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AIRFRAME AND SYSTEMS
CHAPTER 9: LANDING GEAR

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INTRODUCTION

The aircraft's landing gear or undercarriage is of course a vital part of the aircraft structure. It must be able to support the weight of the aircraft, withstand the shock of landing, accept large side loads during crosswind landings, absorb severe braking forces, be steerable and of course retractable. This Chapter will examine the construction and operation of landing gears and the systems associated with them. They are;

- Steering Systems, and
- Wheels and Tyres.

LANDING GEAR CONFIGURATIONS AND GEOMETRY

History has shown that most aircraft designs have adopted the tricycle landing gear configuration using a castoring or steering nose wheel rather than the first types that employed a tail wheel. There are some advantages to the tail wheel arrangement but these are outweighed by the advantages gained by the tricycle configuration. Refer to Figure 9-1.

TAIL WHEEL LANDING GEAR CONFIGURATIONS	
ADVANTAGES	**DISADVANTAGES**
a loss of forward energy in air drag due to the tail down attitude during landing; energy which would otherwise have to be absorbed by the brakes	heavy braking can cause nosing over or overturning
the location of the main wheels forward of the CofG means increased wheel loading when brakes are applied. This reduces the need for anti skid devices	brake drag forces forward of the CofG produce a tendency to swing around
	tail drop on landing produces higher incidence thus a tendency to balloon
	pilot visibility is poor during taxi,
	there is reduced take-off performance due to drag, until the tail can be raised
NOSE WHEEL LANDING GEAR CONFIGURATIONS	
ADVANTAGES	**DISADVANTAGES**
heavy braking cannot cause nosing over or overturning	very little of the forward energy of the aircraft is dissipated aerodynamically on landing, requiring more reliance on brakes
the aircraft is inherently stable on the ground, as the CofG is ahead of the main wheels	the nose gear will be heavier than a tail gear due to the forward pitching of the aircraft during braking increasing the dynamic loads on the nose wheel assembly
on landing, the aircraft pitches forward spoiling wing lift and eliminating the risk of aerodynamic bounce	
pilot visibility is greatly improved	
there is no loss of take-off performance due to drag from a tail down attitude during initial acceleration	

Figure 9-1 Nose and Tail Wheel Landing Gear Configurations

Almost all commercial aircraft use a tricycle type of undercarriage, consisting of the main gear which supports most of the weight of the aircraft via the wing structures, and a nose gear.

Some very large commercial aircraft position extra weight supporting gear assemblies from beneath the fuselage. Additionally, extendable tail skids may form part of the gear configuration.

Military and other special task aircraft often have unusual gear configurations to support very heavy weight in the fuselage. Refer to Figure 9-2.

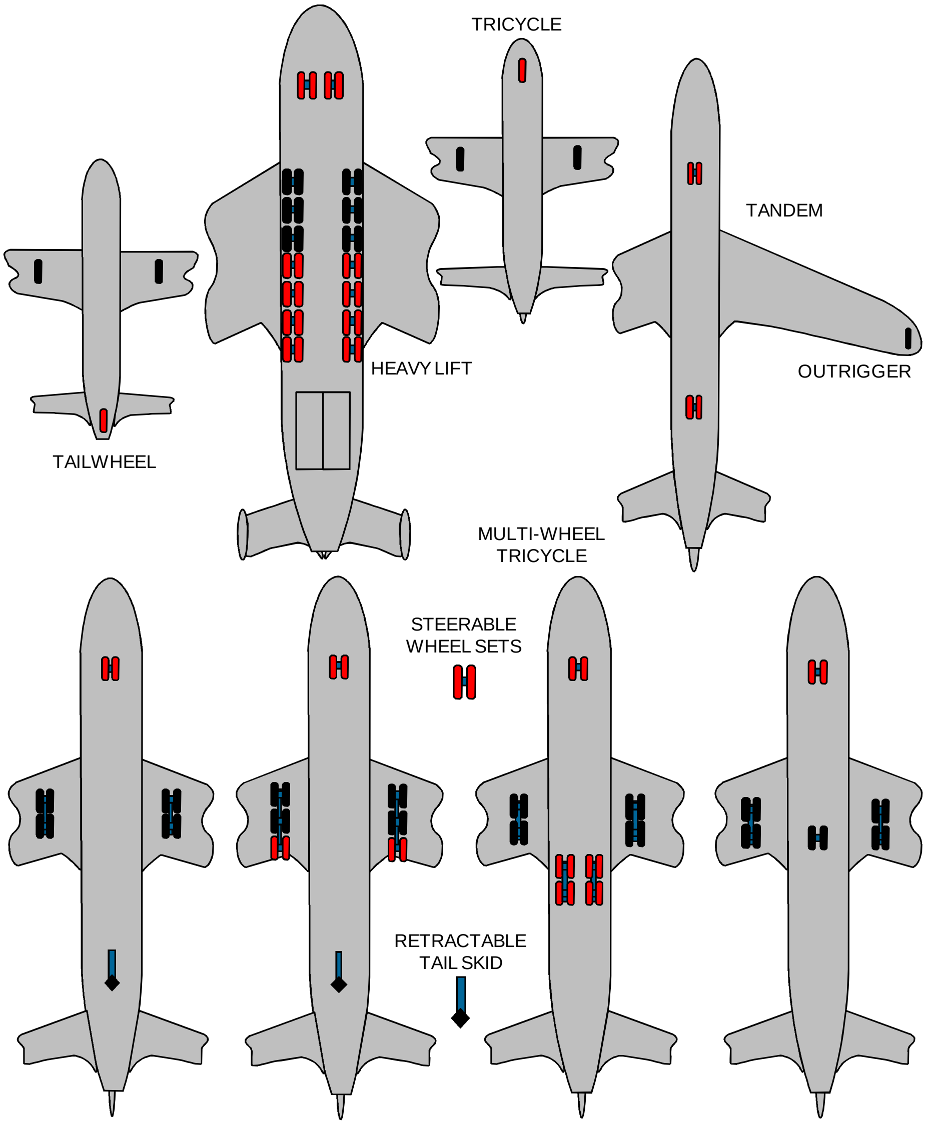

Figure 9-2 Landing Gear Configurations

LANDING GEAR GEOMETRY

The landing gears of all aircraft are set to the designers geometry for the advantages gained for particular aircraft types. There are three geometric parameters to consider;

Castor is the angle of displacement of the wheel axis behind the vertical axis of the gear leg which causes the wheel to trail behind the gear leg with forward movement of the aircraft. It is applicable to nose or tail steerable wheels and aircraft that are steered by differential braking normally have large castor angles.

Camber is the vertical wheel axis angle relative to the aircraft's vertical axis. Camber can be negative with the top of the wheels tilted towards the fuselage, positive with the top of the wheels tilted away from the fuselage or neutral. It is applicable only to the main landing gears.

Toe-in or Toe-out is the angle of the rolling wheels relative to the longitudinal axis of the aircraft. It is only applicable to the main gear assemblies. Toe-in can assist in maintaining directional control.

Most large aircraft have castoring nose wheels, neutral camber and no toe-in or toe-out.

LANDING GEAR CONSTRUCTION

The primary component of all landing gears on all aircraft is the shock absorber strut which absorbs the shock of landing and of course supports the aircraft when on the ground. This component is often referred to as the oleo leg as it contains and operates using air (nitrogen) and oil (hydraulic fluid).

On light aircraft, the landing gear is only small and produces little parasite drag, which can be reduced by the use of fairings. However, on larger commercial aircraft, the drag penalty is unacceptable and therefore the landing gear is made to retract. This of course requires electrical, mechanical and hydraulic infrastructure to allow retraction and extension. Additionally, provision must be made to extend the landing gear when the normal method of extension fails due to malfunction. Nose and body gears require components for steering, main gears for braking. Still more components are added for cockpit indication of position, ground/air sensing logic and over rotation during take-off.

Most main undercarriages retract sideways into the wing or bottom of the aircraft. Some high wing aircraft have special fairings at the base of the fuselage into which the main gear is retracted. Nose landing gears are normally retracted forwards or backwards into a space at the front underside of the aircraft. The following list details the important components common to all retractable landing gear assemblies;

- shock strut,
- trunnion beam,
- drag strut(s),
- side strut(s),
- jury strut,

- torque links,
- unlocking/locking actuator,
- bungee spring(s),
- retraction actuator,
- axles,
- brake units,
- wheels,
- steering actuators,
- position switches and other sensors, and
- ground safety locks or pins.

Additional components are added on multi-wheel assemblies. They are;

- truck beam
- truck positioner actuator
- brake equaliser rod

All of these components perform an important specific function which should be understood. It is important that for landing gear visual inspections specific components can be recognised by pilots.

The following section details the function of each component and the reader should refer to Figure 9-3, *Large Aircraft Main Landing Gear (typical)* and Figure 9-4, *Large Aircraft Nose Landing Gear (typical)* for the location of components on the landing gear assemblies.

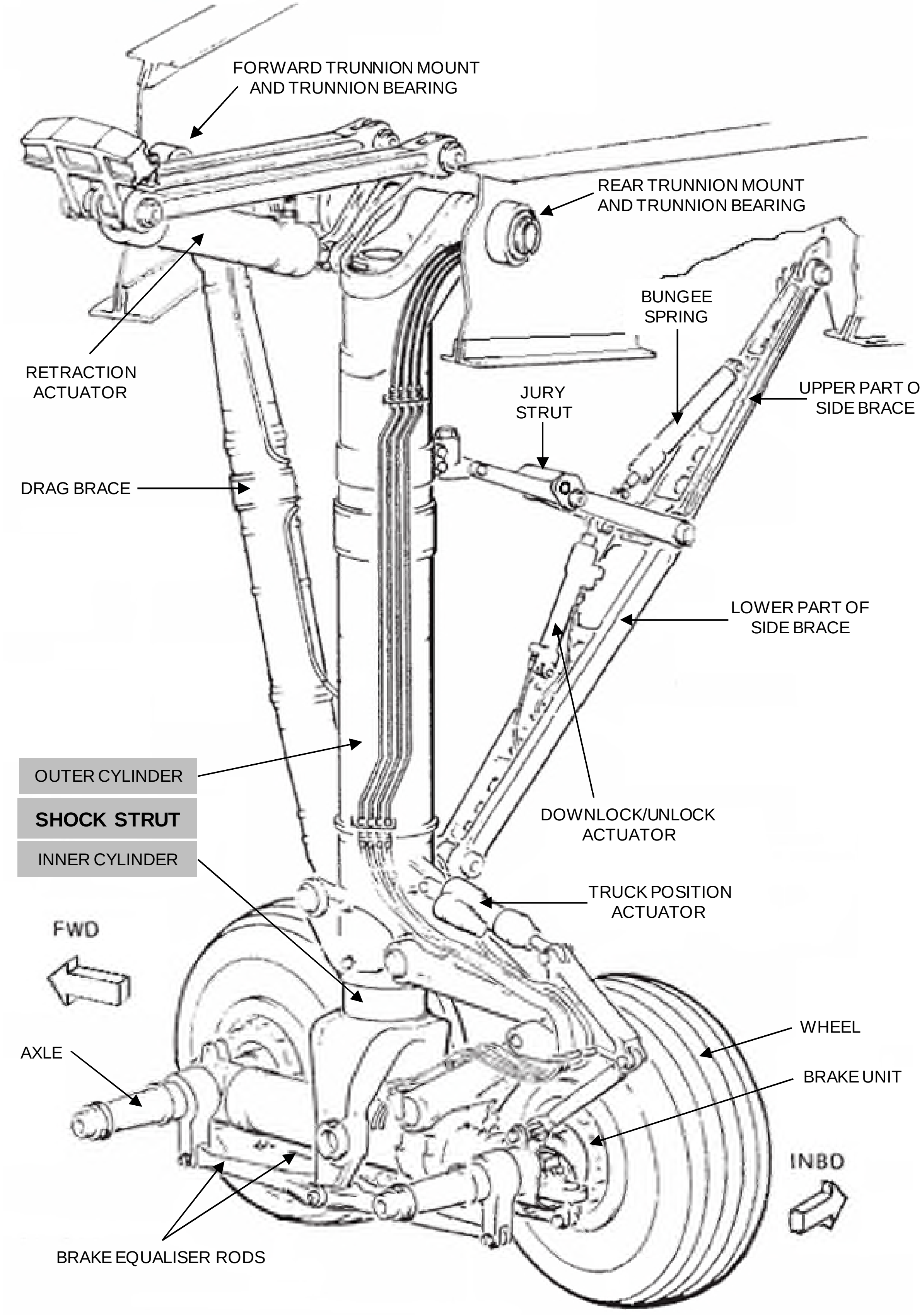

Figure 9-3 Large Aircraft Main Landing Gear (typical)

