ATPL Aircraft General Knowledge – AGK AIRFRAME & SYSTEMS

S1 – Airframe Design & Materials

- Certification standards – to ensure an acceptable safety level for equipment and systems installed on the aeroplane:

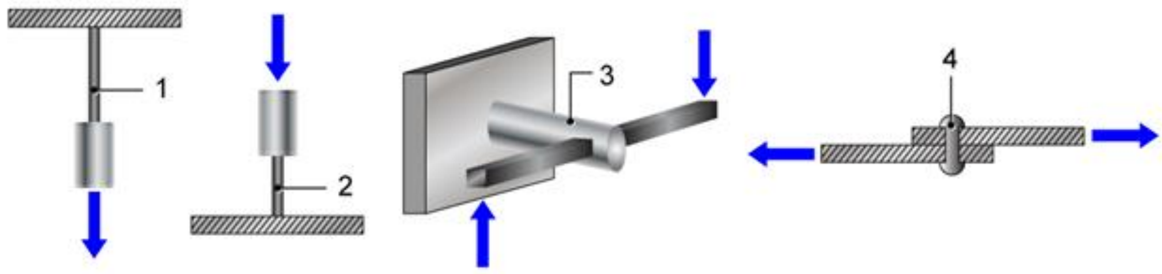
Failure Condition	Effect on Airframe	Effect on Crew	Effect on Passengers	Probability	Probability per flight
Minor	*No significant effect*	*Slight increased workload*	*Slight discomfort*	Probable	1 in 1000
Major	*Significant reduction in aircraft capability*	*Significant increase in workload*	*Physical distress including injury*	Remote	1 in 1000 to 1 in 100,000
Hazardous	*Large reduction in aircraft capability*	*Excessive workload and impaired ability to perform tasks*	*Serious or fatal injury to a small no. passengers*	Extremely remote	1 in 100,000 to 1 in 10 Million
Catastrophic	*Aircraft destruction/ Hull loss*	*Fatalities or incapacitation*	*Multiple fatalities*	Extremely improbable	1 in 10 Million to 1 in 1000 Mil.

- Safe life = Structure has an explicit design life, during which no catastrophic structural damage may occur as a result of normal operation. Measured in:
  - Flight hours
  - Landings
  - Calendar Duration
- Fail safe = Ensures an alternate load path is available in case of failure.
- Damage Tolerant = Maintenance program to detect and repair damage, corrosion or fatigue cracking.

- Stress – Internal force per unit area.
- Strain – Deformation caused by stress on a material.
- Elasticity – Ability of a material to return back to its original shape.
- Plasticity – Ability of a material to withstand stress deformation without failure and return to its original shape.

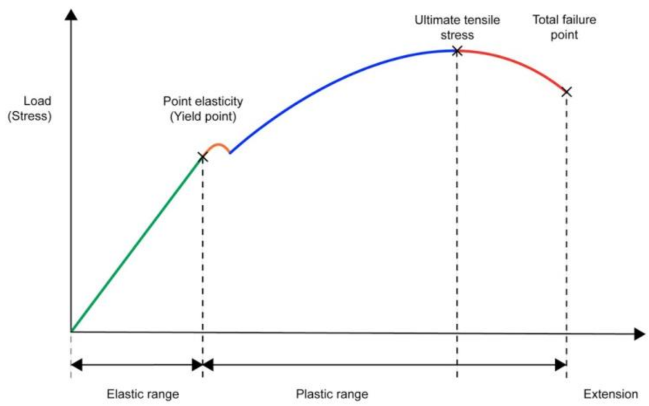
- Design load limit = 2.5G (transport category)
- Ultimate load limit = 150% of 2.5G (= 3.75G)

- For a stress test, it must withstand 2.5G x 1.125 and endure for 3 minutes.
- A load continually being applied and removed = cyclic load.



1. Tension
2. Compression
3. Torsion
4. Shear

- Corrosion: The degree of corrosion is proportional to the degree of moisture.
    - Oxidisation – Metal exposed to air
    - Electrolytic – Electric current between 2 metals



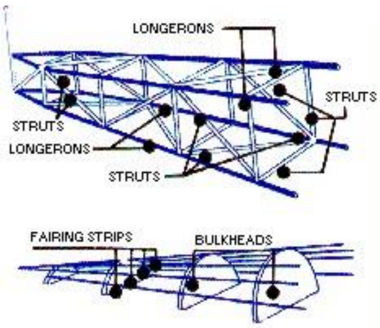
- Titanium Alloy – Turbine blades, fire proof bulkheads.
- Nickel Alloy – Turbine blades and hot end fittings
- Magnesium Alloy – Aircraft wheels and airframe structures & gearbox casing
- Copper – Electrical bus bars and wiring.
- Brass – Pipe fittings, Filter elements, Brushes, Electrical contacts.
- Bronze – Electrical generators and motor bearing brushes.
- Phosphor – Bearing brushes
- Lead – Counter balance weights
- GRP (Glass fibre reinforced plastic) – Pannels, ducting, internal fittings.
- Carbon Fibre – Fairings, cowlings, access panels and flight control surfaces.
- Kevlar – Structure, Cable insulation, floor beams.
- Nomex – Honeycomb in between glass fibre or carbon fibre sheets.

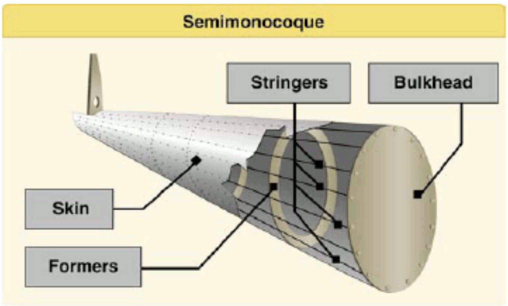
- Composites = 2 or more organic or inorganic components. One material is the matrix (epoxy resin) and the other is the fibre matting (woven glass). Some use a honeycomb structure core.

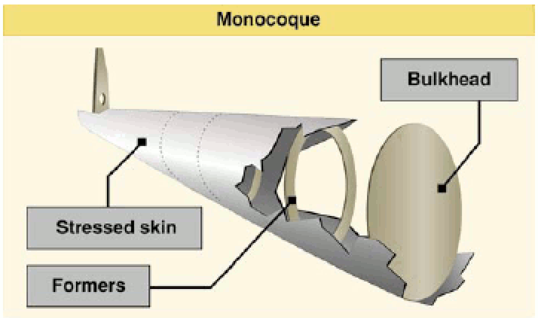
- Hard time maintenance = Definite time limit. It is fail preventative.
- On condition maintenance = Inspection/function check. Removed before its failure in service.
- Conditions are monitored continuously or at specified points.

S2 – Airframe Construction

- Major sub-assemblies = Fuselage, empennage, wings.
- Attachment methods = Riveting, bolting, welding, pinning and adhesives.
- Construction methods = Truss (Space frame), Monocoque or semi-monocoque.



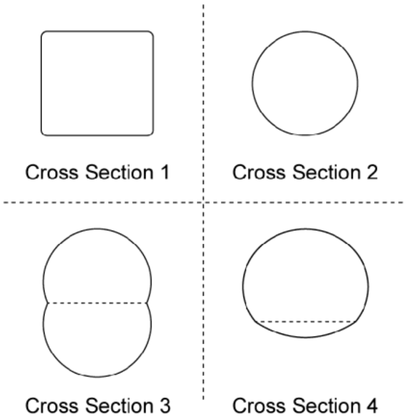




- Truss:
  - Truss carries tensile and compressive loads.
  - Steel wire used to brace the structure.
  - Longerons provide longitudinal stiffness

- Semi-monocoque:
  - Skin – withstands tension and compression stresses.
  - Longerons withstand bending loads.
  - Stringers withstand buckling.
- Monocoque:
  - Skin – Withstands tension and compression stresses.
  - Formers and frames – carry the main loads.
  - **Poor transmission of torsional forces**

- Fuselage is circular – Helps withstand pressure loads and prevents airflow separation.



Best	2
	3
	4
Worst	1

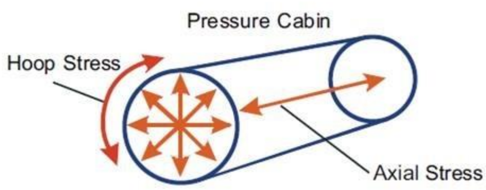


Diagram 1.3f Hoop and Axial Stress

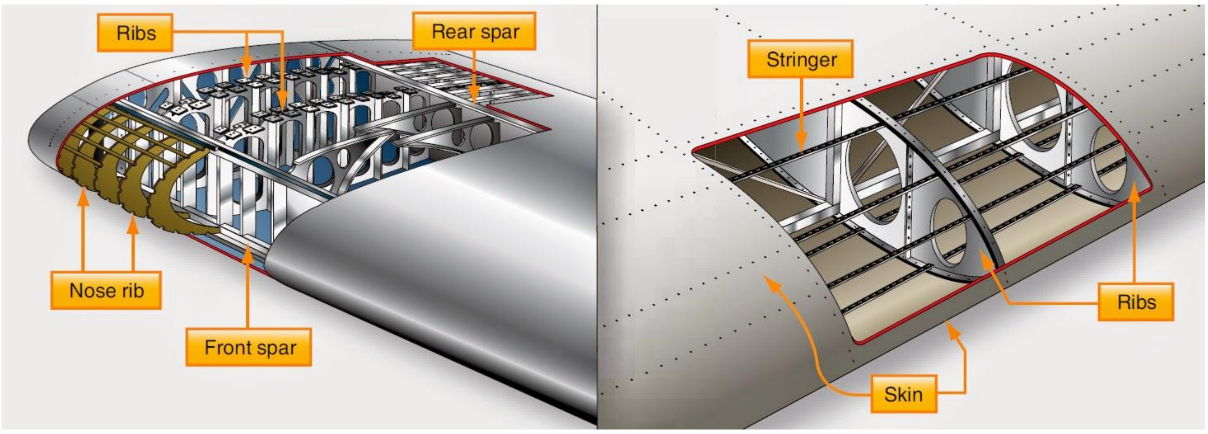
- Pressure hull – normally pressurised to 8-9 PSI.

- Blow out bungs – equalise pressure in case of rapid decompression in the cargo area.

Wing Construction:

- 3 types of wing: Cantilever, Semi-cantilever and externally braced.

- Wing is comprised of main spars – running span-wise along the wing and ribs – running leading edge to trailing edge.



- Torsion box/wing box = the only fixed part of the wing structure.

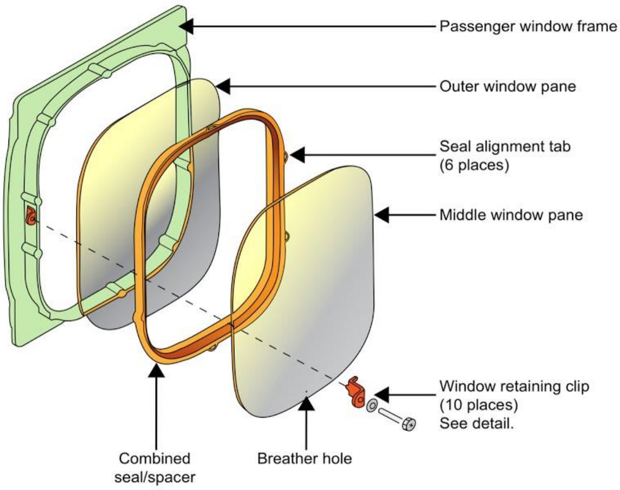
- **Flutter:** Undampened oscillation through the structure due to aerodynamic inbalance. This occurs when the aerodynamic forces couple with the structures natural mode of vibration to produce a rapid periodic motion (fluttering).

S3 – Subsidiary Airframe Components

- Cabin floor attached to longerons and cross beams
- Seat rails mounted on cross beams
- Doors and hatches – inward opening (plug doors).

- Cockpit windows:
    - Sealed to withstand pressurisation forces
    - Withstand stresses due to large temperature differences
    - Withstand significant impact without breaking
    - De-ice/ anti ice facility
    - Excellent optical qualities to allow undistorted vision.

- Cabin windows: →



S4 - Hydraulic Principals

$$Pressure\ (PSI) = \frac{Force\ (Lbs)}{Area\ (in2)}$$

$Input\ force\ x\ Input\ distance = Output\ force\ x\ Output\ distance$

- Air is compressible – whereas oil and water are not.
- Pressure force is felt at right angles to the internal surfaces

- Properties of hydraulic fluids:
    - Incompressible
    - Low Viscosity
    - Good Lubrication
    - Remains liquid over a large range of temperatures
    - Resistant to high temperatures/ non flammable
    - Prevents corrosion
    - Chemically inert
    - Low emulsifying characteristics
    - Low volatility

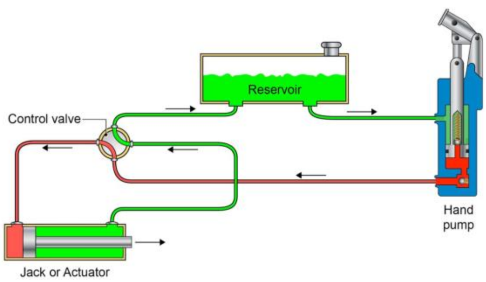
Hydraulic pressure is a function of system pressure and volume flow
Parameters to monitor: • Pressure • Temperature • Quantity

- **Mineral Oil – Coloured Red.**
    - Good lubrication properties
    - Not prone to foaming
    - Good corrosion protection
    - Requires neoprene seals and hoses

- **Synthetic Oil – Coloured Purple (alternatively orange/green)**
    - Less prone to cavitation
    - More resistant to fire/ Able to withstand higher temperatures
    - Requires Teflon seals and hoses

- Mineral and synthetic oils are NOT compatible with each other.

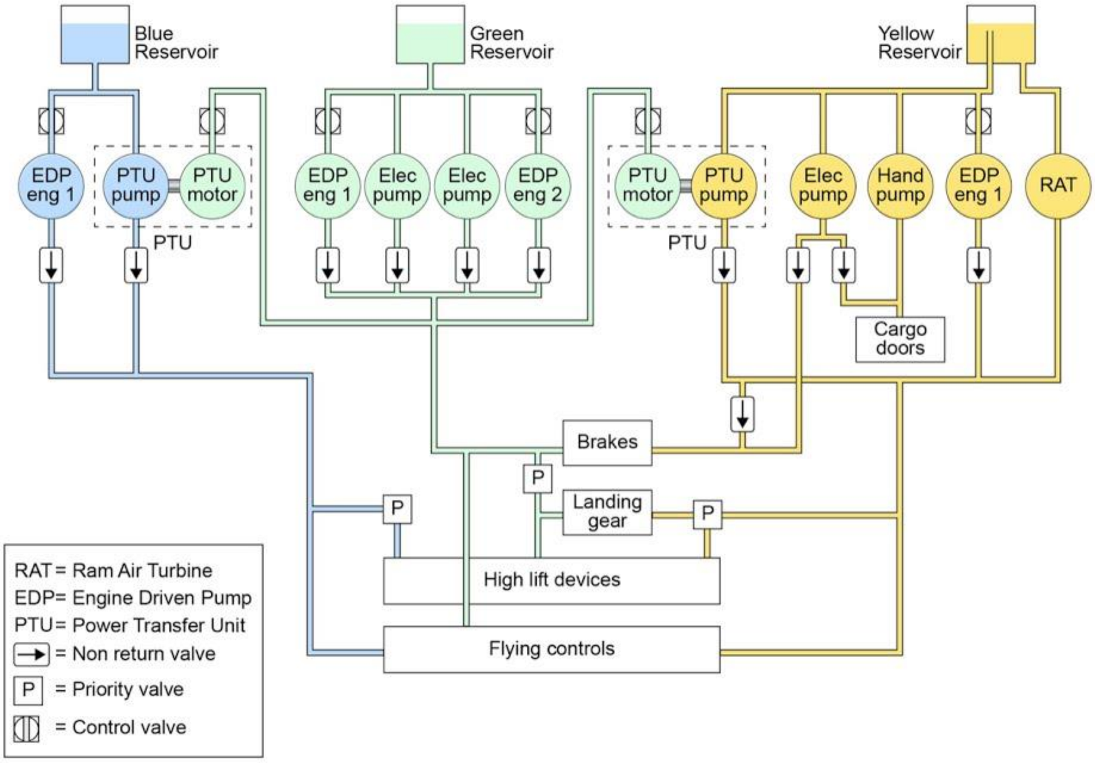
- A Passive system requires human power to raise pressure
- An active system uses one of more pumps
- An open centre system – pressure only when demanded
- A closed centre system – constant pressure at all times



- NRV = Non return valve
- PRV= Pressure Relief valve

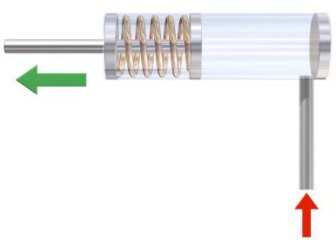
S5 – Hydraulic Systems

- At least 2 independently powered hydraulic systems.

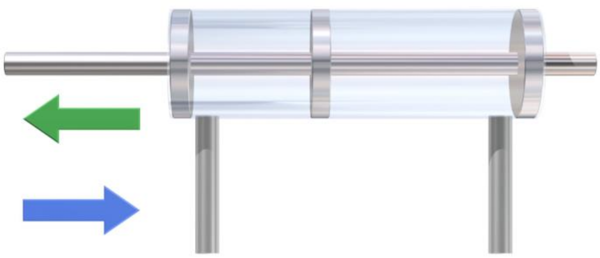


- Requirements of the hydraulic system:
  - Store the required amount of hydraulic fluid, plus reserve to cater for leaks
  - Sufficient volume to cater for expansion (heat)
  - Means to remove air and dissolved gasses
  - Hold an emergency reserve
  - Ensure only fluid can enter the pump inlet
  - Physical means to determine if the system is slack
  - Means of replenishing the system

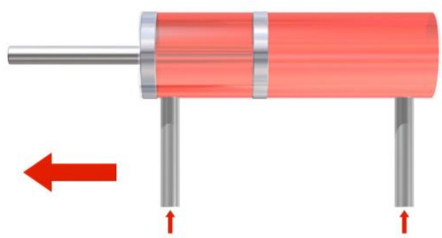
- Actuators – convert hydraulic pressure into movement:



Single Acting Cylinder

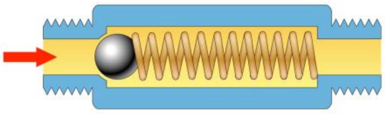


Balanced Double Acting Cylinder

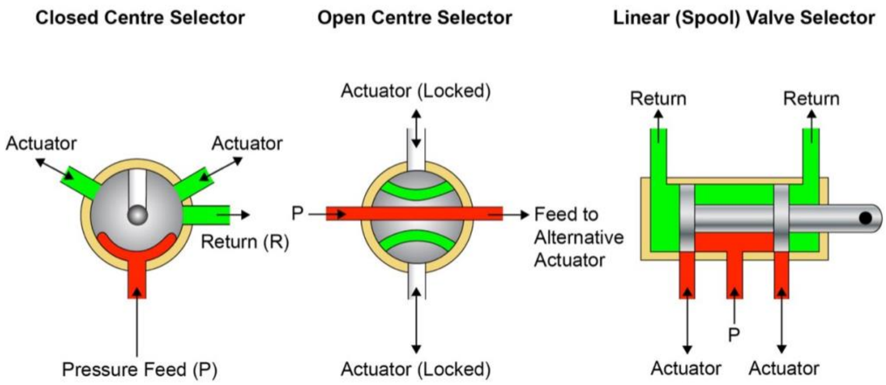


Un- Balanced Double Acting Cylinder

- **Non return valve:**

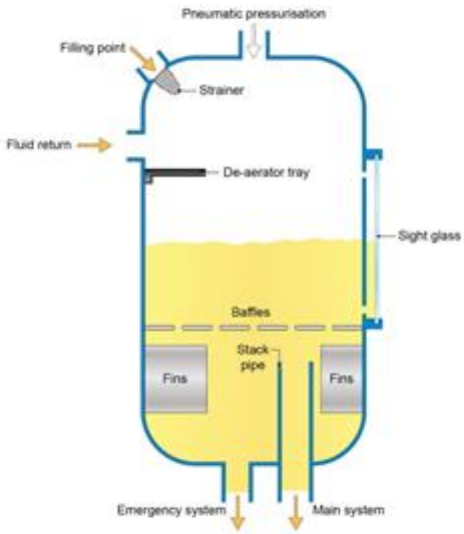


- **Selector Valve:**
- *Creates a hydraulic lock by cutting the flow lines.*
- *Rotary 4 port actuator*



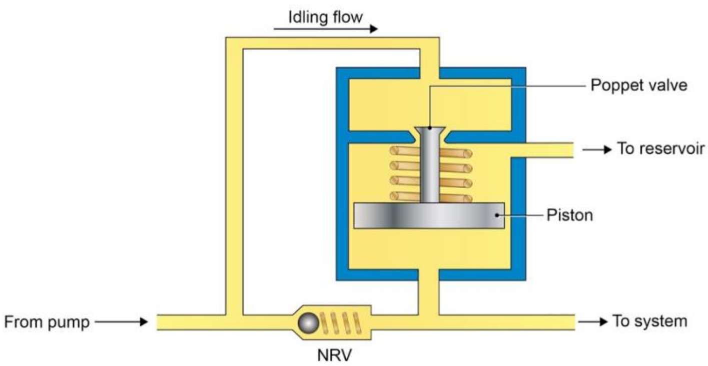
- **Accumulators:**
- A piston moving freely inside a sealed cylinder. Moving cylinder provides a tight seal between the hydraulic fluid and the gas.
- Help to smooth out pressure fluctuations
- Assists ACOV (Automatic shut off valve)
- Store of fluid under pressure for emergencies
- Supplements pump output under peak load
- Store of energy when pump is not running
- Allows thermal expansion

- **Hydraulic Reservoir:**



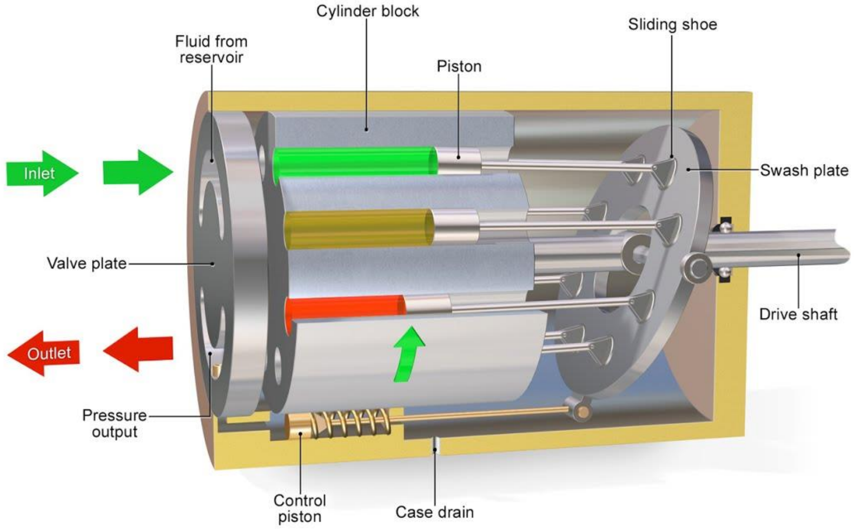
- Constant delivery (fixed volume) pumps have no means of regulating output, so require an automatic cut off valve (ACOV):

- **ACOV: Automatic Cut out valve:**



- When system pressure increases above a fixed level, pressurised hydraulic fluid forces a poppet valve to open. This ‘dumps’ excess pressure.

