SYSTEMS 1 – AIRCRAFT STRUCTURES & AERODYNAMIC LIMITATIONS

STRESSES

- **Load per cross sectional area.**

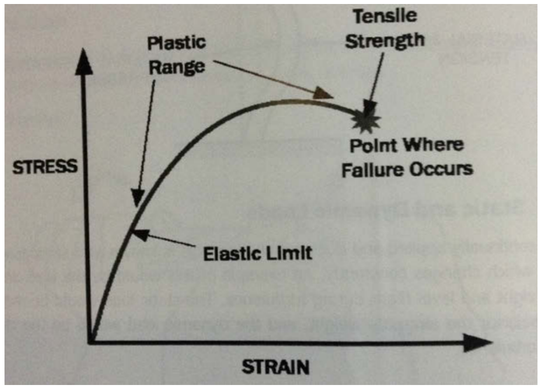
- **Tension** (tensile stress) – EG/ fuselage
- **Compression** – EG/ top of wing
- **Shear** (cutting) – EG/ wing root bolts
- **Torsion** (twisting)
- **Bending –** Compression + Tension + Shear
- **Buckling –** Uneven compressive load

TYPES OF LOADS

- **Static –** Continually applied, no change.
- **Dynamic –** Constantly changes
- **Cyclic –** Continually applied and removed.

STRAINS

- Strain is **deformation** due to stress.
- Initially proportional to stress and will return to original shape.
- **Plastic deformation -** Once **elastic limit** is exceeded, stretching will continue but will not return to original.



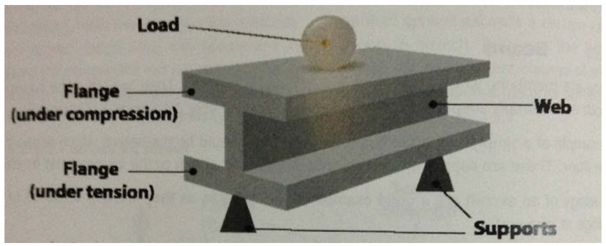
TENSILE STRENGTH

- Even more stretching after the elastic limit will cause the material to neck (get thinner).
- Stress increases since the cross sectional area reduces.
- **Just before failure**, the material has maximum strength per unit of cross sectional area. This is the **tensile strength.**

BASIC STRUCTURAL MEMBERS

BEAMS

- They can be either **simply supported** (both ends) or be **cantilever** (one end only).
- They are subject to bending with one side in tension and the other in compression.
- Beams in aircraft are usually an I / H section and the same strength as a whole beam is possible due to interaction of compression and tension (but it is of course lighter).



BEAM MOMENTS

- Moment = Force x Distance
- Max bending moment on a wing occurs at the root due to furthest distance from load.
- Support is thicker and end is thinner – thus saving weight.

STRUTS

- Struts are designed to withstand mainly **compressive loads.**
- Tend to buckle under load before failure.
- Normally hollow.

TIE

- Ties are designed mainly to withstand **tensile loads.**
- Normally constructed of solid rod or a wire of relatively small diameter.

SYSTEMS 1 – AIRCRAFT STRUCTURES & AERODYNAMIC LIMITATIONS

THE FUSELAGE

THE FUSELAGE

- Accommodates crew and payload
- Supports other components of the aircraft.
- Subject to a number of stresses in flight:
  - Nose and tail droop down causing tension on top and compression underneath.
  - Compounded by tail exerting downforce

TRUSS TYPE FUSELAGE

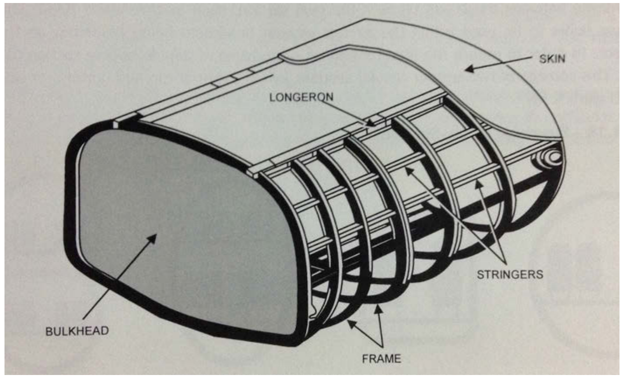
- Frame supports the load, skin is merely to cover and reduce drag.
- **Longerons** run longitudinally and provide the main load bearing.
- Supported both vertically, horizontally and diagonally with **web members** to give complete rigidity.
- No space for payload so mainly on light aircraft.

MONOCOQUE FUSELAGE

- Skin takes all the load.
- No internal load bearing structure although **former rings** sometimes fitted to give shape.
- No ability to add doors etc otherwise ability of skin to withstand stress is destroyed.

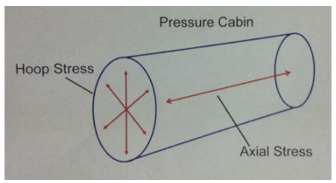
SEMI - MONOCOQUE FUSELAGE

- Majority of stress dissipated by internal components and very little by the skin.
- Gives a strong, relatively light structure with lots of space.
- **Longerons –** Longitudinal (Main stresses)
- **Frames –** Vertical (Stress + gives rigidity)
- **Stringers –** Support the skin
- **Bulkheads –** Airtight for pressurisation



HOOP STRESS

- Large forces which push the fuselage outwards as a result of **pressurisation.**
- Tension in frames.
- Bending in longerons, stringers and skin.



FUSELAGE TYPES

- **Circular**
  - Good for containing hoop stress
  - Lowest amount of skin drag for volume
  - Bad for space
- **Rectangular**
  - Max use of space
  - Bad for pressurization
  - Used in light a/c and non pressurised transporters.
- **Oval**
  - A380 Design
  - Good use of space
  - Best compromise for pressurisation
  - Requires very strong floor beams.
  - **Double bubble** section can be used to reduce total tension on each frame.

PRIMARY VS SECONDARY STRUCTURE

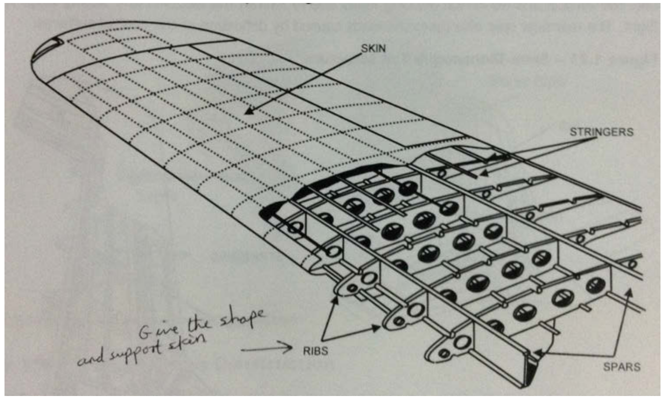
- **Primary** - A critical load-bearing structure.
- **Secondary –** Structural elements mainly to provide enhanced aerodynamics.

SYSTEMS 1 – AIRCRAFT STRUCTURES & AERODYNAMIC LIMITATIONS

THE WINGS / MAINPLANE

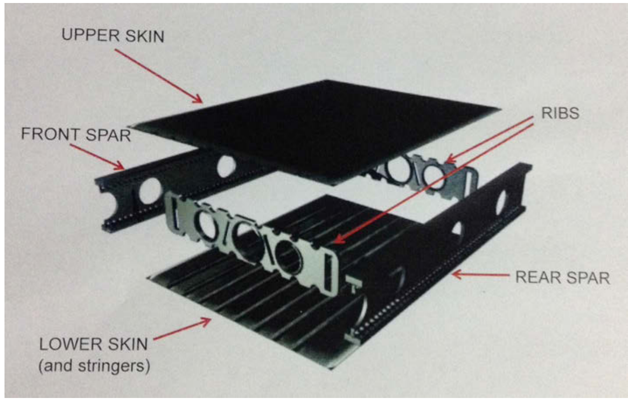
THE WINGS

- Semi-monocoque design
- **Spars** – Withstand bending and torsional loads
- **Ribs** – Gives shape. Holes make it stronger and lighter.
- **Stringers –** Support the skin.
- **Centre spar** can also be included to supported undercarriage etc.



TORSION BOX

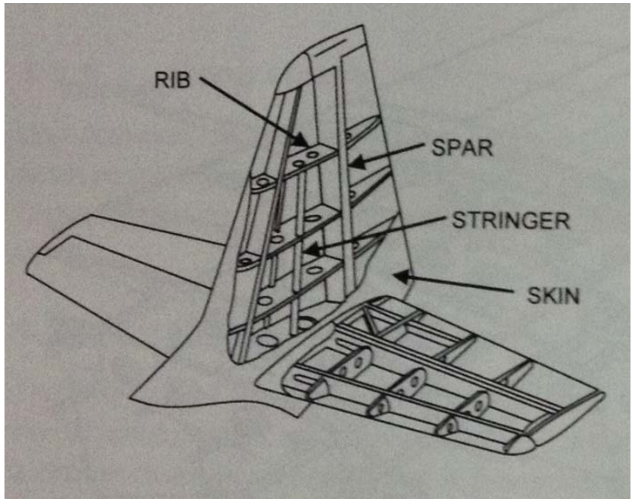
- Supporting the **twisting** motion of lift of the wings.
- **Links** the spars, skins and ribs.
- One in **each wing** plus a **centre spar** to link the two wings.
- Wing torsion can result from positive sweep



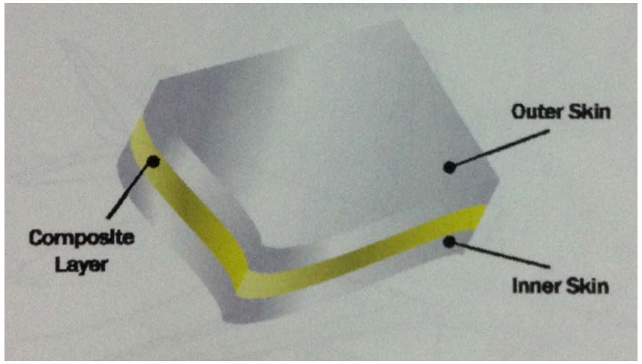
THE TAIL

TAIL SECTION

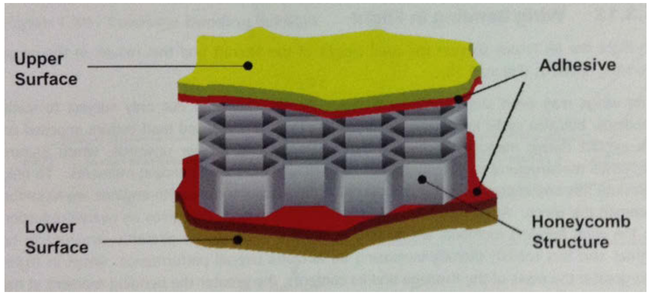
- Semi-monocoque design



SANDWICH TYPE CONSTRUCTION



HONEYCOMB CONSTRUCTION



SYSTEMS 1 – AIRCRAFT STRUCTURES & AERODYNAMIC LIMITATIONS

WING BENDING ON GROUND

- Wings and undercarriage on ground are subject to heavy loads so the **Maximum Ramp Mass** is set to limit stress.

WING BENDING IN FLIGHT

- Lift acts to bend wings upwards.
- Fuel and engines help to reduce bending.
- The greatest bending moment at the wing root occurs with high fuselage mass and zero fuel (wings bending up). The **maximum zero fuel mass** is therefore set to limit stress.
- The leading edge is subject to compression then tension (from root to tip)

FUSELAGE BENDING IN FLIGHT

- Bending moment around fuselage due to **download** on the horizontal stabiliser to counteract the lift-weight couple.