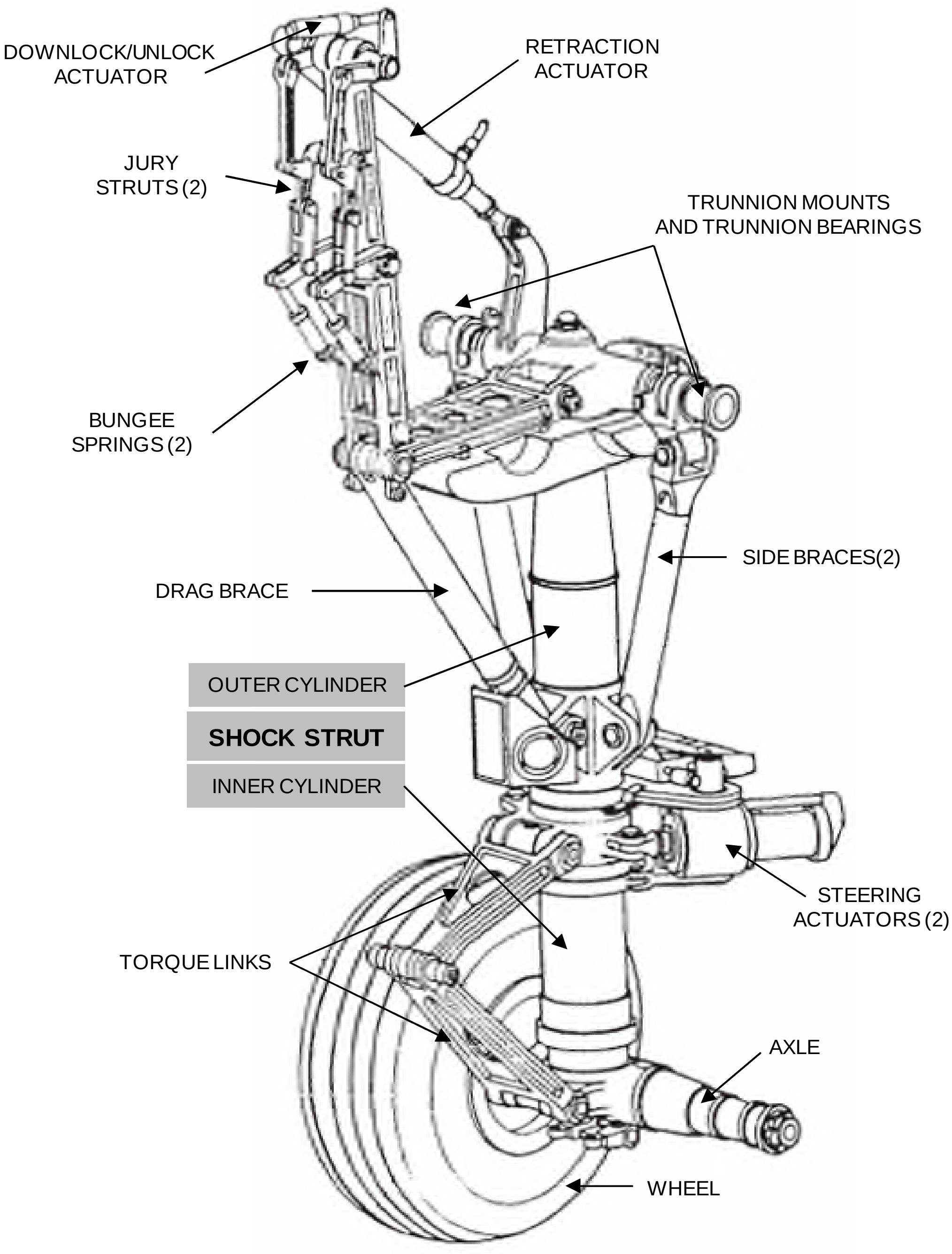

Figure 9-4 Large Aircraft Nose Landing Gear (typical)

LANDING GEAR COMPONENTS

THE SHOCK ABSORBER

The shock strut has three primary functions;

- to absorb the compression loads imposed by the impact of landing,
- to dampen the tendency to recoil, that is to say the shock struts tendency to rapidly extend again immediately after absorbing the landing impact.
- to support the weight of the aircraft when on the ground

The shock strut must also be able to withstand the considerable bending loads which will be experienced when landing, taxying and in particular when the aircraft is turned on the ground.

The shock absorber consists primarily of two cylinders which slide inside one another, much like telescopes. Shock absorber struts are inflated with dry nitrogen to prevent corrosion on the inside of the cylinder and piston. The piston and cylinder are separated by seals internally, and the bottom of the cylinder is sealed where the piston slides in and out. Any leakage at this point must be inspected by qualified maintenance personnel before dispatch.

It is essential that the strut be inflated to the correct pressure. Over inflation will mean a hard strut which will tend to recoil causing bounce. An under inflated strut will possibly bottom out causing serious structural problems. Ground engineers use strut extension charts and pressure gauges to check the extension under load conditions. There are two common types of shock absorbing struts;

- oleo pneumatic shock absorber - without separator, and
- oleo pneumatic shock absorber - with separator.

A third type is available but rarely used which does not require a compressed gas charge. It is referred to as the Liquid Spring Type.

Oleo Pneumatic shock absorber - without separator type consists of a piston (lower strut) to which the wheels are fitted, which slides inside a cylinder (upper strut) which is bolted to the airframe. These form the upper and lower chambers for the movement of fluid.

The lower chamber is always filled with hydraulic fluid (Mil-H-5606), while the upper cylinder is filled with compressed gas, normally dry nitrogen. A restrictor valve is placed between the upper and lower cylinder which provides a passage for the fluid into the upper chamber during compression (landing) and return during extension (recoil).

When the shock strut is compressed on landing, the nitrogen is compressed absorbing the compression load. At the same time the oil is displaced and allowed to flow through a restrictor valve, or recoil control valve, opening the valve and allowing a rapid transfer of fluid.

As the impact or compression load has been absorbed, the shock absorber will start to extend, i.e. recoil. The recoil action is dampened by the restrictor valve closing and allowing a slow transfer of fluid back through the valve assembly. Refer to Figure 9-5.

During pre-flight walk around all landing gear struts should have a similar amount of extension visible. Any strut that appears to have less extension than the opposite strut should be checked by maintenance for correct nitrogen charge. Large aircraft normally have a gauge, visible at ground level to check nitrogen pressures.

As oil transfer is vitally important to the operation of the shock strut any leakage will render the strut immediately unserviceable. The exposed inner cylinder section should be carefully inspected and cleaned after each flight to ensure no damage will occur to the seal when compression occurs.

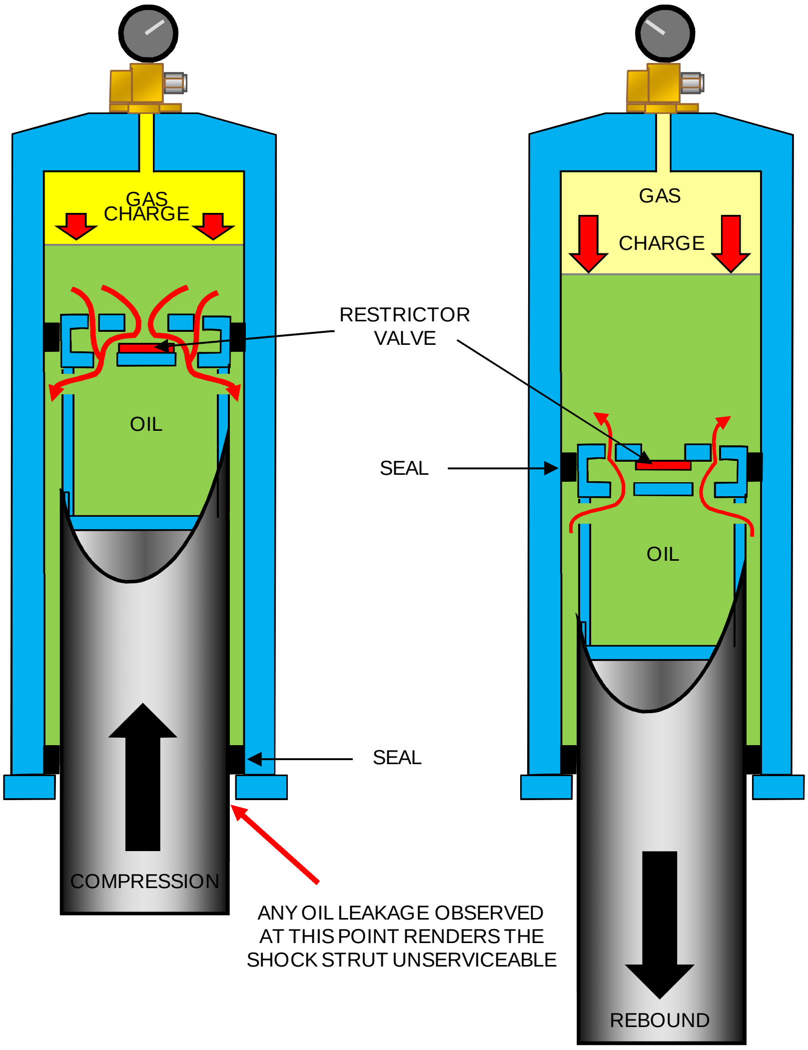

Figure 9-5 Shock Strut without Separator

Oleo Pneumatic shock absorber - with separator types function in the same way as the oleo strut described previously except that the nitrogen charge is held in a separate chamber and does not come in contact with the oil.

TRUNNION BEAM

The function of the Trunnion Beam is to connect the landing shock strut and associated gear structure to the aircraft. Main undercarriage assemblies are usually attached directly to the main wing spars. It is joined to the aircraft's spar structure by trunnion mounts which contain trunnion bearings. This allows the gear assembly to rotate for retraction.

DRAG STRUT

The function of the Drag Strut is to support the shock strut in the longitudinal direction by absorbing forward and aft loads (drag loads). For Main Gears this is normally one large strut. For Nose Gears this is normally in two parts as it is required to fold for retraction.

SIDE STRUT

The function of the Side Strut is to support the shock strut in the lateral direction by absorbing side loads. For Main Gears this is normally in two parts as it is required to fold for retraction. For Nose Gears this is normally two large struts positioned on either side of the shock strut.

JURY STRUT

The function of the Jury Strut is to lock the retractable gear assembly in the locked position when the gear is down. It is the final folding strut to move when locking the gear down and the first folding strut to move when gear is selected up. Mounted on and connected to the jury strut will be four very important items. They are;

- the lock/unlock actuator,
- the down lock sensor for the gear down and locked light in the cockpit,
- the bungee spring(s), and
- the ground safety pin insertion point.

TORQUE LINKS

The function of the torque links is to prevent the inner cylinder of the shock strut from rotating inside the outer cylinder. Torque links allow the strut to compress and extend but will always maintain the correct alignment of the wheels in relation to the direction of travel. For particularly tight turns during towing operations only the nose gear upper and lower torque links may be disconnected. It is imperative that these links are correctly connected and therefore this connection becomes an item to be checked on pre-flight walk around inspections.

LOCK/UNLOCK ACTUATOR

The two functions of this small hydraulic actuator is to;

- force the jury strut into the locked position when the gear is down, and
- unlock the jury strut to begin the retraction of the gear assembly.

BUNGEE SPRINGS

The function of the bungee spring(s) is to force the jury strut into the locked position when the gear is extended by the alternate gear down method. i.e. no hydraulic pressure available.

RETRACTION ACTUATOR

The function of the retraction actuator is of course to retract the gear into the wheel well. Conversely this actuator will provide the hydraulic force to extend the gear when selected down. This actuator will receive hydraulic pressure for retraction from a sequence valve after gear doors have opened and the jury strut is unlocked.

AXLES

The function of the axle is to support both the wheel and the brake unit.

BRAKE UNITS

Brake units are independent self-contained units positioned over the axle for each main gear wheel. It is rare but some aircraft have brake units also fitted to the nose wheels. Brake units and their associated systems will be discussed later in this Chapter.

WHEELS

The wheels and tyres of the landing gear are a vital part of the assembly as they perform many functions. Aircraft wheels and tyres will be discussed later in this Chapter.

STEERING ACTUATOR(S)

The function of the steering actuator(s) is to hydraulically steer the aircraft from a control in the cockpit. Aircraft steering will be discussed later in this Chapter.

POSITION SWITCHES AND OTHER SENSORS

The nose and main landing gear assemblies have many sensors providing gear position and other parameters to the aircraft's logic systems. All landing gears will have sensors for;

- gear up and gear down,
- gear on or off the ground,

Much larger aircraft will include additional sensors for;

- gear steering alignment
- gear truck tilt position
- aircraft over rotation during take-off,
- individual wheel rotational speed,
- individual wheel tyre pressure, and
- individual wheel/brake temperature.

GROUND SAFETY PINS

When aircraft engines are running and hydraulic pressure is available the landing gear jury struts are continuously being held to the lock position by the lock actuator. When aircraft are parked with no hydraulic pressure available the undercarriage should not retract inadvertently due to other mechanical safety features such as over centre locking and the bungee springs.

To ensure that inadvertent retraction cannot take place whilst the aircraft is parked or during towing operations ground safety pins are employed. The ground safety pins are inserted into pre-drilled holes in the landing gear jury struts. This makes it impossible for the jury struts to fold and begin retraction. They are fitted by ground crew shortly after engine shutdown, and remain in place until the aircraft is ready for departure pre-flighting.

