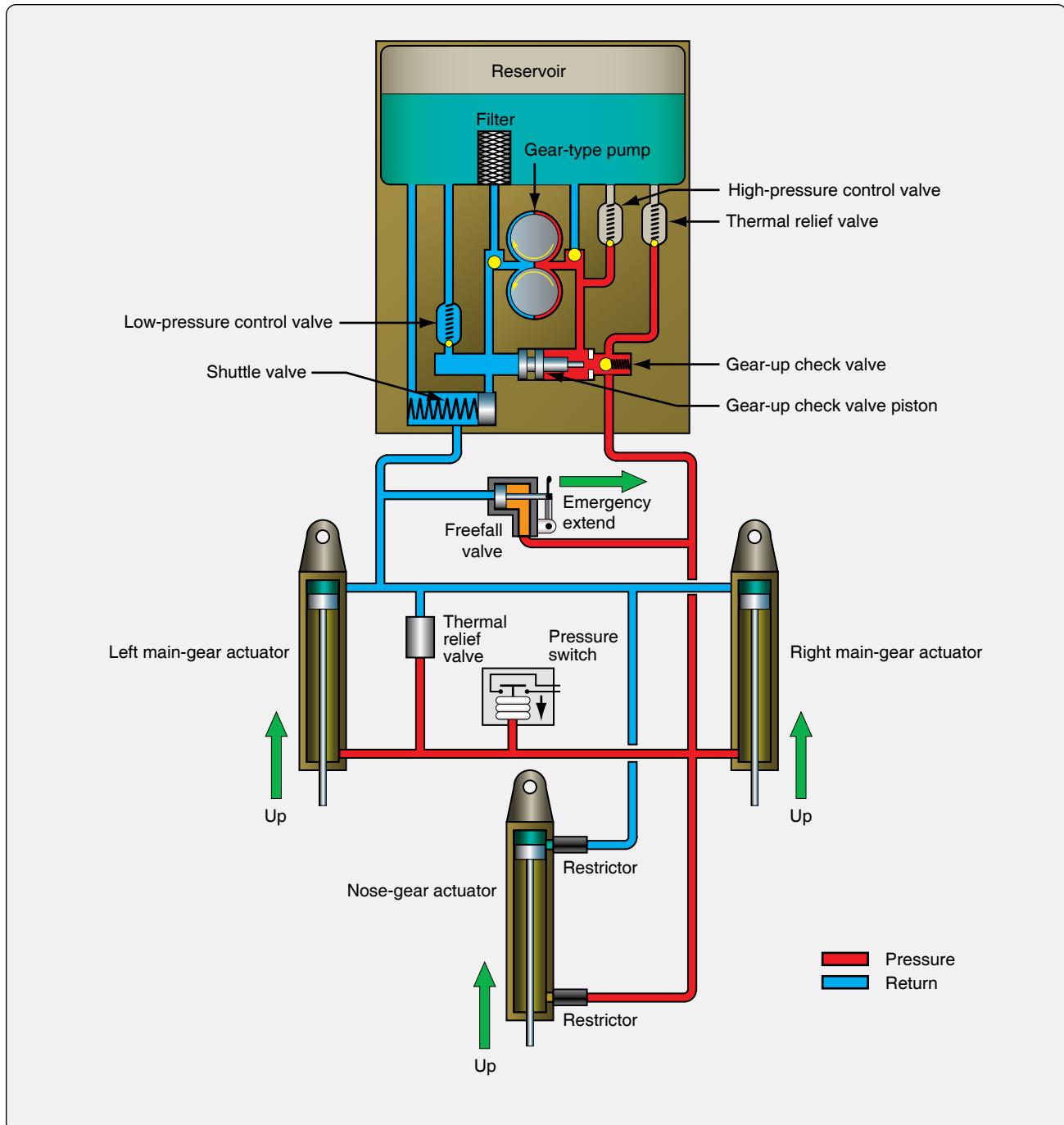
driven to extend or retract the gear by fluid from the power pack. *Figure 13-35* illustrates a power pack system while gear is being lowered. *Figure 13-36* shows the same system while the gear is being raised.

When the flight deck gear selection handle is put in the gear-down position, a switch is made that turns on the electric motor in the power pack. The motor turns in the direction to rotate the hydraulic gear pump so that it pumps fluid to the gear-down side of the actuating cylinders. Pump pressure moves the spring-loaded shuttle valve to the left to allow

fluid to reach all three actuators. Restrictors are used in the nose wheel actuator inlet and outlet ports to slow down the motion of this lighter gear. While hydraulic fluid is pumped to extend the gear, fluid from the upside of the actuators returns to the reservoir through the gear-up check valve. When the gear reach the down and locked position, pressure builds in the gear-down line from the pump and the low-pressure control valve unseats to return the fluid to the reservoir. Electric limit switches turn off the pump when all three gears are down and locked.



**Figure 13-35.** A popular light aircraft gear retraction system that uses a hydraulic power pack in the gear down condition.



**Figure 13-36.** A hydraulic power pack gear retraction system in the gear up condition.

To raise the gear, the flight deck gear handle is moved to the gear-up position. This sends current to the electric motor, which drives the hydraulic gear pump in the opposite direction causing fluid to be pumped to the gear-up side of the actuators. In this direction, pump inlet fluid flows through the filter. Fluid from the pump flows thought the gear-up check valve to the gear-up sides of the actuating cylinders. As the cylinders begin to move, the pistons release the mechanical down locks that hold the gear rigid for ground operations. Fluid from the

gear-down side of the actuators returns to the reservoir through the shuttle valve. When the three gears are fully retracted, pressure builds in the system, and a pressure switch is opened that cuts power to the electric pump motor. The gear are held in the retracted position with hydraulic pressure. If pressure declines, the pressure switch closes to run the pump and raise the pressure until the pressure switch opens again.

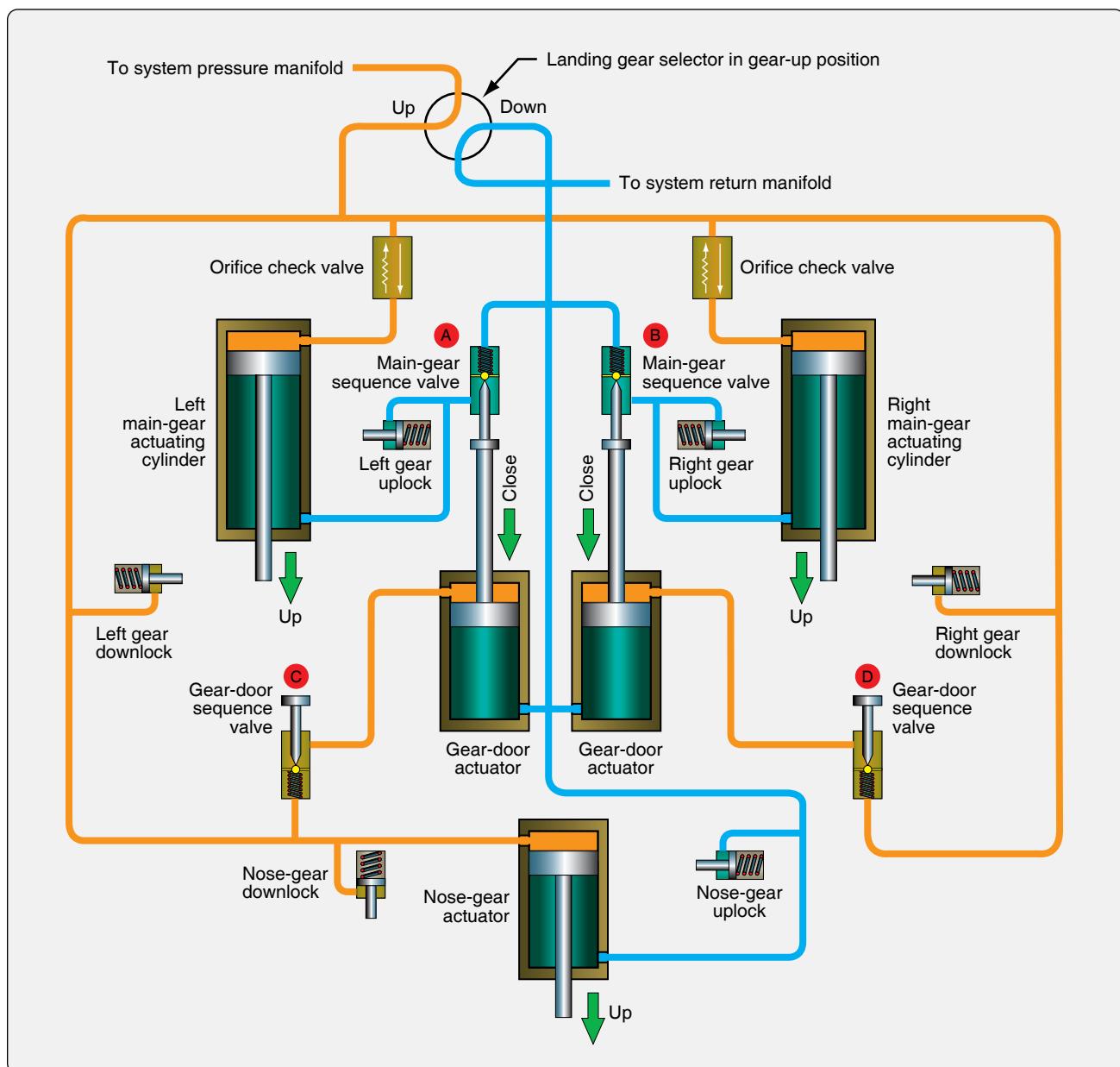
## Large Aircraft Retraction Systems

Large aircraft retraction systems are nearly always powered by hydraulics. Typically, the hydraulic pump is driven off of the engine accessory drive. Auxiliary electric hydraulic pumps are also common. Other devices used in a hydraulically-operated retraction system include actuating cylinders, selector valves, uplocks, downlocks, sequence valves, priority valves, tubing, and other conventional hydraulic system components. These units are interconnected so that they permit properly sequenced retraction and extension of the landing gear and the landing gear doors.

The correct operation of any aircraft landing gear retraction system is extremely important. *Figure 13-37* illustrates an

example of a simple large aircraft hydraulic landing gear system. The system is on an aircraft that has doors that open before the gear is extended and close after the gear is retracted. The nose gear doors operate via mechanical linkage and do not require hydraulic power. There are many gear and gear door arrangements on various aircraft. Some aircraft have gear doors that close to fair the wheel well after the gear is extended. Others have doors mechanically attached to the outside of the gear so that when it stows inward, the door stows with the gear and fairs with the fuselage skin.

In the system illustrated in *Figure 13-37*, when the flight deck gear selector is moved to the gear-up position, it positions a selector valve to allow pump pressure from the hydraulic



**Figure 13-37.** A simple large aircraft hydraulic gear retraction system.

system manifold to access eight different components. The three downlocks are pressurized and unlocked so the gear can be retracted. At the same time, the actuator cylinder on each gear also receives pressurized fluid to the gear-up side of the piston through an unrestricted orifice check valve. This drives the gear into the wheel well. Two sequence valves (C and D) also receive fluid pressure. Gear door operation must be controlled so that it occurs after the gear is stowed. The sequence valves are closed and delay flow to the door actuators. When the gear cylinders are fully retracted, they mechanically contact the sequence valve plungers that open the valves and allow fluid to flow into the close side of the door actuator cylinders. This closes the doors. Sequence valves A and B act as check valves during retraction. They allow fluid to flow one way from the gear-down side of the main gear cylinders back into the hydraulic system return manifold through the selector valve.

To lower the gear, the selector is put in the gear-down position. Pressurized hydraulic fluid flows from the hydraulic manifold to the nose gear uplock, which unlocks the nose gear. Fluid flows to the gear-down side of the nose gear actuator and extends it. Fluid also flows to the open side of the main gear door actuators. As the doors open, sequence valves A and B block fluid from unlocking the main gear uplocks and prevent fluid from reaching the down side of the main gear actuators. When the doors are fully open, the door actuator engages the plungers of both sequence valves to open the valves. The main gear uplocks, then receives fluid pressure and unlock. The main gear cylinder actuators receive fluid on the down side through the open sequence valves to extend the gear. Fluid from each main gear cylinder up-side flows to the hydraulic system return manifold through restrictors in the orifice check valves. The restrictors slow the extension of the gear to prevent impact damage.

