

# LANDING GEAR, WHEELS AND TYRES

# LANDING GEAR

- Purpose:

- To support the weight of the aircraft whilst on the ground
- Enable ground manoeuvres (including the use of nose-wheel steering and brakes)
- Absorb shock loads caused by take-off, landing and taxiing

- Types:

- Floats to land on water (may have wheels inside the floats)
- Skis to land on snow and ice (can usually be retracted)
- Wheels for hard surfaces (may be retractable)

- Layouts:

- Tail dragger (older transport and some light aircraft)
- Bicycle (Harrier)
- Tricycle (most modern aircraft)

- Requirements:

- Absorb impact velocities of:
  - 10ft/sec at the design landing weight
  - 6ft/sec at the design take-off weightcombined with a maximum aft drag component of 25% of the vertical ground reaction
- Equivalent to landing at 115 knots from a 3° glide slope without a flare
- Absorb side loads if landing in cross-wind conditions
  - 25% of the vertical load combined with 75% of the maximum ground reaction and 40% drag load

# MAIN WHEEL (BODY) STEERING

**The purpose of Main Wheel (Body) Steering is to assist the nose wheel in turning the aircraft easier and tighter around corners.**

**The mains wheels (in the A380 just the rear bogies) turn in the opposite direction to the nose wheel.**

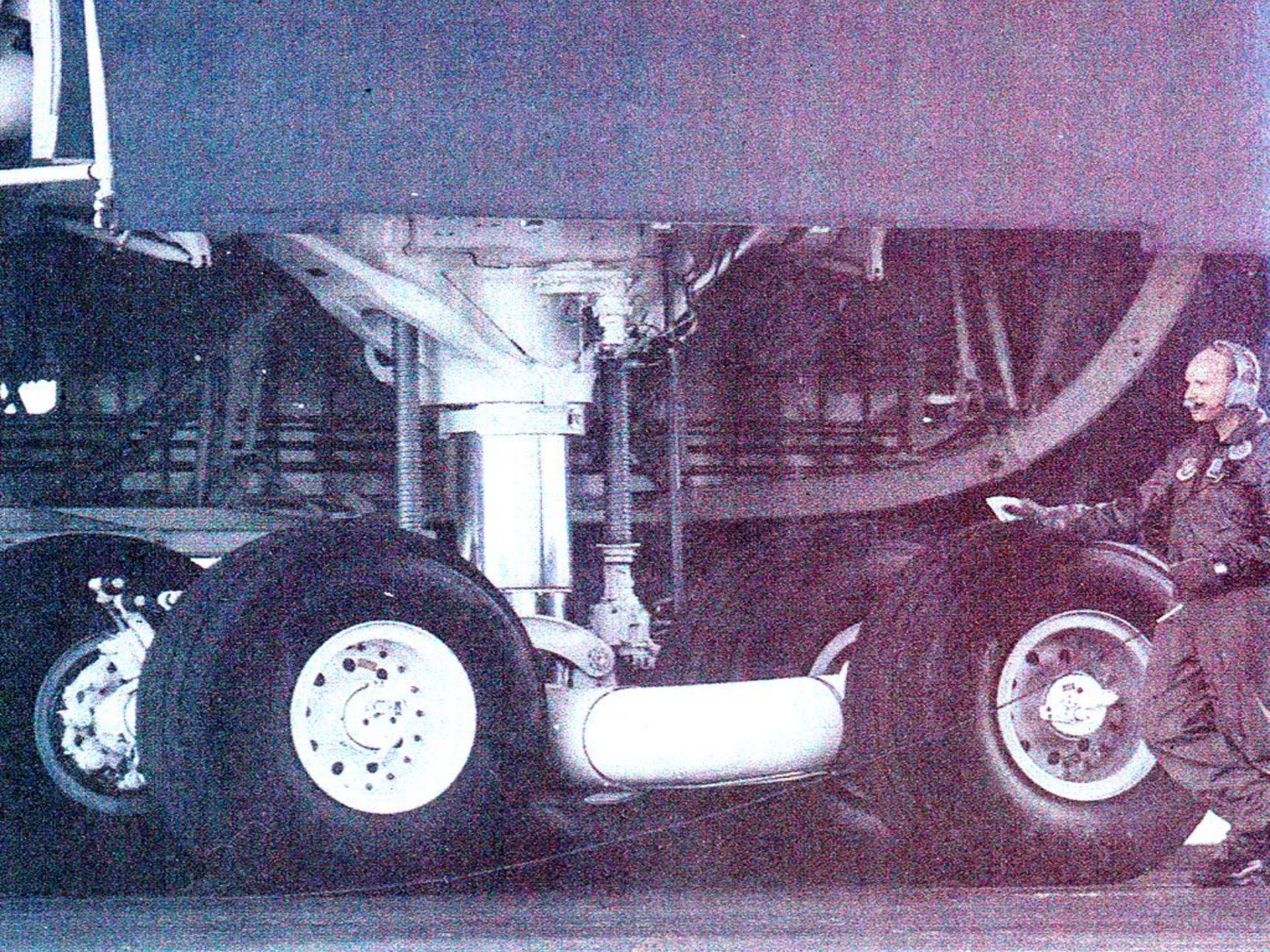


## TRICYCLE LANDING GEAR ADVANTAGES:

- Better cockpit visibility during taxi
- Easier to control on ground, especially in cross winds
- Better directional stability (CG further forward)
- Less likely to nose over
- More horizontal attitude (on ground) for easier loading
- Less drag improves take-off performance
- Braking is more straight forward

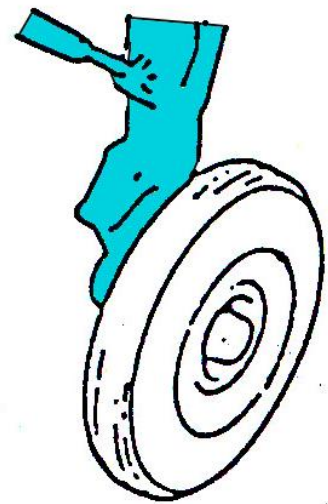




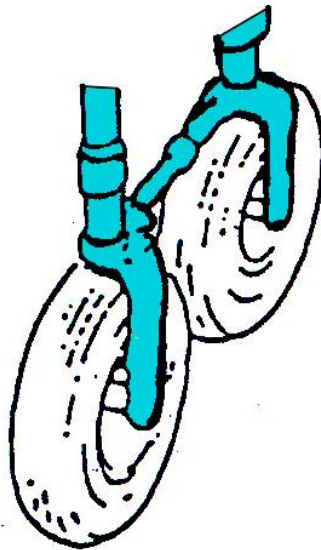




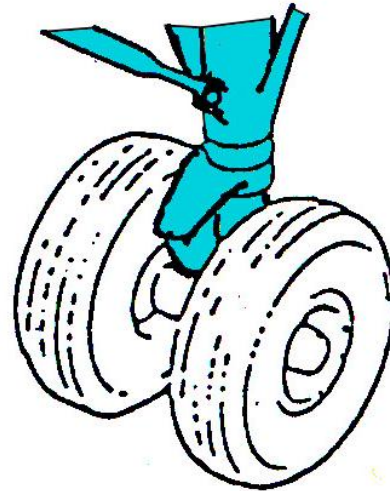
# TYPICAL MAIN WHEEL ARRANGEMENTS



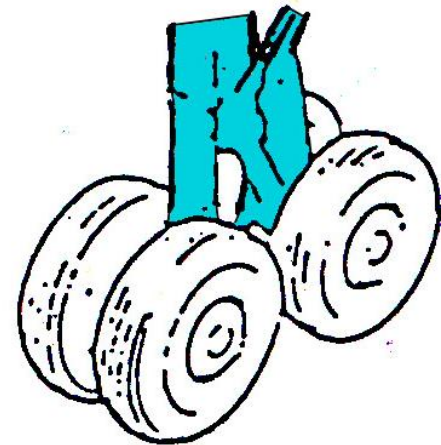
SINGLE



TANDEM



DOUBLE



BOGIE

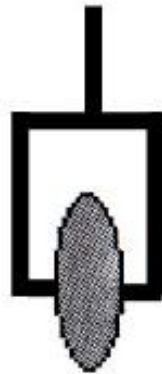
- Why go for more than one wheel?
- Why retractable?
- What types of gear legs?