The ground safety pins must be removed before flight otherwise the gear will not retract when selected up after take-off. This will result in a return to land as fuel consumption with gear down will be too high to continue. To assist in preventing this from occurring, ground safety pins have long red (remove before flight) flags attached to them, so that they can easily be seen from outside the wheel well. Additionally, ground safety pins are typically stowed in the aircraft’s cockpit so they may be checked removed by flight crew. Many aircraft include the ground safety pins as an item on the Before Start Checklist.

TRUCK BEAM

On multi-wheel gear assemblies a truck beam supports the wheels and is attached to the shock strut base with a swivel joint. After take-off, a truck positioning actuator moves the beam to the correct angle or tilt for retraction. The tilted truck beam also helps absorb the landing shock on touchdown as hydraulic resistance is applied by the positioning actuator as the gear settles down to all wheels in contact with the runway.

TRUCK POSITIONING ACTUATOR

The function of the positioning actuator is to position the truck beam as described above.

BRAKE EQUALISER ROD(S)

A brake equaliser rod is only required on multi-wheel gear assemblies. Its function is to help transmit the braking force generated by the brake units to the shock strut base.

GEAR AND DOOR UPLOCKS

Both the gear assemblies and the large gear doors are secured in the retracted position by uplocks which are typically forced to latch by the retracting gear and doors. The uplocks are opened by hydraulic pressure when gear is selected down.

LANDING GEAR DOORS

The doors associated with the landing gear are designed to close off and streamline the airflow over the aircraft surface when the gear is retracted. When the landing gear is extended small doors that remain open do not increase drag too much and are therefore acceptable.

However, on large aircraft a noticeable change in performance can be observed when the very large undercarriage doors are open. Large doors are therefore designed to be sequenced with the gear operation and will close after the gear is extended. Refer to Figure 9-6.

There are three typical types of door design with different methods of operation. They are;

- fixed doors,
- mechanically connected doors, and
- hydraulically operated doors.

Fixed doors are permanently attached to the shock strut so that when the gear assembly is up, the door completes the streamlining of the aircraft surface. When the gear is down the door is exposed to the airflow along with the shock strut.

Mechanically connected doors are attached to the trunnion beam by rods and bellcranks so that upon retraction they close mechanically after the gear is up. Another method is to have a catching hook that engages with the shock strut as it retracts thus closing the doors after it has moved to up. When the gear is down these doors are exposed to the airflow along with the gear.

Hydraulically operated doors are not attached to the gear assembly in any way and are operated by their own hydraulic actuators. The actuators receive hydraulic pressure at the appropriate time in the retraction and extension operation from hydraulic sequence valves. The sequence valves are actuated when the gear is fully up or fully down. Large doors are held in the up position by door uplocks which are unlocked hydraulically at the appropriate time in the retraction/extension sequence.

When the aircraft is on the ground the very large hydraulically operated doors may be opened by maintenance staff for servicing of components. To facilitate this operation a large red coloured handle is typically located in one of the wheel wells. Maintenance staff can operate this handle to release the doors to gain access to wheel wells. This handle must be positioned to the “flight” position otherwise the doors will remain disabled and will not close after take-off.

Figure 9-6 Landing Gear Doors

LANDING GEAR SAFETY FEATURES

All retractable landing gears on all aircraft are provided with safety features to prevent accidental retraction when the aircraft is on the ground. Safety features can be based on mechanical action or electrical/electronic sensing. Most aircraft will employ both methods.

MECHANICAL SAFETY FEATURES

Ground Safety Pins are fitted by hand into a specific location in the folding mechanism when the aircraft is parked or being towed

Over Centre Locking normally occurs when the folding mechanisms of the landing gear are in the down and locked position. The weight of the aircraft increases pressure on the over-centred joint.

Rearward Wheel Axis design places the axis of the wheel behind the axis of the trunnion beam on nose landing gears, meaning the gear has to move forward of the trunnion axis to retract. The weight of the aircraft increases pressure on the wheels keeping them towards the rear of the trunnion axis.

Bungee Springs are primarily intended to pull the jury strut into the locked position when extending gear with no hydraulics, but are also always acting as a permanent force keeping the jury strut in the locked position. Refer to Figure 9-7.

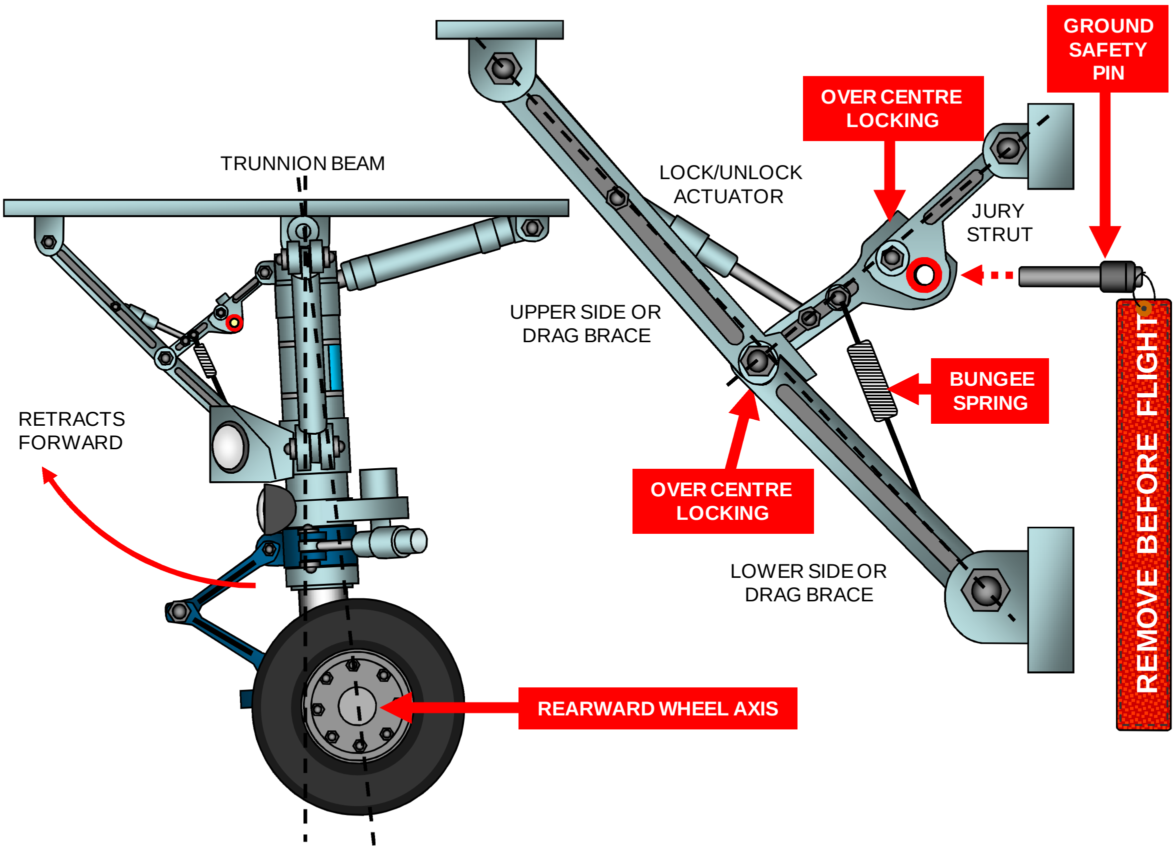

Figure 9-7 Mechanical Safety Features

ELECTRICAL SAFETY FEATURES

Gear Handle Locking is the common method of ensuring the landing gear cannot be retracted on the ground. Gear handles contain a solenoid operated lock which retracts when the aircraft is off the ground after take-off. The solenoid is energised and the lock retracted by;

- airspeed switches (pitot sensed) on small aircraft
- squat switches (micro-switches) on small/medium aircraft, or
- ground/air sensing logic circuits which receive position information (dual proximity switches) from each undercarriage leg on large aircraft.

On large aircraft provision is made to override the gear handle lock if the solenoid fails to operate correctly and the lock does not retract. Refer to Figure 9-8.

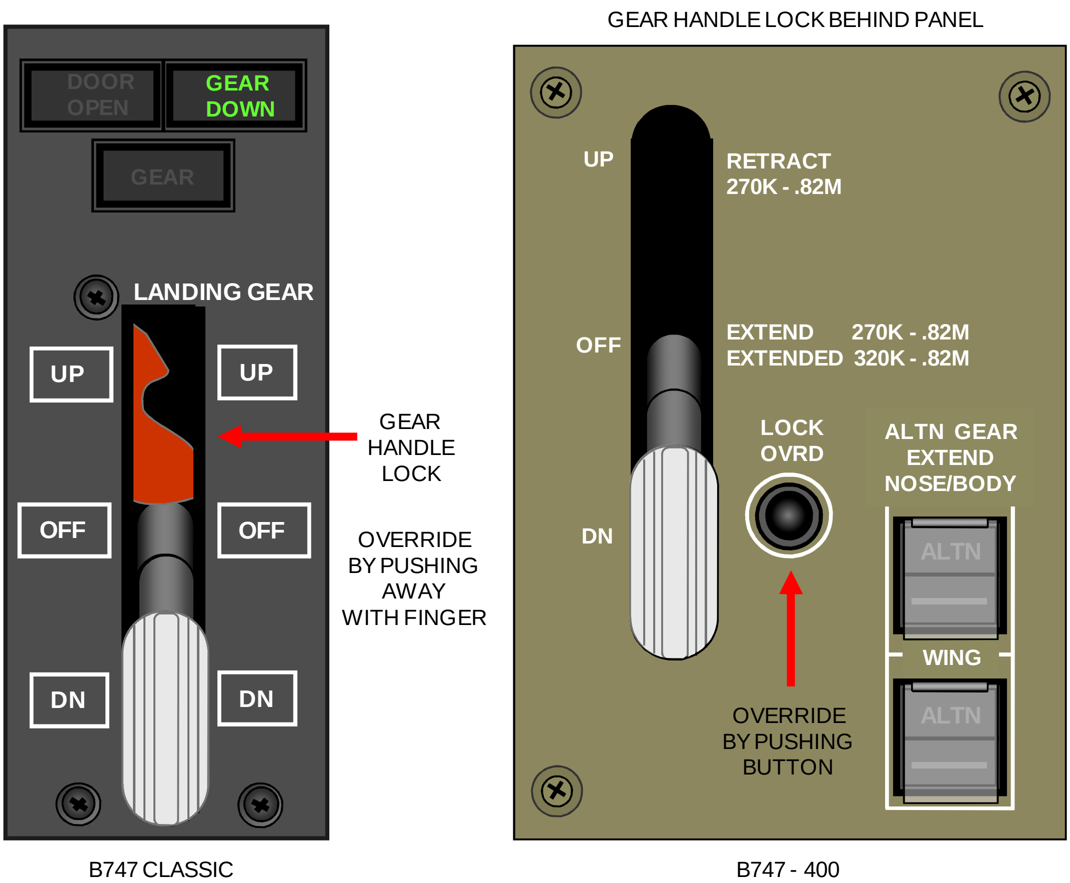

Figure 9-8 Electrical Safety Features

Additionally, undercarriage handles often have a two-action movement (pull out first, then select up) to prevent accidental operation.

LANDING GEAR OPERATION

Landing gear retraction varies with the size of aircraft and the complexity of the gear configuration. The following descriptions are based on a typical small aircraft and a typical large aircraft.

SMALL AIRCRAFT RETRACTION AND EXTENSION

After the aircraft is airborne and the gear handle lock is retracted the gear may be selected UP.

Light aircraft wheels are small and may be braked gently before retraction into the wheel wells.

Hydraulic pressure lifts the gears to the up position followed by mechanically operated doors closing to streamline the aircraft.

Typically the gear is maintained in the up position by hydraulic pressure during flight. This provides an easy alternate method of gear extension should hydraulics fail as no gear or door uplocks need to be released. All that is required is to allow (using an emergency selector valve) the oil present in the actuators to return to the reservoir as the gear falls and locks.

Selecting gear DOWN repositions the normal gear selector to allow hydraulic pressure to extend the gear, mechanically opening the doors in the extension process.

Doors will typically remain open with gear extended as they are small and create minimum drag and on touch down the gear handle lock will engage to stop accidental retraction.

Typical indications of gear position in small aircraft are;

- in transit, either up or down, and
- down and locked (individual green lights for each gear).

Additionally, there will be a landing configuration warning horn if gear is not down, flaps are down and power settings are low.

LARGE AIRCRAFT RETRACTION AND EXTENSION

After the aircraft is airborne the Weight on Wheels (WoW logic) determines that the main gear trucks are correctly tilted, weight is off all wheels and other sensors report that (if fitted) body gear steering is straight. The gear handle lock will be retracted as the gear is safe to retract.

When the gear is selected UP the large undercarriage doors unlock and begin opening. During door opening the main gear wheels are braked automatically to prevent gyroscopic loads effecting retraction. This is referred to as in flight braking and will be discussed later in this Chapter.