- **Constant Pressure (Variable Volume) Pumps:**
- System pressure = 3000psi



Should a hydraulic pump seize during operation – the quill drive will shear to offload and protect the gearbox

- When the swash plate is at its sharpest angle, highest pressure output is obtained. When the swash plate is at a very fine angle, the stroke is minimal resulting in an idling state.
- ACOV not required
- Pump is driven by a gearbox linked to the engine.
- A blocking valve is fitted to offload the pump and minimise starting loads on the engine.

- Hydraulic filters keep the fluid free of contamination and are located downstream of the hydraulic pump.
- Excess debris build up will cause a differential pressure sensor warning light in the cockpit – or a red filter pop out button to indicate the filter needs changing.
- If the filter is blocked – a bypass valve automatically allows unfiltered fluid to flow.

- A priority valve ensures sufficient fluid flow at all times to the primary controls and wheel brakes. It closes and isolates any non-essential circuits if system pressure drops below a set limit.

- A shuttle valve allows one service to be operated by 2 independent supplies, thus generating and adequate supply if one fails.

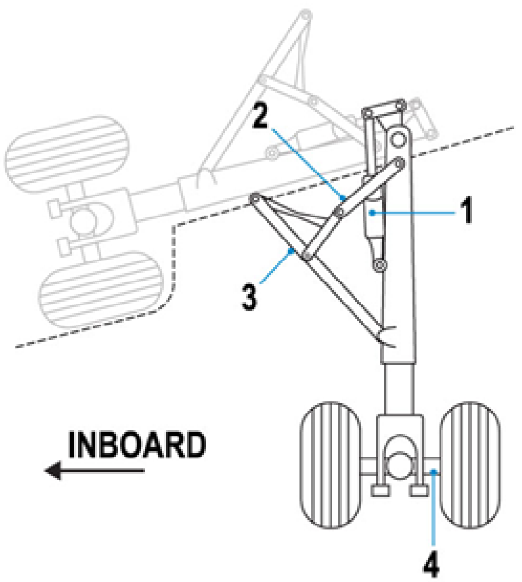
- Hydraulic fuses are fitted upstream of components, to shut off flow and prevent total fluid loss in case of a major leak. The fuse senses differential pressure across the unit.

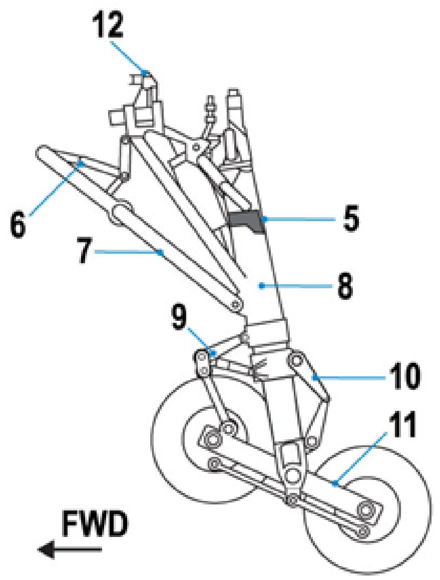
- Shut off valves are operated by an external controller, and isolate flow to components.

CS25-1435: Hydraulic systems must be designed to handle pressure working & pressure limit loads multiplied by 1.5, in conjunction with ultimate structural loads.

S6 – Landing Gear

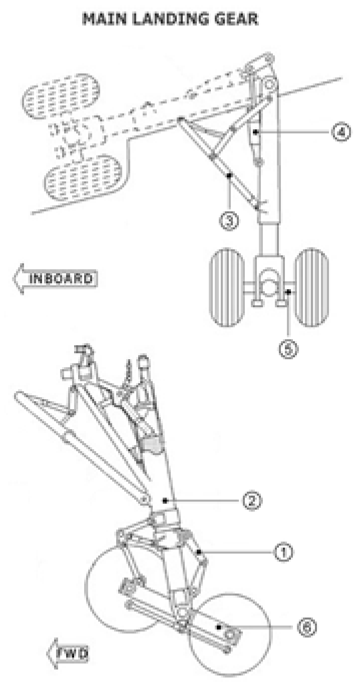
- Landing gear functions:
  - Support the aircraft on the ground
  - Absorb landing shocks
  - Withstand side loads
  - Dampen vibration
  - Minimum friction
  - Withstand air loads
  - Minimum mass and minimum drag



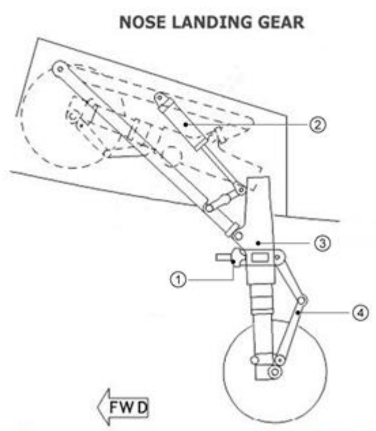


1.Actuating/retracting cylinder
2.Downlock strut
3.Side stay/strut
4.Axle
5.Piston
6.Downlock strut

7.Brace strut
8.Shock strut/main oleo
9.Hydraulic strut
10.Upper torque/torsion link
11.Bogie beam
12.Mounting lug



1 – Torsion Link
2 – Main leg Oleo Strut
3 – Side Stray/Strut
4 – Actuating Cylinder
5 – Axel
6 – Bogie Beam



1. Steering Actuator
2. Retraction Actuator
3. Shock Absorber
4. Torsion Link

Oleo-Pneumatic Strut:

- Absorbs Shock of landing
- Nitrogen: Compressible and acts as the 'Spring'
- Oil: Incompressible and acts as the dampening element

- Torque links/Scissor links prevent rotation of the inner part in relation to the outer

Nose wheel shimmy:

- Damaging oscillation of the nose wheel on the ground.
- Occurs when the wheels tend to describe a sinusoidal motion on the ground.
- This is overcome by an accumulator associated with the steering cylinder.
- Also countered by:
    - Self-centred springs
    - Double nose wheels
    - Twin contact nose wheel types.

Undercarriage:

- Geometric over centre locks are used to lock the gear down.
- Requires no hydraulic power
- Ground lock pin while on the ground
- Uplocks hold the gear in place in the air – hook lock requires hydraulic pressure to engage and release.

Weight on wheels system (Air Ground sensing logic):

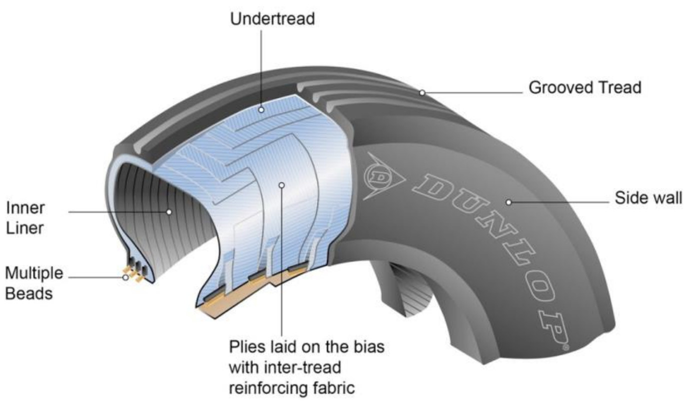
- Sensed via switches
- Used to inhibit:
    - Landing gear lock
    - Nose wheel steering
    - Thrust reversers
    - Ground spoilers
    - Stall Warning
- Gear lever lock prevents gear operation on the ground (can be over-ridden using trigger).

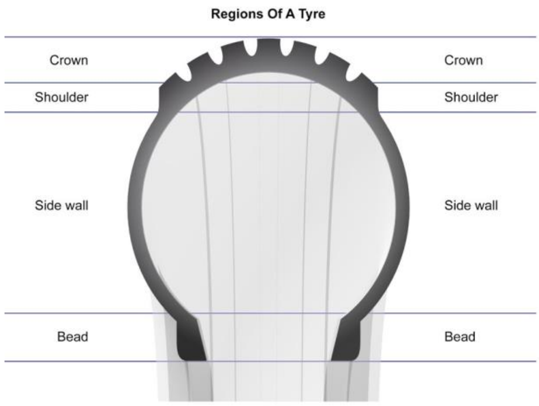
Cockpit Indications:

- **GREEN – Gear is locked Down**
- **RED – Gear is unlocked, travelling or the lever selection disagrees with the gear position**
- **AMBER – Truck not taken up the correct trail position. Gear cannot be raised.**
- **NO LIGHTS – Gear is up and locked**

S7 – Wheels, Tyres and Brakes

- Types of wheel:
  - Well Based – Usually fitted to light aircraft with tubed tyres
  - Detachable flange – Allows for easier tyre replacement
  - Split hub/Divided – Allows the tyre to be mounted on one half and then the other half bolted. This is used in large aircraft





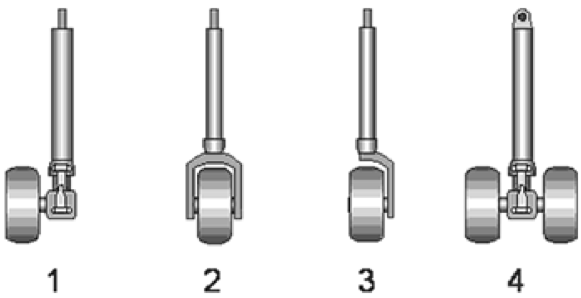
Types of Tyre	
Ply Rating	Ply rating gives an indication of the tyre strength. Higher ply = higher strength.
Tread	Tread pattern forms channels to expel water. Most common tread = ribbed tyre
Tubeless	Airtight lining allowing for no inner tube.
Bias	Cross Ply. Adjacent cords at 90 degrees to eachother
Radial	Piles are perpendicular to the centre of the tyre
Re-tread	New crown and tread added to old worn tyres
Tubed	Valve to inflate separate inner tube inside of the tyre

- Low pressure tyre – 200PSI *120MPH Max
- High pressure tyre – 315PSI *250MPH Max
- Tyres pressurised with nitrogen

- It is expected that a tyre will lose 5% pressure due to gas dissipation – reinflate as normal
- When a tyre loses 10% +, tyre must be changed/ pair if it is on the nose wheel.
- Expected hot tyre pressure – 10% higher.

- Tyre creep – circumferential movement of the tyre around the rim.
- Most likely to occur with new tyres
- Creep marks are to be 1inch wide for tyres 24 inches or less in diameter, or 1.5inches wide for tyres over 24 inches in diameter.
- Providing there is some overlap between the creep marks, the tyre is fine.

- Ribbed/Grooved tyre – Low rolling resistance and good directional/traction stability
- Chined tyre – deflects water away from rear mounted engines
- Marstrand tyre – used on nose wheels to help prevent shimmy



1. Cantilever
2. Fork
3. Half Fork
4. Dual Wheels

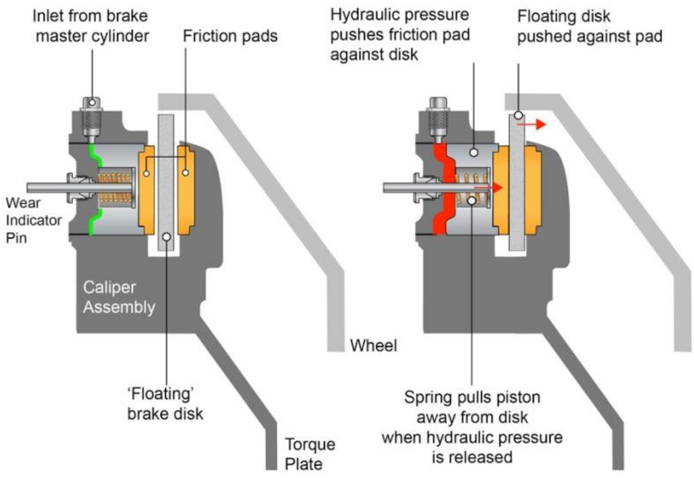
- Indications on tyres:
  - Wear indicating grooves – min tread depth = 2mm
  - Green paint – indicates a vent hole
  - Red paint – Weak point to be aligned with the valve

- Aquaplaning:
  - Water builds up as a bow in front of the tyre, resulting in the tyre floating on the film of water
  - Friction co-efficient = 0
  - $Min\ Speed\ (knot) = 9\ x\ \sqrt{P}$ where P = Pressure in PSI

- Tyre overheat protection = fusible plugs. Allows for a controlled deflation

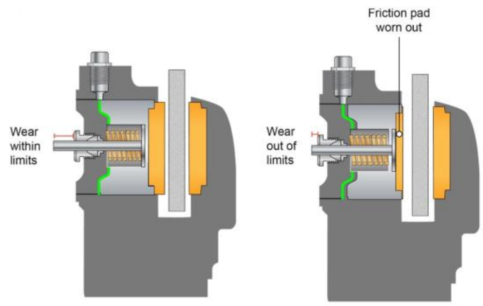
Brakes:

- Convert kinetic energy into heat energy.
- Heat depends on:
  - Mass
  - Brake Speed
  - Runway Slope
  - Wind component
- Following a brake failure, the aircraft must:
  - Halt acceleration by at least half the normal rate
  - Must not require excessive control force
  - Must hold the aircraft against low power conditions
  - No failure of anti-skid should result in loss of control
  - It must disperse heat energy



- Brake disks – typically steel or carbon.
- Brake temperature sensor Thermocouple measured
- Brake fade = reduction in stopping power that will occur after repeated or sustained application of the brakes – especially in high load/high speed

- Brake wear indication – Break wear indicator pins:



- Manufactures will specify brake cooling times.
- ATC must be informed of brake overheat.

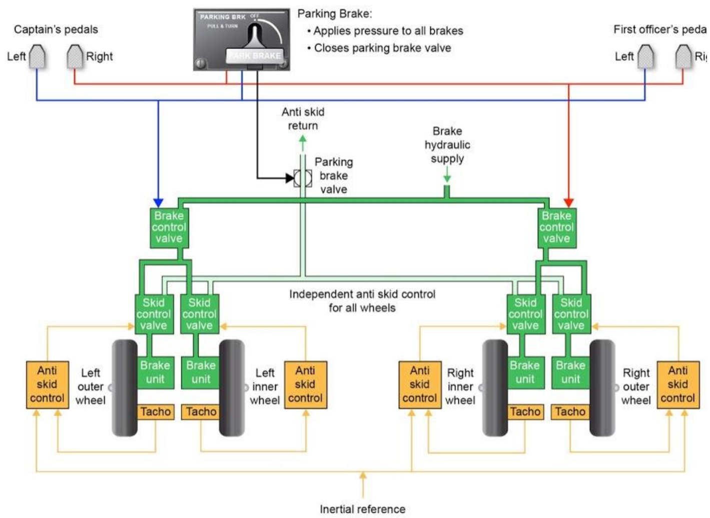
Anti Skid Brakes:

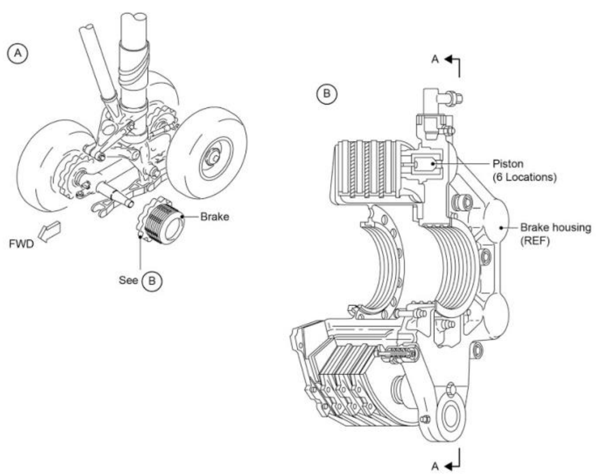
- Maximum braking efficiency
- Reduces landing run
- Better directional control
- Increased tyre life
- Hydroplane protection
- Touchdown protection
- Failsafe protection

- Electronic antiskid system:
  - Tach generator in each wheel
  - Anti-skid controller references signals from each wheel
  - Controller assesses the speed of the aircraft
  - Reduces brake pressure when skid is anticipated
  - Reapplies lower pressure to the brakes.

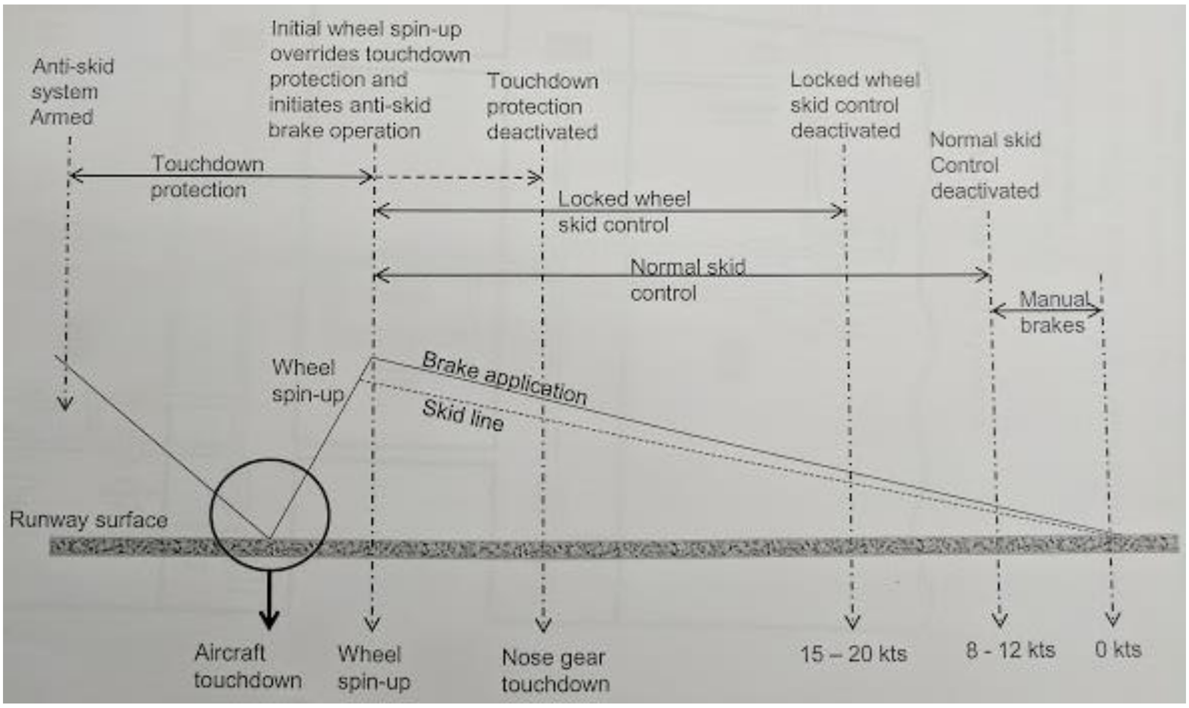
Anti-Skid accounts for:

- Aircraft Speed
- Wheel Speed
- Desired slip ratio





- Anti Skid Operation:



- Autobrake system:
  - Anti Skid ON
  - Auto Brake ON
  - Thrust levers below threshold value
  - Brake pedals NOT DEPRESSED

- On gear retraction:
  - Main wheels are braked
  - Nose wheels stopped with snubber blocks

- Emergency Brakes:
  - Alternate source of hydraulic pressure, via a shuttle valve
  - Accumulator precludes the use of anti-skid
  - Sufficient fluid for 6 full applications

- Parking Brake:
  - Hydraulic lock
  - Over-rides all other braking systems including touchdown protection and antiskid
  - Should not be set if the brakes are hot.

Taxi braking recommendations for carbon and steel brakes

Because the wear mechanisms are different between carbon and steel brakes, different taxi braking techniques are recommended for carbon brakes in order to maximize brake life.

Steel brake wear is directly proportional to the kinetic energy absorbed by the brakes. Maximum steel brake life can be achieved during taxi by using a large number of small, light brake applications, allowing some time for brake cooling between applications. High airplane gross weights and high brake application speeds tend to reduce steel brake life because they require the brakes to absorb a large amount of kinetic energy.

Carbon brake wear is primarily dependent on the total number of brake applications — one firm brake application causes less wear than several light applications. Maximum carbon brake life can be achieved during taxi by using a small number of long, moderately firm brake applications instead of numerous light brake applications. This can be achieved by allowing taxi speed to increase from below target speed to above target speed, then using a single firm brake application to reduce speed below the target and repeating if required, rather than maintaining a constant taxi speed using numerous brake applications. Carbon brake wear is much less sensitive to airplane weight and speed than steel brake wear.

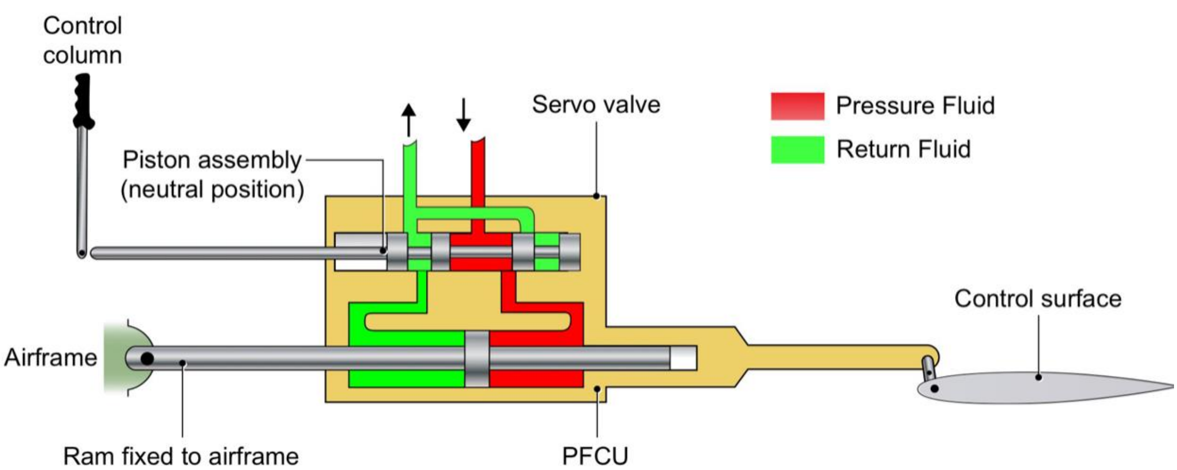
These recommendations are intended as general taxi guidelines only. Safety and passenger comfort should remain the primary considerations.

S8 – Primary Flight Controls

- Primary flight controls allow for the aircraft to be manoeuvred around the centre of gravity.

