

AIRCRAFT PRESSURIZATION SYSTEM

What is pressurize? What is pressurization?

- Pressurize means to increase the pressure.
- While, pressurization is the act of increasing the air pressure inside a space (example: an aircraft cabin)

Introduction

- The higher the altitude, the lower the air pressure.
- The lower air pressure makes it more difficult for human to breathe normally.
- This can cause several difficulties to the human body such as HYPOXIA, TRAPPED GAS and DECOMPRESSION SICKNESS.

Introduction

- 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

Aircraft Structures

- 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

Aircraft Structures (cont.)

- 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

Sources of Pressurization

- 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

- 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

Pressurization System Components (cont.)

◉ 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

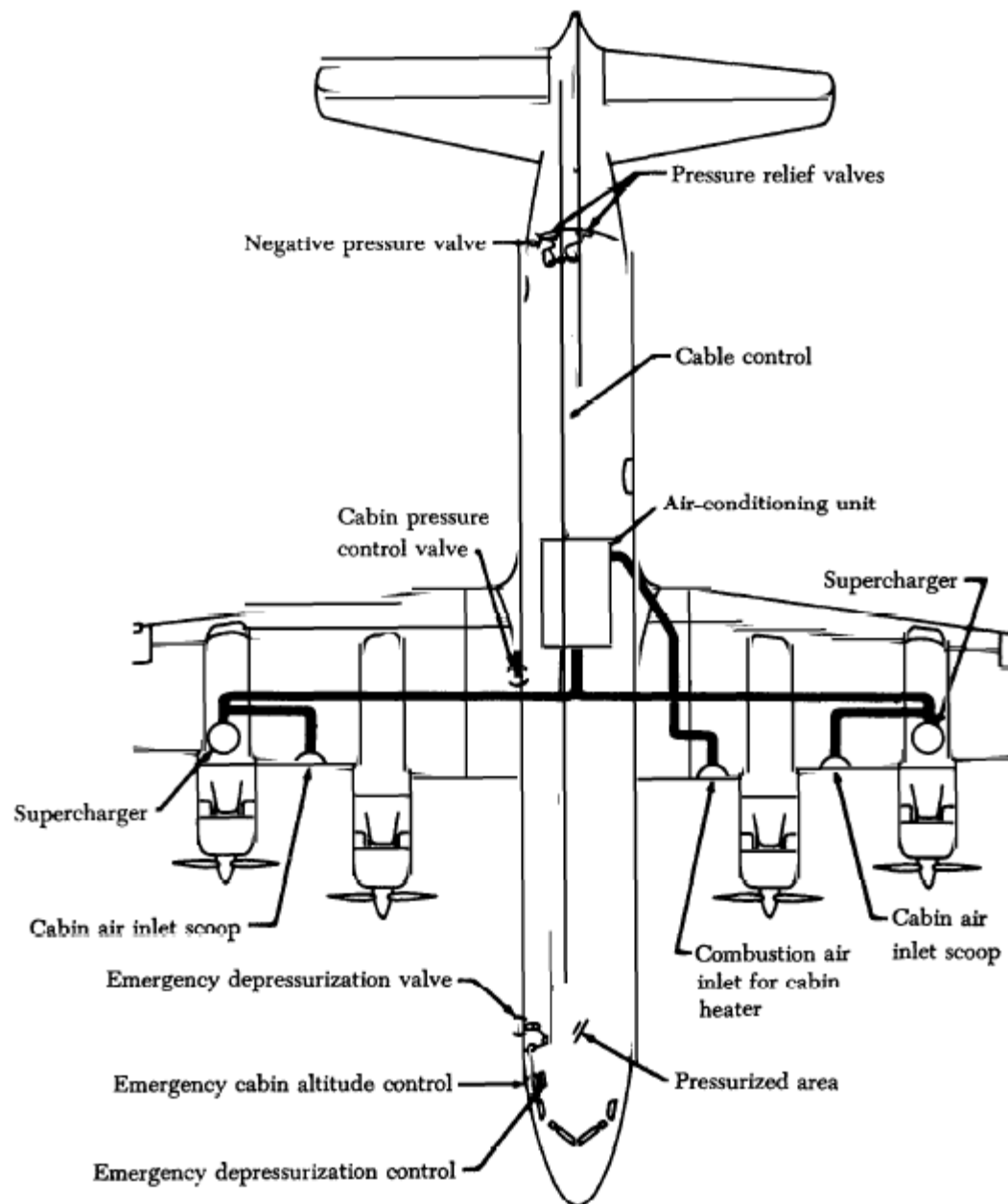
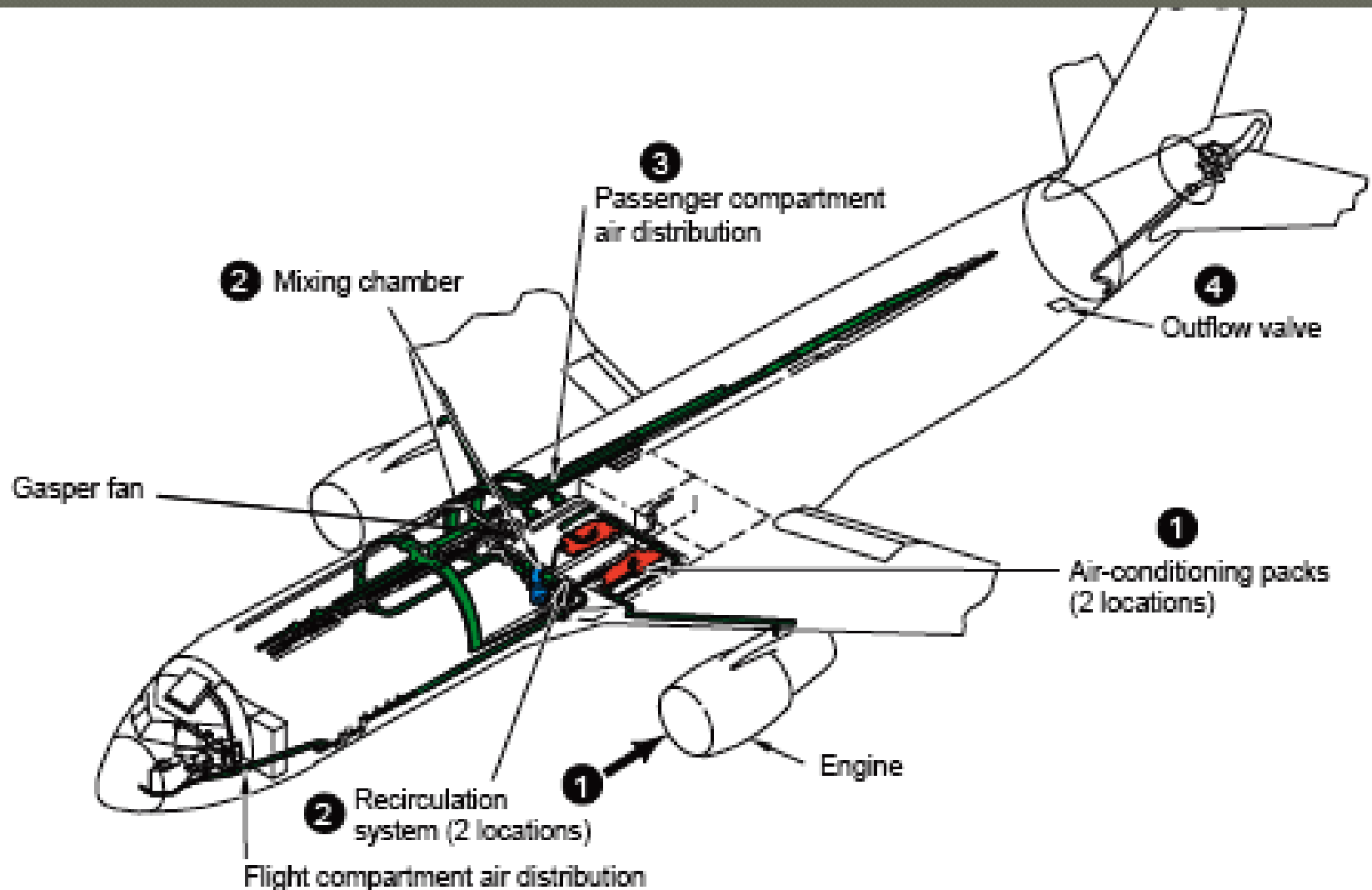


FIGURE 14-3. Basic pressurization system.

How Pressurization Works



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.

How Pressurization Works

- The opening of outflow valve can be controlled by pilot in order to maintain the suitable pressure.

Outflow Valve



What happen to aircraft without Pressurization system?

- 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



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

- 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

Need For Cabin Cooling

- 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

Air Cycle Vs Vapour Cycle

- 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

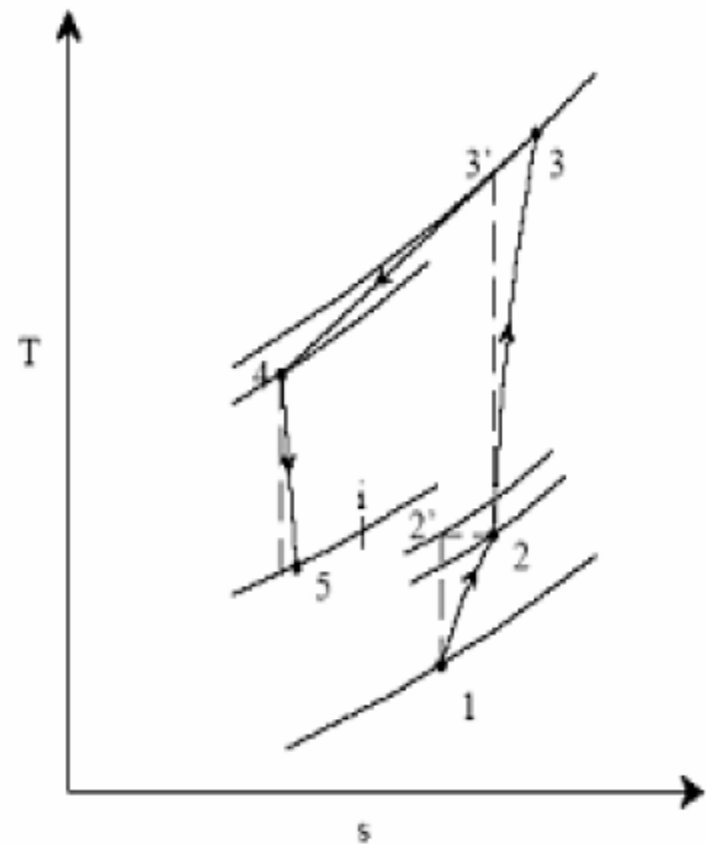
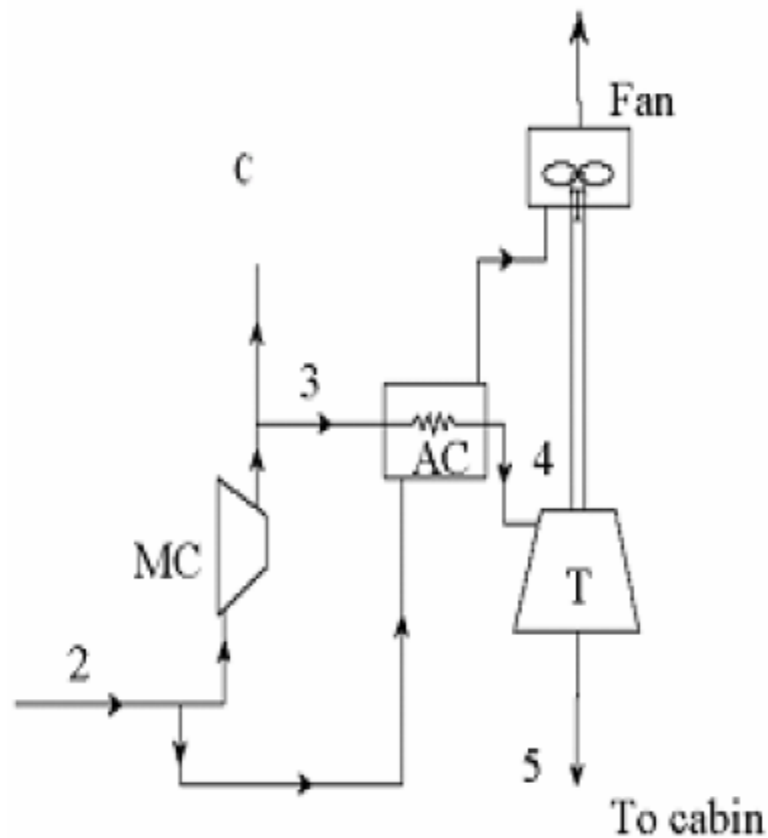
Air Cycle Vs Vapour Cycle