When the doors are fully open, mechanically operated hydraulic sequence valves port hydraulic pressure to the retraction actuators and begin retracting the gears. Refer to Figure 9-9.

As the individual gears reach the full up position they self-engage in the specially designed gear uplocks and mechanically reposition the hydraulic sequence valves to close the large doors.

Nose gear wheels are not braked after take-off and wheel rotation is stopped by friction pads in the top of the nose wheel well.

As the individual large doors gears reach the closed position they self-engage in the specially designed door uplocks. When the last door has closed the retraction or extension sequence is complete.

Typically the gear is maintained in the up position by the uplocks and hydraulic pressure is terminated, either automatically or by positioning the handle to OFF.

The normal extension of the gear is the reverse of retraction except that the heavy gear assemblies will tend to extend too rapidly due to gravity. An orifice check valve is positioned in the hydraulic <u>gear up line</u> to restrict the speed of extension. Refer to Figure 9-9.

After touchdown of all gears the gear handle lock will engage to stop accidental retraction.

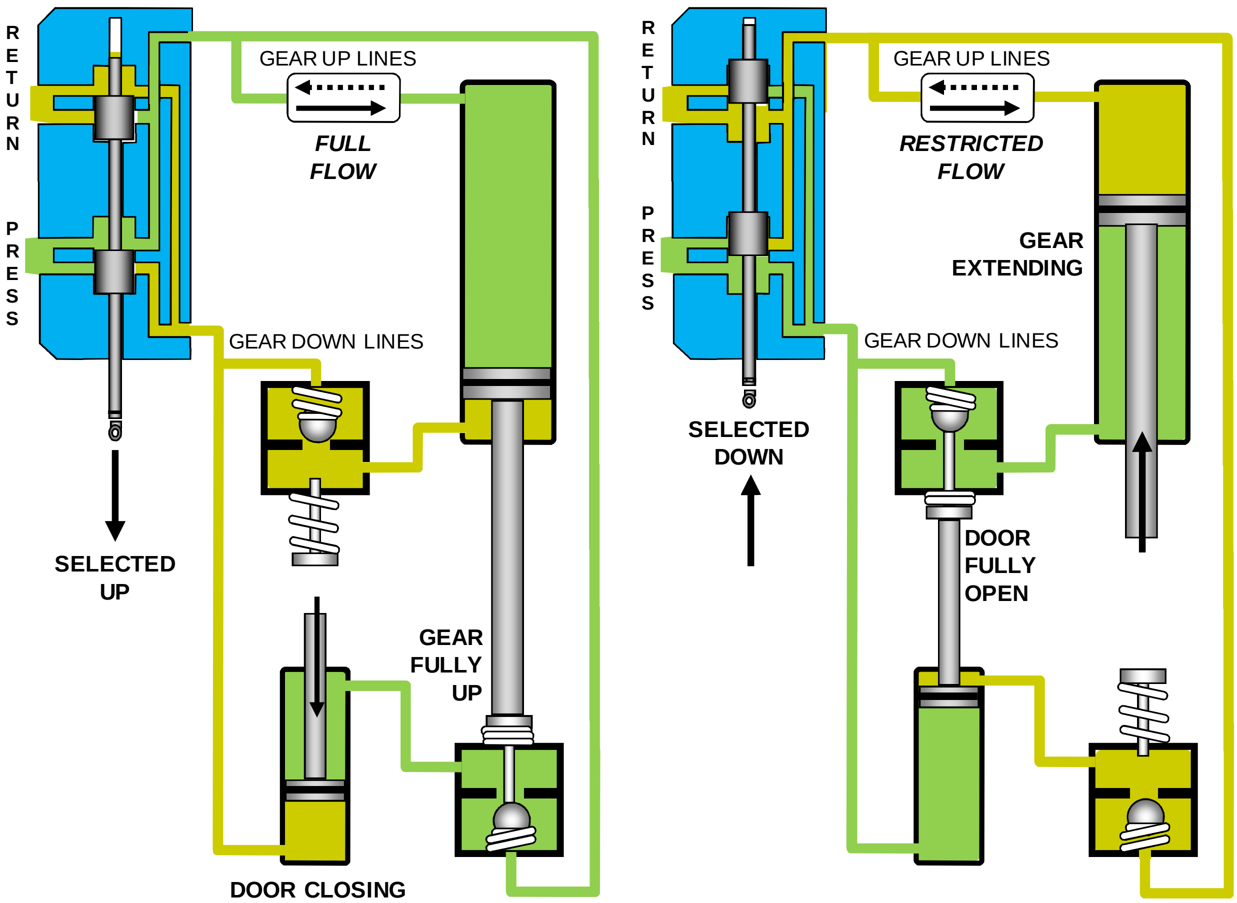

Figure 9-9 Sequence Valve Operation and the Orifice Check Valve

Typical indications of gear position in large aircraft are;

- main gears not tilted correctly for retraction,
- (if fitted) body gear steering not straight for retraction,
- in transit, either up or down,
- down and locked (individual green lights for each gear), and
- gear door not closed.

Additionally, there will be a landing configuration warning horn if gear is not down, flaps are down and power settings are low.

NOTE

Landing gear on all aircraft is subject to airspeed limitations for retraction, extension and flight with gear extended to prevent damage to the gear assemblies and the aircraft's gear mounting structures. Airspeed limitations are normally placarded next to the undercarriage handle.

LANDING GEAR INDICATION AND WARNINGS

In all aircraft fitted with retractable landing gear it is of course vitally important for the crew to be aware of the position of the gear assemblies and the gear doors at all times and in particular in preparation for landing. Additionally, the state of the aircraft, being either on the ground or in the air is sensed to provide a signal for the many systems within the aircraft that change operation or are enabled or disabled.

On small aircraft a single switch, commonly referred to as the squat switch performs the air/ground sensing function but large aircraft with complex landing gears and multiple systems have an entire system devoted to ground/air position. It is commonly referred to as the Weight on Wheels (WoW) Logic System.

LANDING GEAR SENSORS

On large transport aircraft information provided by the landing gear sensors is critical to the correct and safe operation of the aircraft. Sensing devices, often duplicated, are located at numerous points on the main and nose gear assemblies feeding position information to the cockpit and the WoW Logic System on the aircraft. Typically these sensors will provide the following signals;

- gear down and gear up,
- truck tilted correctly,
- ground / air sensing,
- over-rotation on take-off, and
- body gear steering straight.

In smaller, less complex aircraft, the position of the gear and the state of the aircraft, either on the ground or in the air, is normally provided by simple mechanically actioned micro-switches. Refer to Figure 9-10.

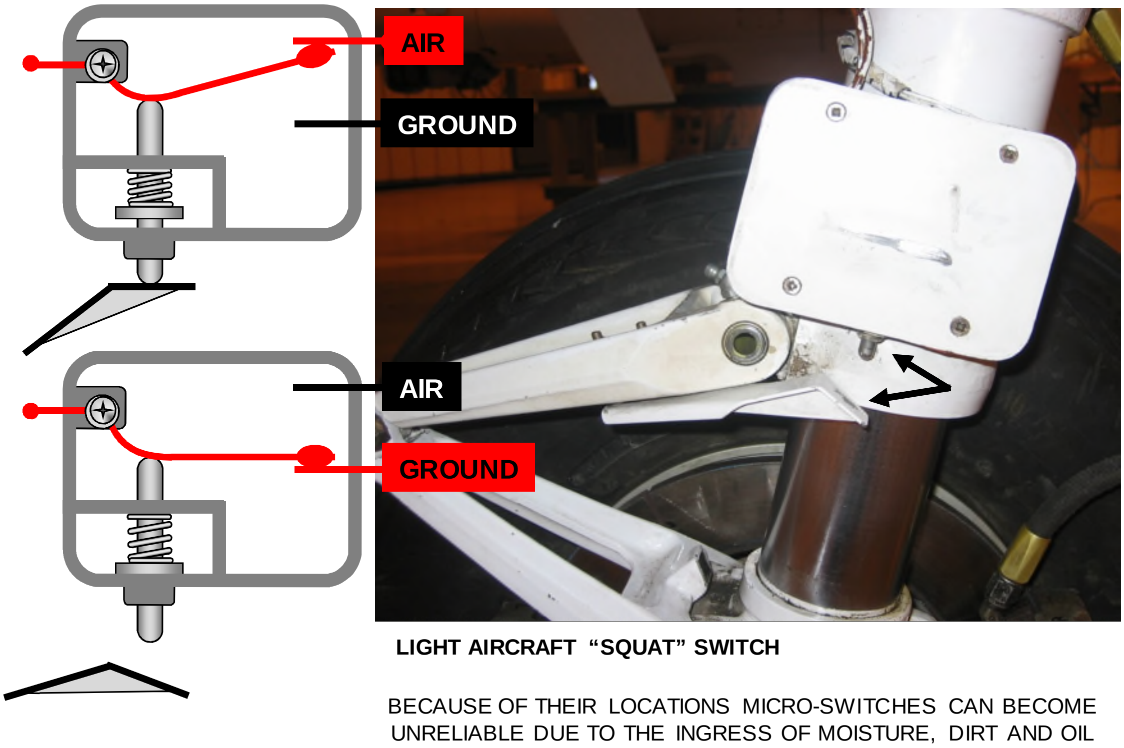

Figure 9-10 Micro-switch Operation

On large transport aircraft with complex landing gear assemblies the preferred sensing devices are proximity switches. Proximity switches consist of two separate components called the SENSOR and the TARGET. The fixed sensor, electrically powered and connected to the system generates a small magnetic field.

When the target, not powered but made of a ferrous metal and attached to the moving part of the gear comes within proximity to the sensor the magnetic field is disrupted and the position is sensed.

The distinct advantage of the proximity switch over the micro-switch is that it is not susceptible to malfunction caused by grease, oil or water which is normally present on gear assemblies. Refer to Figure 9-11.

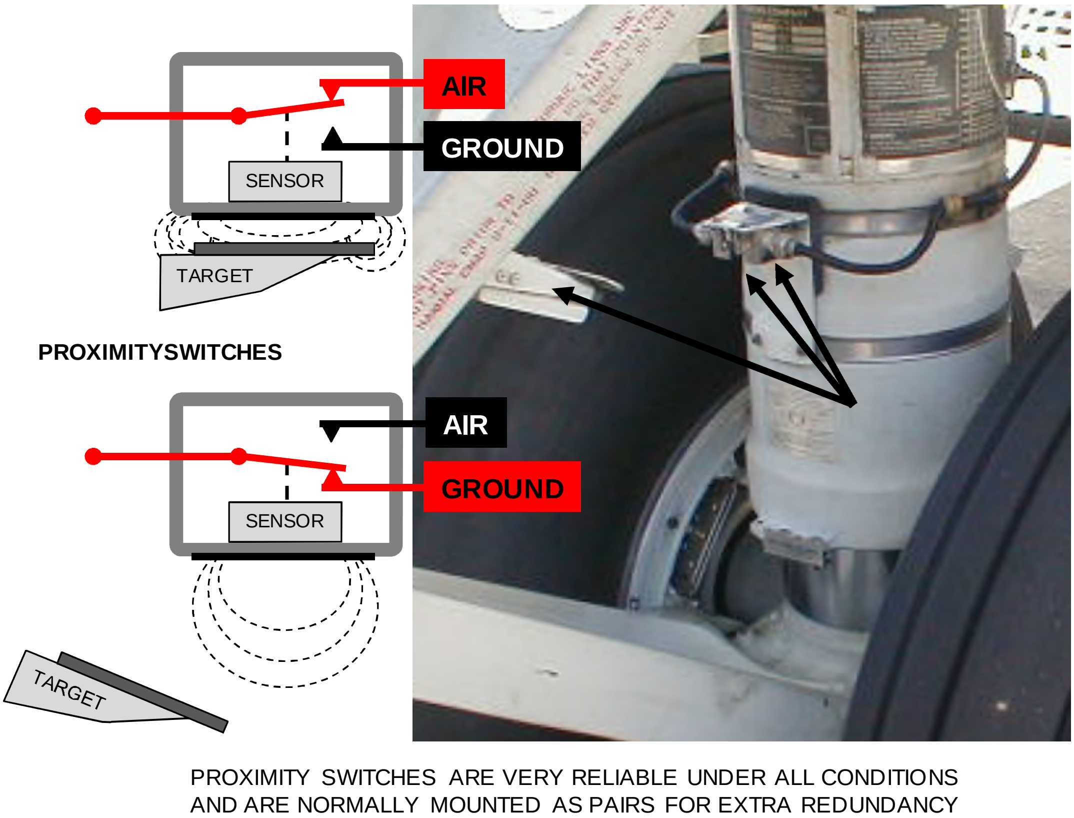

Figure 9-11 Proximity switch Operation

Some proximity sensors provide signals that represent two or more positions of status to the aircraft's systems such as the proximity sensor on the main landing gear torque links which senses over rotation, truck tilt and weight ON or OFF wheels.

WEIGHT ON WHEELS (WOW) LOGIC

Weight on Wheels logic or the ground/air sensing system, receives signal inputs from each individual landing gear, processes the information and outputs signals to the associated aircraft systems.

