CPL Theory
Aircraft Systems (CSYA)

CSYA 8 – Hydraulic & Undercarriage Systems

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3. Disclaimer

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HYDRAULIC SYSTEM

Hydraulic System

- Hydraulic systems can be used to operate aircraft components such as:

    1. Retractable Undercarriage

    2. Flaps

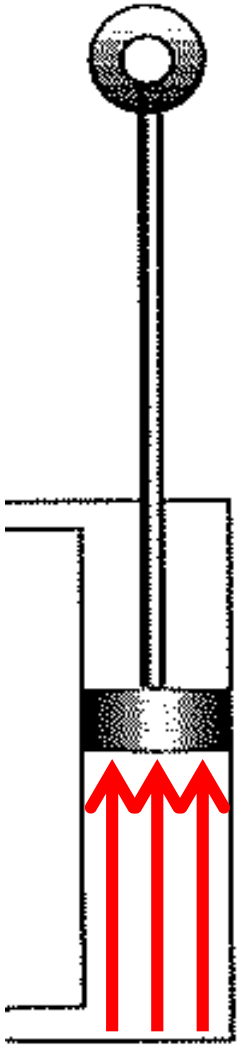
    3. Brakes

    4. Flight Controls

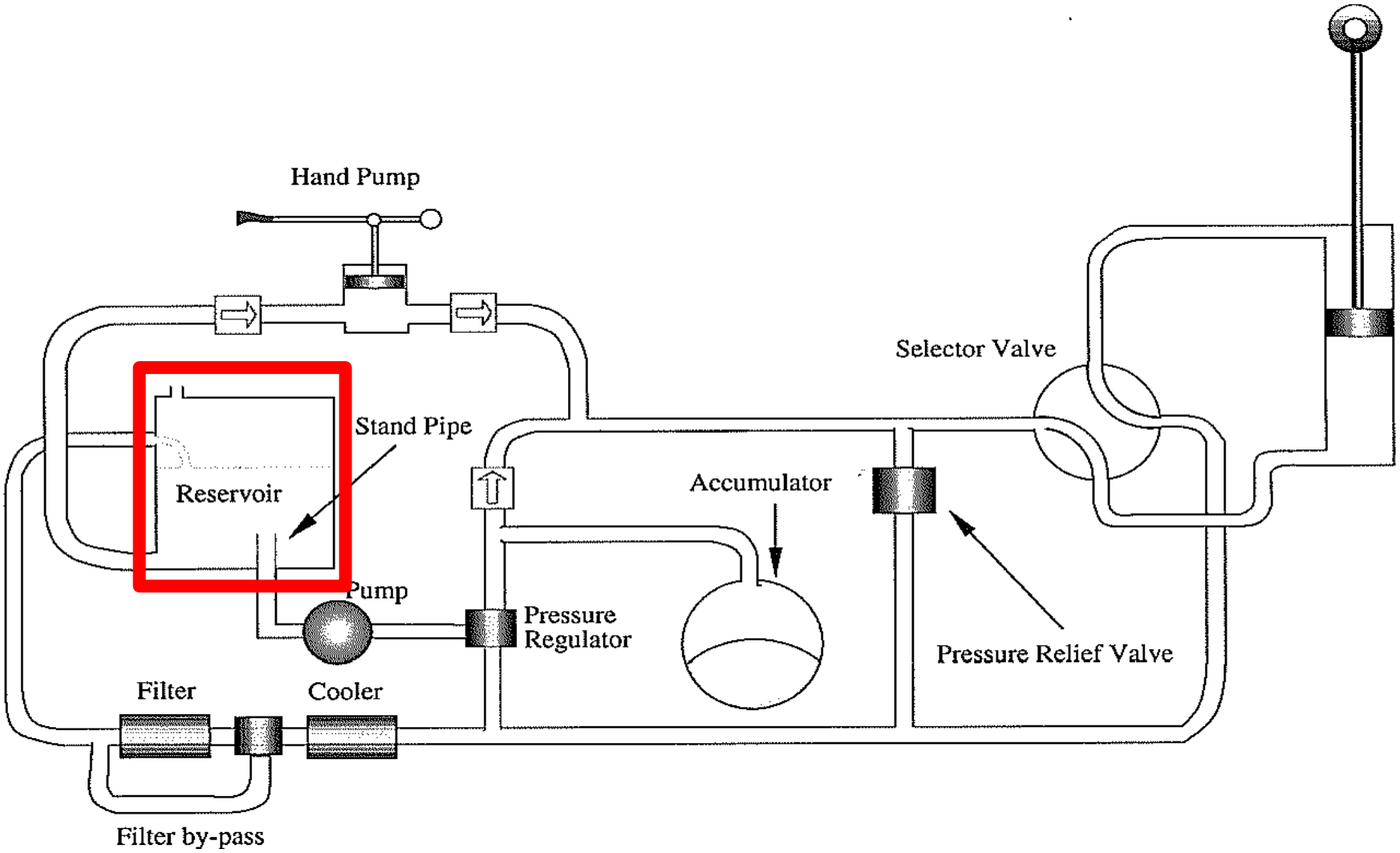
- The principle of operation is:

    1. A pump forces oil under pressure through leads into an actuator (cylinder)

    2. Inside the cylinder, the oil applies a force to a piston which in turn moves a mechanical ram attached to an aircraft component



