PART 1 : SECTION 6

CHAPTER 5

CABIN PRESSURIZATION AND TEMPERATURE CONTROL SYSTEMS

Introduction

1. The information in this chapter refers only to gas-turbine aircraft.

2. Cabin pressurization entails the sealing of the cabin, the supply of air to it from an external source, and subsequent control of the cabin pressure produced. Air conditioning of pressurized cabins entails the purification, circulation, and humidification of the cabin air, and control of its temperature by heating or refrigeration.

Physiological Aspects

3. The reduction of pressure which occurs with increased altitude in unpressurized aircraft has a marked and adverse effect on the mental and physical well-being of the crew and is dealt with in Volume 2, Part 1. These adverse effects can be obviated by maintaining the cabin pressure at a comfortable level.

Selection of Cabin Pressure

4. Selection of the cabin pressure to be adopted for a particular aircraft is influenced by several considerations (see para. 5). The three standard degrees of pressurization are :—

(*a*) Maintaining ground-level pressure within the cabin up to the aircraft's operational ceiling. The differential pressure (*i.e.* the difference between the local atmospheric pressure and that maintained within the cabin) at 50,000 feet would be 13 lb./sq. in.

(*b*) Maintaining a cabin pressure equivalent to an altitude of 8,000 feet (with oxygen carried for emergency use) when flying between that height and the operational ceiling. The differential pressure at 50,000 feet would be $9\frac{1}{4}$ lb./sq. in.

(*c*) Maintaining a cabin pressure equivalent to an altitude of 25,000 feet when flying between that height and the operational ceiling. Oxygen would be required by the crew. The differential pressure at 50,000 feet would be $3\frac{3}{4}$ lb./sq. in.

5. The considerations influencing selection of the degree of cabin pressure to be used are :—

(*a*) *Decompression.* The possibility of a sudden cabin pressure failure (*e.g.* through enemy action) and its subsequent effects.

(*b*) *Pressure Available.* At operational height the limited output of certain pressurizing equipment will be the factor governing the pressure available.

(*c*) *Weight of the Pressurizing Equipment.* The weight of pressurizing equipment will vary according to the differential pressure required and the size of the cabin to be pressurized.

(*d*) *Height at which Pressurizing Starts.* If pressurizing starts at ground level, cabin overheating may occur if provision is not made for cooling the air supply. It is usual to delay pressurizing until a height is reached where overheating is unlikely to occur.

(*e*) *Crew Comfort and Efficiency.* This is, perhaps, the overriding factor in deciding the degree of pressurization to be adopted. Certain structural and mechanical problems connected with large differential pressures have still to be overcome.

British Military Aircraft

6. On British military aircraft with pressure cabins, the practice is to confine the cabin differential pressure to the minimum necessary to maintain the vital fighting efficiency of the crews, and one which will not result in disastrous decompression effects should the cabin be holed. With this low differential pressure the use of oxygen is essential. On large bomber aircraft a higher differential pressure is available for use during flight outside combat areas, thus permitting some economy in the use of the oxygen supply carried in the aircraft.

Structural Reinforcement

7. Cabin reinforcement is necessary when differential pressures above 4 lb./sq. in. are used. In addition, windows, hoods, and other transparent panels have to be thicker, and hence heavier, to resist the internal pressure and prevent their distortion. Clearance holes in these panels, with rubber bushes for the attachment bolts, help in preventing damage caused by the expansion which accompanies temperature increases, and structural vibration and flexing in flight.

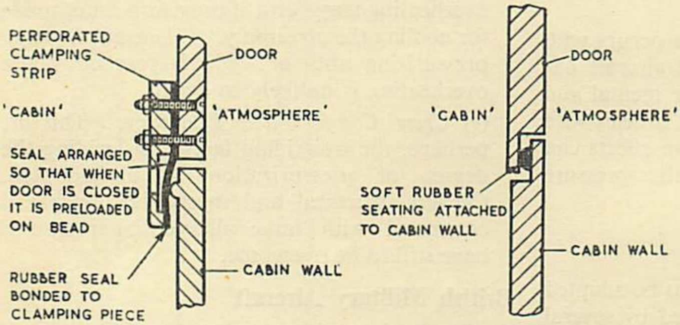
Sealing Problems

8. Ideally a pressurized cabin should be airtight. In practice, leaks are kept to a minimum. For example, a perfect seal around a control rod passing through a bulkhead could only be achieved if accompanied by considerable friction at the gland, and this resistance to the movement of flying controls would be unacceptable. Hence the main effort is centred on the reduction of leaks from static components, such as the cabin structure and electrical plugs and sockets, so that the total leakage does not exceed a reasonable value. The use of remote electrical control on some aircraft services reduces leakage rates.

9. Sealing must be effective under all conditions, including the structural flexing that occurs during flight, and the expansion and contraction caused by temperature variation.

10. **Inward-Opening Doors.** Reduction of air leakage around inward-opening doors (Fig. 1) presents little difficulty, because the differential pressure tends to hold doors of this type against their seals.