- ◉ **Design** of the complete system is much simpler due to low pressures.
- ◉ **Maintenance** required is also less.

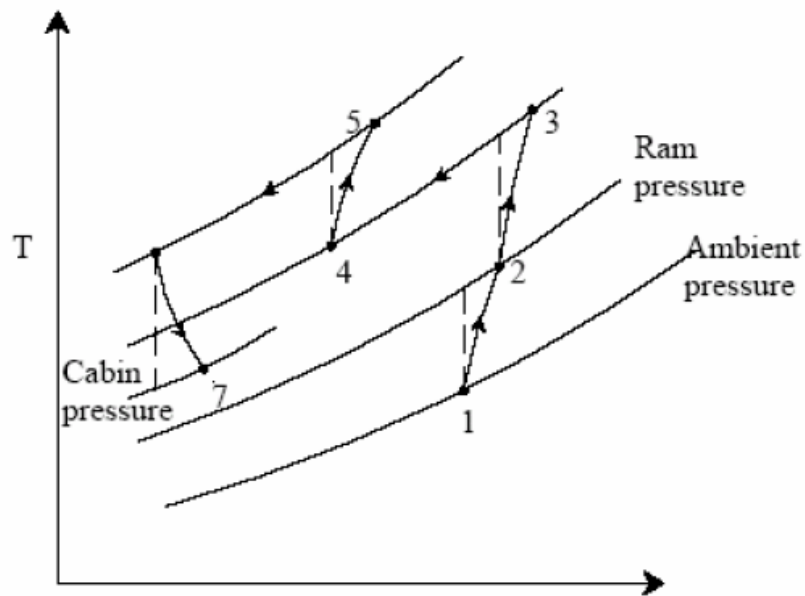
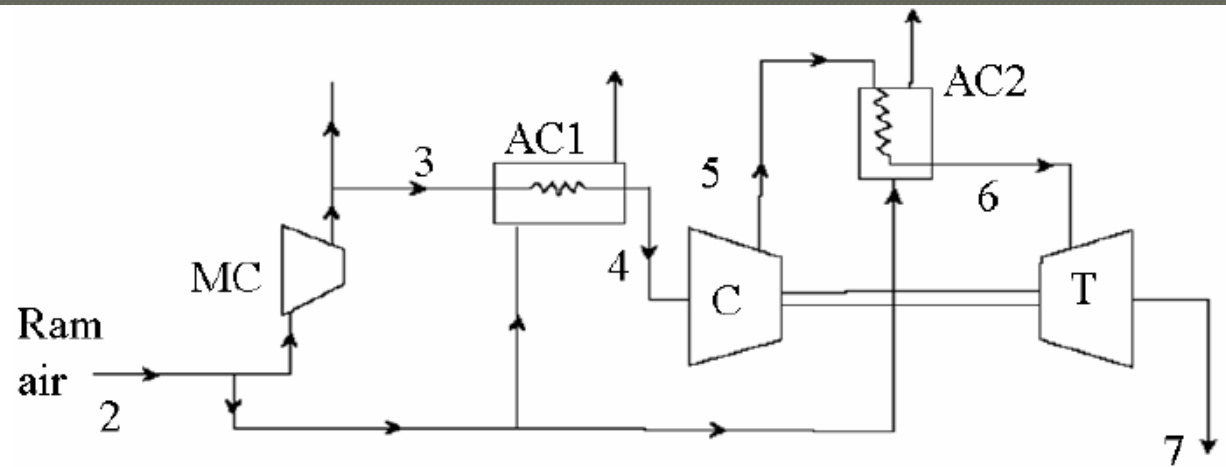
Air-Cycle Cooling System

- 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



Bootstrap System



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)

DART (Contd..)

- 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

DART (Contd..)

- 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

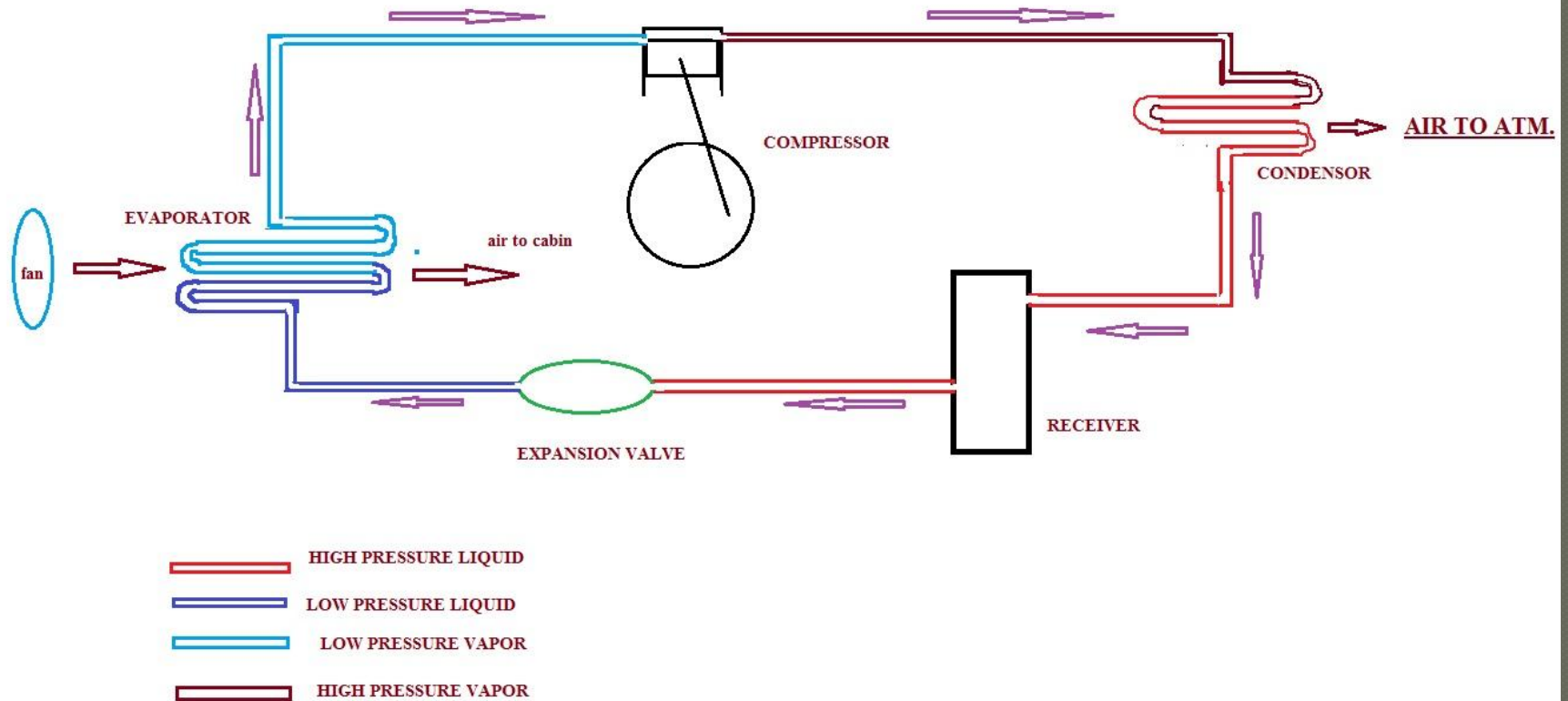
- Vapor-cycle cooling systems are used on **reciprocating-engine aircraft** and in some **small turboprop aircraft**
- This is a **closed system** that uses the **evaporation and condensation of Freon** to **remove heat** from the cabin

Properties of Freon

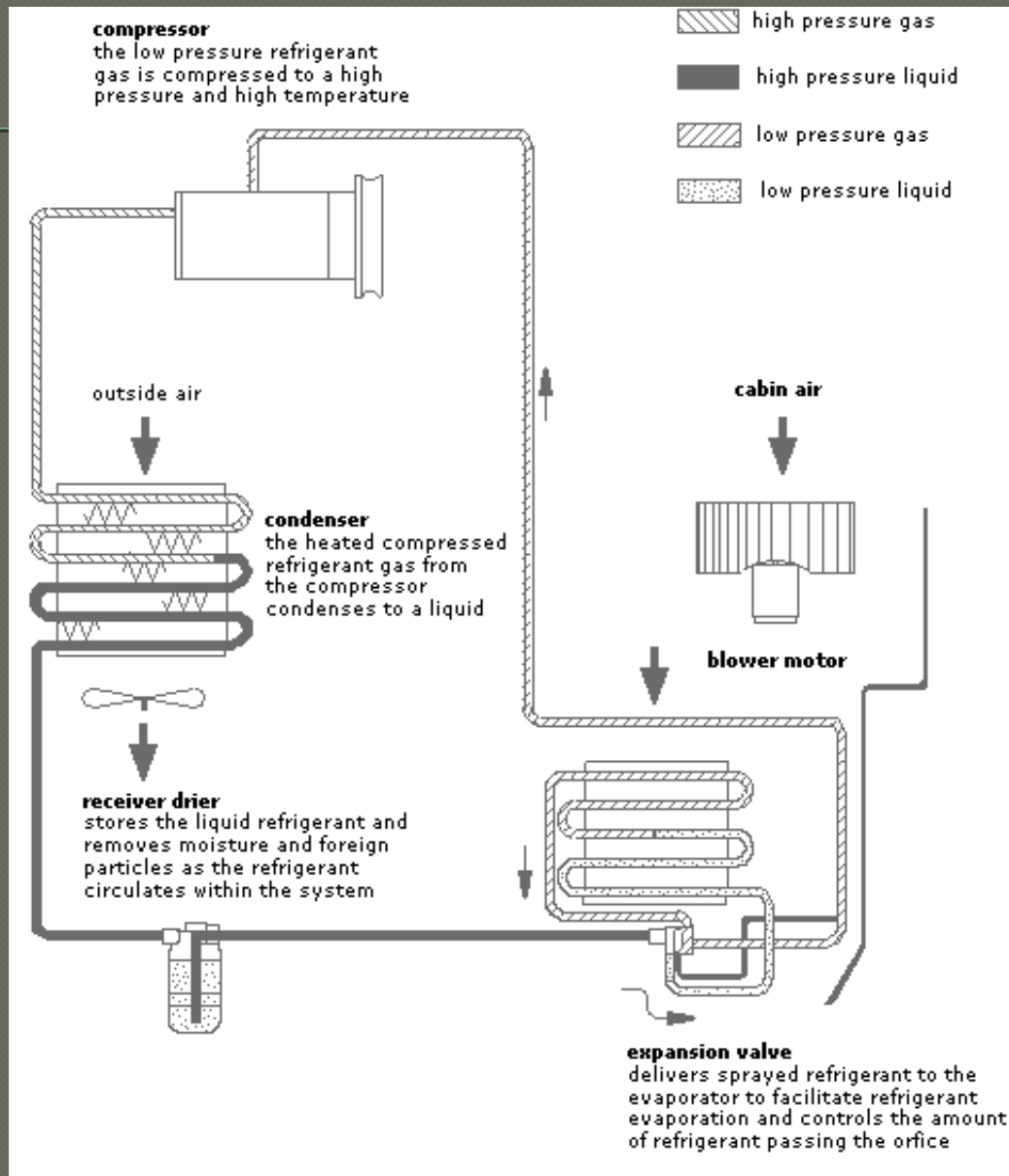
- Freon is colourless, odourless, and non toxic; however, being heavier than air, it will displace oxygen and cause suffocation. When heated over an open flame, it converts to phosgene which is deadly!