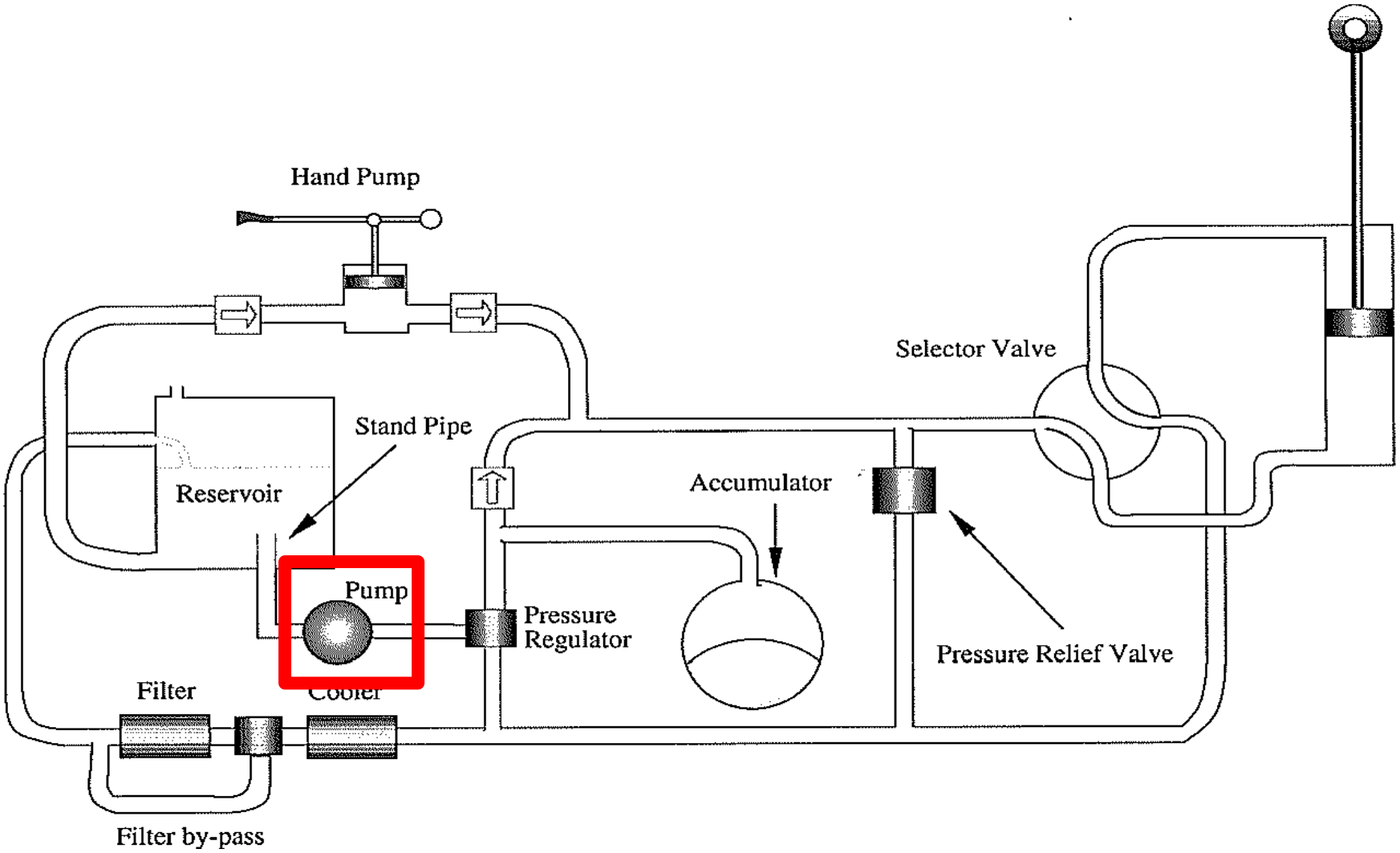
Hydraulic System



Hydraulic System – Reservoir

- The reservoir **stores hydraulic fluid** for use by the system
- It would be possible to have a system without a reservoir, but over time there is always some loss of hydraulic fluid and the reservoir ensures that there will always be a sufficient supply of fluid
- Much like the fuel tanks, **the reservoir must be vented** to the outside atmosphere
- This prevents a lower pressure (vacuum) forming inside the reservoir which would prevent fluid flow
- Hydraulic fluid is fed into the system to the pump through a **standpipe**
- The standpipe entry is above the bottom of the reservoir so that even if a leak in the system occurs, some fluid will remain to provide for the operation of a **hand pump**

Hydraulic System



Hydraulic System – Main Power Pump

- In large hydraulic systems, the pressure may be as high as 5000psi and it is the responsibility of the main pump to maintain this during hydraulic operation

- There are 2 main types of pumps which may be either engine driven or electric:

Constant Displacement/Delivery Pump

- Maintains a **constant flow** of fluid (just like an oil pump)

- When the system is required to operate, the pressure may build up

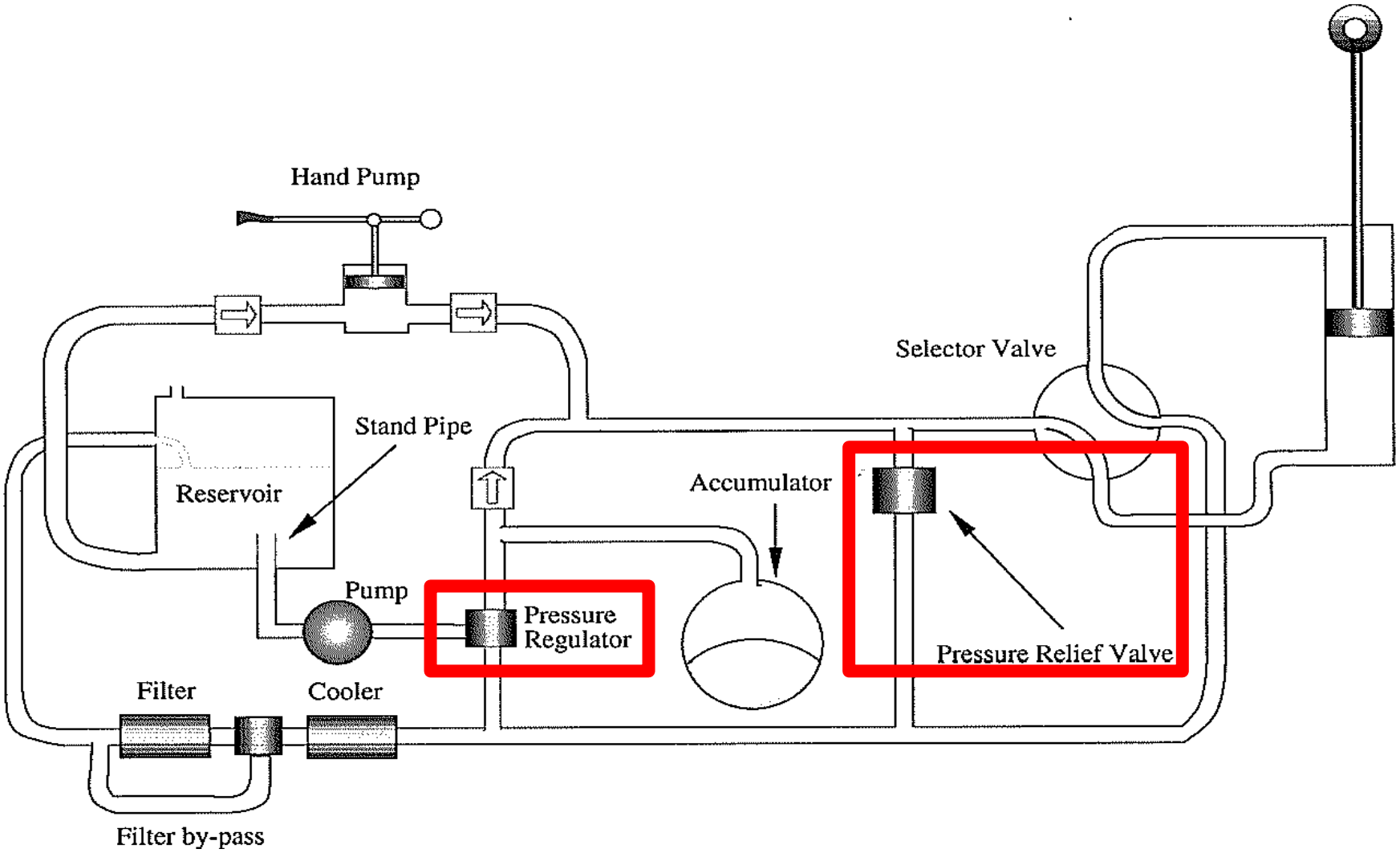
- A **Pressure Regulator** will be fitted to ensure that an excessively high pressure is not reached