11. **Sliding Hoods and Outward-Opening Doors.** The sealing medium normally used is an inflatable rubber tube mounted on the component (Fig. 2). This type of seal requires a pressure greater than the cabin pressure to provide inflation, and this may be obtained either by using air from the aircraft pneumatic system or from the engine compressor. The seal must be deflated before the hood or door is opened or closed. This is accomplished either by a manually-operated cock in the cabin, or by a hood-locking lever which ensures that the seal is inflated when the hood is fully closed, and deflated when the hood-locking lever is moved from the locked position.



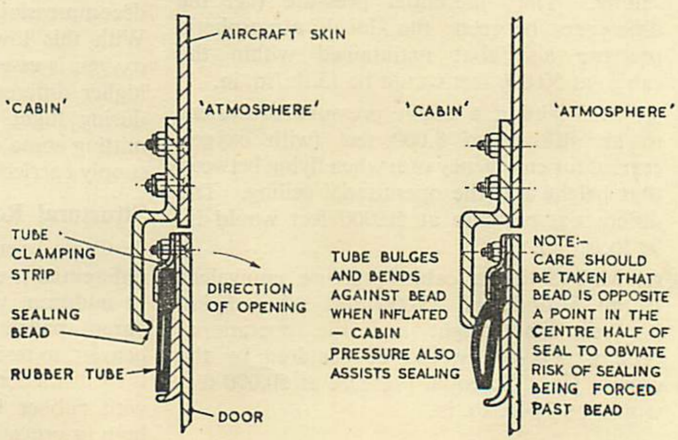
SEALING OF INWARDS OPENING DOOR — 1

SEALING OF INWARDS OPENING DOOR — 2

Fig. 1.

Methods of Sealing

Inwards-Opening Door.



(a) TUBE DEFLATED

(b) TUBE INFLATED

Fig. 2.

Method of Sealing

Outwards-Opening Door.

12. **Aircraft Controls.** Control tubes or cables passing out of the cabin must be adequately sealed against leakage, whilst allowing movement and self-alignment with a minimum of friction. One such device (Fig. 3) consists of rubber bellows which move with the control. The method of permitting the control rods or cables to slide through some form of gland is frequently used, and some typical examples are shown. All are fundamentally similar and rely on grease in conjunction with packing-rings to provide the airtight joint. Such glands must be kept well greased to ensure a good seal and to eliminate friction. Improved sealing of control rods is possible if the movement through the bulkhead is rotary rather than linear.

13. **Instruments.** Instruments which use atmospheric pressure as a datum, *e.g.* altimeters, rate of climb and descent indicators, airspeed indicators, and instruments which are connected pneumatically to points outside the pressure cabin, must have sealed instrument cases vented to a point of static *atmospheric* pressure. This prevents errors which would arise from the use of higher pressure in the cabin. Similarly, Bourdon type pressure-recording instruments must be vented to the outside atmosphere.

Pressurizing—Air Supply and Control

14. **Air Supply.** The air for pressurizing the cabin is normally supplied from the engine compressor casing through a flow valve, which automatically ensures that a constant quantity of air is delivered to the cabin, irrespective of the pressure variation at the entry to the valve.

15. **Pressurizing Control.** The pilot has a control for stopping the supply of air for pressurizing. (This control is sometimes combined with the cabin heating control described later.) On most aircraft, when the pressurizing control is turned off, the cabin is ventilated by ram air entering through a special intake and leaving through a stale-air extraction valve. If the aircraft is below the height at which the cabin pressure control valve closes, the stale air will also leave the cabin through this valve. For emergency control, on some aircraft, ram air is supplied from the nose of the aircraft via a non-return valve : this comes into use automatically when the cabin pressure is low relative to the ram-air pressure, *e.g.* during a rapid descent.

16. **Cabin Pressure—Additional Control Valves.** A pressure control valve in the cabin automatically governs the rate of change of pressure in the cabin, provided that the pressurizing control is turned on. On some aircraft where a high differential pressure is used, an override control is provided to allow rapid reduction of the cabin pressure in an emergency, thus enabling the crew to abandon the aircraft quickly when necessary. This control is unnecessary on low differential pressure aircraft since an almost instantaneous drop of cabin pressure from 4 lb./sq. in. to zero has no ill effect on personnel of aircrew physique.

Cabin Pressure Indicators

17. A simple altimeter which indicates *cabin altitude* is fitted in the cockpit to enable the pilot to check the correct functioning of the pressurizing equipment. In addition, a visual or audible warning device operates whenever the cabin altitude is higher than it should be, *i.e.*, the cabin pressure is too low.

Cabin Ventilation

18. An adjustable louvre for admitting cold air for ventilation is provided in most pressure cabins, for use at low altitudes. It can be closed manually when not required and at altitudes where the cabin is pressurized the louvre closes automatically.

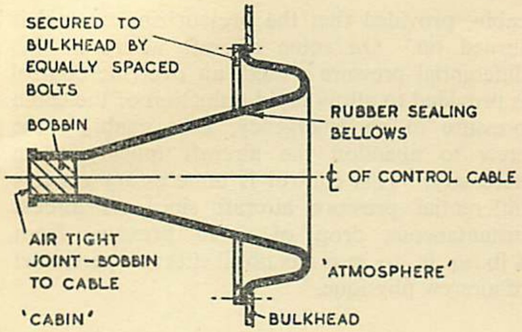
Pressurized Air—Temperature Control

19. The degree of cabin heating is controlled either electrically or manually by the pilot, and (according to the installation) may be varied to allow a greater proportion of hot air to be directed on to the canopy and windscreen for demisting purposes.

