Aircraft Performance: Atmospheric Pressure

FAA Handbook of Aeronautical Knowledge
Chap 10
Atmosphere

• Envelope surrounds earth
• Air has mass, weight, indefinite shape
• Atmosphere
  – 78% Nitrogen
  – 21% Oxygen
  – 1% other gases (argon, helium, etc)
• Most oxygen < 35,000 ft
Atmospheric Pressure

• Factors in:
  – Weather
  – Aerodynamic Lift
  – Flight Instrument
    • Altimeter
    • Vertical Speed Indicator
    • Airspeed Indicator
    • Manifold Pressure Guage
Pressure

• Air has mass
  – Affected by gravity
• Air has weight $\rightarrow$ Force
• Under Standard Atmospheric conditions
  – at Sea Level weight of atmosphere = 14.7 psi
• As air become less dense:
  – Reduces engine power (engine takes in less air)
  – Reduces thrust (propeller is less efficient in thin air)
  – Reduces Lift (thin air exerts less force on the airfoils)
International Standard Atmosphere (ISA)

• Standard atmosphere at Sea level:
  – Temperature 59 degrees F (15 degrees C)
  – Pressure 29.92 in Hg (1013.2 mb)

• Standard Temp Lapse Rate
  – -3.5 degrees F (or 2 degrees C) per 1000 ft altitude gain
    • Upto 36,000 ft (then constant)

• Standard Pressure Lapse Rate
  – -1 in Hg per 1000 ft altitude gain
Non-standard Conditions

• Correction factors must be applied

• Note: aircraft performance is compared and evaluated with respect to standard conditions

• Note: instruments calibrated for standard conditions
Pressure Altitude

- Height above Standard Datum Plane (SDP)

- If the Barometric Reference Setting on the Altimeter is set to 29.92 in Hg, then the altitude is defined by the ISA standard pressure readings (see Figure 10-2, pg 10-3)
Density Altitude

• Used for correlating aerodynamic performance
• Density altitude = pressure altitude corrected for non-standard temperature
• Density Altitude is vertical distance above sea-level (in standard conditions) at which a given density is to be found
• Aircraft performance increases as Density of air increases (lower density altitude)
• Aircraft performance decreases as Density of air decreases (higher density altitude)
Density Altitude

1. Find pressure altitude
2. Correct altitude for non-standard conditions (i.e. Outside Air Temperature)
3. Read of Density Altitude
   • Note: a given pressure altitude may exist for a range of temperature by allowing density to vary
   • Note: A known density occurs for only one temperature and pressure
Density Altitude - Example

• Altimeter set to 29.92 in Hg, shows altitude of 5000’ when temperature is at standard temp
• Altimeters set to 29.92 in Hg, shows altitude of 7000’ when temperature is +20 degrees C above standard
High Density Altitude (worse performance)

- High elevations
- Low atmospheric pressures
- High temperatures
Low Density Altitude (better performance)

- Lower elevations
- High atmospheric pressure
- Low humidity
Ideal Gas Law

• $D = \frac{\text{Mass}}{\text{Volume}}$

• Density of a Gas = Molar Mass $\bullet$ Pressure / Universal Gas Constant $\bullet$ Temp
  - Density is proportional to pressure
  - Density is inversely proportional to temperature

• $PV = nrT$
  - Pressure
  - Volume
  - Temperature
  - $n, r =$ constants
Effects of Pressure on Density

• Density is proportional to Pressure
  – At constant temperature
    • 2 X pressure = 2 X density
    • ½ X pressure = ½ X density
Effect of Temp on Density

- Density varies inversely with Temperature
  - Increasing temp decreases density
  - Decreasing temp increases density
Effect of Humidity on Density

• Water vapor is lighter than air
  – Moist air lighter than dry air

• Humidity increases $\Rightarrow$ Air density decreases
  – Reduces performance

• Humidity defined as % of maximum amount of water the air can hold
  – Varies with temperature
    • Warm air holds more water vapor
    • Cold air holds less water vapor