- Manual flying control:
    - Considered a reversible system
    - Push/Pull arrangements with rods and cables
    - Connected mechanically
    - Turn buckle – maintains cable tension
    - Temperature compensator – Prevents the need to manually tension cables when moving hot/cold
    - Multi cable strand – redundancy.
    - There is an aerodynamic feel as to stresses exerted on the airframe
    - Primary control stops – limits range of movement at the control surface
    - Secondary control stops – limits range of movement at the pilot input stick
    - Gust locks – prevent gusts operating control surfaces
    - Jamming protection – Breakout boxes physically disconnect pilot controls if one becomes jammed.
    - Trim tab – cable or screw jack. Reduces stick forces to zero.

- Fully powered flying controls:
    - Considered a non-reversible system
    - Uses hydraulic actuators to operate control surfaces
    - Hydraulic lock exists with no pilot input
    - Control cables or electrical positioning signalling devices operate servo valves or hydraulic actuators.
    - Movement of the controls the servo valve only
    - This directs hydraulic pressure to either side of the actuator, causing the control surface to move



- Artificial feel systems – to prevent over stress of the control surfaces:
    - Spring feel – applies constant back pressure
    - Q Feel – Isolates dynamic pressure and gives back pressure proportional to Pq
    - Combined feel system:
        - Spring on the ground and less than 40kts
        - Hydraulic Q feel system above 40kts

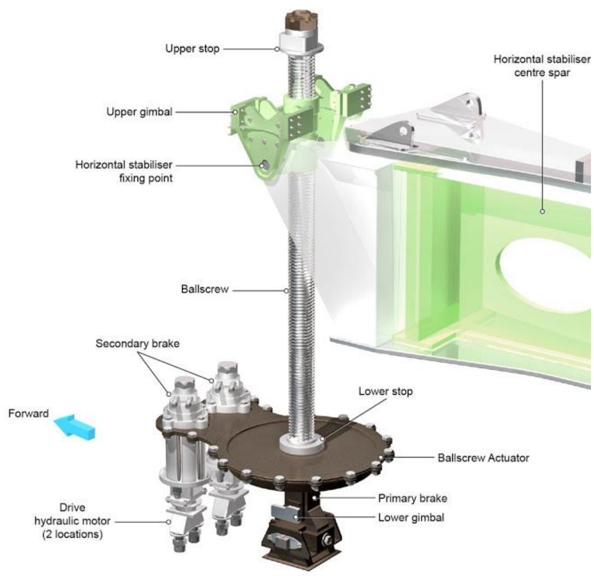
- Rudder Limiter:
    - Protection from large rudder deflections at high speeds
    - Rudder ratio changer limits rudder movement in order to protect the fin
    - Usually 2 parallel systems for redundancy.

Both rudder ratio changer and a variable stop system prevent excessive rudder deflection at high speed.

By changing the ratio, even a full movement of the pedals will not give full deflection of the rudder. So the rudder movement is limited, but not the pedals.

A variable stop system progressively limits deflection of the rudder as speed is increased, but by physically constraining it, NOT by changing the ratio. But within the range of motion that it has, the same relationship between pedal deflection and rudder deflection exists.

- Horizontal Stabiliser Trim:
    - Driven by electronic screw jack
    - Allows full elevator authority
    - Requires 2 independent switches in case of trim runaway

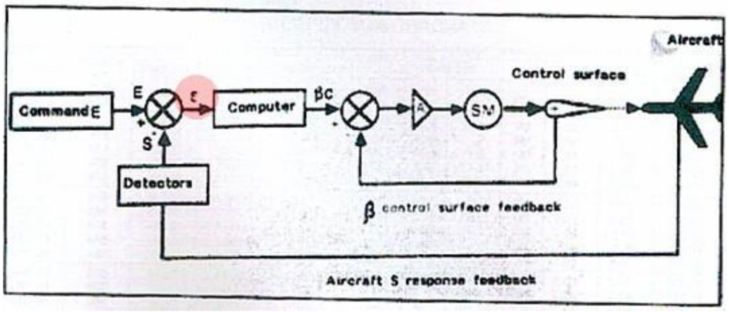


- Blow Back System:
    - Allows a control surface to blow back into a defined, less deflected position to relieve any stress load – thus preventing damage to the aircraft structure.

- Control Locks:
    - Internal locks to prevent gusts from operating the control surfaces.

- Autopilot System:
  - Attitude – Achieved by gyroscopes or accelerometers which send attitude changes about the relevant axis.
  - Error sensing – Achieved by sycrotransmitters or E and I bars, which change with the attitude signal into an electrical error signal
  - Signal Processing – Achieved by a discriminator and amplifier circuit – they process the electrical error signals, providing an output to the servo motor actuator.
  - Servo motor actuator – Moves the control surface
  - Position feedback loop – advises the signal processor of any control surface movement.

Figure 022-42



Fly By Wire Technology:

- Reduced Mass
- Reduced Maintenance
- Rapid Control response
- Built in control parameters
- Gust load alleviation
- Fuel Saving

- Inputs from the pilots are converted to digital signals
- Computers modify the pilots request, before sending appropriate control demand to control surface actuators.

Autopilot Control Laws	
Normal	Provides complete flight envelope protection of the aircraft. The normal law keeps the aircraft within a normal control envelope. The complete protection is overspeed, overstress bank angles and stalling.
Alternate	Some protection from overstress but the aircraft can be stalled. Further system failures will cause reversion to a Direct system.
Direct	Backup mode. Does not provide any protection in any way, and can be overstressed and stalled. It is as if the pilot is manually flying.

S9 – Secondary Flight Controls

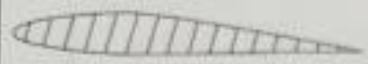
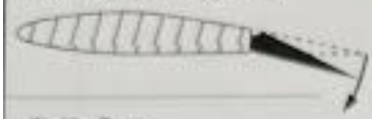
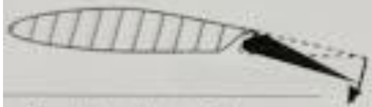
- Secondary Flight Controls:
    - Trailing Edge Flaps
    - Trim
    - Leading Edge Devices
    - Spoilers
    - Speed Brakes
- Flap load relief:
    - When the flaps significantly extend, the aerodynamic load at high speed could cause damage to the structure.
    - Some aircraft have a flap load relief system, which automatically retracts the flaps by one or more stages in such an event.

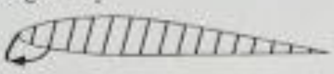
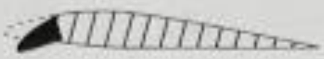
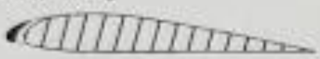
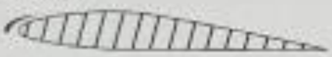
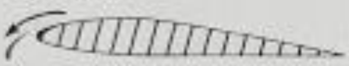
- Flap Asymmetry Protection:
    - Interrupts flap movement whenever the flap position disagrees by a pre-set amount from the intended selection.
    - Detects excessive flap asymmetry and will cut the power to the flaps

- Speed brakes/spoilers:
    - Hydraulically operated
    - Differential operation for roll control
    - Symmetric operation for speed brake and lift dump.

- Spoilers:
    - Spoiler mixer unit – simultaneous use of the spoilers and speed brakes
    - Spoilers in roll:
        - Up going wing – spoilers remain retracted
        - Down going wing – spoilers extend

- Mach Tuck:
    - Speed brakes linked to the ADC to a Mach Meter
    - If Mach No gets too high, speed brakes deploy to slow the aircraft and prevent Mach tuck.
- Lift Dump – Speed brake decrease lift by 80% on landing
- Speed brakes and spoilers have no locks – if hydraulic power is lost, they will trail or blow back.

High-lift devices	Incr. of max. lift	α crit	Remarks
Basic airfoil 	-	15°	Effects of all high-lift devices depend on the shape of basic airfoil.
Plain or camber flap 	50%	12°	Increased camber. Much drag when fully lowered. Nose-down pitching moment.
Split flap 	60%	14°	Increased camber. Even more drag than plain flap. Nose-down pitching moment.
Slotted flap 	65%	16°	Control of boundary layer. Increased camber. Stalling delayed. Not so much drag.
Double slotted flap 	70	18°	Same as single-slotted flap, only to a greater degree. Triple slots sometimes used.
Fowler flap 	90%	15°	Increased camber and wing area. Best flaps for lift. Complicated mechanism. Nose-down pitching moment.

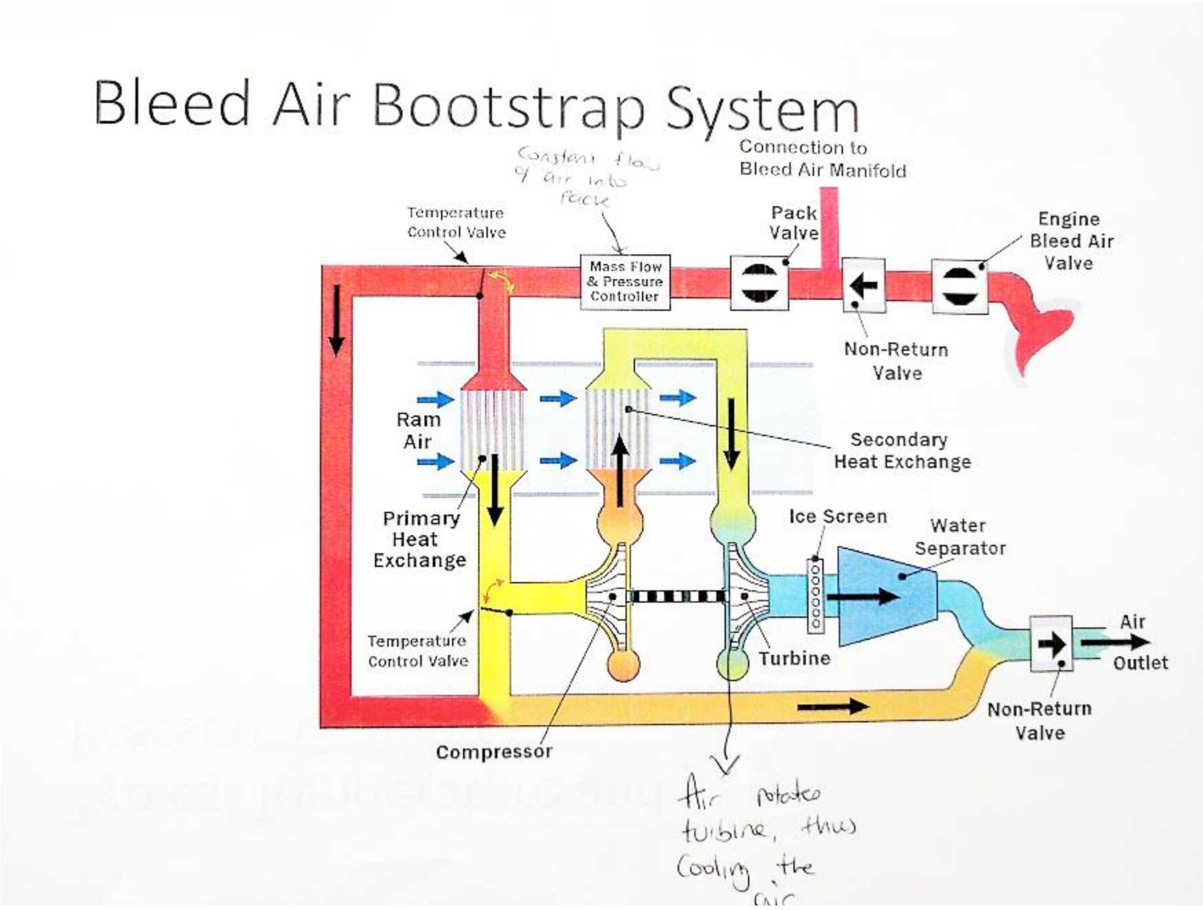
High-lift devices	Incr. of max. lift	α crit	Remarks
Krüger flap 	50%	25°	Nose-flap attached to leading edge. Greater A.o.A. Reduces lift at small deflections. Nose up pitching moment.
Leading edge flap 	40%	20°	Nose-flap. Increased camber. Greater A.o.A. Nose-up pitching moment. Slight extra drag at high speed
Slotted wing 	40%	20°	Control of boundary layer. Greater A.o.A. Slight extra drag at high speed.
Fixed slat 	50%	20°	Control of boundary layer. Greater A.o.A. Extra drag at high speed. Nose up pitching moment.
Movable slat 	60%	22°	Control of boundary layer. Increased camber and area. Greater A.o.A. Nose up pitching moment.

S10 – Pneumatic Systems

- Light aircraft use pneumatics to power gyros and de-icing boots
- Small engine driven vacuum pump is a source of pneumatic power for smaller aircraft
- Larger aircraft use pneumatics for cabin conditioning and pressurisation
- Gas turbine bleed air is a source of pneumatic power for larger aircraft

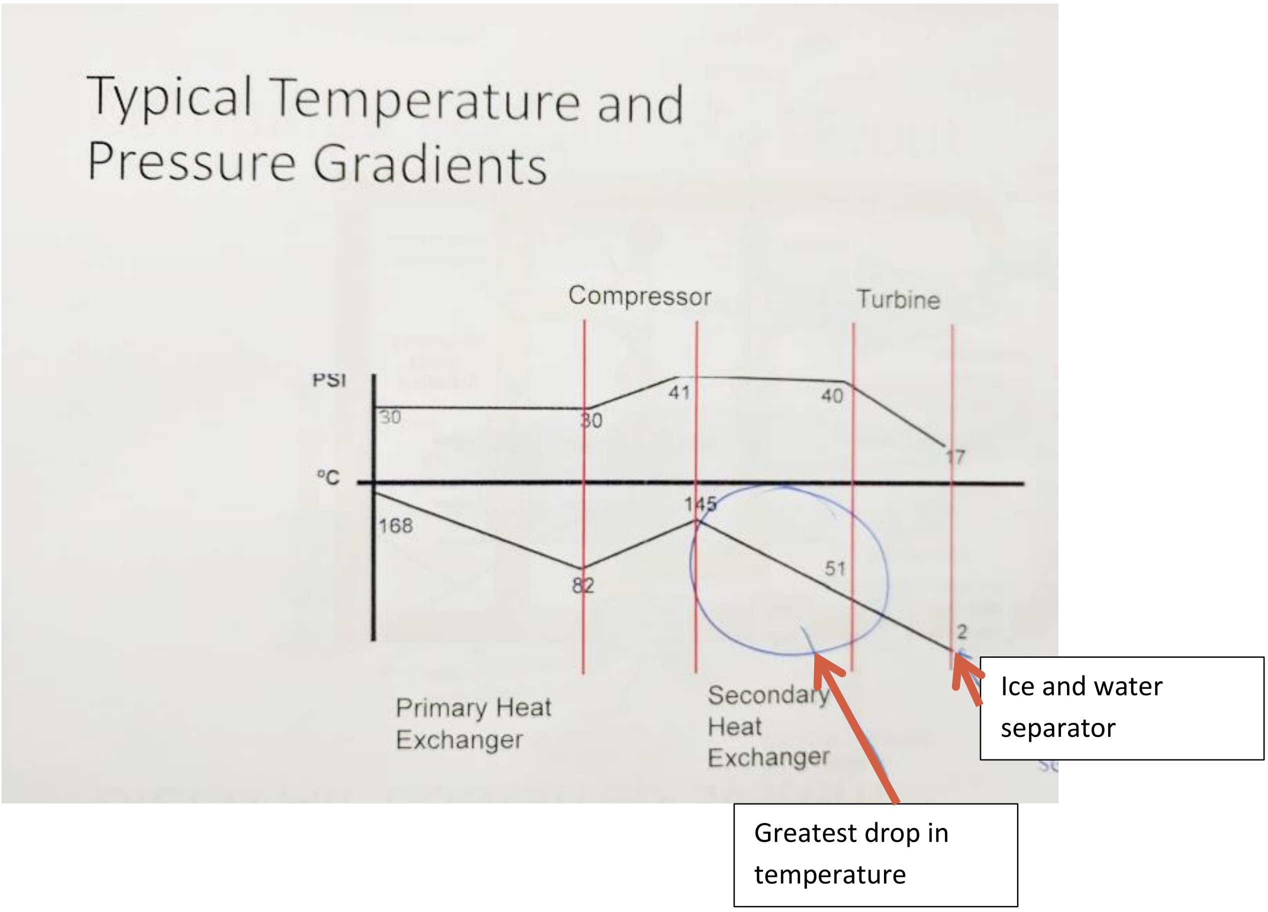
- Light aircraft vacuum pump:
  - Centrifugal compressor
  - Known as a dry pump
  - Rotor driven by the engine via a quill shaft

- Sources of air for gas turbine aircraft:
  - Bleed air from main engines
  - Compressed air (APU)
  - Compressed air (Ground power – external)
- Air can be taken from various stages of the compressor, depending on the requirements for temperature and pressure.
  - It can be fed through an intercooler and distributed through stainless steel ducting for cooling.



- Bleed Air shut off:
  - Cross bleed valve (isolation) separates the left and right side of the bleed air manifold
  - APU has its own shut off valve (SOV)
  - Extensive use of NRV (Non return valves)

  - On the flight deck, supplies and or systems can be isolated in case of malfunction. Monitored for:
    - Over Temperature
    - Over pressure
    - Low Pressure
    - Over Heat/ Duct Leak
- Distribution ducts are high temp and high pressure stainless steel.
- Light alloys are used for lower temperatures and pressures
- Plastic and GRP for very low temperature and low pressure (cabin conditioning)



S11 – Cabin Conditioning & Pressurisation

- Air Conditioning Requirements:
  - Produce 1lb per minute per passenger of fresh air and 0.5lb per passenger per minute in emergency situations.
  - Control cabin temperature between 18-24◦C
  - Ensure carbon monoxide is less than in part in 20,000
- Air Cycle Cooling – 2 types:
  - Displacement blower
  - Bleed Air
    - Based on the principal of dissipating heat by converting energy into work

- Gasper Air = Passenger Ventilation Air:
  - Fan driven system
  - Recirculation fans reduce the load on the packs and reduce demand for bleed air
  - HEPA (High efficiency particulate arresting) filters reduce the spread of airborne pathogens.
  - Riser ducts distribute the passenger air
  - Emergency ram air intake ventilates the cockpit or cabin in case both packs fail
    - Controlled by the ram air push button on A/C panel.
- Pressurisation system must:
  - Maintain atmospheric conditions between 6000-8000ft
  - Provide heating and cooling
  - Provide 1lb air per pax per min
  - Suitably low rate of climb in cabin pressure:
    - Climb = 500fpm
    - Descent = 300fpm

- Pressure hull designed to withstand 7-9 psi differential (PSID). This is a structural limitation and will occur at the max operating altitude.
- In the event that the pressure differential gets too high, an outward relief valve will open (typically called the safety valve and operates at max differential pressure + 0.25psi).

- A/C unit has a constant mass flow and variable mass load.
- If the cabin altitude exceeds 10,000 ft, an alarm will sound.
- In a rapid decompression, outside pressure may exceed interior pressure. An inward relief valve opens at -0.5 psiD
- Cabin to be sealed. Max permissible leak is equivalent to 300fpm rate of climb.

- In the event of a pressurisation failure:
  - 10,000ft AMSL = Audible warnings and visual warnings
  - 13,000ft AMSL= Outflow valves close automatically
  - 14,000ft AMSL= Passenger oxygen masks deploy automatically

S12 – Oxygen Systems

Altitude	Effect
8000ft	Max altitude at which flying efficiency is not impaired
25000ft	Decompression sickness increases rapidly
33000ft	100% Oxygen required
40000ft	100% Oxygen pressurised required

- The crew must don an oxygen mask with 1 hand within 5 seconds of exceeding 10,000ft

- Crew oxygen:
  - Gaseous (stored at 1800 PSI), reduced to 80PSI for distribution and 8-10PSI in the masks.

- Passenger Oxygen:
  - Gaseous or chemically generated
  - Continuous flow of 100% oxygen for 15 minutes
  - 1 mask per seat, plus 10%
  - Must be provided where cabin altitude exceeds 15,000ft
  - When cabin altitude exceeds 14,000ft, barometric valve opens and oxygen flows
  - A passenger mask is provided with 100% oxygen, however the passenger is provided with diluted oxygen with cabin air.

- Portable oxygen:
  - Typically 120l at 1800 PSI.
  - 3 Rates of supply:
    - Normal = 2l per minute
    - High = 4l per minute
    - Emergency = 6l per minute

- Smoke hood:
  - Protects eyes, nose and mouth
  - Provides 15 minutes of oxygen

- Aviation oxygen properties:
  - High purity
  - Very low moisture content

S13 – Anti-Ice, De-Ice and Rain Protection

- De-icing = Removing ice from the airframe.
- Anti-ice = Preventing ice from forming on the airframe.
- Areas to be protected from ice:
    - Aerofoil leading edges
    - Engine intakes
    - Flight Controls
    - Windscreens
    - Sensing Probes
    - Aerials
    - Propellers

Ice Detection:

- Vibrating Rod:
    - Vibrated at 40Hz. Any ice alters the frequency and triggers a warning.
- Spot light (Visual)
- Pressure operated detectors
    - Sensor hole clogged with ice, pressure drops & warning sounded.
- Hot rod detector
- Rotary ice detector

Ice Removal:

- Pneumatic Boots:
    - Rubberised boots with inflatable tubes along leading edges
    - Powered by a vacuum pump
- Fluid Based:
    - Fed through a fine mesh.
    - Used for propellers.
- Thermal:
    - Bleed air based heat system.
- Electric:
    - Used on pitot, AoA vain, windscreen, intakes and propellers.
    - Use a resistive material sandwiched between fibreglass.
    - Single Phase AC for windscreens

Rain Repellent:

- Windscreen wipers.
- Repellent coating
    - Causes rain to form beads which are blown away.

