Canadair Regional Jet systems

- EICAS (engine-indicating and crew-alerting system)
- Electrical (AC and DC!)
- Fire Protection
- Fuel
- APU
- Engines
- Hydraulics
- Landing Gear
- Brakes

Red = we’ll talk about it

- Flight Controls
- Pneumatics
- Air Conditioning
- Pressurization
- Ice - Rain Protection
- Oxygen
- Flight Instruments
- Communications
- Navigation
- Autoflight
Radial Engines

2,000 HP Corsair

A turbine engine that spins a propeller: turboprop.

Popular examples: Pratt & Whitney PT6 (free turbine); Garrett/Honeywell TPE331 (direct drive through transmission). PT6 uses more fuel; the Garrett is more challenging to maintain. New contender: GE Advanced Turboprop (below), based on the Czech Walter design.

Advantages: Lightweight, reliable, and powerful.

Disadvantage: For moderate horsepower, less fuel efficient than piston engines. Cost at least $500,000.

Airframes: Beech King Air, Pilatus PC-12.

Turboprop Engines

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Turbofan ("jet") Engines

- Powerful, reliable, fuel-efficient (Boeing/Airbus size)
- Normally aspirated
- Low noise and vibration
- model planes to A380 with one gap: 4-seaters
- Cost $100,000+
- Birds, gravel? Parachute for single engine!

Compress and Burn Smoothly
Reciprocating (Piston) Engine

• Lycoming and Continental produce designs unchanged since the 1950s (or earlier!)
• In your basic Cessna or Piper:
  • 4-Cylinder
  • Horizontally Opposed
  • Normally Aspirated
  • Direct Drive
  • Air/oil-cooled
  • Carburetor
  • 160-180 HP

Reciprocating Engine Variations

• Fuel-injection: most new airplanes
• Turbocharger: high-altitude power (one oil system!)
• Horizontally opposed = less vibration; go to 6 cylinders for more/smooth power (310-350 HP common)
• Rotax: high RPM, water-cooled, transmission drives prop at a lower speed
One cylinder within a reciprocating internal combustion engine

The Reciprocating Internal Combustion Engine: 4-stroke cycle

4-Stroke Cycle:
- Intake
- Compression
- Combustion
- Exhaust
How are Engines Cooled?

Air-cooled

Oil circulation also cools engine

To help cooling
  • Lower nose in climb
  • Increase airspeed

The Mixture Control

• Adjust to compensate for density changes as aircraft flies at different altitudes and temperatures
• Decreased air density $\rightarrow$ lean mixture
**Fuel/Air Mixture**

- Ratio of air to fuel based on weight
  - Too Lean
    - Engine will run rough
    - Cylinder Head and Oil Temps too high
  - Extra Rich
    - Provides added cooling to engine
    - In some cases can cause roughness also (fouled spark plugs)

**The Carburetor**

- Mixes fuel and air in something close to an appropriate ratio (nowhere near as precise as a 1980s automobile!)
Carburetor Icing

- Conditions for carburetor ice formation
  - Outside air temp 20-70 degrees F
  - High humidity
- Carb. ice detected by loss of RPM
- Carb. Heat used to eliminate ice
- Carb. Heat enrichens mixture
- Carb. Heat reduces performance

Ignition System

- Independent of electrical system
- Magnetos generate electricity for spark
- Each cylinder has two spark plugs
- Each plug within a cylinder is driven by a different mag
- Engine will run on single magneto, but not with as much power.
- No Battery? No Problem!
Abnormal Combustion

- Pre-Ignition: slow burn before the spark
  - Hot spot inside cylinder
- Detonation—explosive burn before the spark
  - Can be caused by wrong fuel grade or too lean mixture
  - Indicated by
    - High Cylinder Head Temperatures
    - High Oil Temperatures
    - “Knocking” sound
  - Corrective actions
    - Lower nose in climb
    - Increase airspeed
    - Enrich mixture

Read: PHAK 7-18-19

Aviation Fuel

- 100LL (low lead) – blue
- Old days: 100/130 (green); 80/87 (red). (LEAN/RICH)
- Future: UL94, G100UL, 91/96UL
- Jet Fuel (tan/straw): hazardous to pistons
- Clear “fuel” in the sump?

Mixture of jet fuel and 100LL may still look blue/legit.
Propellers

Fixed Pitch Propeller
• Non-adjustable

Constant Speed Propeller
• Blade angle changes to maintain selected RPM

Constant Speed Propellers

Three control levers
• Throttle
• Propeller – engine RPM via blade angle
• Mixture

Avoid high power, low RPM

See: PHAK 7-6, AFH 11-5
FLIGHT INSTRUMENTS

“Steam-Gauge” Flight Instruments

Standard 1950s Six Pack:

- Airspeed Indicator (ASI)
- Attitude Indicator (AI)
- Altimeter
- Turn Coordinator
- Directional Gyroscope (DG)
- Vertical Speed Indicator (VSI)
Pitot Static System

Bug in pitot? Tape on static? See PHAK 8-10

Airspeed Indicator (ASI)

