II.I. High Altitude Operations

References: 14 CFR Part 91; AC 61-107; FAA-H-8083-3; POH/AFM; AIM

Objectives
The student should develop knowledge of the elements related to high altitude operations and be able to explain the necessary elements as required in the PTS.

Key Elements
1. Regulations
2. Aviator’s Oxygen
3. Decompression and Hypoxia

Elements
1. Regulatory Requirements
2. Physiological Factors
3. Pressurization in Airplanes
4. Types of Oxygen Systems
5. Aviator’s Breathing Oxygen
6. Care and Storage of High-Pressure Oxygen Bottles
7. Rapid Decompression Problems and their Solutions

Schedule
1. Discuss Objectives
2. Review material
3. Development
4. Conclusion

Equipment
1. White board and markers
2. References

IP’s Actions
1. Discuss lesson objectives
2. Present Lecture
3. Ask and Answer Questions
4. Assign homework

SP’s Actions
1. Participate in discussion
2. Take notes
3. Ask and respond to questions

Completion Standards
The student understands and can explain the elements involved with high altitude operations.
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Instructors Notes:

Introduction:
Attention
So, you want to fly really high? It’s not just that simple. A lot of things change as the altitude increases.

Overview
Review Objectives and Elements/Key ideas

What
The required equipment, how it functions, the unique hazards and regulations associated with flying at high altitudes.

Why
There are many advantages to flying at high altitudes (more efficient, avoid weather/turb) so many modern GA airplanes are being designed to operate in that environment. Therefore it is important that pilots be familiar with at least the basic operating principles.

How:
1. Regulatory Requirements
   A. No person may operate a civil aircraft of US registry at cabin pressure altitudes above:
      i. 12,500’ MSL up to/including 14,000’ unless the required min flight crew is provided with & uses supplemental oxygen for the part of the flight at those alts over 30 min
      ii. 14,000’ unless the required min flight crew is provided with and uses supplemental oxygen during the entire flight time at those altitudes
      iii. 15,000’ unless each occupant of the aircraft is provided with supplemental oxygen
   B. No person may operate a civil aircraft of US registry with a pressurized cabin at flight altitudes above:
      i. FL 250 unless at least a 10 min supply of supplemental oxygen is available for each occupant of the aircraft for use in the event that a descent is necessitated by a loss of cabin pressure
         a. This is in addition to oxygen required above
      ii. FL 350, unless one pilot at the controls of the airplane is wearing and using an oxygen mask that is secured and sealed
         a. The mask must supply oxygen at all times or automatically supply oxygen whenever the cabin pressure altitude of the airplane exceeds 14,000’ MSL
         b. Exception: One pilot need not wear and use an oxygen mask while at or below FL 410 if there are two pilots at the controls and each pilot has a quick donning type of oxygen mask that can be placed on the face with one hand from the ready position within 5 sec, supplying oxygen and properly secured and sealed
         c. If one pilot leaves the controls the remaining pilot shall put on and use an oxygen mask until the other pilot has returned

