AIRCRAFT PRESSURIZATION SYSTEM
Pressurize means to increase the pressure.

While, pressurization is the act of increasing the air pressure inside a space (example: an aircraft cabin)
The higher the altitude, the lower the air pressure.

The lower air pressure makes it more difficult for humans to breathe normally.

This can cause several difficulties to the human body such as HYPOXIA, TRAPPED GAS and DECOMPRESSION SICKNESS.
To overcome this problem, all commercial airplanes must be pressurized.

This is because, pressurization of the cabin limits the fall of air pressure inside the cabin.

Thus, allows the airplane to cruise at altitudes up to 40,000 feet without exposing travelers to dangerously low levels of air pressure.
Cabin Pressurization Systems

- Cabin pressurization provides a comfortable environment for passengers and crew while allowing the aircraft to fly at higher altitudes.

- Flying at high altitudes is more fuel efficient and it allows the aircraft to fly above most undesirable weather conditions.
If an aircraft is to be pressurized, the pressurized section (pressure vessel) must be strong enough to withstand operational stresses.

In general, the maximum altitude at which an aircraft can fly is limited by the maximum allowable cabin differential pressure.

- Cabin differential pressure is the pressure difference between ambient air and the air inside the pressure vessel.
The stronger the aircraft structure, the higher the allowed differential pressure will be.

General cabin pressure differentials allowed by different aircraft types:

- Light aircraft – approx. 3-5 psi
- Large reciprocating-engine aircraft – approx. 5.5 psi
- Turbine-powered transport aircraft – approx. 9psi
Why Aircraft needs to be ‘Pressurized’?

The cabin pressurization system in today's aircraft is designed to provide a safe and comfortable cabin environment at cruising altitudes that can reach upwards of 40,000 feet.

Also this system is important to protect crews & passengers from the physiological risks of high altitudes such as hypoxia, decompression sickness & trapped gas.

At higher altitude, the outside atmospheric pressure is very low, thus give difficulties to our body system to function normally.
Risks of unpressurized aircraft

- **Hypoxia:**
  - Lacks of oxygen
  - Crew/passengers can loss their consciousness.

- **Trapped Gas:**
  - Gases trapped within the bodies (middle ear, sinus, teeth)
  - Crew/passengers may suffer critical pain

- **Decompression sickness:**
  - Bubbles in the bloodstream
  - Crew/passengers may feel tiredness, forgetfulness and can lead to stroke
The source of aircraft pressure varies depending on the type of engine installed on the aircraft and aircraft design.

Although the specific method of pressurizing cabin air varies between different aircraft, pressurization is always done, in some form, by the aircraft engines.
Reciprocating engines can pressurize cabin air through the use of:

- Superchargers
- Turbochargers
- Engine-driven air pumps

The use on superchargers and turbochargers for pressurized air:

- May introduce fumes and oil into the cabin air
- Greatly reduces engine power output
Turbine-engines

- Turbine-engine aircraft usually utilize engine bleed air for pressurization.

- In these systems, high pressure air is "bled" from the turbine-engines compressor.

- This also causes a reduction in engine power but it is not as significant of a loss.
Independent Cabin Compressors

- Some aircraft use independent cabin compressors for pressurization which are used to eliminate the problem of air contamination.

- Independent cabin compressors are driven by either:
  - The engine accessory section
  - Turbine-engine bleed air

- These compressors may use one of two types of pumps:
  - Roots-type positive displacement pumps
  - Centrifugal cabin compressors
Pressurization System Components

- **Heat exchanger**
  - used to cool the hot pressurized air to a usable temperature

- **Outflow valve**
  - primary cabin pressure control, regulates the amount of pressurized air that is allowed to exit the cabin

- **Safety valve (positive pressure relief valve)**
  - prevents cabin over-pressurization by opening automatically at a predetermined pressure
Negative pressure-relief valve
- Prevents cabin pressure from going below that of the ambient air

Dump valve
- Releases all cabin pressure when aircraft lands
- Often controlled by landing gear squat switch
How Pressurization Works

1. Air-conditioning packs (2 locations)
2. Recirculation system (2 locations)
3. Passenger compartment air distribution
4. Outflow valve

- Gasper fan
- Flight compartment air distribution
- Engine
How Pressurization Works

- The combined outside air (50%) and filtered air (50%) is ducted to the cabin and distributed through **overhead outlets**.