Variable Displacement/Delivery Pump

- **Changes the fluid flow** to meet the demands of the system

- Therefore, a Pressure Regulator is not required

Hydraulic System



Hydraulic System – Pressure Regulator & PRV

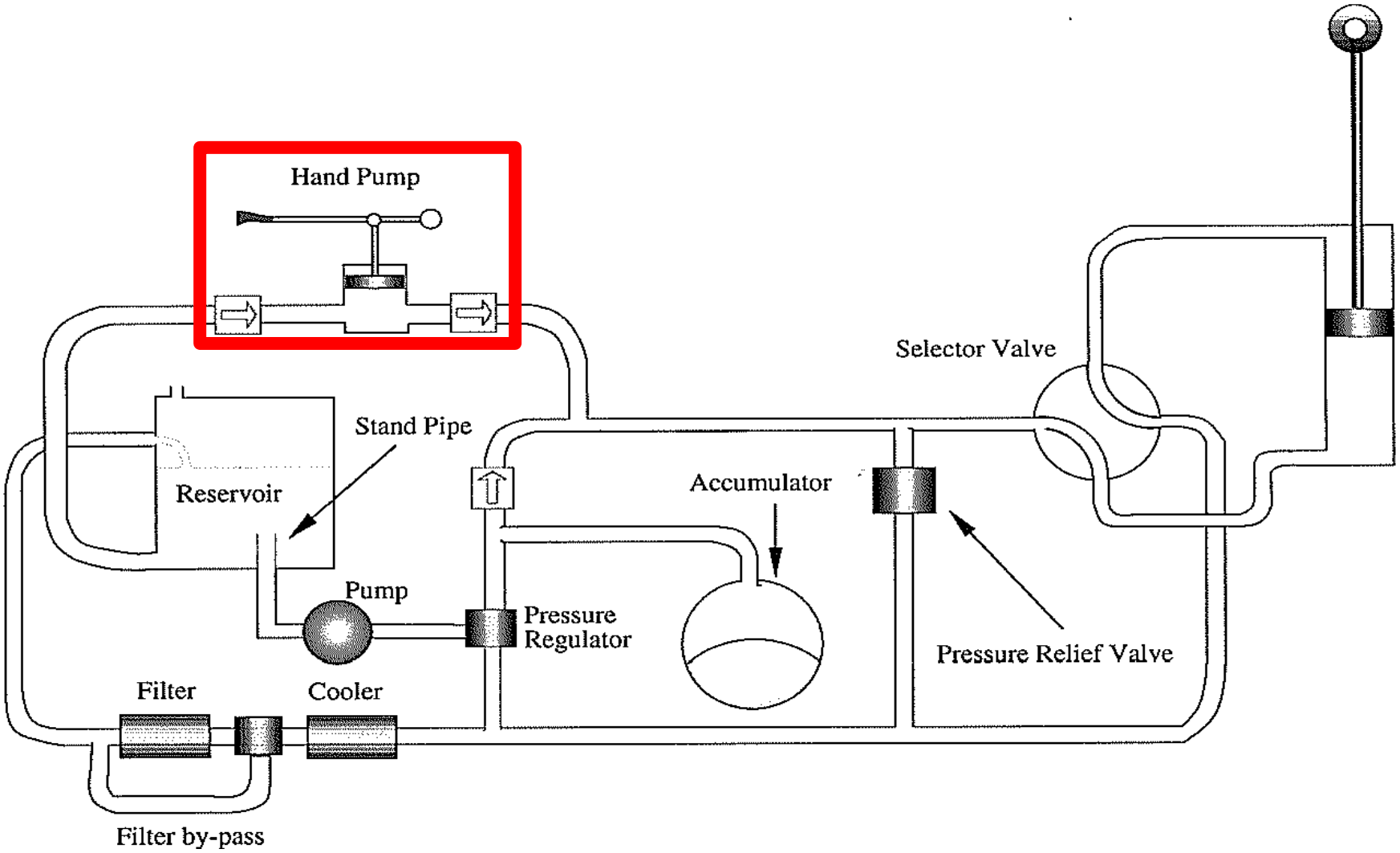
Pressure Regulator

- When the pump is a Constant Displacement type, oil is continuously being pumped under pressure through the system
- This means that when the system is not required to operate, oil may build up in the hydraulic leads
- When the pressure reaches a pre-set value, a spring-loaded valve will open to allow excess fluid to return to the reservoir

Pressure Relief Valve (PRV)

- Back-up valve in case the Pressure Regulator fails - will be set to tolerate a higher pressure than the Pressure Regulator
- If the pressure becomes excessively high, the valve will open and oil will return to the reservoir
- Also known as a **"system relief valve"** as it releases pressure through the entire system, whereas the regulator only unloads the pump

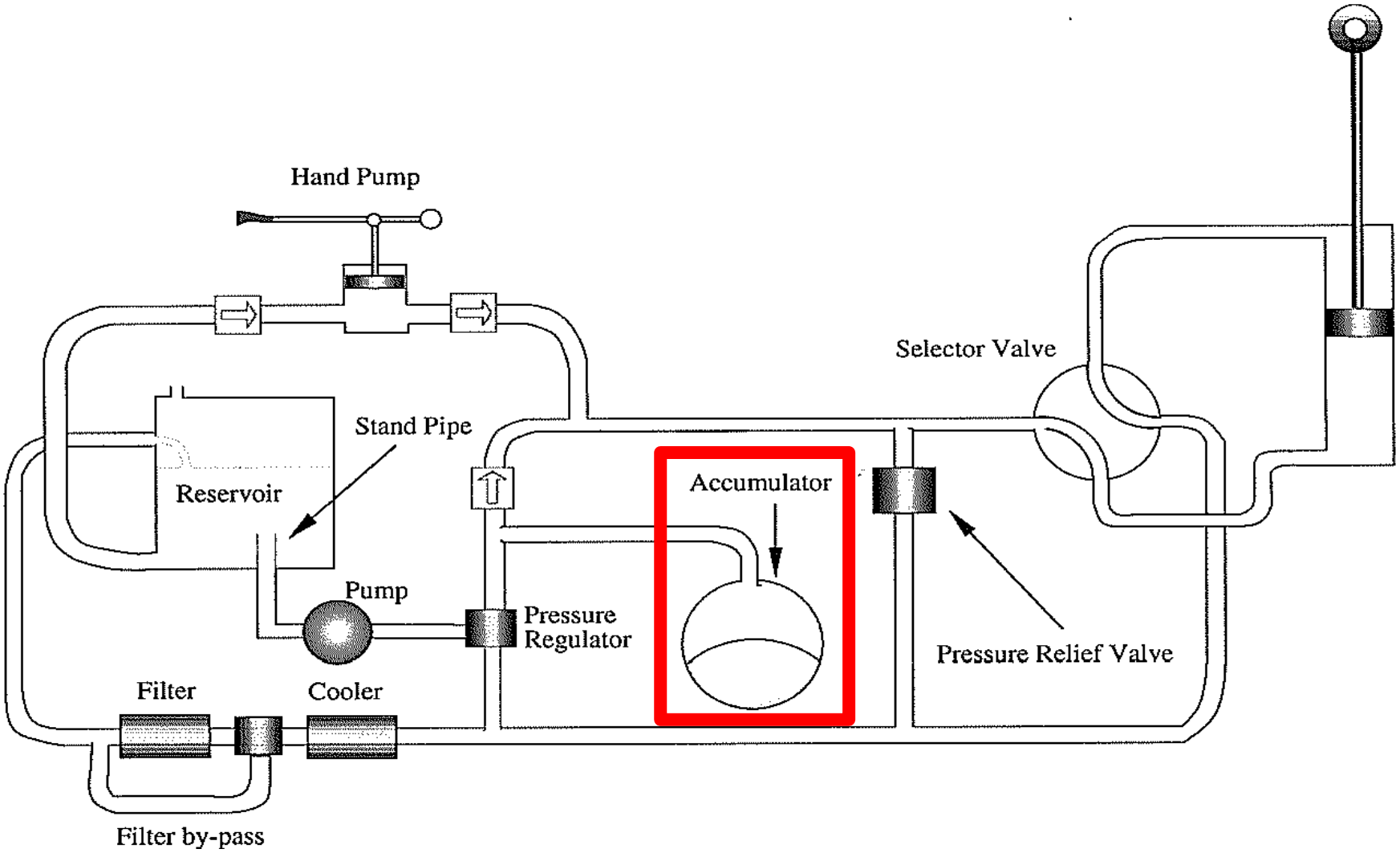
Hydraulic System



Hydraulic System – Hand Pump & Check Valves

- If the hydraulic pump fails, an emergency hand-operated pump is provided
- This is connected to a wheel or lever in the cockpit which must be **manually operated by the pilot**
- Retractable undercarriages and flaps commonly have a hand pump system for emergencies
- **Check valves** in the hydraulic leads ensure that oil flows in one direction only as pumping occurs
- As you can imagine, the hand pump requires a longer amount of time for full travel of the ram