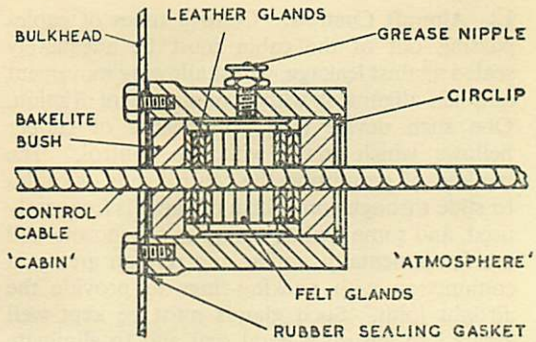
Refrigeration Units

20. The desirable temperature in flight in a pressure cabin is about 20° C. Since this temperature is reached after the air has been heated by the use of radio equipment, skin friction, solar radiation, and heat radiated by the crew, it follows that the temperature of the air entering the cabin should be well below 20° C.

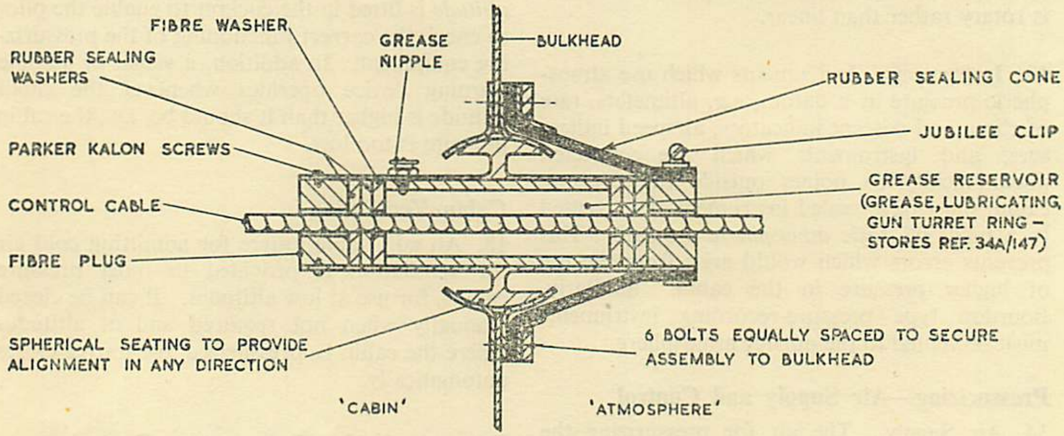
21. Since the temperature of the air supply coming from the engine compressor casing may be as high as 350° C., the air is usually passed through an air-to-air heat exchanger before entering the cabin. If the temperature drop obtained is still insufficient and additional cooling is necessary, a cold air unit is installed in the air conditioning system.



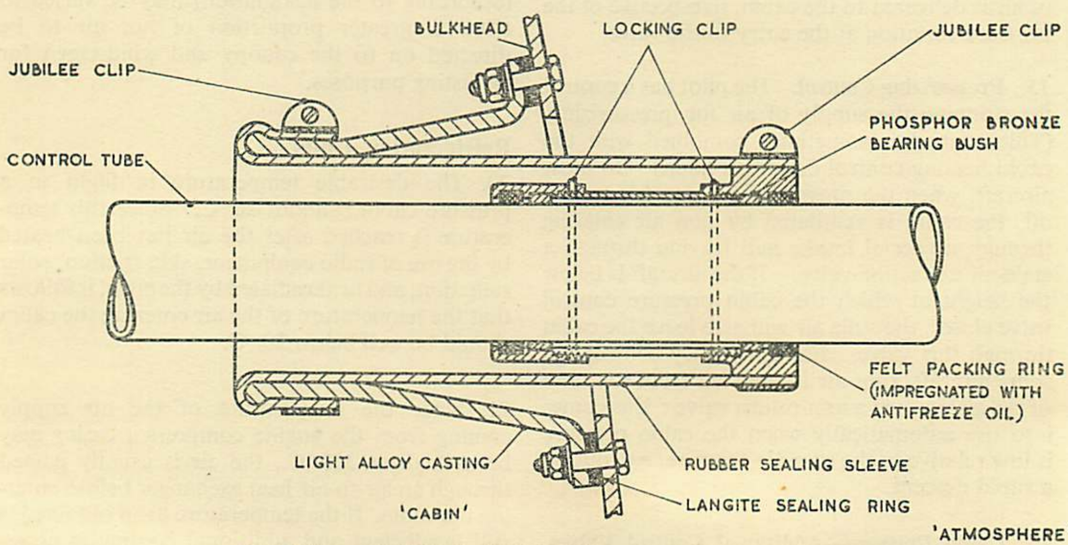
CONTROL SEAL USING RUBBER BAG



FLYING CONTROL SEAL



SELF ALIGNING CONTROL CABLE SEAL



SLIDING CONTROL TUBE SEAL – SELF ALIGNING

Fig. 3. Control Sealing Arrangements.