AIRCRAFT STRUCTURAL MATERIALS

- **Aluminum Alloy**
  - Raw aluminum lacks strength + rigidity
  - Mixed with 4-6% copper = Duralumin
  - Good conductor and improved strength
  - Difficult to weld & good thermal conductivity
- **Magnesium Alloy**
  - Lightweight but lack strength and are brittle.
  - Easily moulded into complex shapes
  - Used in gearbox casing and wheel rims
- **Steel**
  - Bolts etc
  - Carbon added to improve load bearing
  - + chromium = stainless steel
- **Titanium**
  - Very resistance to high temperatures
  - Turbines etc
- **Plastic**
  - Easy to mould but has poor strength.
  - Interiors
- **Fibre Reinforced Plastics (FRPs)**
  - Layers of fibres (glass, Kevlar, carbon) provide the strength and the filler gives the stiffness.
  - CFRP = Carbon Fibre
  - KFRP = Kevlar
  - GFRP = Glass

ATTACHMENT METHODS

- **Riveting**
  - Can be flush or round headed
  - Flush type is more aerodynamic but more expensive.
  - Cracks can originate at rivet points.
- **Bolts**
  - Allows for separation of materials when required.
  - Vibrations can cause nuts to become loose. This is prevented by wire locking.
- **Welding**
  - A very tough bond is created.
  - Load spread over a large area.
- **Pinning**
  - Good for attaching components that experience shear stress.
  - Can be undone at a later date.
- **Adhesives**
  - Easy to use and can bond large areas.
  - Permanent and have relatively low mechanical strength.

SYSTEMS 1 – AIRCRAFT STRUCTURES & AERODYNAMIC LIMITATIONS

DESIGN LIMIT LOAD (DLL)

- Max load a designer thinks a component will be subjected to in the normal lifespan of the aircraft.

DESIGN ULTIMATE LOAD (DUL)

- DUL = 1.5 x DLL
- Components are designed not to fail until this load is reached.
- Gives an extra 'safety factor'
- Must still remain substantially intact after experiencing this load.

FATIGUE

- High repetitive / cyclic stress may cause a small crack which will get bigger over time.
- As cross section is reduced, the stress increases to a point where a sudden fracture will occur. This is **fatigue failure.**
- The greater the magnitude of the cyclic stress, the earlier failure will occur.
- **Fatigue life** is the number of cycles left in a component.

OXIDATION

- **When a substance mixes with oxygen in the air to form a different substance.**
- **Corrosion –** When metal mixes with oxygen

- Can be accelerated by **moisture.**
- **Electrolytic oxidation** – Accelerated by a flow of electrons due to two dissimilar materials touching each other.
    - Prevented by bonding.

DESIGN PHILOSPHIES

SAFE LIFE

- Each component tested to destruction and a safety factor then applied.
- All components must be replaced when they reach the safe life number of cycles.
- Requires lots of aircraft downtime.

FAIL SAFE

- More load bearing members than required are installed to give redundancy in the event of failure.
- Large increase in weight.

DAMAGE TOLERANT

- Compromise between safe life and fail safe.
- Components are made **thicker and stronger** than required so they still have the required strength if damaged / fatigued / corroded.

CABIN WINDOWS

- Two panes of laminated glass separated by an air gap.
- Lamination increases resistance to stress.

COCKPIT WINDOWS

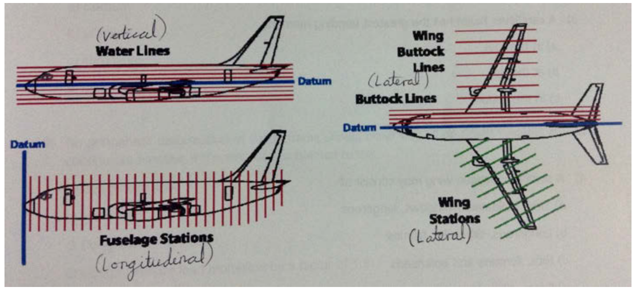
- 3 layers of glass separated by 2 layers of polythene.
- Iridium heating layer also used:
    - Prevents glass breaking from its brittle nature at low temperatures.
    - Anti-Ice

SYSTEMS 1 – AIRCRAFT STRUCTURES & AERODYNAMIC LIMITATIONS

AIRCRAFT DOORS

- **Inwards opening** so when cabin is pressurised they cannot be opened.
- Unpressurised doors will open outwards but **hinges are on the forward edge** so airflow keeps them almost shut in case they are opened.

POSITION REFERENCING



CLASSIFICATION	PROBABILITY	CREW WORKLOAD	PAX EFFECTS	SAFETY MARGINS
MINOR	FREQUENT / REASONABLY PROBABLE (10^{-3})	Slight Increase	Physical Discomfort	No effect / slight reduction
MAJOR	REMOTE (10^{-5})	Significant Increase	Physical Distress (Inc Possible Injuries)	Significant reduction
HAZARDOUS	EXTREMELY REMOTE (10^{-7})	Excessive Workload (Inc Physical Distress)	Serious or fatal injury to small number of pax	Large reduction
CATASTROPHIC	EXTREMELY REMOTE (10^{-9})	Multiple fatalities		Possible hull loss

SYSTEMS 2 – HYDRAULICS

PASCALS LAW

- **If a force is applied to a liquid in a confined space, then this force is felt equally in all directions.**
- Fluid is not compressible.

CONVERSIONS

- **1 inch = 2.54 cm**
- **1 lbs = 0.454 kgs**
- PSI (lbs / inch^2) is used in aviation

MULTIPLACTION OF FORCES

- Changing the area of pistons will give us a **multiplication of forces.**
- A system with greater PSI will allow a smaller area to be used.

ADVANTAGES OF HYDRAULIC SYSTEMS

- Multiplication of forces
- Flexibility
- Compact
- Economical
- Remotely controlled surfaces

DISADVANTAGES OF HYDRAULIC SYSTEMS

- Expensive
- Risk of leakage
- Susceptible to contamination

HYDRAULIC FLUID PROPERTIES

- Incompressible
- Low viscosity (flows easily)
- Good lubrication properties
- Remains liquid over a large range of temps
- Fire resistant
- Prevent corrosion

MINERAL BASED FLUIDS

- **Red** in colour
- Used in **military / turboprops**
- Good lubrication
- Good corrosion prevention
- Not prone to foaming

SYNTHETIC BASED FLUIDS

- **Purple / green / amber** in colour
- Used in **commercial aircraft**
- A.KA Skydrol / Phosphate Ester Based
- Less prone to cavitation
- Reduced fire risk (assume none)
- Can withstand higher pressures

FLUID TYPES CANNOT BE MIXED

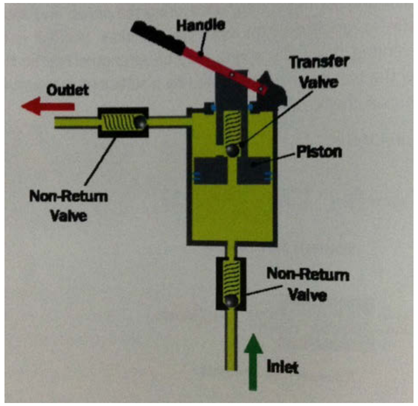
- **Seal damage**
- **Internal leaks**
- **Reduced efficiency**

SINGLE ACTING HAND PUMP

- Does not provide a continuous flow as pump needs to be refilled after every stroke.

DOUBLE ACTING HAND PUMP

- As piston moves up, fluid expelled via the top non-return valve and bottom non return valve allows fluid into bottom of cylinder.
- As piston move down, transfer valve opens and fluid is expelled via the top non return valve.
- Hand pumps used by ground personnel only.



SYSTEMS 2 – HYDRAULICS

PRESSURISED RESERVOIR

- Uses air from the **high pressure compressor** to pressurise the reservoir.
    - Connected to an air pressure regulator (APR) on the reservoir.
    - Downstream of the HPC an air – to – cooler is used along with a de-hydrator to remove moisture that results from cooling.
- Pressurisation prevents **cavitation.**
    - Formation of air bubbles due to low pressure which can damage the system.
- Pressurisation can also be achieved through a **piston** within the reservoir.
- **Variations** in fluid level caused by:
    - Actuator displacement
    - Thermal expansion
- When system is pressurised, level in the reservoir will fall.

SINGLE ACTING ACTUATOR

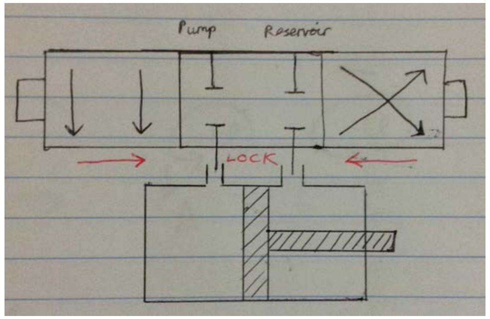
- **Fluid on one side** of the piston and a spring on the other.
- Most suited for when a force is only required in **one direction.**
- A selector valve is used to **extract / retract**

HYDRAULIC LOCK

- **Actuator Stationary + No Fluid Flow**

DOUBLE ACTING ACTUATOR

- **Fluid on both sides** of the piston.
- Significant force can bow be applied in **both directions.**
- A **4 port rotary selector** is used.
    - Solenoid used to move between the different positions.



BALANCED DOUBLE ACTING

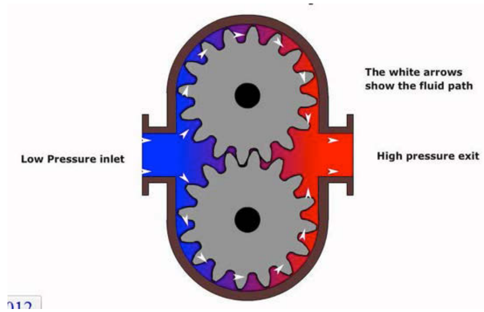
- **Volume differential** requires more fluid to move to the right compared with left.
- A **dummy piston rod** is fitted to balance.

TYPES OF PUMPS

- Hand
- Engine
- Electrical
- RAT
- PTU
- Air Driven Pumps

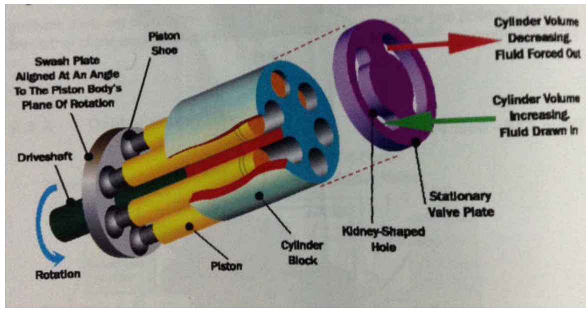
GEAR PUMP

- **Engine Driven**
- One of the gears is the 'driven gear'
- **Pressure differential** between gears forces fluid between the teeth cavities.
    - Increasing Volume = Low Pressure
    - Decreasing Volume = High Pressure



PISTON PUMP

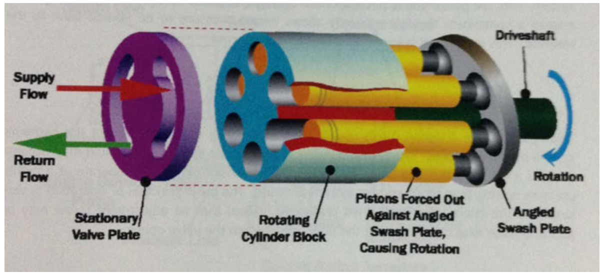
- **Constant Volume Engine Driven Pump**
- **AKA Constant Delivery Pump**
- Used in the main systems such as flight controls and landing gears.
- Has a **larger capacity** than gear pump.
- **Regulator (ACOV) required** as there is always a supply of oil into the system.



SYSTEMS 2 – HYDRAULICS

HYDRAULIC MOTOR

- Used for flaps and slats.
- High pressure supply (via a piston pump) is pumped in and converted into rotary movement.



PRESSURE RELIEF VALVE

- When system pressure **overcomes the spring tension** the valve opens.
- An **adjustment screw** is provided to prevent the ball floating (internal leakage).
  - Oil is forced through the narrow gap by the side of the ball causing a temperature increase.
- In isolated oil lines, this PRV acts as a **thermal pressure relief valve.**
  - Brake system, flap system etc

OPEN CENTRE SYSTEM

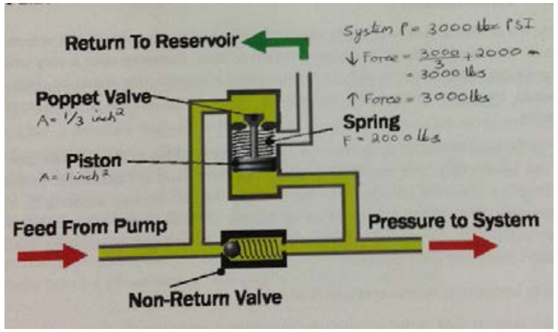
- Actuators in **series**
- Can only operate one at a time

CLOSED CENTRE SYSTEM

- Actuators in **parallel**
- Several can be operated at the same time

AUTOMATIC CUT OFF VALVE

- Required in a **closed centre** hydraulic system using a **constant volume** pump.
- **Regulates the system pressure** and routes fluid back to reservoir when there is no demand.
- The PRV acts as a 'back-up' in this case.
- An internal leak will cause the ACOV to cut in frequently.