There are numerous systems on large transport aircraft that receive status signals from WoW logic. Some systems will need to be turned ON, others turned OFF and others to CHANGE their mode of operation.

For interest, refer to Figure 9-12 which details some of the many associated systems.

SYSTEM STATUS IN THE AIR	SYSTEM	SYSTEM STATUS ON THE GROUND
	SIGNALS FROM MAIN GEARS	
AIR MODE	PRESSURISATION SYSTEM	GROUND MODE
AIR MODE	AIR-CONDITIONING SYSTEM	GROUND MODE
AIR MODE	AVIONICS COOLING	GROUND MODE
OPERATIVE	FUEL JETTISON SYSTEM	DISABLED
OPERATIVE	WING ANTI-ICE	GROUND TEST ONLY
FULL POWER	PITOT PROBE HEATING	REDUCED POWER
FLIGHT IDLE	ENGINE FUEL CONTROL	GROUND IDLE
REMOVED	GEAR HANDLE LOCK	LOCKED
DISABLED	ENGINE THRUST REVERSERS	OPERATIVE
FLT SPOILERS	FLT CONTROLS - SPOILERS	ALL SPOILERS
OPERATIVE	FLT CONTROLS - AUTOPILOT	MAY BE DISABLED
DISABLED	TAKE-OFF WARNING SYSTEM	OPERATIVE
	SIGNALS FROM NOSE GEAR	
OPERATIVE	STALL WARNING SYSTEM	DISABLED
DISABLED	STABILISER TRIM WARNING	OPERATIVE

Figure 9-12 Systems associated with WoW logic

Landing Gear Sensor Locations

Sensors are located on different components of the landing gear assemblies and it is important to know their locations for an understanding of the operation.

Downlock Sensors are typically located at the JURY STRUT joint which is the last action of the extending gear assembly.

Uplock Sensors are either inside or next to the UPLOCK HOOK which is the last action of the retracting gear assembly.

Door Closed Sensors are usually inside the DOOR UPLOCK HOOK which is the last action of the extending or retracting cycle of the landing gear.

WoW Sensors are normally operated by the gear TORQUE LINKS which are fully expanded when the shock absorber is extended after lift-off.

Other Sensors depending on the aircraft type may be fitted for OVERROTATION, GEAR TILT and STEERING and these will be fitted on the components or use existing sensors for information.

LANDING GEAR FLIGHT DECK INDICATIONS

There are many different methods used to indicate the gear position on retractable landing gears. As technology has improved so have indications changed, however all aircraft follow a similar pattern to display gear indication, which is;

- ***GEAR DOWN*** – illuminated green lights or a wheel symbol display
- ***GEAR UP*** – no lights illuminated or the word UP on a symbol display
- ***GEAR IN TRANSIT*** – illuminated red light or a barbers pole on a symbol display
- ***GEAR DISAGREES WITH THE GEAR HANDLE*** – red or white illuminated light in the gear handle knob.
- ***GEAR DOOR NOT CLOSED*** – illuminated amber light
- ***GEAR NOT DOWN with the aircraft in the LANDING CONFIGURATION*** – illuminated red light accompanied by an aural cue. Refer to Figure 9-13.

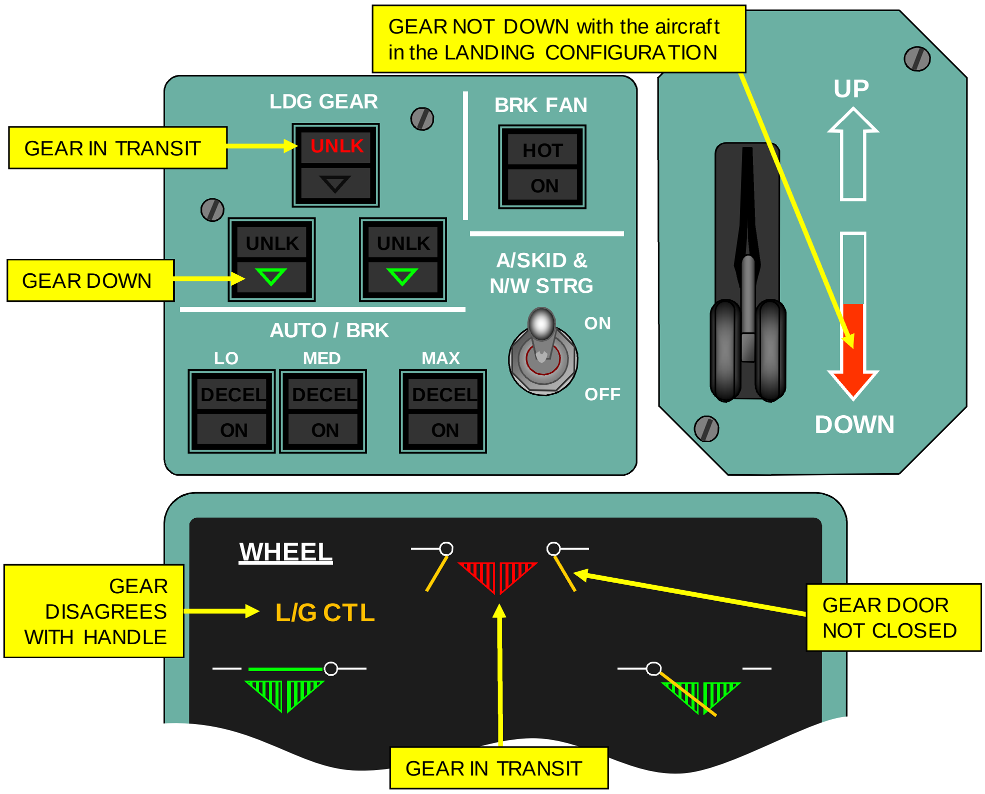

Figure 9-13 Landing Gear Indications

For interest on older large transport aircraft it was common to have a visual method to confirm the gear down and locked condition if the normal indications failed or the crew was in any doubt due to malfunction. This was typically a telescopic tube that could be viewed from the cabin floor or avionics bay rear wall. The viewing crewmember could see painted markers on the landing gear assemblies if the gears were down and locked.

Refer to Figure 9-14 for a summary of landing gear sensors.

POSITION SIGNAL	SENSOR LOCATION	SENSOR TYPE	CONTROL	RESULT
NOSE GEAR ON/OFF THE GROUND	NOSE GEAR TORQUE LINKS	PROXIMITY SWITCH	GROUND/AIR LOGIC	GEAR HANDLE LOCK
MAIN GEAR ON/OFF THE GROUND	MAIN GEAR TORQUE LINKS	PROXIMITY SWITCH	GROUND/AIR LOGIC	GEAR HANDLE LOCK
OVER ROTATION ON TAKE-OFF	MAIN GEAR TORQUE LINKS	PROXIMITY SWITCH	GROUND/AIR LOGIC	WARNING OR STICK PUSH
MAIN GEARS CORRECTLY TILTED	MAIN GEAR TORQUE LINKS	PROXIMITY SWITCH	GROUND/AIR LOGIC	GEAR HANDLE LOCK
MAIN GEAR STEERING STRAIGHT	STEERING ACTUATORS	MICRO-SWITCH OR PROXIMITY SWITCH	GEAR CONTROL CIRCUIT	GEAR HANDLE LOCK
GEARS UP AND LOCKED	GEAR UPLOCK HOOKS	MICRO-SWITCH OR PROXIMITY SWITCH	GEAR CONTROL CIRCUIT	NO LIGHTS
GEARS DOWN AND LOCKED	JURY STRUT	PROXIMITY SWITCH	GEAR CONTROL CIRCUIT	GREEN LIGHTS
GEAR DOORS CLOSED	DOOR UPLOCK HOOKS	MICRO-SWITCH OR PROXIMITY SWITCH	GEAR CONTROL CIRCUIT	NO LIGHTS

Figure 9-14 Summary of Landing Gear Sensors and Indications

LANDING GEAR CONFIGURATION WARNING SYSTEM

Almost all aircraft, large or small, will be fitted with a configuration warning system to alert the crew that the aircraft is in a landing configuration and the gear is not down and locked.

This system typically monitors TWO or more of;

- flap position,
- thrust setting,
- radio altitude, and
- airspeed.

and will, when certain conditions are met, annunciate a RED light warning accompanied by an AURAL alert to the crew to remind them the landing gear is not down and locked. The system may use a staged alert based on thrust and flap selection. Refer to Figure 9-15.

Modern aircraft typically include now radio altitude as well as thrust and flap position for the landing configuration warning.

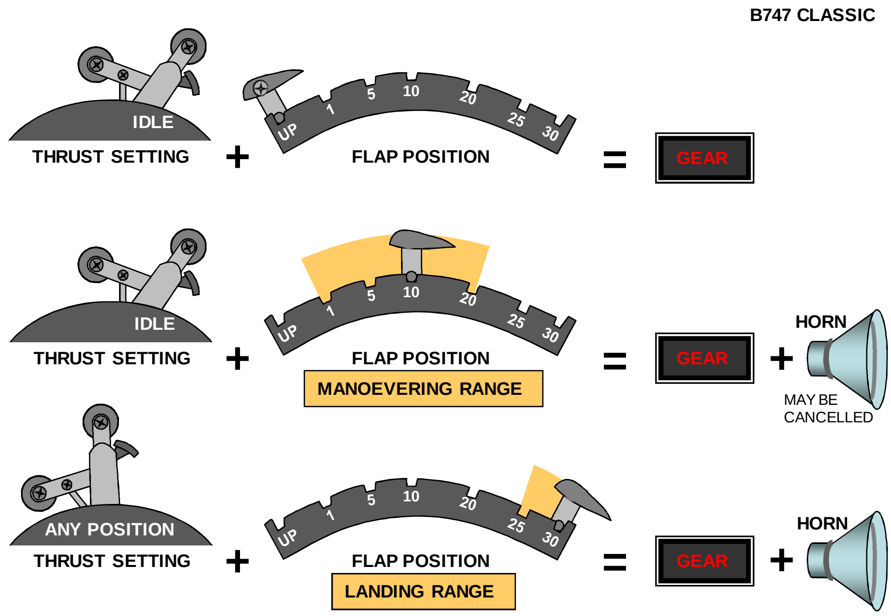

Figure 9-15 Staged Landing gear Configuration Alert

LANDING GEAR REDUNDANCY AND ALTERNATE OPERATION

LARGE AIRCRAFT ALTERNATE EXTENSION

If hydraulic systems fail or electrical malfunction occurs the landing gear may be extended by using an alternate method. Typically on large aircraft this will be a "free fall" method.

Normally actioned using an Alternate Extension Checklist (Refer to Figure 9-16) the crew will operate separate switches that electrically rotate the large door and the landing gear uplocks to open, allowing the gear to free fall by gravity. Refer to Figure 9-17.

L / G GRAVITY EXTENSION

MAX SPEED .... 200 KTS
Speed with main landing gear doors open is limited to 200 KTS to avoid vibrations transmitted through the cabin floor.
– L / G GRVTY EXTN .... DOWN

CAUTION
Both switch guards have to be open before selecting DOWN.

– L / G LEVER .... DOWN
The landing gear lever should be confirmed in the DOWN position for the following reasons:
- *To extinguish the UNLK lts on landing gear indications panel.*
- *To prevent the L/G CTL ECAM message on WHEEL page and the L/G NOT DOWN warning on ECAM.*
- *To minimize the risk of landing gear retraction on the ground, due to unknown system fault, when the free fall system is reset.*

– GEAR DOWN indications .... CHECK

CAUTION
N/W STRG is lost, main and nose gear doors remain open.

Figure 9-16 Example Alternate Extension Checklist

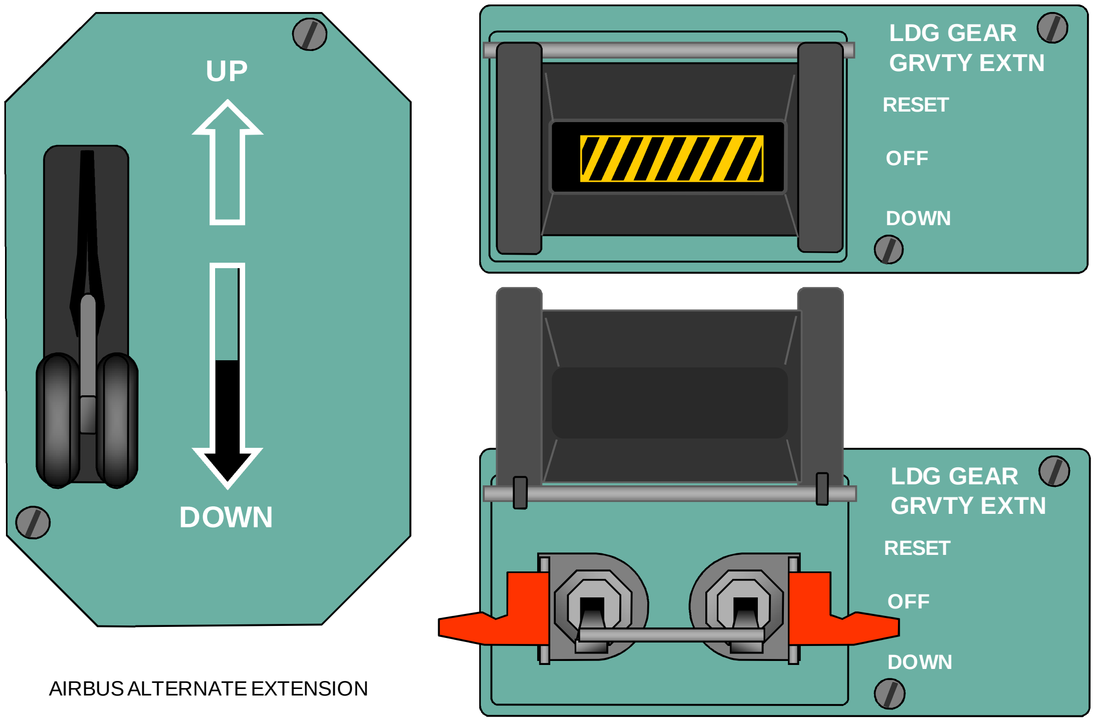

Figure 9-17 Normal and Alternate Landing Gear Controls

The extending gear pushes the large gear doors out of the way and the doors will remain open for the remainder of the flight.