# WHEEL ATTACHMENT TYPES



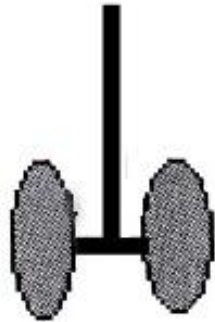
Cantilever



Forked



Half-forked



Dual

# WHEEL ATTACHMENT TYPES

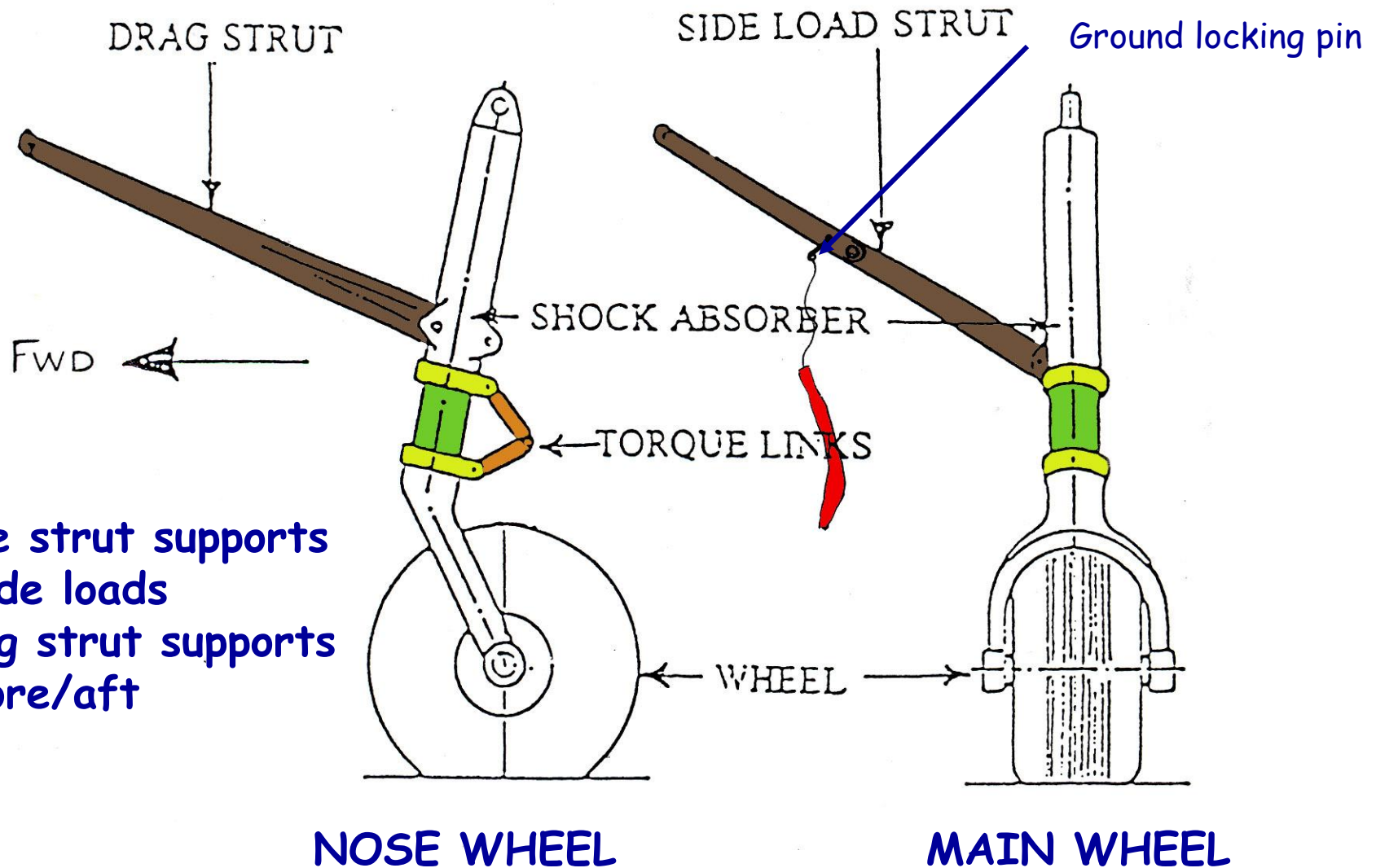


**Forked**



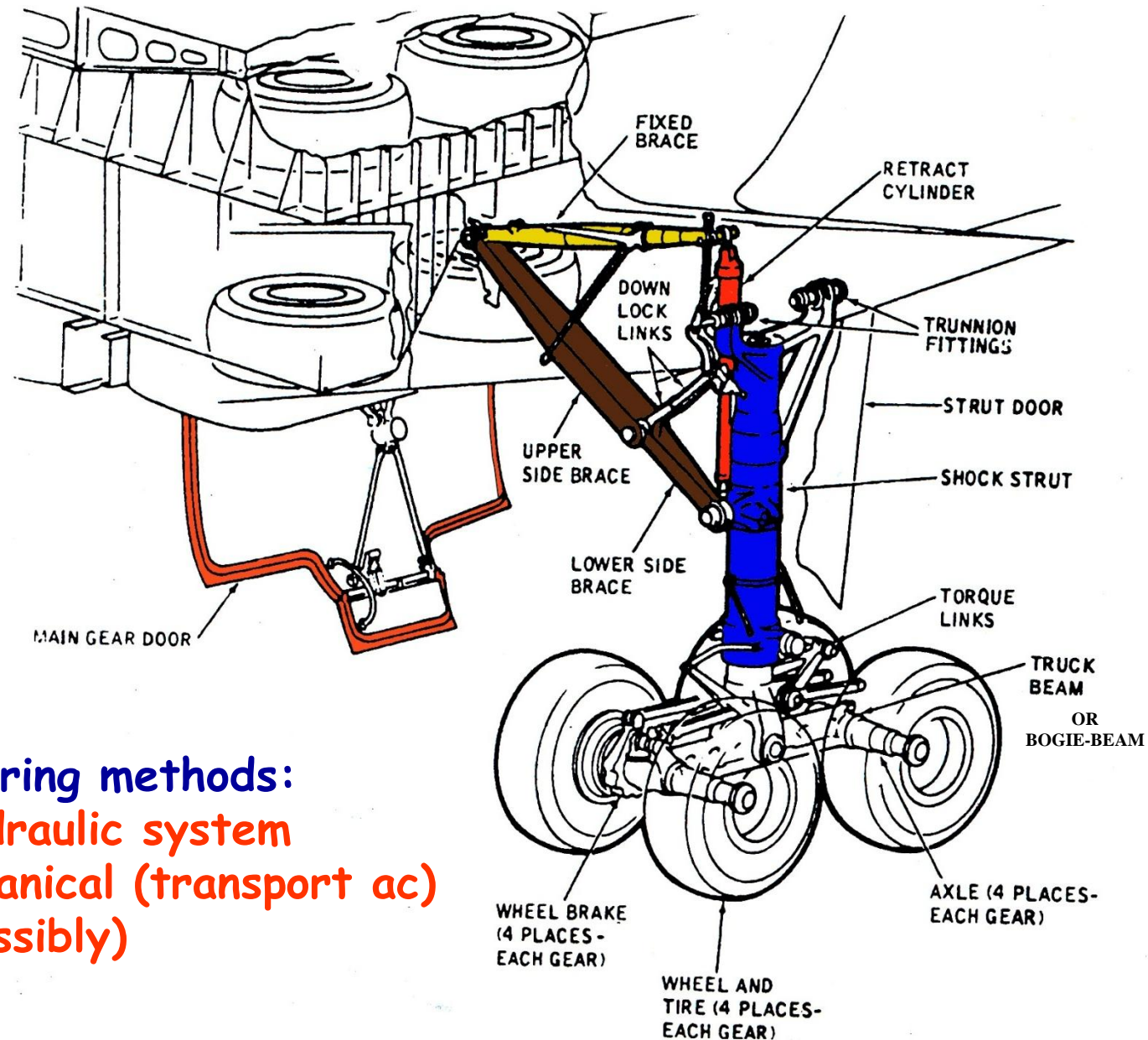
**Half-Forked**

# LANDING GEAR - STRUTS

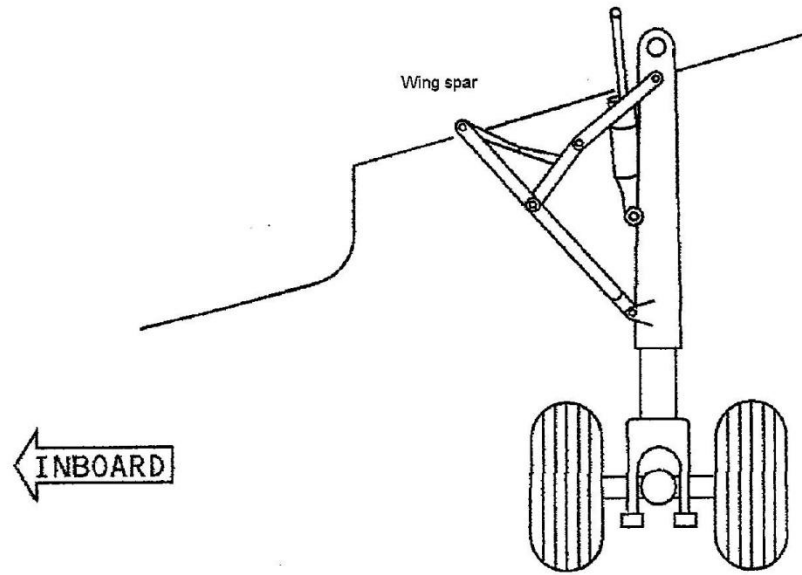




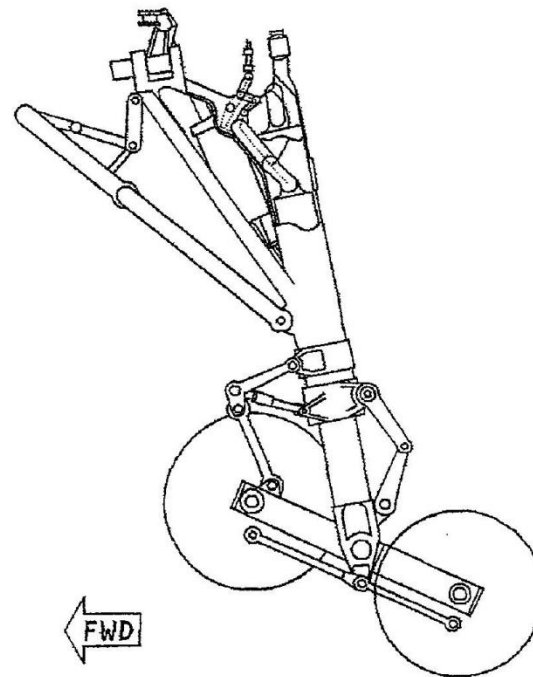
# LARGE AIRCRAFT MAIN UNDERCARRIAGE



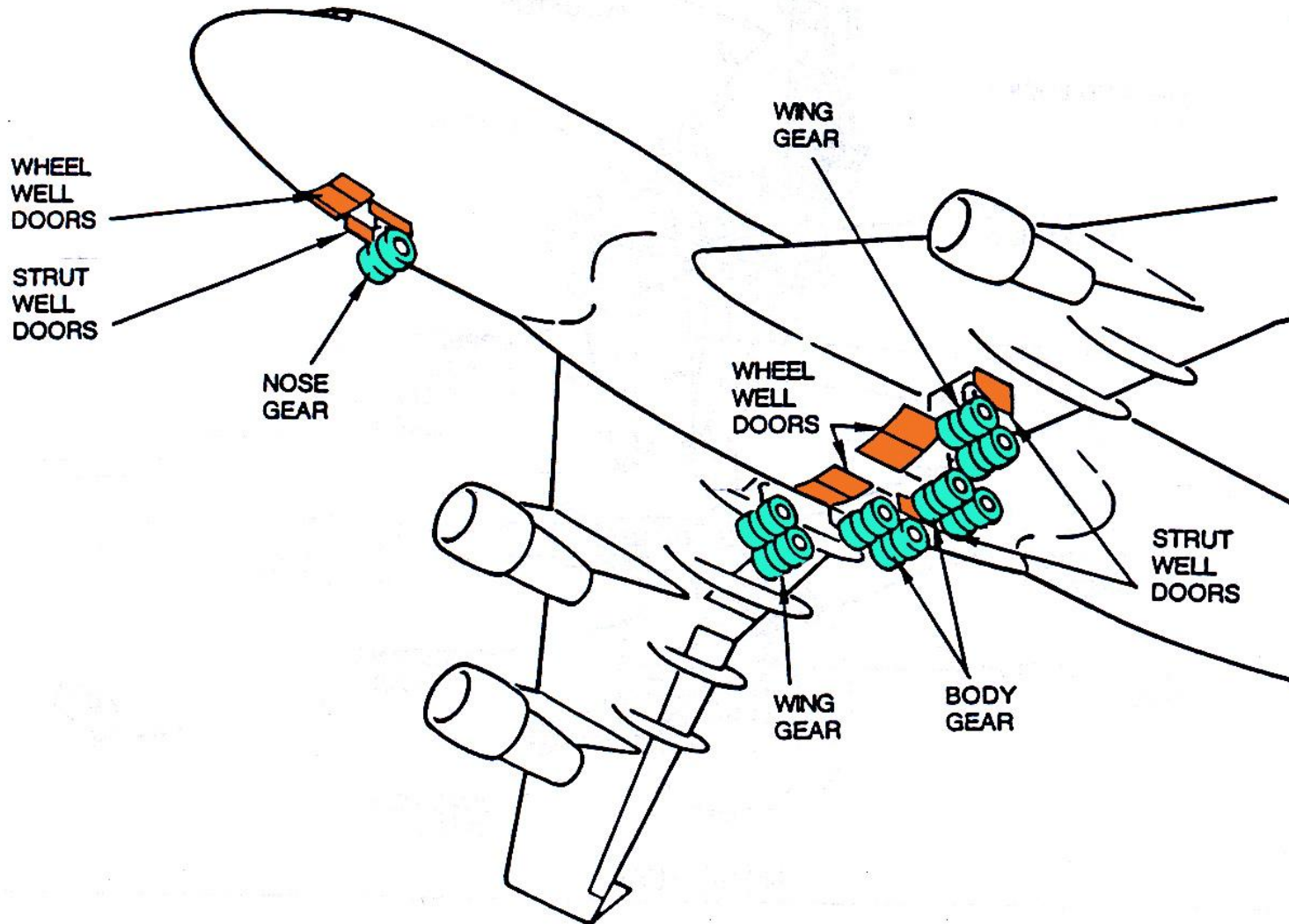
- Alternative lowering methods:
  - secondary hydraulic system
  - freefall/mechanical (transport ac)
  - pneumatic (possibly)



# Main Landing Gear



# 747 LANDING GEAR ARRANGEMENT





# **SPEED LIMITATIONS**

**$V_{LE}$**

**Maximum speed with the Landing Gear extended.**

**$V_{LO}$**

**Maximum operating speed for the landing gear. Slower than  $V_{LE}$  with the doors becoming the limiting factor.**

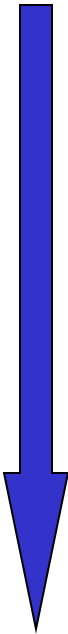
# 747 MAIN GEAR



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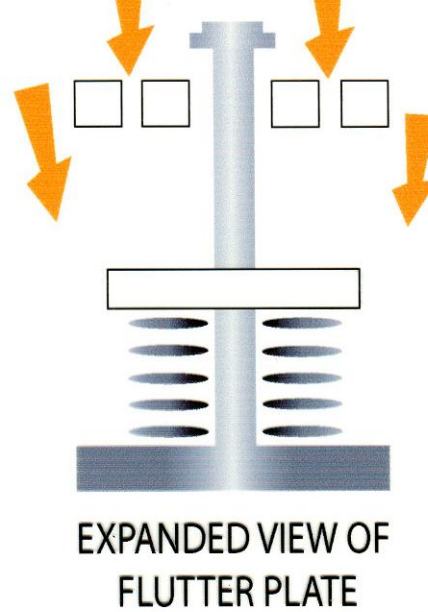
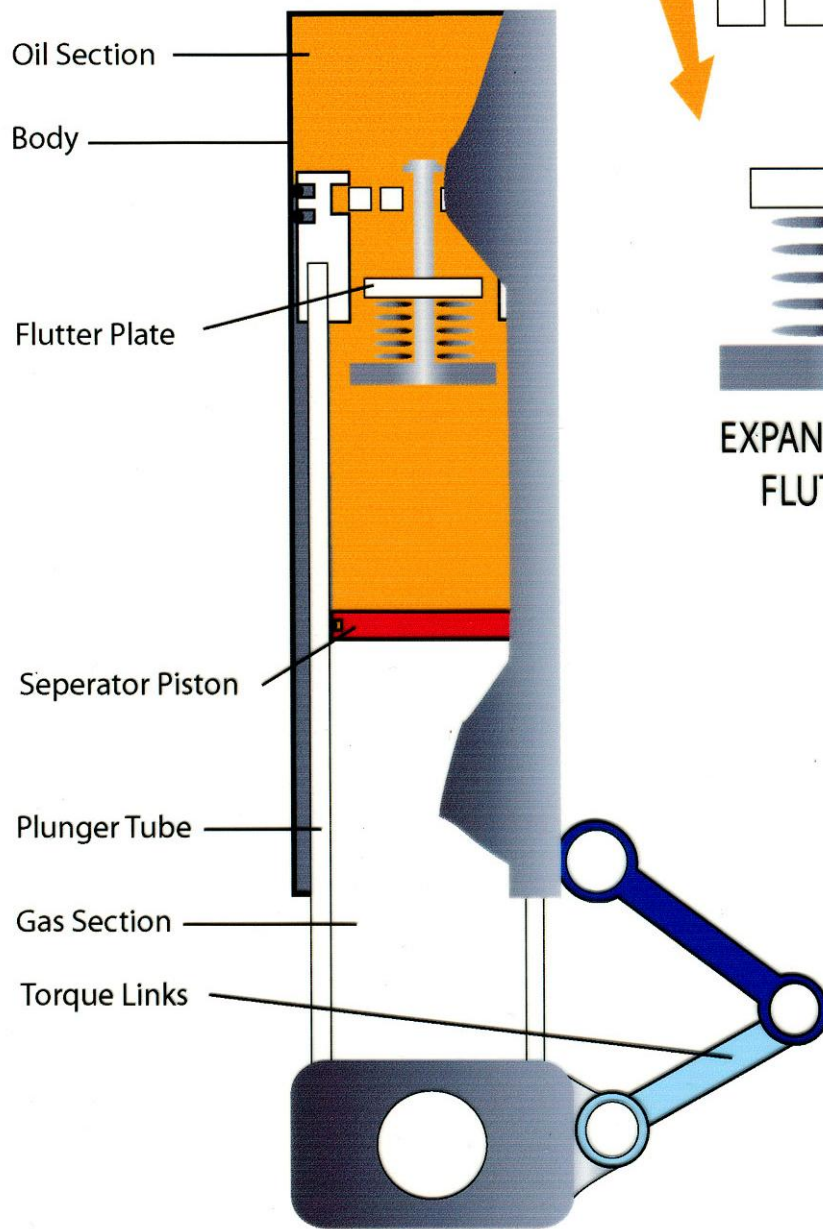
[AIRLINERS.NET](http://AIRLINERS.NET)