Vapour Cycle System

VAPOR CYCLE SYSTEM



Vapour Cycle System



Vapour Cycle Cooling System

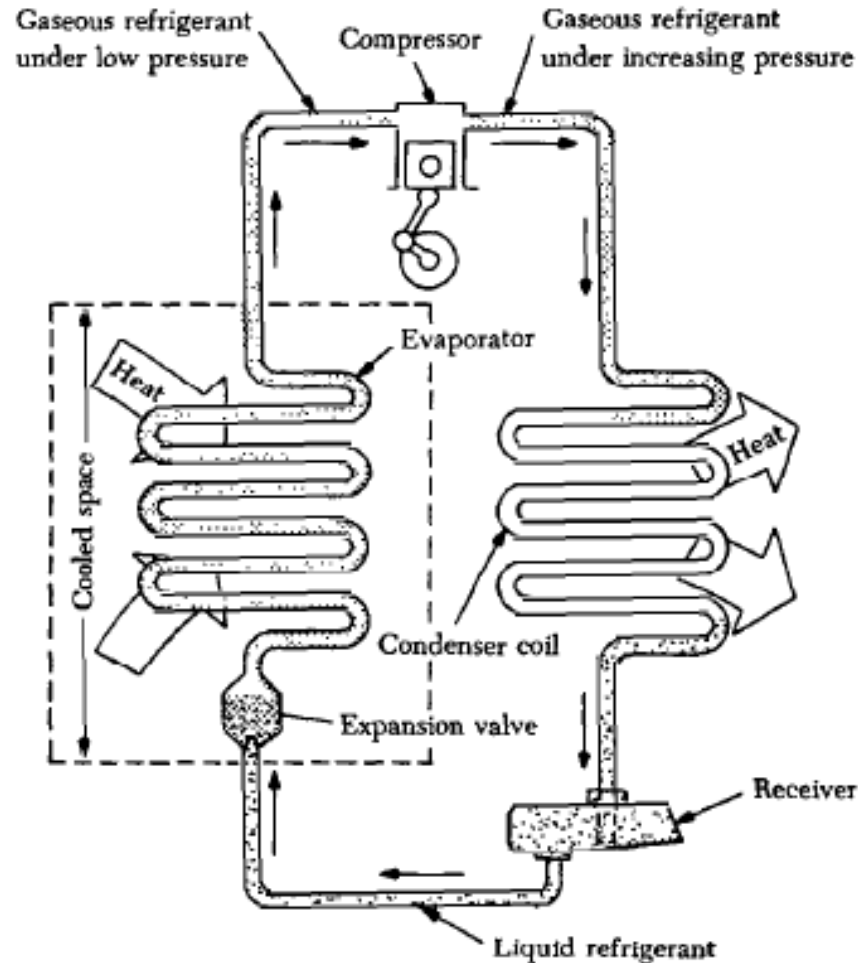


FIGURE 14-37. Refrigeration cycle.

Operation

- 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.

Operation

- 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**.

Operation

- 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 a 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

Need for 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

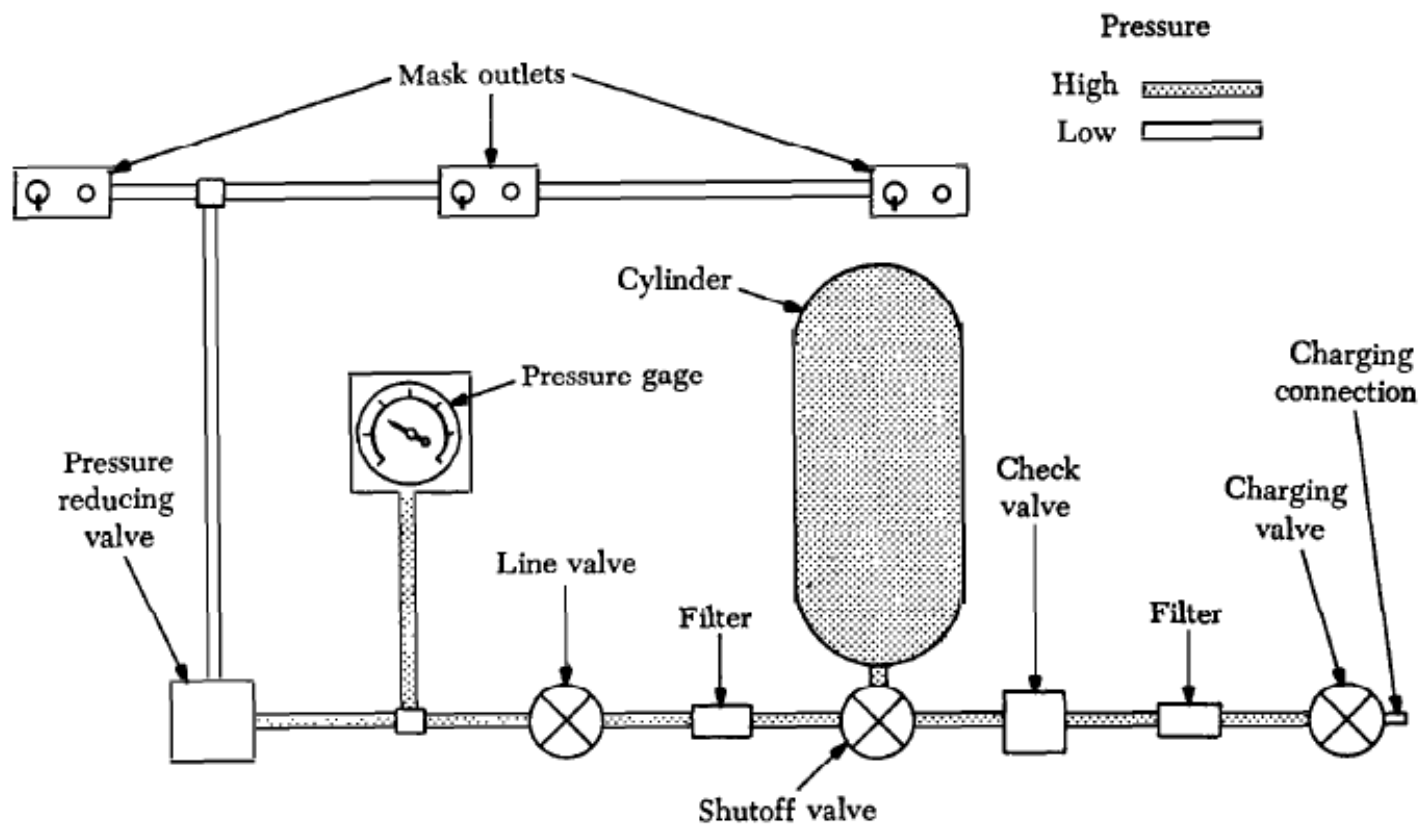
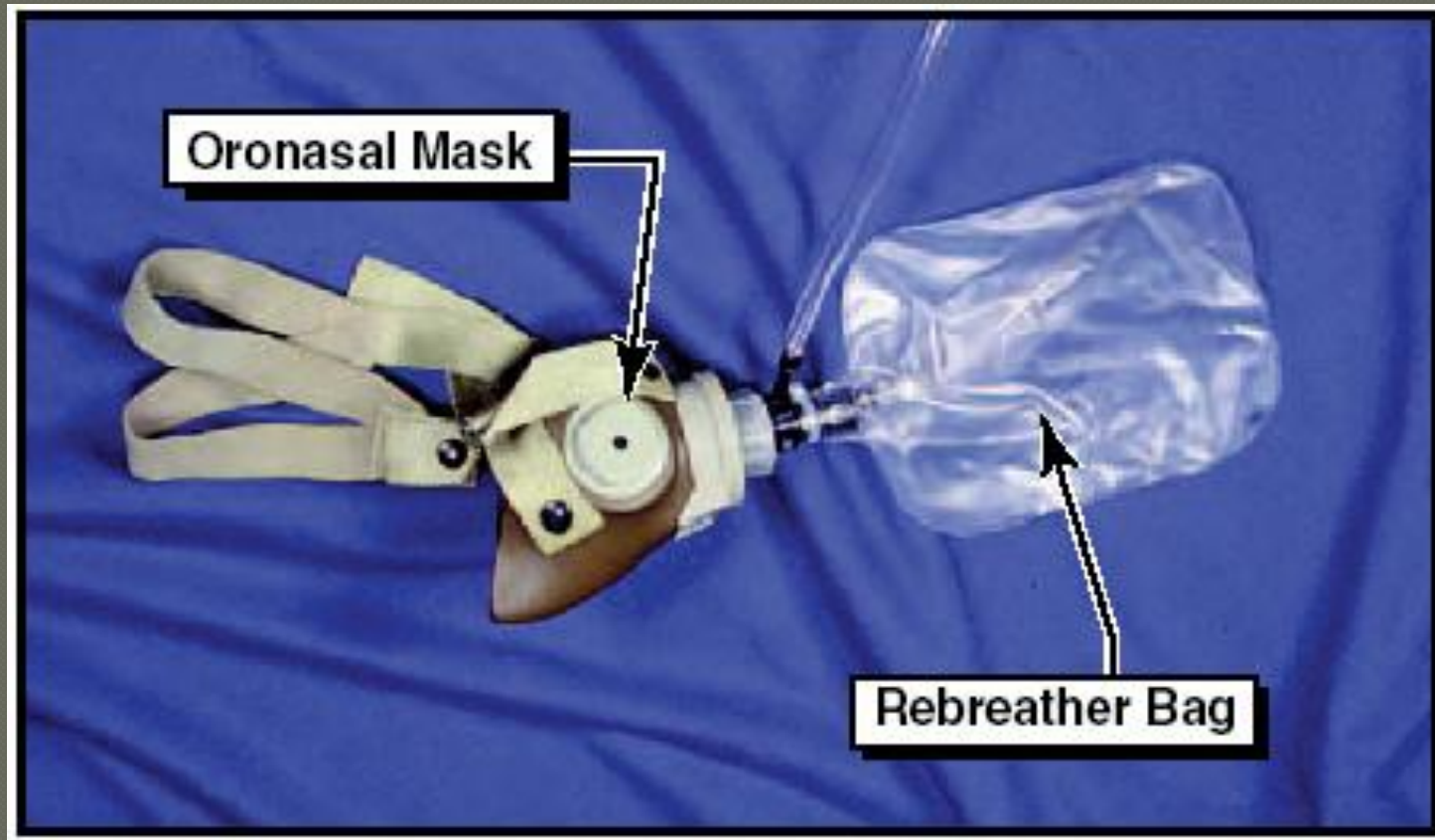


FIGURE 14-45. Continuous-flow oxygen system.