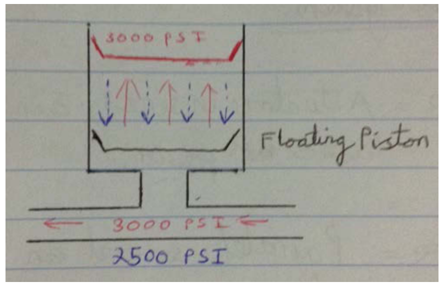
- **Insufficient pre-charge pressure causes:**
  - Reduced brake applications in the event of failure
  - Frequent ACOV operation
  - Pressure fluctuation + chattering

PRESSURE FILTER

- **Pressure Filter** – Supply filter located after the pump.
- **Scavenge Filter** – Return filter located before reservoir.
- Rated in **microns** (1 micron = 1/1000 mm) which is the smallest particle it will allow.
- A **pressure differential** builds up on the filter as particles are trapped.
  - Causes the bypass filter to open.
  - Tell tale button (for engineers) is popped plus a cockpit indication is given.

ACCUMMULATORS

- Works as an **energy storage**
- Removes the need for a pump so large to cope with **extremes of demand.**
- **Pre-charged to 1/3 SP with Nitrogen**
  - Compressible
  - Inert (no reaction with oil)
- A floating piston ensures the lines receive extra pressure when system pressure fluctuates or is not enough.
- Floating piston / bladder / diaphragm type



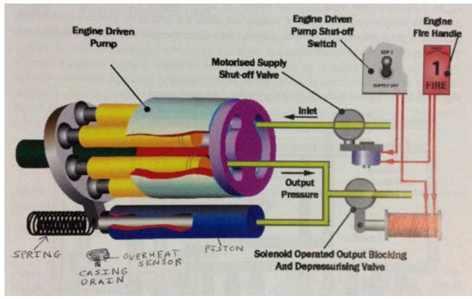
SYSTEMS 2 – HYDRAULICS

CONSTANT PRESSURE PUMP

- A.K.A **Variable Displacement Pump**
- Output pressure is also delivered to a piston.
- When pressure required is met, spring force is overcome and swash plates reduces angle (and hence output).
- Swash plate return to max angle when there is demand requiring an increase in output.
- **Removes the need for an ACOV.**
- A **casing drain** is used to monitor condition of the pump by collecting an oil sample.
    - Also includes an overheat sensor

ENGINE DRIVEN PUMP CONTROL

- Activation of the **fire handle** causes a solenoid to automatically block the output.
    - Pressure build up causes swash plate to lower its angle and reduce output until the engine stops.
- Activation of the **shut-off switch** blocks the inlet supply.
    - Allows the pump to be turned off without having to shut down engine.



TWIN ENGINE JET SYSTEM

- **3 Hydraulic Systems**
    - Blue
    - Green
    - Yellow (Emergency)
- Each has their own reservoir
- Fluid cannot be transferred between them.

DOUBLE ACTING TANDEN ACTUATOR

- Fed directly by **two systems** to provide redundancy in the case of failure.
- Used for the **critical systems.**

POWER TRANSFER UNIT

- Used to transfer power from one system to another **without exchanging any fluid.**
- Comprises of **two mechanically coupled hydraulic pumps.**
    - The pump in the good system acts as a hydraulic motor to allow the pump in the failed system to operate.

RAM AIR TURBINE (RAT)

- An emergency hydraulic pump.
- Power by a **constant speed turbine** suspended into the relative airflow.
- Used in the yellow system.

ELECTRICALLY DRIVEN PUMP

- Used to supplement the engine driven pumps if required.

PUMP PREFERENCES

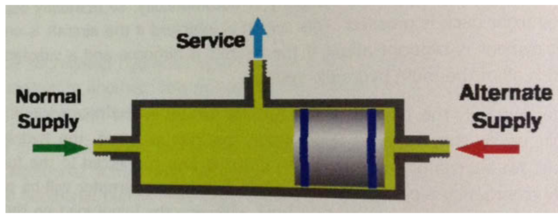
1. Engine Driven Pump
2. Power Transfer Unit
3. Electrically Driven Pumps
4. Ram Air Turbine

NON RETURN VALVE

- AKA **Check Valve**
- Flow stops when input press < output press
- Similar to an electronic diode (flow in one direction only)

SHUTTLE VALVE

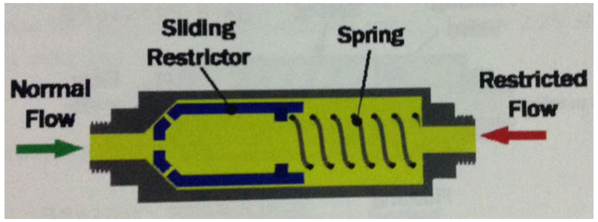
- **Allows two hydraulic sources to supply one service.**
- Will use the system supplying the **highest pressure.**



SYSTEMS 2 – HYDRAULICS

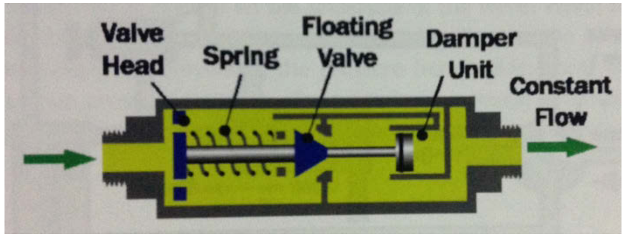
RESTRICTOR VALVE

- **Permits a full flow in one direction and a limited flow in the other.**
- Fitted to u/c up line (extension) and flap up line (retraction)



FLOW CONTROL VALVES

- Maintains a **constant flow** of fluid to an actuator required to operate at **constant speed.**

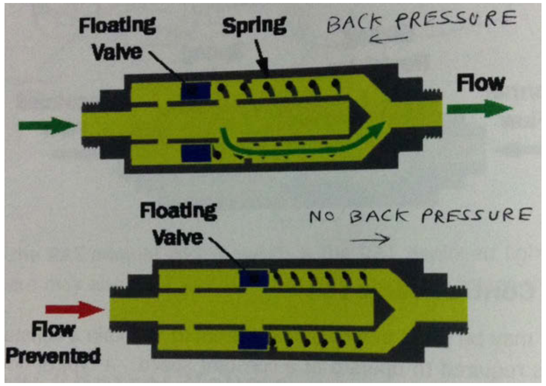


SEQUENCE VALVE

- **Ensures the correct order of operation** in systems such as the landing gear (undercarriage + door actuator).
- Hydraulic & Mechanical sequence valves are possible.

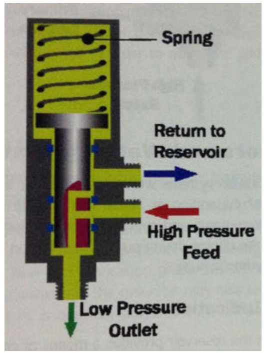
HYDRAULIC FUSE

- **Prevents a loss of hydraulic fluid in the event of a leak** occurring downstream of the fuse.



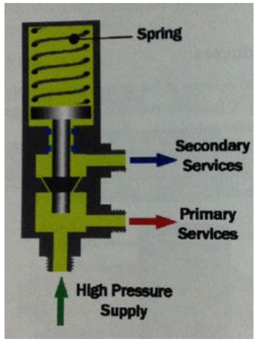
PRESSURE REDUCERS

- Not all systems are required to operate at full pressure.
- EG/ Autobrakes
- Can be adjusted in flight whereas PRV is fixed.



PRESSURE MAINTAING (PRIORITY) VALVE

- Will shut off hydraulic supply to non-essential services in the event of a significant reduction in system pressure.



PRESSURE RELAY

- Used in **older aircraft** that use a direct reading gauge such as a Bourdon Tube.
- **Prevents fluid from entering the cockpit** in the event of a fracture.
- Fitted between system and pressure gauge.

HYDRAULIC FLUID HEAT EXCHANGER

- Friction within the engine driven pump heats up the oil.
- Oil from the case drain is cooled before returning to the reservoir.
- Ram air or fuel may be used as the cooling medium, reducing total drag of the aircraft.

SYSTEMS 2 – HYDRAULICS

HYDRAULIC SEALS

- Shape used varies depending on **pressures** and **direction** from which the pressure is applied.
- U & V = Pressure from one direction
- O & Square = Pressure from both directions

HOSE ASSEMBLIES

- Part of the hydraulic system **most prone to failure.**
- **Bulge in hose** or an **oily residue** around the joints are sign of impending burst.

POWER PACK HYDRAULIC SYSTEMS

- Normally used in light aircraft where gear is the **only hydraulic system.**
- Pump is powered by a **DC electric motor.**
- Pump **only active for a few seconds** during extention / retraction.
- Load on engine and maintenance requirements are significantly reduced.

WORKING PRESSURE

- **The maximum steady pressure within a system under normal operating conditions.**

LIMIT PRESSURE

- **Anticipated max pressure acting on a components.**
- Includes a tolerance and any possible variations in normal operating modes but excludes transient pressures (due fluid hammer effects).

SAFETY FACTOR

- System must be designed to handle PW and PL loads multiplied by a safety factor.

LEAK IDENTIFICATION

- Internal Leak: Rise in temperature
- External Leak: Fall in reservoir level

THERMAL RELIEF VALVES

- Fitted to isolated lines.

OVERHEAT DETECTORS

- Can be installed at the pumps.

SYSTEMS 4 – LANDING GEAR

TAILDRAGGER DESIGN

- **Simple** and **lightweight**
- **Loading whilst tilted**
- **Reduced forward visibility**
- **Pitch down tendency** on braking
- **Group Loop**
- **Poor braking action** (due increased AoA on landing)

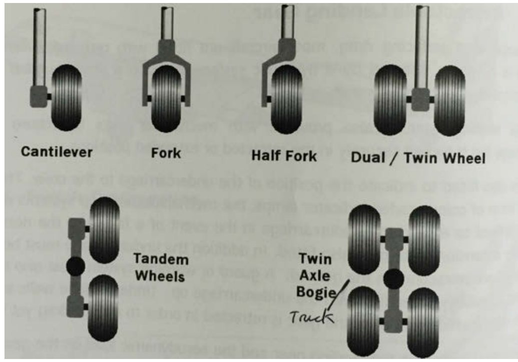
- Above are removed by the **tricycle design**

GEAR TYPES

Main | Body | Nose | Body | Main

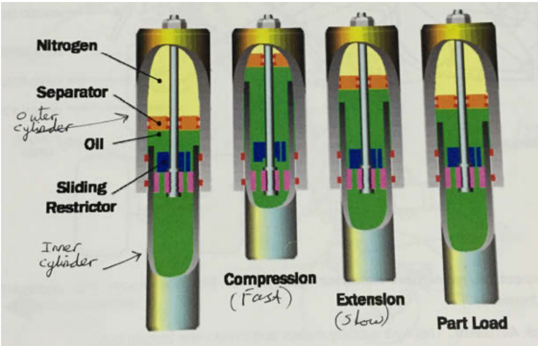
- **Main & Body = Braking**
- **Nose = Steerable** but **no braking**

GEAR ARRANGEMENTS



SHOCK ABSORBERS

- Provides **gradual vertical deceleration**.
- A.KA. **Ole-Pneumatic Strut**
- Consists of **Nitrogen** (pre-charged) and **Oil.**
    - Oil is the dampening agent. It limits the speed of extension and compression in the strut.
    - Nitrogen acts as a spring
- **Inner cylinder** is connected to the **wheel**
- **Outer cylinder** is connect to the **airframe**
- **Sliding restrictor** prevents bouncing
    - AKA Metering Orifice
    - Low resistance during compression
    - High resistance during extension
- **A separator** is normally present although not required.
    - Lighter, simpler and cheaper without
    - Oil and nitrogen mix however and damping ability reduced with cycles.