Hydraulic System



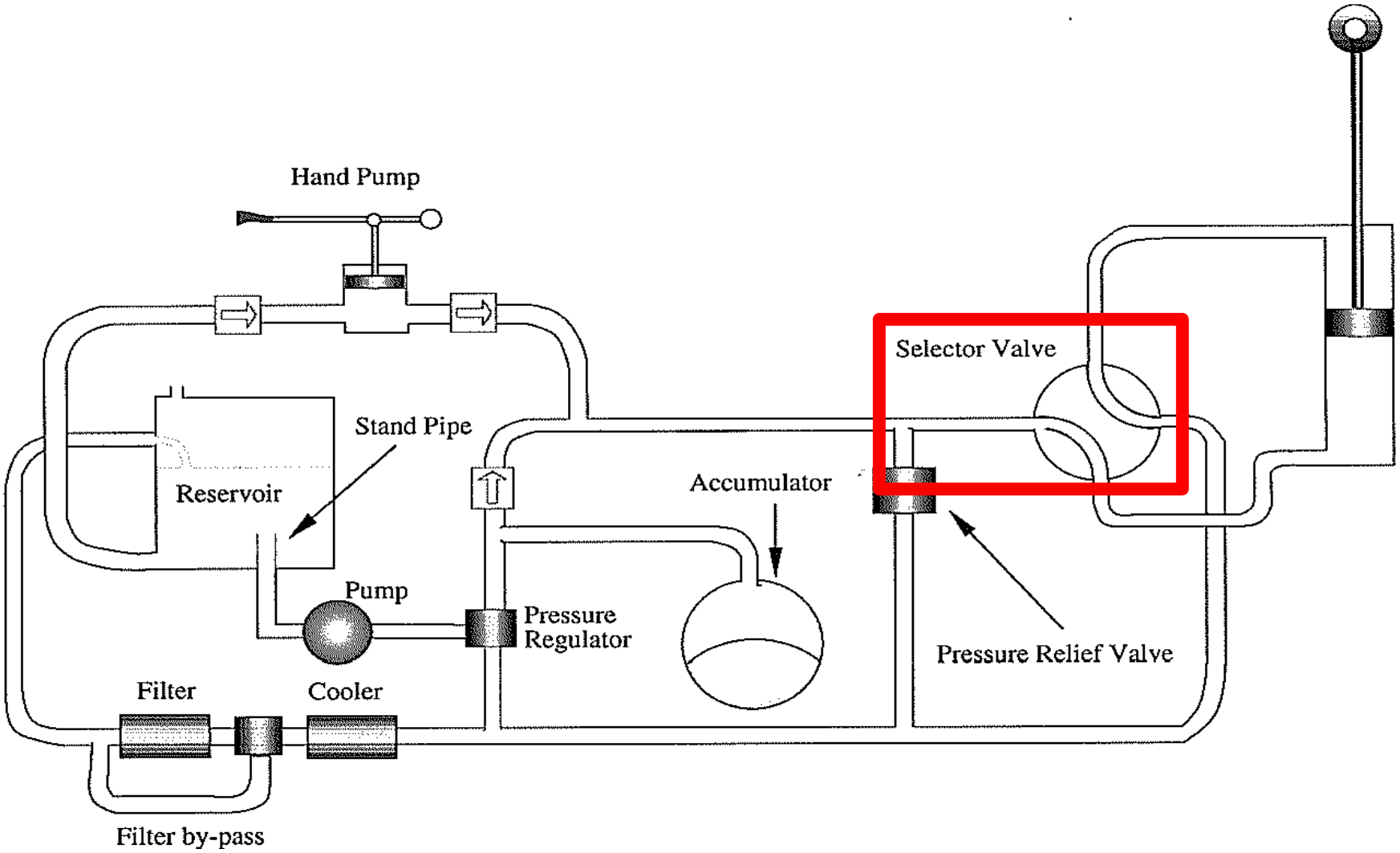
Hydraulic System – Accumulator

- Located between the pump and the actuator
- Stores oil under pressure for the following purposes:

  1. **To assist the pump when system demand is high**
  2. **To provide a limited source of pressure if the pump fails**
  3. **To smooth out the operation of the system and reduce noise by absorbing shocks and surges of oil**

- The accumulator is actually split into 2 halves – one half is a flexible **diaphragm**
- When the diaphragm is inflated with a compressed gas, the oil inside the other half of the accumulator is pressurised and becomes ready for use