Continuous flow mask and rebreather bag



Pressure Demand System

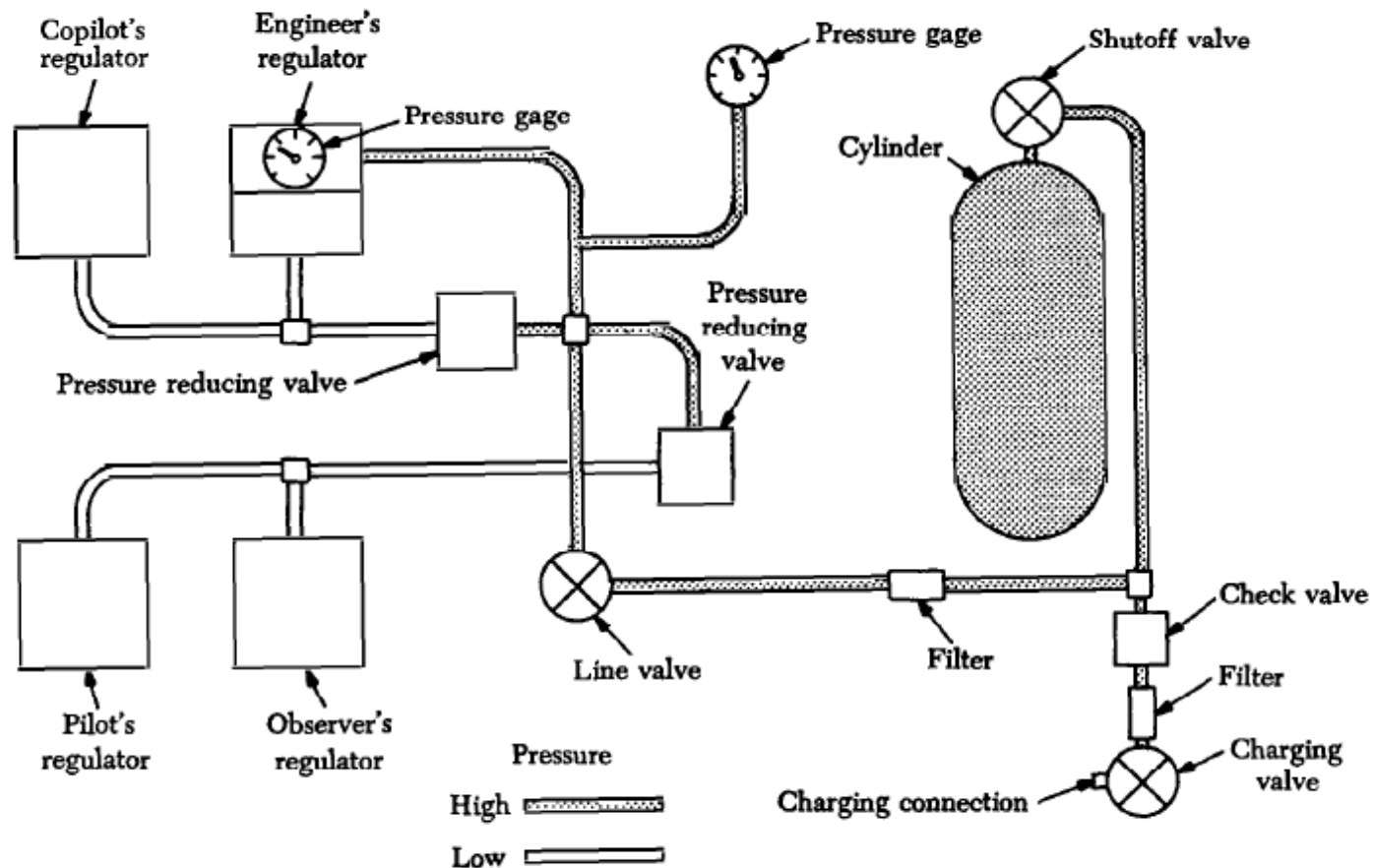


FIGURE 14-46. Typical pressure-demand oxygen system.

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

Portable Oxygen Equipment

- 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.

Solid State Oxygen Systems

- **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.

Solid State Oxygen Systems

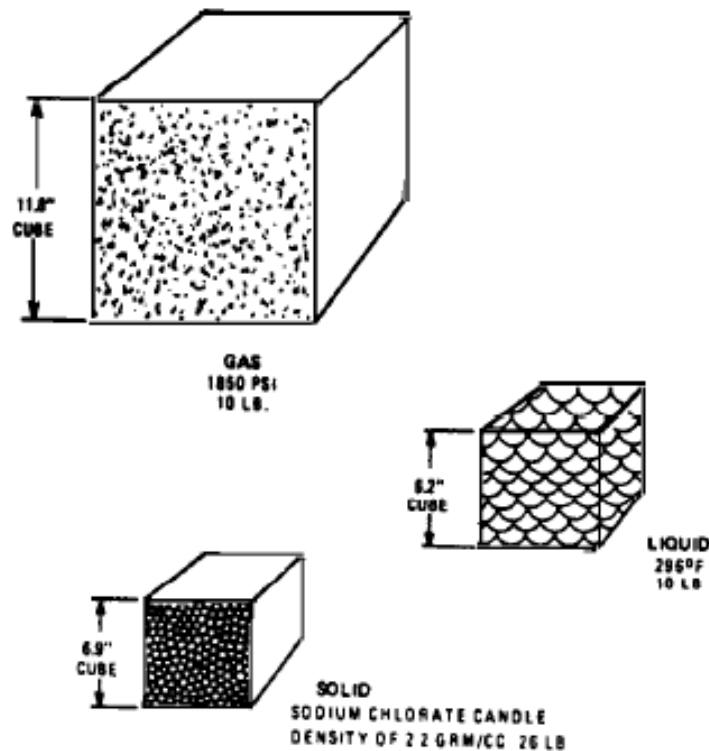


FIGURE 14-47. Volume comparison.

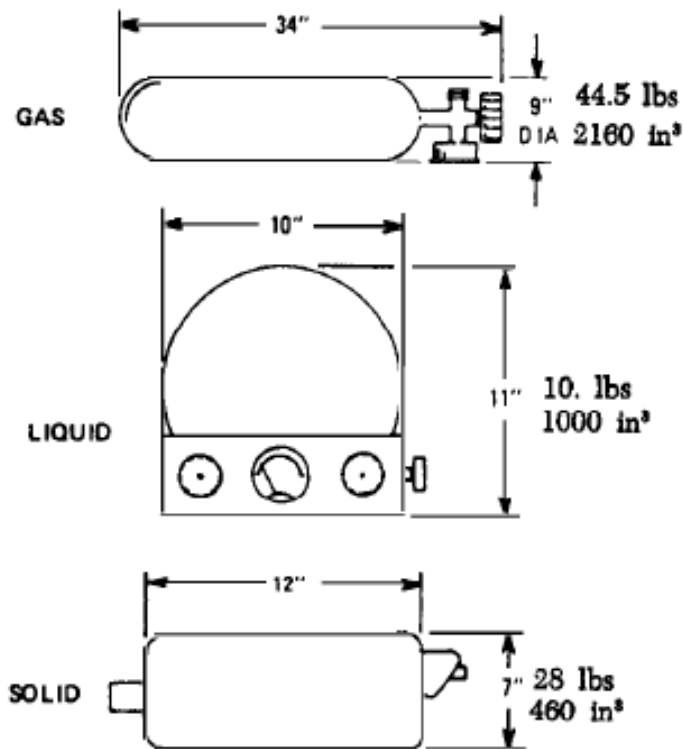


FIGURE 14-48. Weight and volume comparison—gas, liquid and solid oxygen storage.

Solid State Oxygen Systems

- Solid state describes the chemical source, sodium chlorate (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

