

References: 14 CFR part 91, AC 61-107, AIM,
POH/AFM, FAA-H-8083-3, FAA-S-8081-12

Objectives	<ul style="list-style-type: none"> The student will understand the elements related to high altitude operations
Elements	<ul style="list-style-type: none"> Regulatory Requirements Physiological Factors Pressurization in Airplanes Types of Oxygen Systems Aviator's Breathing Oxygen Care and Storage of High-Pressure Oxygen Bottles Rapid Decompression Problems & Their Solutions
Schedule	<ul style="list-style-type: none"> Review lesson objectives Review lesson material Conclusion & Review
Equipment	<ul style="list-style-type: none"> White Board / Markers References
CFI Actions	<ul style="list-style-type: none"> Present lesson Use teaching aids Ask/ answer questions
Student Actions	<ul style="list-style-type: none"> Participate in discussion Take notes Ask / answer questions Chair Fly at home
Completion Standards	<ul style="list-style-type: none"> The student can explain the elements involved with high altitude operations

Additional Notes: _____

CE = Common Error

Introduction

Overview

Review objectives / Elements

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 (jet engines are more efficient, weather and turbulence can be avoided, etc.), so many modern GA airplanes are being designed to operate in this environment, which is why it is so important that pilots be familiar with at least the basic operating principles.

How

Regulations 91.211

NO PERSON MAY OPERATE A CIVIL AIRCRAFT OF US REGISTRY AT CABIN PRESSURE ALTITUDES ABOVE

- **12,500' MSL up to / including 14,000'** unless the required minimum flight crew is provided with and uses supplemental oxygen for the part of the flight at those altitudes **over 30 minutes**
- **14,000'** unless **the required min flight crew** is provided with and uses supplemental oxygen during the **entire flight time at those altitudes**
- **15,000'** unless each occupant of the aircraft is provided with supplemental oxygen (offered)

NO PERSON MAY OPERATE A CIVIL AIRCRAFT OF US REGISTRY WITH A PRESSURIZED CABIN AT FLIGHT ALTITUDES ABOVE:

- **FL 250** unless at least a **10-minute supply of supplemental oxygen** is available for **each occupant of the aircraft** for use if a descent is necessitated by a loss of cabin pressure
 - This is in addition to oxygen required above
- **FL 350**, unless **one pilot** at the controls of the airplane **is wearing and using an oxygen mask that is secured and sealed**
 - The mask must supply oxygen at all times or automatically supply oxygen whenever the cabin pressure altitude of the airplane exceeds 14,000' MSL
 - **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 seconds, supplying oxygen and properly secured and sealed

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- **If one pilot leaves the controls, the remaining pilot shall put on and use an oxygen mask until the other pilot has returned**

Physiological Hazards (See Aeromedical Factors Lesson Plan)

THE HUMAN BODY FUNCTIONS NORMALLY FROM SEA LEVEL TO ABOUT 12,000' MSL

- **Brain oxygen saturation is at a level for normal function (Optimal functioning is 96% saturation)**
 - At 12,000', oxygen saturation is approx. 87%, which gets close to a performance affecting level
 - Above 12,000' oxygen saturation decreases, and performance is affected

HYPOXIA (REDUCED OXYGEN, OR NOT ENOUGH OXYGEN)

- **The concern is getting enough oxygen to the brain, since it is particularly vulnerable to deprivation**
- **Hypoxic Hypoxia** (Insufficient oxygen available to the lungs)
- **Hypemic Hypoxia** (The blood cannot transport enough oxygen to the tissues/cells)
- **Stagnant Hypoxia** (Oxygen rich blood isn't moving to the tissues)
- **Histotoxic Hypoxia** ("Histo" refers to tissues or cells, and "Toxic" means poison)

SYMPTOMS OF HYPOXIA

- **Cyanosis; Headache; Decreased reaction time/Impaired judgment; Euphoria; Visual Impairment; Drowsiness/Lightheaded or dizzy sensation; Tingling in fingers or toes and Numbness**
 - Even with these symptoms, hypoxia can cause a pilot to have a false sense of security