There are numerous hydraulic landing gear retraction system designs. Priority valves are sometimes used instead of mechanically operated sequence valves. This controls some gear component activation timing via hydraulic pressure. Particulars of any gear system are found in the aircraft maintenance manual. The aircraft technician must be thoroughly familiar with the operation and maintenance requirements of this crucial system.

### **Emergency Extension Systems**

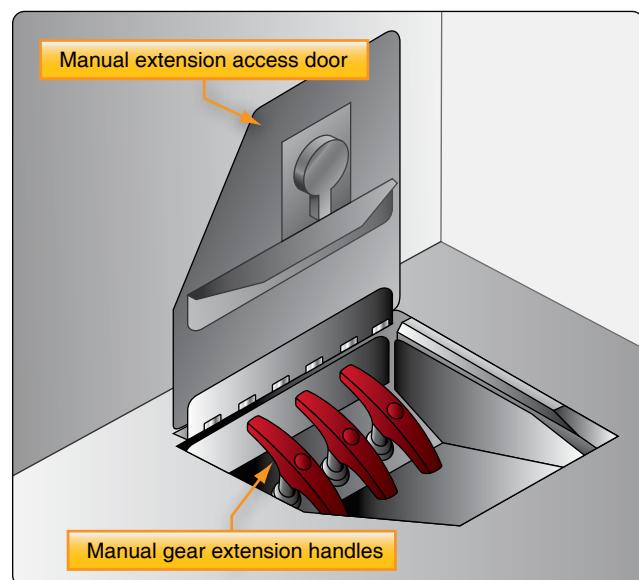
The emergency extension system lowers the landing gear if the main power system fails. There are numerous ways in which this is done depending on the size and complexity of the aircraft. Some aircraft have an emergency release handle in the flight deck that is connected through a mechanical linkage to the gear uplocks. When the handle is operated, it releases the uplocks and allows the gear to free-fall to the

extended position under the force created by gravity acting upon the gear. Other aircraft use a non-mechanical back-up, such as pneumatic power, to unlatch the gear.

The popular small aircraft retraction system shown in *Figures 13-35* and *13-36* uses a free-fall valve for emergency gear extension. Activated from the flight deck, when the free-fall valve is opened, hydraulic fluid is allowed to flow from the gear-up side of the actuators to the gear-down side of the actuators, independent of the power pack. Pressure holding the gear up is relieved, and the gear extends due to its weight. Air moving past the gear aids in the extension and helps push the gear into the down-and-locked position.

Large and high-performance aircraft are equipped with redundant hydraulic systems. This makes emergency extension less common since a different source of hydraulic power can be selected if the gear does not function normally. If the gear still fails to extend, some sort of unlatching device is used to release the uplocks and allow the gear to free fall. [*Figure 13-38*]

In some small aircraft, the design configuration makes emergency extension of the gear by gravity and air loads alone impossible or impractical. Force of some kind must therefore be applied. Manual extension systems, wherein the pilot mechanically cranks the gear into position, are common. Consult the aircraft maintenance manual for all emergency landing gear extension system descriptions of operation, performance standards, and emergency extension tests as required.



**Figure 13-38.** These emergency gear extension handles in a Boeing 737 are located under a floor panel on the flight deck. Each handle releases the gear uplock via a cable system so the gear can freefall into the extended position.

## Landing Gear Safety Devices

There are numerous landing gear safety devices. The most common are those that prevent the gear from retracting or collapsing while on the ground. Gear indicators are another safety device. They are used to communicate to the pilot the position status of each individual landing gear at any time. A further safety device is the nose wheel centering device mentioned previously in this chapter.

### Safety Switch

A landing gear squat switch, or safety switch, is found on most aircraft. This is a switch positioned to open and close depending on the extension or compression of the main landing gear strut. [Figure 13-39] The squat switch is wired into any number of system operating circuits. One circuit prevents the gear from being retracted while the aircraft is

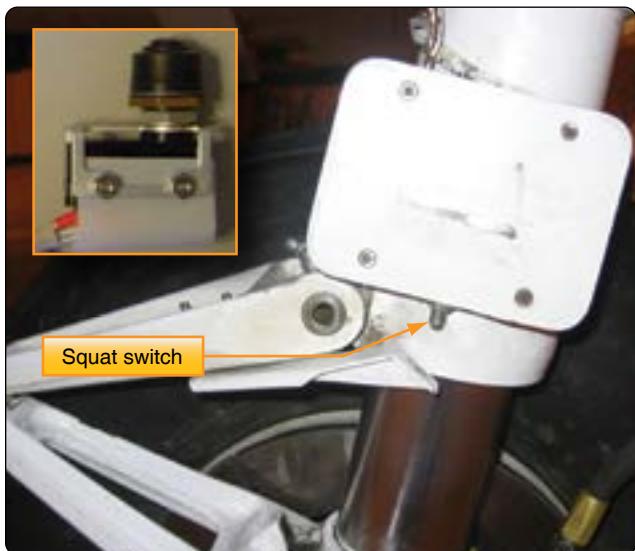


Figure 13-39. Typical landing gear squat switches.

on the ground. There are different ways to achieve this lock-out. A solenoid that extends a shaft to physically disable the gear position selector is one such method found on many aircraft. When the landing gear is compressed, the squat safety switch is open, and the center shaft of the solenoid protrudes a hardened lock-pin through the landing gear control handle so that it cannot be moved to the up position. At takeoff, the landing gear strut extends. The safety switch closes and allows current to flow in the safety circuit. The solenoid energizes and retracts the lock-pin from the selector handle. This permits the gear to be raised. [Figure 13-40]

The use of proximity sensors for gear position safety switches is common in high-performance aircraft. An electromagnetic sensor returns a different voltage to a gear logic unit depending on the proximity of a conductive target to the switch. No physical contact is made. When the gear is in the designed position, the metallic target is close to the inductor in the sensor which reduces the return voltage. This type of sensing is especially useful in the landing gear environment where switches with moving parts can become contaminated with dirt and moisture from runways and taxi ways. The technician is required to ensure that sensor targets are installed the correct distance away from the sensor. Go-no go gauges are often used to set the distance. [Figure 13-41]

### Ground Locks

Ground locks are commonly used on aircraft landing gear as extra insurance that the landing gear will remain down and locked while the aircraft is on the ground. They are external devices that are placed in the retraction mechanism to prevent its movement. A ground lock can be as simple as a pin placed into the pre-drilled holes of gear components that keep the gear from collapsing. Another commonly used ground lock clamps onto the exposed piston of the gear retraction cylinder

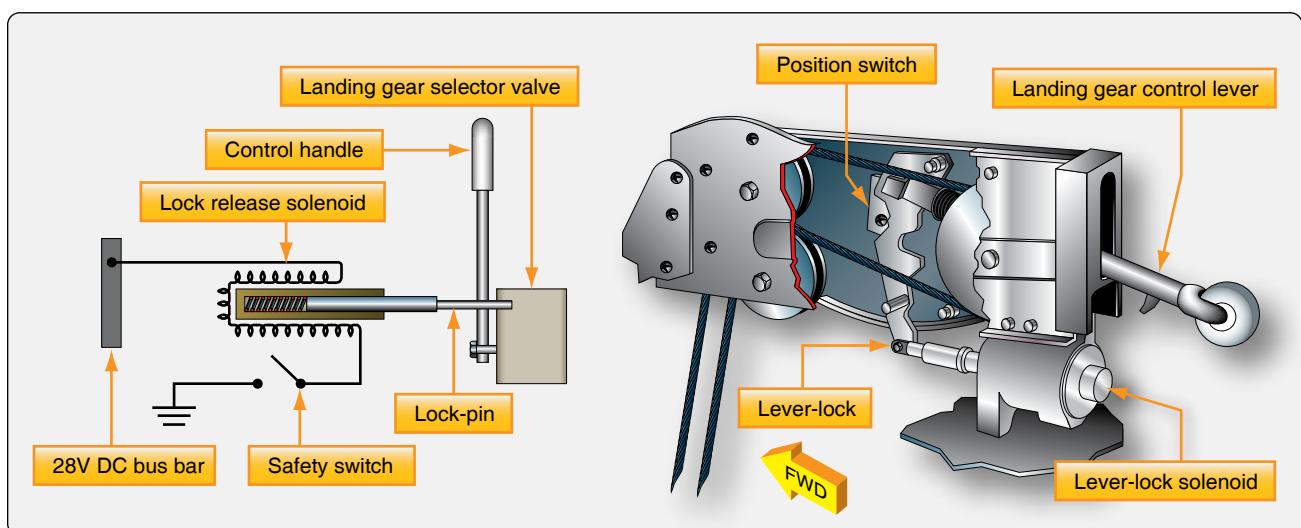
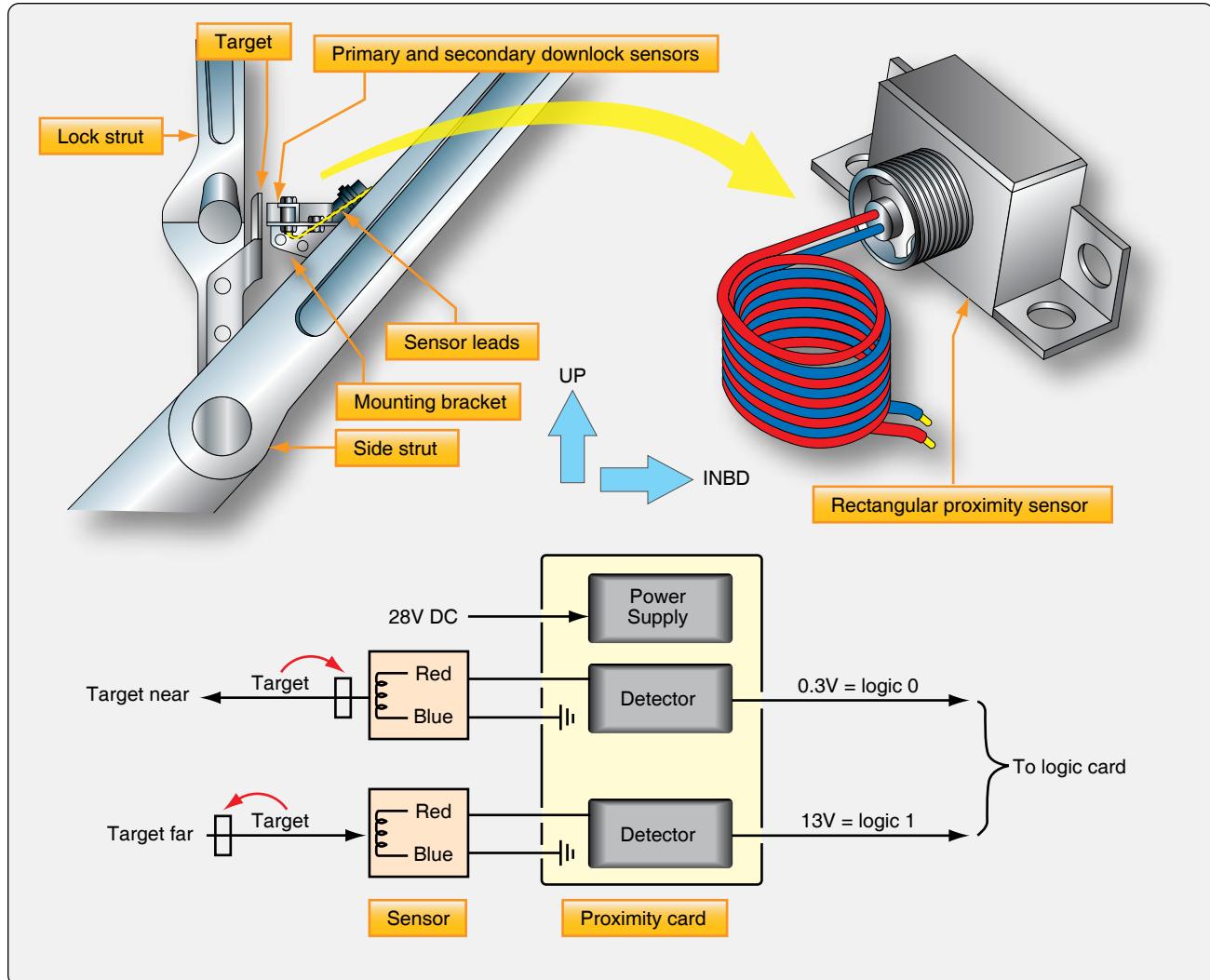


Figure 13-40. A landing gear safety circuit with solenoid that locks the control handle and selector valve from being able to move into the gear up position when the aircraft is on the ground. The safety switch, or squat switch, is located on the aircraft landing gear.