TORQUE LINKS

- **Prevents inner cylinder rotating within the outer cylinder**.
- Also **limits max entension** when in flight.
- **Bearings** required to enable smooth movement.
- A **ground / air safety switch** (squat switch) can be fitted to the torque link.
    - Prevents gear retraction on ground

SHIMMY DAMPER

- Shimmy is **oscillations during ground ops**
- Possible on both **main and nose gears.**
- **Causes of shimmy:**
    - Uneven tyre pressures
    - U/S shimmy damper
    - Work torque link bearings
- **Shimmy damper** connected to strut / toque link to reduce effects.

CENTERING CYLINDER

- Centres the landing gear after takeoff to ensure it fits within the wheel well.

STEERING CYLINDER

- Allows for **hydraulic steering.**
- Operated by **rudder pedals / tiller**

SYSTEMS 4 – LANDING GEAR

GROUND LOCKS

- **Prevent retraction** of gear when static on the ground.
- Must be **removed before flight.**

NOSEWHEEL STEERING

- **Tiller** provides greater deflection than rudder.
- 747 body gear also rotates in opposite direction to nosewheel.
- **NWS disconnect** allows powered steering to be turned off for push / tow.

UP-LOCK

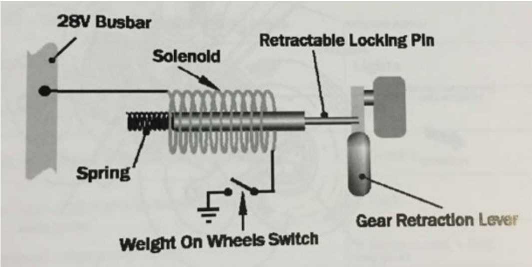
- **Hydraulically operated** uplock.
- **Spring "over-centre"** used to hold hook in a locked / unlocked position.

DOWN-LOCK

- **Hydraulically locked.**
- **Overcentre geometric lock** used.

ACCIDENTAL RETRACTION PREVENTION

- When weight comes off wheels, the switch is closed and a solenoid removes the locking pin from gear handle.
- An **override** button is present for emergency use.



GEAR INDICATIONS

- **None =** Up & Locked
- **Red =** In Transit
- **Green =** Down & Locked

- Truck light (amber) illuminates when trucks not in level position for retraction.
- A door position light will also illuminate if doors are not locked.

PISTON VS MOTOR

- Piston actuators are used instead of hydraulic motors as **alternate gear extension can be done easier.** (Linear vs rotary)

BOGIE LANDING GEAR

- Used when **4 / 6 wheels** are on one strut.
- Allowed to pitch up and down to ensure all 4 wheels take equal loads.
- Allows smaller wheels to be used.
- Taxiing with a **small turning radius** will give the greatest loads on a torsion link if fitted.

HYDRAULIC RETRACTION SYSTEM

- Extension is slowed with a **restrictor valve** to prevent rapid extension when combined with airflow.
  - Prevents cavitation
  - Normally on mains only
- Actuator dimension cause nosewheel to retract faster than mains.

EMERGENCY EXTENSION

- **Uplocks removed** and gear lower in free fall due to **gravity.**
- **Main doors will remain open**
- Initially 3 greens and 2 reds
  - Selector still in up position
  - 1 red to indicate open doors once selector is moved to down position.

SYSTEMS 4 – LANDING GEAR

WHEELS BRAKE PURPOSE

- **Convert kinetic energy into heat energy.**
- Heat generated depends on:
  - Aircraft mass
  - Brake application speed
  - Runway slope
  - Wind component

LP BRAKE SYSTEM

- **Shuttle valve** used to decide whether footbrake or parking brake pressure is used.

DRUM BRAKE

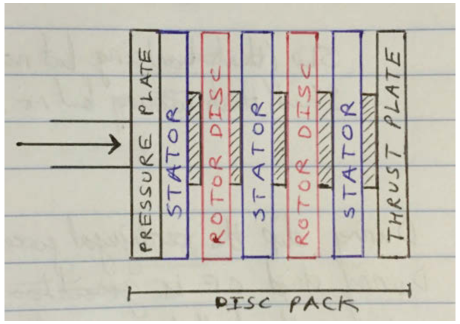
- Type fitted to most cars.
- Poor heat dissipation
- Rapid expansion when heated.

DISC BRAKE

- C152 style
- Disc rotates with wheel
- Two brake pads either side of wheel
  - One fixed and one moved by a small actuator.

MULTI DISC BRAKE UNIT

- **Actuator** used to **compress the pressure plate.**
- Rotor discs move with the wheel whilst stator discs remain fixed.
- Either side of the stator disc are **friction pads.**



- **Wear measurement pin** becomes flush when brake pads are worn.
  - Brakes must be set when checking.
- **Carbon fibre brakes** most commonly used nowadays:
  - Lighter
  - Absorb more heat
  - Stopping capability improves with temperature
- Some **disadvantages of carbon** brakes:
  - Expensive
  - Corrosive (react with de-ice fluid)
  - More prone to wear when cold
  - Very susceptible to wear when snubbed during taxi.

- Brake unit dragging caused by incorrect operation of the adjuster assemblies.

ANTI-SKID UNIT

- **Purpose**
  - Provides max braking efficiency
  - Reduced landing run
  - Better directional control
  - Increases tyre life

- **Function 1 – Normal Skid Control**

$$\boldsymbol{Slip\ Ratio = \frac{NLG\ Speed - MLG\ Speed}{NLG\ Speed} \times 100\%}$$

  - NLG is used as the **ground speed reference** since it's not used for braking
  - 10 – 30 % is the ideal ratio
  - When ratio exceeded, brakes released

- **Function 2 – Touchdown Protection**
  - When weight off wheels, an artificial full skid signal is generated before touchdown.

- **Function 3 – Locked Wheel Protection**
  - Brakes fully released when wheels locked to prevent a skid.

- **Function 4 – Failsafe Protection**
  - Returns brake system to full manual operation in case of systems failure.

- System **disconnects when <20 kts**
- Works on the principle of **decreasing pressure at the slower turning wheels.**

SYSTEMS 4 – LANDING GEAR

AUTOBRAKE SYSTEM

- **Prerequisites:**
  - Hydraulic Pressure
  - Autobrake System ON
  - Deceleration rate selected
  - Anti-skid ON and serviceable
  - Spoilers armed
  - Brake pedals not depressed
  - Idle throttle setting

- **Disengage Triggers:**
  - Anti-skid system selected OFF
  - Manual braking applied
  - Speedbrake lever moved forwards
  - Throttle levers advanced

- Normal autobrake settings provide **constant deceleration.**
- RTO is **not controlled.**

- Autobrakes become most effective once reverse thrust has been disengaged.

BRAKE TEMPERATURE SENSORS

- **Fitted to each brake unit**
- Refuelling not possible when brakes are overheated.
- Overheat warning can be fitted to the wheel / undercarriage bay.

BRAKE FADE

- In a **drum brake system**, heat from friction causes **radial expansion** which reduces stopping power.

- In a **multi-disc brake**, when oil is heated to its boiling point **vapour bubbles** are formed making it less effective.

BRAKE OVERHEAT

- Loss of braking performance
- Fire hazard
- Tyre deflation / explosion
  - Explosion prevented by a <u>fusible plug</u> that deflates tyre gradually.

BRAKE FAILURE

- Runway excursions
- Unwanted a/c ground movement

BRAKE FIRE

- Never use water based extinguishers.
- **Dry powder** is the extinguishing agent.

PARKING BRAKE

- No parking brakes **in hangar** – allows for emergency evacuation.
- No parking brakes **during refueling** – allows to aircraft to adapt to CoG changes.
- When ON, all other braking systems including ASU and TD protection are **inhibited.**
  - Do not set park brake in flight.

BRAKE ACCUMULATOR

- Pressurised to 3000 psi
- **Minimum of 6 brake applications** available to stop aircraft.
- Once 1000 psi is present, only Nitrogen is in the accumulator so it has been used up.

BRAKE EFFECTIVENESS

- No spoilers = 60% of weight on wheels
- With spoilers = 80% of weight on wheels
- Braking effectiveness and drag increased by 130% with spoilers deployed.

WHEEL TYPES

- Usually of aluminium / magnesium alloy
- Most aircraft are tubeless
- C152 is a tubed tyre
- Inflated with Nitrogen (inert)

SYSTEMS 4 – LANDING GEAR

TUBELESS TYRES

- Has a **radial side casing**
- Requires **solid / branched wheels**

- **Less weight**
- **Less chance of punctures and deflation.**
- **Will not burst** in event of puncture
- **Has a better adjustment to wheels**
- **Runs cooler** due to lack of friction between tyre and tube.

TYRE STRESS

- **High Impact Load**
- **High Speeds**
- **High Temperature Due Braking**

- **Tyre Limiting Speed** – Max Ground Speed
- If a tyre is left in the same spot for a long period of time a **flat spot can occur**.

- **Crown** – Withstands the wear of normal operation (contains tread).
- **Shoulder** – Not designed to take wear.
- **Sidewalls** – Thinnest and weakest section designed to flex when load applied.
- **Bead** – Fits against rim of wheel.

TYRE VENTING

- Tyres are made from piles. **More piles gives a stronger tyre.**
- A **casing vent** is installed on tubeless tyres to prevent Nitrogen from getting between the piles and causing separation which will reduce their strength.
- Indicated by **green dots** on tyre.

TYRE CREEP

- **Movement of tyre around the rim.**
- Can result in **inflation valve** being ripped out causing deflation.
- Check tyre creep before flight.

TREAD PATTERNS

- **Ribbed Tread**
  - Most widely used
  - Low rolling resistance
  - Good directional stability + traction
- **All Weather Tyres**
- **Chined Tyres**
  - Deflect water away from rear mounted engines.
- **Anti-Shimmy**
  - Twin contact tread

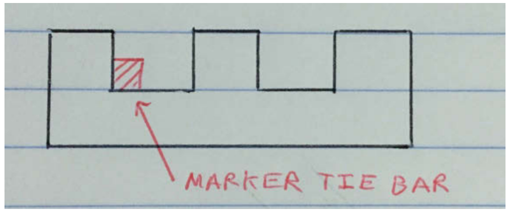
AQUAPLANING

- Occurs when **runway is contaminated**
  - > 3mm standing water / snow / slush
- **Zero friction coefficient**
- **Rubber reversion** (burning) can occur when aquaplaning as standing water becomes **superheated.**
- If tyre pressure is too low, aquaplaning can occur at a lower speed.

$$\textbf{Aquaplaning Speed} = 9 \times \sqrt{P}\ (psi)$$
$$\textbf{Aquaplaning Speed} = 34 \times \sqrt{P}\ (bar)$$

TYRE WEAR

- When **marker tie bar** becomes visible / flush, tread must be replaced.



TYRE WEAR

- **Taxy less than 20 kts / 40 kph to reduce tyre wear**

SYSTEMS 4 – LANDING GEAR

TYRE INFLATION / PRESSURE

- **Nitrogen** used to inflate tyres.
- **Ventilation holes = Expected loss of 5%.**
  - Tyres should be reinflated as normal.
- **5 – 10% drop** should be inflated and a note made in the tech log.
  - Should be subsequently rejected if it falls below 5%.
- **> 10% drop** should be rejected

- **Hot tyre pressures** will be approx. 10% above normal pressure.
- A tyre fitted to an aircraft should only be inflated by 4%

- If aircraft has taxied with a deflated tyre, that tyre and its **axial companion** should be scrapped (due supporting excessive load).
  - If more than one tyre has been used deflated, all tyres on that undercarriage must be scrapped.

TYRE DAMAGE

- The following have a **detrimental effect** on tyre rubber:
  - Hydraluic fluid
  - Oil
  - Grease
- If not removed, the tyre will **swell and become soft and spongy.**
- **Cut Tolerances –** Reject if:
  - Cut penetrates casing piles
  - Cuts exposes the casing cords
- **Bulges –** Sign of delamination.
- **Excessive Shoulder Wear –** Underinflation

SYSTEMS 3 – FLYING CONTROLS

TYPES OF FLYING CONTROLS

- **Mechanically Operated**
    - Reversible Controls
    - Cables / Push-Pull Roads
- **Hydraulically Operated**
    - Irreversible Controls
    - Power Assisted / Fully Powered
- **Fly-By-Wire**
    - No mechanical connection between cockpit and control surface.