S14 – Fuel and Fuel Systems:

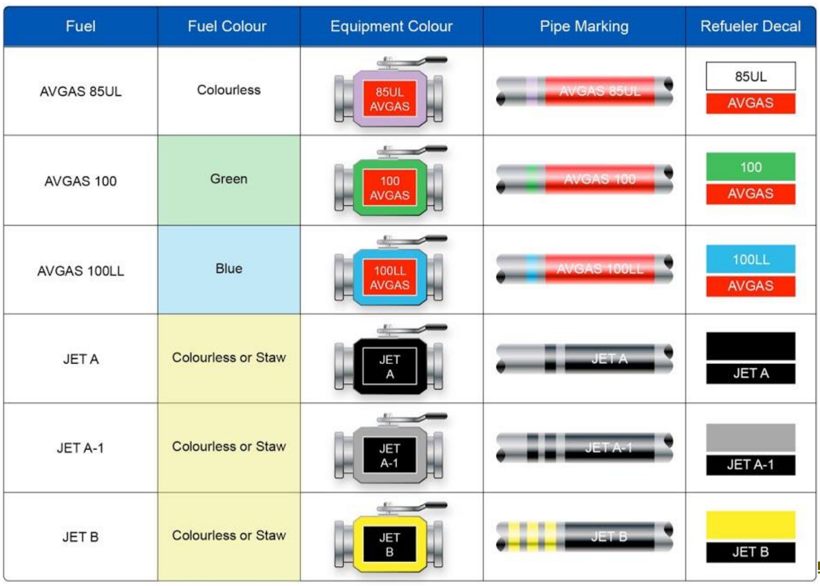
- Requirements of fuel:
  - Ease of flow under all operating conditions
  - Complete combustion under all operating conditions
  - High calorific value (energy density)
  - Low flash point
  - Good anti-knock properties
  - Non corrosive
  - Low fire hazard
  - Ease of engine start
  - Lubricant

Fuel	SG at 15◦C	Flash Point ◦C	Wax Point ◦C
JET A1 (AVTUR)	0.8	38.7	-50
JET A (AVTUR)	0.8	38.7	-40
JET B (AVTAG)	0.77	-20	-55

Fuel		SG
AVGAS 80	Low Lead. Red Dye	0.72
AVGAS 100	High lead content. Green Dye	
AVGAS 100LL	Medium lead content. Blue Dye	

Fuel Properties:

- Flash point – Volatility of fuel. Lowest temperature it can vaporise.
  - Flammable fuels – flash point below 38◦C
  - Combustible fuels – flash point above 38◦C
- Waxing = solidification of fuel. Deposits paraffin wax crystals and begins to form around - 40◦C
- AVTUR is more viscous than AVGAS and so holds water in suspension. Promotes ice formation and bacteria growth.
- FS11 – Fuel system icing inhibitor.
  - Reduces icing, Fungicidal properties & HITEC lubricant



Fuel	Fuel Colour	Equipment Colour	Pipe Marking	Refueler Decal
AVGAS 85UL	Colourless	85UL AVGAS	AVGAS 85UL	85UL AVGAS
AVGAS 100	Green	100 AVGAS	AVGAS 100	100 AVGAS
AVGAS 100LL	Blue	100LL AVGAS	AVGAS 100LL	100LL AVGAS
JET A	Colourless or Staw	JET A	JET A	JET A
JET A-1	Colourless or Staw	JET A-1	JET A-1	JET A-1
JET B	Colourless or Staw	JET B	JET B	JET B

- Types of fuel tank:
  - Rigid (Drum)
  - Flexible(bag)
  - Integral tank (inside the torsion box)

- Fuel Filtration: Coarse around pump inlets.
  - LP filters: fitted between booster and HP pump
  - HP filters: fitted between HP pump and injector
- LP booster pump – mounted inside fuel pumps in pairs. 115v 3 phase AC motor driven centrifugal pumps.
- A bypass valve is immediately upstream of the LP pump to allow fuel flow in the event of the failure of the LP pump.

- Tanks need to be vented:
  - To equalise tank pressure with ambient when refuelling/defueling
  - To allow air into the tank during fuel consumption
  - To allow for thermal expansion
  - To act as a source of pressure in flight, to raise boiling point

- Fuel vented from the main tank is collected in the surge tank.
  - This is subsequently transferred back into the main tank
  - Each tank must have an expansion space of not less than 2% capacity
  - It must not be possible to fill on the ground.

- Fuel-oil heat exchanger – used to heat fuel to prevent waxing.

- Fuel jettison system – must jettison 10-15 mins worth of fuel.

Fuel Gauge:

- 1: Float Type

- 2: Resistance Type

- 3: Capacitance Type

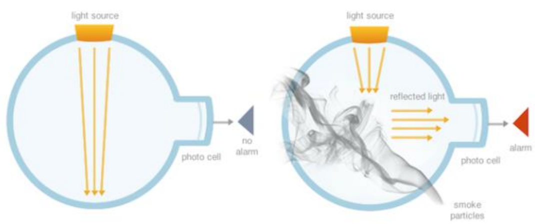
S15 – Fire & Smoke Protection

Fire Class	Materials	Extinguisher
A	Paper, Wood, Rubber, Plastics	Water
B	Petrol, Oil, Grease, Solvent, Paint	Halon, CO2, Dry chemical or Foam
C	Gas	CO2 or Halon
D	Combustible metals	Dry Chemical

Compartment	Materials
A	Compartments in which fire is easily detected and all part of the compartment is accessible in flight. EG Cabin
B	Compartments where the crew have the access to reach any part of the compartment with a hand held fire extinguisher and where provision is made to prevent fire and smoke reaching passengers. EG Avionics bay
C	Equipped with smoke/fire detectors and built in extinguishers EG Cargo bay
D	Fire will not endanger the aircraft or passengers.
E	Cargo Aircraft

- Fire warning system requirements:
  - Audio and visual warnings
  - Indication of the location of the fire
  - Indication of when the fire has been extinguished
  - Test facility

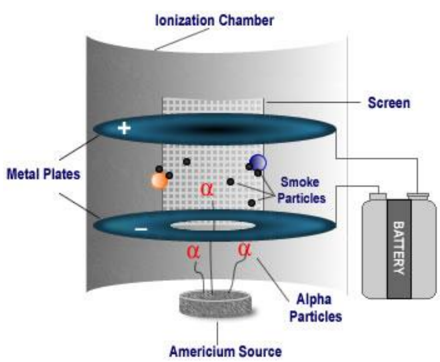
<u>Optical/ Labyrinth Smoke detector:</u>



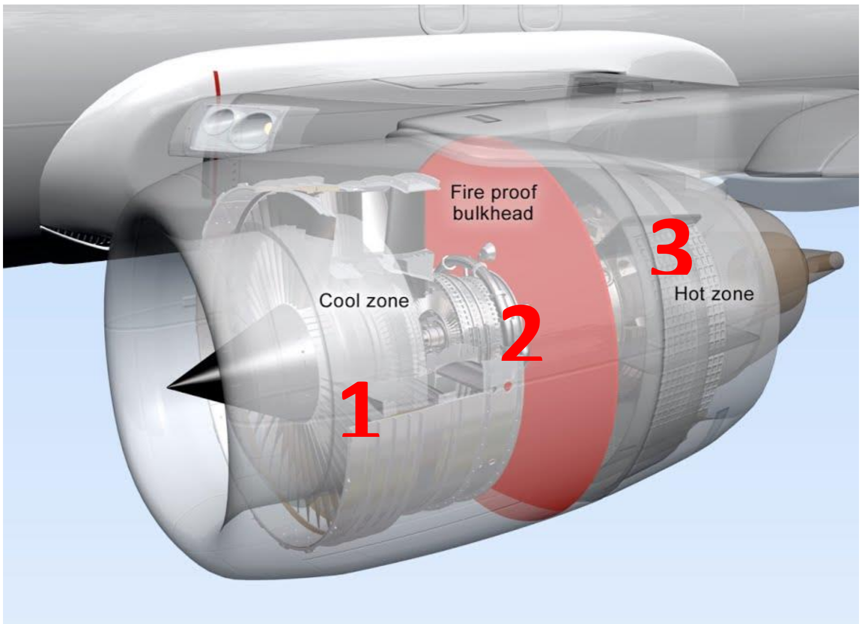
- Light source and light sensitive resistor
- Light only detected when smoke is present.

<u>Ionised Radiation Smoke detector:</u>

- Small source of alpha radiation and 2 charged plates



Turbine Engines – Fire Zones:



1: Accessory gearbox, lubricating oil, hydraulic fluid. **Equipped with fire detection.**

2: Area around the compressor. Hotter than zone 1 but can support combustion.

3: Area around combustion chamber. High temp but no external source of fuel.

Fire detection inside the engine:

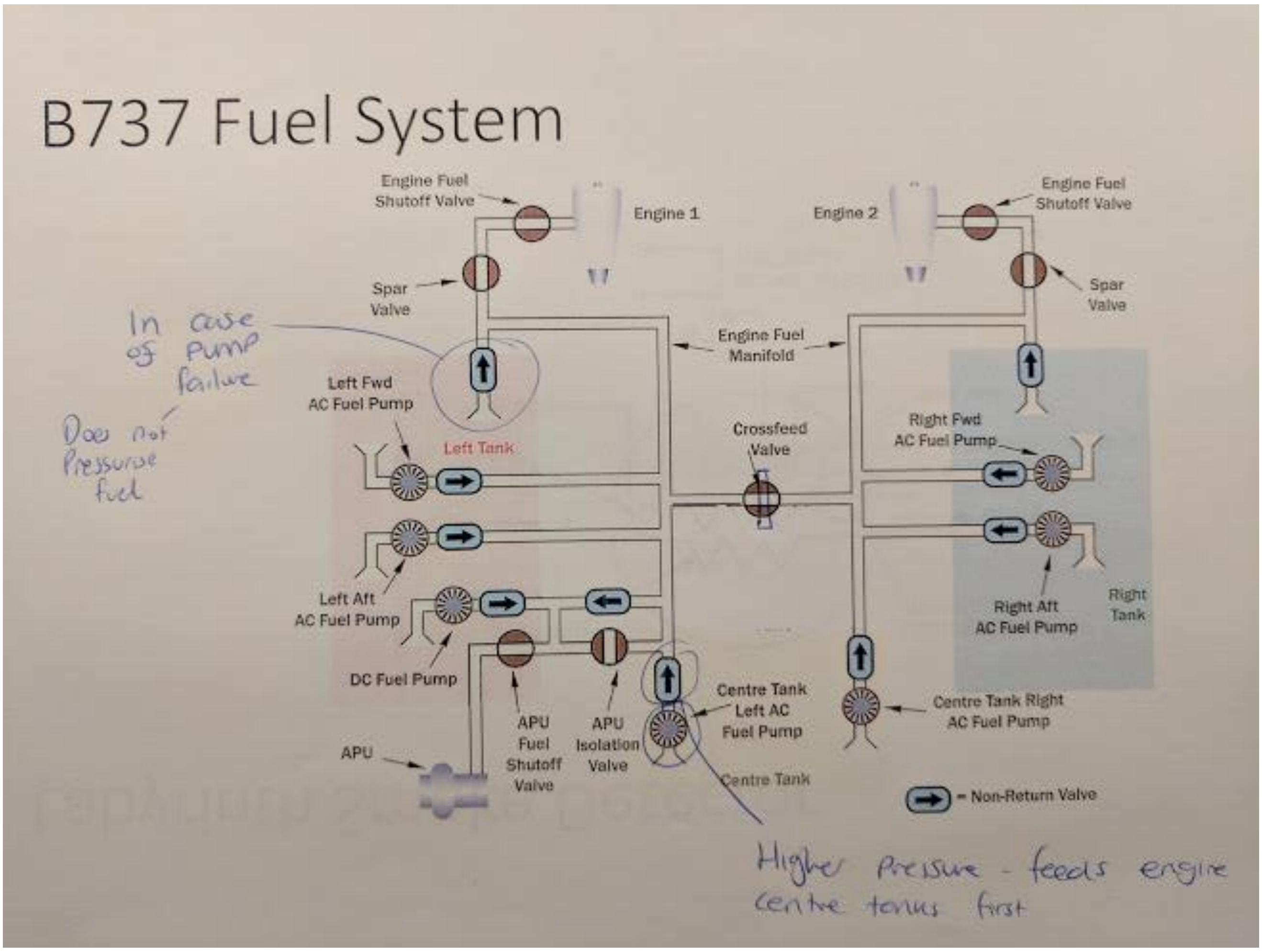
- Continuous fire wire:
  - Resistive wire with a negative temperature co-efficient
  - Capacitive type – more reliable.

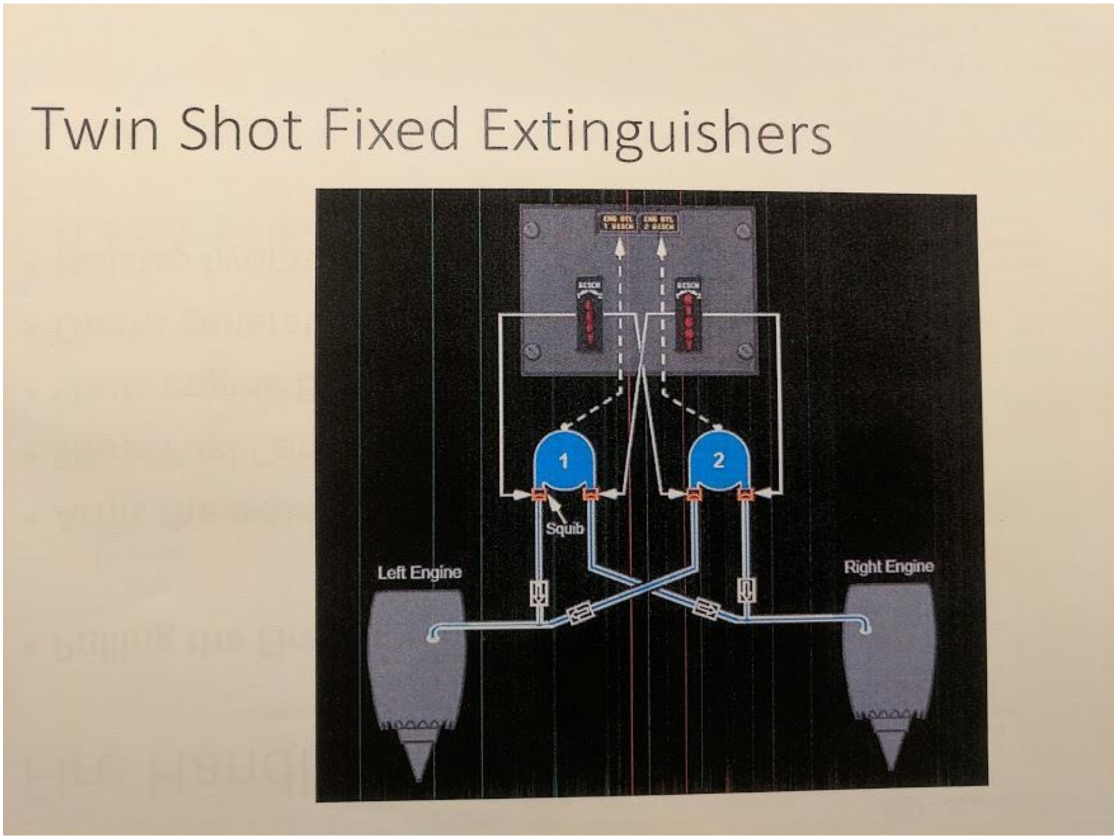
- Systron donner fire detection:
  - Hydrogen core with helium gas – which expands when heated.
  - Leak in gas will trigger a fault indication.

- Graviner overheat detection:
  - Bimetallic tube
  - Expansion causes breaker to connect.

- Infrared detector

- Fixed extinguisher:
  - Operated by squibs (small electric charge)
  - 2 shots required
  - Operated by the DC battery Hot bus bar
- Fire T Handle:
  - Arms extinguisher
  - Closes fuel control valve & fuel spar valve
  - Shuts engine bleed air valve
  - Opens Generator Field Relay and Generator contact breaker
  - Isolates hydraulic pump


B737 Fuel System
Engine Fuel Shutoff Valve
Engine 1
Engine 2
Engine Fuel Shutoff Valve
Spar Valve
Spar Valve
In case of pump failure
Does not pressurise fuel
Engine Fuel Manifold
Left Fwd AC Fuel Pump
Left Tank
Crossfeed Valve
Right Fwd AC Fuel Pump
Left Aft AC Fuel Pump
Right Aft AC Fuel Pump
Right Tank
DC Fuel Pump
APU
APU Fuel Shutoff Valve
APU Isolation Valve
Centre Tank Left AC Fuel Pump
Centre Tank Right AC Fuel Pump
Centre Tank
= Non-Return Valve
Higher pressure - feeds engine centre tanks first


Twin Shot Fixed Extinguishers
1
2
Squib
Left Engine
Right Engine

ATPL Aircraft General Knowledge – AGK ELECTRICS

E1 – DC Theory

- Electrons are negatively charged, protons are positive. Electron flow is –ve to +ve
- PD or EMF is measured in volts
- Current is measured in amps
- Resistance is measured in ohms
- Power is measured in watts and is the rate of doing work.
- Conductance is measured in siemen.
- Ohms law: V= I x R
- P = I x V
- Factors affecting resistance:
  - Specific Resistance
  - Length
  - Cross sectional area

$$Resistance = \frac{Length}{Cross\ Sectional\ Area}\ x\ Specific\ Resistance$$

- Resistors in series = R1 + R2 + R3 = RT
- Resistors in parallel = 1/R1 + 1/R2 + 1/R3 = 1/RT

- A volt meter is connected in parallel
- An ammeter is connected in series

- Kirchofs first law = The sum of current entering a junction must equal the sum of the currents leaving the junction.
- Kirchofs second law = In any closed circuit, the sum of the voltage drops equals the supply voltage.

- Single path (unipole) earth return: Uses the aircraft structure as a return path.
  - Resistance reduced
  - Weight reduced
  - Easier fault finding
  - More prone to short circuit faults
- Dipole earth return: uses wires to ground the circuits.

- A capacitor stores electrical charge, and is measured in Farads.
- Factors affecting capacitance:
  - Area of the plates (greater area = greater capacitance)
  - Distance between plates (greater distance = less capacitance)
  - Nature of dielectric
- A capacitor will appear to pass AC and block DC
- Capacitors in series and parallel add the same as resistors.

- Fuse – non resettable.
- Circuit Breaker – resettable
- They protect against current overload

- A trip free circuit cannot be reset until the fault has been removed
- A circuit breaker should only be reset once
- A short circuit will cause a fuse to blow.

- A current limiter is used to protect large parts of a circuit.

- Types of switches:
  - Rocker switch
  - Push switch
  - Inductive proximity switch
    - Magnetic – typically used in undercarriage systems
  - Micro switch
  - Rotary switch
  - Toggle switch
  - Guarded switch

- An aircraft must carry a spare 10%, or 3 of each rated fuse, whichever is greater.

E2 – Static Electricity

- Created when 2 surfaces contact. Caused by:
  - Friction
  - Lightning
  - Electrical Systems

- Bonding strips: Connect the whole aircraft structure for static discharge:
  - Same potential
  - Safe passage for lightning
  - Equalises static pressure
  - Improves radio transmissions

- Static discharge wicks = trailing edge to discharge static electricity.

- To prevent radio interference from electrical components, conductors must be screened with an insulating material

- Static electricity is discharged through the wheels when on the ground.

E3 - Batteries

- A basic battery contains an electrolyte and an anode (-) and a cathode (+).
- A battery only produces DC.
- Reduction occurs at the cathode and oxidisation at the anode
- A primary cell is non-rechargeable. A secondary cell is rechargeable.

- Lead acid = 6 x 2.2v. SG when charged = 1.27 and when discharged = 1.1
- Alkaline = 10 x 1.3v. SG when charged = 1.26 and when discharged = 1.26

- Lithium ion battery:
  - Good energy density
  - No memory effect
  - Low loss of charge when not in use

- Cross flow vent – removes hydrogen

- Spillage of electrolyte:
  - ACID – Bicarbonate of soda
  - ALKALI – Boric Acid

- Battery capacity – the measure of the total energy a battery contains and its size + number of plates. Capacity measured in amp hours.
- To check state of charge of a Lead Acid battery: compare on load and off load voltage.

- Batteries in series = Sum of voltages but individual capacity
- Batteries in parallel = individual voltage but sum of capacities.

- Batteries are checked at 3 monthly intervals
- Min capacity is 80% of the rated capacity

- Ni-Cad battery – Potassium hydroxide.
- Overcharging can cause thermal runaway – protected by a thermal switch
  - Ni-Cad do not deteriorate if left stored
  - Not prone to spillage
  - Stable voltage under load.

- Main aircraft batteries must last 30 minutes after failure
- Emergency lighting must last 10 minutes

E4 - Magnetism

- North and South poles cannot exist independently
- Strength of a magnetic field increased by:
  - Increase current
  - Increase number of coils
  - Insert a soft iron core

- Relay = electromagnetic switch. Hinged arm and one set of contacts.

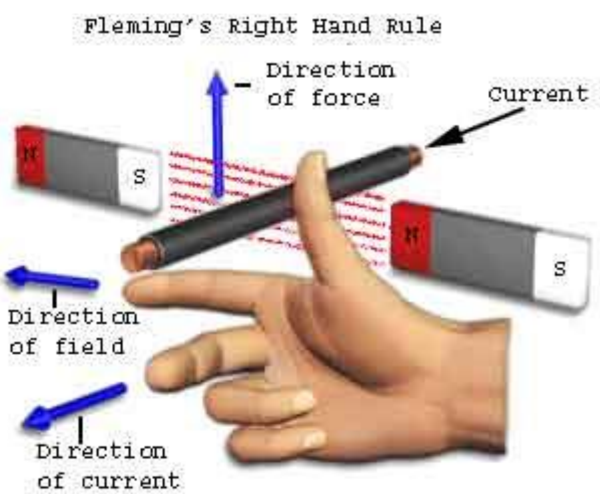
- Solenoid = Twin contacts and a moving core.

- When a coil of wire cuts through lines of magnetic flux, an EMF (electromotive force) is induced. This is called inductance.

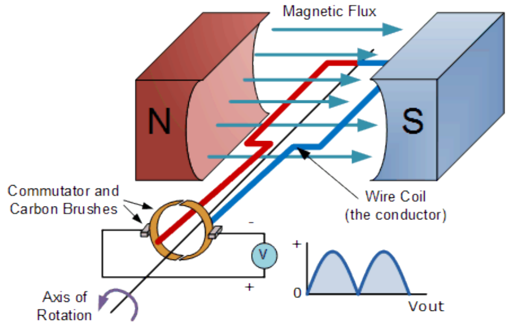
E5 – DC Generators

- All generators use the principal of electromagnetic induction to generate electricity
- Faraday's Law: EMF depends on:
  - Strength of the magnetic field
  - Speed of the conductor relative to the magnetic field
  - Angle at which the conductor cuts the field
  - Length of the conductor

- Flemings Right Hand Rule for generators:

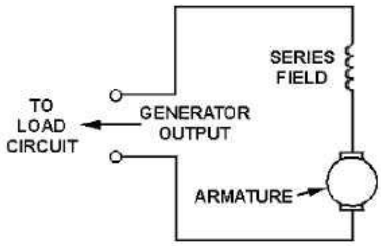


DC Generator:

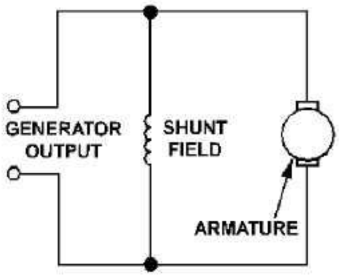


- Rotating armature and a stationary field
- Current and voltage in the armature are AC
    - A commutator converts AC to DC
- Normally excited by residual magnetism

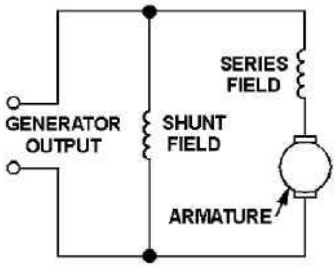
- **Series wound generator:**
    - Field windings in series with the load, and as load increases, so does the generator output voltage.



- **Shunt (parallel) wound generator:**
    - Field windings in parallel with the load, and as the load increases, generator output voltage decreases.