**Figure 13-41.** Proximity sensors are used instead of contact switches on many landing gear.

that prevents it from retracting. All ground locks should have red streamers attached to them, so they are visible and removed before flight. Ground locks are typically carried in the aircraft and put into place by the flight crew during the post landing walk-around. [Figure 13-42]

### Landing Gear Position Indicators

To provide a visual indication of landing gear position, indicators are installed in the flight deck or flight compartment. Gear warning devices are incorporated on all retractable gear aircraft and usually consist of a horn or some other aural device and a red warning light. The horn blows and the light comes on when one or more throttles are retarded and the landing gear is in any position other than down and locked.

Position indicators are typically:

Off = gear up and locked

Red = unsafe

Green = down and locked

There is usually an amber in transit light to indicate a gear that is in transition.

Landing gear position indicators are located on the instrument panel adjacent to the gear selector handle. They are used to inform the pilot of gear position status. There are many arrangements for gear indication. Usually, there is a dedicated light for each gear. The most common display for the landing gear being down and locked is an illuminated green light. Three green lights means it is safe to land. All lights out typically indicates that the gear is up and locked, or there may be gear up indicator lights. Gear in transit lights are used on some aircraft as are barber pole displays when a gear is not up or down and locked. Blinking indicator lights also indicate gear in transit. Some manufacturer's use a gear disagree annunciation when the landing gear is not in the same position as the selector. Many aircraft monitor gear



**Figure 13-42.** Gear pin ground lock devices.

door position in addition to the gear itself. Consult the aircraft manufacturer's maintenance and operating manuals for a complete description of the landing gear indication system. [Figure 13-43 and Figure 13-44]

### Nose Wheel Centering

Since most aircraft have steerable nose wheel gear assemblies for taxiing, a means for aligning the nose gear before retraction is needed. Centering cams built into the shock strut structure accomplish this. An upper cam is free to mate into a lower cam recess when the gear is fully extended. This aligns the gear for retraction. When weight returns to the wheels after landing, the shock strut is compressed, and the centering cams separate allowing the lower shock strut (piston) to rotate in the upper strut cylinder. This rotation is controlled to steer the aircraft. [Figure 13-45] Small aircraft sometimes incorporate an external roller or guide pin on the strut. As the strut is folded into the wheel well during retraction, the roller or guide pin engages a ramp or track mounted to the wheel well structure. The ramp/track guides the roller or pin in such a manner that the nose wheel is straightened as it enters the wheel well.

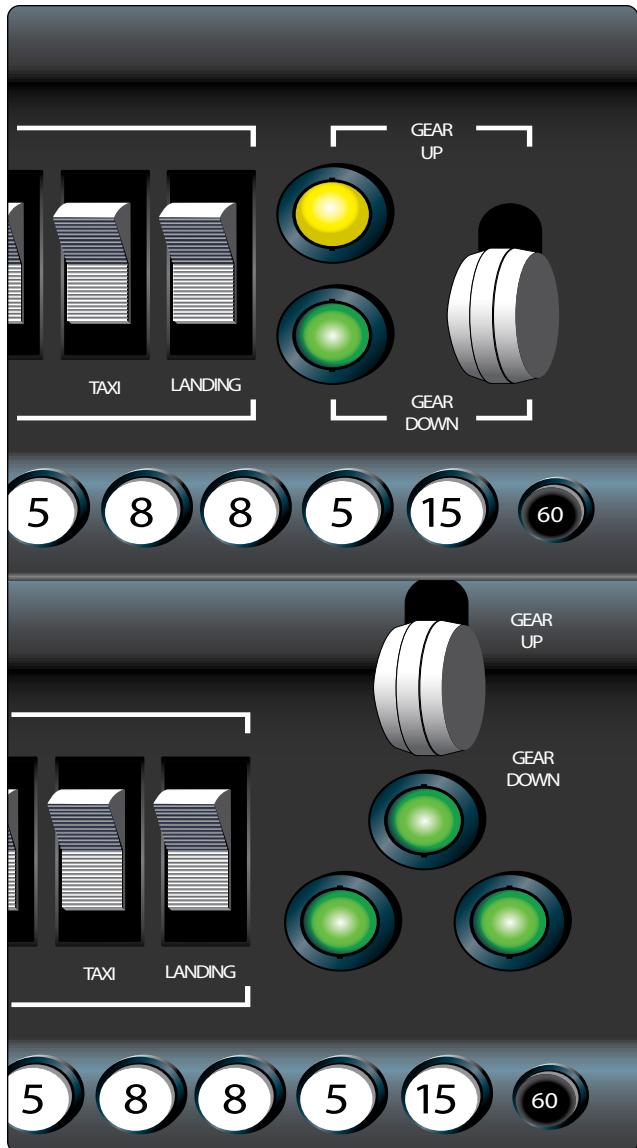


**Figure 13-43.** Landing gear selector panels with position indicator lights. The Boeing 737 panel illuminates red lights above the green lights when the gear is in transit.

### Landing Gear System Maintenance

The moving parts and dirty environment of the landing gear make this an area of regular maintenance. Because of the stresses and pressures acting on the landing gear, inspection, servicing, and other maintenance becomes a continuous process. The most important job in the maintenance of the aircraft landing gear system is thorough accurate inspections. To properly perform inspections, all surfaces should be cleaned to ensure that no trouble spots are undetected.

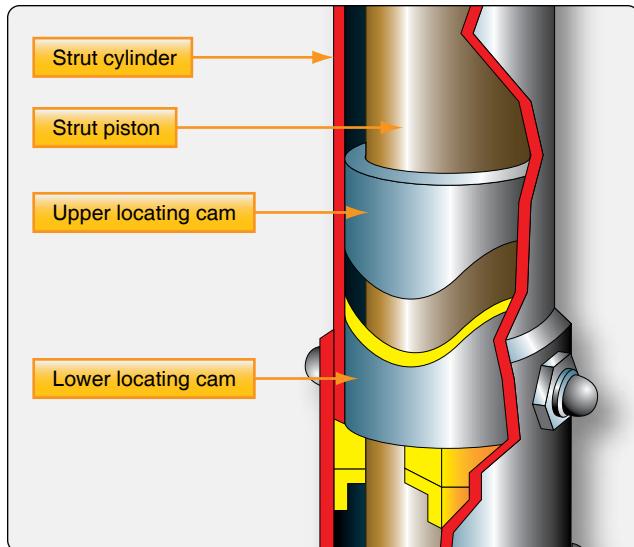
Periodically, it is necessary to inspect shock struts, trunnion and brace assemblies and bearings, shimmy dampers, wheels,



**Figure 13-44.** Typical landing gear indicator lights and lever as found on small aircraft.

wheel bearings, tires, and brakes. Landing gear position indicators, lights, and warning horns must also be checked for proper operation. During all inspections and visits to the wheel wells, ensure all ground safety locks are installed.

Other landing gear inspection items include checking emergency control handles and systems for proper position and condition. Inspect landing gear wheels for cleanliness, corrosion, and cracks. Check wheel tie bolts for looseness. Examine anti-skid wiring for deterioration. Check tires for wear, cuts, deterioration, presence of grease or oil, alignment of slippage marks, and proper inflation. Inspect landing gear mechanism for condition, operation, and proper adjustment. Lubricate the landing gear, including the nose wheel steering. Check steering system cables for wear, broken strands,



**Figure 13-45.** A cutaway view of a nose gear internal centering cam.

alignment, and safetying. Inspect landing gear shock struts for such conditions as cracks, corrosion, breaks, and security. Where applicable, check brake clearances and wear.

Various types of lubricant are required to lubricate points of friction and wear on landing gear. Specific products to be used are given by the manufacturer in the maintenance manual. Lubrication may be accomplished by hand or with a grease gun. Follow manufacturer's instructions. Before applying grease to a pressure grease fitting, be sure the fitting is wiped clean of dirt and debris, as well as old hardened grease. Dust and sand mixed with grease produce a very destructive abrasive compound. Wipe off all excess grease while greasing the gear. The piston rods of all exposed strut cylinders and actuating cylinders should be clean at all times.

Periodically, wheel bearings must be removed, cleaned, inspected, and lubricated. When cleaning a wheel bearing, use the recommended cleaning solvent. Do not use gasoline or jet fuel. Dry the bearing by directing a blast of dry air between the rollers. Do not direct the air so that it spins the bearing as without lubrication, this could cause the bearing to fly apart resulting in injury. When inspecting the bearing, check for defects that would render it unserviceable, such as cracks, flaking, broken bearing surfaces, roughness due to impact pressure or surface wear, corrosion or pitting, discoloration from excessive heat, cracked or broken bearing cages, and scored or loose bearing cups or cones that would affect proper seating on the axle or wheel. If any discrepancies are found, replace the bearing with a serviceable unit. Bearings should be lubricated immediately after cleaning and inspection to prevent corrosion.

To lubricate a tapered roller bearing, use a bearing lubrication

tool or place a small amount of the approved grease on the palm of the hand. Grasp the bearing with the other hands and press the larger diameter side of the bearing into the grease to force it completely through the space between the bearing rollers and the cone. Gradually turn the bearing so that all of the rollers have been completely packed with grease. [Figure 13-46]

### Landing Gear Rigging & Adjustment

Occasionally, it becomes necessary to adjust the landing gear switches, doors, linkages, latches, and locks to ensure proper operation of the landing gear system and doors. When landing gear actuating cylinders are replaced and when length adjustments are made, over-travel must be checked. Over-travel is the action of the cylinder piston beyond the movement necessary for landing gear extension and retraction. The additional action operates the landing gear latch mechanisms.

A wide variety of aircraft types and landing gear system designs result in procedures for rigging and adjustment that vary from aircraft to aircraft. Uplock and downlock clearances, linkage adjustments, limit switch adjustments, and other adjustments must be confirmed by the technician in the manufacturer's maintenance data before taking action. The following examples of various adjustments are given to convey concepts, rather than actual procedures for any particular aircraft.

### Adjusting Landing Gear Latches

The adjustment of various latches is a primary concern to the aircraft technician. Latches are generally used in landing gear systems to hold the gear up or down and/or to hold the gear doors open or closed. Despite numerous variations, all latches are designed to do the same thing. They must operate automatically at the proper time, and they must hold the unit in the desired position. A typical landing gear door latch is

examined below. Many gear up latches operate similarly. Clearances and dimensional measurements of rollers, shafts, bushings, pins, bolts, etc., are common.

On this particular aircraft, the landing gear door is held closed by two latches. To have the door locked securely, both latches must grip and hold the door tightly against the aircraft structure. The principle components of each latch mechanism are shown in Figure 13-47. They are a hydraulic latch cylinder, a latch hook, a spring-loaded crank-and-lever linkage with sector, and the latch roller.

When hydraulic pressure is applied, the cylinder operates the linkage to engage (or disengage) the hook with (or from) the roller on the gear door. In the gear-down sequence, the hook is disengaged by the spring load on the linkage. In the gear-up sequence, when the closing door is in contact with the latch hook, the cylinder operates the linkage to engage the latch hook with the door roller. Cables on the landing gear emergency extension system are connected to the sector to permit emergency release of the latch rollers. An uplock switch is installed on, and actuated by, each latch to provide a gear up indication in the flight deck.