CABLE COMPONENTS

- **Turnbuckle –** Joins cables together and provides cable tension.
- **Rigging Pins –** Allows for adjustment of push-pull rod length.
- **Bell Crank –** Allows for changing of push-pull rod angle.
- **Pulleys –** Change direction of control cables
- **Fairleads –** Keeps cables straight and clear of the structure.

CONTROL LIMIT STOPS

- **Protects the structure from excessive loads.**
- **Lock wired & adjustable**
- **Primary Stops –** Located on control surface
- **Secondary Stops –** Located in cockpit
    - Provide redundancy in case of primary failure.

MASS BALANCE

- **Reduced flutter**
- Fitted **forward of the hinge**

AILERON UPFLOAT

- **Reduces flutter**
- Neutral position of ailerons is set above the trailing edge of the wing.
- Upgoing wing produced more drag and downgoing produces less.

GUST LOCKS

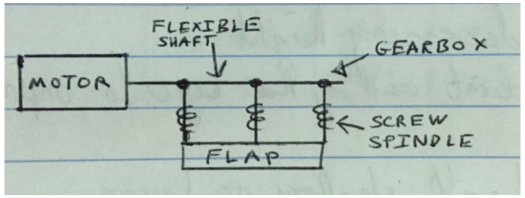
- Can be both internal / external
- External locks consist of **two wooden blocks with neoprene rubber insets** to protect the surfaces.

TRIM TABS

- Can be operated both mechanically and electrically.
- Electrical type requires **two switches to be operated simultaneously.**
    - Prevents uncommanded trim runaway
- Operated via **a screw jack.**

ELECTRICAL FLAPS

- Driven by a **reversible motor geared through a lead screw.**
    - Electric motor – small aircraft
    - Hydraulic motor – larger aircraft
- **Lead screw** prevents aerodynamic loads from driving back the motor
- **Micro-switch** used to cut off supply when flap reaches the requested position.
- **Flap asymmetry** will lock flaps in position when detected.



SYSTEMS 3 – FLYING CONTROLS

POWERED FLYING CONTROLS

POWERED FLYING CONTROLS

- The following components are required in a powered flying control system:
  - Control Input System
  - Power Flying Control Unit (PFCU)
  - Artificial Feel Unit

CONTROL INPUT SYSTEM

- Allows for the mechanical positioning of the servo valve within the PFCU.

PFCU

- When **hydraulic lock** occurs, aerodynamic loads cannot move the control surface. This is therefore an **irreversible system.**

ARTIFICIAL FEEL

- **Prevents overstressing** the aircraft.
- Failure of the unit will result in light controls at all speeds.

- **Simple Spring Feel Unit**
- **Q Feel Unit**
- **Hydraulic Q Feel Unit**
- **Combined System Layout**

FAIL SAFE SYSTEMS

- **Manual Reversion**
  - Release Unit
  - By-Pass Unit
- **Dual PCFU**

TRIMMING POWERED FLYING CONTROLS

WHY TRIM

- **Pitch trim** required for changes in:
  - Speed
  - Power
  - CG Positions
- **Yaw trim** required for:
  - Changes in prop torque
  - Counter-acting asymmetric power on multi-engine aircraft
- **Roll trim** is not normally required by can be used to correct for low-wing tendencies and lateral displacements of the CG

VARIABLE INCIDENCE STABILISER

- Results in **less form drag**
- Since the elevator is in the neutral position when trimmed, the range of pitch control is not reduced. **Full deflection** still possible.
- **Two switches** are used to **prevent trim runaway.**
- Operated by all 3 hydraulic systems for redundancy.
- **Manual trim option** provided in case of pitch trim malfunction.

POSITION INDICATORS

POSITION TRANSMITTERS

- **Position transmitters** installed on each control surface to indicate position to the flight deck crew.

LIFT AUGMENTATION DEVICES

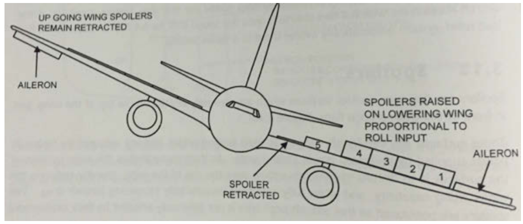
LIFT AUGMENTATION DEVICES

- Normally powered via a **hydraulic motor**
- **Load limit devices** will prevent flap extention below the limiting speed and automatically retract them if their operating speed is exceeded.

SPOILERS

ROLL SPOILERS

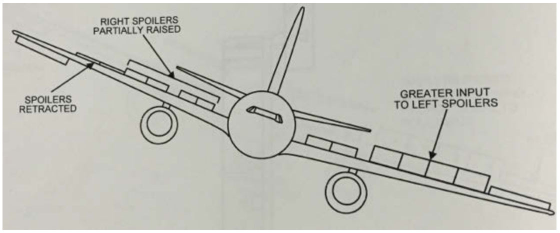
- **Mechanically linked** to the ailerons.
- Remain retracted on the upgoing wing and extended on the downgoing wing.
- The inner most spoiler remains retracted to prevent **tail buffet.**



SYSTEMS 3 – FLYING CONTROLS

ROLL + SPEEDBRAKE OPERATION

- If the speedbrakes are extended and a roll command is input, a **spoiler mix unit** will determine the correct deflection to apply.
- There will be greater extension on the downgoing and only partial extention on the upgoing wing.



LIFT DUMPERS

- Lever moves automatically from armed to UP position.
- Conditions required:
    - Anti-skid unit operative
    - Speedbrake lever ARMED
    - Weight on wheels
    - Rotation of wheels
    - Thrust levers idle

TAIL UNIT AIRBRAKES

- Some aircraft (BAE 146) have roll spoilers and lift dumpers on top of the wing and **separate airbrakes installed on the tail section.**

REVERSE THRUST

REVERSE THRUST

- Active when the **blocker doors** are deployed.

AUTOPILOT

AUTOPILOT INPUTS

- Command signal energises **electrical coil windings** which cause a **transfer valve** to relay inputs to the power control unit.

FLY BY WIRE

FBW ADVANTAGES

- Reduced Mass
- Reduced Maintenance
- More rapid control response
- Remote sensing / fault diagnostics
- Automatic gust load alleviation
- Fuel saving

FBW COMPUTERS

- ELAC (x2) = Elevator / Aileron Computer
- SEC (x3) = Spoiler / Elevator
- FAC (x2) = Flight Augmentation Computer

- There are multiple versions of each computer to provide redundancy.
- Furthermore, pitch axis control for example will be spread across the ELAC and SEC computers to provide further redundancy.

- In the event of complete computer failure, **rudder pedals and stabiliser trim** can still be operated manually.

FBW MODES

- **Normal**
    - Complete envelope protection
    - Reversion to alternate / direct can occur in event of system failures.
- **Alternate**
    - Partial protection provided
    - Possible to stall the aircraft
- **Direct**
    - No protection provided
    - Control surfaces move in direct proportion to the amount of control input.

SYSTEMS 5 – AIR CON, PNEUMATICS & PRESSURISATION

PRESSURE & ALTITUDE

- Oxygen accounts from 21% of atmosphere
- **Partial pressure** of O_2 will decrease with height however.
- At MSL: 1013 x 21% = 212 hPa (Approx)
- At 18,000 ft: 500 x 21% = 106 hPa (Approx)

- A **cabin altitude limit of 8,000 ft** is normally used where the partial pressure is 750 x 21% = 150 hP

PNEUMATIC AIR

- Used for cabin pressurisation, air con, reservoir pressurisation etc.

- Can be generated using a turbocharger, roots displacement blower or bleed air.

PISTON ENGINE SYSTEM

TURBO-CHARGER DESIGN

- Turbocharger is utilised
- Can be the same one as used for power augmentation.

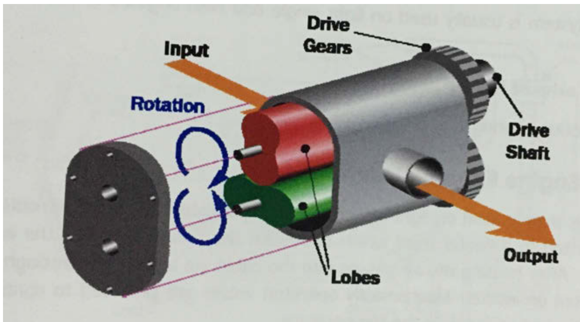
TURBO-CHARGER DISADVANTAGES

- Possible carbon monoxide poisoning
- At high altitude, engine requires more of the air from turbo-charger so pressurisation and air con ability etc is reduced.

ROOTS DISPLACEMENT BLOWER

ROOTS DISPLACEMENT BLOWER

- Another method of obtaining pressurised air for various services is via a **dedicated cabin compressor.**
- It is **connected to the AGB.**
- Ram air is fed in and compressed.
- Prevents extracting air from the turbocharger (in piston aircraft) or the compressor (in gas turbine aircraft) which lowers the engine efficiency.



BLEED AIR SYSTEM

BLEED AIR SYSTEM

- The most common way of providing pressurised air on large aircraft is using bleed air.
- Air is **extracted from the HPC**
- Normally extracted from the **5th Stage** (Intermediate Pressure Stage).
- At **low RPM,** this is done from **9th Stage** (High Pressure Stage) at the pressure at the 5th is too low.
- A **check valve** prevents air from the 9th stage entering the 5th stage.

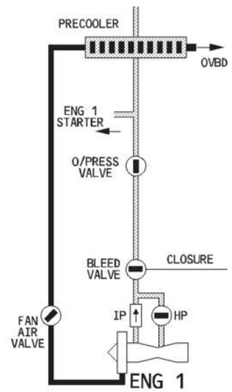
AUXILLARY POWER UNIT

- On the ground when the engines are not running, the APU provides the bleed air.

HEAT EXCHANGERS

- Used to cool the bleed air to approx. 200^{0}C

- Utilises bleed air from the engine fan.

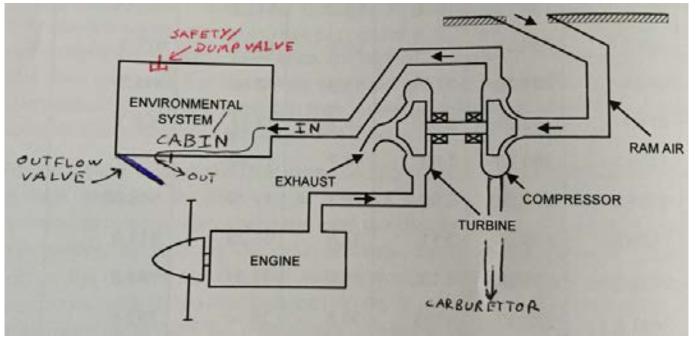


SYSTEMS 5 – AIR CON, PNEUMATICS & PRESSURISATION

PISTON ENGINE CABIN PRESSURISATION

TURBOCHARGER

- Achieved using the **turbocharger** design.



OUTFLOW VALVE

- To fulfill the pressurisation function, an **outflow valve** is used to regulate the cabin altitude.
- Closed at high altitude.
- There is always a **constant flow in and out** otherwise the pressure would build up and the cabin would explode.
- A **cabin altitude controller** controls the position of the outflow.

OTHER COMPONENTS

- **Cabin altimeter** is used to provide an indication of the cabin altitude.
- **Safety / dump valve** opens when the pressure differential becomes too great.
  - Protects against failure of the outflow valve.

TEMPERATURE CONTROL

METHODS

- Control of temperature is achieved by either:
  - Engine Exhaust Heating
  - Combustion Heating
  - Air Cycle Cooling

ENGINE EXHAUST HEATING

- Used on **light aircraft.**
- **Ram air** enters through forward facing air intakes.
- Some of this is passed through a **heater muff** where exhaust gas in close proximity heats the air as required.
- When stationary, a **fresh air blower** is used when there is no ram air.
- Air is dumped overboard via a vent on the underside of the aircraft once used.