# GEAR LOWERING SEQUENCE AND INDICATIONS

SELECTION (Lever Position)	POSITION	INDICATION	
		Doors	Gear
DOWN (on ground)    UP	Doors - closed/locked Gear - down/locked	No lights	3 Greens
	Doors - opening Gear - down/locked	3 amber	3 Greens 3 Reds
	Doors - open/locked Gear - travelling	3 amber	3 Reds
	Doors - open Gear - up/locked	3 amber	No lights
	Doors - closed/locked Gear - up/locked	No lights	

NB: Main gear down lock is a **mechanical geometric over-centre lock**

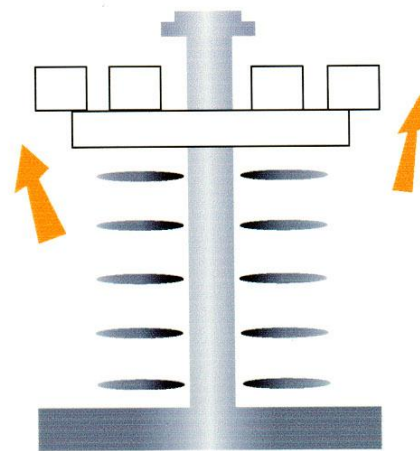
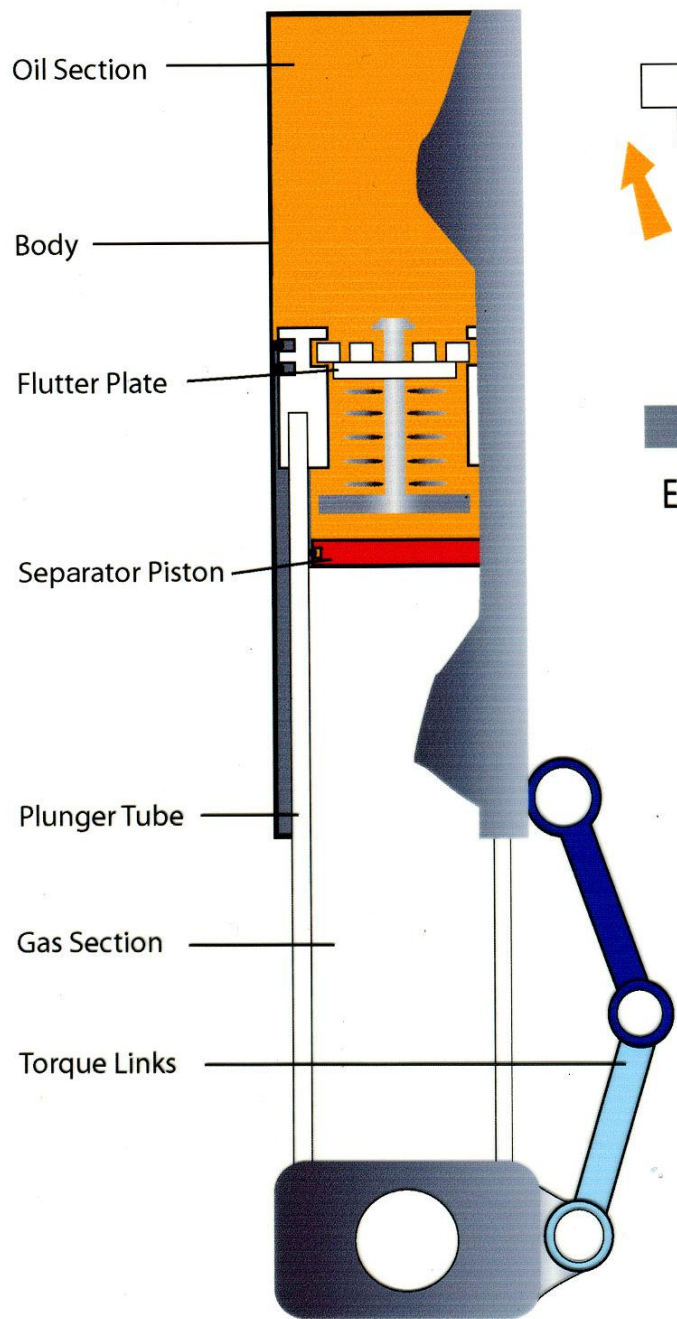




### On compression (landing):

- Plunger tube moves up and displaces oil through the flutter plate (unrestricted)
- This moves the separator piston down and compresses the gas to keep oil/gas pressures equal
- This builds up excess pressure in the oleo from the impact

OLEO-PNEUMATIC LEG (COMPRESSED)



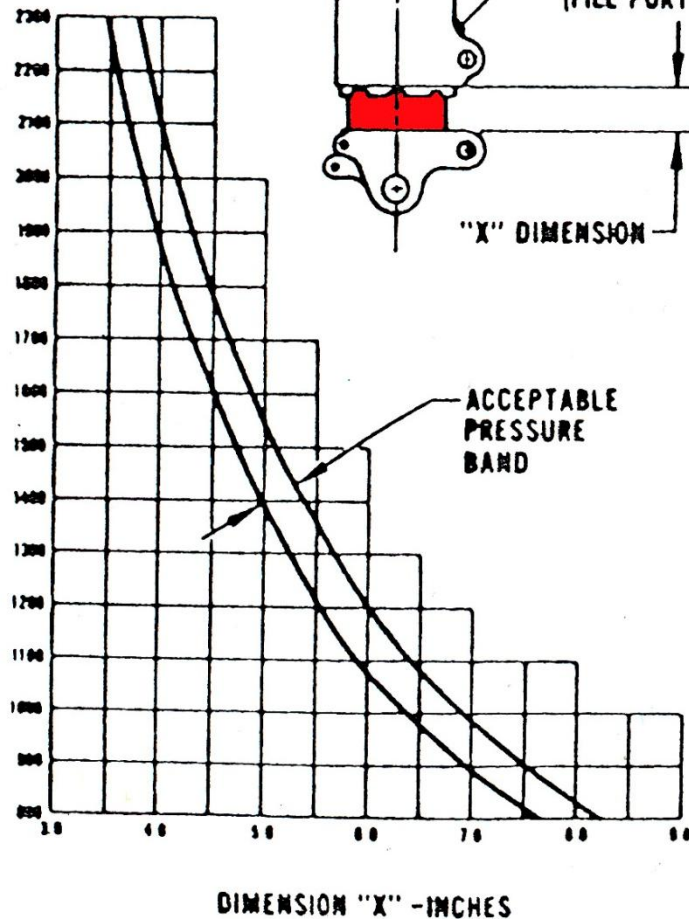
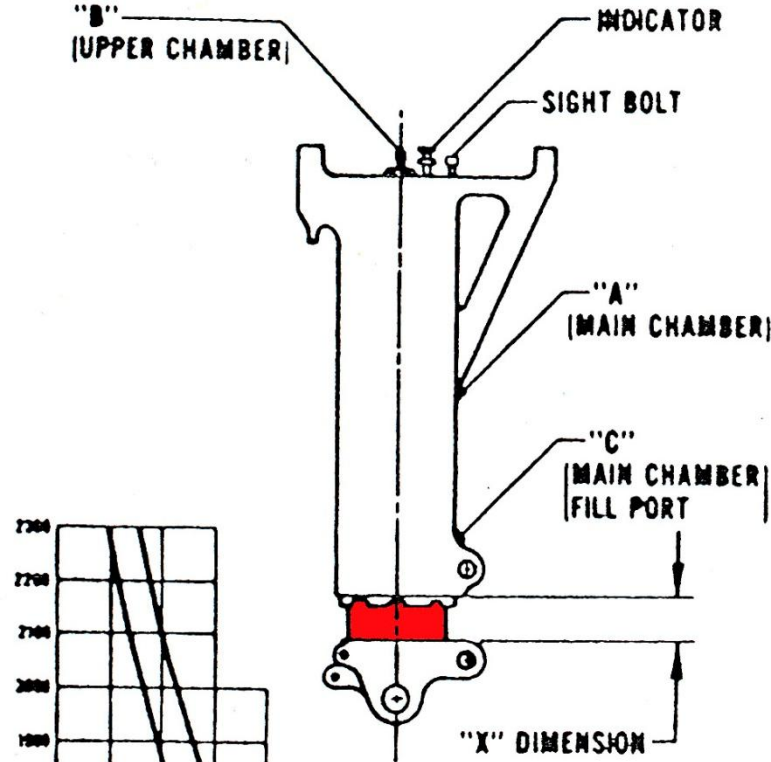
EXPANDED VIEW OF  
FLUTTER PLATE

### On the rebound:

- The excess pressure (more than required to support the weight of the aircraft) now pushes the plunger tube down
- This causes the flutter plate to close and restrict the oil flow up through it
- Thus the rebound is damped
- The rebound continues until the gas/oil pressure is sufficient to support the weight of the aircraft

OLEO-PNEUMATIC LEG (EXTENDED)

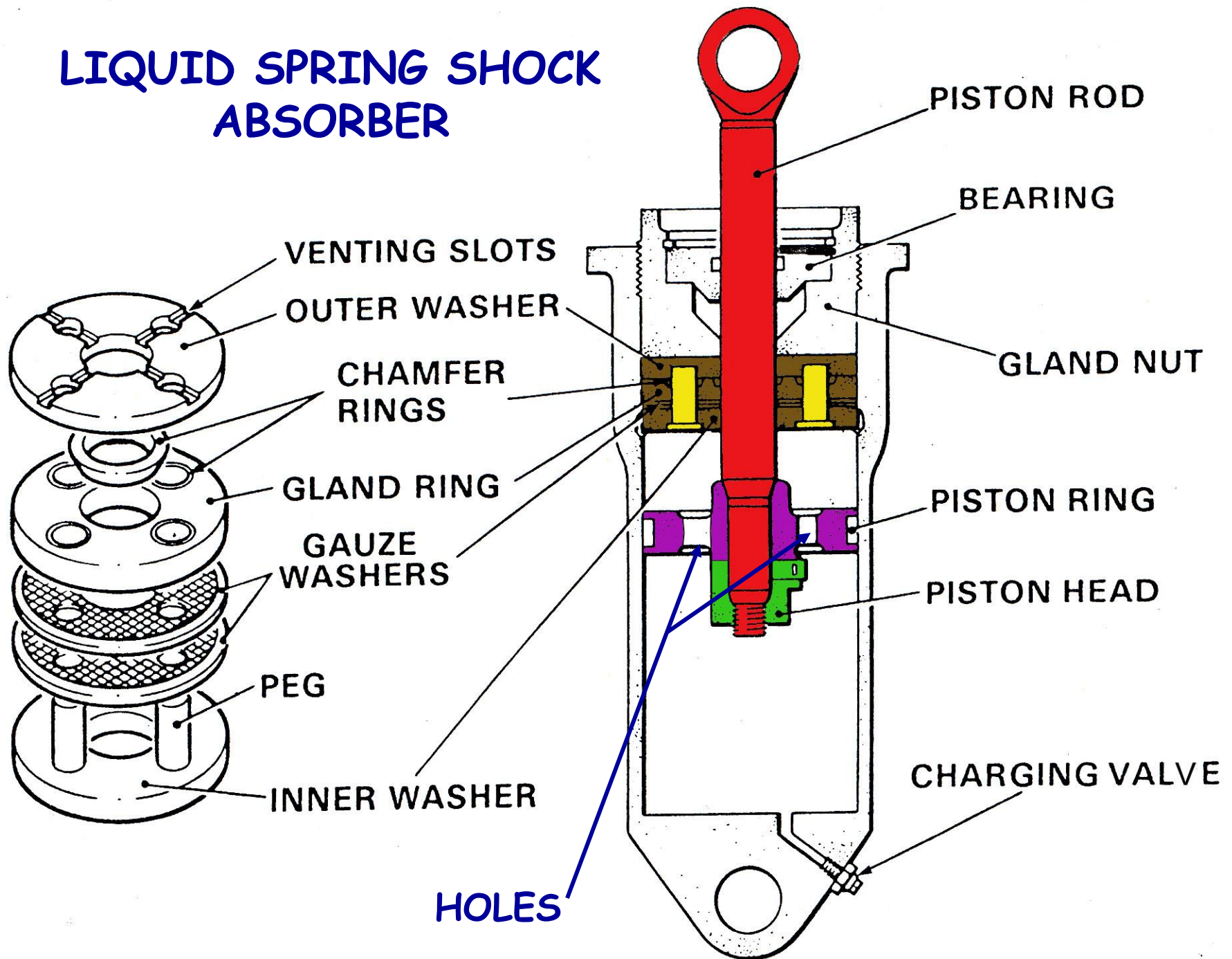
# OLEO PNEUMATIC LEG - IMPORTANT DIMENSIONS