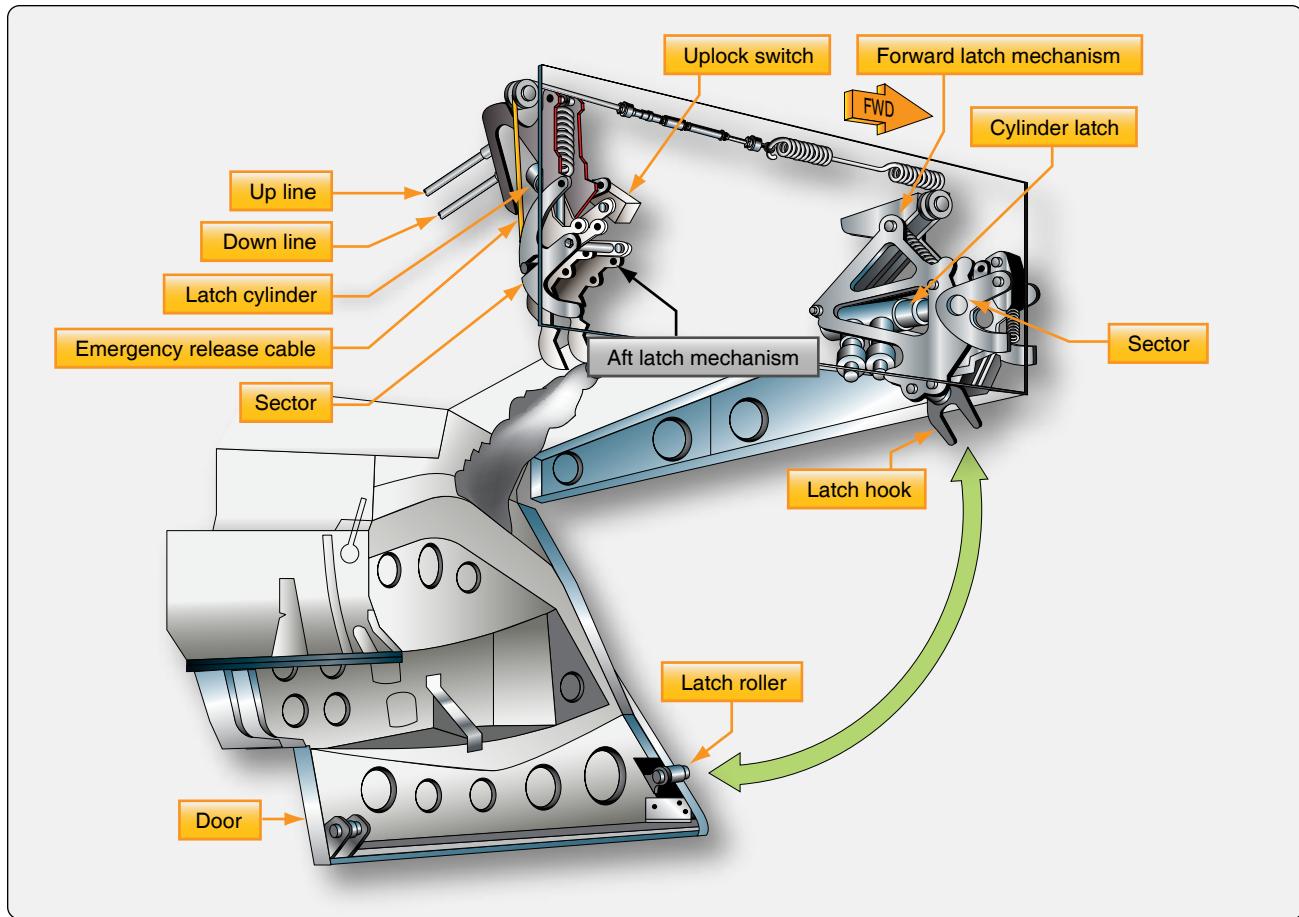
With the gear up and the door latched, inspect the latch roller for proper clearance as shown in Figure 13-48A. On this installation, the required clearance is  $\frac{1}{8} \pm \frac{3}{32}$ -inch. If the roller is not within tolerance, it may be adjusted by loosening its mounting bolts and raising or lowering the latch roller support. This is accomplished via the elongated holes and serrated locking surfaces of the latch roller support and serrated plate. [Figure 13-48B]

### Gear Door Clearances

Landing gear doors have specific allowable clearances between the doors and the aircraft structure that must be maintained. Adjustments are typically made at the hinge



**Figure 13-46.** Packing grease into a clean, dry bearing can be done by hand in the absence of a bearing grease tool. Press the bearing into the grease on the palm of the hand until it passes completely through the gap between the rollers and the inner race all the way around the bearing.



**Figure 13-47.** An example of a main landing gear door latch mechanism.

installations or to the connecting links that support and move the door. On some installations, door hinges are adjusted by placing a serrated hinge with an elongated mounting hole in the proper position in a hinge support fitting. Using serrated washers, the mounting bolt is torqued to hold the position. *Figure 13-49* illustrates this type of mounting, which allows linear adjustments via the elongated hole.

The distance landing gear doors open or close may depend upon the length of the door linkage. Rod end adjustments are common to fit the door. Adjustments to door stops are also a possibility. The manufacturer's maintenance manual specifies the length of the linkages and gives procedure for adjusting the stops. Follow all specified procedures that are accomplished with the aircraft on jacks and the gear retracted. Doors that are too tight can cause structural damage. Doors that are too loose catch wind in flight, which could cause wear and potential failure, as well as parasite drag.

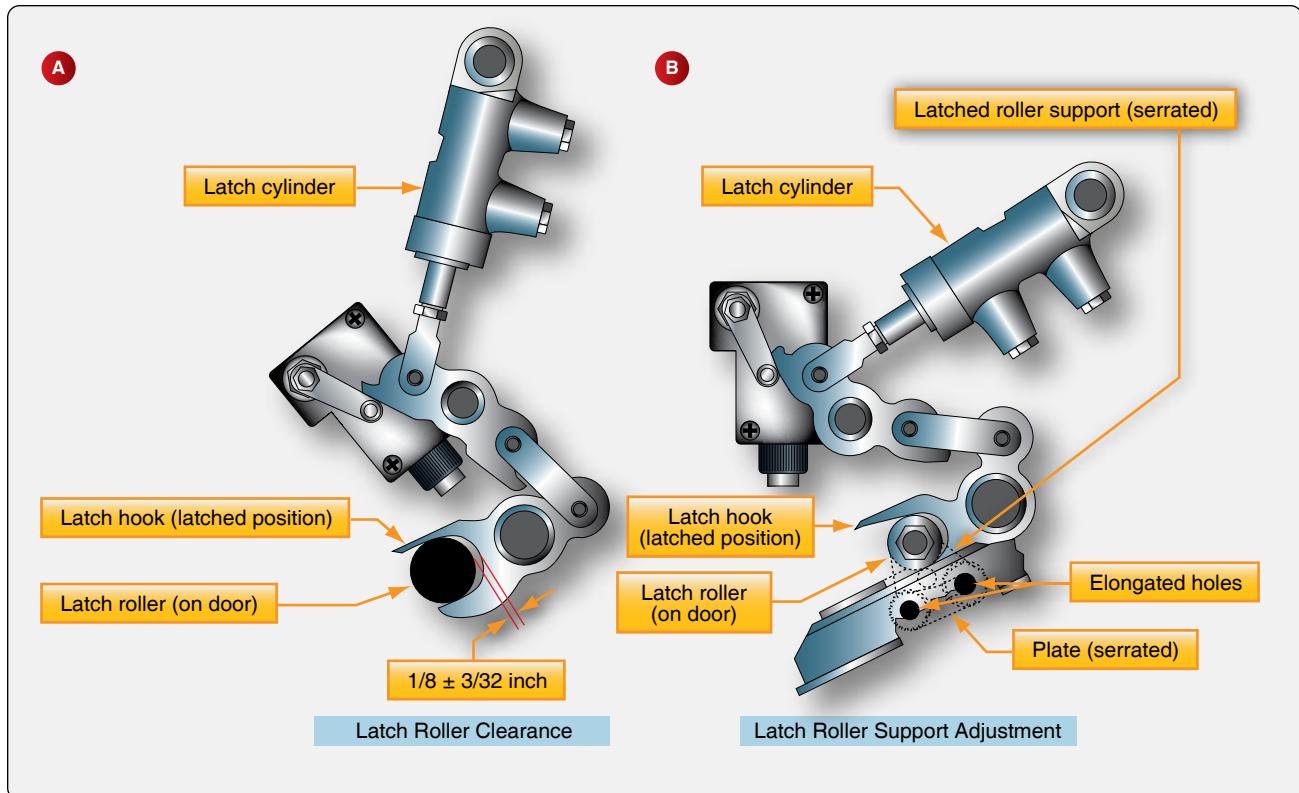
#### **Drag & Side Brace Adjustment**

Each landing gear has specific adjustments and tolerances per the manufacturer that permit the gear to function as intended. A common geometry used to lock a landing gear in the down position involves a collapsible side brace that is extended and

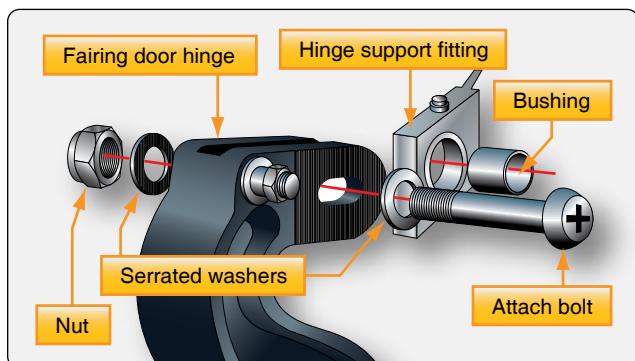
held in an over-center position through the use of a locking link. Springs and actuators may also contribute to the motion of the linkage. Adjustments and tests are needed to ensure proper operation.

*Figure 13-50* illustrates a landing gear on a small aircraft with such a side brace. It consists of an upper and lower link hinged at the center that permits the brace to jackknife during retraction of the gear. The upper end pivots on a trunnion attached to structure in the wheel well overhead. The lower end is attached to the shock strut. A locking link is incorporated between the upper end of the shock strut and the lower drag link. It is adjustable to provide the correct amount of over-center travel of the side brace links. This locks the gear securely in the down position to prevent collapse of the gear.

To adjust the over-center position of the side brace locking link, the aircraft must be placed on jacks. With the landing gear in the down position, the lock link end fitting is adjusted so that the side brace links are held firmly over-center. When the gear is held inboard six inches from the down and locked position and then released, the gear must free fall into the locked down position.



**Figure 13-48.** Main landing gear door latch roller clearance measurement and adjustment.



**Figure 13-49.** An adjustable door hinge installation for setting door clearance.

In addition to the amount the side brace links are adjusted to travel over center, down lock spring tension must also be checked. This is accomplished with a spring scale. The tension on this particular gear is between 40 and 60 pounds. Check the manufacturer's maintenance data for each aircraft to ensure correct tensions exist and proper adjustments are made.

### Landing Gear Retraction Test

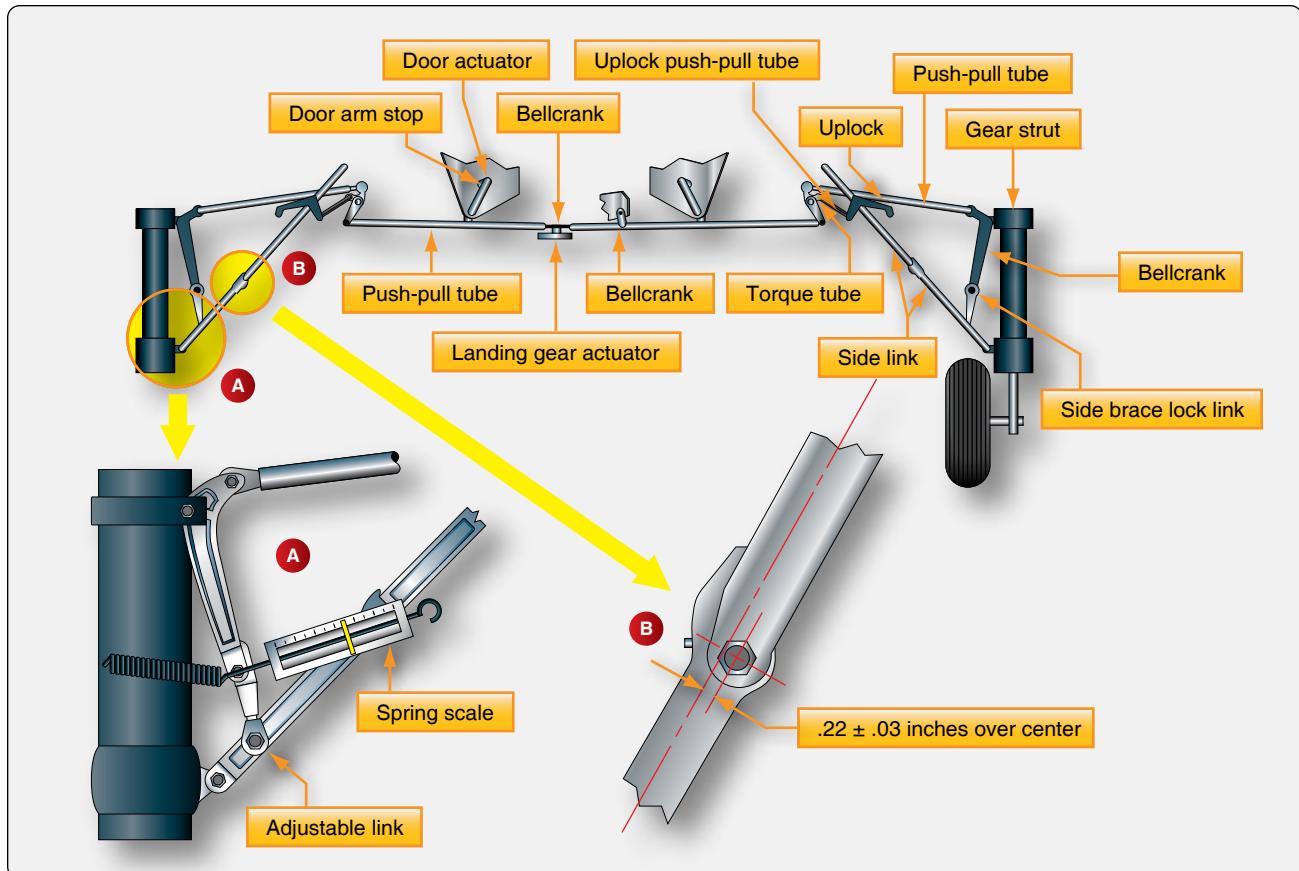
The proper functioning of a landing gear system and components can be checked by performing a landing gear retraction test. This is also known as swinging the gear. The aircraft is properly supported on jacks for this check, and

the landing gear should be cleaned and lubricated if needed. The gear is then raised and lowered as though the aircraft were in flight while a close visual inspection is performed. All parts of the system should be observed for security and proper operation. The emergency back-up extension system should be checked whenever swinging the gear.