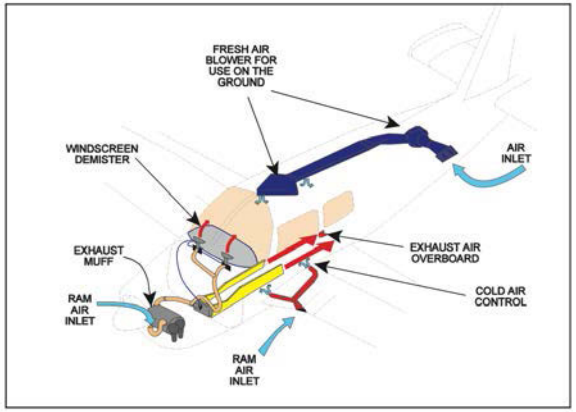


Figure 10.2: Light aircraft hot and cold air system.

COMBUSTION HEATING

- Used on the Seneca for example.
- Part of the fuel supply is used to power a combustion heater.
- A **temperature sensor** will **cycle the fuel supply** as required to achieve the temperature level as set by the pilot.
- In flight, **ram air** is supplied via a fan.
- Stationary, a **combustion blower** provides the required air supply in the absence of ram air.
  - Switched off in flight.

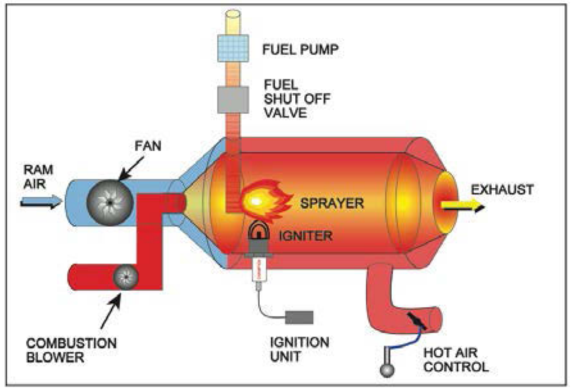


Figure 10.3: A combustion heater.

- Blockage of either the ram air / combustion air supply causes a **differential pressure switch** to cut the fuel supply.
- In the event the outlet air temp becomes too great, a **limit switch** will temporarily stop the supply of fuel (hence combustion) thus allowing air to cool.
- A second protection with a higher temp limit than the limit switch is also installed in case the limit switch fails or temp is too great.
  - Reset can only be done on the ground.

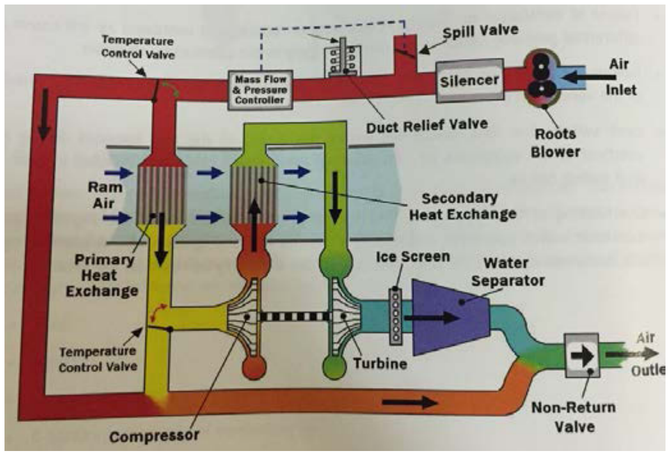
SYSTEMS 5 – AIR CON, PNEUMATICS & PRESSURISATION

AIR CYCLE COOLING

AIR CYCLE COOLING

- Main method of temperature control within modern jet transport aircraft.
- The following system designs can be used:
  - Displacement Blower (Bootstrap)
  - Bleed Air (Bootstrap)
  - Brake Turbine System
  - Turbo Fan System
- Air cycle machines are commonly known as **air conditioning packs**.

AIR CYCLE COOLING – DISPLACEMENT BLOWER



"BOOTSTRAP SYSTEM"

- It is called a **bootstrap** system it becomes **self-sustaining** once started.
  - Turbine drives compressor which drives turbine etc.

ROOTS BLOWER

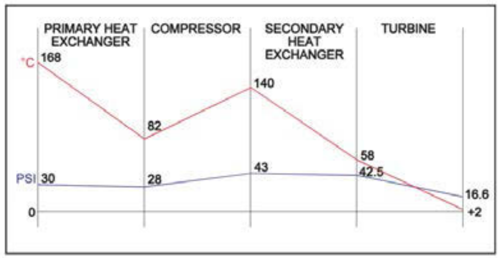
- Utilises the **roots blower** to provide pneumatic air.
- It does not compress air but merely helps air to **overcome the back pressure** that exists in the system.
- A **silencer** is fitted to reduce noise created when air passes through the roots blower.

SPILL VALVE

- **Vents excess air flow** to atmosphere.
- Controlled via the **mass flow controller.**
- At high RPMs (blower is driven by the AGB), the spill valve will open to ensure a **constant mass flow** is delivered.

OPERATION

- Air is **pre-cooled** by ram air across the **primary heat exchanger.**
- The pressure of the air is boosted by the **compressor** in order to make the energy conversion at the turbine stage more efficient.
- A **secondary heat exchanger** removes the heat generated as a result of compression.
- Air expands in order to drive the **turbine** which results in **lower temperature** and pressure.



WATER SEPERATOR

- **Removes excess water vapour** from air.
- An **ice screen** can also be fitted to prevent blockage of the turbine.

- Water vapour will condense, releasing latent heat and reducing the cooling effect.
- Water vapour must also be removed before entering cabin.

TEMPERATURE CONTROL

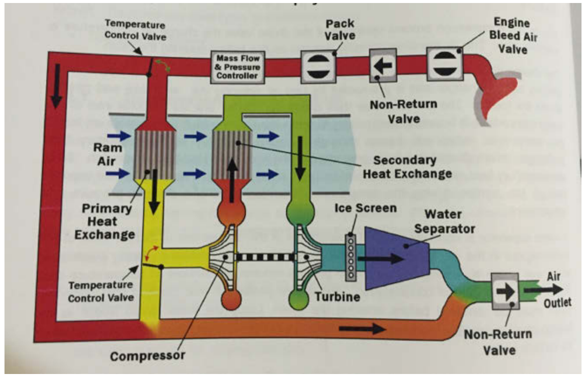
- Warm (uncooled) air is mixed with the cooled air as required to ensure the correct temperature is delivered to the cabin.

SYSTEMS 5 – AIR CON, PNEUMATICS & PRESSURISATION

AIR COOLING – BLEED AIR (BOOTSTRAP)

OPERATION

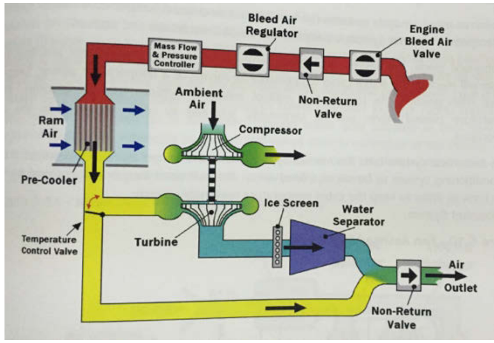
- Same as bootstrap system except bleed air is used instead of the blower as the pneumatic air supply.
- The **engine bleed air valve** is normally open but is closed when the fire handle is pulled.



OTHER AIR CYCLE SYSTEMS

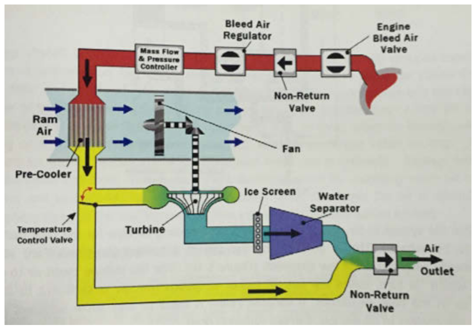
BRAKE TURBINE SYSTEM

- Uses **only one heat exchanger** so is lighter.
- The compressor functions as a brake to ensure turbine rpm does not become too great.
- Cannot be used when stationary however due to lack of ambient airflow through compressor.



TURBO FAN SYSTEM

- Turbine drives a fan to assist with the ram air cooling through the heat exchanger.
- This is a development of the brake turbine system which allow for cooling whilst on the ground.



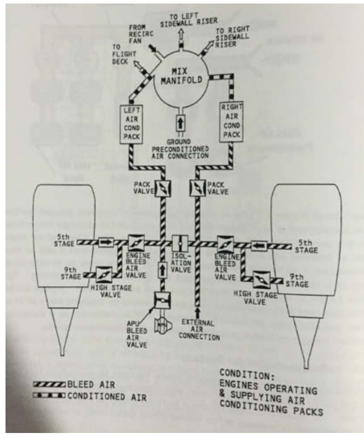
DUCTING SYSTEM

MIX MANIFOLD

- The airflow that is circulated within the cabin comes from the **mix manifold.**
- This receives inputs from the following sources:
  - Packs (ACMs)
  - Ground pre-conditioned air
  - Cabin re-circulated air

- In order **prevent an increase in fuel consumption** by continuously using bleed air, air from the cabin is sent back to the mixing unit.
  - It passes through filters which ensure it is 99% clean before entering mix unit.

- This **recirculated air is mixed with fresh air** from the packs and distributed to the cabin.
- Flight deck is supplied with air straight from the left pack without mixing.
  - Switches to right pack in case of left pack failure.

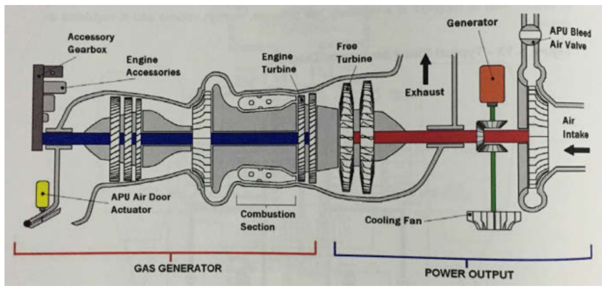


SYSTEMS 5 – AIR CON, PNEUMATICS & PRESSURISATION

AUXILLARY POWER UNIT

PURPOSE

- The APU is a **gas turbine engine** that can be used on the ground or in flight (on some types)
- It is a **free turbine** type with the turbine driving a compressor that **provides pneumatic air.**
- It can be used to **provide bleed air in case of a pack failure or when engines are not running.**
- It is used to provide bleed air for engine start.
- It also drives a gearbox to which a generator is attached so **electrical power can be provided.**



OTHER USES OF PNEUMATIC AIR

OTHER USES

- Cargo brake systems
- Ice protection systems
- Pressurisation of hydraulic reservoirs
- Pneumatic engine start
- Thrust reverse

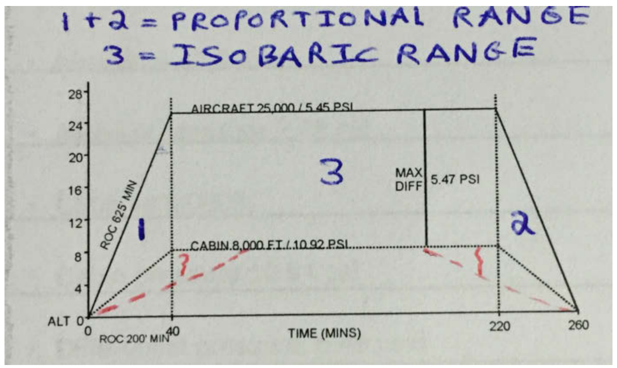
PRESSURISATION

LEGAL REQUIREMENTS

- Cabin conditions equivalent to **8,000 ft or less**
- Heating / cooling facilities to ensure a comfortable cabin temperature
- 1 lb of air per pax minute (0.4 lb in emergency)
- ROC < 500 fpm & ROD < 300 fpm

PRESSURISATION CONSIDERATIONS

- A suitably low cabin ROC and ROD must be achieved for **passenger comfort.**
- Too low cabin ROC and ROD however can cause the **maximum pressure differential** to be exceeded (red line).
- Pressurisation results in **hoop stresses.**
    - Structure must be strong enough to withstand pressurisation without being too heavy.