- **Compound wound generator:**
    - Some in series and some in parallel, so the output voltage remains constant.



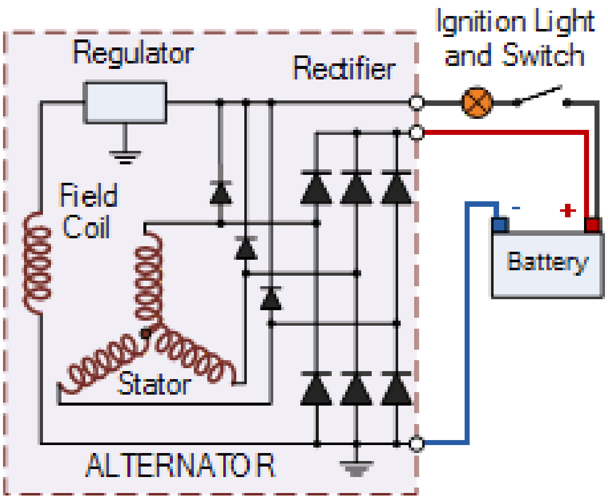
- For 2 DC generators to operate in parallel (a twin engine a/c with generators for each engine), output voltage must be the same. This is achieved by an equalising circuit:
    - Equalising circuit balances voltages and applies correcting values to the field current through equalising coils in the voltage regulators.
    - It is the voltage that is equalised (NOT field current)

- If a generator fails in flight – turn off any unnecessary loads
- Generator failure is indicated by the ammeter showing zero and a warning light

- A voltage regulator controls the strength of the field current, to maintain constant voltage output.
  - In series with the electromagnetic field / shunt field coil
  - In parallel to the generator
- A generator cut out prevents the battery powering the generator if generator voltage falls below battery voltage
- Generator cut-out contacts are held open by spring tension, and closed by electromagnetism.

DC Alternator:

- Rotating field and stationary armature
- Converts AC to DC with a rectifier



Summary:

	Armature	Field
Generator	Rotating	Stationary
Alternator	Stationary	Rotating

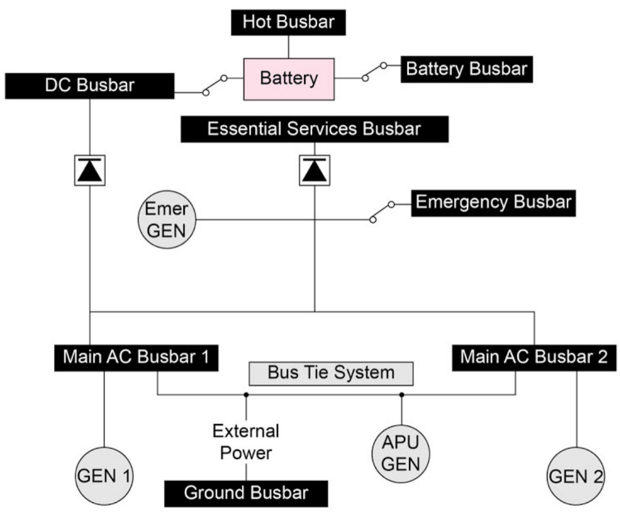
DC to AC using an inverter

AC to DC using a rectifier

Generators and alternators convert mechanical energy into electrical energy

E6 – Aircraft Distribution Systems

- A bus bar is a low resistance conductor, which allows a power supply to be connected to each of the items of load simultaneously.
- All consumers of a bus bar are connected in parallel.



The hot/vital bus bar is directly connected to the battery, and cannot be isolated from it.

3 types of bus bar:

- Hot/Vital
  - Fire extinguishers ect
- Essential
  - Radios, Nav equipment
- Non-essential
  - Ovens, lights

- Load shedding is where electrical loads are reduced.
- A faulty bus bar can be isolated by a current limiter, or by isolation relays

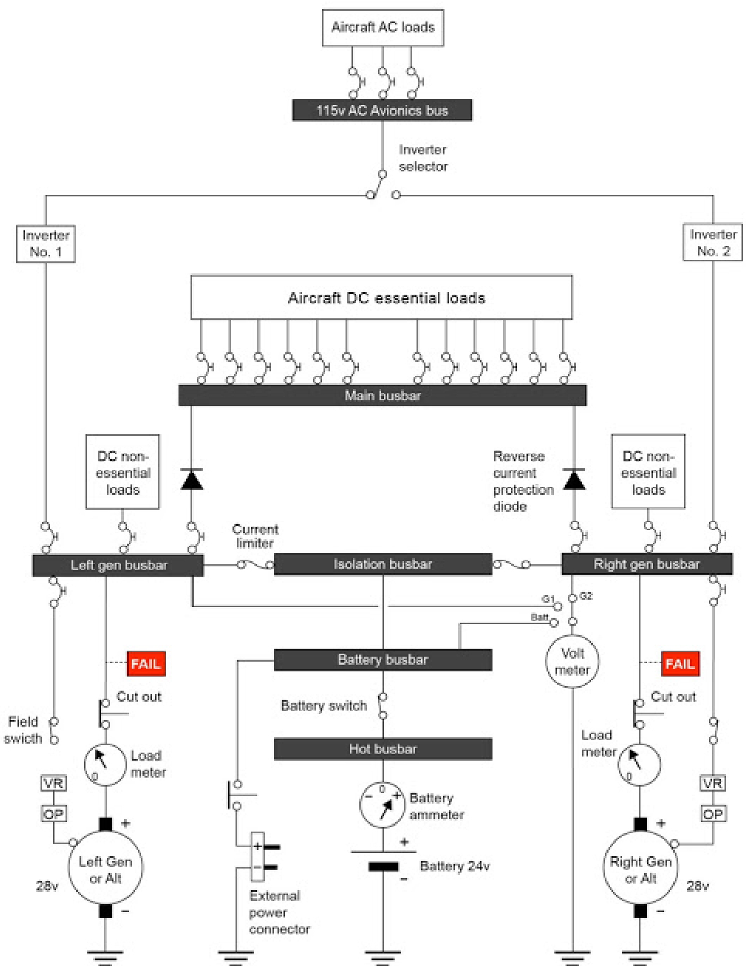
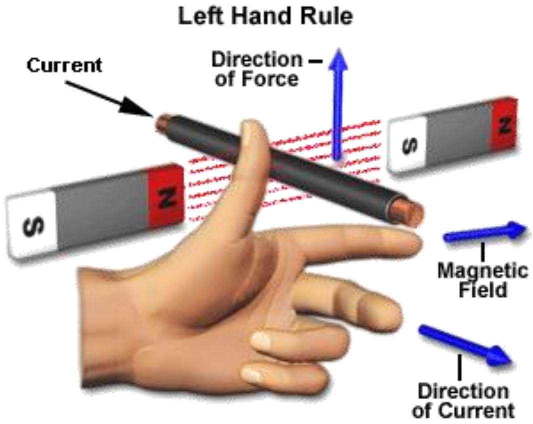


Figure 8.10 Twin engine DC electrical system layout

E7 – DC Motors

- A motor converts electrical energy into mechanical energy.

- Flemings left hand rule for motors:



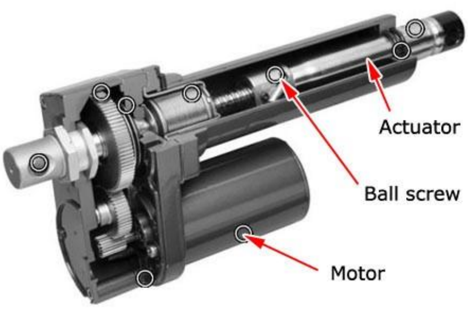
- Series wound motor:
    - High start torque and used for starter motors and actuators.

- Shunt (parallel) wound motor:
    - Constant speed and used for pumps and fans.

- Compound wound motor:
    - Combine the characteristics of both motors.

Actuators:

- High speed, reversible, series wound motor – who's output is converted to driving torque by a step down gearbox.
- Self-contained units.
- Reversible linear thrust over small distances or a low speed turning effort.
    - Linear = used for control trim or temperature control
    - Rotary = used for fuel/air/hydraulic shut off valves



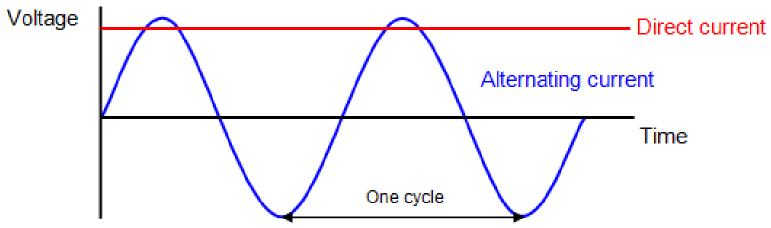
Electro-Magnetic Brakes:

- Energised to RELEASE the brake and de-energised to apply the brake.
- In series with the field coil
- Prevents over travel and creep when the motor is turned off

- A limit switch limits the normal range of travel.

E8 – AC Theory

- AC voltage is sinusoidal.
- AC can be efficiently changed from one voltage to another by using a transformer.



- The current alternates around a mean point
- RMS (Root mean squared) value is the effective value of voltage or current
    - $RMS\ Value = Peak\ value\ x\ 0.707$

- Number of cycles in 1 second = Frequency = Hertz
    - Depends on:
        - Speed of rotor
        - Number of magnetic poles in a rotor
- $Period = \frac{1}{Frequency}$

- $Frequency\ of\ an\ AC\ Generator = \frac{NP}{60}$ – *Where N = RPM and P = Number of poles per phase*

- Typical frequency of an aircraft AC supply = 400Hz.

- Inductance = The ability of a circuit to create a magnetic field. Measured in Henries.
    - Depends on:
        - Number of coils
        - Soft iron core
    - Current lags voltage.

Resistance	Ohms	**R**	Voltage and current in phase
Inductance	Henries	**L**	Current Lags voltage
Capacitance	Farads	**C**	Current leads voltage

- Inductive resistance = An inductor opposes changes to the current flow of AC.
- Impedance = the vector sum of resistance and total reactance.

- In an AC circuit, the capacitor is constantly charging and discharging.
- Time lag causes the voltage across a capacitor in constant opposition to the supply voltage.
- This creates an opposition to current flow, called capacitive resistance (Xc).

$$Xc = \frac{1}{2\pi FC}$$

Where:
F = Frequency
C = Capacitance
Xc = Capacitive resistance

- Opposite to inductance is inductive resistance (X_L).
- Proportional to the inductance of the inductor and the frequency of the supplied voltage.

$$X_L = 2\pi f L$$ *where:*

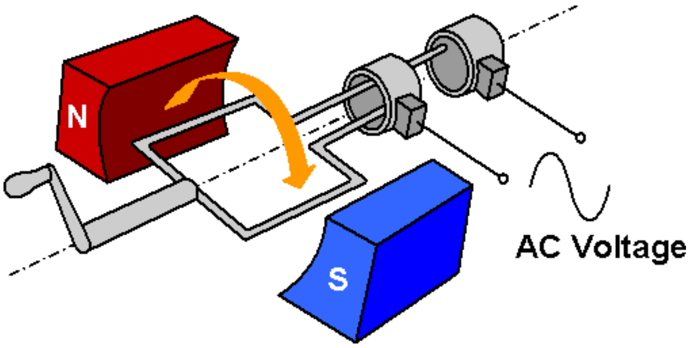
F = Frequency
L = Inductance
XL = Inductive Resistance

	X_C	X_L
Frequency Increases	↓	↑
Frequency Decreases	↑	↓

CIVIL: *Capacitive I LEADS V*
Inductive V LEADS I

- In a circuit where XC = XL, the circuit is resonant – as they cancel each other out.

E9 – Single Phase AC Generators



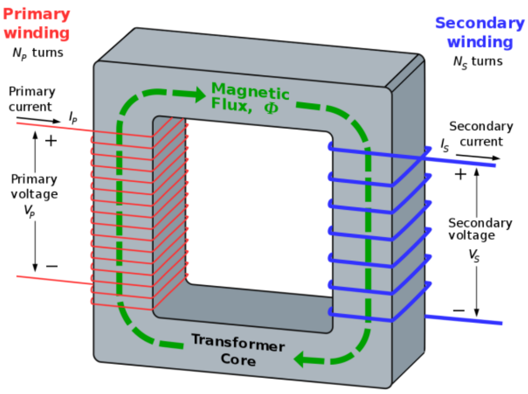
- Power rating of an AC generator is given in KVA (Kilo-Volt hours)

- Real power = Power absorbed by resistive loads and measured in KW (Kilo-Watts)
- Reactive power = power absorbed by reactive loads and measured in KVAR (Kilo-volt amp reactive)
- Apparent power = total power absorbed and measured in KVA (kilo-volt-amps)

- Power factor = the ratio of real power and apparent power. Can never exceed 1.

$$Power\ Factor = \frac{True\ Power}{Apparent\ Power}$$

E10 - Transformers



- Used to:
  - convert one voltage to another
  - isolate sections of circuits from one another
  - allow the passage of AC whilst blocking DC current

$$Turns\ Ratio: \frac{V_s}{V_p} = \frac{N_s}{N_p}$$

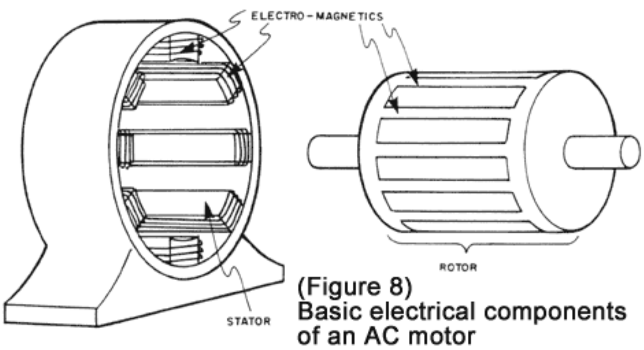
- Transformers are rated in KVA (Kilo-Volt Amps)

- Isolation Transformer = Same number of coils in the primary and secondary windings:
  - Used to spilt larger circuits
  - So that problems don't damage entire systems

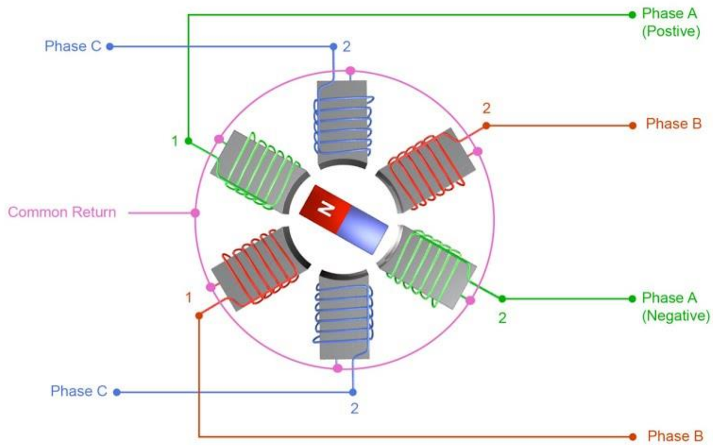
- Transformer Rectifier Unit (TRU); Transforms and rectifies AC – DC
- Rotary or static inverter: DC – AC
- Auto Transformers convert 115v AC to 26v DC for instrument supplies.

E11 – AC Motors

- AC motors work on the principal of a rotating magnetic field, produced by supplying AC to stator windings.
- The rotor of a synchronous motor will rotate at a synchronous speed.
- The rotor of an induction motor will rotate at less than a synchronous speed. The difference is called slip.
  - An induction motor can also be called an asynchronous motor.
- A 3 phase AC motor can be reversed by reversing any 2 phase connections
- If 1 phase of a 3 phase AC motor becomes open, the motor will run at ½ speed and will not start again if stopped.
- If an AC induction motor is supplied with an under frequency, it will under speed and over heat



(Figure 8)
Basic electrical components
of an AC motor

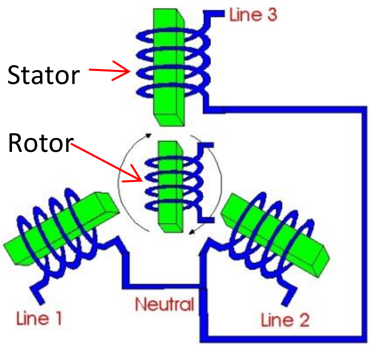


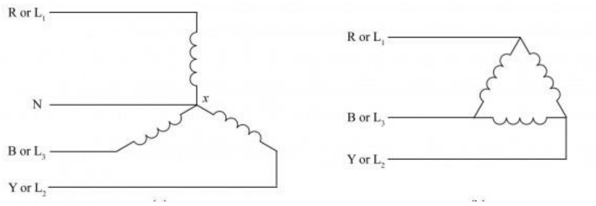
E12 – 3 Phase AC

- Advantages of 3 Phase:
    - Higher efficiency
    - Fewer conductors required for transmission and distribution
    - 3 Phase has better characteristics
    - Same source can be used for single/3 phase supplies.

3 Phase Generators:

- 3 Outputs of the same voltage and frequency, from 1 generator
- Phase windings are spaced 120◦ apart
- Phase angle is calculated by comparing one phase with the reference phase.
- Can be star or delta connected:





Star Delta

Star Connection:

- P.D for each phase is called the phase voltage (VP) = 115v
- P.D across any 2 lines is called line voltage (VL) = 200v
- $Line\ voltage = Phase\ Voltage\ x\ 1.73$
- When the star system is supplying equal loads in each line, then the magnitude of the phase voltage is the same. – this is a balanced system.
- Line and phase CURRENT are the same.
- Earth connection is the neural point.

Voltage and frequency:

- Voltage output of a 3 phase generator is controlled by adjusting the field excitation via a voltage regulator.
- Frequency is controlled by the rotational speed, and the number of magnetic field poles.

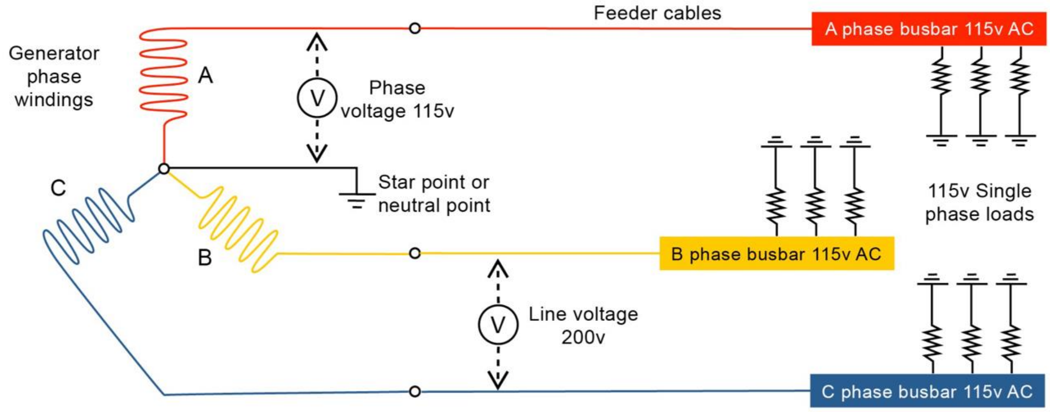
$Frequency = \frac{NP}{60}$ Where: *N = RPM*
P = Number of pole pairs

- 3 Phase power supplies must have a positive phase sequence (a,b,c)
  - Having a negative phase sequence would cause the motor to run in the wrong direction.
- An earth fault on one phase will only affect one phase.

Brushless Generators:

- Require an exciter generator and will be self-excited
  - Exciter control relay will control the current to the voltage regulator and exciter field.
  - The relay will trip and reduce generator output to zero if over excitation occurs.
- Very efficient – no arcing and sparking
- Driven by a constant speed drive unit (CSDU)
  - Hydraulic motor – dictated by a hydraulic pump
  - Varied angle of swash plate
  - Self-contained

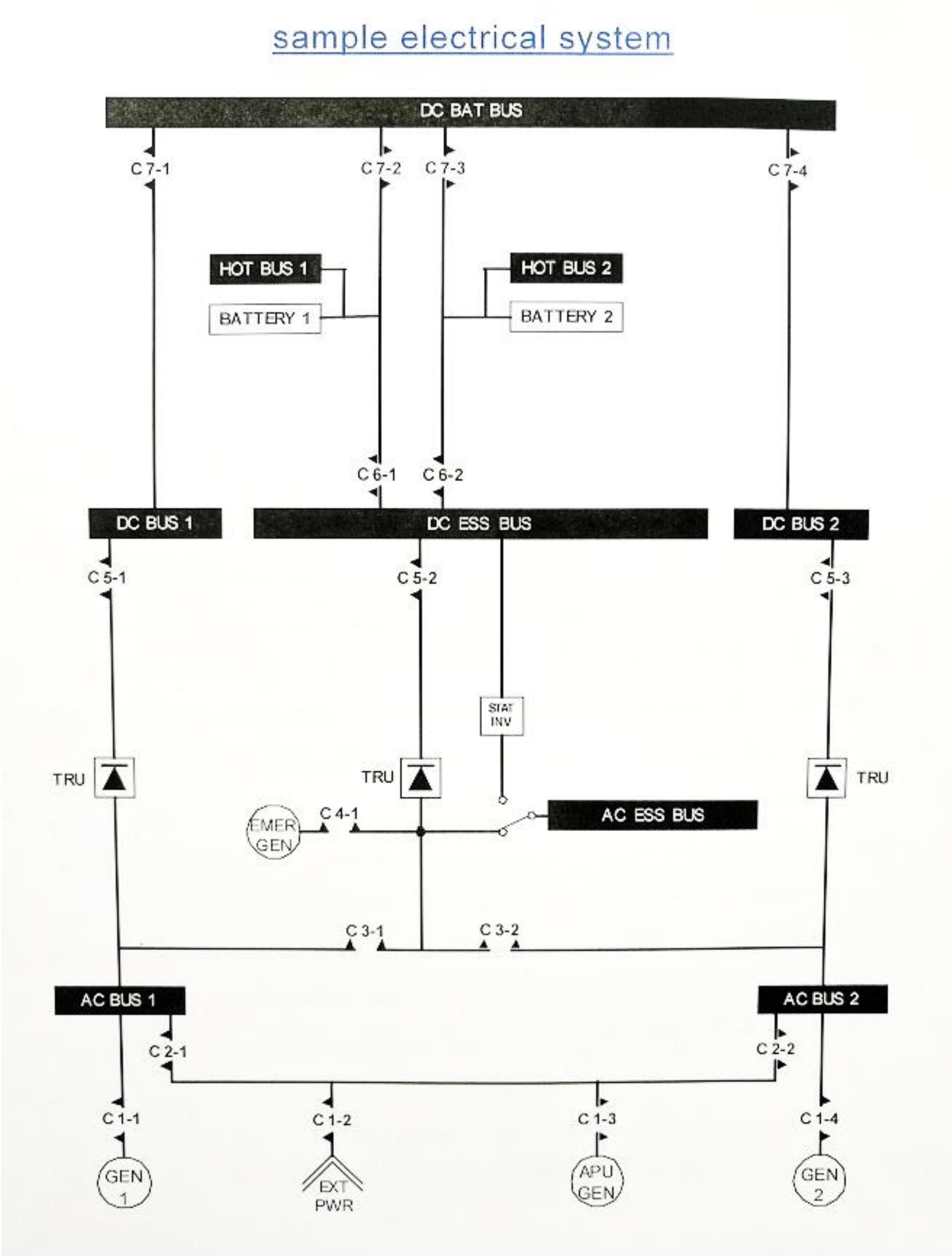
3 Phase Distribution:



- AC Power supply systems can be:
  - Frequency Wild = Unregulated
    - Produced when the generator rotor speed varies with engine speed.
    - Used in engine anti/de-ice systems
    - CANNOT be paralleled
  - Constant frequency = Regulated
    - Split bus bar system
    - Connected in parallel
- Generator Control Unit = GCU. It contains
  - Voltage Regulator
  - Frequency Control
  - Protection Circuits

Spilt bus bar:

- No more than 1 generator per bus bar.
- TRU = Transformer Rectifier Unit



- A generator circuit breaker allows the generator to be connected to its load bus bar
- A bus tie breaker (BTB) connects 2 bus bars together
    - Closes after generator failure so 1 generator can power 2 bus bars
    - A fault on the tie bus can ground the entire AC system

- The following conditions must be met for AC generators to be paralleled:
    - Voltage within tolerance (110v – 120v)
    - Frequencies within tolerance (395-405Hz)
    - Phase sequence correct
    - Phase displacement within tolerance.