USEFUL CONSCIOUSNESS

- **The max time to make rational, lifesaving decisions and carry them out at a given altitude**
 - Above 10,000' the time begins decreasing

TREATMENT

- **Flying at lower altitudes (Emergency Descent) and use supplemental oxygen**
- **Prolonged oxygen use can be harmful to health (100% aviation oxygen can create toxic symptoms if used for too long)**
 - The sudden supply of pure oxygen following decompression can often aggravate hypoxia
 - Oxygen should be taken gradually to build up in small doses
 - If symptoms are aggravated it may not mean the oxygen is not working, do not discard the oxygen supply and continue (this may even further increase the hypoxia)
- **Symptoms: bronchial cough, fever, vomiting, nervousness, irregular heartbeat, lowered energy**

NITROGEN

- **When nitrogen is inhaled, most is exhaled with CO₂, but some is absorbed into the body**
 - Normally Nitrogen in the body isn't a problem, because it's in a liquid state
 - But, if the ambient pressure lowers drastically (high altitudes), it could return to a gas in the form of bubbles
- **Evolving and expanding gases in the body are known as decompression sickness**
 - **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
 - **Evolved Gas:** When the pressure drops sufficiently, nitrogen forms bubbles which can have adverse effects on some body tissues
 - Scuba diving compounds this problem

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VISION DETERIORATES WITH ALTITUDE

- The eyes require oxygen
- Glare and deteriorated vision are enhanced at night when the body is more susceptible to hypoxia

Pressurization in Airplanes

- Cabin Pressurization Is the Compression Of Air To Maintain A Cabin Altitude Lower Than The Flight Altitude
 - This removes the need for full-time use of supplemental oxygen
- 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)

HOW IT WORKS

- 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)
- ### Differential Pressure
- the difference between cabin pressure and atmospheric pressure normally expressed in psi (the higher the plane goes, the higher the differential to a limit)
 - Max differential pressure varies by make/model of plane – the higher it is, the higher you can go
 - Turbine powered aircraft – bleed air from the engine compressor section is used to pressurize the cabin
 - In most light planes, the turbocharger's compressor or engine driven pneumatic pump pressurizes the cabin
 - Compression heats the air, so it's routed through a heat exchange unit before entering the cabin
 - The cabin pressure control system provides pressure regulation, pressure relief and vacuum relief and the means for selecting the desired cabin altitude
 - A cabin pressure regulator, an outflow valve, and a safety valve are used to accomplish this

Cabin Pressure Regulator

- Controls cabin pressure – if we reach the max differential pressure, an increase in altitude outside will result in an increase in cabin altitude
 - The flow of compressed air is regulated by an outflow valve which keeps pressure constant by releasing excess pressure into the atmosphere
 - The Safety Valve is a combo of a pressure relief, vacuum relief, and dump valve
 - Pressure Relief prevents the cabin pressure from exceeding a predetermined differential pressure
 - Vacuum Relief prevents ambient pressure from exceeding cabin pressure by allowing external air to enter when ambient pressure exceeds cabin pressure
 - The Dump Valve dumps cabin air to the atmosphere (switch in the cockpit)

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INSTRUMENTS

- **Cabin differential pressure gauge indicates the difference between inside and outside pressure**
- **Cabin Altimeter shows the altitude inside the airplane**
 - Differential pressure gauge and cabin altimeter can be combined into one instrument
- **Cabin Rate of Climb / Descent**
 - This shows how quickly the cabin altitude is changing during a climb or descent

Types of Oxygen Systems

CONTINUOUS FLOW

- **Most common in GA planes**
- **Usually for passengers and has a reservoir bag which collects oxygen from the system when exhaling**
- **Ambient air is added to the oxygen during inhalation after the reservoir oxygen supply is depleted**
- **Exhaled air is released into the cabin**