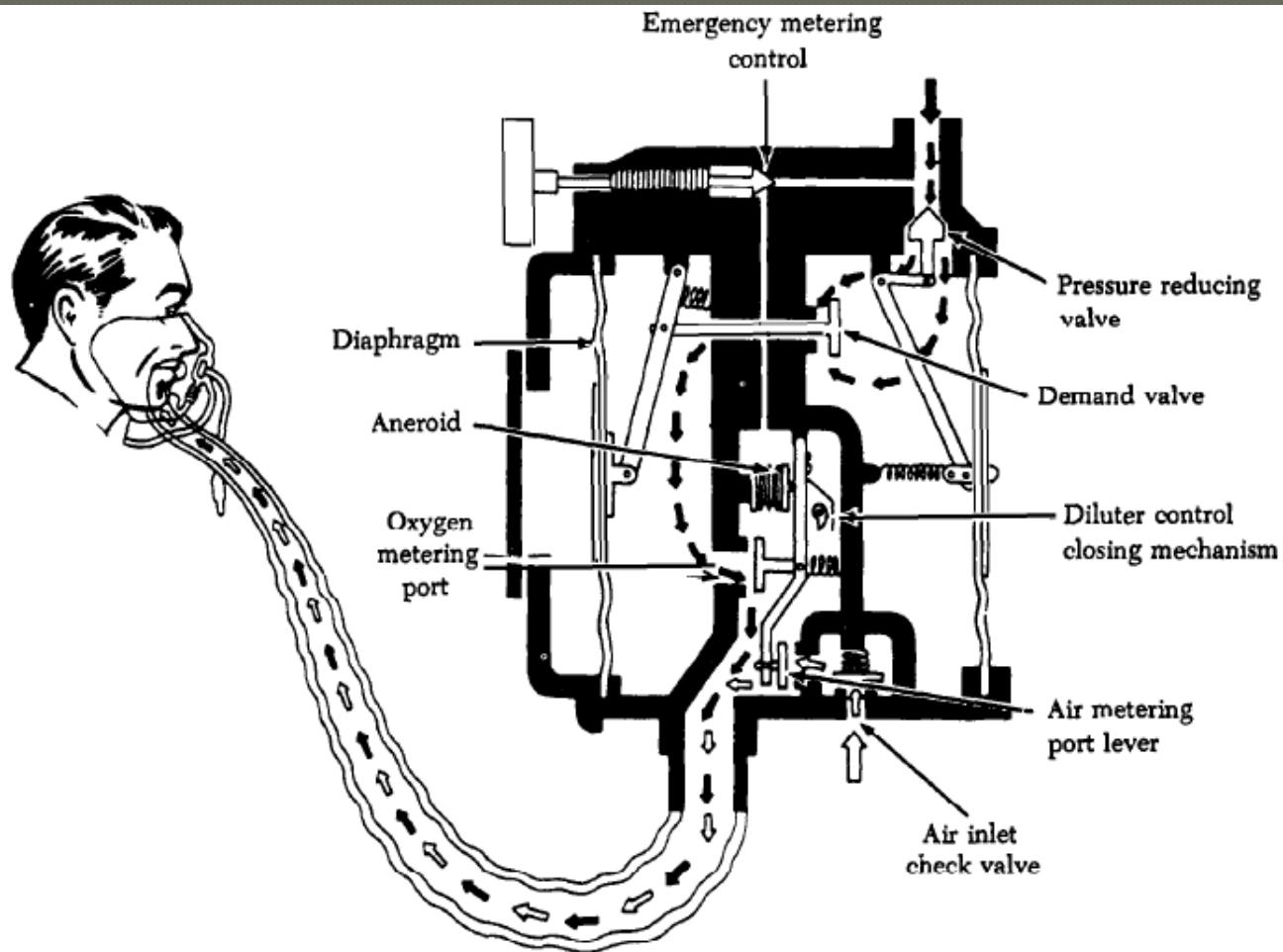


FIGURE 14-53. Schematic of a diluter-demand regulator.

Continuous Flow Regulators

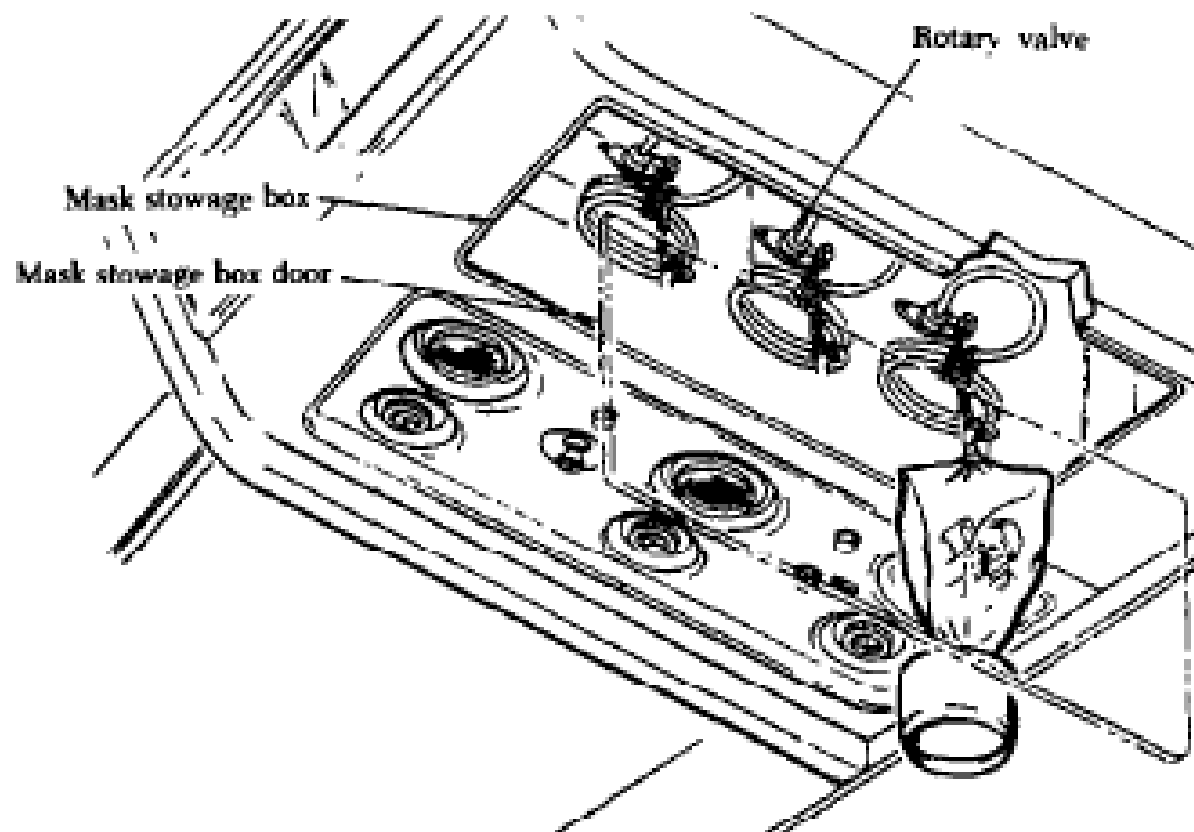


FIGURE 14-58. Typical passenger service unit.

Oxygen Mask

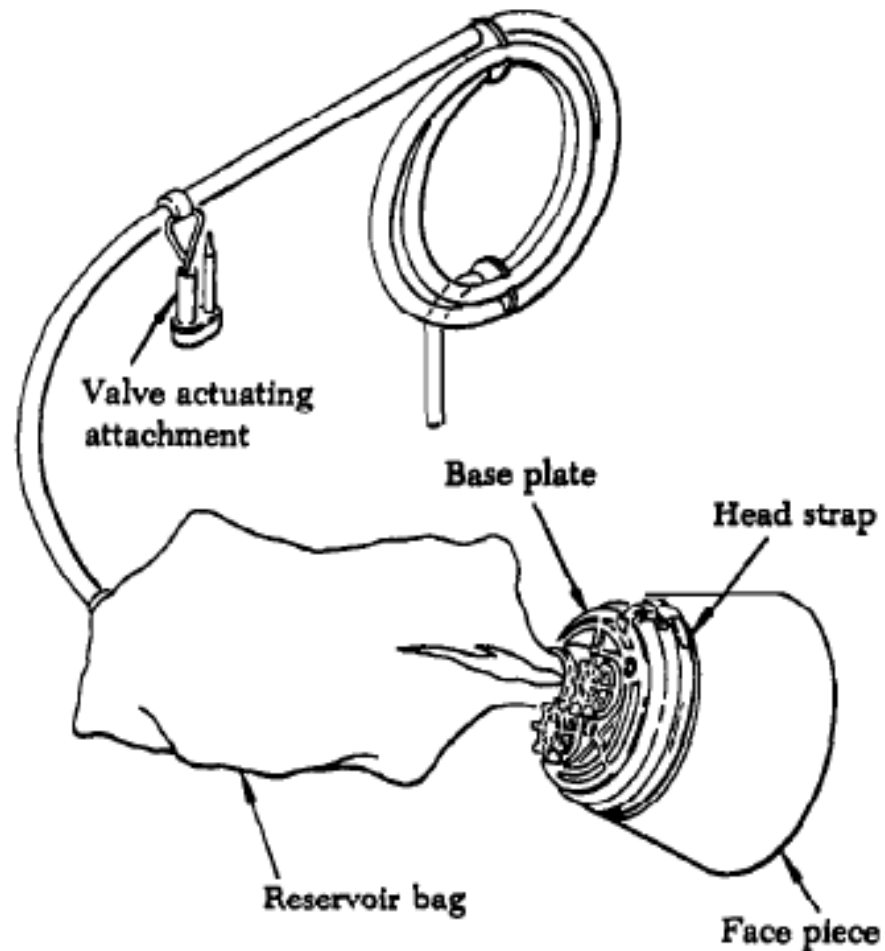


FIGURE 14-61. Passenger oxygen mask.

AIRCRAFT FIRE PROTECTION SYSTEM

Need for Fire Protection System

- ◉ **Fire** is one of the **most dangerous threats** to an aircraft
- ◉ The potential fire zones of modern multi-engine aircraft are protected by a **fixed fire protection system**
- ◉ A '**fire zone**' is an area or region of an aircraft designed by the manufacturer to **require fire detection and or fire extinguishing equipment and a high degree of inherent fire resistance.**

Fire Suppression Systems

Fire suppression system includes

- ① Fire detection system
- ② Smoke detection system
- ③ Fire extinguishing system

Requirements For Fire Protection Systems

- ① Fire warning system must provide an **immediate warning** of fire or overheat by means of a **red light** and an **audible signal** in the flight deck.
- ① The system must **accurately indicate** that a **fire had been extinguished** and **indicate** if the fire re-ignites.

Requirements For Fire Protection Systems

- ① The system must be **durable and resistant to damage** from all the environmental factors that may exist in the location where it is installed.
- ② The system must include an **accurate and effective method for testing** to assure system integrity.
- ③ The system must be **easily inspected, removed and installed**.

Requirements For Fire Protection Systems

- ① The system and components must be designed so the **possibility of false indications is unlikely.**
- ① The system must require a **minimum of electrical power** and must operate from the aircraft electrical system **without inverters** or other special equipment.

Fire Detection Systems

- ◉ It should signal the presence of fire.
- ◉ They are installed in locations where there are greatest possibilities of a fire.
- ◉ The Fire detection systems are:
 - ◉ Thermal Switch
 - ◉ Thermocouple
 - ◉ Continuous loop Systems
 - ◉ Fenwal
 - ◉ Kidde
 - ◉ Systron donner

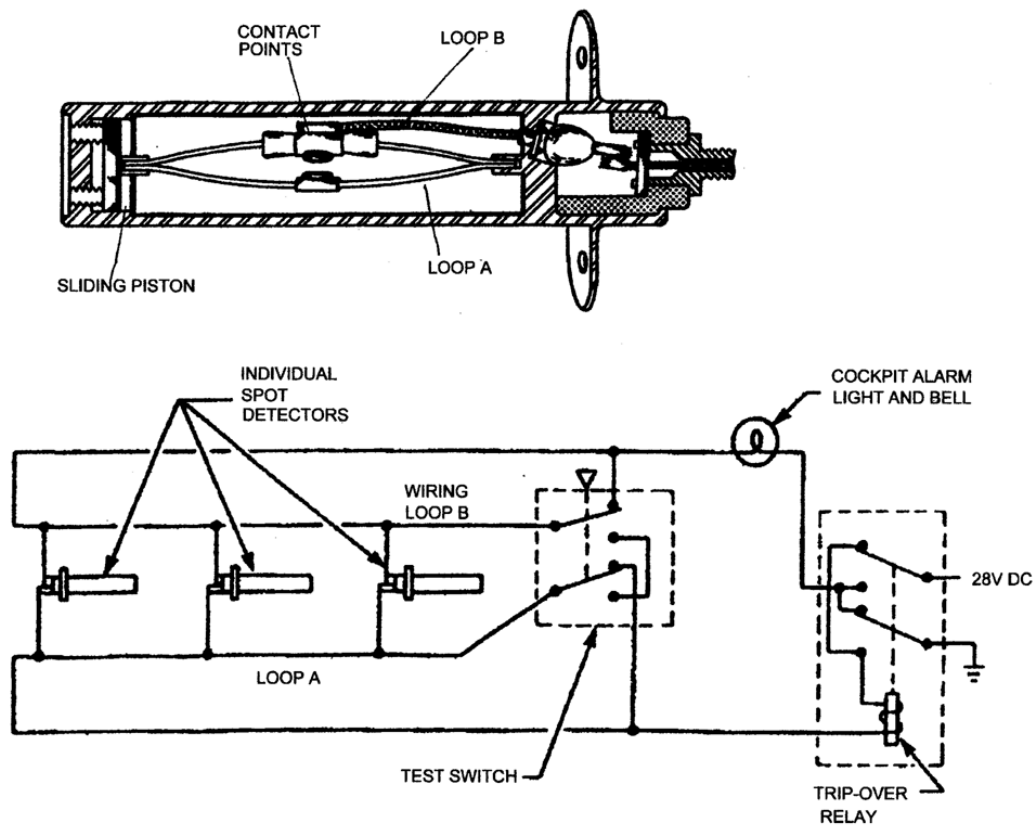
Thermal Switch System

- A circuit in which **one or more thermal switches** are connected in an electrical circuit which also has a **warning light and an aural alarm** to **warn the flight crew** that an over-heat condition is present.
- If **more than one thermal switch** is used they are **connected in parallel**, so closing of any one switch will provide warning.