Load Sharing:

- REAL LOAD SHARING:
    - A load sharing loop – adjusting the mechanical governor of the CSDU's simultaneously – via the load controllers in the GCU (generator control unit)

- REACTIVE LOAD SHARING:
    - Load sharing loop – adjusting the excitation of the paralleled generator field simultaneously – via the voltage regulators within the GCU (generator control unit)

- In the event of complete aircraft system failure – the RAT (Ram Air Turbine) will be deployed.
    - Drives hydraulic pump
    - AC generator (to deliver 115-200v 400Hz emergency loads)

E13 - Semiconductors

- Highly resistive in its natural state

- Conductivity altered by doping
    - Adding atoms of a second material
    - PN Junction creates a diode
    - PNP junction creates a transistor.

- Zener diode – allows reverse current if the voltage exceeds a threshold value

- Transistor – Used as a switch or amplifying device.

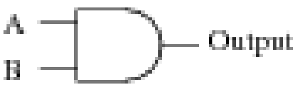
E14 - Logic

- INTEGRATED CIRCUIT – Simultaneous forming onto a small chip.

Advantages	Disadvantages
Small and Light	Easily damaged by high current or voltage
Consume little power	Cannot be repaired
Very reliable	
Operate at high speed	

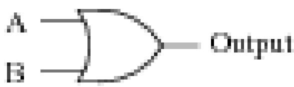
Logic Circuits

AND



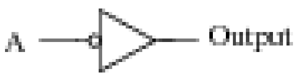
A	B	Output
0	0	0
0	1	0
1	0	0
1	1	1

OR



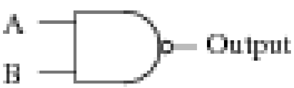
A	B	Output
0	0	0
0	1	1
1	0	1
1	1	1

NOT



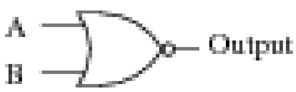
A	Output
0	1
1	0

NAND



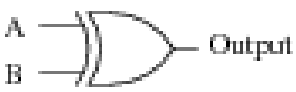
A	B	Output
0	0	1
0	1	1
1	0	1
1	1	0

NOR



A	B	Output
0	0	1
0	1	0
1	0	0
1	1	0

XOR



A	B	Output
0	0	0
0	1	1
1	0	1
1	1	0

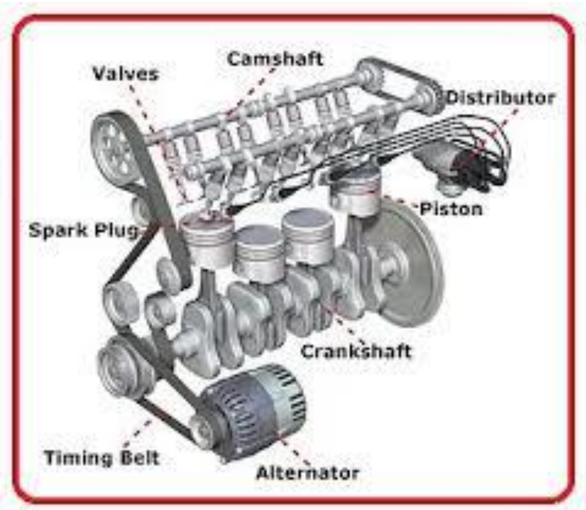
ATPL Aircraft General Knowledge – AGK ENGINES

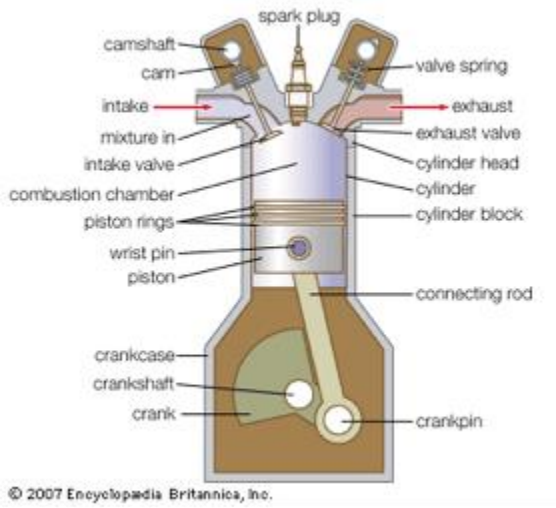
P(P)1 – Principals of Operation

- $Pressure = \frac{Force}{Area}$

- $Power = \frac{Energy}{Time}$

- OTTO Cycle = Induction – Compression – Power – Exhaust
- Total mixture drawn is called charge – and ignited by a spark plug
- Stroke = distance between TDC (Top dead centre) and BDC (bottom dead centre)
- Swept volume = Volume between TDC and BDC
- 720◦ of crankshaft rotation in a 4 stroke cycle





- AVGAS flame rate = 60-80 ft/min

	Induction	Compression	Power	Exhaust
Valve Open	**15◦ before TDC – INTAKE OPEN**	15◦ after BDC	TDC	10◦ before BDC
Valve Close	**15◦ after BDC – INTAKE CLOSE**	TDC	**10◦ before BDC – EXHAUST OPEN**	**10◦ after TDC – EXHAUST CLOSE**

- Valve overlap = Inlet and exhaust valves open at the same time
- Valve lead and lag = maximises the amount of time that the mixture can enter the cylinder
- Lead and lag measured in degrees of the crankshaft rotation

- Rate of combustion remains fairly constant, however speed of pistons is not
  - At high RPM, piston is moving rapidly so **Spark is ADVANCED**
  - At low RPM, pistons are moving slowly so **Spark is RETARDED**

P(P)2 – Piston Engine Design

- Engine power is determined by the mass of the mixture in the cylinder
    - More mass = more power
    - Number and size of pistons can be increased to increase mass
    - Multiple cylinders produce smoother power delivery
- 4 Stroke engines have a power stroke being delivered at all times.
- $Firing\ Interval = \frac{720}{Number\ of\ cylinders}$

	Crankshaft	Cylinders
Rotary Engine	Fixed	Rotating
Radial Engine	Rotating	Fixed *Requires an odd number of cylinders

- Hydraulicing = pooling of oil inside cylinders
    - This can cause the engine cylinder head to separate from the engine

Additional Engine Types	
All in line	Reduced frontal area, but harder to cool Limited to 6 cylinders
V Engine	2 engines set at an angle to each other with a single crankshaft Increased number of cylinders for a given length
Horizontally opposed	Most common. Short, rigid construction Normally air cooled

- Throw = Distance between the axis and bottom of BDC.
- Stroke = 2 x throw
- Typical cylinder firing order = 1,3,4,2

- Cam shaft = rotates at ½ the speed of the crankshaft and operates valves via push rods.
- Inlet and outlet valves
    - Poppet valves mounted in the cylinder head
    - Closed under spring pressure
    - Steel alloy to withstand stress
    - Exhaust valve is hollowed and filled with sodium for cooling

- Crank assembly comprises:
    - Crankshaft
    - Connecting rods
    - Pistons

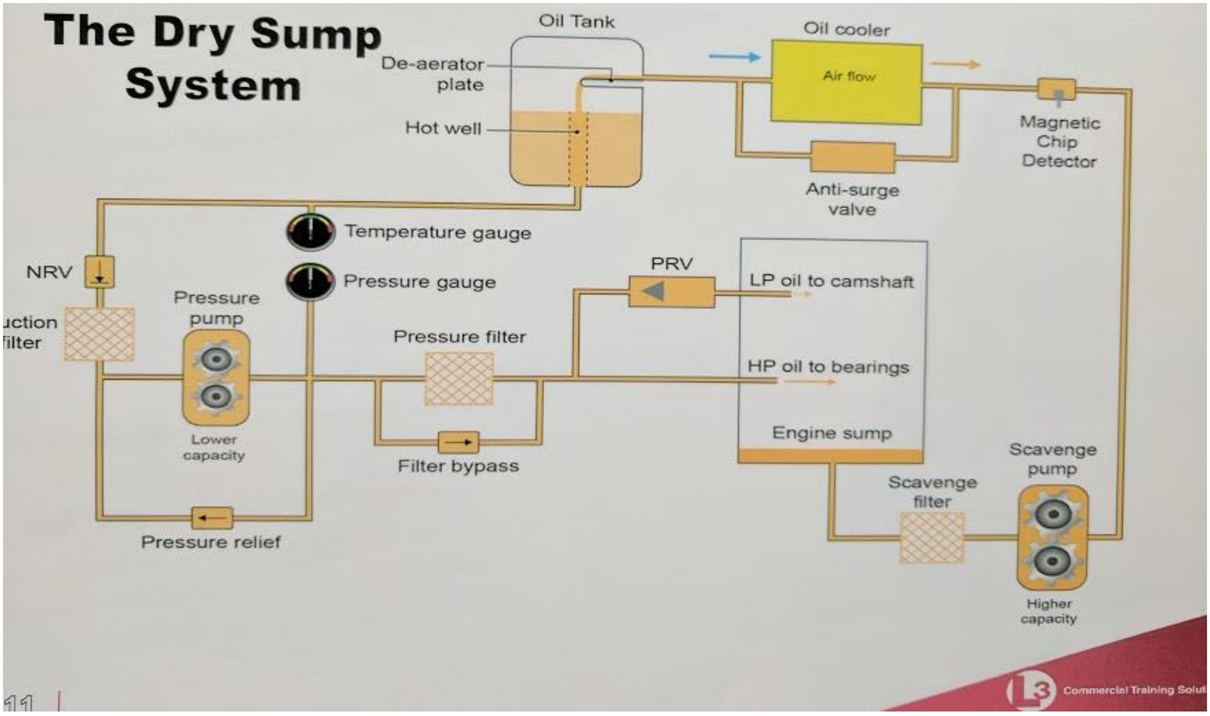
P(P)3 – Lubrication and Cooling

- Oil:
  - Cooling – absorbs heat and disperses
  - Cleaning – Removes carbon deposits and metal flakes
  - Protection – Protects from corrosion
  - Hydraulic operations – Operates valve gear and variable pitch props.

  - Pressurised at 60-70 PSI
  - Viscosity reduces with increased temperature

- Requirements of aero oil:
  - Maintain low viscosity over a large temperature range
  - Have a low evaporation rate
  - Inhibit corrosion
  - Not react with materials it comes into contact with
  - Discourage the formation of sludge

Dry Sump	Wet Sump
• Oil held in a tank remote from the engine • Temp measured AFTER the tank • Magnetic Chip detector • Oil pressure rise 30 secs after start • SCAVANGE PUMP	• Oil held in a tank below the crank case • Pressurised oil feeds bearings • Splash lubrication



- Liquid cooling – mixture of water and glycol
- Air cooling – Baffles control flow of cooling air. Cowl flaps increase cooling

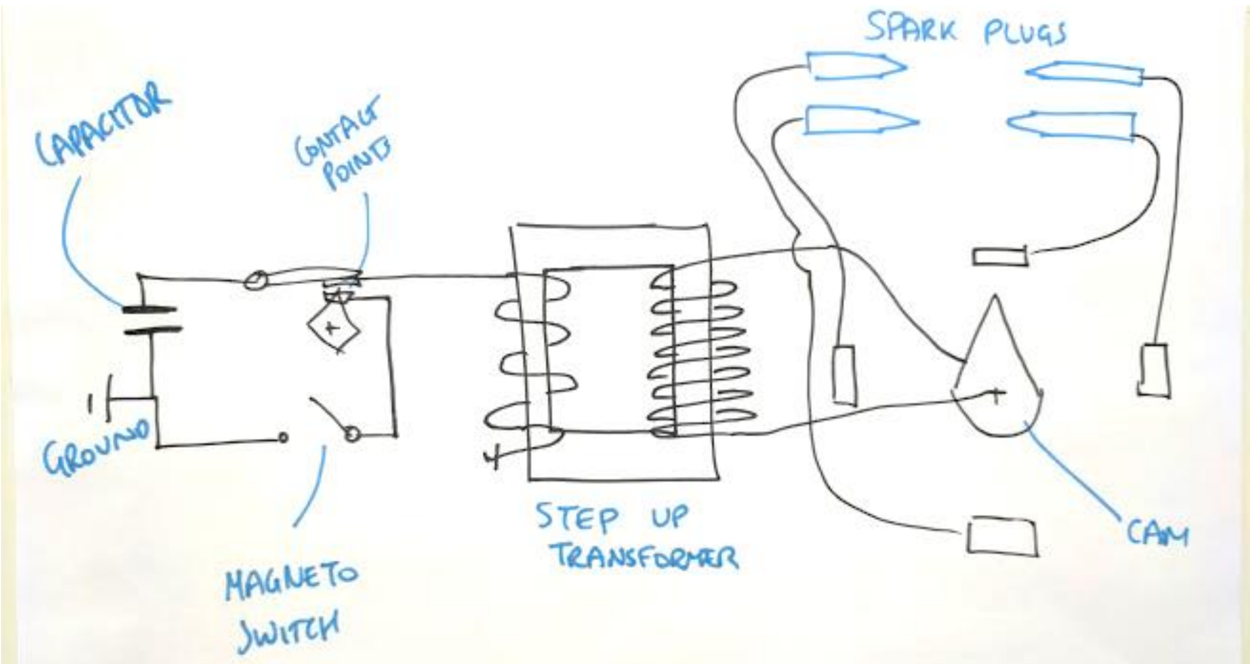
- CHT = Cylinder Head Temperature
    - Hottest temperature within the engine
    - Indicates engine health
    - Measured by a thermocouple
- CHT is affected by:
    - Amount of power produced
    - Aircraft speed
    - Temperature of cooling air
    - Ratio of the mixture

- Engine is most likely to overheat at LOW speed and HIGH RPM.

P(P)4 – Starting & Ignition

- Electric starter motor powered by the battery
- Starter warning light – if on for 30 secs after start **STARTER MOTOR HAS NOT DISENGAGED**

- A magneto is a self-contained device. It delivers high power voltage to the spark plugs.
- Ignition lead = P lead. Open = ON.
    - If the P lead is broken, the ignition will remain on.
- Magnetos can be pressurised to prevent internal arcing at altitude
- Magneto output voltage is directly proportional to engine RPM



- Twin Spark plugs – Accelerates the combustion process. Quicker rise to peak cylinder pressure and gives a noticeable increase in power

- Impulse coupling:
  - Spring device.
  - Provides a larger pulse on start-up
  - Retards the spark

- LT Booster – Vibrator connected to provide sparks to start the engine. Direct to primary windings.
- HT Booster – Direct to secondary windings – Bypasses the LT system.

- Distributer – provides secondary current to the spark plugs

- Complete dead cut = power failure of ½ the ignition circuit
- No drop in RPM = ½ the ignition circuit not earthed
- Excessive RPM drop = ignition problem
- Rough running = Malfunction of the spark plug

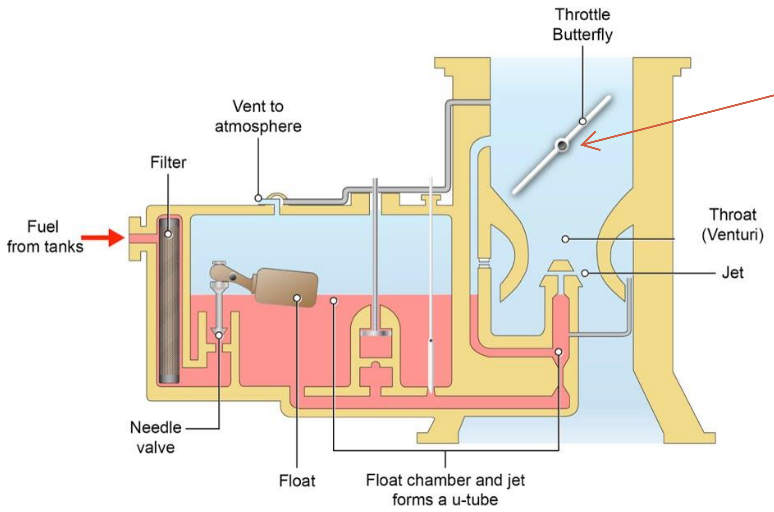
- Dead cut check to be carried out before shutdown to ensure ignition is not live

P(P)5 – Carburettor and Injection Systems

- AVGAS 100 = octane rating of 100
- Higher octane rating = higher maximum compression ratio
- AVGAS 100LL = Same octane rating as AVGAS100, but with lower lead.
  - Flame rate = 60-80 ft/min
  - Detonation flame rate = 1000ft/sec
- Detonation can be caused by:
  - Wrong fuel
  - Too weak (lean) mixture
  - Anything causing a high CHT:
    - Carb heat @ High power
    - Overheated cylinder
    - High power and low RPM

- Lead is an additive to control detonation.

- Stoichiometric fuel ratio = 15:1
- 12:1 = 30% Rich
- >15:1 = lean
- Lean Mixture = higher engine temperatures.



Engine fuel supply is controlled by the throttle

- Pressure balance duct – prevents lower fuel mixture with ram effect at high speed
- Diffuser – weakens the mixture with increasing altitude (decreasing density)
- Power enrichment CAM – Bypasses the pressure duct and allows fast acceleration for emergencies
- Slow running jet – provides small fuel flow at near idle power when the butterfly throttle is nearly closed

- Signs of Carb icing:
  - Fixed Pitch Prop = Unexplained drop in RPM
  - Var pitch Prop = drop in manifold air pressure
- Carb Heat:
  - Heat exchange from exhaust gasses, to feed in hot air and melt the ice.
  - It is unfiltered
  - Gives a reduced power output
  - Causes a richer mixture

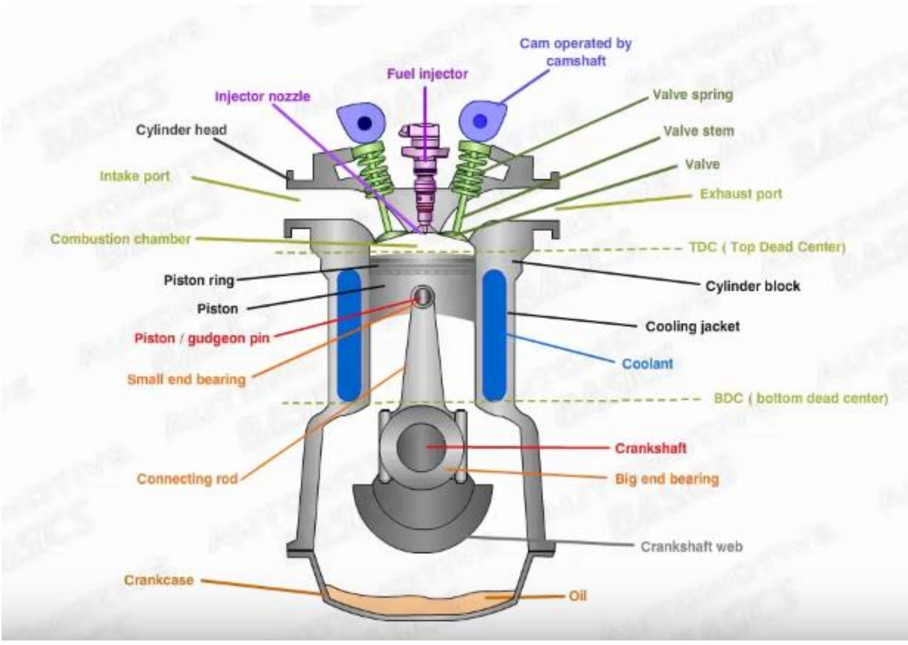
- Fuel Injection:
  - Indirect – provides fuel to inlets
  - Direct – provides fuel directly into the cylinders

- Engine priming:
  - Provides a rich mixture needed for start-up
  - Manual or electric priming pump

P(P)6 – Diesel Engines

- No ignition system
- Higher compression ratio
- JET A1:
    - S.G = 0.82
    - Less volatile and a higher flash point than AVGAS
    - Poor lubricant
    - Needs a special fuel pump
- Diesel Engines:
    - More fuel efficient
    - Less scheduled maintenance
    - Suited to turbocharging
    - No ignition system – cheaper & more reliable
    - Lower power : weight ratio
    - Longer stroke
    - JET A1 cheaper than AVGAS
    - Heavier than a petrol engine
    - High pressure (24,000 PSI)
- No throttle valve – Fuel injected into cylinders.
- Power set by fuel flow
- Injection using a common rail
- Glow plug = electrically heated coil – powered by battery. Backup.
- Liquid cooled with a heat exchanger

- At TDC – a precise amount of fuel is injected. It immediately ignites.



P(P)7 – Power, Efficiency and Control

- Power is dictated by:
  - Mass of charge
  - Number of times per second the charge is put into cylinders.

- $Power = \frac{Force\ x\ Distance}{Time}$

TORQUE AND RPM

- **P -- Mean Pressure**
- **L -- Stroke Length**
- **A -- Area**
- **N – Number of cylinders**
- **E -- RPM/2**

We are able to change :

P – Air fuel ratio (mixture)

E – RPM

- $$Cylinder\ Displacement = Piston\ Area\ x\ Stroke\ x\ No\ Cylinders$$

- Compression ratio = Total Volume : Clearance Volume

- Square engine = where the piston diameter = stroke

- Increase in power in the initial climb is due to reduced back pressure of exhaust gasses (as they are exhausted faster due to drop in outside pressure)

- RPM gauge displays crankshaft RPM
- Manifold pressure gauge – often in inHg
- Boost pressure gauge – how much pressure above/below ambient
  - Psi relative to sea level pressure
  - Before start – shows atmospheric pressure
  - After start – shows lower than atmospheric pressure
- Oil pressure gauge – Measured **After the pressure filter**
- Oil temperature gauge = Measured in the **Return line**
- CHT (Cylinder head temperature) gauge = Measured in the hottest cylinder.
- EGT (Exhaust gas temperature) gauge. 15:1 gives highest EGT.
  - Lean gives economy cruise
  - Rich gives a performance cruise.
- Fuel pressure gauge – Measures fuel pump output pressure
- Induction temperature gauge – measures temperature at carburettor inlet

- Engine to be shut down if the starter warning light remains on for >30 seconds
- +ve oil pressire should be indicated within 30 seconds

- Prolonged idling of the engine can cause spark plug fouling.