SAFETY VALVES

- **Positive Pressure Relief Valve**
    - Opens when the Max Pressure Differential + 0.25 psi is exceeded
- **Inward Pressure Relief Valve**
    - Opens when ambient pressure exceeds the cabin pressure by 0.5 – 1 psi
    - Protects from structural compression in a rapid descent for example.
- **Dump Valve**
    - Operated by the flight crew
    - Cabin pressure is rapidly reduced to zero
    - Allows for clearing of cabin air in event of smoke etc
- **Blow Out Panels**
    - Fitted between cabin and cargo compartments.
    - Prevents collapsing of the floor in event of cargo section undergoing rapid decompression (cargo door blow out).

PRE-PRESSURISATION

- Occurs on ground when throttle levers are advanced more than **10 degrees.**
- Cabin pressurised slightly below ambient
- Allows for smoother transition when climbing
- Prevents inflow of exhaust gases.

SYSTEMS 5 – AIR CON, PNEUMATICS & PRESSURISATION

PRESSURE CONTROLLERS

- In AUTO mode, computers automatically control the required pressurisation.
- There is an AUTO 1 & AUTO 2 option.
  - AUTO 1 = AC from engine 1
  - AUTO 2 = AC from engine 2

- Should AC sources fail, MAN can be selected.
- Uses DC power source.
- Pilots must manually set ROC & ROD

- Cabin altimeter and "cabin VSI" installed to monitor pressurisation.

- For AUTO to function, following **inputs must be provided** to the system:
  - FLT ALT
  - LAND ALT
  - CABIN ALT

OUTFLOW VALVE OPERATION

- Controlled by pressure controllers.
- Open on ground and closed at altitude.
- **There is always a constant mass flow into the cabin.**
- Within the **isobaric** range (cruise) there is also a **constant mass flow out.**
- Within the **proportional range**, there is a **variable mass flow out** as the valve is continuously adjusted.

DOOR SEALING

- Seals are fitted with adjustable rubber seals.
- These expand with an increase in pressure differential to ensure adequate sealing.

- Unlocked door indications will be present above doors and delivered to flight deck.

CABIN SEALING

- Control runs, pipelines etc may have to pass through bulkheads.
- Adequate sealing must be ensured to maintain cabin pressure.
- Max leak rate is 300 fpm

TYPICAL FLIGHT PROFILE

- Ground / Flight switch changed to flight before takeoff.
  - **Pre-pressurised to 0.1 psi**
- After takeoff, ground / air logic switched is activated.
  - System enters **proportional control**
- System changes to **isobaric** control whilst in the cruise.
- Reverts back to **proportional control** for the descent.
  - Aims to achieve 0.1 psi on touchdown
- After landing, ground / flight switch changed to ground.
  - Outflow valve fully opens to equalize cabin pressure

ALTITUDE TRIGGERS

- **10,000 ft**
  - Pilots provided with audible and visual warnings.
  - Must don masks at this point.

- **14,000 ft**
  - Pax oxygen automatically deployed

- **15,000 ft**
  - Outflow valve automatically closes

RESIDUAL DOOR INDICATION

- If cabin is still pressurised after landing, a residual pressure light illuminates on the door.
- Pushing this switches open the outflow valve manually to equalize the pressure.

DITCHING SWITCH

- Will close all discharge valves to prevent inflow of water in the event of ditching.

SYSTEMS 5 – AIR CON, PNEUMATICS & PRESSURISATION

DECOMPRESSION TYPES

- **Explosive Decompression**
  - Catastrophic Leak
  - Equalised in less than 0.5 seconds
  - Very high risk of lung trauma
- **Rapid Decompression**
  - Equalised in more than 0.5 seconds
  - Risk of lung damage still present bu significantly reduced.
- **Gradual Decompression**
  - Occurs very slowly
  - May not be sensed before hypoxia sets in

FACTORS AFFECTING DECOMPRESSION

- Decompression will be **most severe with:**
  - Small Cabin
  - Large Structural Damage
  - High Pressure Differential

SIGNS OF EXPLOSIVE / RAPID DECOMP.

- **Loud bang** (contact between air masses)
- **Cloud / Fog** (Increase in RH due lower temp)
- **Rush of air**
- **Decrease in temperature**
- **Release of oxygen masks**

OXYGEN SYSTEMS

OXYGEN REQUIREMENTS (UNPRESSURISED)

- Oxygen must be available if flown above 10,000 ft

OXYGEN REQUIREMENTS (PRESSURISED)

- In pressurized passenger aircraft, supplementary oxygen is normally only used temporarily in emergency until a descent to a lower altitude has been achieved.

- Emergency oxygen equipment must be provided for pressurised **aircraft certified to operate above 25,000 ft.**
- Pressurised aircraft certified to 25,000 ft or less do not require emergency oxygen equipment if they can descend to 13,000 ft or below within 4 minutes (when taking into account route structure).

CREW OXYGEN REQUIREMENTS

- Above 25,000 ft with no quick donning masks require one pilot to be wearing a mask.
- Above 41,000 ft one pilot should wear a mask even if quick donning is fitted (depends on state regulations)

Time of Useful Consciousness	
Altitude	Time
18,000 ft	30 minutes approx.
25,000 ft	5 to 3 minutes
30,000 ft	90 to 45 seconds
35,000 ft	45 to 30 seconds
45,000 ft	About 12 seconds

OXYGEN SYSTEMS - CREW

CREW OXYGEN SYSTEM

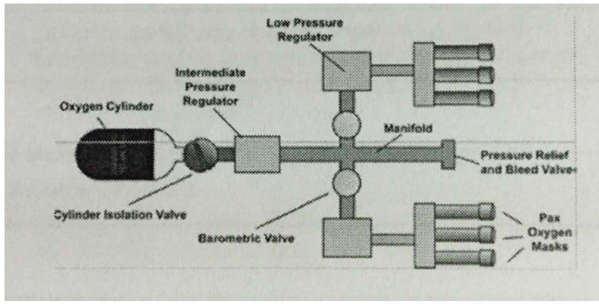
- Normally consists of a **diluter demand system with oxygen stored in high pressure gaseous form.**
- Oxygen is stored at 1800 psi and reduced in pressure before consumption.
- **The pure oxygen is mixed with cabin air** in order to save oxygen and prevent physiological side effects.
  - 100% Pure is provided at 33,000 ft
  - Below 33,000 ft an aneroid controller mixes the oxygen and cabin air in the appropriate amount.
- Flow of air is only provided when the pilot inhales. This is indicated by a **blinker indicator.**
- There are **3 settings available:**
  - Normal – Automatically mixed as req.
  - 100% - Pure oxygen provided
  - EMER – 100% pure oxygen provided at an overpressure to prevent inhalation of fumes etc.

SYSTEMS 5 – AIR CON, PNEUMATICS & PRESSURISATION

OXYGEN SYSTEMS - PASSENGERS

CONTINOUS FLOW W/GASEOUS OXYGEN

- When the cabin altitude reaches 14,000 ft, a **barometric valve** opens and oxygen flows to the low pressure regulator.
- **Pneumatic pressure** opens the PSU doors and masks are deployed to the half-hung position.
- When face masks are **pulled down,** the valve opens and oxygen flows.
- Holes on the masks allow the oxygen to be **mixed with cabin air.**
- **In smoke conditions, pax masks should not be used** as the oxygen widens the trachea allowing for deeper smoke inhalation.
- Should an overpressure occur (due to a leak in the cylinder for example) a **blow-out disc** will be activated. This a pre-flight check item.
- America = Green Oxygen Bottles
- Europe = Black Oxygen Bottles

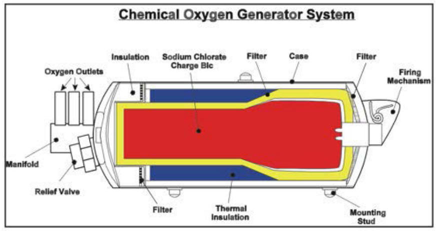


NUMBER OF MASKS

- Seating Capacity > 200 required 10% more masks to be fitted.

CONTINOUS FLOW W/CHEMICAL OXYGEN

- Instead of gaseous oxygen, chemical oxygen can be used. This is the most common type.
- As there is no barometric valve, a **28V electrical signal** releases the masks to the half-hung position.
- When pulled down, **a firing mechanism** is triggered and a chemical reaction produced 100% oxygen.
- **Thermal insulation** is required due to the high temperatures arising from the reaction.



- Again, this is mixed with cabin air in the mask face.
- A **cylinder is fitted to each row.**
- When one mask is pulled down, oxygen is then supplied to all masks within the row.

PORTABLE OXYGEN

PORTABLE OXYGEN

- Typically hold 120 litres at 1800 psi
- Normal Mode – 2 litres/min
- High Mode – 4 litres/min
- EMER Mode – 10 litres/min

EROS – QUICK DONNING MASKS

EROS (QUICK DONNING) MASKS

- **Emergency Regulating Oxygen System**
- When tabs are depressed, the mask is pre-filled with oxygen allowing it to be fitted to the head.
- When tabs are released, the oxygen is drained and it fastens to the head.

SMOKE HOODS

SMOKE HOODS

- Provide **complete coverage of the head.**
- Contain a chemical oxygen generator.
- Provides a minimum of 15 mins supply.

SYSTEMS 6 – FUEL SYSTEMS

USES OF THE FUEL SYSTEM

- Engine Fuel
- APU Fuel
- Trim Tank
- Fuel / Oil Heat Exchangers
- Wing Bending Relief

1 – FUEL TANK

- Vented to **prevent tank deformation and fuel starvation.**

2 – RECEPTACLES

- Access to tank for fuelling.
- Small Aircraft = Gravity (Over-Wing)
- Large Aircraft = Pressure (Under-Wing)

3 – BAFFLE PLATES

- Prevent **fuel surging** where the fuel pools on one side of the tank during turns.

4 – DRAIN VALVE

- For removal of water that condenses and collects at the bottom of the tank.

5 – FEEDERBOX

- Contains **two low pressure, electrically driven fuel pumps of the centrifugal type.**
- Provides an **uninterrupted, de-aerated, supply of fuel to the engine driven pumps.**
- 2 pumps are installed to ensure continuous supply irrespective of attitude.
- Non-return valve prevent flow back to the tank when in extreme attitudes.

6 – LOW PRESSURE FUEL SHUT OFF VALVE

- **Normally open**
- Closed with activation of the fire handle

8 – CROSS FEED VALVE

- **Normally Closed**
- Used in event of engine failure to ensure fuel is balanced on each side of the aircraft.
- Allows the left tank to feed the right engine for example.

9 – ENGINE DRIVEN PUMP

- **High Pressure Pumps**
- Connected to the AGB

10 – FUEL / OIL HEAT EXCHANGER

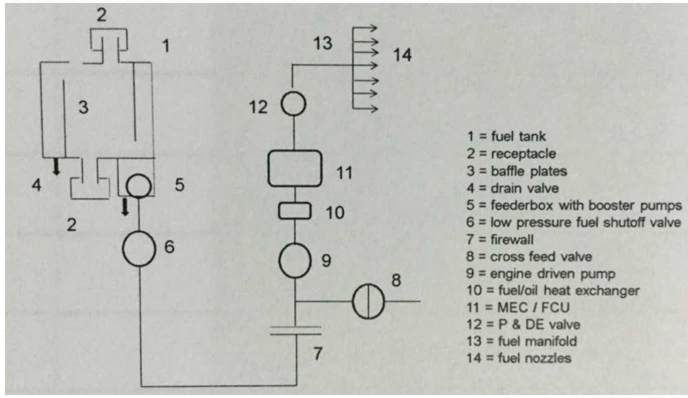
- Used to cool the oil and heat the fuel.
- Warming the fuel helps keep the fuel above it's **pour point.**
  - This is the temperature at which it becomes too viscous if cooled below it.

11 – MEC / FCU

- Connected to the AGB
- Contains the HP Fuel Cock

12 – P&D VALVE

- Ensures fuel pressure is high enough to allow proper atomization of the fuel and adjustment of the variable geometry
- Drain function ensure the manifold is drain after shutdown.



SYSTEMS 6 – FUEL SYSTEMS

CALORIFIC VALUE

- The amount of heat release by burning 1 kg fuel.
- Fuel requires a high calorific value.
- Higher value = less fuel required

FUEL TYPES

- Mixing of JET A / JET A1 / AVTAG is permitted.
- If just using AVTAG, FCU must be adjusted to account for the lower specific gravity.
- Fuelling with AVTAG not permitted with pax on board due to the low flash point.