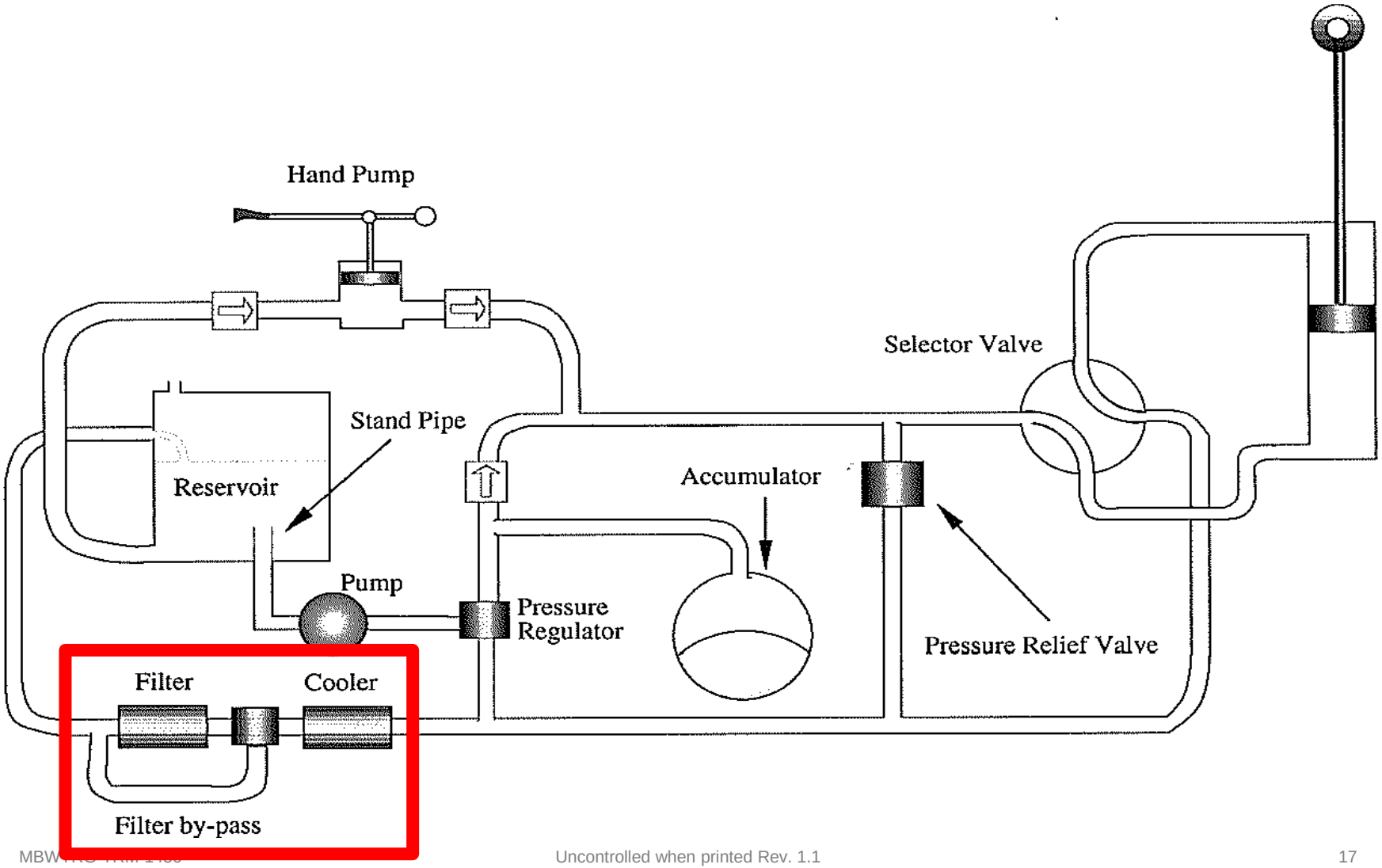
Hydraulic System



Hydraulic System – Control Valve

- The control valve directs oil to a particular side of the piston
- Rotating the control valve directs the oil from the pump to the other side of the piston
- This applies a force in the opposite direction and moves the ram connected to the aircraft component the other way
- This means that hydraulic systems are capable of operating in either direction with equal power

Hydraulic System



Hydraulic System – Other Components

Cooler

- Larger systems require a cooler which is placed in the return line to the reservoir

Filter

- The system must be kept free of all impurities, including solid particles and sludge
- A dirty system will restrict fluid flow and wear down seals
- Most systems will also have a filter bypass
- If the filter becomes blocked, the bypass valve will open and allow fluid to continue to circulate through the system – dirty fluid is better than no fluid

Hydraulic System – Other Components

Alternate System

- Some systems may have a secondary power pump and reservoir for redundancy

- If the primary pump fails, a **shuttle valve** opens, allowing the 2nd pump to operate

Flow Restrictors

- On larger aircraft, the hydraulic system powers more than one component

- Restrictors are used to restrict the volume of fluid flowing to a particular system e.g. the undercarriage may require more fluid for operation than the flaps

HYDRAULIC FLUIDS

Hydraulic Fluids

- As well as supplying the pressure required to move hydraulic components, hydraulic fluid also lubricates and cools the pump and actuating system

- Desirable properties of hydraulic fluids include:

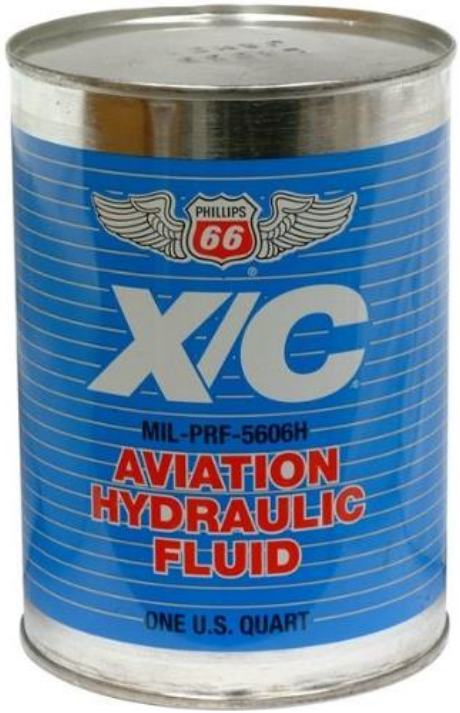
  1. Low compressibility

  2. Low volatility (little change in viscosity)

  3. Non-corrosive

  4. High flash-point (fire resistant)

  5. Material compatible



- Most hydraulic fluids are oil or water based but chemical compounds may also be used

Hydraulic Fluids

Vegetable-Based

- Can be employed in systems where rubber seals are used (material compatible)
- Not widely used as they can form a “sludge” which causes blockages and corrosion

Mineral-Based

- Made from petroleum and usually coloured red to distinguish from other oils
- Cannot be used with rubber seals
- (not material compatible)
- Widely used as they meet all desirable properties of a hydraulic fluid

Synthetic

- One synthetic fluid known as “Skydrol” is widely used for large jet aircraft
- Meets all desirable properties of a hydraulic fluid and is virtually non-flammable
- Can only be used in systems designed for its use

HYDRAULIC SYSTEM FAULTS

Hydraulic System Faults

Air in the System

- Air may be sucked into the hydraulic leads through faulty seals
- This means the pump may overheat as there is not a constant flow of fluid for lubrication and cooling

A Leak in the System

- Pistons which have just been actuated may return to their original position
- An extreme leak may result in malfunction of some components

Low Accumulator Pressure

- This means the pump must do all the work – resulting in slower operation
- Reduction in emergency supply of fluid in the event of a pump failure
- Reduced dampening of pressure surges and shocks