Thermal Switch System

- ◉ The thermal switch, sometimes called a **spot detector**, works by **expansion of the outer casing** in the unit.
- ◉ When exposed to heat, the casing becomes longer, causing **the two contacts inside to meet**, thus **closing the circuit**.
- ◉ **Closing the circuit** activates the **warning system** on the flight deck.

Fenwal Spot Detector



Thermocouple System

- Also called a “**rate of rise**” detection system.
- A circuit where **one or more thermocouples are connected in series** to activate an alarm when there is **a sufficient temperature increase at the sensor.**
- Thermocouples are made of **two dissimilar metals (chromel and constantan)** which are twisted together inside an open frame.

Thermocouple System

- The frame **allows air to flow** over the wires without exposing the wires to damage.
- The exposed wires make a **hot junction**.
- The **cold junction** is located **under the insulating material** in the sensor unit.

Thermocouple System

- When there is a **difference in temperature** a **current is created**.
 - **About 4 milliamperes**
- The current created **sets off a sensitive relay** activating the alarm.
- If the **temperature rise is slow** so that the cold junction heats up along with the hot junction then the **relay will not be activated**.

Thermocouple System

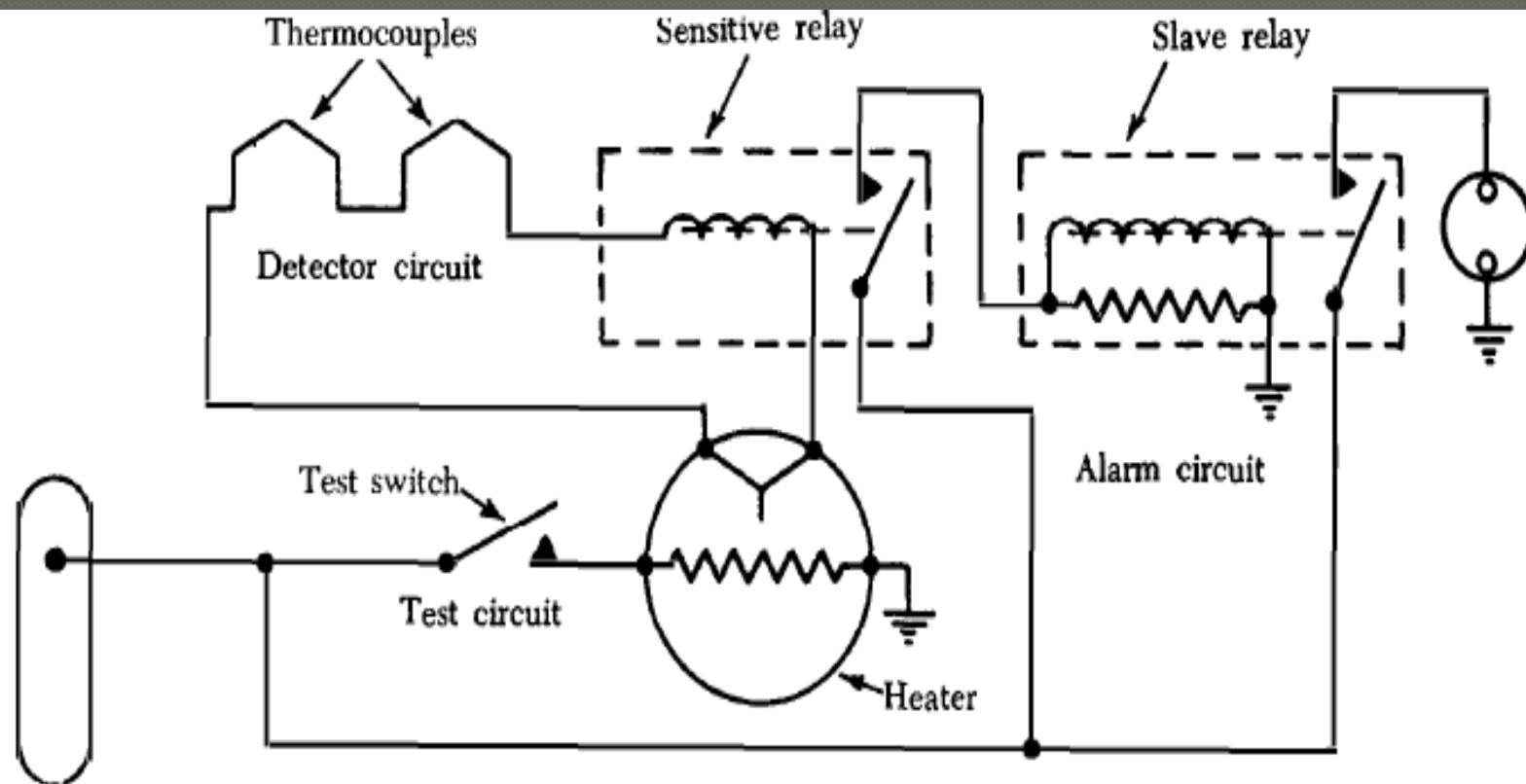


FIGURE 10-4. Thermocouple fire warning circuit.

Continuous Loop Systems – Fenwal System

- Consists of small, lightweight, flexible **Inconel tube** with a **pure nickel conductor** wire-center conductors.
- The space between the nickel conductor and tubing wall is filled with **porous aluminum-oxide, ceramic insulating material**.

Continuous Loop Systems – Fenwal System

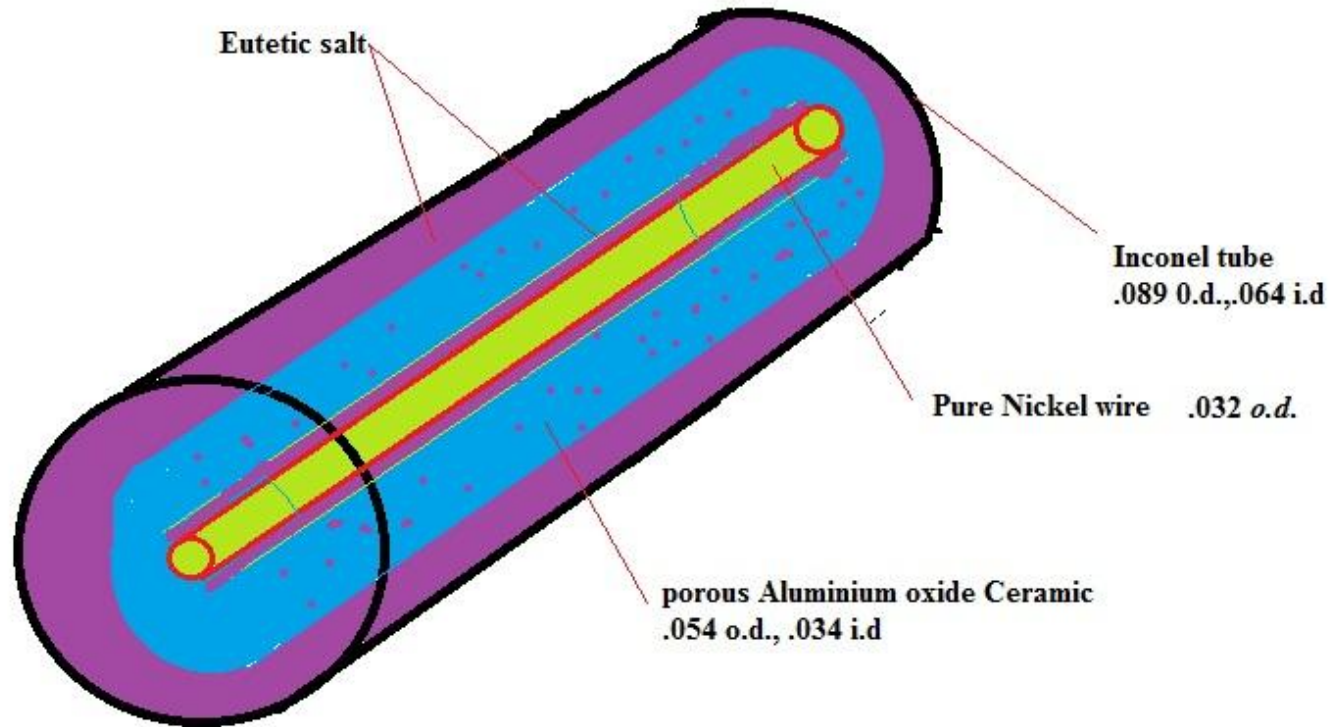
- Any voids or clearances are saturated with a eutectic salt mixture which has a low melting point.
- The tube is hermetically sealed at both ends with insulating material and threading fittings.
- When heated sufficiently, current can flow between the center wire and the tube wall because the eutectic salt melts, and the resistance drops rapidly.

Continuous Loop Systems – Fenwal System

- The **increased current flow** provides a **signal** which is used in the **control unit** to **sound the alarm system**.
- Once the fire is **extinguished** or the over-heat condition is corrected **the eutectic salt increases its resistance** and the system will return to a stand-by mode.