22. **Heat Exchangers.** A heat exchanger (Fig. 4) is similar in action to a car radiator except that it is air, and not water, which is cooled by the passage of the ram air through the exchanger; also the air to be cooled can be routed to make four or more passes across the cooler. Heat exchangers are sometimes referred to as pre-coolers, or, where they are fitted between the compressor and turbine of a cold air unit, they may be termed *intercoolers*.

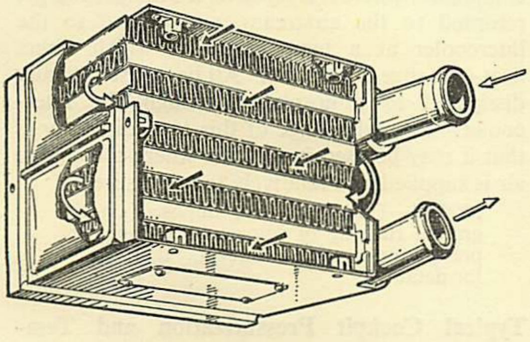


Fig. 4. Airflow through a Heat Exchanger.

23. **Cold Air Units.** The principle of the cold air unit is that when air is made to drive a compressor by flowing through a turbine, the turbine extracts pressure and heat energy from the airflow, which, therefore, emerges from the turbine in an expanded form, *i.e.* at a lower pressure and temperature. There are three forms of cold air unit in service: the brake-turbine, turbo-fan and turbo-compressor. For ease of explanation they are described below in that order, although the turbo-compressor type was the first used in service aircraft.

24. **Brake-Turbine Cold Air Unit.** In the brake-turbine cold air unit (Fig. 5) charge air from the engine compressor passes through the ram-air cooled heat-exchanger to enter the turbine (through which it expands); this results in a pressure drop and a considerable fall in temperature. Mounted on a common shaft with the turbine is a centrifugal compressor which is driven by the turbine and which, in absorbing the mechanical energy of the turbine, functions as a brake. The air passing through the compressor is obtained from and discharged to atmosphere; the compressor is thus external to the flow of charge air and has no other function than that of a brake to the turbine. In operation the energy removed from the air by the turbine is used to drive the compressor. A cold air unit of this type is used if the space available for installation is restricted. As a variant of this basic type, it is possible to discharge the air from the compressor through a jet-pump to induce an airflow through the heat-exchanger. This enables the charge air to be cooled when the aircraft is on the ground.

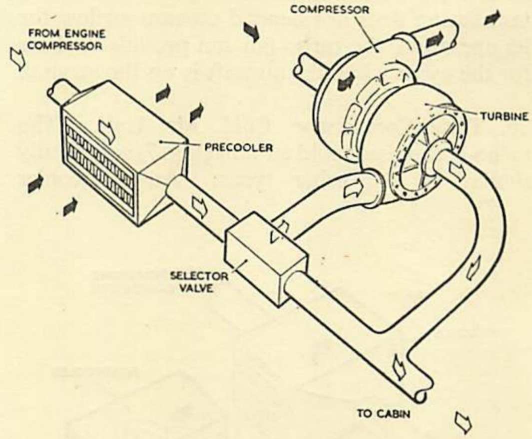


Fig. 5. Brake-Turbine, Typical Installation.

25. **Turbo-Fan Cold Air Unit.** The turbo-fan cold air unit (Fig. 6) is similar to the brake-turbine type, but is more bulky. In this type the turbine drives a centrifugal fan which is large

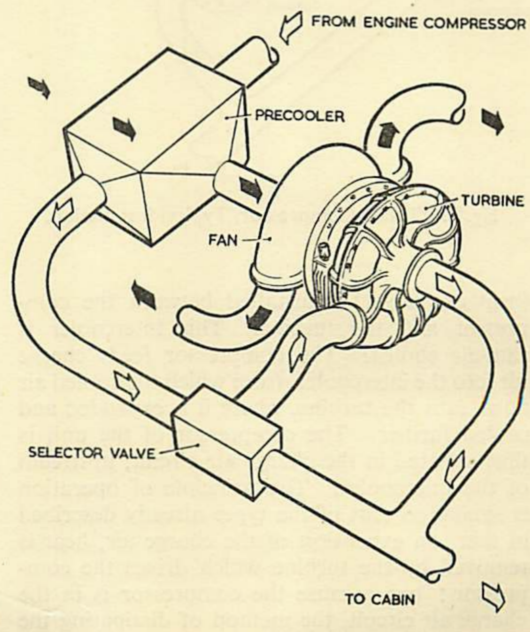


Fig. 6. Turbo-Fan, Typical Installation.

enough to pass the cooling airflow required by the heat-exchanger. To obtain the maximum cooling effect, air is drawn through the heat-exchanger by the fan then discharged to atmosphere. The air discharged by the fan cannot be used for further cooling purposes because its temperature is increased considerably in passing through the pre-cooler and fan. The energy extracted from the charge air by the turbine is used to drive the fan. Since the pre-cooler in this installation does not depend on ram airflow for its operation, the turbo-fan can provide cool air for the cabin while the aircraft is on the ground.