HYDRAULIC BRAKING

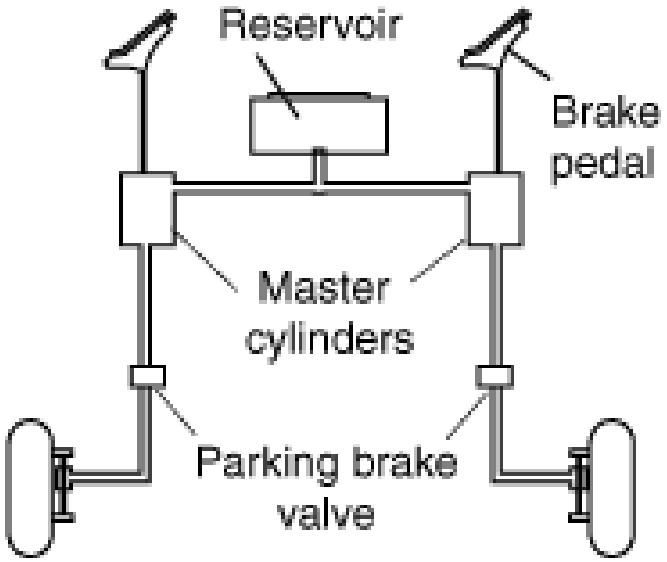
Hydraulic Braking

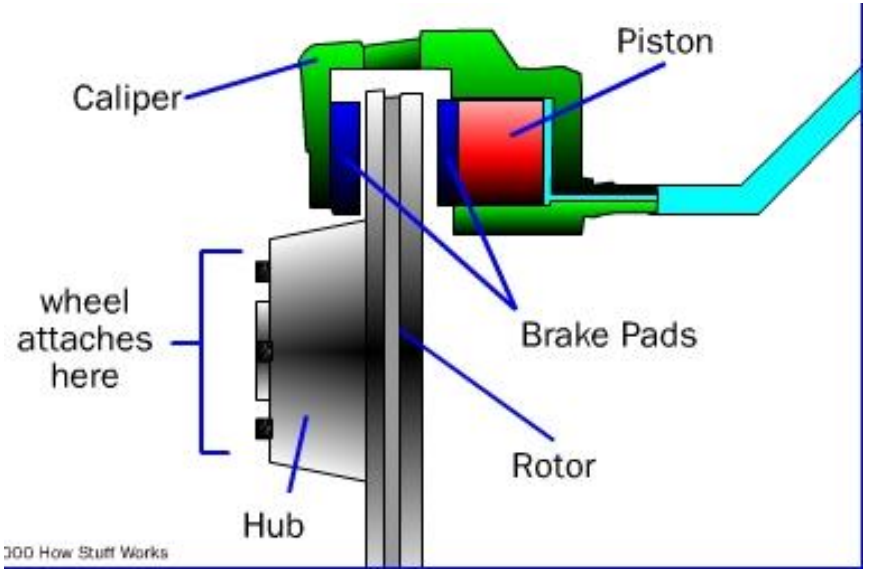
- In most light aircraft, wheel brakes are usually hydraulically operated disc brakes
- Each **toe pedal** controls the brake of each respective wheel – **differential braking**
- They can also be used together to provide straight line braking
- This supplements **nosewheel steering**, where pressing the left rudder pedal turns the nosewheel and therefore the aeroplane to the left
- The combination of differential braking and nosewheel steering allows for tight ground manoeuvring and braking whilst turning

Hydraulic Braking

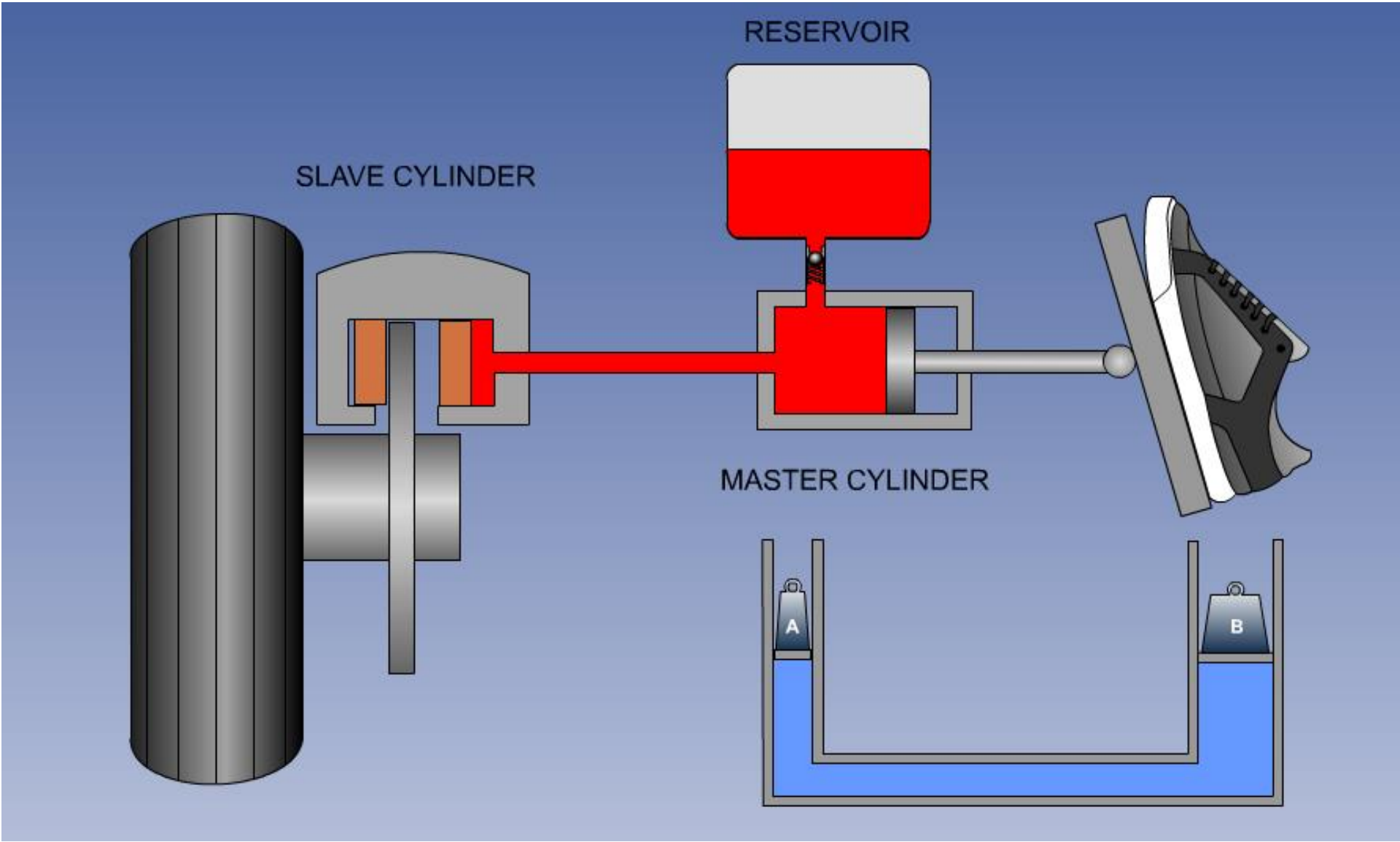
The braking system works as follows:

- A reservoir supplies brake fluid to **master cylinders** (1 for each toe brake)
- When a toe brake is pressed, the pressure is transmitted via the hydraulic fluid from the master cylinder to the **slave cylinder**
- Inside the slave cylinder, the pressure causes **callipers** to clamp a set of **brake pads** onto the **disc**, which is part of the wheel assembly
- When the toe brake is released, the pressure is released and the wheel allowed to rotate freely again