- Most likely cause of the fescalised (shiny) portion of the leg being too small is low gas ( $N_2$ ) pressure
- Could result in oleo 'bottoming-out' on landing
- If oil levels are too low, the rebound is not properly damped



# LIQUID SPRING SHOCK ABSORBER



# NOSE LANDING GEAR

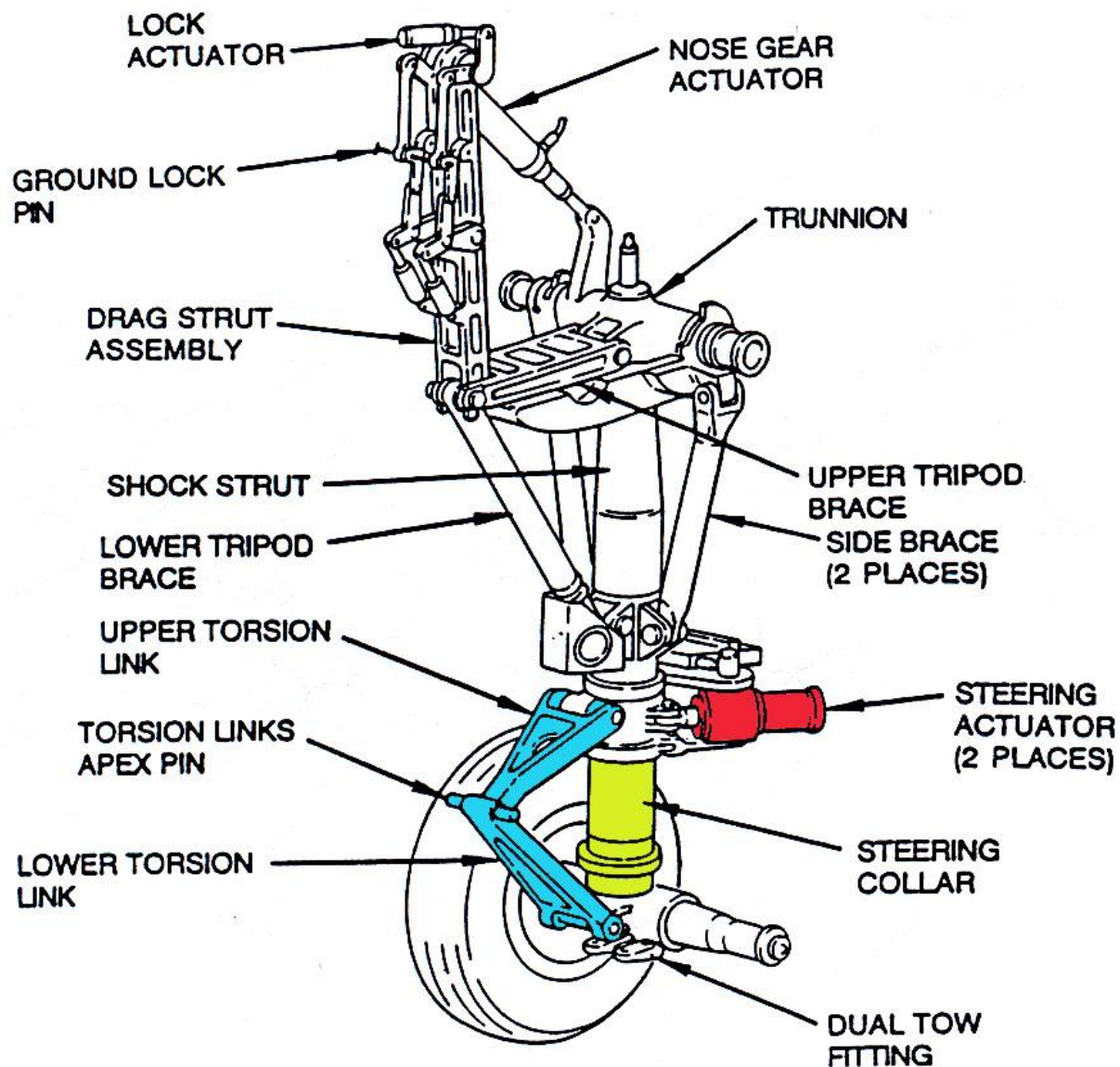
## Requirements:

- Nose Wheel Steering (NWS) - max angles (about  $55^\circ$  and warning system)
- Self-centring
  - To ensure that wheels are in line before retraction
  - To ensure that wheels are in line for landing after lowering
- Shock absorbing
- Anti-shimmy

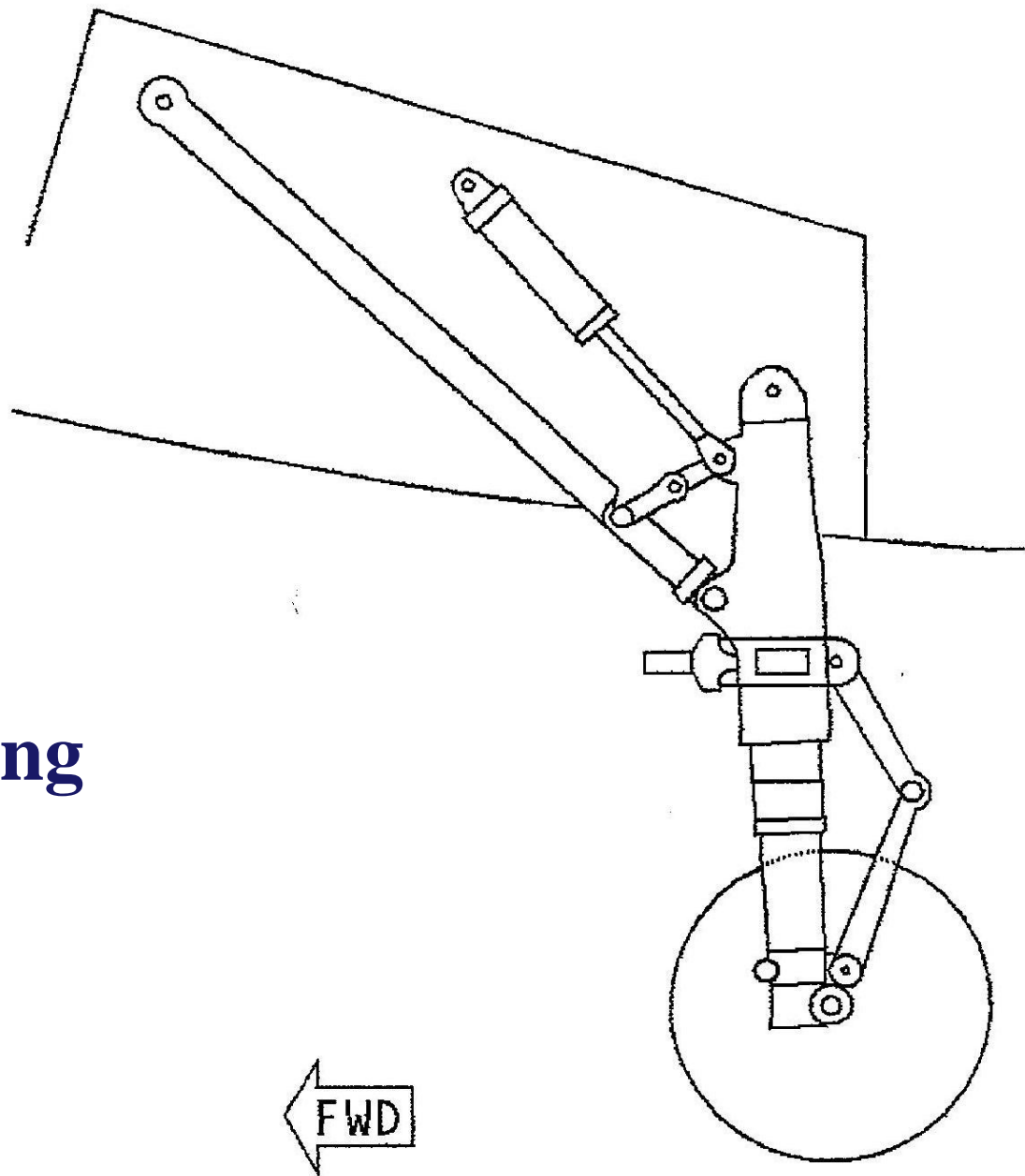
Shimmy is the rapid sinusoidal oscillation of the nosewheel and is divergent in nature

nb The nosewheel carries about 10% of the weight of the aircraft

# 747 NOSE GEAR



# Nose Landing Gear





# CAUSES OF SHIMMY

- Uneven tyre pressures
- Unevenly worn tyres
- Unbalanced wheels
- Worn shimmy damper or wheel bearings
- Worn torque link will make things worse

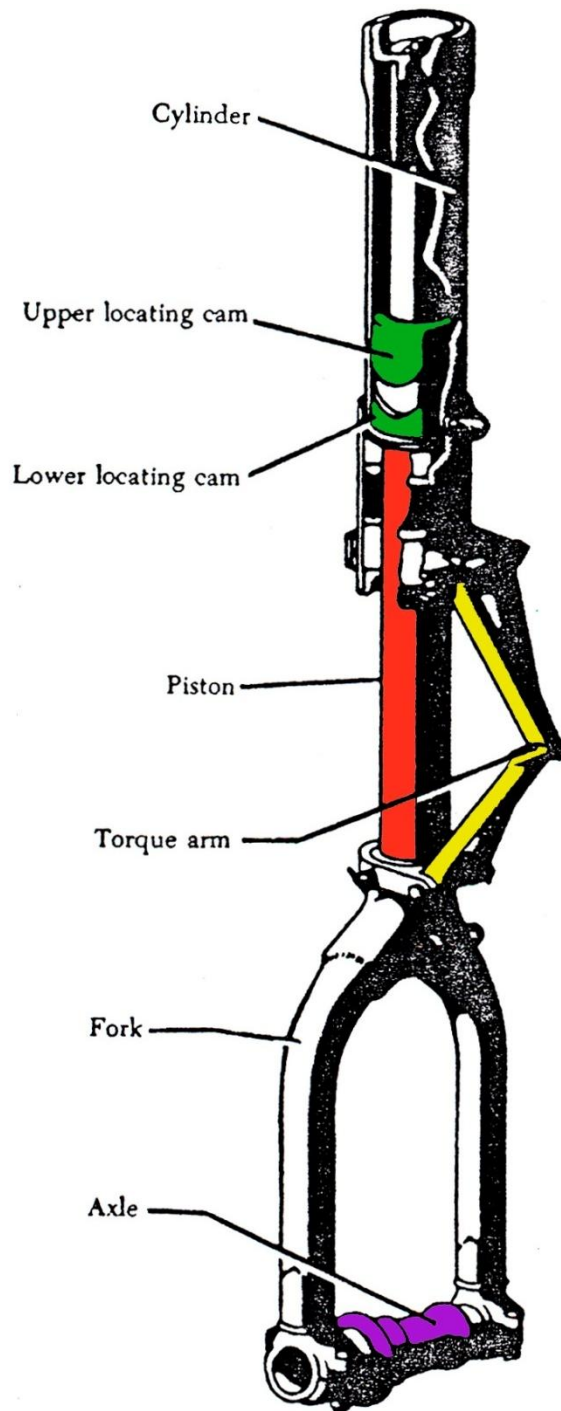
## ANTI-SHIMMY DESIGNS

- Twin wheels
- Marstrand tyres
- Shimmy damper (Light aircraft - friction damper  
Large aircraft - Hydraulic dampers  
or within steering apparatus)
- Limiting the castoring ability of the nosewheel