26. **Turbo-Compressor Cold Air Unit.** The turbo-compressor cold air unit (Fig. 7) is generally similar to the other types. An intercooler

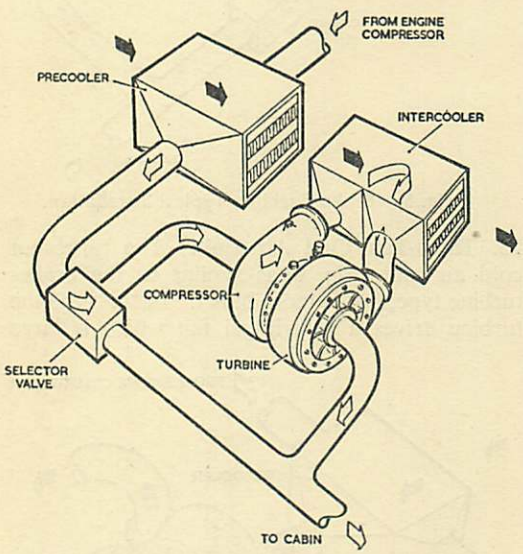


Fig. 7. Turbo-Compressor, Typical Installation.

(heat exchanger) is installed between the compressor and the turbine. This intercooler is ram-air cooled. The compressor feeds charge air into the intercooler, from which the cooled air flows into the turbine, where it is expanded and cooled further. The compressor of the unit is thus situated in the charge air circuit, upstream of the intercooler. The principle of operation is similar to that of the types already described in that, on expansion of the charge air, heat is removed by the turbine which drives the compressor ; but because the compressor is in the charge air circuit, the method of dissipating the turbine energy differs from the methods previously described. When cold air is selected, charge air enters the compressor and passes to the intercooler, subsequently entering the turbine volute and expanding through the nozzle ring and turbine into the supply ducting. The temperature of the air emerging from the intercooler is too low to permit further cooling by direct surface heat-exchange, but further cooling is obtained by the action of the turbine on the charge air, where the heat energy extracted by the turbine is converted to mechanical energy. In this form the energy is transmitted to the compressor where it is reconverted to heat energy, returned to the airstream, and passed to the intercooler at a temperature at which direct heat-exchange is possible. All heat lost is finally dissipated to atmosphere through the intercooler. One advantage of this type of cooler is that it may be used in systems where the charge air is supplied at a relatively low pressure.

NOTE.—Time limits are imposed on the ground running of some cold air units, to prevent overheating. Refer to Pilots' Notes for details.

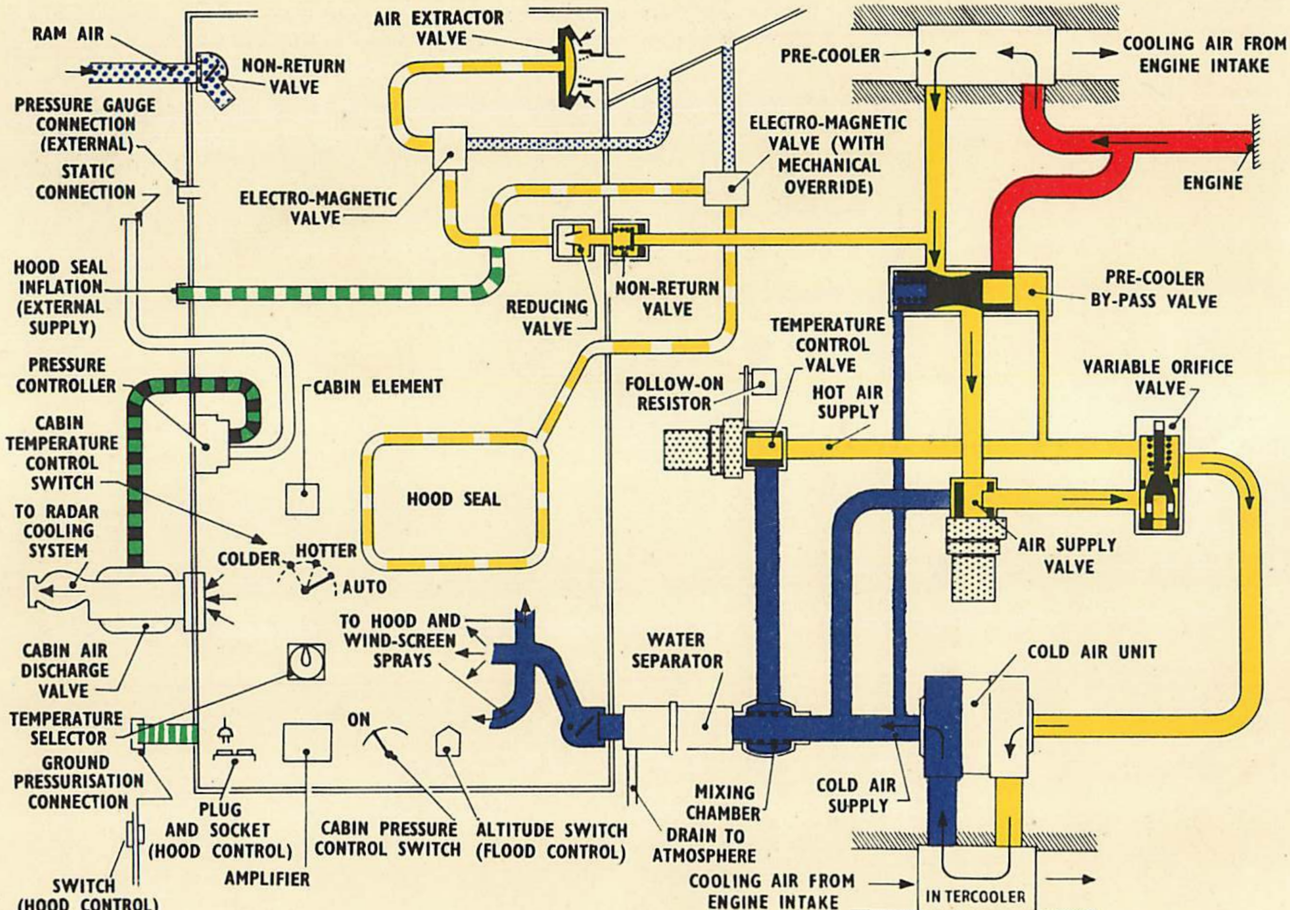
Typical Cockpit Pressurization and Temperature Control System