Large aircraft typically position the nose gear so that it extends rearward assisted by the airflow to lock down and as previously mentioned the heavy gear assemblies will tend to extend rapidly requiring the use of the orifice check valve in the hydraulic gear up line to restrict the speed of extension.

The normal landing gear handle should be selected down as well to position other switches in the handle to match the gear down position.

Due to space restraints some smaller aircraft design the landing gears to extend forward into the airflow. This can make a "free fall" landing gear difficult to extend fully and lock. Aircraft such as this will typically have an additional feature such as a hand pump or stored air bottle which may be applied to the gear down through a selector to ensure a down and locked condition is achieved.

For interest, aircraft such as the B747 has a form of redundancy in that the aircraft may be safely landed on nose and body gears only or nose and wing gears only.

LANDING GEAR STEERING SYSTEMS

INTRODUCTION

All aircraft require some method of steering to provide manoeuvring capability on the ground. Depending on the size, weight and configuration of the landing gear, steering systems will vary considerably. Aircraft may be steered by using two designed methods. They are;

- Nose or Tail Wheel Steering actuated by specific steering controls, and
- Differential Brake Steering actuated by operating the appropriate brake pedal.

The above steering methods may be assisted in tight turns by the application of differential engine thrust on multi-engine aircraft.

Very large commercial aircraft and some specialist freighter or military aircraft often include some of the main landing gear wheels in the steering system operation.

TAIL WHEEL STEERING SYSTEMS

Older large tail wheel aircraft are normally fitted with a simple cable operated system connected to the rudder pedals. This provides a simple method of steering the aircraft when only small steering angles are required. When tight turns are required these systems normally have a control in the cockpit to disengage the cables and allow the tail wheel to trail freely during turns as the aircraft is differentially braked.

DIFFERENTIAL BRAKE STEERING

Many small aircraft with both nose wheel and tail wheel gear configurations use differential braking as their normal method of steering. The wheel is steered or castored when a dragging force is applied to one side of the aircraft by brake application. When brake pressure is released aircraft of this type will quickly begin to steer straight ahead as the turned wheel castors back to the trail position.

NOSE WHEEL STEERING SYSTEMS

Medium to large transport category aircraft are required to turn off runways at fairly high speeds, taxi and manoeuvre into very crowded parking areas and park adjacent to aerobridges with great accuracy. This requires a complex steering mechanism powered by the aircraft's hydraulic systems.

A modern aircraft nose wheel steering system will provide the following functions;

- accurate steering control using the rudder pedals for maintaining the runway centreline,
- accurate steering control using a hand operated control in the cockpit for normal turns,
- control of other steerable wheels on main landing gears in tight turns,
- protection against nose-wheel shimmy
- the ability to self-centre the nose wheel after take-off prior to retraction,
- the ability to castor if the differential braking method is used to steer the aircraft, and
- the ability to be easily disabled for pushback and towing operations.

Hydraulically operated steering systems will obviously use hydraulic actuators to turn the nose wheel(s) to and maintain the required steering angle. Steering actuators are mounted on the outer cylinder of the shock strut and steer the nose wheels by turning the upper torque link, which in turn causes the lower torque link and the inner cylinder to turn.

Figure 9-18 illustrates two common applications of hydraulic actuators.

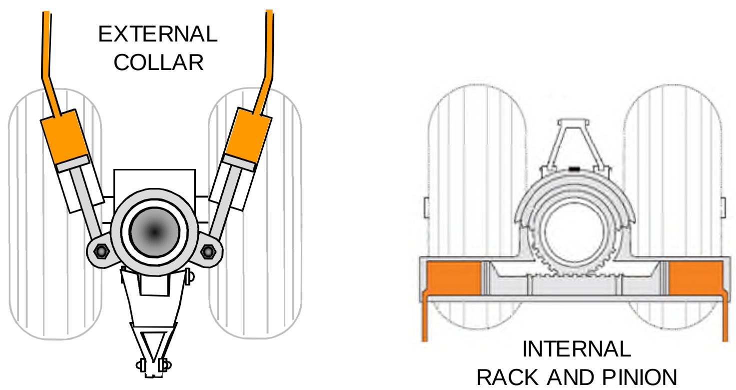

Figure 9-18 Nose Wheel Steering Actuators

When the steering control wheel or tiller is turned, cables operate the hydraulic steering control valve via a rocker arm mechanism. Hydraulic fluid is ported to the appropriate steering actuator and the wheels begin to turn.

The cable control, also connected to the nose wheels, provides position feedback to the rocker arm mechanism which will eventually centre the steering control valve as the turning angle is achieved. Provided the pilot holds the required turn at the control wheel the steered angle is maintained. Refer to Figure 9-19.

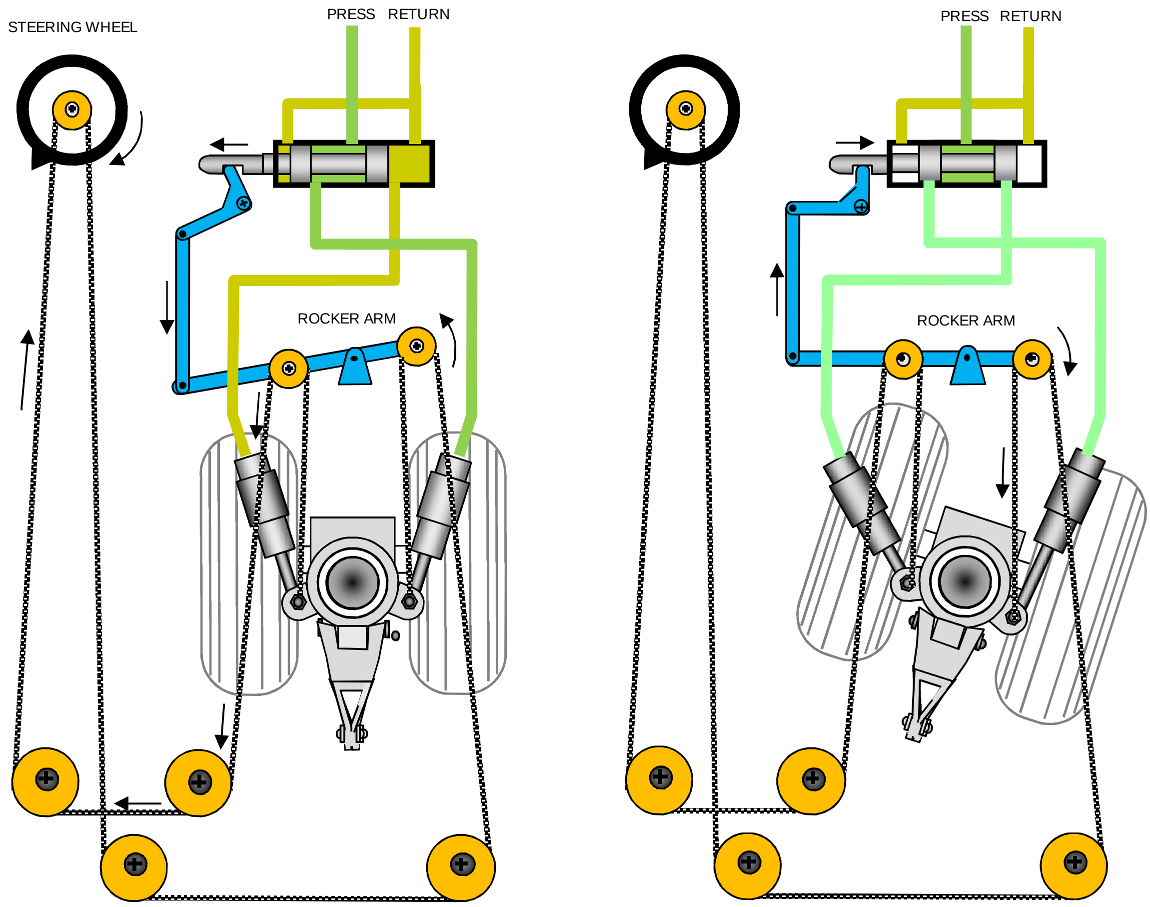

Figure 9-19 Nose Wheel Steering Operation

For interest, on modern aircraft, nose wheel steering is accomplished by electrical connections and computer control. Electronic signals replace the pulleys and cables, and computers control the metering valve. Steering angles are adjusted for ground speed and control inputs now include the autopilot. Refer to Figure 9-20.

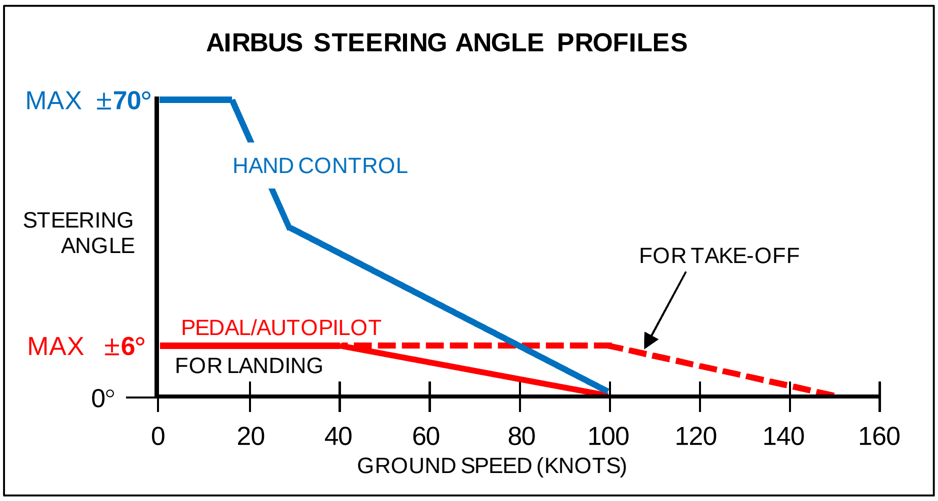

Figure 9-20 Nose Wheel Steering Profiles

Many large aircraft are fitted with body gear or wing bogie steering systems. These are used to relieve the landing gear assemblies and mounting structures from excessive loads imposed by the tighter turning circles required of today's commercial aircraft.

Steering of the main gears is normally achieved by an electronic link with the nose gear steering system, so that when nose wheels reach a predetermined angle, such as ± 20° on the B747, the body gear steering becomes active and proportionally turns in the opposite direction.

Steerable wheel assemblies must of course be centred after take-off for correct retraction into the wheel wells. If not positioned correctly serious damage could occur and to prevent this from happening, a mechanical self centring method is used on all steerable gear assemblies.

LANDING GEAR SELF CENTRING MECHANISM

The gear self centring mechanism consist of two shaped collars referred to as SELF CENTRING CAMS. One cam is located on the top of the inner cylinder of the shock strut (piston) and the other inside at the bottom of in the outer cylinder.

When the aircraft is on the ground and the shock strut is compressed the cams are apart, allowing the piston to turn in the outer cylinder when steered.

As the aircraft takes off and the shock strut extends the two cams engage and align the inner cylinder, and therefore the wheels, to the straight ahead position. The engaged cams also ensure that the steerable wheels are pointing straight ahead for touchdown. Refer to Figure 9-21.

On some aircraft, the possibility of retraction with the gear not correctly positioned, is also prevented by the interlocking of the gear selector handle lock with the position of the steerable wheel sets.