# MARSTRAND TYRE



# NOSE UNDERCARRIAGE LEG



- On light aircraft the steering input is effected by the rudder pedals
- On large aircraft the input is by the use of a steering wheel (or sometimes a tiller device)
- Self-centring device is a roller/spring system (light aircraft)
- Self-centring device on heavy aircraft is part of the nosewheel steering system

# LANDING GEAR POSITION WARNING

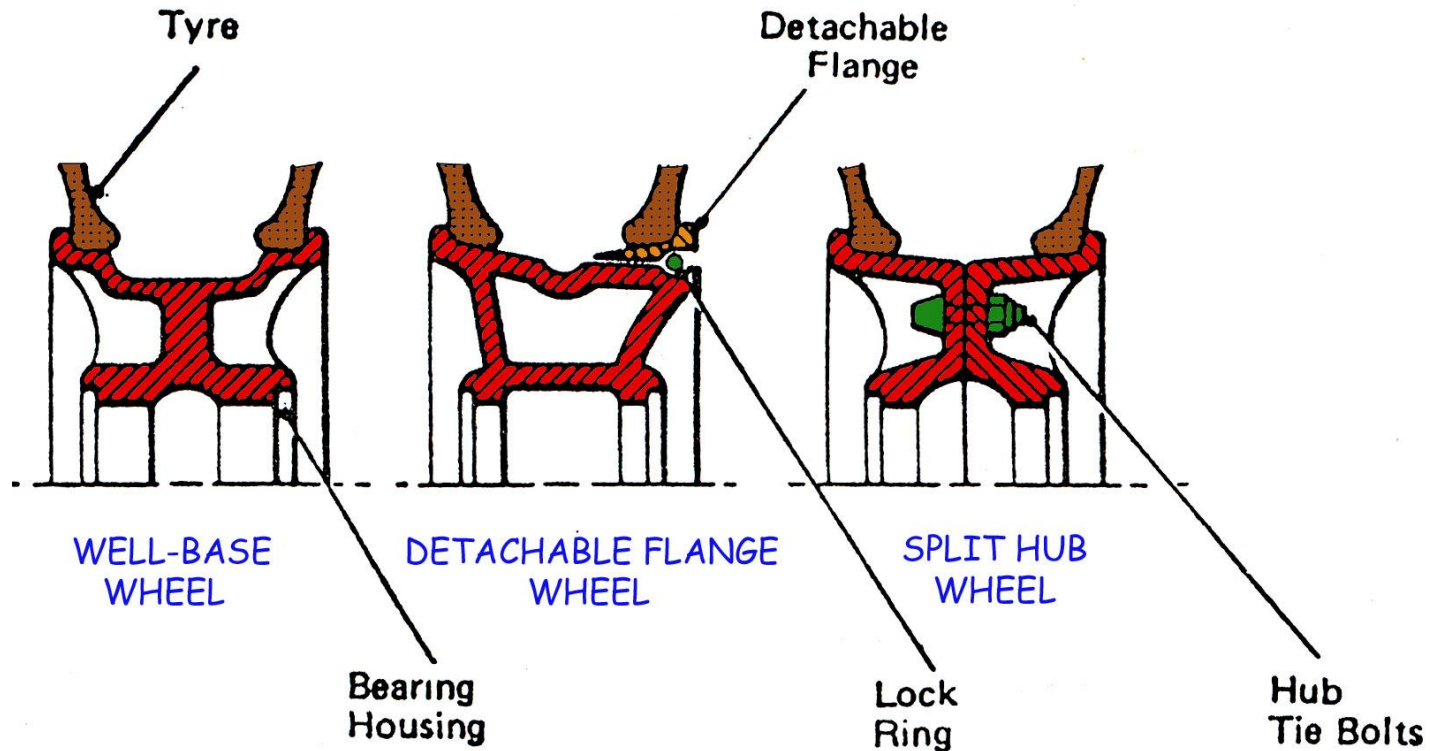
- Although the undercarriage lights are the main indication of gear position, large transport aircraft also have a warning system. This operates as follows:
  - When aircraft is in the landing configuration (flaps/slats etc) and throttles are set below a predetermined value
  - Any part of the landing gear is not locked down
  - A warning horn will sound continuously until either the gear becomes locked down (3 greens) or the throttles are advanced (as for a go-around)



# WEIGHT-ON-WHEELS SWITCHES

- Weight-on-wheels (also called 'squat switches' or 'undercarriage safety switches') are normally **micro** or **magnetic proximity** switches mounted on **torsion link** to make or break electrical circuits when oleo extends/retracts
- Are used to:
  - Disable undercarriage selector whilst on ground (normally by inserting a solenoid operated pin to prevent physically the undercarriage lever being moved). The squat switches on both main gear legs need to break to allow gear retraction **once airborne** (secondary method of preventing gear being selected up on ground is ground locking pins physically stop legs moving)
- May also be used to:
  - Prevent use of reverse thrust in-flight
  - Control outflow valves on the ground (pressurisation)
  - Prevent use of airframe anti-icing on the ground
  - Enable auto-spoiler deploy and auto-braking system
  - Control electrical output to some anti-icing systems on the ground (eg galley outflow)
  - Record landing times

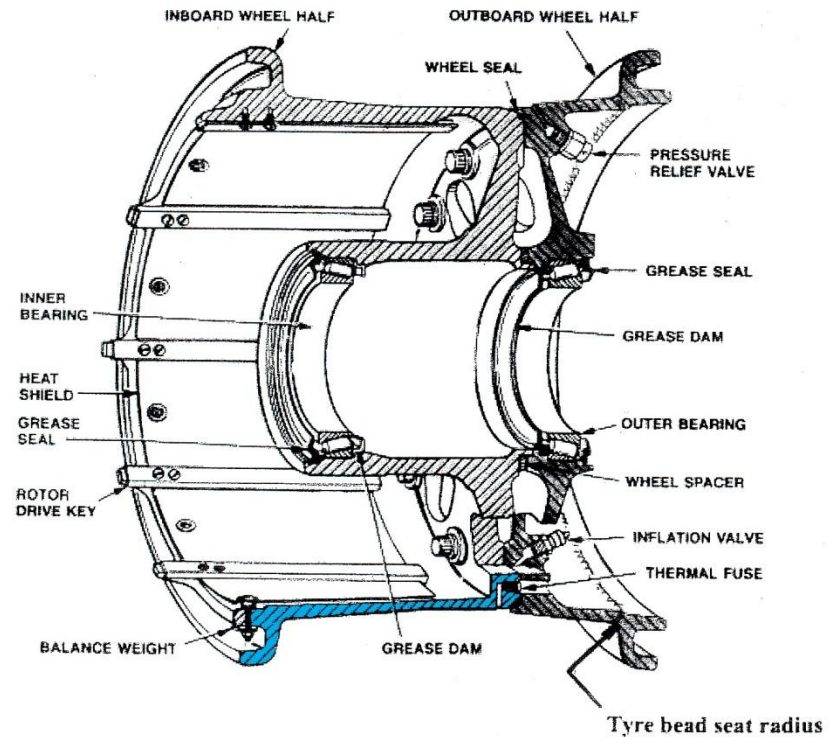
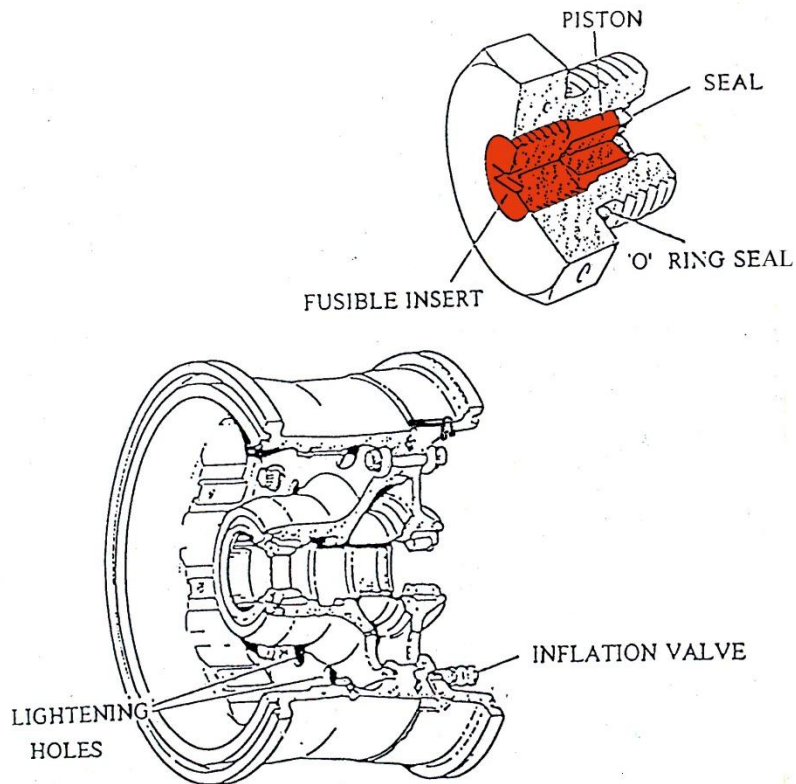
# WHEELS



## 3 main types of wheels:

- Well-based - similar to car and fitted to light aircraft (tubed tyres)
- Detachable flange - one side of wheel can be removed by taking out locking ring (tubeless tyres)
- Split hub - breaks directly down the centre and is bolted together once tyre has been fitted (tubeless tyres)

# FUSIBLE PLUGS



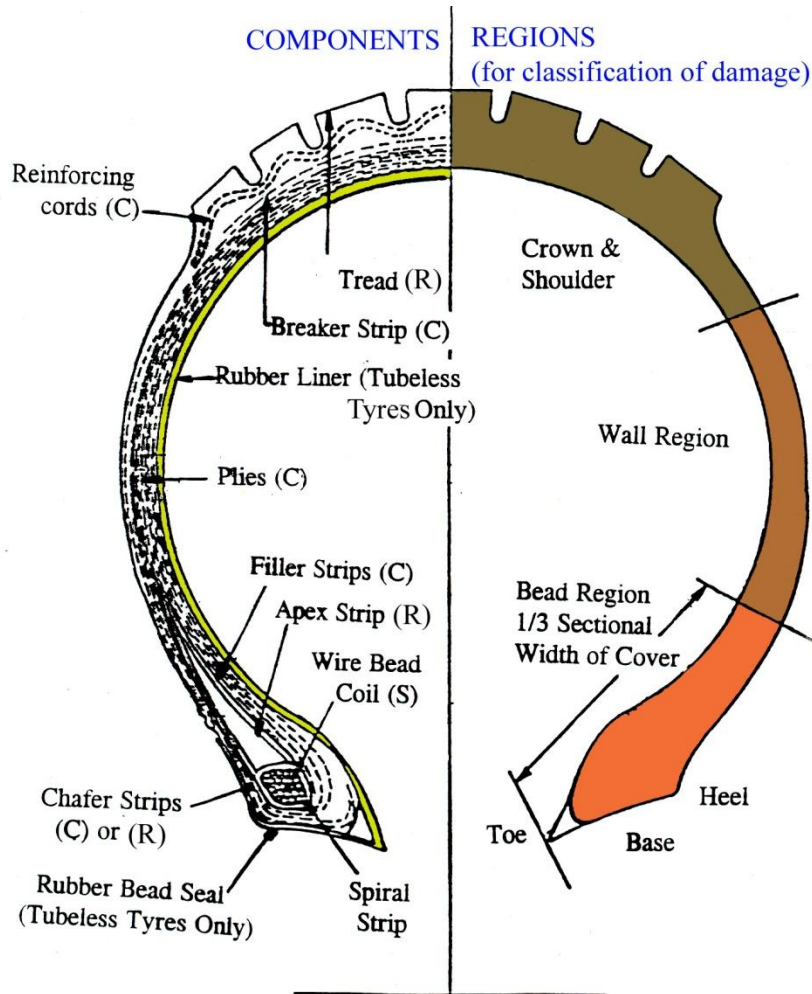
- Fusible insert melts at a pre-set temperature to allow a controlled deflation of the tyre (before it explodes)
- Will probably melt following a max weight RTO
- Fitted on wheel rim

# TYRES

- 2 main tyre classes - tubed/tubeless
- Advantages of **tubeless** tyres are:
  - $7\frac{1}{2}\%$  weight saving
  - $10^{\circ}\text{C}$  cooler running
  - Less danger of deflation by puncture
  - Reduced permeability losses
  - Elimination of possible tube problems  
(bending/breaking of inflation valve after tyre creep)
- Main tyre pressure = 200 psi