Standard color coded markings
- White arc – flaps
- Green arc – normal
- Yellow arc – smooth air
- Red line – never exceed speed
ASI and V-speeds

- $V_{SO}$ – Stall speed in landing configuration
  - Lower limit of white arc
- $V_{S1}$ – Stall speed in specified configuration (clean)
  - Lower limit of green arc
- $V_{FE}$ – Max flap extension speed
  - Upper limit of white arc
- $V_{NO}$ – Max structural cruising speed
  - Boundary between yellow and green arc
- $V_{NE}$ – Never exceed speed
  - Red radial line
- $V_A$ – Maneuvering speed
  - Not indicated on ASI
The SR20 needs this

Altimeter

- Pressure sensing from static port
- Hundreds, thousands, ten thousands hand
- Kollsman Window to adjust for nonstandard prevailing pressure
- (10,180’)

Source: public domain
Our Previously Wonderful Standard Atmosphere

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Altimeter: Under the hood

Source: public domain
Altitude Definitions

- True – actual height above sea level
- Indicated – what is shown on altimeter
- Absolute – height above the ground
- Pressure – height above standard datum plane (29.92” Hg), read from altimeter set to 29.92”
- Density – pressure alt. corrected for non standard temperature

Altitudes

- Pressure Alt. = Density Alt.
  - At standard temperature
- Pressure Alt. = True Alt.
  - Standard atmospheric conditions
    - 15 deg C, 29.92 inches of Mercury
High to Low Look Out Below

- Turn knob 1” higher in Kollsman Window and the altimeter will read 1000’ higher
- Inadvertently do this flying from high pressure to low pressure weather.

High to Low (Temp) Look Out Below

- True altitude < indicated when pressure is lower than Kollsman Window setting
- Same situation if air is colder than standard
Vertical Speed Indicator (VSI)

- Indicates rate of climb or descent in hundreds of feet per minute
- Slight lag unless it is an “IVSI,” more common in helicopters

VSI: Under the hood
Gyroscopes: Main Properties

- Rigidity in space
  - Gyroscopes resist attempts to reorient themselves
- Gyroscopic precession
  - A deflective force applied to a spinning gyroscope acts as if applied 90 degrees in the direction of rotation

PHAK 8-15

Gyroscopes: Precession

Figure 8-19. Precession of a gyroscope resulting from an applied deflective force.
Turn Coordinator

- Gyroscopic Instrument
- Angled to indicate both initial rate of roll and rate of yaw
- Ball indicates “quality” (coordination) of turn

PHAK 8-16

Turn Coordinator Turning

- Slipping turn
- Skidding turn
- Coordinated turn
Attitude Indicator (AI)

- Gyroscopic
- Indicates pitch and bank
- Set reference “airplane” in level flight only

Archaic: “Artificial Horizon”

AI: Under the hood

Gimbal rotation
Bank index
Roll gimbal
Gyro
Horizon reference arm
Pitch gimbal
Magnetic Compass

- Aligns itself with magnetic north pole
- Accurate when straight and level
- Full of errors! (read PHAK 8-24)

Magnetic Variation

- True North Pole
  - Earth’s rotation axis, where line of longitude meet
- Magnetic North Pole
  - compass points here
  - Moves over time
Local Magnetic Variation

• True north != magnetic north
• VORs in magnetic
• Isogonic lines
• “east is least; west is best”: true + W variation = mag
National Magnetic Variation

Compass error due to stuff in the plane.

Read PHAK 8-24 for the rest:
• dip-related
• acceleration-related

Ask New Age passengers to leave the healing magnets at home.
Heading Indicator or “DG”

- Directional Gyroscope
- Does not seek north
- Pilot periodically aligns to Magnetic Compass

HI/DG: Under the hood

Main drive gear
Compass card gear
Gimbal rotation
Gimbal
Adjustment gears
Gyro
Adjustment knob

Source: public domain
HSI: Horizontal Situation Indicator

- Looks similar to Heading Indicator
- Normally “slaved” to compass
- Combines navigation and heading information

TAA: Technologically Advanced Aircraft

“glass” (LCD) cockpit popular since 2003 in light aircraft

Pioneered by Cirrus with Avidyne (MIT spin-off). Adopted industry-wide by 2007, mostly with Garmin.

Aftermarket electronic flight instruments are widely available as retrofits for aircraft built 1930-2000.
Ballistic Airframe Parachute

Pioneered on ultralights.

1999: Cirrus SR20 first certified airplane to include.

Today: most experimental and some certified aircraft, including Cirrus Jet(!)

Summary

• Piston engines can have quirks; turbines will just quit
• Six pack: Airspeed (pitot), Attitude (gyro), Altitude (static), Turn/Ball (gyro), DG/HSI (gyro), VSI (static)
• Altimeter measures percentage of atmosphere above/below
• Compass full of errors except when straight and level
• Aircraft manufacturers are really systems integrators.
  • Study: pitot-static failures
  • Study: compass errors

Source: public domain
Questions?