Continuous Loop Systems – Fenwal System

FENWAL FIRE DETECTOR



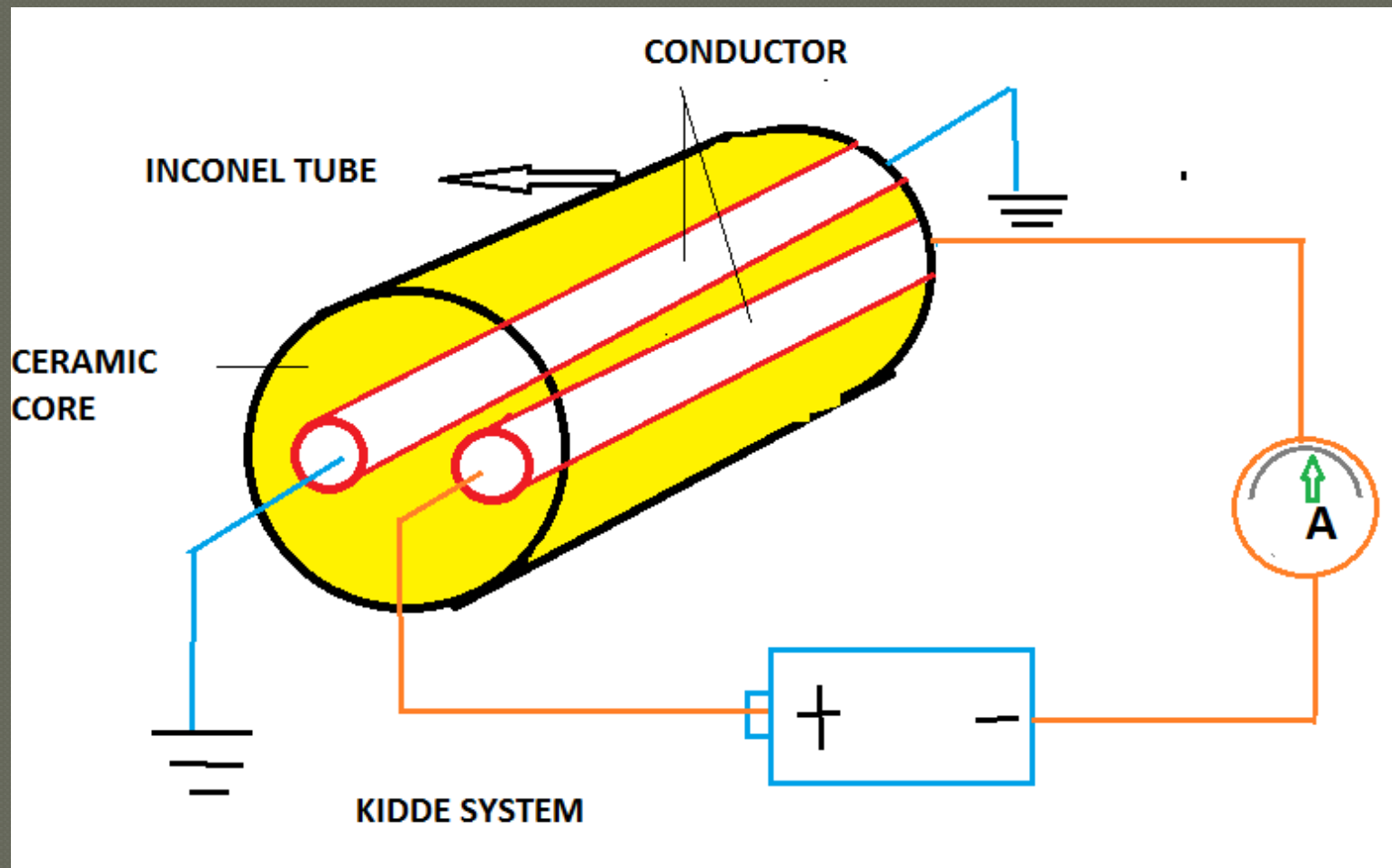
Continuous Loop Systems – Kiddle System

- Utilizes an Inconel tube with ceramic core material embedded with two electrical conductors.
 - One conductor is welded to the case at each end and acts as an internal ground.
 - The second conductor is a hot lead that provides a current signal when ceramic core material changes its resistance with change in temperature.
- When heated the ceramic core material drops in resistance.

Continuous Loop Systems – Kiddle System

- The **change in resistance** is sensed by the electronic control circuit monitoring the system and sends a **warning signal** to illuminate the **fire warning light** and **activate the aural warning device**.
- When the **condition is corrected**, the system returns to **stand-by mode**.

Continuous Loop Systems – Kiddle System



Continuous Length Systems – Pneumatic System (Systron-Donner)

- ◉ Continuous-length system
- ◉ The sensing element consists of a stainless steel tube containing two separate gases plus a gas absorption material in the form of wire inside the tube.
- ◉ Normally the tube is filled with helium gas under pressure.

Continuous Length Systems – Pneumatic System (Systron-Donner)

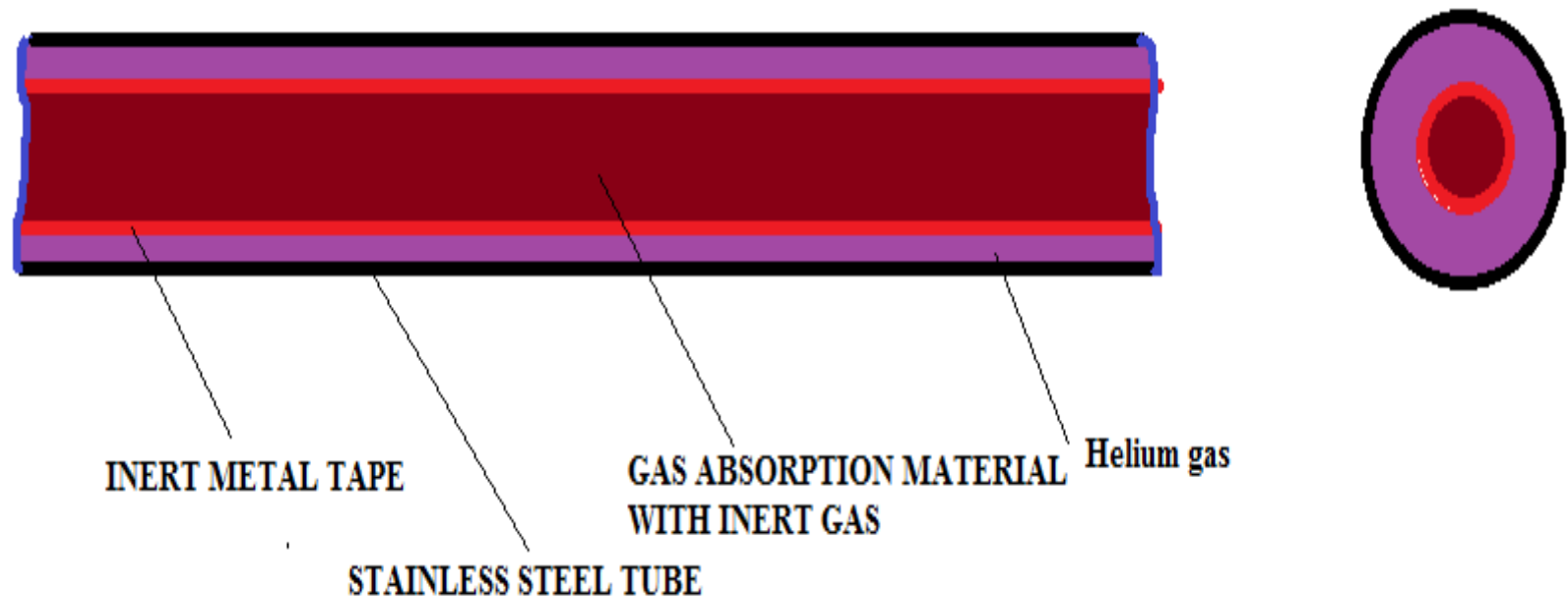
- The **titanium center wire**, which is the **gas absorption material**, contains **hydrogen gas**.
- The wire is wrapped in a helical fashion with an **inert metal tape** for stabilization and protection.
- Gaps between the turns of tape allow for **rapid release of the hydrogen gas** from the wire when the temperature reaches the required level.

Continuous Length Systems – Pneumatic System (Systron-Donner)

- The sensor acts in accordance with the law of gases
 - If the **volume is held constant**, its **pressure will increase as temperature increases**.
 - The **helium gas** in the **tube exerts a pressure** which closes the **pneumatic switch** and operates the warning system.
- After the situation is corrected the **titanium reabsorbs the hydrogen** and the system returns to a stand-by mode.

Continuous Length Systems – Pneumatic System (Systron-Donner)

Systron Donner



AIRCRAFT ANTI-ICING AND DE-ICING SYSTEM

Negative Effects of Ice Buildup

- Destroys smooth flow of air over wing, leading to severe decrease in lift and increase in drag forces
- Can change pitching moment
- As angle of attack is increased to compensate for decreased lift, more accumulation can occur on lower wing surface
- Causes damage to external equipment such as antennae and can clog inlets, and cause impact damage to fuselage and engines
- Considered a cumulative hazard because as ice builds up on the wing, it increasingly changes the flight characteristics



Effects of Icing

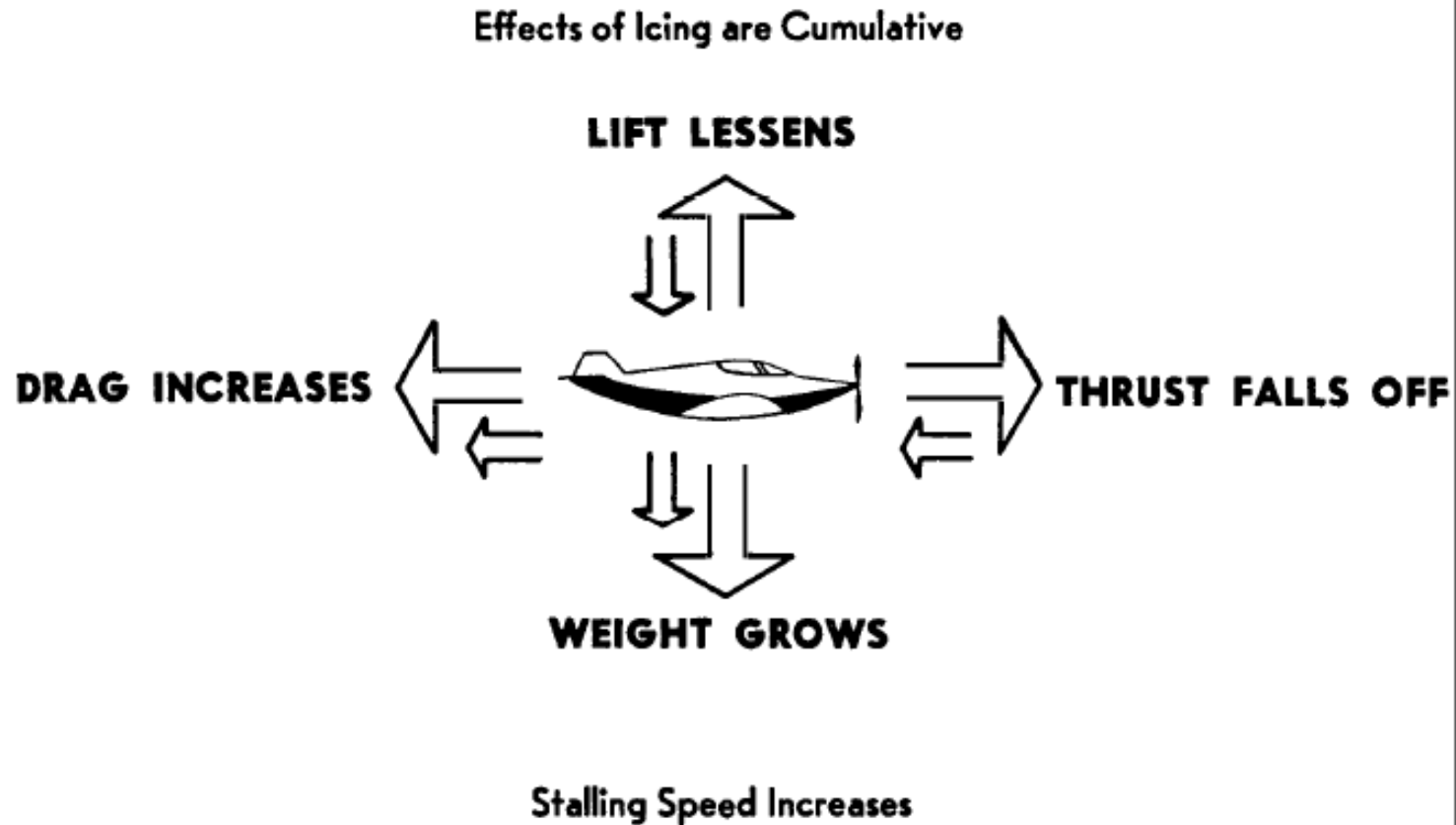
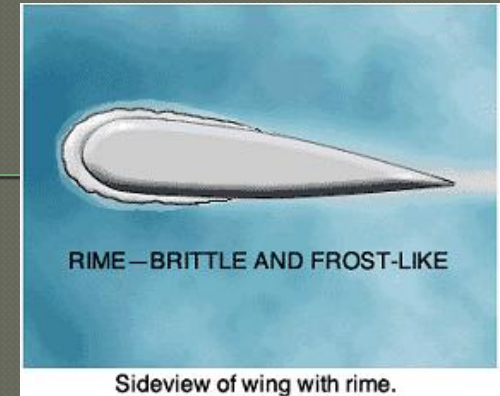


FIGURE 7-1. Effects of structural icing.