# TYRE CONSTRUCTION



## KEY

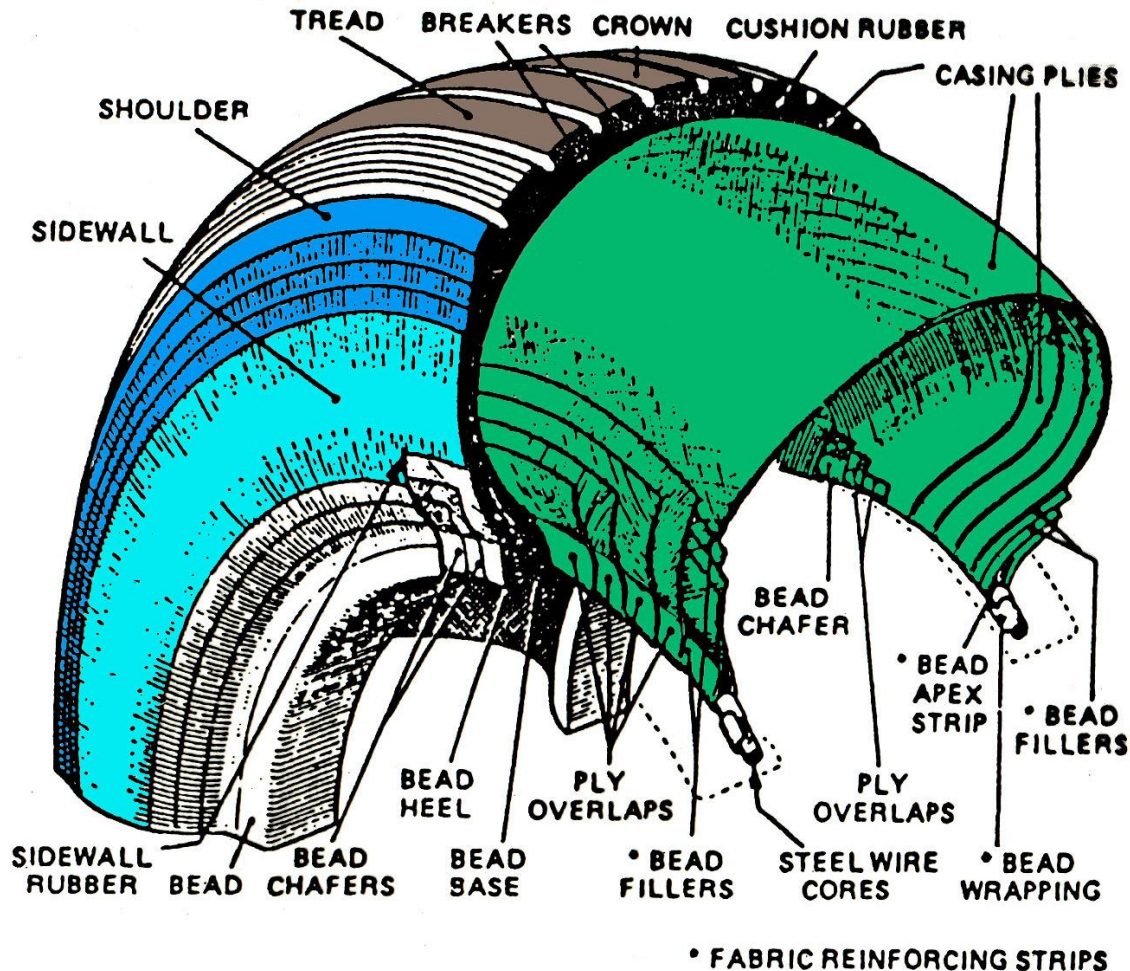
- (C) Rayon or Nylon
- (R) Compounded Rubber
- (S) Steel

## • 4 key areas:

- Crown
- Shoulder
- Wall region (weakest area)
- Bead region

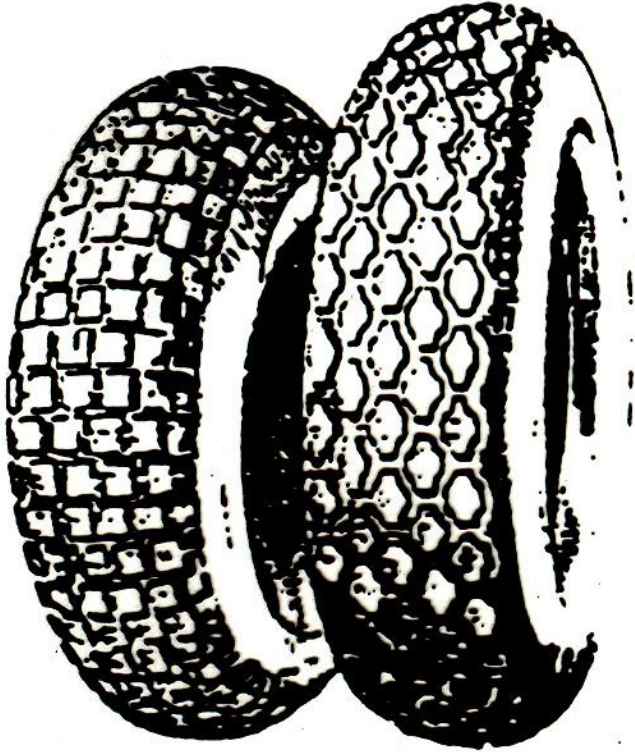
- Over-inflation leads to crown wear
- Under-inflation leads to shoulder wear
- During construction gas builds up between layers - awl holes drilled to let out gas (signified by grey/green spot)
- Tyre is permeable - rubber liner put around inside of tyre to reduce permeability
- Red spot/triangle shows lightest area of tyre; put against heaviest area of wheel to facilitate balancing
- Tread indicators show minimum acceptable tread - 2mm/marker bar are the limits

# TYRE CUT-AWAY

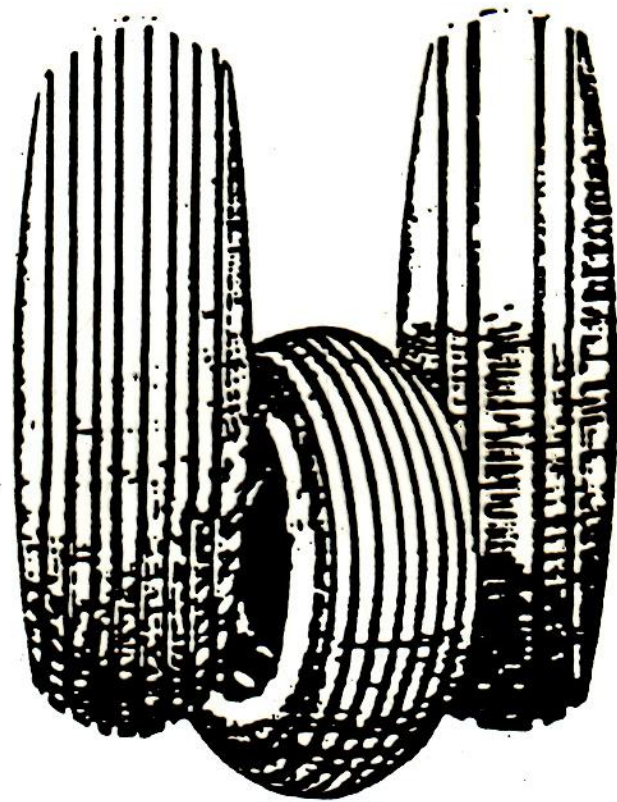


- 2 different tyre designs - radial (plies in same direction)/cross-ply (plies knitted at an angle)
- Radial are more flexible than cross-ply
- Number of plies is an indication of tyre strength

# TREAD PATTERNS



**BLOCK TREAD**  
(Non-paved surfaces)



**RIBBED TREAD**  
(Paved surfaces)

- Nb Aircraft tyres are commonly re-treaded many times before being discarded



# CHINED TYRE

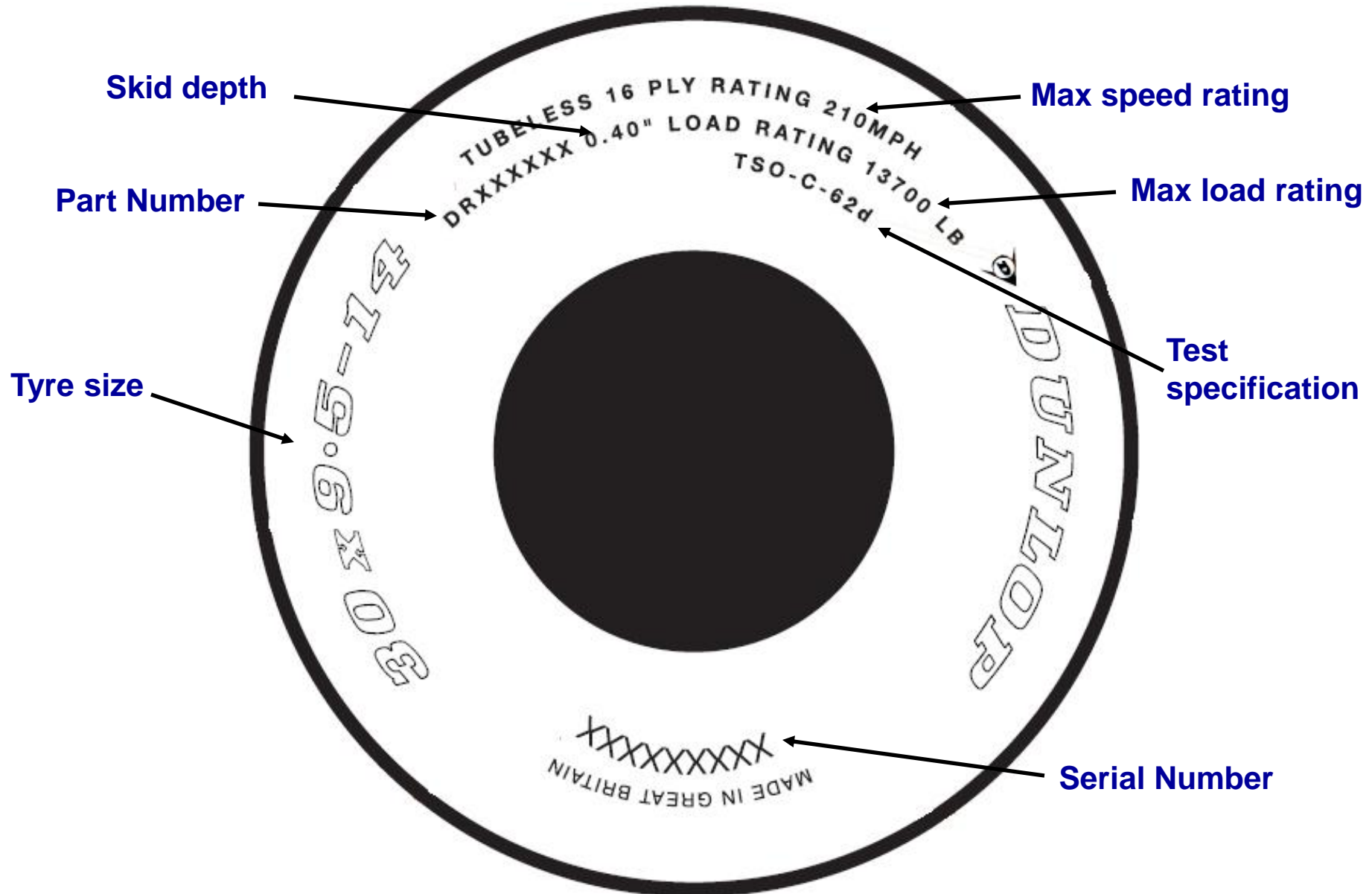
Fitted on the nosewheels of aircraft with fuselage-mounted engines to prevent water ingestion from wet runways