- Inside the cabin, the air flows in a circular pattern.

- About half of the air exiting the cabin is exhausted from the airplane through an **outflow valve**.

- The other half is drawn by fans through **special filters under the cabin floor** to be filtered again.

- The airflow is continuous and is used for maintaining a comfortable cabin temperature & pressure.
The opening of outflow valve can be controlled by pilot in order to maintain the suitable pressure.
The failure of pressurization system can lead to aircraft accident.

There are many accidents occurred due to this reason.

For example, Helios Airway Flight 522 Plane Crash.

This accident also known as No Oxygen Disaster.
Helios Airway Flight 522
No Oxygen Disaster
Before take-off, crew failed to correctly set pressurization system.

This cause, all crews and passengers on board suffering Hypoxia.

As pilot also suffering hypoxia, he became unconscious and failed to perform emergency landing.

As a results, aircraft fly by its own and finally crashed due to lack of fuel. All 121 on board were killed.
Failure of pressurization system also can cause by any damage to the aircraft that causes a break in the aircraft structure which enabling cabin air to escape outside the aircraft.

This situation causes a rapid reduction of air pressure inside the cabin thus aircraft loss of cabin pressurization.
A Boeing 747 operating as United Airlines Flight 811 from Los Angeles to Auckland is above the Pacific Ocean when part of the RH forward fuselage rips off.

An electrical short circuit caused the cargo door lock mechanism to fail and the cargo door was blown open by the force of the cabin pressurization.

Nine people are ejected from the aircraft; some are still strapped to their seats. The Boeing 747 safely lands at Honolulu without any more loss of life.
Loss of cabin pressurization

Qantas Flight, Big Hole in the Fuselage
Loss of pressurization

A Qantas Airways Boeing 747-400, from Hong Kong (China) to Melbourne, (Australia) with 346 passengers and 19 crew

In mid-flight, cabin pressure was suddenly lost because of big hole below the fuselage.

The pilot then initiated an emergency descent and perform emergency landing at Manila airport.

No injuries have been reported
Advantages of Cabin Pressurization

- Reduce significantly the occurrences of hypoxia and decompression sickness.
- Minimize trapped-gas expansion.
- Reduce crew fatigue because cabin temperature and ventilation can be controlled within desired ranges.
- Eliminate the need for supplemental-oxygen equipment.
Prevention & Treatment of Hypoxia

- **Prevention of Hypoxia**
  - Make sure cabin pressurization system functioning well.

- **Treatment of Hypoxia:**
  - Put on the Oxygen Mask
  - Descends to altitude below 10’000 ft.
  - Contact ATC for emergency landing clearance
  - Landing at the nearest airport as soon as possible.
AIRCRAFT AIR-CONDITIONING SYSTEM
To keep the cabin temperatures at comfortable level.

- Large internal heat generation due to occupants, equipment etc.
- Heat generation due to skin friction caused by the fast moving aircraft
Need For Cabin Cooling (Contd..)

- At high altitudes, the outside pressure will be sub-atmospheric. When air at this low pressure is compressed and supplied to the cabin at pressures close to atmospheric, the temperature increases significantly.

- Solar radiation
Need For Cabin Cooling (Contd..)

- For low speed aircraft flying at low altitudes, cooling system may not be required.

- For high speed aircraft flying at high altitudes, a cooling system is a must.
Types of Air-conditioning System

- Air Cycle Refrigeration System
  - Simple System
  - Boot Strap System
  - Regenerative System
  - Reduced Ambient Air System
- Vapour Compression Refrigeration System
**Air Cycle Vs Vapour Cycle**

- Even though the COP of air cycle refrigeration is very low compared to vapour compression refrigeration systems, it is still found to be most suitable for aircraft refrigeration systems as:

- Air is cheap, safe, non-toxic and non-flammable. Leakage of air is not a problem.
Cold air can directly be used for cooling thus eliminating the low temperature heat exchanger (open systems) leading to lower weight.