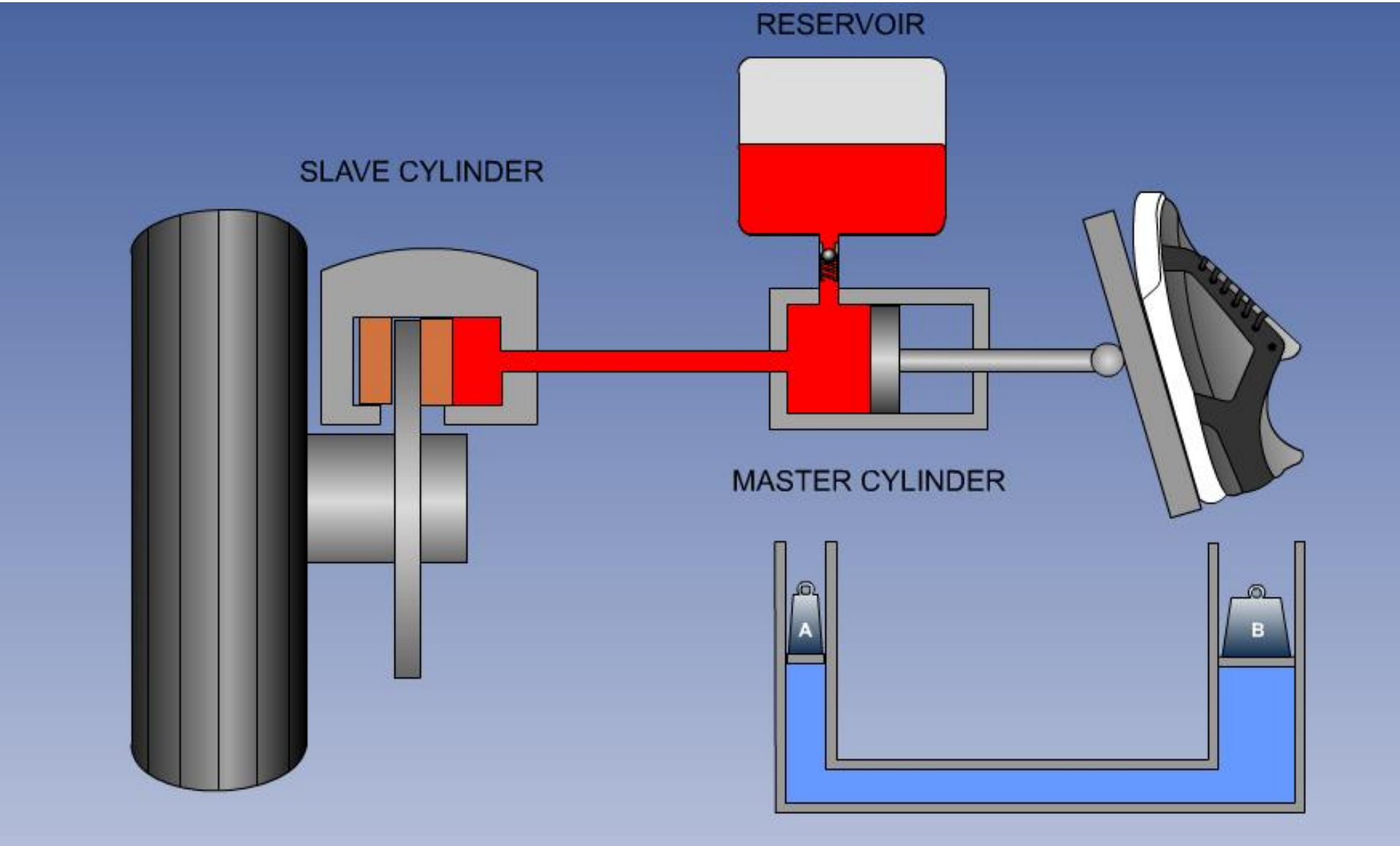




Hydraulic Braking



Hydraulic Braking



Hydraulic Braking

- It is important to not “ride the brakes” as this will wear out the brake pads
- You may also encounter the following abnormalities:

A Leak in the Brake System

- A leak will cause fluid to be lost, especially when pressure is applied to the brake
- The initial application of brakes will feel normal but as fluid levels decrease, **effective braking will reduce**
- Eventually, pushing the brake even to its full travel may not produce any braking

Air in the Brake System

- Air bubbles may be sucked into the master cylinder and through the brake lines
- As air is compressible, **the brakes will feel “spongy”**
- Effective braking will be reduced and the system must be “bled” of all air

Hydraulic Braking

- Pilot action in relation to the above abnormalities should include:

1. A test of the braking as soon as the aircraft begins to move

2. Do not take the problem into the air

3. The park brake may be used as brakes in some aircraft

UNDERCARRIAGE SYSTEMS

Undercarriage Systems

- Undercarriages come in two main configurations:
  1. **Nose-Wheel (Tricycle) – CoG is ahead of the main wheels**
  2. **Tail-Wheel (Tail-Dragger) – CoG is behind the main wheels**

- All undercarriage systems feature main wheels which are strongly built to carry the loads of landing and take-off and taxi over rough surfaces

- The tail or nose-wheel is not as strong as the main wheels and cannot withstand as high a load

- Most undercarriage systems feature some form of shock absorbing device to protect the airframe and people on-board from excessive vibration and shocks

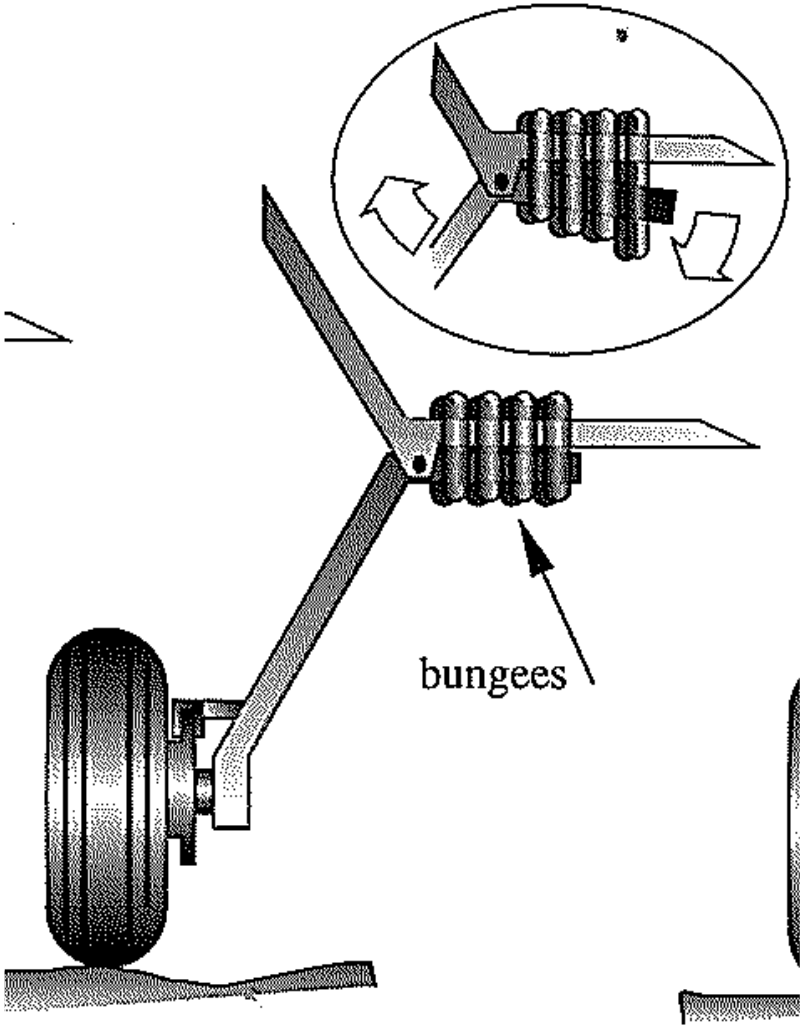
- Common shock-absorbing systems include:
  1. **Spring Steel Struts**
  2. **Bungee Cords**
  3. **Oleo-Pneumatic Struts**

Undercarriage Systems

Bungee Cords

- Large elastic bands attached to the landing gear struts

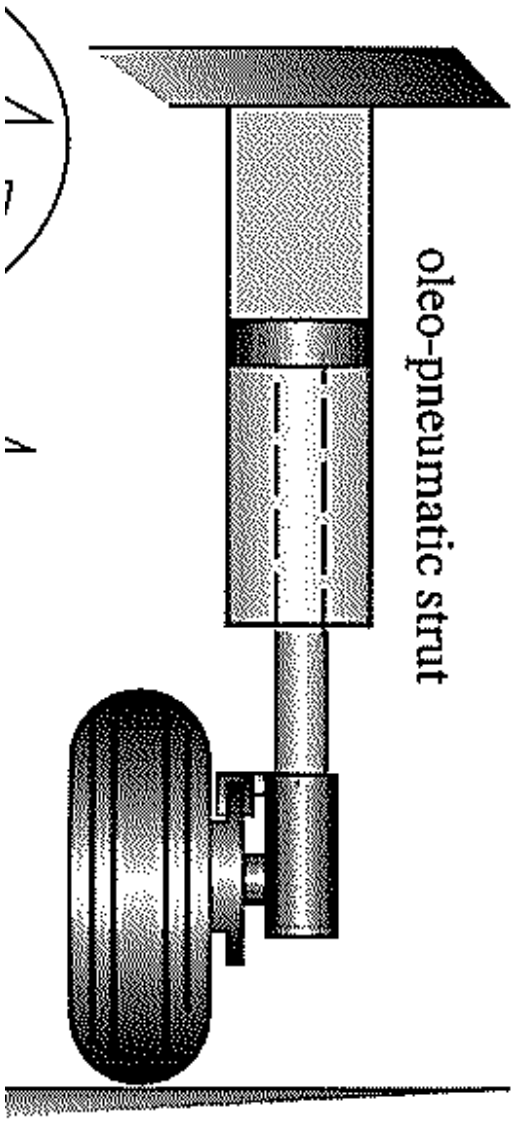
- Absorb shocks by stretching under a load