Chine is on the outboard part of the tyre

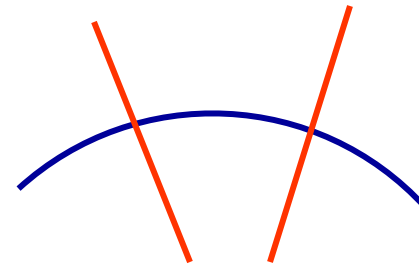
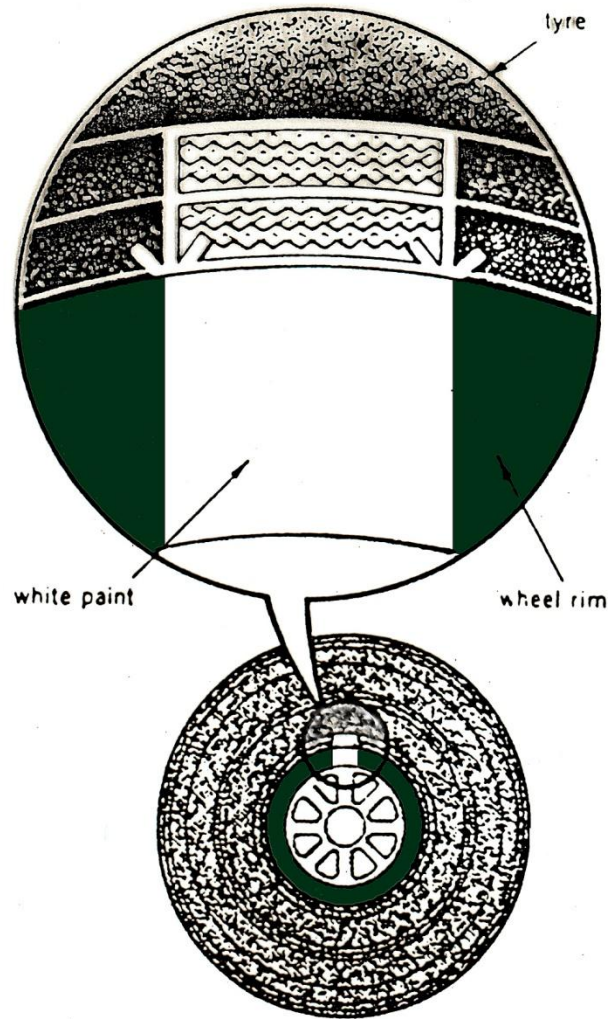




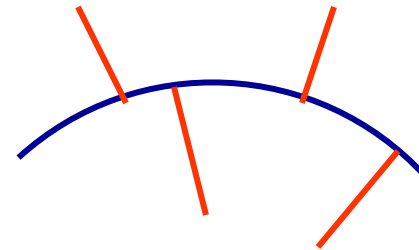
# TYPICAL CROSS-PLY TYRE DATA



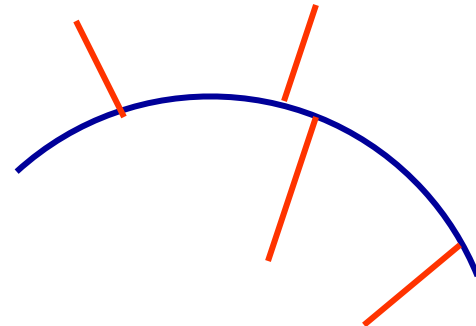
# TYRE CREEP



No creep



Acceptable creep



Unacceptable creep

- Up to 24" diameter - 1" of creep OK
- 24" and above - 1½" of creep OK

# TYRE PRE-FLIGHT INSPECTION

Tyre pre-flight inspection should include the following items:

- Creep within limits
- No cuts or scores
- No swelling or bulges, especially in the side wall
- No embedded objects
- No signs of heat damage, particularly around the bead
- The tyre appears correctly inflated (tolerance of 5 - 10% above the loaded inflation pressure is generally specified)

Tread separation and tyre burst:

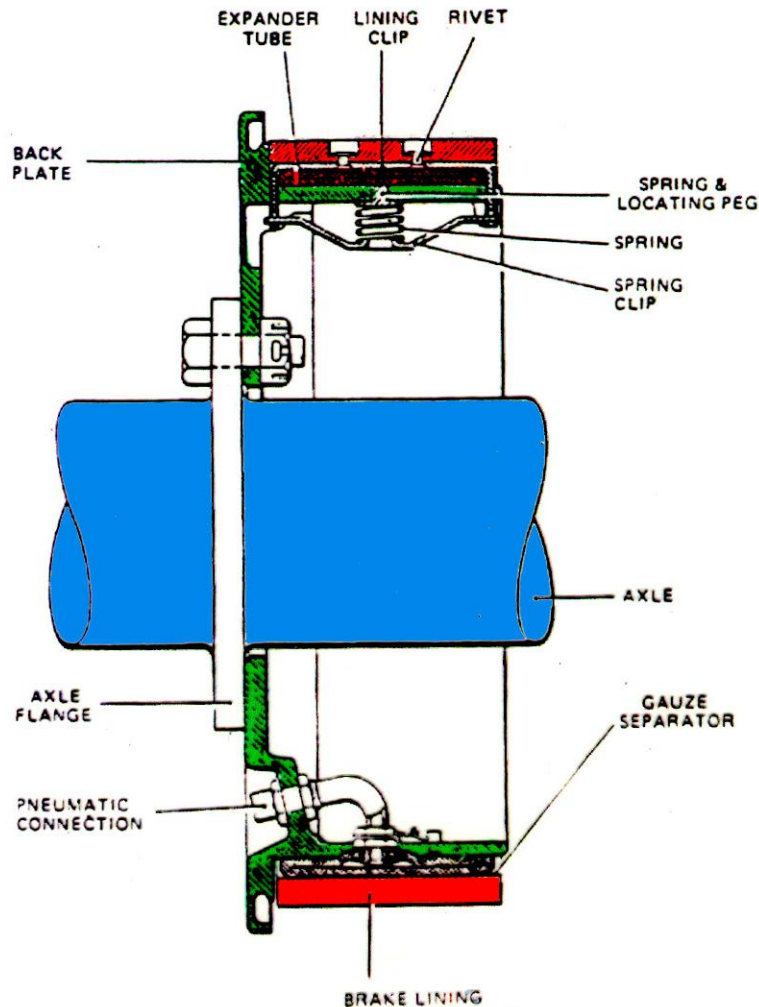
- Smaller footprint (increased loading on remaining tyres),
- Lower braking efficiency,
- FOD (possible damage to hydraulic lines, engine ingestion)

# BRAKES

- Purpose is to convert **kinetic energy** to **heat energy**, via friction pads and dissipate the heat to atmosphere
- Brakes usually fitted just to the main wheels and **may be torque limited**.
- Type of brake unit is primarily a function of the weight of the aircraft. For **large transport aeroplanes** the main **power source** for brakes in **normal** and **alternate operations** is **hydraulic**.
- Three types are:
  - **Drum brakes** (not used on modern aircraft)
  - **Single disc brakes** (used on light aircraft)
  - **Multi-disc brakes** (used on heavier aircraft)
- In addition, anti-skid units are fitted to all modern commercial transport aircraft and there is generally an automatic brake application system available

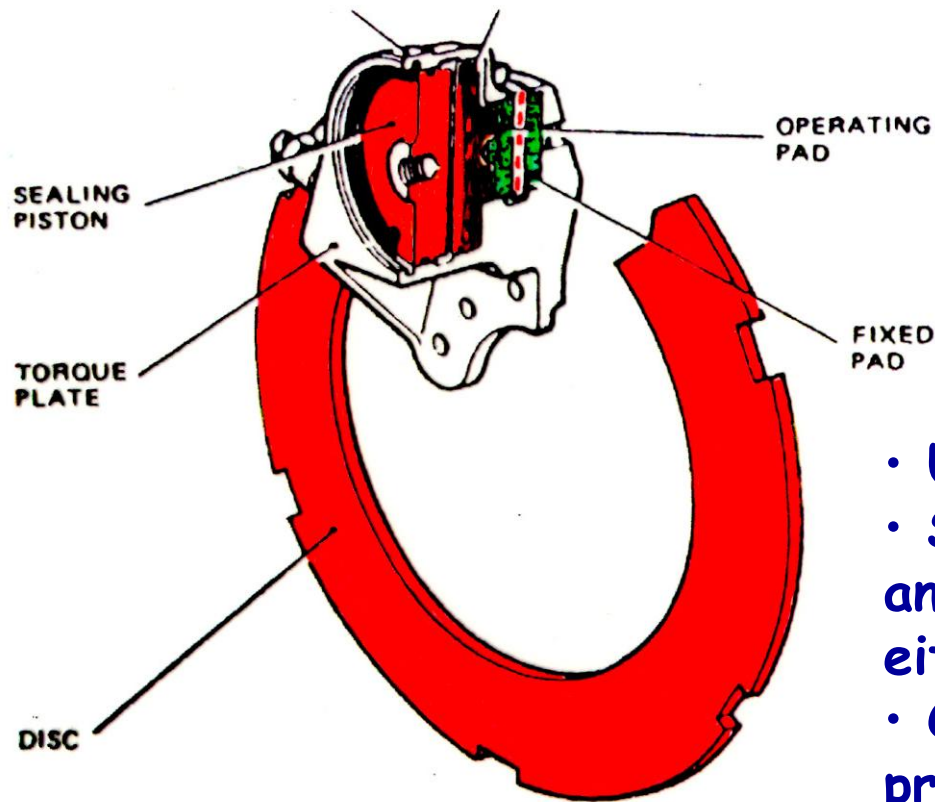


# DRUM BRAKES



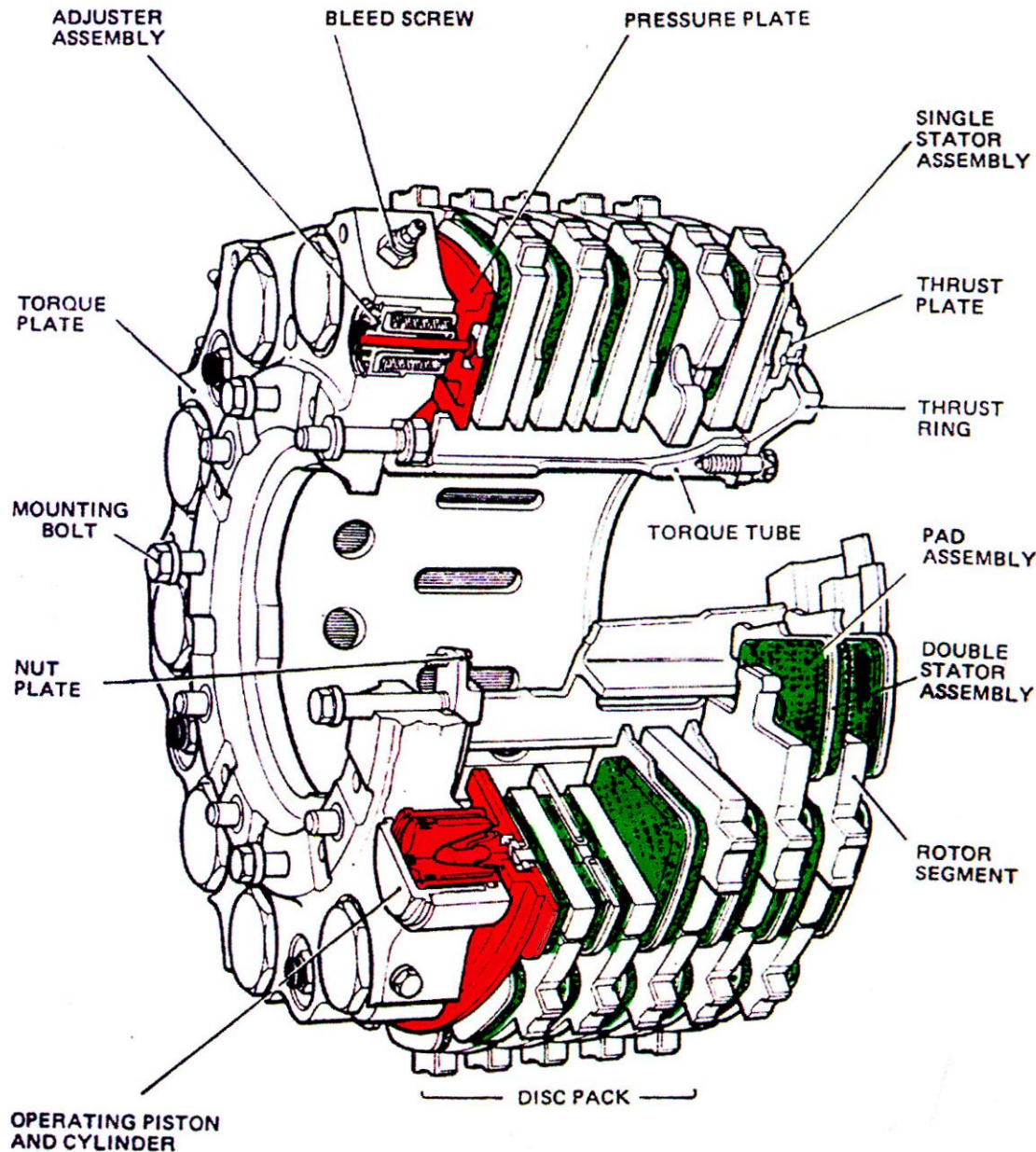
- Pneumatically or hydraulically operated
- During operation, asbestos lined shoes contact a rotating drum when a brake application is made
- When the brakes are released, a spring moves the friction material away from the drum
- Suffer from **brake fade** caused by gas given off by the vaporisation, at high temperatures, of the binding material in the brake linings becoming trapped between the brake pad and rotor. This makes the pad float on a blanket of vapour causing reduced effectiveness