27. In the system shown in Fig. 8, hot air from a restricted tapping on the engine passes to a pre-cooler. A bypass valve permits the hot air to bypass the pre-cooler under certain conditions of flight. From the pre-cooler the air passes to an air supply valve for normal air supply, or under certain conditions for *flood air* (see para. 32).

28. For normal supply, the air leaves this valve and continues to a variable orifice type mass flow controller which has two outlets, one conveying the hot air to the cockpit through the temperature control valve, and the other passing hot air to a cold air unit.

29. When the selector valve is turned on, the air passes to the compressor and thence via the intercooler to the turbine of the cold air unit, from which the cold air is piped to a mixing chamber. The hot and cold air streams rejoin in this mixing chamber, and the combined flow is delivered via a water separator (which removes excess moisture from the air) through a non-return valve to the cockpit ventilation galleries. These galleries supply sprays for windscreen and canopy demisting. A direct discharge is also provided elsewhere in the cockpit.

30. Spent air is expelled from the cockpit through a cabin pressure control valve situated on the front bulkhead of the cockpit ; the outlet

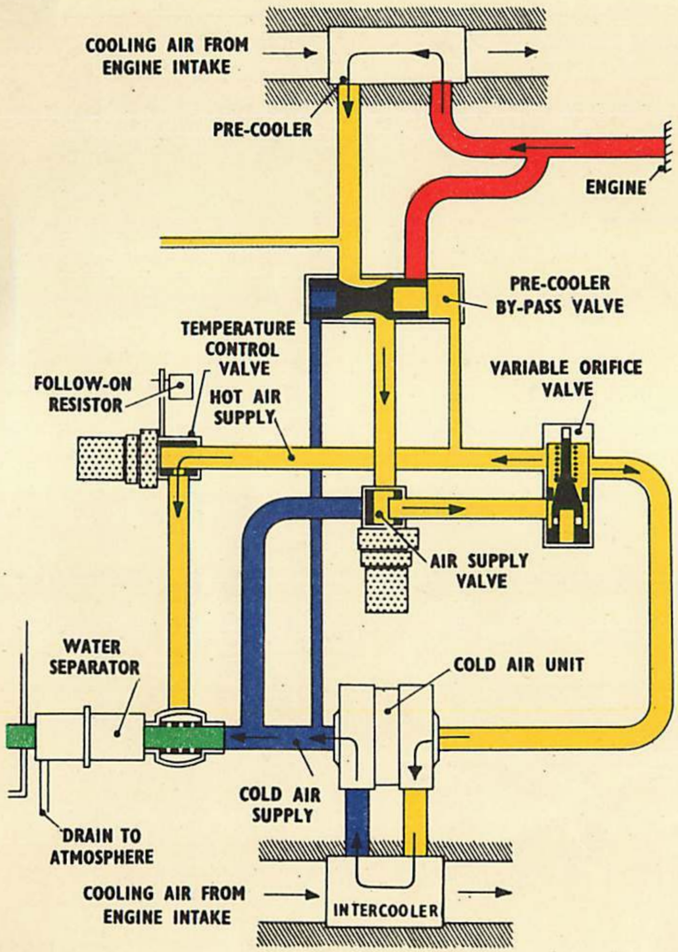


A DIAGRAM FOR 'FULLY COLD' DELIVERY
(ALL AIR THROUGH COLD AIR UNIT)