Retraction tests are performed at various times, such as during annual inspection. Any time a landing gear component is replaced that could affect the correct functioning of the landing gear system, a retraction test should follow when adjustments to landing gear linkages or components that affect gear system performance are made. It may be necessary to swing the gear after a hard or overweight landing. It is also common to swing the gear while attempting to locate a malfunction within the system. For all required retraction tests and the specific inspection points to check, consult the manufacturer's maintenance manual for the aircraft in question as each landing gear system is unique.

The following is a list of general inspection items to be performed while swinging the gear:

1. Check the landing gear for proper extension and retraction.
2. Check all switches, lights, and warning devices for proper operation.



**Figure 13-50.** Over-center adjustments on a small aircraft main gear.

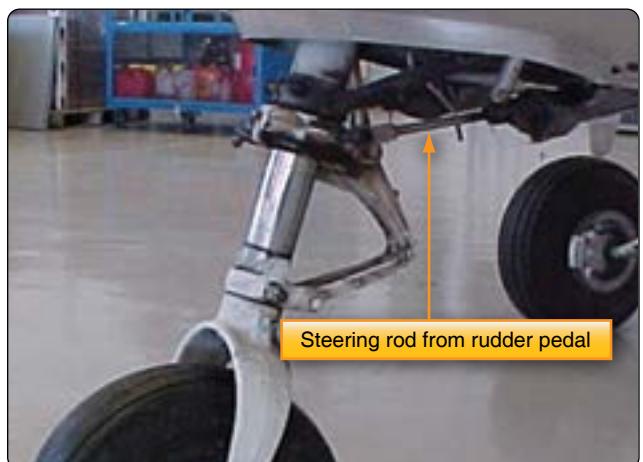
3. Check the landing gear doors for clearance and freedom from binding.
4. Check landing gear linkage for proper operation, adjustment, and general condition.
5. Check the alternate/emergency extension or retraction systems for proper operation.
6. Investigate any unusual sounds, such as those caused by rubbing, binding, chafing, or vibration.

### Nose Wheel Steering Systems

The nose wheel on most aircraft is steerable from the flight deck via a nose wheel steering system. This allows the aircraft to be directed during ground operation. A few simple aircraft have nose wheel assemblies that caster. Such aircraft are steered during taxi by differential braking.

#### Small Aircraft

Most small aircraft have steering capabilities through the use of a simple system of mechanical linkages connected to the rudder pedals. Push-pull tubes are connected to pedal horns on the lower strut cylinder. As the pedals are depressed, the movement is transferred to the strut piston axle and wheel assembly which rotates to the left or right. [Figure 13-51]



**Figure 13-51.** Nose wheel steering on a light aircraft often uses a push-pull rod system connected to the rudder pedals.

#### Large Aircraft

Due to their mass and the need for positive control, large aircraft utilize a power source for nose wheel steering. Hydraulic power predominates. There are many different designs for large aircraft nose steering systems. Most share similar characteristics and components. Control of the steering is from the flight deck through the use of a small wheel, tiller, or joystick typically mounted on the left side wall. Switching the system on and off is possible on some

aircraft. Mechanical, electrical, or hydraulic connections transmit the controller input movement to a steering control unit. The control unit is a hydraulic metering or control valve. It directs hydraulic fluid under pressure to one or two actuators designed with various linkages to rotate the lower strut. An accumulator and relief valve, or similar pressurizing assembly, keeps fluid in the actuators and system under pressure at all times. This permits the steering actuating cylinders to also act as shimmy dampers. A follow-up mechanism consists of various gears, cables, rods, drums, and/or bell-crank, etc. It returns the metering valve to a neutral position once the steering angle has been reached. Many systems incorporate an input subsystem from the rudder pedals for small degrees of turns made while directing the aircraft at high speed during takeoff and landing. Safety valves are typical in all systems to relieve pressure during hydraulic failure so the nose wheel can swivel.

The following explanation accompanies Figures 13-52, 13-53, and 13-54, which illustrate a large aircraft nose wheel steering system and components. These figures and explanation are for instructional purposes only.

The nose wheel steering wheel connects through a shaft to a steering drum located inside the flight deck control pedestal. The rotation of this drum transmits the steering signal by means of cables and pulleys to the control drum of the differential assembly. Movement of the differential assembly is transmitted by the differential link to the metering valve assembly where it moves the selector valve to the selected position. This provides the hydraulic power for turning the nose gear.

As shown in *Figure 13-53*, pressure from the aircraft hydraulic system is directed through the open safety shutoff valve into a line leading to the metering valve. The metering valve then routes the pressurized fluid out of port A, through the right turn alternating line, and into steering cylinder A. This is a one-port cylinder and pressure forces the piston to begin extension. Since the rod of this piston connects to the nose steering spindle on the nose gear shock strut which pivots at point X, the extension of the piston turns the steering spindle gradually toward the right. As the nose wheel turns, fluid is forced out of steering cylinder B through the left turn alternating line and into port B of the metering valve. The metering valve directs this return fluid into a compensator that routes the fluid into the aircraft hydraulic system return manifold.

As described, hydraulic pressure starts the nose gear turning. However, the gear should not be turned too far. The nose gear steering system contains devices to stop the gear at the selected angle of turn and hold it there. This is accomplished with follow-up linkage. As stated, the nose gear is turned

by the steering spindle as the piston of cylinder A extends. The rear of the spindle contains gear teeth that mesh with a gear on the bottom of the orifice rod. [*Figure 13-52*] As the nose gear and spindle turn, the orifice rod also turns but in the opposite direction. This rotation is transmitted by the two sections of the orifice rod to the scissor follow-up links located at the top of the nose gear strut. As the follow-up links return, they rotate the connected follow-up drum, which transmits the movement by cables and pulleys to the differential assembly. Operation of the differential assembly causes the differential arm and links to move the metering valve back toward the neutral position.

The metering valve and the compensator unit of the nose wheel steering system are illustrated in *Figure 13-54*. The compensator unit system keeps fluid in the steering cylinders pressurized at all times. This hydraulic unit consists of a three-port housing that encloses a spring-loaded piston and poppet. The left port is an air vent that prevents trapped air at the rear of the piston from interfering with the movement of the piston. The second port located at the top of the compensator connects through a line to the metering valve return port. The third port is located at the right side of the compensator. This port connects to the hydraulic system return manifold. It routes the steering system return fluid into the manifold when the poppet valve is open.

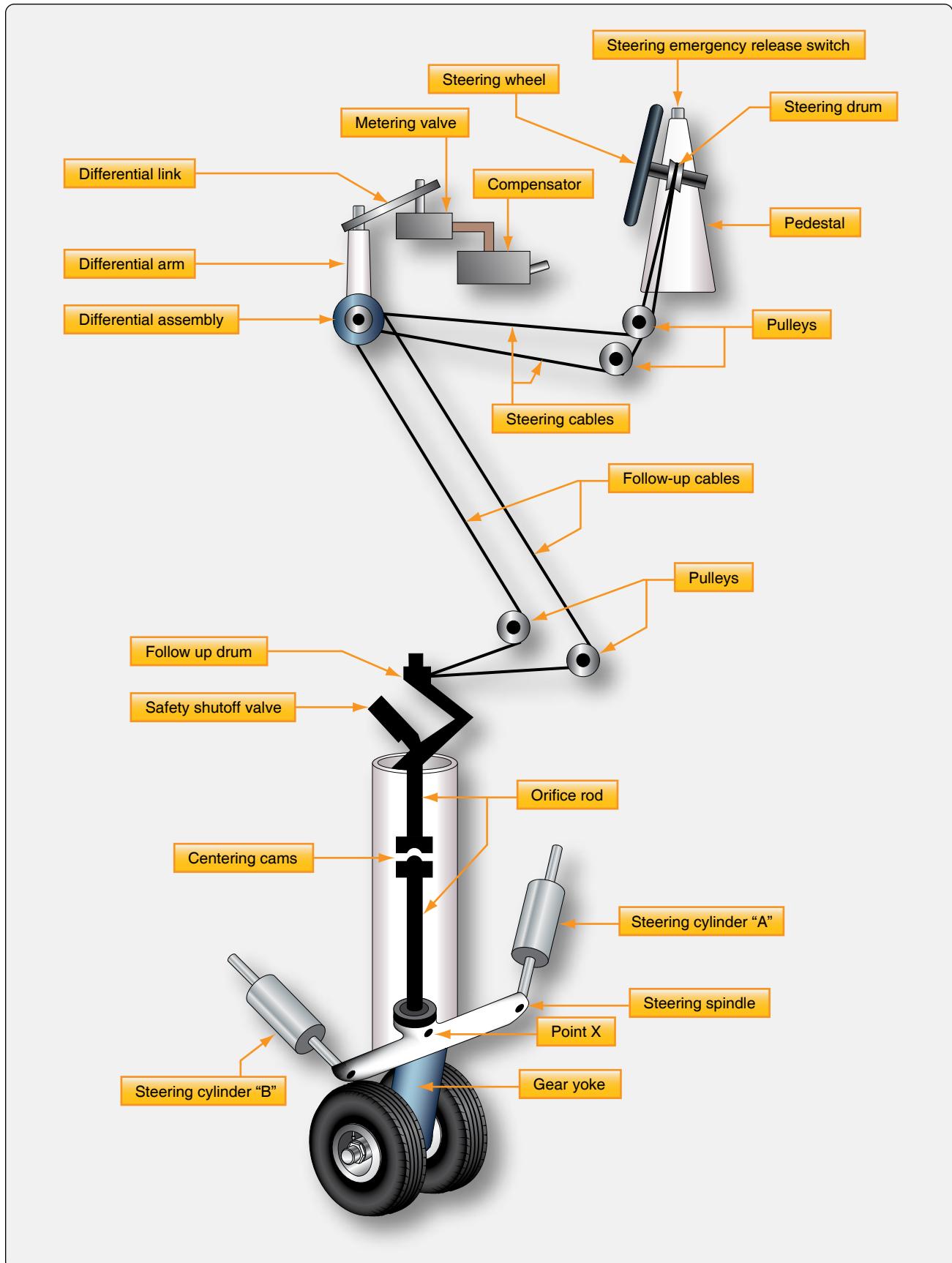
The compensator poppet opens when pressure acting on the piston becomes high enough to compress the spring. In this system, 100 psi is required. Therefore, fluid in the metering valve return line is contained under that pressure. The 100-psi pressure also exists throughout the metering valve and back through the cylinder return lines. This pressurizes the steering cylinders at all times and permits them to function as shimmy dampers.