2. Physiological Hazards
   A. The human body functions normally from sea level to 12,000’ MSL
      i. Brain oxygen saturation is at a level for normal function (Optimal functioning is 96% saturation)
         a. At 12,000’, oxygen saturation is approx 87%, which gets close to a performance affecting level
   B. Hypoxia (Reduced Oxygen, or not enough oxygen)
      i. The concern is getting enough oxygen to the brain, since it is particularly vulnerable to deprivation
      ii. Hypoxic Hypoxia (Insufficient oxygen available to the lungs)
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iii. Hypemic Hypoxia (The blood cannot transport enough oxygen to the tissues/cells)
iv. Stagnant Hypoxia (Oxygen rich blood isn’t moving to the tissues)
v. Histotoxic Hypoxia (“Histo” refers to tissues or cells, and “Toxic” means poison)
vi. Symptoms of Hypoxia
   a. Cyanosis; Headache; Decreased reaction time/Impaired judgment; Euphoria; Visual Impairment; Drowsiness/Lightheaded or dizzy sensation; Tingling in fingers or toes and Numbness
   • Even with all of these symptoms, hypoxia can cause a pilot to have a false sense of security
vii. Useful Consciousness
   a. The max time to make rational, life saving decisions and carry them out at a given altitude
   • Above 10,000’ the time begins decreasing rapidly
viii. Treatment
   a. Flying at lower altitudes (Emergency Decent) and use supplemental oxygen
C. Prolonged O use can be harmful to health (100% aviation O can create toxic symptoms if used too long)
i. The sudden supply of pure oxygen following decompression can often aggravate hypoxia
   a. Therefore, oxygen should be taken gradually to build up in small doses
ii. Symptoms: bronchial cough, fever, vomiting, nervousness, irregular heartbeat, lowered energy
D. Nitrogen
   i. When nitrogen is inhaled, most is exhaled with CO₂, but some is absorbed into the body
   a. Normally Nitrogen in the body isn’t a problem, because it’s in a liquid state
   • But, if the ambient pressure lowers drastically, it could return to a gas in the form of bubbles
   ii. Evolving and expanding gases in the body are known as decompression sickness
   a. Trapped Gas: expanding/contracting gas in certain cavities during altitude changes can result in abdominal pain, toothache, or pain in ears and sinuses if the pressure change can’t be equalized
   b. Evolved Gas: When the pressure drops sufficiently, nitrogen forms bubbles which can have adverse effects on some body tissues
   • Scuba diving compounds this problem
E. Vision tends to deteriorate with Altitude
   i. The eyes require oxygen
   ii. Glare and deteriorated vision are enhanced at night when the body is more susceptible to hypoxia
   iii. Empty visual field by cloudless, blue skies during the day can cause inaccuracies when judging traffic
3. Pressurization in Airplanes
A. Cabin pressurization is the compression of air to maintain a cabin altitude lower than the flight altitude
   i. This removes the need for full-time use of supplemental oxygen
   ii. A cabin pressure altitude of approx 8,000’ is maintained and prevents rapid changes of cabin altitude that may be uncomfortable or cause injury to passengers/crew (prevents against hypoxia)
B. How it Works
   i. The cabin, flight and baggage compartments are incorporated into a sealed unit capable of containing air under a higher pressure than the outside atmospheric pressure (Differential Pressure)
   a. Differential Pressure - the difference between cabin pressure and atmospheric pressure normally expressed in psi (the higher the plane goes, the higher the differential)
   b. Max differential pressure varies by make/model of plane – the higher it is, the higher you can go
   ii. Turbine powered aircraft – bleed air is from the engine compressor section is used to pressurize
   iii. In most light planes, the turbocharger’s compressor or engine driven pneumatic pump pressurizes
   a. Compression heats the air, so it’s routed through a heat exchange unit before entering the cabin
   iv. The cabin pressure control system provides pressure regulation, pressure relief and vacuum relief and the means for selecting the desired cabin altitude
a. A cabin pressure regulator, an outflow valve, and a safety valve are used to accomplish this
   • CPR – controls cabin pressure – if we reach the max difference, an increase in altitude outside will result in an increase inside
   • The flow of compressed air is regulated by an outflow valve which keeps pressure constant by releasing excess pressure into the atmosphere
   • Safety Valve is a combo of a pressure relief, vacuum relief, and dump valve
     a. Pressure Relief prevents the cabin pressure from exceeding a predetermined differential pressure above ambient pressure
     b. Vacuum Relief prevents ambient pressure from exceeding cabin pressure by allowing external air to enter when ambient pressure exceeds cabin pressure
   • Dump Valve dumps cabin air to the atmosphere (switch in the cockpit)

v. Instruments
   a. Cabin differential pressure gauge indicates the difference between inside and outside pressure
   b. Cabin Altimeter shows the altitude inside the airplane
   • Differential pressure gauge and cabin altimeter can be combined into one instrument
   c. Cabin Rate of Climb/Descent