CABIN TEMPERATURE CONTROL SWITCH IN AUTO AND TEMPERATURE SELECTOR SET TO PROVIDE LOW TEMPERATURE AIR

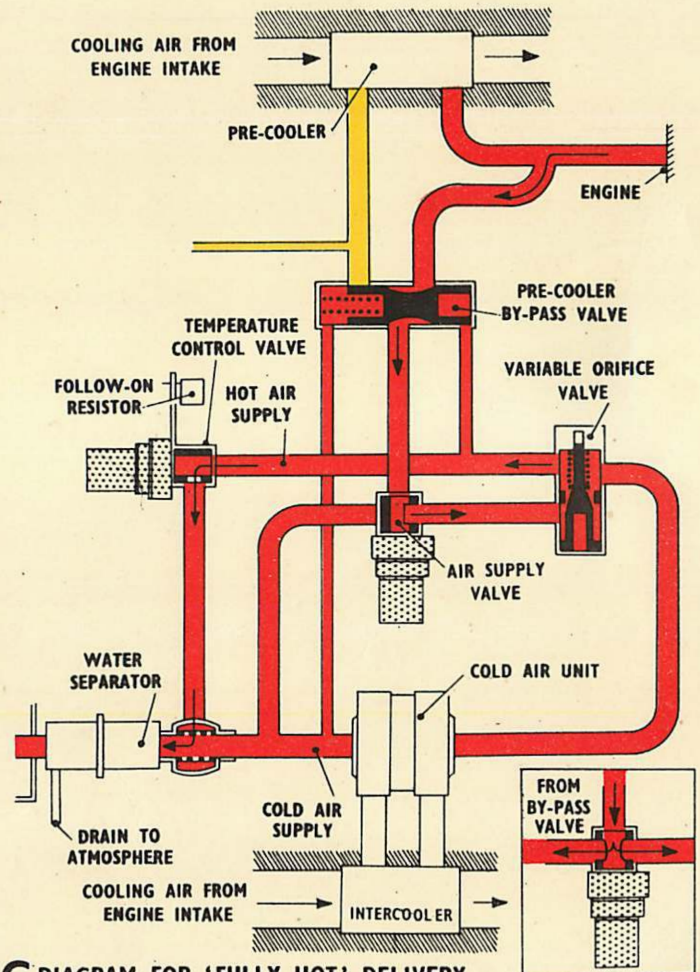
ALTERNATIVELY FOR MANUAL SETTING "COLDER" ON SWITCH

Fig. 8. Typical Air-Conditioning System



B DIAGRAM FOR 'INTERMEDIATE TEMPERATURES'
(MIXTURE OF HOT AND COLD AIR)

CABIN TEMPERATURE CONTROL SWITCH IN AUTO AND TEMPERATURE SELECTOR SET TO PROVIDE REQUIRED TEMPERATURE OF AIR



C DIAGRAM FOR 'FULLY HOT' DELIVERY
(COLD AIR UNIT BY-PASSED)

CABIN TEMPERATURE CONTROL SWITCH IN AUTO AND TEMPERATURE SELECTOR SET TO PROVIDE HIGH TEMPERATURE AIR ALTERNATIVELY FOR MANUAL SETTING "**HOTTER**" ON SWITCH

POSITION OF AIR SUPPLY VALVE FOR CONDITIONS OF FLOOD

Fig. 8. Typical Air-Conditioning System

of this valve is shrouded. Piping in the nose of the aircraft, downstream of the shroud, permits the waste air to circulate in jackets around the radar equipment for cooling purposes before final discharge to atmosphere in the nose of the aircraft.

31. **Ram Air Supply.** An alternative air supply for emergency cockpit ventilation is provided by a forward-facing air scoop in the nose of the aircraft. From the scoop, air passes through a non-return valve and restrictor direct into the cockpit. Ram air comes into use automatically when the cockpit pressure is low relative to ram air pressure. Ram air is also provided when the main supply is turned off, which automatically causes the cabin air extractor valve to open.

32. **Flood Air.** Flood air from the air supply valve is fed into the cold air unit outlet duct, and is controlled by an altitude switch which automatically opens the air supply valve to the FLOOD position whenever the cockpit altitude exceeds a pre-set figure, thus preventing a low cockpit pressure occurring at that altitude.

33. **Hood Seal.** A common supply of air for the seal and extractor valve is taken just downstream of the pre-cooler via a combined non-return, pressure-reducing and safety valve, which maintains the seal at the required pressure. This supply of air branches off via a solenoid valve to the hood seal and extractor valve. When the seal is deflated, the exhaust is bled to atmosphere. Switching off the master ON/OFF switch does not affect the seal. The hood seal valve is inflated when the hood is closed and remains inflated if the electrical power fails. The hood seal solenoid and hood winding motor are energized from a common control switch. The seal is inflated when the solenoid is de-energized. A time delay is incorporated in the circuit to allow the seal to deflate before the hood starts to open. The solenoid also incorporates a mechanical override which, operating in conjunction with the hood jettison gear, ensures that the hood seal is deflated before the hood is jettisoned.

34. **Cabin Air-Extractor Valve.** This is a pneumatically operated valve which is operated via a solenoid from the supply of pressurized air from the engine, and is automatically opened when the main air supply valve is closed. In the event of electrical power failure the valve remains closed.

35. **Warning Devices for Loss of Cabin Pressure.** Warning of loss of cabin pressure is given visually by a warning lamp in the cockpit, which is operated by a switch in the cabin pressure control valve whenever the cabin differential pressure falls by $\frac{1}{2}$ to 1 lb./sq. in. below datum. In addition, a device which sounds a warning note in the pilot's headphones is operated automatically by an altitude switch. The aural warning functions at cabin altitudes above 37,000 feet (approximately), and has a silencing push-button to suppress the audible warning and a test switch to ground-check the audible warning and flood circuits.