### **Shimmy Dampers**

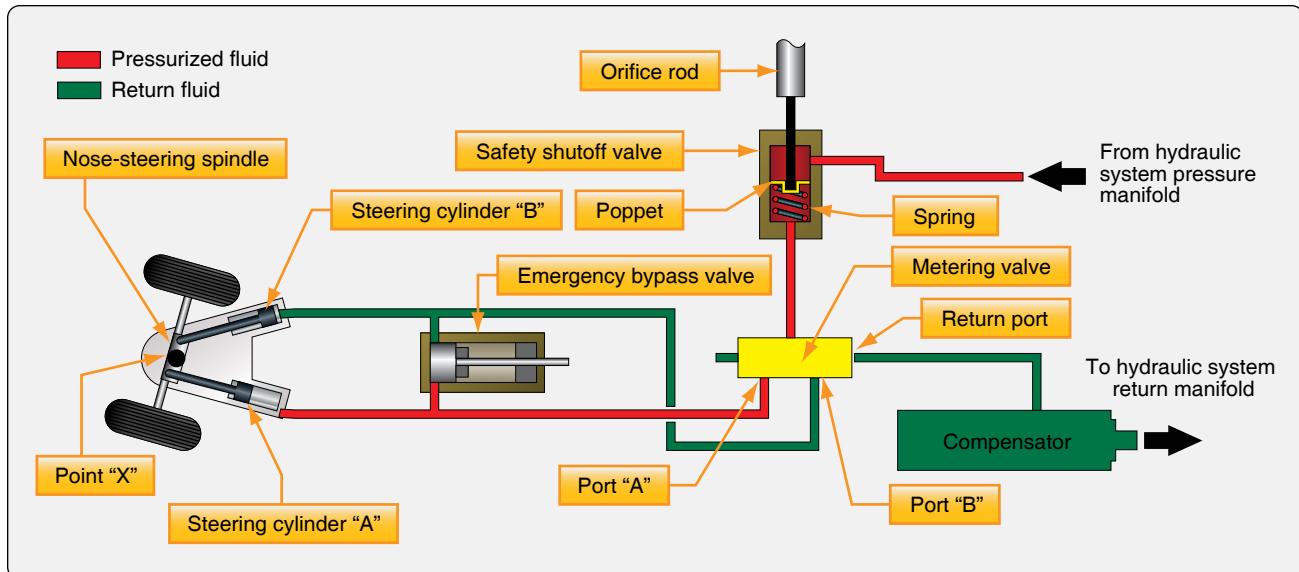
Torque links attached from the stationary upper cylinder of a nose wheel strut to the bottom moveable cylinder or piston of the strut are not sufficient to prevent most nose gear from the tendency to oscillate rapidly, or shimmy, at certain speeds. This vibration must be controlled through the use of a shimmy damper. A shimmy damper controls nose wheel shimmy through hydraulic damping. The damper can be built integrally within the nose gear, but most often it is an external unit attached between the upper and lower shock struts. It is active during all phases of ground operation while permitting the nose gear steering system to function normally.

### **Steering Damper**

As mentioned above, large aircraft with hydraulic steering hold pressure in the steering cylinders to provide the required damping. This is known as steering damping. Some older



**Figure 13-52.** Example of a large aircraft hydraulic nose wheel steering system with hydraulic and mechanical units.



**Figure 13-53.** Hydraulic system flow diagram of large aircraft nose wheel steering system.

transport category aircraft have steering dampers that are vane-type. Nevertheless, they function to steer the nose wheel, as well as to dampen vibration.

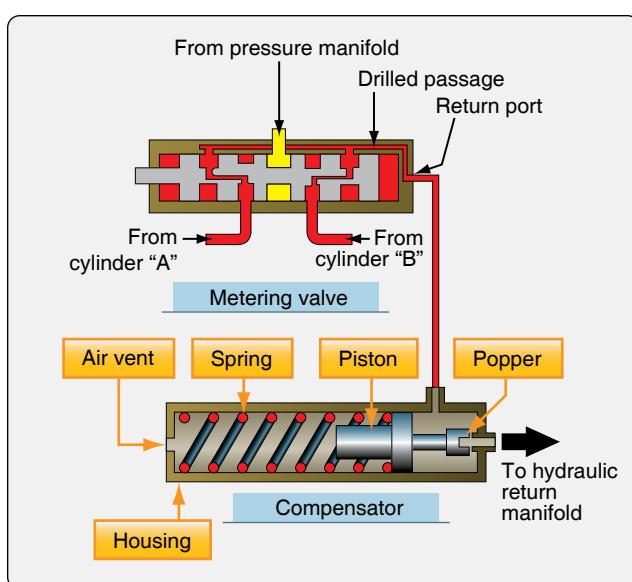
### Piston-Type

Aircraft not equipped with hydraulic nose wheel steering utilize an additional external shimmy damper unit. The case is attached firmly to the upper shock strut cylinder. The shaft is attached to the lower shock strut cylinder and to a piston inside the shimmy damper. As the lower strut cylinder tries to shimmy, hydraulic fluid is forced through a bleed hole in the piston. The restricted flow through the bleed hole damps the oscillation. [Figure 13-55]

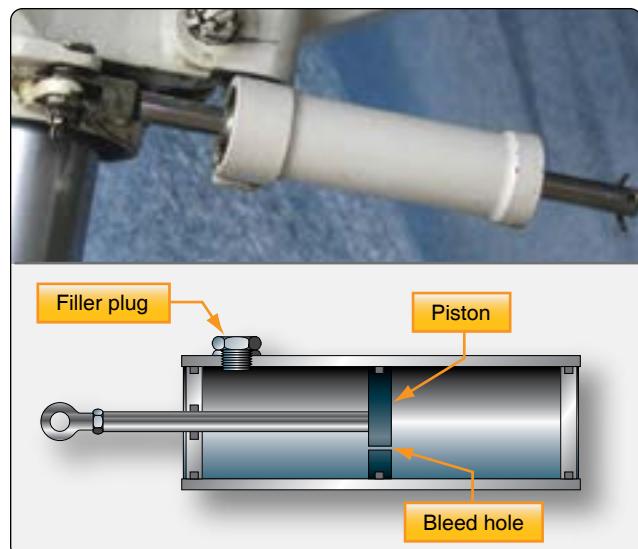
A piston-type shimmy damper may contain a fill port to add fluid or it may be a sealed unit. Regardless, the unit should be checked for leaks regularly. To ensure proper operation, a piston-type hydraulic shimmy damper should be filled to capacity.

### Vane-Type

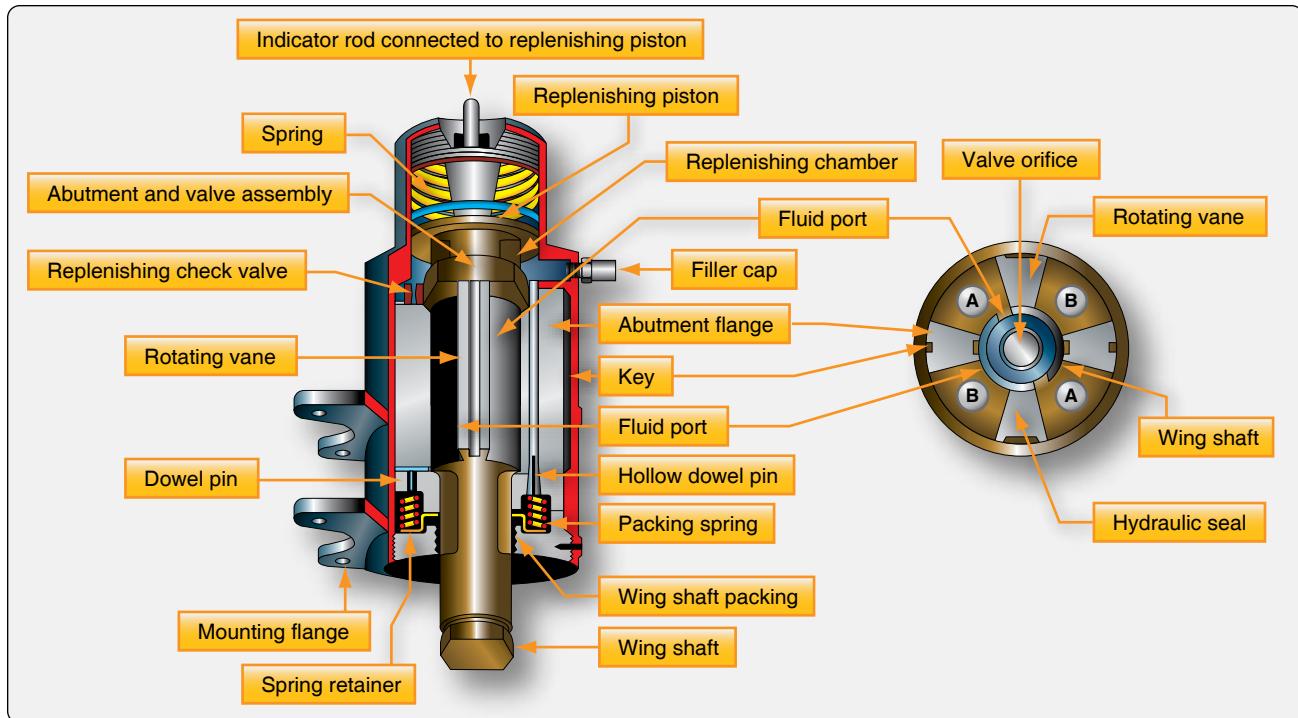
A vane-type shimmy damper is sometimes used. [Figure 13-56] It uses fluid chambers created by the vanes separated by a valve orifice in a center shaft. As the nose gear tries to oscillate, vanes rotate to change the size of internal chambers filled with fluid. The chamber size can only change as fast



**Figure 13-54.** Hydraulic system flow diagram of large aircraft nose wheel steering system.



**Figure 13-55.** A shimmy damper on the nose strut of a small aircraft. The diagram shows the basic internal arrangement of most shimmy dampers. The damper in the photo is essentially the same except the piston shaft extends through both ends of the damper cylinder body.



**Figure 13-56.** A typical vane-type shimmy damper.

as the fluid can be forced through the orifice. Thus, the gear oscillation is dissipated by the rate of fluid flow. An internal spring-loaded replenishing reservoir keeps pressurized fluid in the working chambers and thermal compensation of the orifice size is included. As with the piston type shimmy damper, the vane-type damper should be inspected for leaks and kept serviced. A fluid level indicator protrudes from the reservoir end of the unit.

### Non-Hydraulic Shimmy Damper

Non-hydraulic shimmy dampers are currently certified for many aircraft. They look and fit similar to piston-type shimmy dampers but contain no fluid inside. In place of the metal piston, a rubber piston presses out against the inner diameter of the damper housing when the shimmy motion is received through the shaft. The rubber piston rides on a very thin film of grease and the rubbing action between the piston and the housing provides the damping.

This is known as surface-effect damping. The materials used to construct this type of shimmy damper provide a long service life without the need to ever add fluid to the unit. [Figure 13-57]

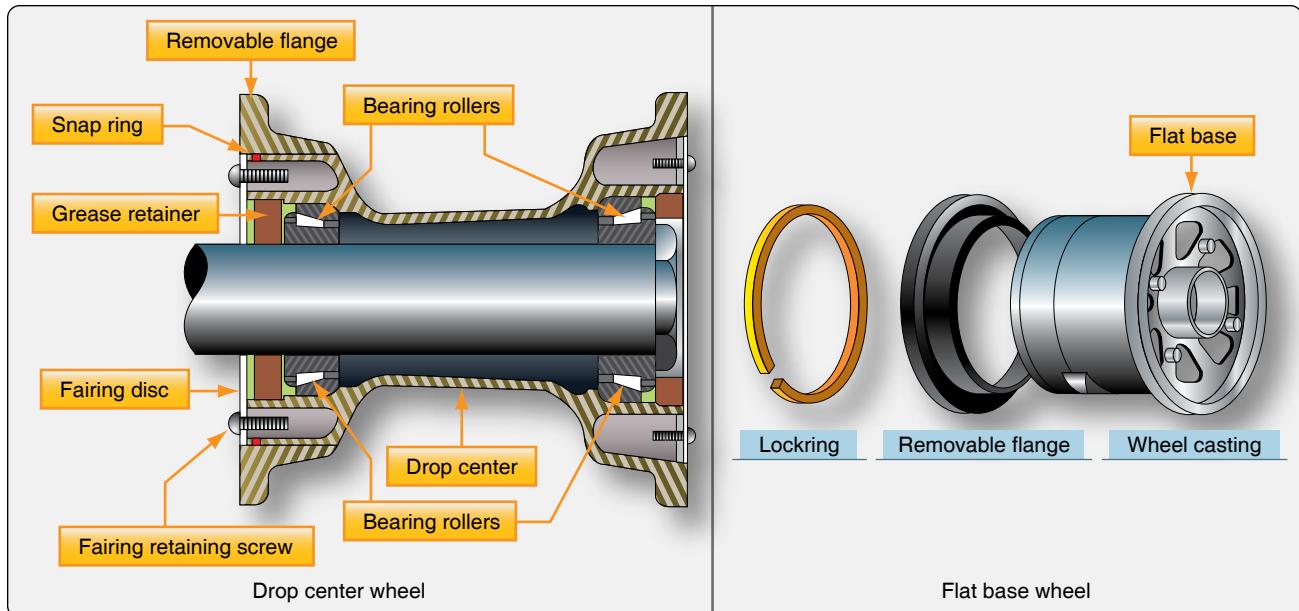
### Aircraft Wheels

Aircraft wheels are an important component of a landing gear system. With tires mounted upon them, they support the entire weight of the aircraft during taxi, takeoff, and landing. The typical aircraft wheel is lightweight, strong, and made