DILUTER DEMAND

- **Supplies oxygen only when the user inhales through the mask**
- **Depending on the altitude, the regulator can provide 100% oxygen or mix cabin air and the oxygen**
 - The mask provides a tight seal and can be used safely up to 40,000'

PRESSURE DEMAND

- **Oxygen is supplied to the mask under pressure at cabin altitudes above 34,000'**
 - Provide a positive pressure application of oxygen that allow the lungs to be pressurized with oxygen
 - Safe at altitudes above 40,000'
 - Some systems include the regulator on the mask to eliminate purging a long hose of air

Aviator's Breathing Oxygen

- **Aviators Oxygen Is Specified At 99.5% Pure Oxygen and Not More Than .005 mg Of Water Per Liter**
 - It is recommended that aviator's breathing oxygen be used at all times, medical and industrial oxygen may not be safe
- **Medical Oxygen Has Too Much Water, Which Can Collect in Various Parts of The System and Freeze**
 - Freezing may reduce/stop the flow of oxygen
- **Industrial Oxygen Is Not Intended for Breathing and May Have Impurities in It (Metal Shavings, Etc.)**

Care & Storage of High-Pressure Oxygen Bottles

- **If the Airplane Does Not Have A Fixed Installation Bottle, Portable Oxygen Equipment Must Be Accessible in Flight**
- **Oxygen Is Usually Stored At 1,800 – 2,200 Psi**
 - When the ambient temperature surrounding the cylinder decreases, pressure within will decrease

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- If a drop in indicated pressure is noted due to temperature, there is no reason to suspect depletion of the supply
- **High pressure containers should be marked with the psi tolerance before filling to the pressure**
- **Be Aware of The Danger of Fire When Using Oxygen**
 - Materials that are nearly fire proof in ordinary air may be susceptible to burning in pure oxygen
 - Oils and greases may catch fire if exposed to pure oxygen and cannot be in oxygen systems
 - Smoking during any kind of oxygen equipment use is prohibited
 - Before each flight, thoroughly inspect and test all oxygen equipment
- **Examine the Equipment - Available Supply, Operational Check, And Assure It Is Readily Available**
- **To Assure Safety, Periodic Inspections and Servicing Should Be Done**

Rapid Decompression Problems & Solutions

- **Decompression Is the Inability of The Pressurization System to Maintain Its Designed Pressure Differential**
 - This can be caused by a malfunction in the pressurization system or structural damage to the plane
 - If the turbo charger fails, not only will the airplane descend, but pressurization will be lost

EXPLOSIVE DECOMPRESSION

- **A Change in Cabin Pressure Faster Than the Lungs Can Decompress (< 0.5 Seconds)**

RAPID DECOMPRESSION

- **A Change in Cabin Pressure Where the Lungs Can Decompress Faster Than the Cabin (Therefore There Is No Likelihood of Lung Damage)**
- **Indications of A Rapid or Explosive Decompression**
 - During explosive decompression, there may be noise and one may feel dazed for a second
 - During most decompressions, the cabin will fill with fog, dust, flying debris
 - Fog is the result of the rapid change in temperature and change of relative humidity
 - Air will rush from the mouth and nose due to the escape from the lungs
 - Differential air pressure on either side of the eardrum should clear automatically
 - Exposure to wind blast and extremely cold temperatures may occur
- **The Primary Danger of Decompression Is Hypoxia**
 - If proper use of oxygen equipment is not accomplished quickly unconsciousness may occur
- **Recovery from All Types of Decompression Involves Donning Oxygen Masks and An Emergency Descent**
 - The top priority is reaching a safe altitude
 - Be aware, cold shock in piston engines can result from rapid high-altitude descents, cracking cylinders
 - The time to make a recovery before loss of useful consciousness is much less with an explosive decompression

Conclusion & Review

Review the Main Lesson Points

Cabin pressurization 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 & understand the normal and emergency operating procedures.

review

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. "Aviator's Breathing Oxygen."
5. Care and storage of high-pressure oxygen bottles.
6. Problems associated with rapid decompression.
7. Cabin pressurization.