Typical System—Controls

36. In a typical cabin pressurization and temperature control system the pilot has three controls in the cockpit. These are :—

(*a*) *Pressurizing Control.* Cockpit pressurization is controlled by an ON/OFF switch which controls the air supply valve actuator, air extractor valve, and temperature control valve actuator. The pressurizing control switch can be overridden to close the air supply valve and energize the air extractor valve when the hood is opened. Simultaneously the pre-cooler bypass is closed.

(*b*) *Temperature Control Lever.* Cockpit temperature is controlled by a lever marked AUTO, COLDER, and HOTTER. The control has a central gate to which the lever should be returned when the desired temperature is selected by means of a temperature selector in the cockpit.

(*c*) *Temperature Selector.* This selector works in conjunction with an electronic temperature controller (described in A.P.1275A, Vol. 1), and consists of a rotary switch graduated from COOL to WARM, which may be adjusted to a desired temperature. As stated in sub-para. (*b*), this selector is intended for use when the temperature control lever is set to AUTO.

Typical System—Operation

37. It should be noted that the system is inoperative when the hood is open.

38. To operate the pressurizing and temperature controls in flight, proceed as follows :—

(*a*) Turn on the master pressure control switch.

(*b*) Adjust the temperature control lever between the HOTTER–COLDER positions to give the desired temperature, then engage lever in the central gate.

(*c*) If a certain temperature is desired, select that temperature on the temperature selector and set the temperature control lever to AUTO.

39. Cabin altimeter readings for various actual altitudes, and cabin altimeter readings at which the red warning light comes on (should a drop in pressure occur), are given in the relevant Pilots' Notes. If a loss of pressure causes the cockpit altitude to exceed a pre-set figure, the altitude switch operates to supply *flood air* to the cabin, and the aural warning sounds.

Formation of White Mist

40. With the cold air unit in operation, under certain weather conditions the temperature of the air supplied to the cockpit or cabin may be reduced below its dewpoint, causing a white mist or small ice crystals to be discharged into the cockpit. This can be countered by partially or completely bypassing the cold air unit, *i.e.* by moving the temperature control lever to a warmer position.

Use of Leak Stoppers

41. Pressure cabin leak stoppers consist of three short, small-diameter metal tubes attached to a square of gauze, and a square of rubberized nylon fabric. They are folded in such a manner that they may be brought into immediate use. When a pressure cabin is holed, the metal tubes can be used to bridge the damaged area, and the gauze is spread out and moulded to the local contour forming a support for the much larger square of rubberized nylon which completes the seal. The pressure within the cabin ensures the leak stopper remaining *in situ*, regardless of its position. More than one leak stopper may be used, provided that the tubular struts bridge the hole.

Use of Fire Extinguishers

42. To prevent the entry of toxic fumes into the cockpit when fire extinguishers are used, in some aircraft the pressurizing air supply isolating control is automatically closed, and the cabin air extraction valve opened. Ram air ventilation then takes the place of pressurizing. Normally the pressurizing control should be turned off when engine fire extinguishers are operated as a precaution against entry of toxic fumes.

Canopy Misting

43. After prolonged exposure to very low temperatures the canopy becomes *cold soaked* and takes on the temperature of the outside air. Subsequent descent to lower, warmer altitudes involves contact of the very cold canopy with air of high water vapour content. The water vapour content condenses and freezes on to the canopy, both internally and externally, in the form of mist, which persists until the canopy is warmed up and the ice crystals melted by the local air temperature. If a descent is made rapidly to low altitudes the misting will be more severe than if a gradual descent is made.

44. Internal misting can be prevented to a large extent by directing the warm incoming cockpit air against the inside of the windscreen and canopy, or, if this cannot be done, by wiping the vision panels with a glycol-soaked cloth (which should always be carried in aircraft susceptible to canopy misting).

45. External icing can be prevented by a wide jet of very hot air released from the base of the windscreen, or by electrically heating the windscreen by a grid of fine wires. The external windscreen heaters on some aircraft are very powerful and should be operated only for the minimum period necessary to clear the icing, otherwise the windscreen may be damaged by excessive heat.

Dry Air Sandwich-Type Canopies

46. These canopies are made of two thicknesses of transparent material with an interposing air space. It is important that the air sandwiched between the two surfaces is kept dry, since any moisture would cause misting of the surfaces in suitable conditions. Air is circulated through this space, but is passed through a desiccating agent (usually silica gel) before entering the air space. The drying agent is contained in cartridges mounted where they can be seen readily by the crew ; each cartridge has a small window which enables the silica gel to be seen. The crystals are of various shades of blue, ranging to almost white when serviceable ; but when pink, the cartridges are saturated and therefore unserviceable.

Jettisoning of Damaged Canopies

47. A canopy which has been badly damaged should not be jettisoned unless the aircraft is to be abandoned immediately. This is because the impaired aerodynamic characteristics may cause the canopy to strike the tail surfaces, damaging them, and causing control difficulties.


CPL V WOOTON
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