Undercarriage Systems

Oleo-Pneumatic Strut

- Often just called an oleo strut
- A piston acts against a compressed gas and oil inside a cylinder
- The gas (usually **nitrogen**) absorbs most of the shocks
- The oil smooths out operation and prevents excessive bouncing



Undercarriage Systems

Oleo-Pneumatic Strut

- If unrestricted, the wheel is actually free to rotate inside the cylinder, meaning an aircraft may land with a wheel in the wrong orientation!

- A **torque link** is fitted to prevent it from turning to the left or right

- It is the torque link that also allows the nose wheel to be steered on the ground through the rudder pedals in aircraft fitted with nose wheel steering

- The torque link flexes like an elbow joint as the piston moves up the cylinder during periods of high load

Undercarriage Systems

Oleo-Pneumatic Strut

- Oleos may also develop a rapid vibration known as **"shimmy"**
- This can place severe stress on the nose wheel assembly
- A shock absorber known as a **shimmy damper** is fitted to reduce these vibrations
- Over time, the pressure in the shimmy damper will reduce, increasing vibration

- To reduce load on the nose wheel, it is good practice to maintain backpressure on the controls when possible
- The oleos should be inspected for proper inflation before flight – there should be a minimum length of polished steel shaft visible when the aircraft is parked

Undercarriage Systems – Retractable Gear

- Many aircraft are equipped with retractable undercarriage systems which allow the wheels to be fully or partially hidden away in the fuselage

- This will **reduce parasite drag** during flight, but also **increase weight**

- The system is usually **electrically** or **hydraulically** powered, but can also be powered pneumatically.

- Retractable systems vary greatly between aircraft and you should consult the POH for full details on any one system

- Some features which are common to all systems include:

    1. **Downlocks**
    2. **Squat Switches**
    3. **Uplocks**
    4. **Gear Position Indicators**

Undercarriage Systems – Retractable Gear

Downlocks

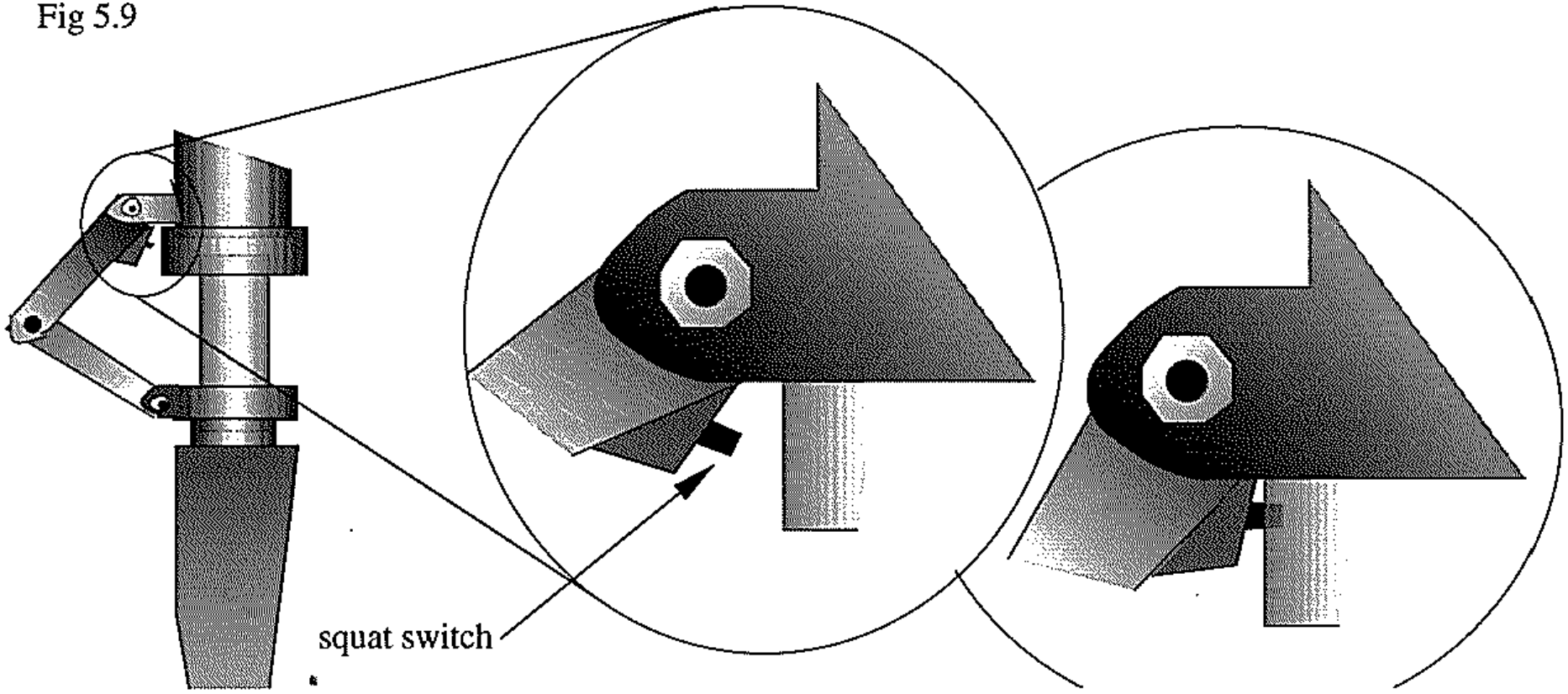
- Designed to lock the landing gear in the down position – retraction is not possible unless selected by the pilot
- Often mechanical latches that move into place at the end of the extension cycle

Squat Switch

- A squat switch may be located on the gear assembly
- When weight is on the wheels (i.e. when the aircraft is on the ground), the switch will be depressed
- This prevents the undercarriage from retracting accidentally on the ground
- Even if the pilot selects “gear up,” the undercarriage will not retract

Undercarriage Systems – Retractable Gear

Fig 5.9



Undercarriage Systems – Retractable Gear

Uplocks

- Similar to downlocks – mechanical latches that lock the gear in the "up" position

Gear Position Indicator

- The successful extension of the gear is usually indicated by **"3 greens"** in the cockpit
- These are 3 green lights that will illuminate when their respective wheel is down and locked
- If a light does not illuminate – the wheel may not be down and locked properly
- However, the fault may be in the green light bulb – a test feature for the lights is provided for this purpose
- In some aircraft, including the PA44, the green lights may also appear off in the daytime when the nav. or cockpit lights are on – this is to reduce glare at night time

Undercarriage Systems – Retractable Gear

Gear Position Indicator

- Many systems also have a “gear unsafe” warning horn/light

- If the throttle is closed beyond a certain point – usually in the approach range, a microswitch on the throttle may cause the “gear unsafe” indication to activate

- This is to help prevent an approach commencing without the gear being selected down