LOW FUEL TEMPERATURES

- Must be avoided – change of altitude may be required.
- Low temps result in **increased viscosity and formation of wax / paraffin crystals.**

VAPOUR LOCKS

- With a decrease in temperature, a decrease in boiling point occurs.
- This makes formation of vapour lock more likely.
- **Pressurisaton of fuel tank** and **use of fuel booster pump**s helps prevent this.

CONTAMINATION

- AVTUR is more viscous than AVGAS so water suspension is more likely.
- Water detectors and drain valves required.

FUEL SYSTEM ICING INHIBITOR (FCII)

- Used in small aircraft / military aircraft.
- **Additive is added** to the fuel in order to:
  - Reduce tendency of water in the fuel to freeze
  - Reduce fungus formation
  - Act a lubricant for the HP fuel pump which is immersed in fuel.

TYPES OF LEAKS ETC

- **Dripping** – Drops at slow rate
- **Leaking** – Drops at fast rate
- **Seaping** – Uninterrupted flow

TANK TYPES

- **Rigid**
  - C152
  - Small tank installed at wing root
- **Flexible / Bladder Cell**
  - Helicopters & some commercial aircraft
  - Rubber layers ensure self-sealing in event of puncture
- **Integrated / Wet Tank**
  - Fuel is carried in the wing
  - Max space with min weight
  - Ribs act as baffleplates

FILTRATION

- Mesh installed around LP pump inlets
- Filters installed after both LP and HP pumps

FUEL SYSTEM TYPES

- **Gravity** (C152)
- **Pump-Feed** (PA28)
- **Multi-Engine Type**
  - Cross feed mandatory
  - Fuel transfer optional
- **Large Jet Fuel System**

LARGE JET FUEL SYSTEM

LOW PRESSURE PUMPS

- **Two centrifugal type AC pumps are installed in each inner tank and the centre tank.**
- Ensures a continuous supply at varying attitudes.
- Should the booster pumps fail, the HP pumps will still draw fuel but a decrease in altitude or throttle setting may be required.
  - Especially true when using AVTAG due to its low volatility which has an increased chance of vapour lock with LP pump fail

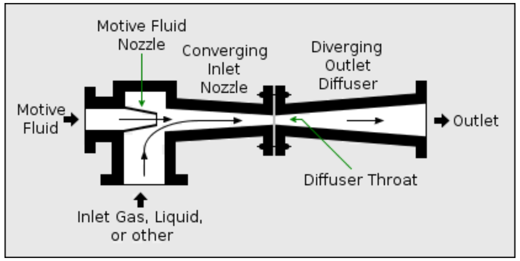
SYSTEMS 6 – FUEL SYSTEMS

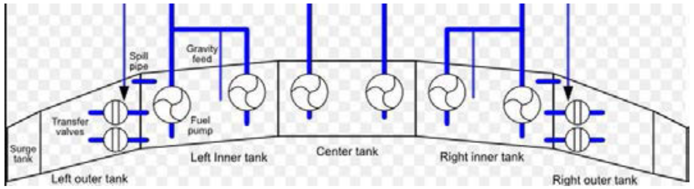
APU PUMP

- The APU uses a DC pump to draw its fuel supply from one of the tanks.

JET EJECTOR PUMP

- Used to allow for a flow of fuel from the outer to inner tanks.
- Uses the LP booster pump to create suction through a venturi, thus drawing the fuel through.





TANK OPERATION

- Inner tanks used first down to 5000 kgs
- Contents of the trim tank are then transferred to the inner tank.
- Contents of the outer tanks are then transferred to the inner tank.

SURGE / VENT TANK

- To prevent damage from the movement of fuel during maneuvers, in the case of over-refueling and expansion.
- Fuel that enters the surge tank is transferred back to the main tanks via gravity.

TANK VENTS

- Fitted to the bottom of the tanks where there is higher pressure.

FUEL JETTISON (DUMP)

- Required when MTOW significantly > MLM
- Required to jettison enough fuel in 10 -15 min
- After jettison, fuel remaining must be sufficient to takeoff and climb to 10,000 ft with a 45 minute reserve.

FUEL GAUGES

- **Fuel Volume Types**
  - Float Type
  - Resistance Type
  - Both prone to error from variations in temperature and different attitudes.
- **Fuel Weight Types**
  - Capacitive Type
  - Compensates for attitude changes

TOTALISER & FUEL USED

- **Totaliser** indicated total FOB
- **Fuel used** indicator is reset with each engine start and indicates fuel used.

VISUAL FUEL MEASUREMENT

- **Drip Stick**
  - Located under the wing
  - Suffers from leakage down the stick
- **Magnetic Drop Stick**
  - Located under the wing
  - Rests on top of a float and does not leak so is more user friendly.

FLOW METER

- Fuel flows through and **impeller motor** which allows for measurement of fuel flow rate.

REFUELING TYPES

- **Open Line / Gravity (Overwing)**
  - No electrics allowed
- **Pressure (Under Wing)**
  - Electrics required

DEFUELING

- Refueling requires an **empty bowser**

SYSTEMS 6 – FUEL SYSTEMS

REFUELING ZONE

- Extends **at least 6m radially** from the filling and venting points.
- **Within this zone:**
  - No Smoking
  - GPU as far away as possible
  - Filler caps removed after APU start
  - Fire extinguishers readily accessible

REFUELING PRECAUTIONS

- No pax on board for AVGAS / Jet B (AVTAG)
- No fuelling:
  - Within 30m of radar equipment in test / use
  - Within 20nm of TS
  - Within 6m of flash equipment
  - With overheated brakes

SYSTEMS 7 – ICE PROTECTION

ICING CONDITIONS

- Visible moisture, standing water / snow present with a temperature of:
  - OAT < 10⁰C (Ground Ops + T/O)
  - TAT < 10⁰C (In Flight)
- The critical temperature range is +10⁰C to –10⁰C as large SCWDs exist at these temps.

ANTI-ICING

- **Prevention** of ice formation
- **Electrical Anti-Ice**
  - Probe & Sensor Heating
- **Thermal Anti-Ice**
  - Wing Heating, Engine Inlets
  - Air extracted from HPC
  - From wing heating, the inside of the wing is heated.
- **Fluid Anti-Ice**
  - DA42 for example
  - Fluid exits through tiny holes in the leading edge (weeping wing) and covers the surface in a thin layer of anti-ice fluid.
  - Prevents SCDWs from freezing
  - Sprayed onto props via a feed tube

DE-ICING

- **Removal of ice**
- Used on **turbo-props** where continuous anti-icing decreases EPR too much due to HPC extraction.
- On demand use of HPC air is preffered.
- **De-Icing Boots**
  - Pneumatically operated
  - Small aircraft use a vacuum pump
  - Larger aircraft use HPC air
  - A sequence is used (root boots – tip boots – elevator boots – rudder boots)
  - Symmetrical operation minimizes aerodynamic disturbance

FLUID TYPES

- **Type I**
  - Unthickened (low viscosity)
  - High glycol content
  - Usually clear
  - Mainly de-icing rather than anti-ice
- **Type II**
  - Thickened (high viscosity)
  - Usually straw colour
  - Additional anti-ice properties
- **Type IV**
  - Same as type II with longer HOT
- **Heating** may be required in order improve spray ability in cold temperatures.
- **Overheating** can result in a gelled formation that will not shear on takeoff.

WINDSHIELD HEATING

- Heated to prevents **brittleness and icing.**
- **Temperature control** prevents overheating which can lead to delamination.

PROP ANTI-ICE

- **Lower part** of propeller is **electrically heated** to prevent the build up of ice.
- **Spinner oscillates slightly** in order to prevent ice build up.

INTAKE ICING

- **Most likely at low forward airspeed with high RPM.**
  - Intake pressure < ambient pressure
- Also more likely with **TAS > 250 kts**
  - High catch efficiency

UNDERCARRIAGE ICING

- Consider cycling undercarriage after takeoff from contaminated runways to remove deposits.
- Prevents deposits freezing at altitude with the lower temperature.

SYSTEMS 7 – ICE PROTECTION

RAIN REPLLENT SYSTEM

- Only to be used in rain conditions in conjunction with the wipers.

ICE DETECTION METHODS

- **Spot Lights**
  - Refract when ice is present
- **Vibrating Rod Detectors**
  - Ice accretion changes oscillation frequency
- **Pressure Detectors**
  - Normally open switch (due air pressure) that is closed when ice blocks the air intake.
- **Hot Rod Detectors**
  - Visible from the cockpit
  - Intentionally 'attracts icing' and contains and heating element
- **Rotary Ice Detectors**
  - Rate of rotation decreases with ice accretion

COLD SOAKED WING

- **Tanks contains very cold fuel** after landing from a flight at high altitudes.
- Moisture in the air can cause **hoar frost** to form.
- Precipitation can cause **clear ice** to form.
- **Fueling tanks** after the last flight of the day to warm the tank contents can prevent ice forming overnight.

SYSTEMS 8 – FIRE AND EMERGENCY EQUIPMENT

TRIANGLE OF FIRE

- Fuel + Oxygen + Heat

EXTINGUISHERS

- Type A & C fires most common on aircraft
- Water and Halon most common on aircraft.

COMPARTMENT CLASSIFICATIONS

- Compartments are classified to indicate fire risk

- A – Pax Cabin
- B – Avionics
- C – Baggage / Cargo
- D – Cargo (Doesn't endanger pax)
- E – Cargo Aircraft Only

ENGINE ZONE CLASSIFICATIONS

- Zone 1- AGB (Coolest)
- Zone 2 – Surrounds compressor (Hot although no components to actively support combustion)
- Zone 3 – Surrounds combustion chamber (Hottest zone)

FIRE DETECTION

- **Engines, APU and wheel wells** fitted with fire detectors.
- Circuit tested for **continuity** before each flight
- Only engine and APU have fire extinguishers fitted.

- **Detector Types**
    - Resistive
    - Capactive
    - Systron (Pressure Based)

- **Dual Loop Logic** is used in the resistive and capacitive types.
    - Requires both loops to indicate overheat before warning is triggered.

FIRE EXTINGUISHER OPS

- **Silence Master Caution**
- **Throttle Lever – Idle**
- **HP Cock - Closed**
    - Fuel now removed from triangle
- **Extinguisher 1 - Discharge**
    - Oxygen now removed from triangle
- **Extinguisher 2 – Discharge if required**
    - Oxygen now removed from triangle

SMOKE DETECTORS

- Fitted to cargo and lavatories (places where constant observations not possible)
- The lavatories use automatic fire extinguishers in the bins

- **Smoke Detector Types**
    - Labyrinth Seal
    - Ionised Radiation
    - Photoelectric

INERTIA CRASH SWITCH

- Operates all LPSOVs and fire extinguishers.

HALON BCF USE

- Non-alcoholic liquid to be used afterwards
- Face masks should be worn during use

	FIRE TYPE			
E	A – Solids (Grey		C – Elect (Light G	
	✓	✓	✓	
	✓	✓	✓	
				✓
		✓	✓	
	✓			

SYSTEMS 8 – FIRE AND EMERGENCY EQUIPMENT

FIRE EXTINGUISHER REQUIREMENTS

- 7 – 30 Pax = 1
- 31 – 60 Pax = 2
- 61 – 200 Pax = 3
- Every extra 100 pax = +1
- Does not include flight deck requirements

FIRST AID KIT REQUIREMENTS

- 0 – 99 Pax = 1
- 100 – 199 = 2
- 200 – 299 = 3
- 300 + = 4

SLIDES

- Required when exit sill height is > 6 ft from surface
- The upperdeck and overwing exits only function as slides and cannot be used as rafts.

EVACUATION TIME

- When capacity > 44 seats
- 90 seconds with ½ of exits and emergency lighting in operation

BREAK-IN PANEL

- Areas marked on the fuselage where there are no hydraulics / electrical lines etc behind.
- Allows entry points for emergency services.

LOCATOR BEACON

- Functions for 48 Hrs
- Range of 80 miles

PYROTECHNICS

- Flare (red) for use at night
- Smoke (orange) for use during the day
- Flare end is marked with a ribbed end