Types of Ice

- **Rime:** Has a **rough** milky white appearance and generally follows the surface closely
- **Clear/Glaze:** Clear and smooth but usually contain some air pockets that result in a lumpy translucent appearance, denser, harder and more **difficult to break than rime ice**
- **Mixed**



Ice Prevention

● Methods:

- Heating surfaces **using hot air**
- Heating by **electrical elements**
- Breaking up ice formations, usually by **inflatable boots**
- **Alcohol spray.**

Methods of Ice Control

<i>Location of Ice</i>	<i>Method of Control</i>
1. Leading edge of the wing	Pneumatic, Thermal
2. Leading edges of vertical and horizontal stabilizers	Pneumatic, Thermal
3. Windshields, windows, and radomes	Electrical, Alcohol
4. Heater and Engine air inlets	Electrical
5. Stall warning transmitters	Electrical
6. Pitot tubes	Electrical
7. Flight controls	Pneumatic, Thermal
8. Propeller blade leading edges	Electrical, Alcohol
9. Carburetors	Thermal, Alcohol
10. Lavatory drains	Electrical

Types of Ice Removal

◉ Anti-Icing

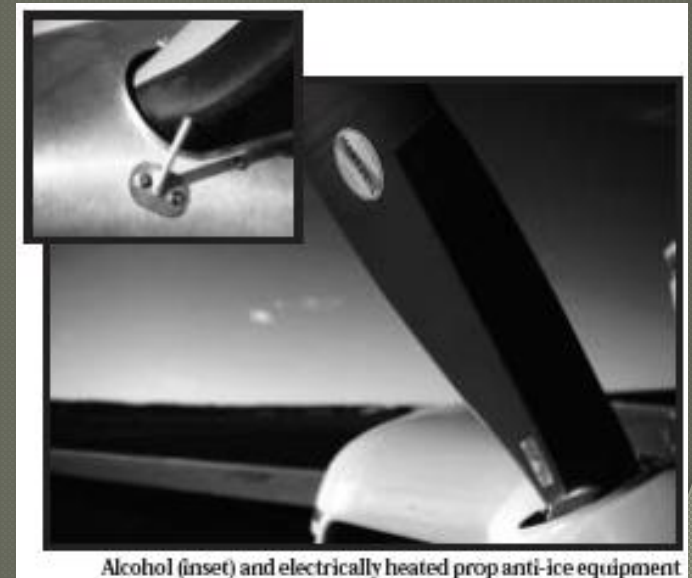
- Preemptive, turned on before the flight enters icing conditions
- Includes: thermal heat, prop heat, pitot heat, fuel vent heat, windshield heat, and fluid surface de-icers

◉ De-Icing

- Reactive, used after there has been significant ice build up
- Includes surface de-ice equipment such as boots, weeping wing systems, and heated wings

Propeller Anti-Icers

- Ice usually appears on propeller before it forms on the wing
- Can be treated with chemicals from slinger rings on the prop hub
- Graphite electric resistance heaters on leading edges of blades can also be used



Alcohol (inset) and electrically heated prop anti-ice equipment

Windshield Anti-Icers

Usually uses resistance heat to clear windshield or chemical sprays while on the ground



- Liquids used include: ethylene glycol, propylene glycol, Grade B Isopropyl alcohol, urea, sodium acetate, potassium acetate, sodium formate, and chloride salts
- Chemicals are often **bad for the environment**

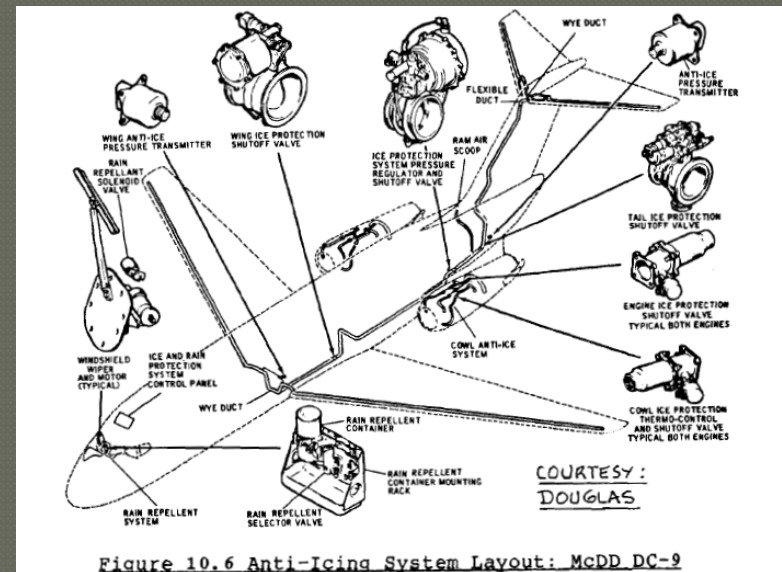
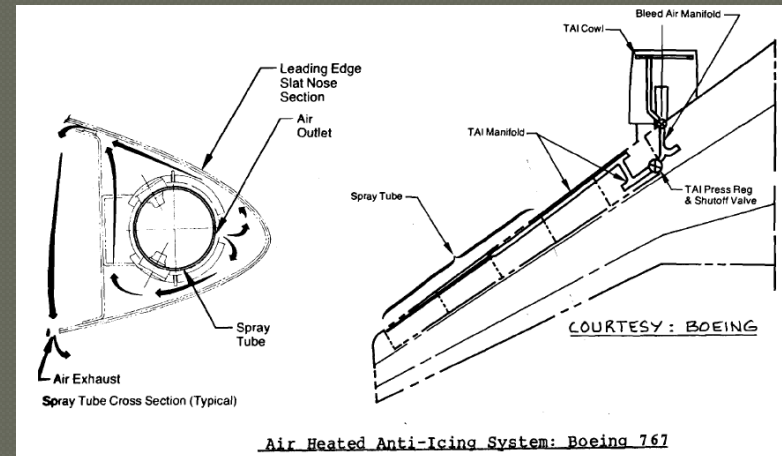
Thermal Heat

● Air Heated

- Bleed air from engine heats inlet cowls to keep ice from forming
- Bleed air can be ducted to wings to heat wing surface as well
- Ice can also build up within engine, so shutoff valves need to be incorporated in design
- Usually used to protect leading edge slat, and engine inlet cowls

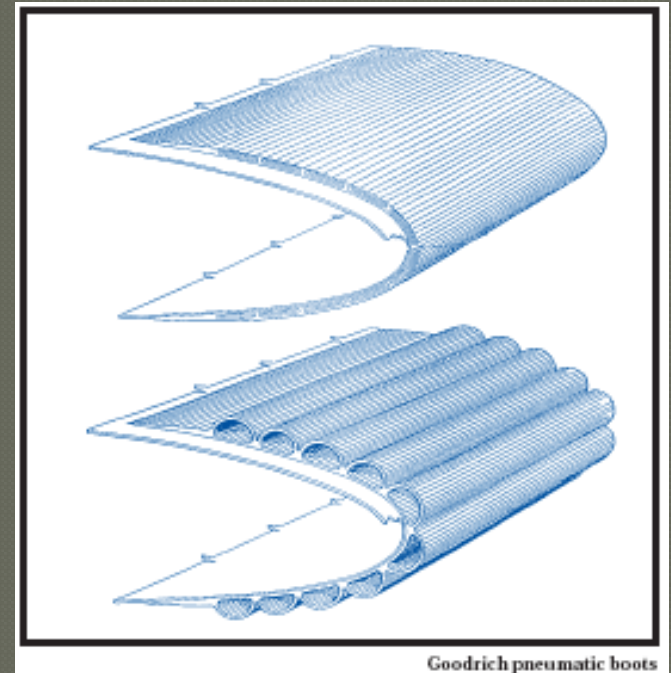
● Resistance heater

- Used to prevent ice from forming on pitot tubes, stall vanes, temperature probes, and drain masts



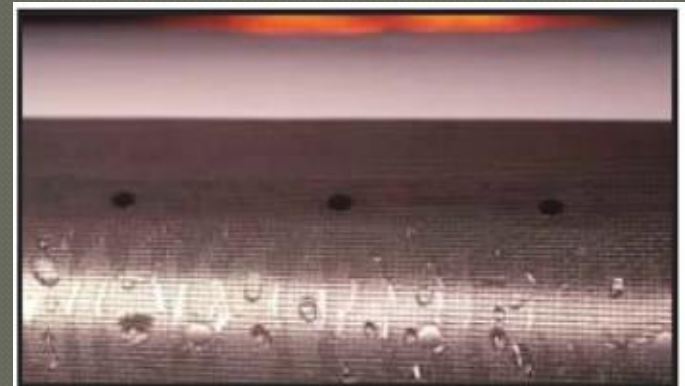
Boots

- Inflatable rubber strips that run along the leading edge of wing and tail surfaces
- When inflated, they expand knocking ice off of wing surface
- After ice has been removed, suction is applied to boots, returning them to the original shape for normal flight
- Usually used on smaller planes



Weeping Wing

- Fluid is pumped through mesh screen on leading edge of wing and tail
- Chemical is distributed over wing surface, melting ice
- Can also be used on propeller blades and windshields



TKS patented alcohol deicer system



Typical Anti-Icing

● C-130:

- Engine bleed air used for anti-icing wing and empennage leading edges, radome, and engine inlet air ducts.
- Electrical heat provides anti-icing for propellers, windshield, and pitot tubes.

● 777:

- Engine bleed air used to heat engine cowl inlets. If leak is detected in Anti-Ice duct, affected engine Anti-Ice valves close.
- Wing Anti-Ice System provides bleed air to three leading edge slats on each wing. Wing Anti-Ice is only available in flight.