Separate compressor for cooling system is not required. This reduces the weight per kW cooling considerably. Typically, less than 50% of an equivalent vapour compression system.
Air Cycle Vs Vapour Cycle

- **Design** of the complete system is much simpler due to low pressures.
- **Maintenance required** is also less.
Air-Cycle Cooling System

- Air-cycle cooling systems are used on modern large turbine-powered aircraft.
- These systems use the compression and expansion of air to adjust the temperature in passenger and crew compartments.
Air Cycle Refrigeration System

Diagram showing the components and flow of the air cycle refrigeration system.
Bootstrap System

Diagram:
- Ram air enter at point 2
- MC (possibly a cooling or humidification component)
- AC1 (possibly an air conditioning component)
- C (another cooling or humidification component)
- T (possibly a heating or ventilation component)
- AC2 (another air conditioning component)

Graph:
- T-axis (temperature)
- Cabin pressure
- Ambient pressure
- Ram pressure
- Points 1, 2, 3, 4, 5, 6, 7 on the graph
Dry Air Rated Temperature (DART)

- It is the temperature of the air at the exit of the cooling turbine in the absence of moisture condensation.

- The dew point temperature and hence moisture content of the air should be very low, i.e., the air should be very dry. (To avoid Condensation during expansion in turbine)
A comparison between different aircraft refrigeration systems based on DART at different Mach numbers shows that:

- DART increases monotonically with Mach number for all the systems except the reduced ambient system.
- The simple system is adequate at low Mach numbers.
At high Mach numbers either bootstrap system or regenerative system should be used.

Reduced ambient temperature system is best suited for very high Mach number, supersonic aircrafts.
Vapour Cycle Cooling System

- Vapor-cycle cooling systems are used on reciprocating-engine aircraft and in some small turboprop aircraft.
- This is a closed system that uses the evaporation and condensation of Freon to remove heat from the cabin.
Freon is colourless, odourless, and non toxic; however, being heavier than air, it will displace oxygen and cause suffocation. When heated over an open flame, it converts to phosgene which is deadly!
Vapour Cycle System

VAPOR CYCLE SYSTEM

EVAPORATOR

fan

air to cabin

EXPANSION VALVE

COMPRESSOR

CONDENSOR

RECEIVER

AIR TO ATM.

HIGH PRESSURE LIQUID

LOW PRESSURE LIQUID

LOW PRESSURE VAPOR

HIGH PRESSURE VAPOR
Vapour Cycle System

**Compressor**
the low pressure refrigerant gas is compressed to a high pressure and high temperature

**Condenser**
the heated compressed refrigerant gas from the compressor condenses to a liquid

**Receiver Drier**
stores the liquid refrigerant and removes moisture and foreign particles as the refrigerant circulates within the system

**Expansion Valve**
delivers sprayed refrigerant to the evaporator to facilitate refrigerant evaporation and controls the amount of refrigerant passing the orifice

**Cabin Air**

**Blower Motor**
Vapour Cycle Cooling System

Figure 14-37. Refrigeration cycle.
FREON is used as refrigerant in the vapour cycle cooling system. It has a boiling point of 4°C.

At the receiver, the refrigerant is having high pressure, so that FREON will have high boiling point.

When the system is switched on, the compressor starts delivering the pressure and thus making flow.
The highly pressurized FREON at the receiver is in liquid phase. When the Freon flows through the circuit, first it expands at the Expansion valve. So pressure has been dropped (i.e. Boiling point decreased).

The less pressure Freon then goes to the evaporator stage. Evaporator will be exposed to Cabin. We blow the warm air of cabin over the evaporator coils by fan, and thus doing a forced convection.

The heat transferred to the Freon makes it to change the phase which is from liquid to vapour.
The low pressure Freon vapour is then compressed by the Compressor and thus it delivers high temperature high pressure Freon vapour.

This high pressure and high temperature Freon vapour enters the Condenser coils where the cool air from atmosphere will be blown over the coils (here too making a forced convection). Condenser will be exposed to the Atmosphere. Because of heat transfer the Freon losses heat and returns to liquid phase.