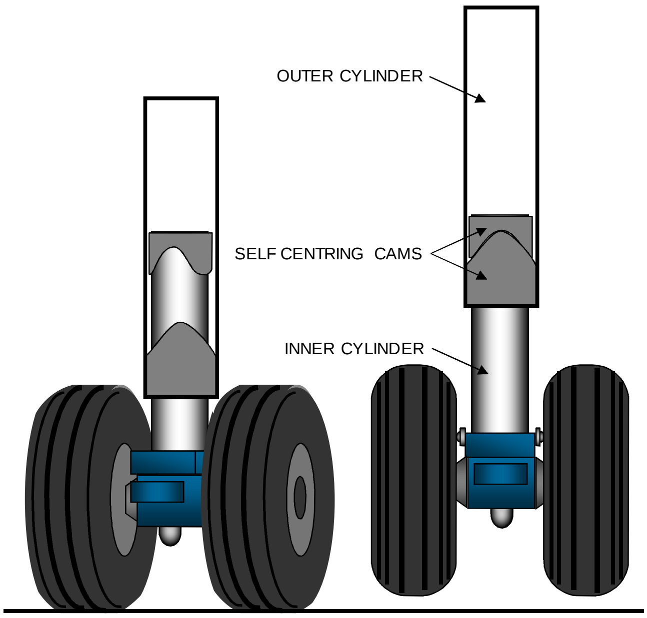

Figure 9-21 **Self Centring Cams**

SHIMMY DAMPING

Castoring nose and tail wheels are subject to shimmy as speed increases. Shimmy is the term used to describe the tendency for the gear wheel(s) to oscillate from side to side. On large hydraulically steered aircraft, shimmy can occur due to uneven wheel bearing wear, wear in the nose gear steering system or even a strong cross-wind. A device used to resist or dampen out the oscillations is called a shimmy damper. One type is shown below.

A piston can move inside a cylinder filled with fluid. The piston has an orifice (hole) which restricts rapid movement of the oil and therefore the piston.

The cylinder is connected to a stationary structure, the piston to the rotating section of the strut. Any rapid movement such as shimmy, is restricted but slower castoring or steering operations can take place. Refer to Figure 9-22

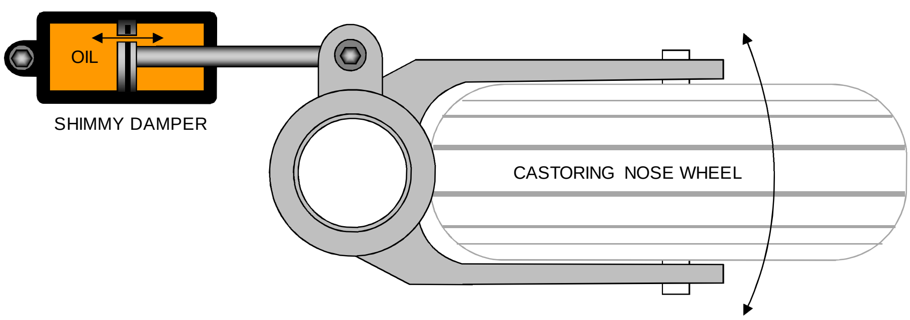

Figure 9-22 **Shimmy Damper**

LANDING GEAR WHEELS

Aircraft wheels are usually manufactured from aluminium alloy or magnesium alloy. They are treated to prevent corrosion and sometimes painted with a polyurethane coating as additional protection. Wheels must absorb all the forces the aircraft is subjected to during landing and taxying, as well as absorbing the intense heat created by braking, whilst being subjected to corrosive substances and harsh weather conditions.

Aircraft wheels are always constructed in a way that requires disassembly to replace the tyre. An assembled wheel will have three basic parts:

- the hub, which carries the wheel bearings.
- a solid disc, sometimes ventilated, which is the body of the wheel, and
- flanged rims that hold the tyre when it is fitted.

Two methods of wheel construction are the split rim and removable flange types. When disassembled the tyre can be easily replaced, the wheel reassembled and tyre inflated ready for use. Refer to Figure 9-23.

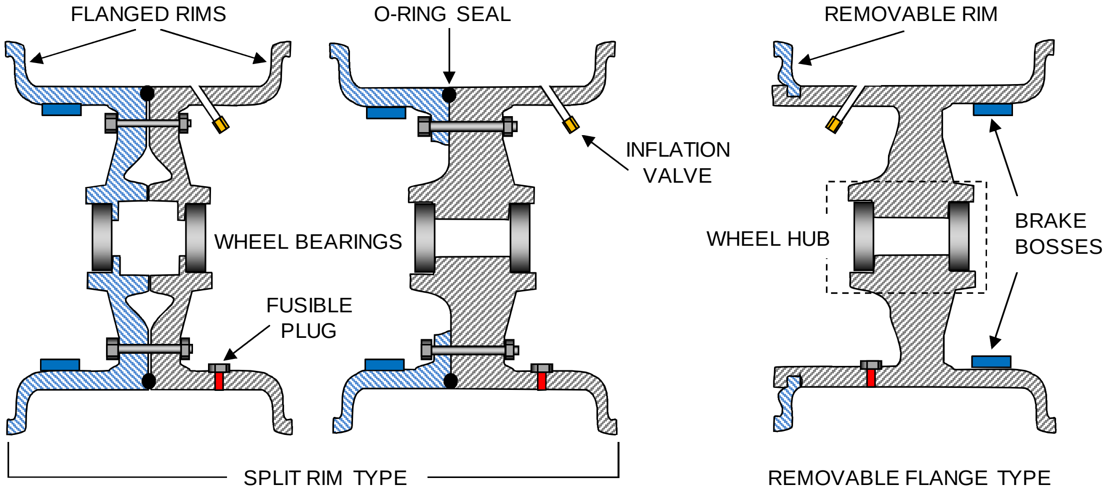

Figure 9-23 Wheel Construction and Types

The common type used on large commercial aircraft is the <u>split rim</u> which is typically fitted with a tubeless tyre. The half assemblies are fastened together by tie bolts, equally spaced around the wheel. A tubeless tyre valve stem is fitted to one of the half assemblies to inflate the tyre.

Leakage of the air through the rim is prevented by a rubber seal placed around the mating halves of the rim. Tapered roller bearings are fitted in the hubs to support the wheel on the axle.

All main landing gear wheels are normally braked and therefore require additional components to engage with the brake unit. These are called keyways or bosses and will be described in the section of this chapter relating to brakes.

Aircraft wheels that are braked absorb very high temperatures and if overheated can cause tyre blowout. To protect the tyre from heat absorption wheels are often fitted with heat shields around the inner section of the half assembly that surrounds the brake unit.

For interest some modern aircraft wheels are fitted with integral brake cooling fans.

To prevent an explosive tyre blowout due to overheating all aircraft wheels are fitted with a pressure relieving device called a fusible plug.

FUSIBLE PLUGS

Fusible plugs consist of a plug screwed into the wheel containing a heat sensitive alloy, which will melt at a predetermined temperature.

This allows air to escape from the wheel to prevent tyre blowout in the event of an overheated wheel. Typically, a maximum stop abort at heavy weights would result in some of the tyres gently deflating due to the action of the fusible plugs.

There are usually three fitted to each wheel, and they should be checked for softness on a regular basis. If any softness is found all fusible plugs on that wheel assembly should be changed. Refer to Figure 9-24.

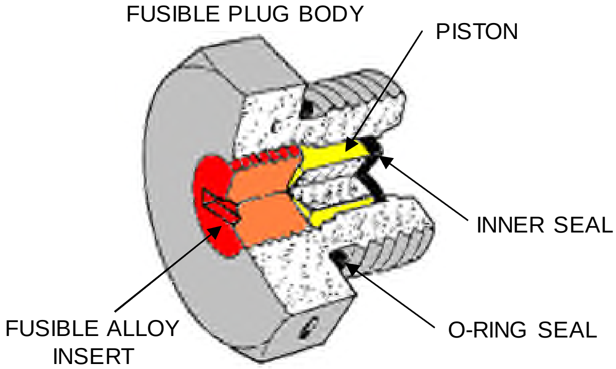

Figure 9-24 Fusible Plug

LANDING GEAR TYRES

Aircraft tyres may be of two types, tube and tubeless.

Tubed Tyres are designed to have an inner tube fitted. The tube has its own inflation valve fitted which must fit through the rim to allow inflation. One of the major problems associated with tubed tyres is that they generate more heat because of friction between the case and tube. They are also more difficult to repair and are more prone to punctures.

Tubeless Tyres are almost of the same construction as a tubed tyre, except that a layer of rubber is sprayed around the inside of the tyre to provide additional sealing.

Tyre Construction

Whether tubeless or tubed, aircraft tyres provide a cushion of air that helps absorb the shock of landing and take-off, support the weight of the aircraft and provide the necessary traction for braking and stopping the aircraft on a variety of landing surfaces. The main component parts are illustrated in Figure 9-25.

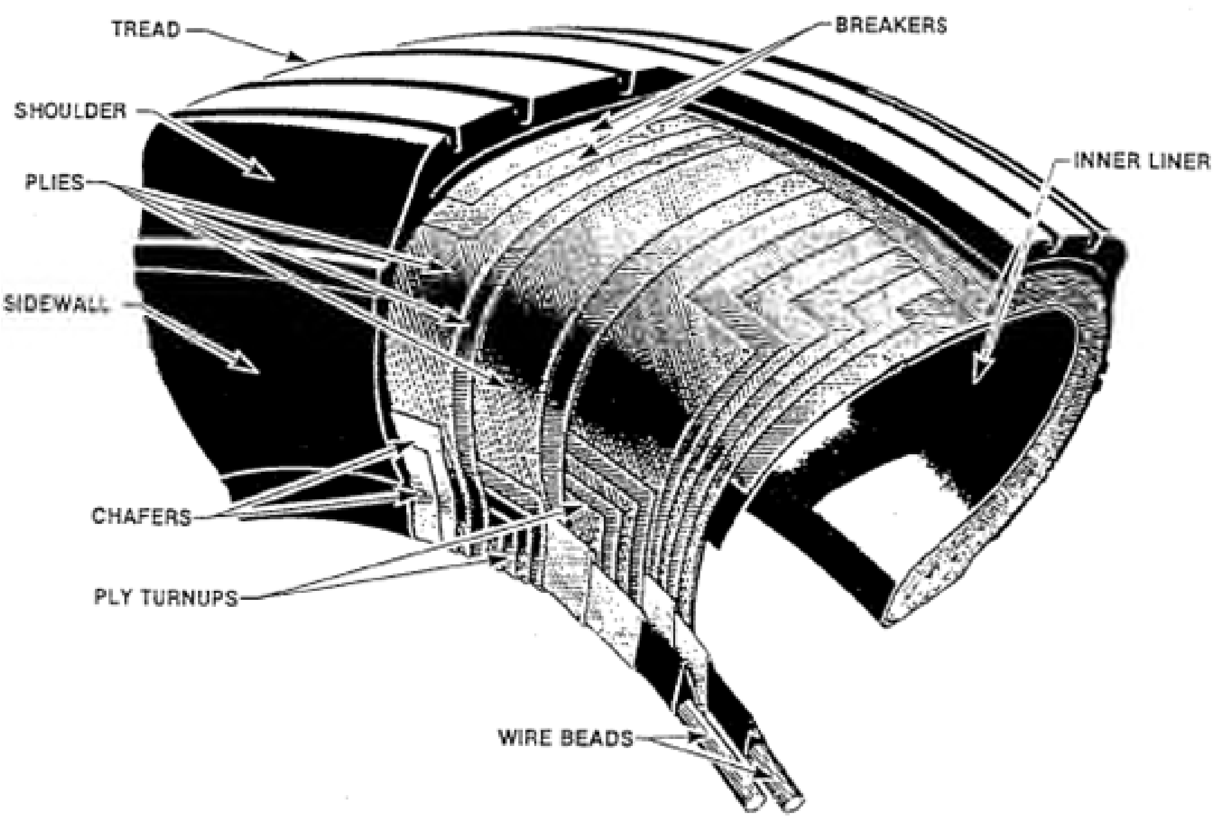

Figure 9-25 Tyre Construction

Aircraft tyres are one of the strongest pneumatic tyres made, being able to withstand landings at speeds up to 250 mph and support static and dynamic loads as high as 33 tons.

The functions of the component parts are described in the table, Figure 9-26.

COMPONENT OF THE TYRE	FUNCTION OF THE COMPONENT
TREAD	Made of tough, durable rubber compound into which the tread pattern is formed. The tread is made up of RIBS and GROOVES
CROWN	The centre portion of the tyre tread.
SHOULDER	The edge of the tread on either side
CASING PLIES	Diagonal lines of rubber coated nylon cord layered it different angles beneath the tread, provide the tyre with its strength. The casing plies are supported by ply turnups and chafers.
BREAKER STRIP	Located between the casing plies and the underside of the tread, these strips spread the loads on the tread over the entire tyre. Breaker strips may be plastic strips.
TYRE BEADS	Made of steel wires embedded in rubber and wrapped in fabric. The beads anchor the tyre to the rim.
INNER LINER	On tubeless tyres this inner layer stops air leaking into and through the casing plies.
SIDEWALL	The body of the tyre supporting the tread. Normally the part of the tyre which is imprinted with tyre specification markings.

Figure 9-26 Function of the Tyre Components

Tyre Tread Patterns

Aircraft tyres use only two tread patterns, one for hard tarmac runways and one specifically for unsealed surfaces. Refer to Figure 9-27.