# SINGLE DISC BRAKE



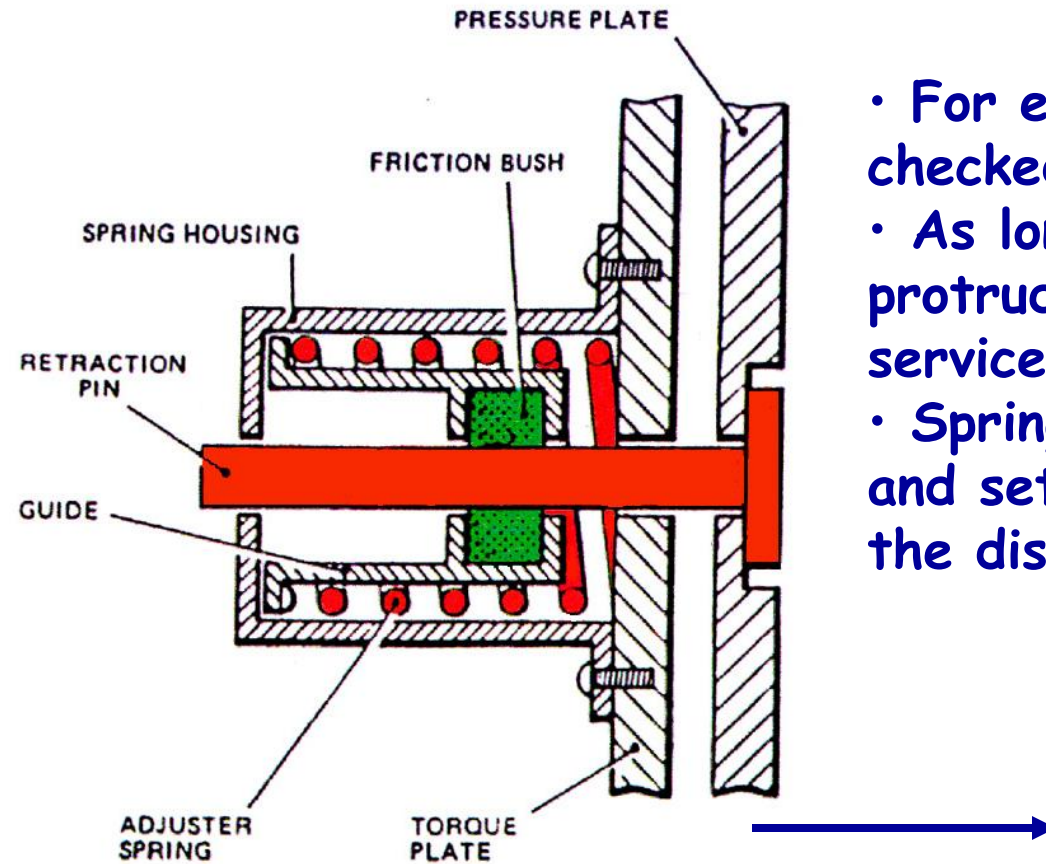
- Used on light aircraft
- Single disc is driven by the wheel and has 2 stationary brake pads either side of it
- On application, hydraulic pressure squeezes the pads onto the disc (more pressure squeezes pads harder)

# MULTI-DISC BRAKES



- Consists of interleaved stators and rotors
- Brake application compresses the stator discs together and bring them into contact with the rotors
- Adjuster assembly maintains the correct distance between the stators and rotors as they wear through use
- Older aircraft use steel discs and 1800 (1900) psi; newer use carbon fibre and 3000 psi

# ADJUSTER ASSEMBLY



- For examination purposes, brakes are checked **ON**
- As long as there is some pin protruding, the brakes are deemed serviceable
- Spring pulls off brakes when released and sets the running distance between the discs and linings

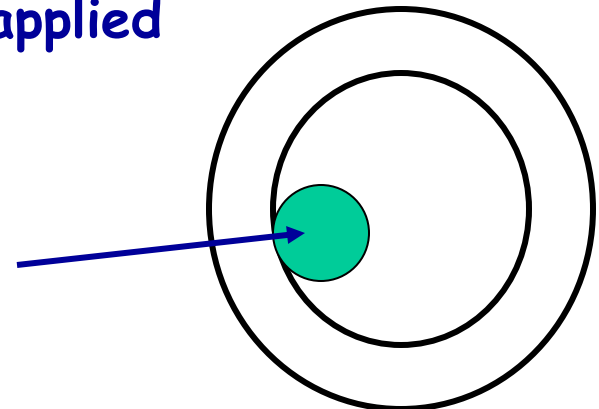
Pressure plate moves in this direction when brakes applied; with brake pad wear, it must move further and eventually pin will not protrude when brakes on



# ANTI-SKID SYSTEMS

- Transport aircraft are commonly fitted with anti-skid devices to maximise braking efficiency by preventing wheel skids in wet or icy conditions
- Two types:
  - **Electronic**; wheel rotation speed checked electronically against a reference (nose-wheel speed in airbus), any discrepancy results in a reduction in brake pressure **on the individual wheel only**. When wheel speeds up, pressure reapplied
  - **Mechanical (maxaret unit)**; a flywheel within the maxaret unit (inside the wheel rim) rotates at the same speed as the tyre. When wheel slows rapidly (because of a skid) the maxaret unit will tend to over-run against spring pressure, generate an error signal and reduce brake pressure **on the individual wheel only**. When wheel speeds up, pressure reapplied
- Can happen many times a second

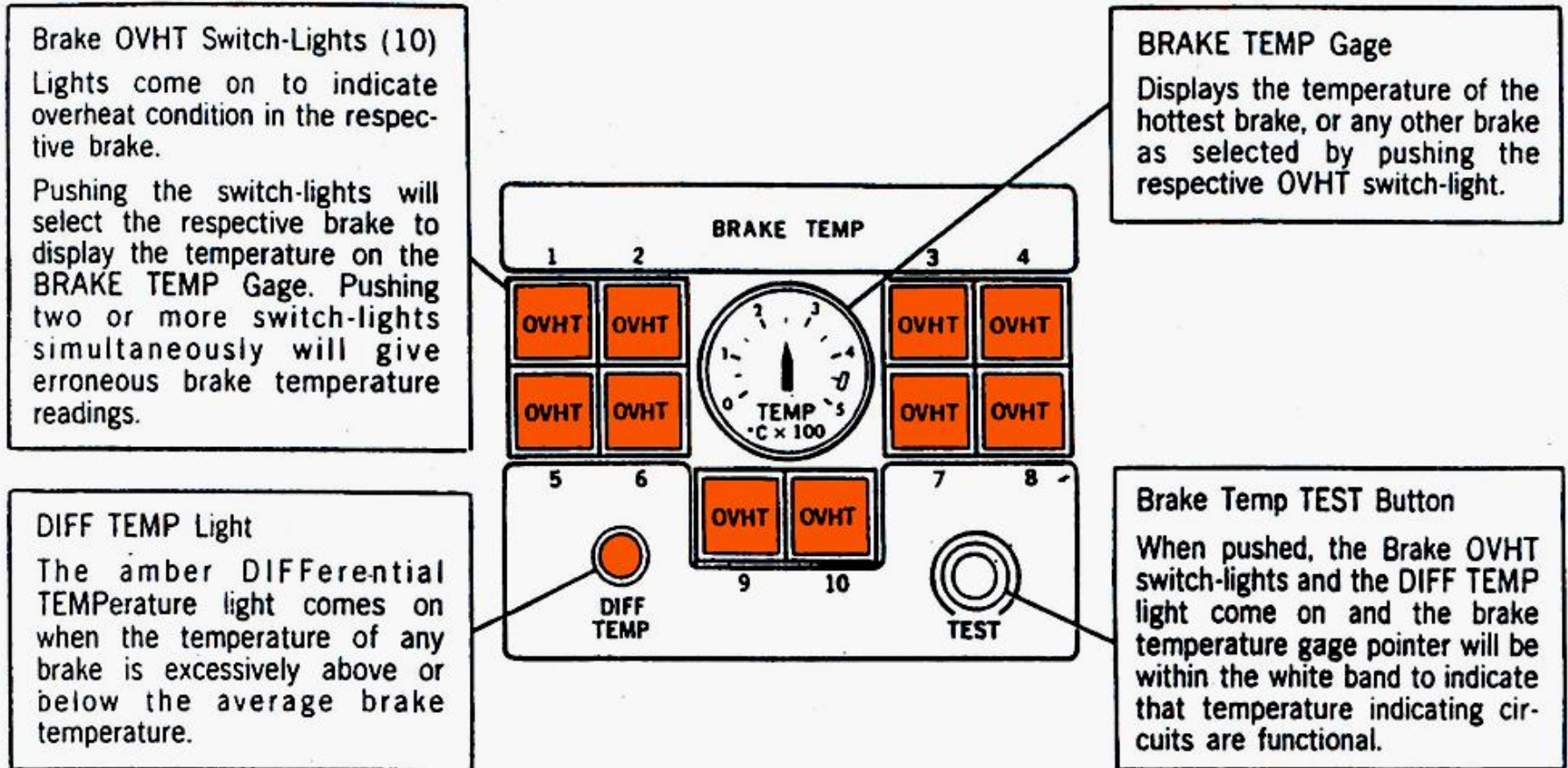
Maxaret unit



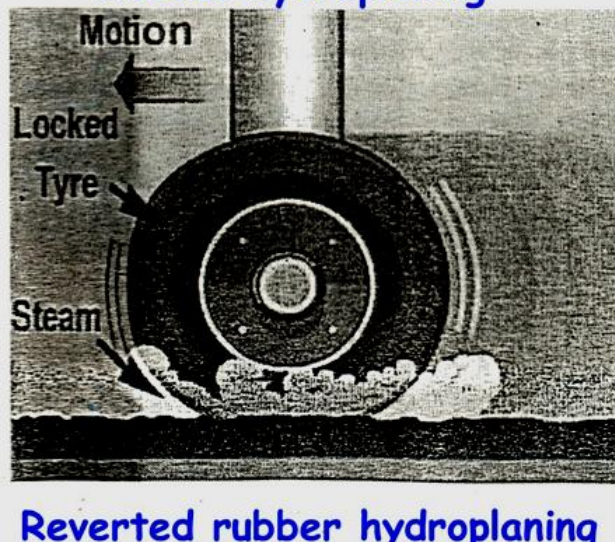
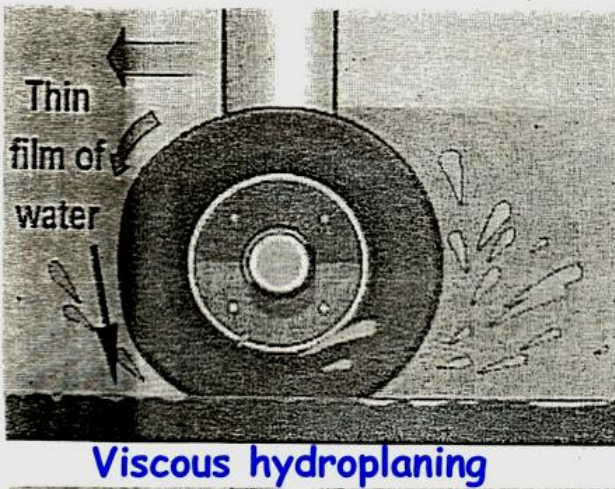
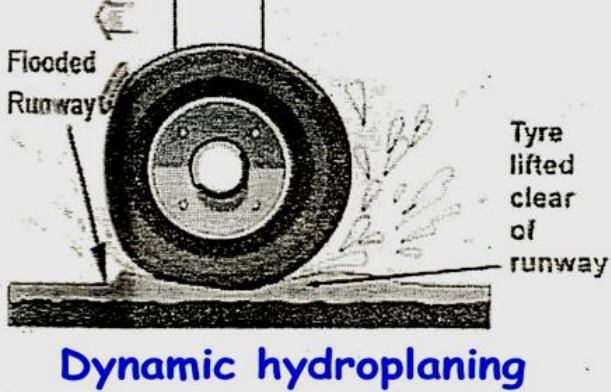
# AUTO BRAKING SYSTEMS

- Auto-brakes can be operated on 2 occasions:
  - On undercarriage retraction; brakes may be automatically applied (at a reduced pressure of 3- 400 psi) to prevent gyroscopic forces affecting the retraction process
  - On landing; if auto-brakes are 'armed' before landing, operation of the squat switches will bring on the brakes at a pre-set level (between 1 and 5 typically). They may be cancelled by touching the brake pedals, by advancing the throttles or pushing the TOGA button

# BRAKE PACK TEMPERATURE INDICATOR



- 10 brake units because the early 737s had nose-wheel brakes



# HYDRO-(AQUA) PLANING

- Dynamic hydroplaning needs a build-up of water greater than tread depth below the tyre
- The following minimum speeds are generally accepted for the onset of dynamic hydroplaning:

## - Rotating tyres

$$V = 9\sqrt{\text{tyre pressure (psi)}}$$

## - Non-rotating tyres

$$V = 7.7\sqrt{\text{tyre pressure (psi)}}$$

Note: 1 bar = 14.5 psi