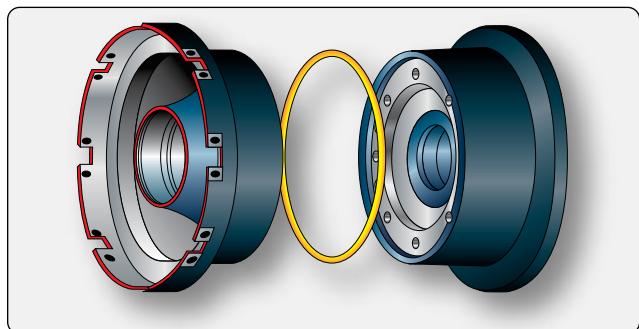


**Figure 13-57.** A non-hydraulic shimmy damper uses a rubber piston with lubricant that dampens via motion against the inner diameter of the unit housing.

from aluminum alloy. Some magnesium alloy wheels also exist. Early aircraft wheels were of single piece construction, much the same as the modern automobile wheel. As aircraft tires were improved for the purpose they serve, they were made stiffer to better absorb the forces of landing without blowing out or separating from the rim. Stretching such a tire over a single piece wheel rim was not possible. A two-piece wheel was developed. Early two-piece aircraft wheels were essentially one-piece wheels with a removable rim to allow mounting access for the tire. These are still found on older aircraft. [Figure 13-58] Later, wheels with two nearly symmetrical halves were developed. Nearly all modern aircraft wheels are of this two-piece construction. [Figures 13-59 and 13-60]



**Figure 13-58.** Removable flange wheels found on older aircraft are either drop center or flat base types.



**Figure 13-59.** Two-piece split-wheel aircraft wheels found on modern light aircraft.

## Wheel Construction

The typical modern two-piece aircraft wheel is cast or forged from aluminum or magnesium alloy. The halves are bolted together and contain a groove at the mating surface for an o-ring, which seals the rim since most modern aircraft utilize tubeless tires. The bead seat area of a wheel is where the tire actually contacts the wheel. It is the critical area that accepts the significant tensile loads from the tire during landing. To strengthen this area during manufacturing, the bead seat area is typically rolled to prestress it with a compressive stress load.

### Inboard Wheel Half

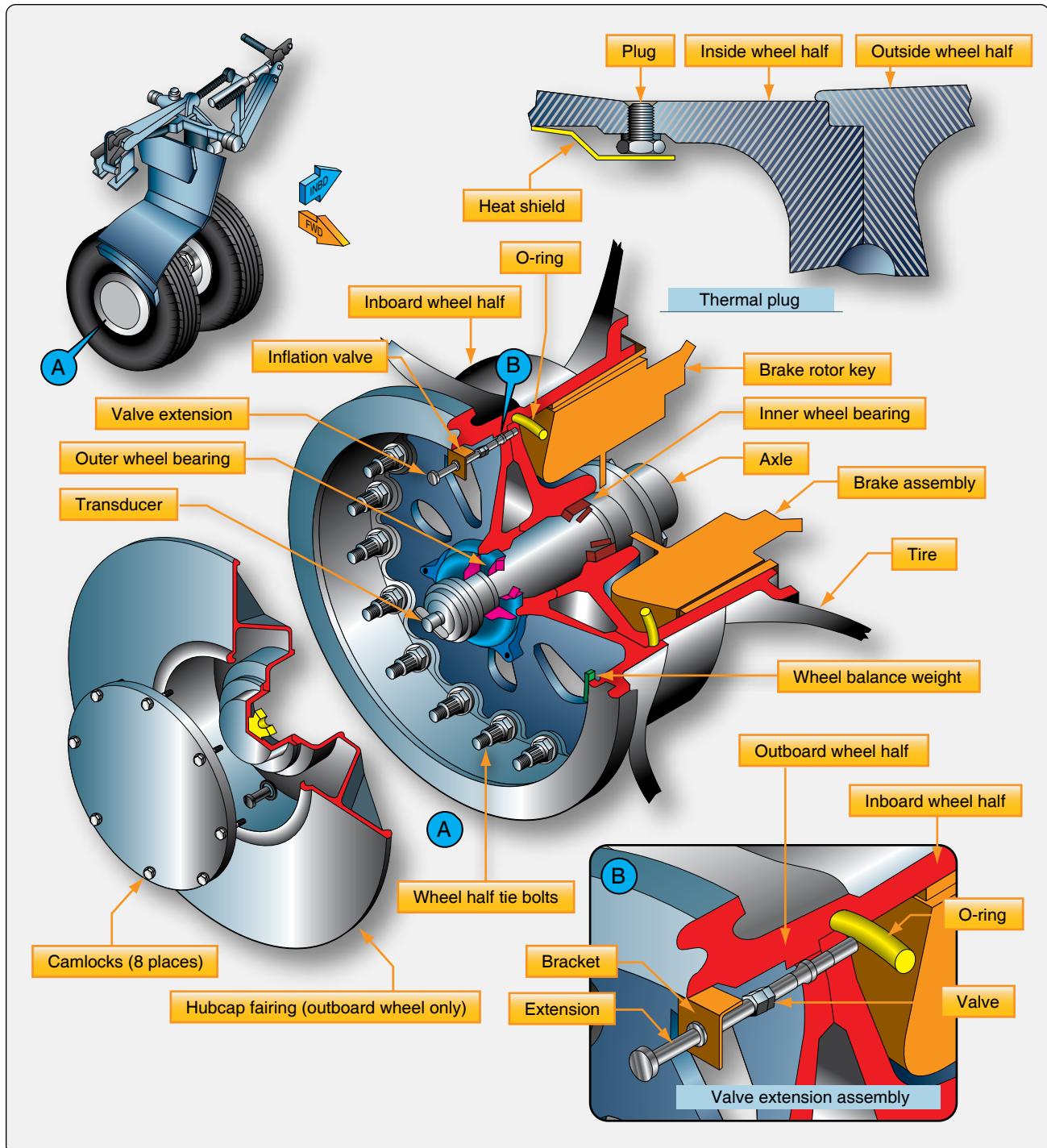
Wheel halves are not identical. The primary reason for this is that the inboard wheel half must have a means for accepting and driving the rotor(s) of the aircraft brakes that are mounted on both main wheels. Tangs on the rotor are fitted into steel reinforced keyways on many wheels. Other wheels have steel keys bolted to the inner wheel halves. These are made

to fit slots in the perimeter of the brake rotor. Some small aircraft wheels have provisions for bolting the brake rotor to the inner wheel half. Regardless, the inner wheel half is distinguishable from the outer wheel half by its brake mounting feature. [Figure 13-61]

Both wheel halves contain a bearing cavity formed into the center that accepts the polished steel bearing cup, tapered roller bearing, and grease retainer of a typical wheel bearing set-up. A groove may also be machined to accept a retaining clip to hold the bearing assembly in place when the wheel assembly is removed. The wheel bearings are a very important part of the wheel assembly and are discussed in a later section of this chapter.

The inner wheel half of a wheel used on a high-performance aircraft is likely to have one or more thermal plugs. [Figure 13-62] During heavy braking, temperatures can become so great that tire temperature and pressure rise to a level resulting in explosion of the wheel and tire assembly. The thermal plug core is filled with a low melting point alloy. Before tire and wheel temperatures reach the point of explosion, the core melts and deflates the tire. The tire must be removed from service, and the wheel must be inspected in accordance with the wheel manufacturer's instructions before return to service if a thermal plug melts. Adjacent wheel assemblies should also be inspected for signs of damage. A heat shield is commonly installed under the inserts designed to engage the brake rotor to assist in protecting the wheel and tire assembly from overheating.

An overinflation safety plug may also be installed in the inner wheel half. This is designed to rupture and release all



**Figure 13-60.** Features of a two piece aircraft wheel found on a modern airliner.

of the air in the tire should it be over inflated. The fill valve is also often installed in the inner wheel half with the stem extending through holes in the outer wheel half to permit access for inflation and deflation.

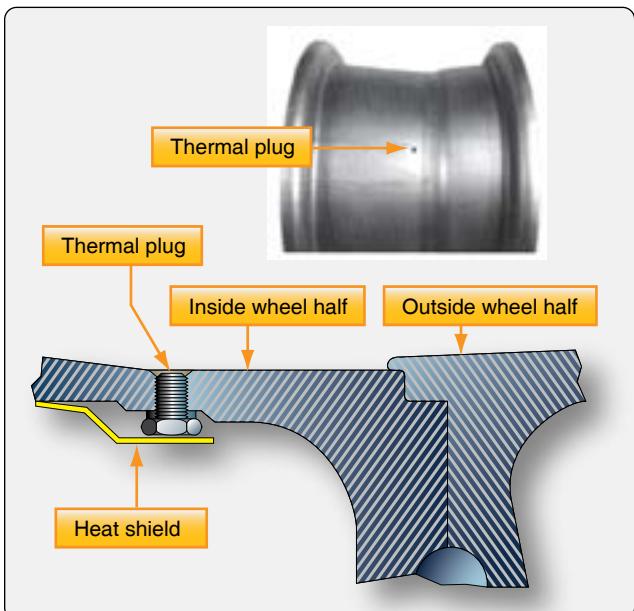
### Outboard Wheel Half

The outboard wheel half bolts to the inboard wheel half to make up the wheel assembly upon which the tire is mounted.

The center boss is constructed to receive a bearing cup and bearing assembly as it does on the inboard wheel half. The outer bearing and end of the axle is capped to prevent contaminants from entering this area. Aircraft with anti-skid brake systems typically mount the wheel-spin transducer here. It is sealed and may also serve as a hub cap. The 737 outer wheel half illustrated in *Figure 13-60* also has a hub cap fairing over the entire wheel half. This is to fair it with



**Figure 13-61.** Keys on the inner wheel half of an aircraft wheel used to engage and rotate the rotors of a disc brake.



**Figure 13-62.** Heavy use of the aircraft brakes can cause tire air temperature and pressure to rise to a level resulting in explosion of the wheel assembly. To alleviate this, thermal plug(s) mounted in the inner wheel half of a high performance aircraft wheels are made with a fusible core that melts and releases the air from the tire before explosion.

the wind since the outer wheel half does not close behind a gear door on this aircraft. Hub caps may also be found on fixed gear aircraft.

The outboard wheel half provides a convenient location of the valve stem used to inflate and deflate tubeless tires. Alternately, it may contain a hole through which a valve stem extension may pass from the inner wheel half or the valve stem itself may fit through such a hole if a tube-type tire is used.

## Wheel Inspection

An aircraft wheel assembly is inspected while on the aircraft as often as possible. A more detailed inspection and any testing or repairs may be accomplished with the wheel assembly removed from the aircraft.

### On Aircraft Inspection

The general condition of the aircraft wheel assemblies can be inspected while on the aircraft. Any signs of suspected damage that may require removal of the wheel assembly from the aircraft should be investigated.

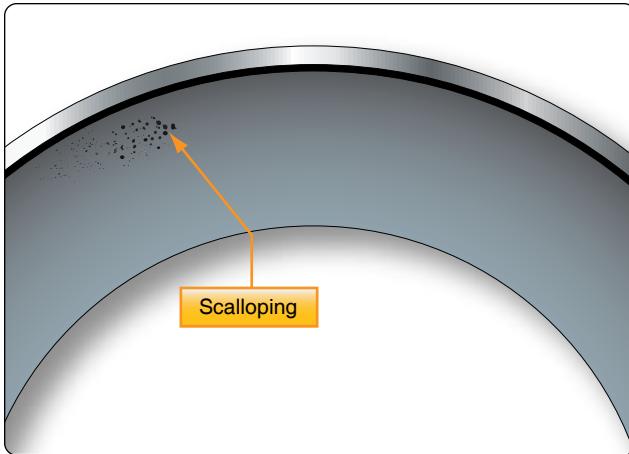
### Proper Installation

The landing gear area is such a hostile environment that the technician should inspect the landing gear including the wheels, tires, and brakes whenever possible. Proper installation of the wheels should not be taken for granted. All wheel tie bolts and nuts must be in place and secure. A missing bolt is grounds for removal, and a thorough inspection of the wheel halves in accordance with the wheel manufacturer's procedures must be performed due to the stresses that may have occurred. The wheel hub dust cap and anti-skid sensor should also be secure. The inboard wheel half should interface with the brake rotor with no signs of chafing or excessive movement. All brake keys on the wheel must be present and secure.