- Allow engine to cool at low RPM before shutdown, and perform a dead cut check
- A weak mixture can cause a high CHT

- Rough running engine may be caused by:
  - Carb ice
  - Moisture in the ignition circuit
  - Fuel delivery problems
  - Uneven compression in the cylinder

- Black exhaust smoke = Too rich mixture
- Blue exhaust smoke = Oil burning. Worn or broken piston rings

- High CHT on the ground – check cowl flaps

P(P)8 – Super/Turbo Charging

- A supercharger is powered by the crankshaft
  - Centrifugal compressor – radial compression
- A turbocharger Is powered by exhaust gasses (impeller)

- An Altitude boosted supercharger will pump compressed air into the cylinders to delay the drop in power due to the increasing density altitude.
  - Ground boosted supercharger increases max power at MSL.
  - Does require a stronger engine structure and better cooling.
- Boost or pressure gauge or MAP will display the pressure of the air being supplied at the inlet manifold.

- A turbocharger draws exhaust gas through an impeller
  - No power taken from the engine
  - Lighter and less complex
  - Exhaust driven system takes time as RPM increases
  - Suffers turbo lag

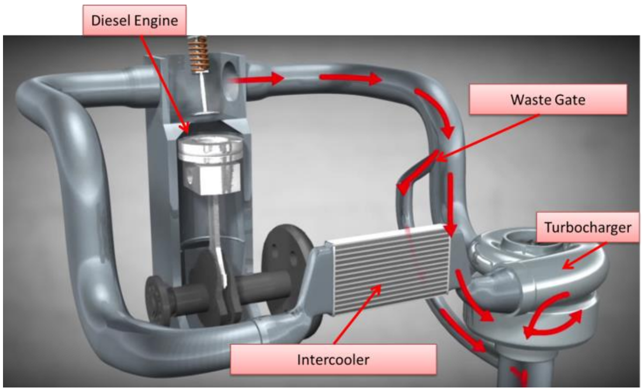
- Waste gate system:
  - Default position is open – bypasses the turbocharger (held by spring pressure)
  - Oil pressure used to close the waste gate

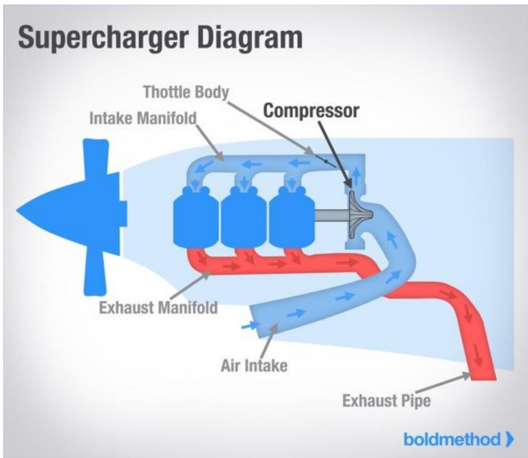
- The critical altitude = the altitude the engine can no longer provide sea level power
  - Aka Full Throttle height

Phase of Flight	Waste gate position
@ Engine Start	OPEN
@ Idle Power	CLOSED
@ Take off	Partially OPEN
@ Climb	CLOSED
@ Critical Altitude	CLOSED
Above Critical Altitude	CLOSED

- Intercooler – Cools the mixture
- Differential pressure controller – Maintains constant differential pressure to prevent the turbo charger working too hard

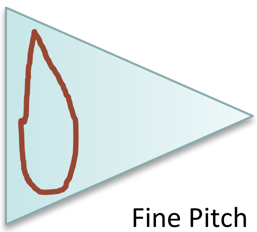
- Rated power = the maximum power at which the engine can be operated continuously.
- Rated boost = MAP allowed at rated power



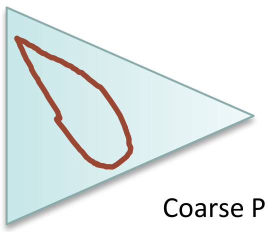


P(P)9 – Propeller Aerodynamics

- Solidity = Increased material area in the propeller disk
  - Increased absorption of power
  - Lost efficiency
- Propeller blade angle is taken at 70% span.
  - Optimises cruise performance
- AoA = Angle between RAF and chord line



Fine Pitch



Coarse Pitch

- For take-off – a fine pitch is used
- Optimal AoA = 4°
- Reverse pitch angle is set by going past fine pitch

	Increase TAS	Increase RPM
Fixed Pitch	↓	↑
Variable Pitch	↑	

- Blade Pitch:
  - Feathered = 90° - Minimum drag for a failed engine
  - Fine = 0° - Minimum drag for engine start
  - Reverse = -18° - Used for reverse thrust
- Beta range operations - 0° to negative blade angle
  - MUST be on the ground
- Alpha range operations – Positive blade angle
- Auto feather – loss of an engine in flight
- A variable pitch propeller has 80-85% efficiency across a large operating range
- **ATM = Aerodynamic Twisting Moment**
  - Coarsening force
- **CTM = Centrifugal Twisting Moment**
  - Fining force
- **CTM is a bigger force than ATM**
- If the propeller is wind milling, both CTM and ATM act to fine the blade
- A wind milling propeller is driven by aerodynamic forces – not the engine.

P(P) 10 – Propeller Systems

- The aerodynamic force acting parallel and in the opposite direction to the plane of rotation = torque drag.

- Changing blade angle → PCU = Pitch control unit.

    - Double acting Variable Pitch Propeller:
        - Piston assembly in a hub with oil pressure on either side. Pushes the prop to coarse or fine.
    - Single acting Variable Pitch propeller:
        - Piston assembly with 2 springs and oil pressure opposing the spring.

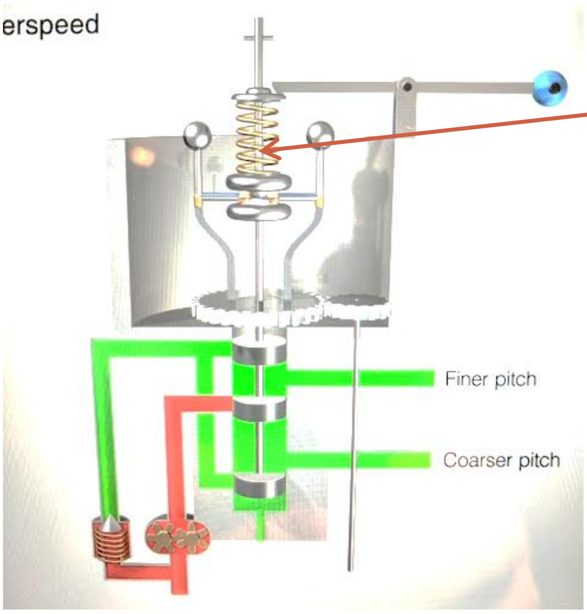
	Fine	Coarse
SEP	SPRING (Engine Failure)	Oil
MEP	Oil	Spring & Counter weight (feather)

- Counterweights are attached to the blade route to overcome CTM. Helps with auto-feather.

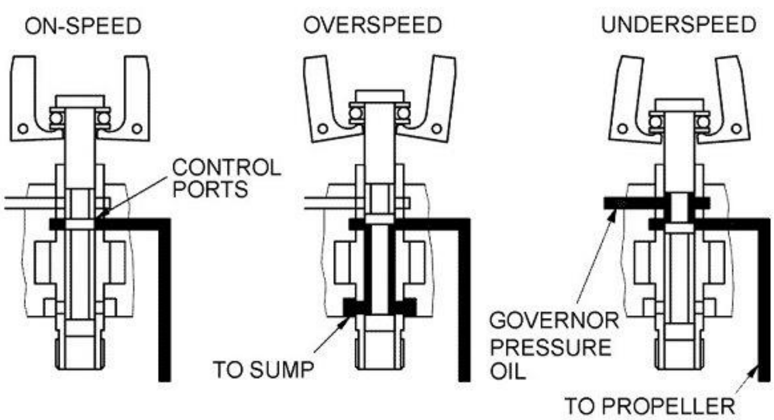
- Centrifugal latch – Prevents the blades from moving to the fully feathered position during shutdown.

Constant Speed Unit (CSU):

- PCU must be controlled automatically
- For prop RPM to be stable, engine torque must match torque drag
- Changes in forward speed change the torque drag.
- CSU automatically matches engine torque to torque drag:
    - RPM falls: Prop moves to a FINE pitch
    - RPM rises: Prop moves to a COARSE pitch



Manually, push down on spring to increase RPM



- Over speed condition – maximum coarse
- Feathered condition – maximum coarse
- If the engine malfunctions, oil pressure may not be available to the CSU
  - Feathering systems must have a separate oil reservoir with sufficient oil to allow the propeller to be feathered – usually supplemented with an electric pump.

- Synchronising = 2 Propellers with the same RPM
- Sycrophased = Blades oriented such that the beat on the fuselage is displaced

Indicating Power:

- Fixed Pitch:
  - Thrust proportional to RPM
  - Required power set is RPM
- Variable Pitch:
  - Power is a function of mass flow
  - Required power set is MAP
- A torque gauge indicates the amount of torque being applied to the engine via the propeller shaft.

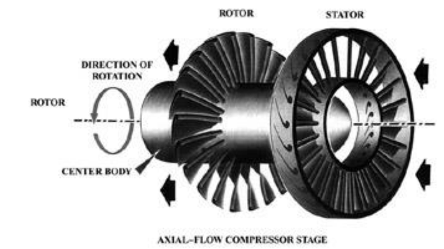
Rev Up, Throttle Back

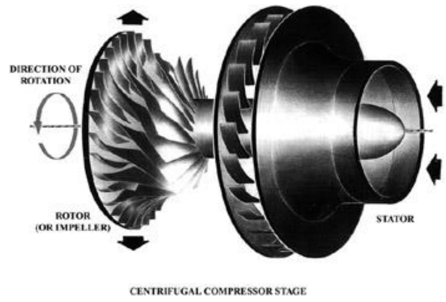
- Takeoff roll = RPM Full then throttle (MAP)
- Decrease power = Throttle back then cruise RPM

- Condition lever (turboprops) – do not require adjustment in flight. Once set, power changes made by the power levers.

- CSU Checks:
  - After engine start: operate engine lever to exercise the CSU and encourage oil flow.
  - Feather check
  - Set RPM fully forward for take-off and downwind to land

P(GT) 11 – Gas Turbine Principals & Designs



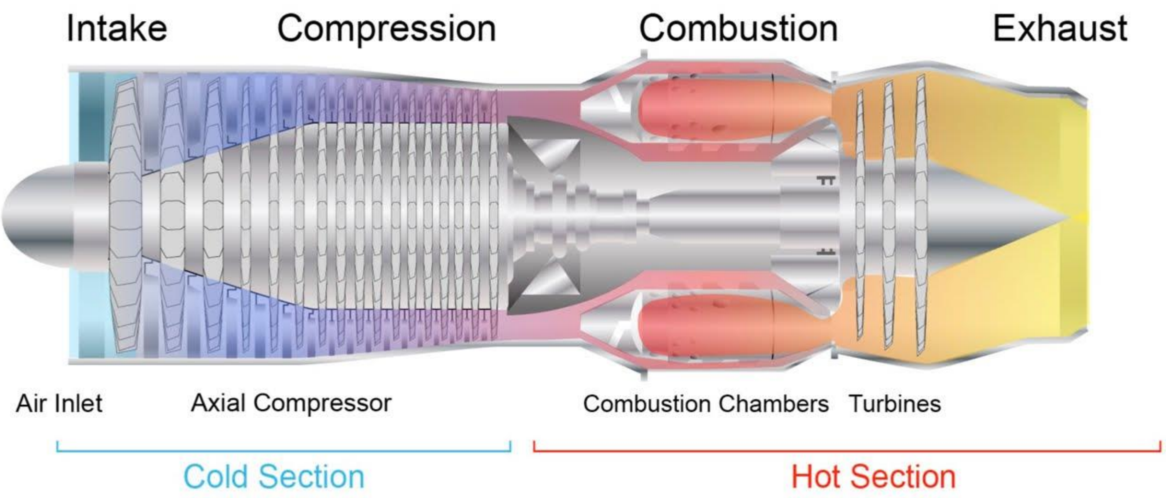


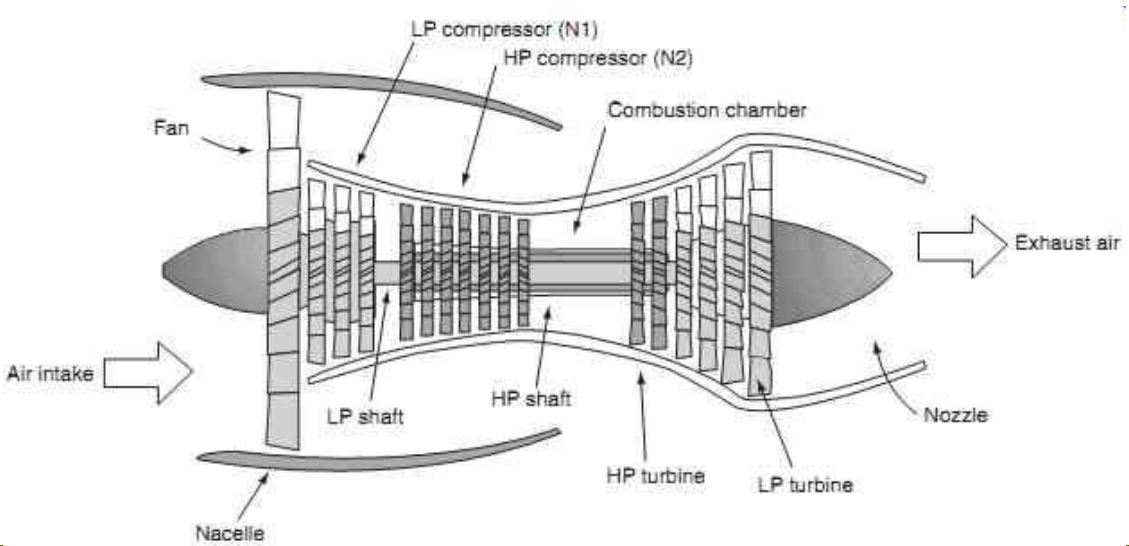
- Gas turbine Brayton Cycle : Compression- Combustion – Expansion- Exhaust
  - All 4 processes occur continuously.
- Highest pressure is found at the compressor delivery fan.

- TURBOJET = All the air flows through the compressor
- TURBOFAN = Air bypassed the core of the engine

- Axial Flow: Each stage = 1.1/1.2 : 1
- 35:1 Overall

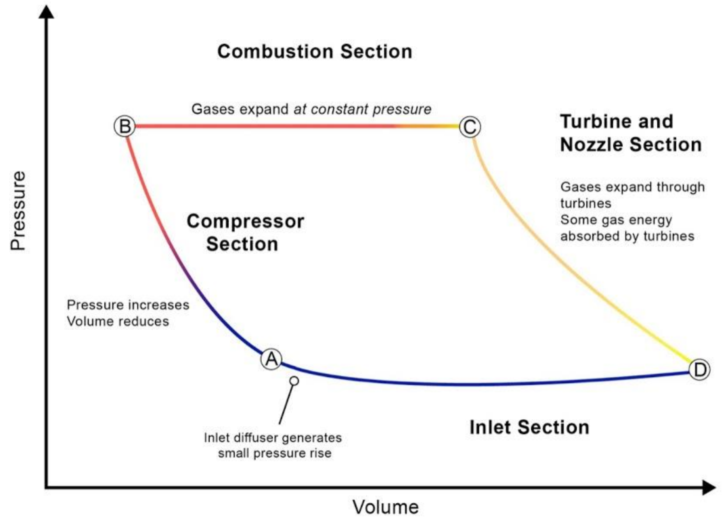
- Centrifugal Flow: 4.5:1 Overall





- Power set by N1 RPM
- Ignition on start only.
- Air-Fuel ratio for combustion = 50-150:1
- $Thrust = M \; x \; (VJET - VFLIGHT)$ - thrust is measured in N/LB (NEWTON POUNDS)

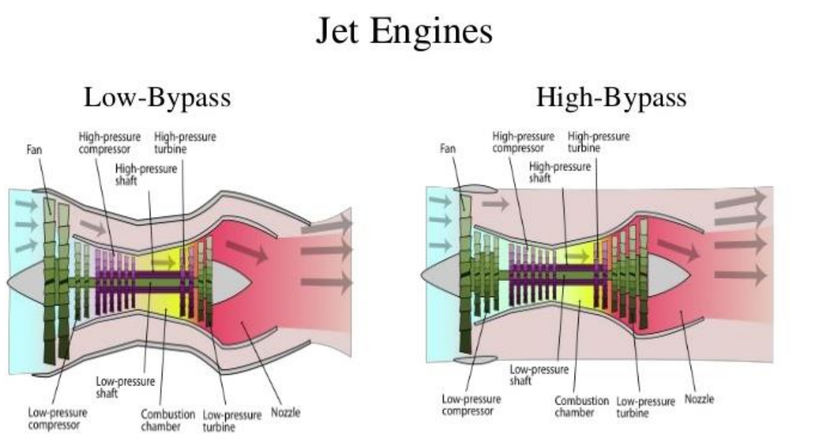
- Maximum thrust is produced on the ground, as the difference between VJET and VFLIGHT is the greatest.

- 

- SFC = Specific Fuel consumption. It is the amount of fuel required to produce 1 unit of thrust per unit time.

Propulsive Efficiency:

- Propeller systems are more efficient at low altitude
- Jet engines are more efficient at high altitude
- A Turboprop is best suited to intermediate altitudes.

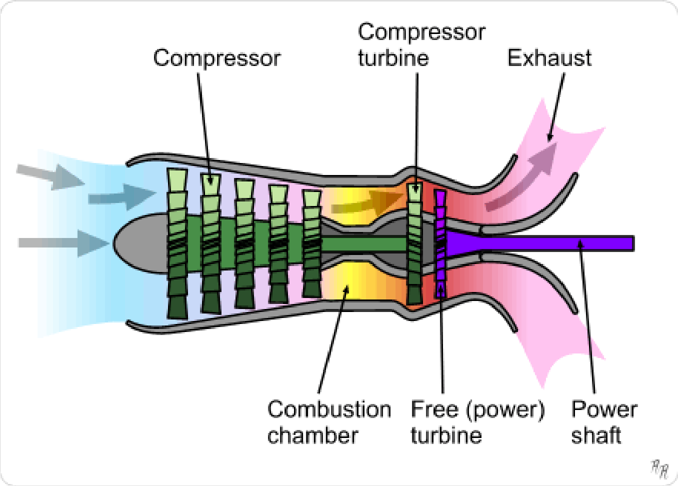


Low-bypass ratio leads to high exhaust speed, high flight speeds, and low fuel efficiency

High bypass ratio leads to low exhaust speed, lower flight speeds, and higher fuel efficiency

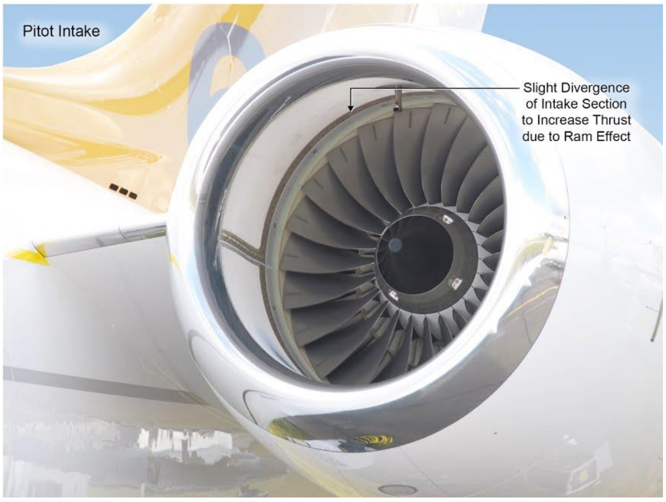
- Advantages of a bypass engine:
  - Bypass air is cool, so they are more thermally efficient
  - Bypass air is given smaller acceleration, so has greater propulsive efficiency
  - Compressor sections can run at their optimal speeds
  - Small core reduces weight
  - Bypass air reduces noise

- Free power turbine:

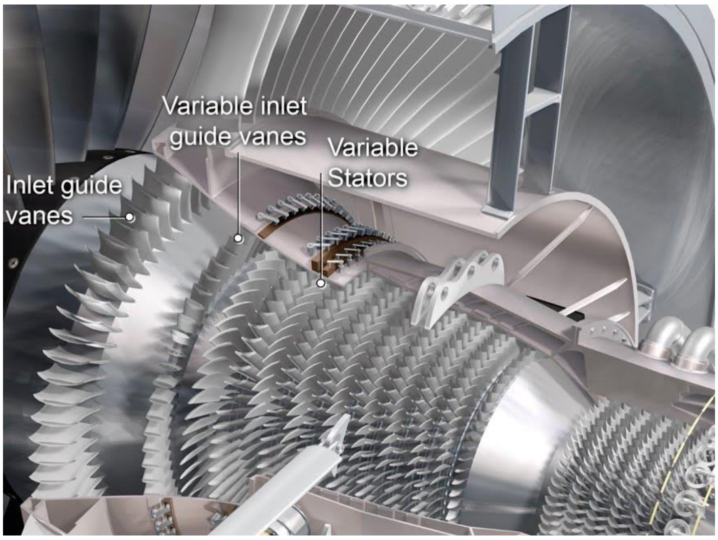


P(GT)12 – Gas Turbine Air Inlet

- Subsonic inlet from a large range
- Intake from a divergent duct – pre compression
- Rounded intake to prevent flow separation
- Intake lip – stainless steel – heated to prevent ice
- Design cruise mach number – dictates the shape of the intake



P(GT)13 - Compressor

- Impeller accelerates the air outwards. It is then slowed down and compressed.
- Pressure ratio is the ratio of compressor delivery (output) to inlet pressure.
- 2 Types:
  - Centrifugal – air flows radially from the centre of the compressor to its perimeter.
    - An Impeller
      - Air enters the eye and propelled rapidly outwards.
      - Air leaves tangentially into the diffuser.
      - A double entry impeller gives double the mass flow (not double the compression)
    - A Diffuser
    - A Casing
  - Axial Flow – Flow is parallel to the axis of the engine.
    - Aerofoil blades accelerate air towards a series of stationary stator blades. The stator blades are fixed to the compressor casing.
    - Each set of rotors and stators is called a stage
- 

- An overall increase in temperature after each stage of compression
- Overall velocity remains constant

Compressor Stall & Surge:

- Blade stall can be caused by:
    - Damage to blades
    - Ice formation
    - Extreme incident angles – caused by poor inlet conditions as a result of a strong crosswind or high slipstream angles.
- Symptoms of compressor stall:
    - High EGT
    - Reduced thrust
    - Loud rumbling or banging
    - Fluctuating RPM and fuel flow
    - Compressor surge (hot gasses flow through the compressor or in extreme cases, complete flow reversal)
- A centrifugal compressor is less likely to suffer stall and surge.
- Avoiding stall & surge:
    - Thorough pre flight checks of fan blades
    - De and Anti ice
    - Avoid start in strong crosswinds

Centrifugal	Axial
+ Cheaper + Less prone to stall and surge + Reasonably Efficient - Low compression ratio of 5:1 compared to 35:1 for axial flow - Requires a larger frontal area	+ Very efficient + High compression Ratio (35:1) - Vulnerable to FOD - Can suffer aerodynamic instability

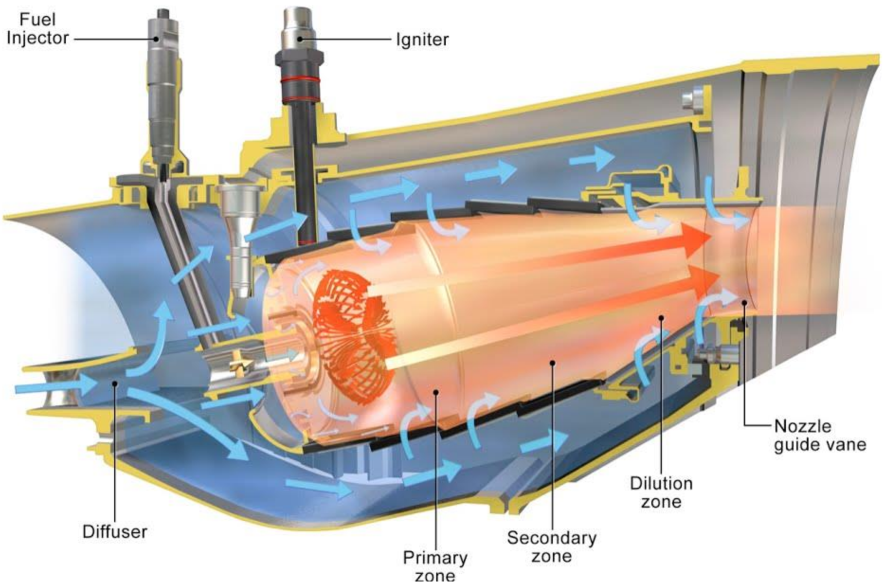
- As much as 90% of the air can be sent down the bypass duct of an axial compressor.
    - Sent through guide veins to remove swirl and maximise thrust

- Blades are loosely fit onto the fan, to take up their optimal position when subjected to large centrifugal forces.