Figure 9-26 Tyre Tread Patterns

SPECIAL TYRE TYPES

Some aircraft are fitted with specifically designed tyres which perform an additional function as well as the normal tyre requirements. Two of these are;

- the Marstrand or twin contact tyre which acts like twin nose wheels to reduce the effect of shimmy, and
- the chine tyre which deflects standing water away from engine intakes during the take-off roll.

SPECIFICATION TYRE MARKINGS

Aircraft tyres must have certain information imprinted on the tyre so that tyre specifications may be easily verified in accordance with the Aircraft's Operating Manual. They are;

- tyre part number
- tyre size,
- ply rating
- load rating,
- speed rating
- number of retreads carried out, and
- date of manufacture and serial number.

Tyre Part Number is the only positive identifier for whether a tyre is suitable for a particular application.

Tyre Size is normally indicated as this example (26 x 12.00 -16). In this example the outside diameter is 26, the inner edge to edge width is 12.00 and the bead diameter is 16.

Ply Rating indicates the number of plies used in the construction of the tyre.

Load Rating indicates the maximum load that each tyre can hold

Speed Rating is important information as it indicates the maximum operating speed of the tyre on the ground. Normally only tyres used above 160 mph will have a speed rating printed on them.

Retread tyres are fitted to aircraft wheels and the number of retreads carried out is recorded on the tyre.

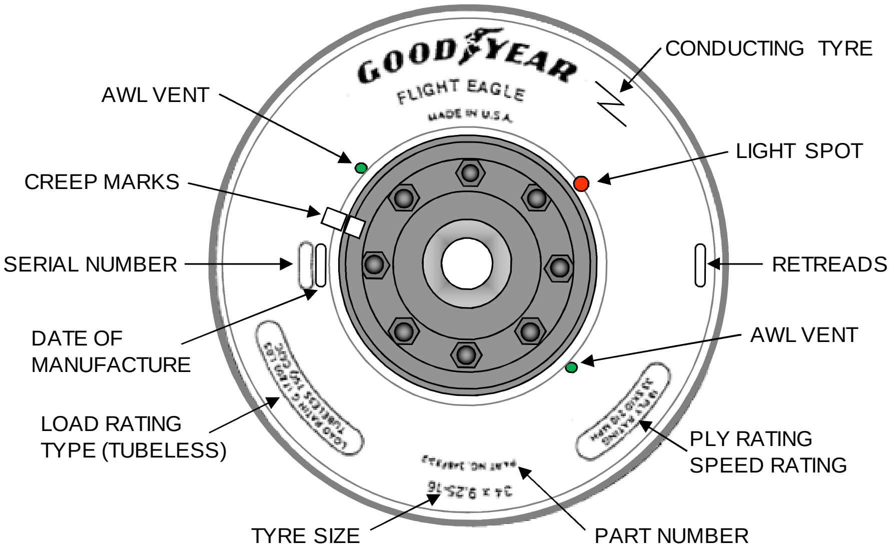

Figure 9-27 Tyre Markings

OTHER TYRE MARKINGS

Aircraft tyres typically display a range of other tyre markings which have specific meanings as described in Figure 9-27.

TYRE MARKING	MEANING OF THE MARKING
CONDUCTING TYRE	Aircraft are prone to the build up of static electricity, which can lead to a potential difference between the aircraft structure and ground. To help overcome this situation some aircraft tyres are capable of earthing the aircraft to ground. Normally either the nose wheel or one of the main wheels is fitted with a conductive tyre. To aid in identification the tyres are marked in one of the following ways: 1. The word CONDUCTING, 2. The letters ECTA – (Electrically Conducting Tyre Assembly), or 3. The symbol - Z
RED DOT	A red dot on the sidewall indicates the “light-spot” on the tyre which aids in the balance of the wheel assembly. It is normally aligned adjacent to the heaviest spot of the wheel.
GREY OR GREEN DOT	Green or grey dots are used to indicate Awl vents. These are small holes placed in the casing during manufacture to allow air to escape.
CREEP MARK	Indicates the amount a tyre has moved in relation to the wheel since assembly. Refer to the description of tyre creep.
MANUFACTURERS NAME	Identifies the tyre source. Normally all the aircraft wheels are fitted with tyres from the same manufacturer.

Figure 9-27 Other Tyre Markings

TYRE CREEP

Tyre creep occurs when the tyre moves around the rim from its original assembled position.

This is a major problem on tubed tyre wheel assemblies. If the tyre moves too far it will pull the valve out of the tube causing a blow out.

Tubed tyres have a set of arrows etched into or painted on the rubber. When fitted to a wheel assembly they lie up against the metal rim of the wheel. The rim is then painted white between the arrows.

Any movement of the tyre around the rim will cause the arrows to move in relation to the white marking. The maximum a tyre may creep is to the edge of the white painted area. Refer to Figure 9-28.

Creep marks may also be found on large tubeless tyres to indicate abnormal movement of the tyre in relation to the wheel.

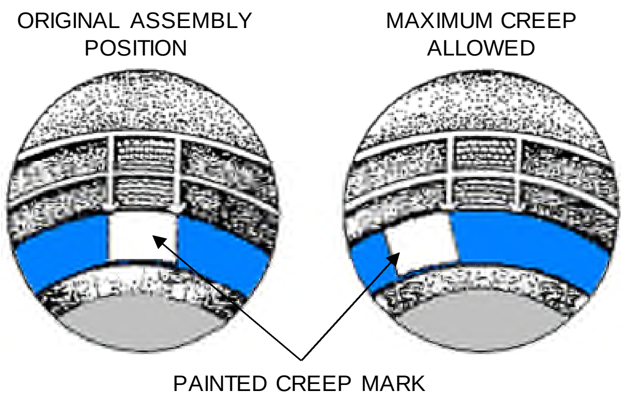

Figure 9-28 Creep Indication

TYRE WEAR AND OTHER UNSERVICEABILITY

Most tyres fitted to commercial aircraft have wear indicators built into the tread pattern. If they have no tread pattern the maintenance manual or flight manual will have strict guides as to the serviceability of the tyres.

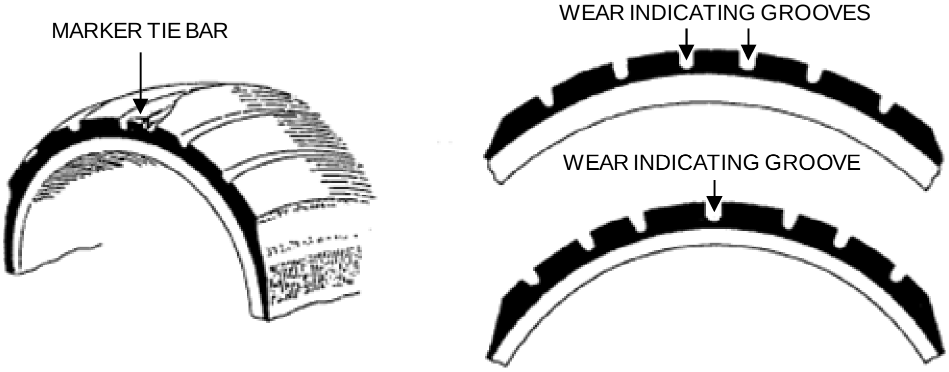

Figure 9-29 Tyre Wear Indication

Tyres should be replaced if the following limits are exceeded;

- grooved tyres with marker tie bars should be replaced when worn to the top of the marker tie bar,
- grooved tyres without a marker tie bar should be replaced when worn to within 2 mm of the bottom of the wear indicator groove(s),
- pattern (block) tread tyres can be worn to the depth of the pattern and then replaced, and
- twin contact (Marstrand) tyres can be worn until the centre portion of the tyre is in contact with the ground.

A tyre that has been operated at the correct pressure will wear the tread uniformly. However, if the tyre has been operated in an over-inflated condition the centre tread or crown will be worn away while the shoulder of the tyre will have plenty of tread left. Under-inflation will have the opposite effect, and the shoulder tread will be worn while the centre tread will be satisfactory.

The importance of keeping tyres inflated to the correct value cannot be overstressed. Under-inflated tyres may rotate on the rim so much as to pull the inflation valve out of the tube. Over-inflated tyres can cause severe vibrations during taxi operations, uneven tyre wear and if they become hot enough may cause blow out of the tyre. A normal tolerance level of 5-10% above or below the recommended inflation value is normally acceptable.

Uneven tread wear can also indicate a problem with;

- the landing gear alignment,
- malfunctioning brakes, and
- worn shock struts.

The other major problems that tyres suffer from are cuts and bulges, both of which should be reported to ground maintenance personnel.

LANDING GEAR TERMINOLOGIES AND DEFINITIONS

The following table defines old and/or common terms that you may encounter with reference to landing gear. Refer to Figure 9-30.

TERM REFERRED	DEFINITION
Oleo Leg	Another name for the Landing Gear Shock Absorber assembly.
Shock Strut	Another name for the Landing Gear Shock Absorber assembly.
Dangling the Dunlops	Extending the landing gear.
Dashpot	Another name for the Truck Positioner Actuator.
Hop Damper	Another name for the Truck Positioner Actuator.
Scissor Links	Another name for the Torque Links.
Squat Switch	The common name for a switch used to sense the Ground or Air state of the aircraft. Normally a mechanically actuated microswitch.

Figure 9-30 Landing Gear Terms and Definitions

LANDING GEAR QUESTIONS

The following questions will examine your understanding of the landing gear, the associated systems and their operation. The answers may be found in the text or diagrams of this Handbook.

1. Hydraulic system cautions are typically;

a. high system temperature, low reservoir level, low pump pressure.
b. low pump pressure only.
c. low pump temperature, low reservoir level, low pump pressure.

2. In a typical transport aircraft with three or four hydraulic systems the;

a. landing gear is powered by at least three of the systems for triple redundancy.
b. primary and alternate pumps are powered differently and any emergency pumps may be RATs or PTUs.
c. primary and demand pumps are powered differently and any emergency pumps may be RATS or EDPs.

3. Accidental landing gear retraction is prevented on the ground by means of;

a. down locks.
b. WoW logic.
c. over-centre locking.

4. When gear down is selected;

a. sequence valves prevent the doors opening until the gear is fully extended.
b. the down locks must be released to permit gear extension.
c. the door actuators activate the gear sequence valves.

5. Undercarriage red warning lights indicate;

a. gear not locked down.
b. gear up.
c. anti-skid system failure.

6. Locking the landing gears down in the event of hydraulic system failure is achieved by;

a. the jury strut.
b. the bungee springs.
c. electrically or mechanically unlocking the uplocks.

7. The tendency of steerable nose wheels to oscillate left and right as speed increases is prevented by;

a. torque links.
b. placing the nose wheels axle axis as far aft as possible.
c. shimmy dampers.

8. Large aircraft tyres are fitted to the wheels by;

a. separating the wheel hub into two parts.
b. easing the tyre over the hub rim.
c. first inflating the tyre to increase its diameter.

9. Tyre creep is;

a. movement of the crown relative to the bead.
b. movement of the tyre relative to the wheel.
c. movement of the tyre relative to the tube.

10. Excessive wear at the tyre crown indicates;

a. under inflation.
b. over inflation.
c. anti-skid system failure.

11. Tyre sidewall markings indicate the tyre's;

a. load rating and limiting speed.
b. maximum inflation pressure and braking distance.
c. friction rating and load rating.

12. The purpose of a drag brace on a nose landing gear assembly is;

a. to prevent sideways movement of the shock strut.
b. to prevent fore and aft movement of the shock strut.
c. to allow retraction of the shock strut.

13. In large transport aircraft the alternate method of releasing the gear uplocks is normally achieved by;

a. hand pump operation.
b. hydraulic motors powered from another hydraulic system.
c. electric motors.

14. When the landing gear is extended by the alternate method due to hydraulic failure;

a. the large gear doors will be electrically closed.
b. the large gear doors will remain open.
c. the large gear doors will close just enough for landing ground clearance.

15. Over rotation of the aircraft during take-off is sensed by;

a. the AoA vane .
b. the main gear torque links.
c. the main and nose gear torque links.

16. Gear down and locked indications are provided by sensors located at the;

a. downlock actuator.
b. torque links.
c. jury struts.

17. Some undercarriage handles incorporate a light in the handle which indicates;

a. the gear has been selected down.
b. that the position of the gear disagrees with the position of the handle.
c. that gear is unsafe for landing.

18. A landing gear red configuration warning light accompanied by an aural warning is normally initiated when;

a. the gear is not down with low airspeed, any thrust and no flap selected.
b. the gear is not down with low altitude, idle thrust and landing flap selected.
c. the gear is not down with high alpha angle, any thrust and no flap selected.

19. During pushback or towing the nose wheel steering is disabled from cockpit control by;

a. by connecting the tow bar (automatically disconnects steering).
b. by inserting a towing pin in the nose gear steering mechanism.
c. by selecting nose wheel steering to OFF in the cockpit.

20. Steering the nose wheels on large commercial aircraft is normally achieved by using;

a. the rudder pedals and a control wheel.
b. the rudder pedals and differential braking.
c. the control wheel assisted by differential braking.