Examine the wheels for cracks, flaked paint, and any evidence of overheating. Inspect thermal plugs to ensure no sign of the fusible alloy having been melted. Thermal plugs that have permitted pressure loss in the tire require that the wheel assembly be removed for inspection. All other wheels with brakes and thermal plugs should be inspected closely while on the aircraft to determine if they too have overheated. Each wheel should be observed overall to ensure it is not abnormally tilted. Flanges should not be missing any pieces, and there should be no areas on the wheel that show significant impact damage.

### Axle Nut Torque

Axle nut torque is of extreme importance on an aircraft wheel installation. If the nut is too loose, the bearing and wheel assembly may have excessive movement. The bearing cup(s) could loosen and spin, which could damage the wheel. There could also be impact damage from the bearing rollers which leads to bearing failure. [Figure 13-63] An over-torqued axle nut prevents the bearing from properly accepting the weight load of the aircraft. The bearing spins without sufficient lubrication to absorb the heat caused by the higher friction level. This too leads to bearing failure. All aircraft axle nuts must be installed and torqued in accordance with the airframe manufacturer's maintenance procedures.



**Figure 13-63.** Improper loose torque on the axle nut can cause excessive end play leading to bearing race damage known as scalloping. Eventually, this leads to bearing failure.

### Off Aircraft Wheel Inspection

Discrepancies found while inspecting a wheel mounted on the aircraft may require further inspection with the wheel removed from the aircraft. Other items such as bearing condition, can only be performed with the wheel assembly removed. A complete inspection of the wheel requires that the tire be removed from the wheel rim. Observe the following caution when removing a wheel assembly from an aircraft.

**Caution:** Deflate the tire before starting the procedure of removing the wheel assembly from the aircraft. Wheel assemblies have been known to explode while removing the axle nut, especially when dealing with high pressure, high performance tires. The torque of the nut can be the only force holding together a defective wheel or one with broken tie bolts. When loosened, the high internal pressure of the

tire can create a catastrophic failure that could be lethal to the technician. It is also important to let aircraft tires cool before removal. Three hours or more is needed for cool down. Approach the wheel assembly from the front or rear, not broadside. Do not stand in the path of the released air and valve core trajectory when removing air from the tire as it could seriously injure the technician should it release from the valve stem.

**Note:** As a precautionary measure, remove only one tire and wheel assembly from a pair at a time. This leaves a tire and wheel assembly in place should the aircraft fall off its jack, resulting in less chance of damage to the aircraft and injury to personnel.

#### Loosening the Tire from the Wheel Rim

After inflation and usage, an aircraft tire has a tendency to adhere to the wheel, and the bead must be broken to remove the tire. There are mechanical and hydraulic presses designed for this purpose. In the absence of a device specifically made for the job, an arbor press can be used with patience working sequentially around the wheel as close as possible to the bead. [Figure 13-64] As stated above, there should be no air pressure in the tire while it is being pressed off of the wheel. Never pry a tire off of the rim with a screwdriver or other device. The wheels are relatively soft. Any nick or deformation causes a stress concentration that can easily lead to wheel failure.

#### Disassembly of the Wheel

Disassembly of the wheel should take place in a clean area on a flat surface, such as a table. Remove the wheel bearing first and set aside for cleaning and inspecting. The tie bolts can then be removed. Do not use an impact tool to disassemble the tie bolts. Aircraft wheels are made of relatively soft



**Figure 13-64.** Tire beads must be broken from the wheel to remove the tire. A mechanical removal tool designed for breaking the bead is shown in (A); a hydraulic press designed with the capacity for large aircraft wheels is shown in (B); and an arbor press is shown in (C). All are tools available to the technician for this purpose.

aluminum and magnesium alloys. They are not designed to receive the repeated hammering of an impact tool and will be damaged if used.

#### *Cleaning the Wheel Assembly*

Clean the wheel halves with the solvent recommended by the wheel manufacturer. Use of a soft brush helps this process. Avoid abrasive techniques, materials, and tools, such as scrapers, capable of removing the finish off of the wheel. Corrosion can quickly form and weaken the wheel if the finish is missing in an area. When the wheels are clean, they can be dried with compressed air.

#### *Cleaning the Wheel Bearings*

The bearings should be removed from the wheel to be cleaned with the recommended solvent, such as varsol, naptha, or Stoddard® solvent. Soaking the bearings in solvent is acceptable to loosen any dried-on grease. Bearings are brushed clean with a soft bristle brush and dried with compressed air. Never rotate the bearing while drying with compressed air. The high-speed metal to metal contact of the bearing rollers with the race causes heat that damages the metal surfaces. The bearing parts could also cause injury should the bearing come apart. Always avoid steam cleaning of bearings. The surface finish of the metals will be compromised leading to early failure.

#### *Wheel Bearing Inspection*

Once cleaned, the wheel bearing is inspected. There are many unacceptable conditions of the bearing and bearing cup, which are grounds for rejection. In fact, nearly any flaw detected in a bearing assembly is likely to be grounds for replacement.

Common conditions of a bearing that are cause for rejection are as follows:

Galling—caused by rubbing of mating surfaces. The metal gets so hot it welds, and the surface metal is destroyed as the motion continues and pulls the metal apart in the direction of motion. [Figure 13-65]

Spalling—a chipped away portion of the hardened surface of a bearing roller or race. [Figure 13-66]

Overheating—caused by lack of sufficient lubrication results in a bluish tint to the metal surface. The ends of the rollers shown were overheated causing the metal to flow and deform, as well as discolor. The bearing cup raceway is usually discolored as well. [Figure 13-67]

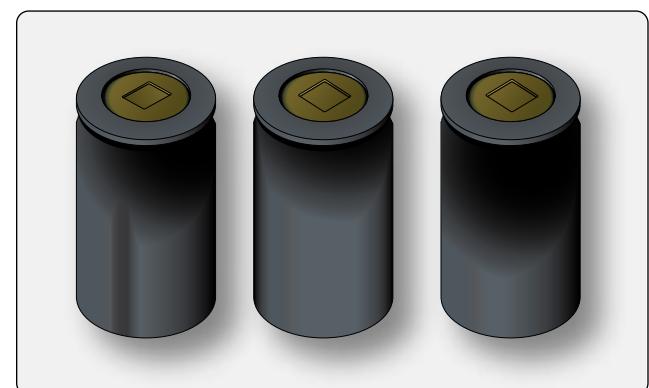
Brinelling—caused by excessive impact. It appears as indentations in the bearing cup raceways. Any static overload



**Figure 13-65.** Galling is caused by rubbing of mating surfaces. The metal gets so hot it welds, and the surface metal is destroyed as the motion continues and pulls the metal apart in the direction of motion.



**Figure 13-66.** Spalling is a chipped away portion of the hardened surface of a bearing roller or race.



**Figure 13-67.** Overheating caused by lack of sufficient lubrication results in a bluish tint to the metal surface. The ends of the rollers shown were overheated causing the metal to flow and deform, as well as discolor. The bearing cup raceway is usually discolored as well.

or severe impact can cause true brinelling that leads to vibration and premature bearing failure. [Figure 13-68]

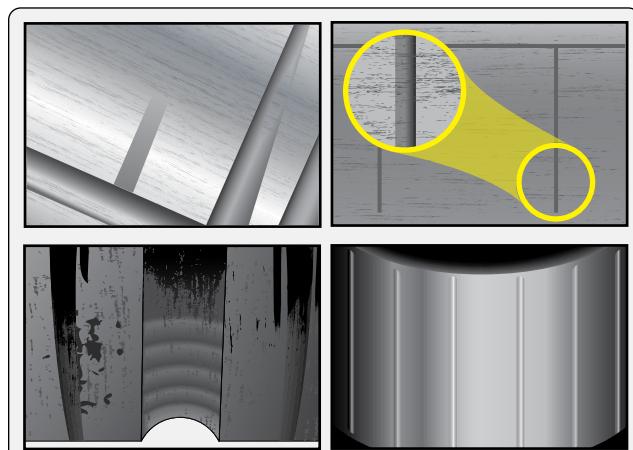
False Brinelling—caused by vibration of the bearing while in a static state. Even with a static overload, lubricant can be forced from between the rollers and the raceway. Submicroscopic particles removed at the points of metal-to-metal contact oxidize. They work to remove more particles spreading the damage. This is also known as frictional corrosion. It can be identified by a rusty coloring of the lubricant. [Figure 13-69]

Staining and surface marks—located on the bearing cup as grayish black streaks with the same spacing as the rollers and caused by water that has gotten into the bearing. It is the first stage of deeper corrosion that follows. [Figure 13-70]

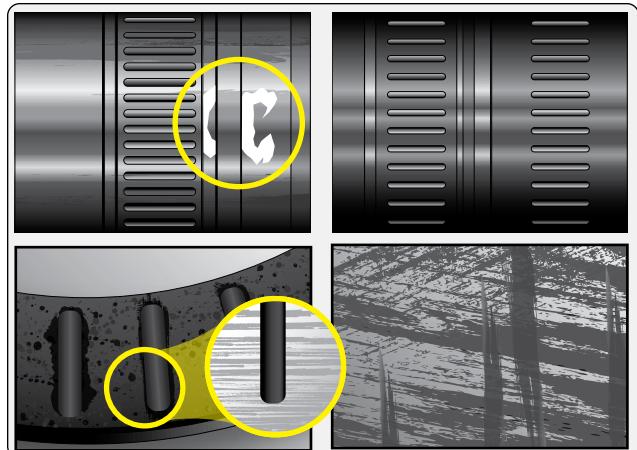
Etching and corrosion—caused when water and the damage caused by water penetrates the surface treatment of the bearing element. It appears as a reddish/brown discoloration. [Figure 13-71]

Bruising—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 13-72]

The bearing cup does not require removal for inspection; however, it must be firmly seated in the wheel half boss. There should be no evidence that a cup is loose or able to spin. [Figure 13-73] The cup is usually removed by heating the wheel in a controlled oven and pressing it out or tapping it out with a non-metallic drift. The installation procedure is similar. The wheel is heated, and the cup is cooled with dry ice before it is tapped into place with a non-metallic hammer or drift. The outside of the race is often sprayed with



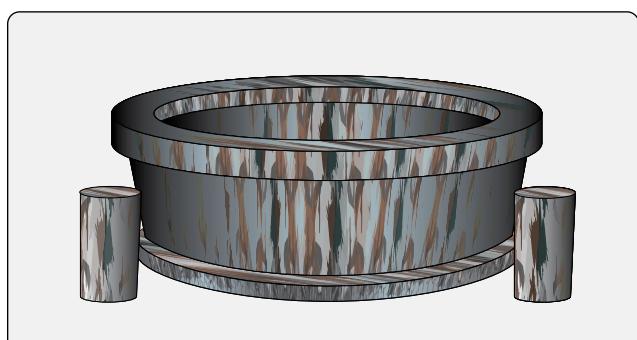
**Figure 13-68.** Brinelling is caused by excessive impact. It appears as indentations in the bearing cup raceways. Any static overload or severe impact can cause true brinelling, which leads to vibration and premature bearing failure.



**Figure 13-69.** False brinelling is caused by vibration of the bearing while in a static state. Even with a static overload, it can force the lubricant from between the rollers and the raceway. Submicroscopic particles removed at the points of metal-to-metal contact oxidize. They work to remove more particles spreading the damage. This is also known as frictional corrosion. It can be identified by a rusty coloring of the lubricant.



**Figure 13-70.** Staining and surface marks on the bearing cup that are grayish black streaks with the same spacing as the rollers are caused by water that has gotten into the bearing. It is the first stage of deeper corrosion that will follow.



**Figure 13-71.** Etching and corrosion is caused when water, and the damage caused by water, penetrates the surface treatment of the bearing element. It appears as a reddish/brown discoloration.