It goes to the receiver (high pressure low temperature Freon liquid)
**Maintenance**

- **Before** doing any type of maintenance activities to the vapour cycle system, we have to **purge** the system with inert gas in an **open atmosphere**.

- To know the Freon level in the circuit, a **sight glass arrangement** will be employed between **Receiver to Expansion valve**. If the unit requires additional refrigerant, **bubbles will be present** in the sight glass otherwise **steady**.
AIRCRAFT OXYGEN SYSTEM
With increase in altitude, the air pressure decreases. As a result, the amount of oxygen available to support life functions decreases.

They are provided to supply the required amount of oxygen to keep a sufficient concentration of oxygen in the lungs to permit normal activity.
Types

Based on type of aircraft, operational requirements and pressurization system.

- Continuous Flow System
- Pressure Demand System
- Portable Equipment
Continuous Flow System

Figure 14-45. Continuous-flow oxygen system.
Continuous flow mask and rebreather bag
Figure 14-46. Typical pressure-demand oxygen system.
Portable Oxygen Equipment

Components:

- Lightweight steel alloy oxygen cylinder
- Combined flow control/reducing valve
- Pressure Gauge
- Breathing mask, with connecting flexible tube
- Carrying bag with the necessary straps for attachment to the wearer
The charged cylinder pressure is usually 1,800 psi.

A popular size for portable equipment is the 120 litre capacity cylinder.

Based on type of equipment, rate of flow can be:

- **Normal** (2 litre per minute : 60 minutes)
- **High** (4 litre per minute : 30 minutes)
- **Emergency** (10 litre per minute : 12 minutes)
**Oxygen Cylinder**

High Pressure Cylinders:

- Made of heat treated alloy
- **Green** Colour
- AVIATORS’ BREATHING OXYGEN in white, 1-inch letters
- Variety of capacities and shape
- Maximum charge of 2000 psi but are filled to 1800 to 1850 psi.
Oxygen Cylinder

Low Pressure Cylinders:

- Made of stainless steel / heat treated low alloy steel
- Light Yellow Colour
- AVIATORS’ BREATHING OXYGEN in white, 1-inch letters
- Variety of capacities and shape
- Maximum charge of 450 psi but are filled to 400 to 425 psi.
Emergency supplemented oxygen is a necessity in any pressurized aircraft flying above 25,000 ft.

Chemical oxygen generators can be used to fulfill the new requirements.

The chemical oxygen generator differs from the compressed oxygen cylinder and the liquid oxygen converter in that the oxygen is actually produced at the time of delivery.
Solid State Oxygen Systems

- Solid-state oxygen generators have been in use from **1920**.
- First used in **Mine rescues**.
- During World War II the **Japanese, British and Americans**, all worked to develop oxygen generators for **aircraft and submarines**.
Figure 14-47. Volume comparison.

Figure 14-48. Weight and volume comparison—gas, liquid and solid oxygen storage.
Solid State Oxygen Systems

Solid state describes the chemical source, sodium chlorate ($\text{NaClO}_3$), when heated to 478°F, sodium chlorate releases up to 45% of its weight as gaseous oxygen.

The necessary heat for de-composition of the sodium chlorate is supplied by iron which is mixed with the chlorate.
Advantages

- It is **most efficient space wise**
- Less equipment and maintenance is required for **solid state oxygen converters**.
Oxygen Plumbing

- All lines are metal except where flexibility is required.
- Rubber hoses are used for flexibility.
- There are several different sizes and types of oxygen tubing.
  - Low-pressure system: Aluminium alloy
  - High-pressure system: Copper alloys
- The tape coding consists of a green band overprinted with the words “BREATHING OXYGEN” and a black rectangular symbol overprinted on a white background.
Oxygen Valves

- Filler Valves
- Check Valves
- Shutoff Valves
- Pressure Reducer Valves
- Pressure Relief Valves
Regulators

- Diluter Demand Regulators
- Continuous Flow Regulator
Diluter-Demand Regulators

Figure 14-53. Schematic of a diluter-demand regulator.
Continuous Flow Regulators

Figure 14-58. Typical passenger service unit.
Oxygen Mask

Figure 14-61. Passenger oxygen mask.