4. Types of Oxygen Systems
   A. Continuous Flow
      i. Most common in GA planes
      ii. Usually for passengers and has a reservoir bag which collects oxygen from the system when exhaling
      iii. Ambient air is added to the oxygen during inhalation after the reservoir oxygen supply is depleted
      iv. Exhaled air is released into the cabin
   B. Diluter Demand – Supply oxygen only when the user inhales through the mask
      i. Depending on the altitude, the regulator can provide 100% oxygen or mix cabin air and the oxygen
      ii. The mask provides a tight seal and can be used safely up to 40,000’
   C. Pressure Demand – oxygen is supplied to the mask under pressure at cabin altitudes above 34,000’
      i. Provide a positive pressure application of oxygen that allow the lungs to be pressurized with oxygen
      ii. Safe at altitudes above 40,000’
      iii. Some systems include the regulator on the mask to eliminate purging a long hose of air

5. Aviator’s Breathing Oxygen
   A. Aviators oxygen is specified at 99.5% pure oxygen and not more than .005mg of water per liter
   B. Medical oxygen has too much water, which can collect in various parts of the system and freeze
      i. Freezing may reduce/stop the flow of oxygen
   C. Industrial oxygen is not intended for breathing and may have impurities in it (metal shavings, etc)

6. Care and Storage of High-Pressure Oxygen Bottles
   A. If the airplane does not have a fixed installation, portable oxygen equipment must be accessible in flight
   B. Oxygen is usually stored at 1,800 – 2,200 psi
      i. When the ambient temp surrounding the cylinder decreases, pressure within will decrease
         a. If a drop in indicated pressure is noted, there is no reason to suspect depletion of the supply
      ii. High pressure containers should be marked with the psi tolerance before filling to the pressure
   C. Be aware of the danger of fire when using oxygen
      i. Materials that are nearly fire proof in ordinary air may be susceptible to burning in pure oxygen
         a. Oils and greases may catch fire if exposed to pure oxygen and cannot be in oxygen systems
      ii. Smoking during any kind of oxygen equipment use is prohibited
      iii. Before each flight, thoroughly inspect and test all oxygen equipment
   D. Examine the equipment - available supply, operational check, and assure it is readily available
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E. To assure safety, periodic inspections and servicing should be done

7. Rapid Decompression Problems and their Solutions
   A. Decompression is the inability of the pressurization system to maintain its designed pressure differential
      i. This can be caused by a malfunction in the pressurization system or structural damage to the plane
         a. If the turbo charger fails, not only will the airplane descend, but pressurization will be lost
   B. Explosive Decompression – A change in cabin pressure faster than the lungs can decompress (<0.5 sec)
   C. Rapid Decompression – A change in cabin pressure where the lungs can decompress faster than the cabin (therefore there is no likelihood of lung damage)
      i. During explosive decompression, there may be noise and one may feel dazed for a second
      ii. During most decompressions, the cabin will fill with fog, dust, flying debris
         a. Fog is the result of the rapid change in temp and change of relative humidity
      iii. Air will rush from the mouth and nose due to the escape from the lungs
      iv. Differential air pressure on either side of the eardrum should clear automatically.
      v. Exposure to wind blast and extremely cold temperatures may occur
   D. The primary danger of decompression is hypoxia
      i. If proper use of oxygen equipment is not accomplished quickly unconsciousness may occur quickly
         a. Effective performance time is reduced by one-third to one-fourth its normal time
   E. Recovery from all types of decompression involves donning oxygen masks and an emergency descent
      i. Top priority is reaching a safe altitude
         a. Be aware, cold shock in piston engines can result from rapid high-alt descent, cracking cylinders
         b. The time to make a recovery before loss of useful consciousness is much less with explosive

Conclusion:
Brief review of the main points
The fundamental concept of cabin pressurization is that it is the compression of air in the airplane’s cabin to maintain a cabin altitude lower than the actual flight altitude. If your airplane is equipped with a pressurization system, you must know the normal and emergency operating procedures.

PTS Requirements:
To determine that the applicant exhibits instructional knowledge of the elements of high altitude operations by describing:
   1. Regulatory requirements for use of oxygen.
   2. Physiological hazards associated with high altitude operations.
   3. Characteristics of a pressurized airplane and various types of supplemental oxygen systems.
   4. Importance of “aviator’s breathing oxygen.”
   5. Care and storage of high-pressure oxygen bottles.
   6. Problems associated with rapid decompression and corresponding solutions.