- Bleed air is taken downstream of the compressor stage.
    - Air conditioning/Pressurisation
    - Pressurising hydraulic resivoirs
    - Engine start
    - Engine and Airframe anti-ice
- Internal Air:
    - Internal engine and accessory cooling
    - Bearing Chamber sealing
    - Prevention of hot gas ingestion into the turbine disk cavities
    - Engine anti-ice (uses HP air)
- Auxiliary/Accessory gearbox – Always driven by the HP compressor spool

P(GT)14 - Combustion

- Combustion chamber – mix fuel with compressed air and burn.
- Requirements:
    - High efficiency and maximum heat release
    - Combustion stability
    - Reliable and consistent ignition
    - EGT doesn't exceed turbine blade limit temperature
    - Low emissions and fuel consumption
    - High durability
- Gas velocity at the entry to the flame tube is too high – and so a swirl vane slows the air for combustion.
- An array of fuel injectors spray fuel into the recirculating air
- Fuel and air burnt at the stoichiometric ratio of 15:1
- The wall of the flame tube is protected by a film of cooling air (secondary air)



Designs:

- Annular combustion design:
    - Common
    - Ceramic lining for protection
    - Uniform delivery to turbine disks

- Reverse flow chamber:
    - Reduced size
    - Some loss in efficiency

Fuel Injection:

- **Air spray Injector:**
    - Sprays fuel between 2 turbulent flows of air
    - Does not require high fuel pressure

- **Duplex Fuel Nozzle:**
    - Primary wide nozzle for engine start
    - Secondary fine nozzle for after engine start
    - Diversion airflow to prevent the build-up of carbon.

Ignition Systems:

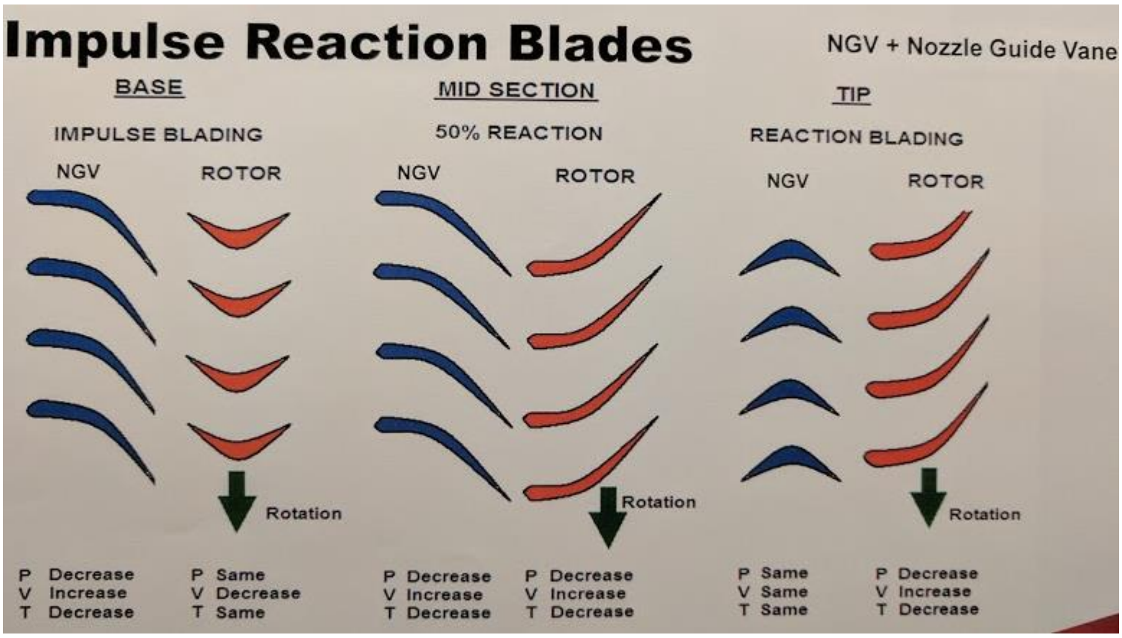
- Normally only required for start
- Always fitted with redundancies and can be powered by AC or DC.

- High Energy Ignition Unit (HEIU):
    - 2 Power settings:
        - 12 Joule for high power, short periods
            - High altitude starts and ground starting
        - 3-6 joule for continuous ignition
            - Used:
                - Take off on contaminated runways
                - Icing conditions
                - Turbulence

- 60-100 sparks per minute
- No timed ignition

P(GT)15 – Turbine System

- The most highly stressed component in the engine
- Each stage comprises a set of fixed nozzle guide veins and a rotating disk containing many turbine blades.
- The entire assembly is located within a divergent duct, to ensure there a lot of back pressure
- NGV = nozzle guide veins – direct the gas at the correct speed onto the turbine blades
- There are 3 types of turbine:
  - 1) Impulse:
    - Nozzle guide veins form convergent ducts which accelerate the gas and reduce its pressure. The accelerated gas hits the crescent shaped blades causing an impulse force to drive the turbine.
    -
  - 2) Reaction:
    - The nozzle guide veins simply direct the gas onto the blades. There is no change in velocity or pressure across them.
  - 3) Impulse- Reaction Blades:
    - A combination of the two above.

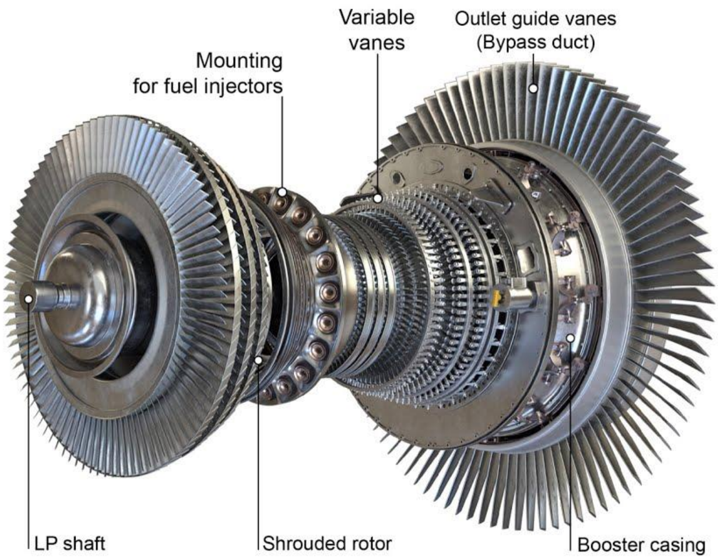


	Impulse Blade (BASE)		Implulse-Reaction (MID)		Reaction (TIP)	
	NGV	ROTOR	NGV	ROTOR	NGV	ROTOR
PRESSURE	↓	*Same*	↓	↓	*Same*	↓
VELOCITY	↑	↓	↑	↑	*Same*	↑
TEMPERATURE	↓	*Same*	↓	↓	*Same*	↓

- Turbine Blades:
  - Steadily increase in length during operating life (creep)
    - Sets a finite life for the turbine blades
  - Cast from high temperature nickel alloy
  - Coated with a ceramic thermal barrier
  - Shrouded to prevent tip losses
  - Normally attached with a fir tree root.

- Methods of cooling:
  - Convective
    - Large vented voids inside the blade to promote convection
  - Impingement
    - Jets of cooling air are played onto the internal surfaces of the blades
  - Film
    - Internal air passages are fed with high pressure cooling air.

- Active clearance control:
  - Method for controlling blade tip clearance
  - Hot bleed air is played onto the turbine casing
  - As temperature increases, the casing expands to the same size



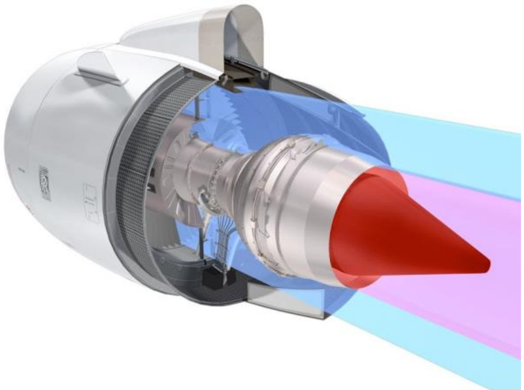
- High cycle fatigue = Can lead to component failure
- Low cycle fatigue = Lower number of larger stresses

P(GT)16 – Exhaust Systems

- Maximise exhaust by adding a divergent duct after the throat.

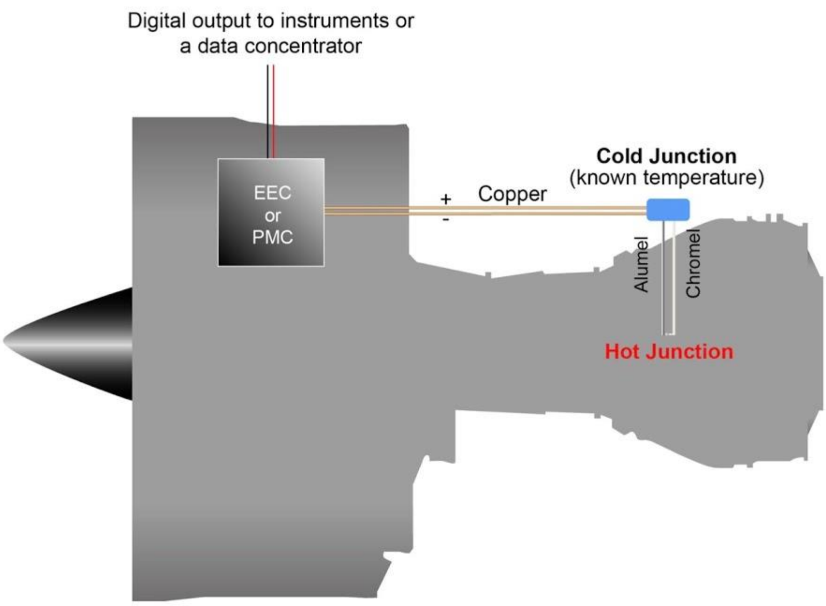
- High bypass engines – exhausted by co-axial nozzles

- Noise suppression:
    - Concentric exhausts allow the low speed air to surround the high speed noisy core air.
    - Scardled nacelle can also reduce noise.



- Thrust reverse:
    - HIGH BYPASS: Reverse bypass air
    - LOW/MED BYPASS: Clamshell or reverse buckets
    - Requirements:
        - Weight on wheels
        - Idle throttle

- EGT (Exhaust gas temperature) measurement:
    - Measured by a thermocouple
    - 2 wires – Chrome-nickel and Aluminium-nickel are joint at the hot junction
    - A small voltage is produced when there is a temperature difference between the hot junction and cold junction (refrence)



P(GT)17 – Bearings & Lubrication

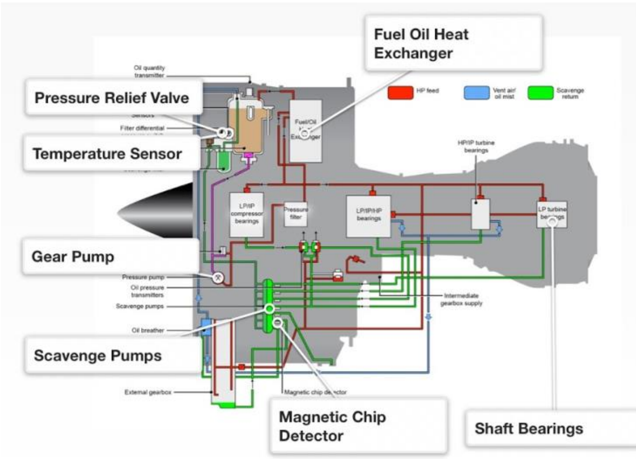
- Ball bearings carry weight and thrust loads
- Roller bearings carry side loads and allow for thermal expansion

- Oil system requirements:
    - Reduce friction and wear between moving parts
    - Carry heat away from the main engine bearings
    - Lubricate the accessory gearbox

- All gas turbine engines are dry sump

- Magnetic chip detectors:
    - Individual for each scavenge pump return line
    - Can be checked for early diagnostics.

- Oil quantity increase: Leak in the oil heat exchanger so fuel is added to the oil. This is a double fault.



- Labyrinth seal = Uses high pressure bleed air for sealing
    - Fast rundown time on the engine PLUS high oil consumption = labyrinth seal rubbing on one side, and leaking on the other.

- Types of oil system:
    - 1) Pressure relief valve system:
        - Powerful pump provides oil pressure to the bearing chambers. The pressure is controlled by the pressure relief valve.
        - Works well for low bearing chamber pressure

    - 2) Full Flow Oil System:
        - Oil flow and bearing housing pressure are directly proportional to the engine speed
        - Permits higher bearing pressures and ensures an optimum flow at all engine speeds.

- Low viscosity synthetic oils are used in all gas turbine engines.

P(GT)18 – Fuel Systems

- Requirements:
    - Control fuel to the combustion chamber for starting and stopping
    - Introduce finely atomised fuel to the combustion chamber
    - Provide pilot control – Smooth acceleration and deceleration
    - Enable pilot selected fuel flow to be over-ridden if limits are likely to be exceeded.

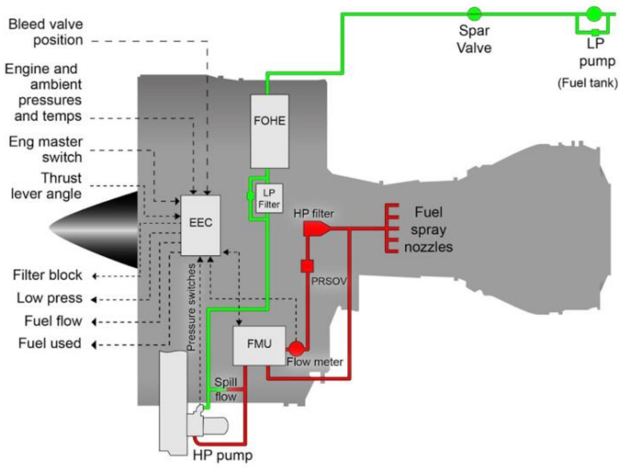
- Fuel control unit (FCU) senses:
    - Thrust lever position
    - Air Temperature
    - Air Pressure
    - Rapid acceleration/deceleration
    - Engine speed
    - EGT
    - Compressor Delivery Pressure

- Accelerator control unit (ACU) limits fuel flow and prevents over-fuelling
- Barometric Pressure control unit compensates for changes in intake pressure

- FADEC = Full authority Digital engine control
    - Closed loop system establishes engine power to control engine pressure ratio (EPR) which is computed as a function of the throttle lever angle, TAT, altitude and mach number.
    - Positioning the throttle lever aligns the control EPR command with the thrust management computer reference indicator –setting thrust.

- Failure of the FADEC system:
    - Minimise fuel flow
    - Variable stator veins to open fully
    - Oil cooler wide open
    - ACC (Active Clearance Control) shut off

- Advantages of FADEC:
    - Saves fuel
    - Full modulation of ACC
    - Idle speed remains constant
    - Greater precision
    - Improved engine start
    - Automatic engine limit protection



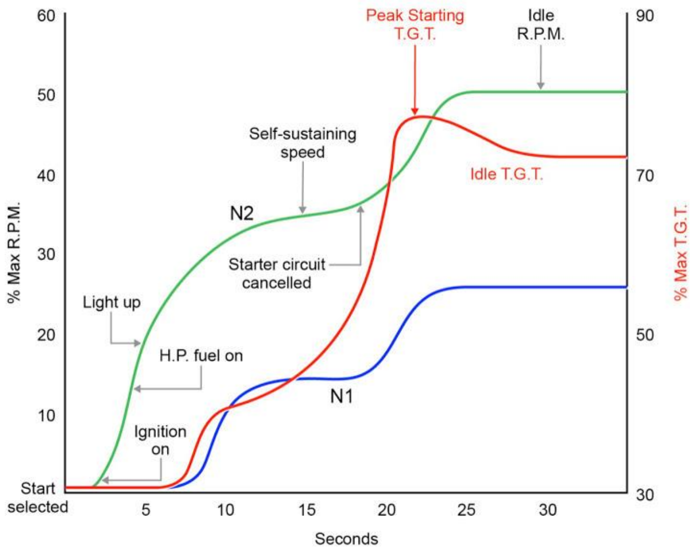
P(GT)19 – Control and Operation

- Start requirements:
  - Supply of air delivered to the compressor
  - Supply of fuel
  - Source of ignition
- Air supply and ignition systems are required to operate simultaneously during engine start, but it must be possible to operate these systems independently.

- Air turbine starter motor
- Rotates HP spool for starting
- Air for starting:
  - APU
  - External ground supply
  - Cross bleed from another engine

- Ignition process is started immediately – to prevent the build-up of fuel

- Self-switching speed = the speed at which the engine will accelerate without the aid of the starter motor (@30-40%)



N1 = Fan Speed

N2 = HP compressor Speed

- Start malfunction – Restarts limited to 3 over a period of time, with a suitable rest period in-between

- **<u>DRY START:</u>**
  - Fuel fails to flow to the engine. Light up does not occur and no EGT rise.
  - The start must be cancelled
  - Indications:
    - Low and stagnating RPM
    - No EGT rise
    - No fuel flow

- **HUNG START:**
  - Engine lights up, but fails to accelerate.
  - The engine will 'hang' at apx 20%
  - Can be the result of stall and surge
  - Indications:
    - Low and stagnating RPM
    - Low fuel flow
    - High EGT

- **HOT START:**
  - Light up is followed by a rapid rise in EGT
  - Caused by excess fuel in the carburettor, low pressure to the starter motor, excessive tailwind or early opening of the fuel valve.

- **WET START:**
  - Engine fails to light up and fuel continues to enter.
  - Indications:
    - Low and stable RPM
    - No EGT rise
    - Some indicated fuel flow
  - If a wet start occurs, you must carry out a dry run before restart

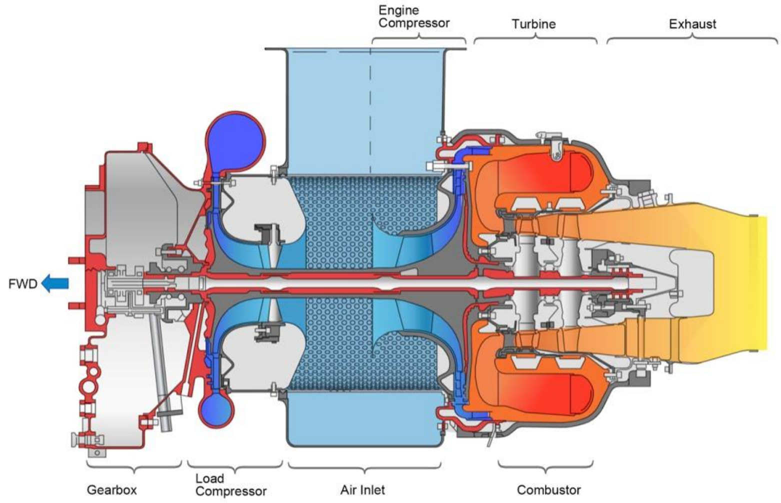
- **AIR START:**
  - Does not normally require the starter motor – as the compressor is wind milling
  - Once conditions are met, and fuel is available, turn on the ignition

- **CONTINUOUS IGNITION:**
  - Risk of flame extinction
  - Automatic selector when anti ice is on or on takeoff/approach

- EPR is an indication of engine thrust and is a ratio between compressor inlet and turbine outlet.
- Take-off thrust – limited to 5 minutes
- Max contingency thrust (OEI) – limited to 2.5 minutes
- Intermediate contingency thrust – unlimited duration
- Max continuous thrust (All Engine)

P(GT)20 – Auxiliary Power Unit – APU

- Allows the aircraft to operate independently of the ground supply unit
- Critical element of an ETOPS rating



- An electric motor is connected to a drive shaft, in the accessory gear box.
- Power drawn from the batteries or an external power source.

- APU runs at a constant speed

- Fuel supply from one tank via a solenoid operated valve& regulated by the Fuel Control Unit (FCU) that controls the acceleration of the APU by proportioning fuel flow and load

- Fire detection:
  - Continuous wire
  - Single shot extinguisher
  - Auto extinguish feature

- Automatic APU shutdown:
  - Over speed
  - High EGT/ Loss of EGT signal
  - Low oil pressure
  - High oil temperature
  - Airspeed and/or altitude limits exceeded
  - APU over speed
  - APU fire detection system
  - Opening the bleed valve before 95% speed
  - High bleed air temperature.