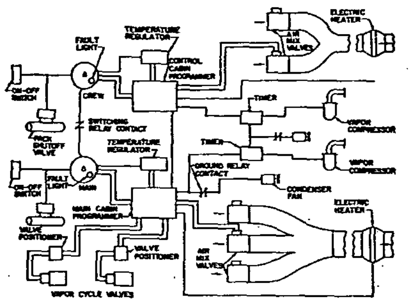


Fig. 5 .... *Typical Temperature Control System for Vapor-Cycle Refrigeration Unit*

system, while pressurization air is cooled by the air-cycle system. Other variations are possible and may be best suited for the particular application.

TEMPERATURE CONTROL SYSTEM

A block diagram of a typical temperature control system for an airplane with vapor-cycle refrigeration is shown in Fig. 5. This system regulates cabin temperature by controlling in sequence the various components of the air-conditioning system and provides, at the flight engineer's station, an indication of system operation. Separate control components allow independent temperature regulation in the main and control cabins and provide either automatic control of selected temperatures between 65 F and 85 F, or manual control for heating or cooling. The system includes temperature selectors, temperature regulators, programmers, temperature sensing devices, and miscellaneous components.

The temperature selectors affect the regulators, in the automatic range, to adjust the heating or cooling signal to the programmers. In the manual range, the selectors bypass the regulators to provide faster temperature adjustments, and to provide control in case of a failure in the automatic circuit. The regulators automatically establish and maintain the cabin temperature within 1.5 F deg of the temperature selected in the automatic range. Bridge circuits in the regulators are influenced by various temperature sensing devices.

The cabin bridge is affected by the temperature selector in the automatic range, and the cabin temperature sensing element. The anticipator bridge is affected by an ambient sensing element and by the fast and slow elements in the supply duct temperature sensor. The topping bridge is affected by a sensing element to limit duct temperature to 160 F ($\pm$5 F deg).

Each programmer is controlled directly by the respective temperature selector for manual control, or by the temperature regulator during automatic operation. In flight, modulated operation of the electric heaters, air mix valve assemblies and refrigeration packs is controlled in stages through the programmers according to heating or cooling requirements. On the ground, through the action of the air-ground switch on the landing gear, the main and control cabin air mix valves are moved to the full cool position to provide minimum restriction for the recirculation fans. Heating or cooling is then accomplished by modulation of the electric heaters or refrigeration packs.

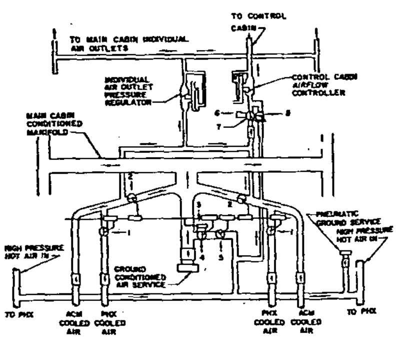
A neon *fault* light included on the selector dial face, when illuminated, indicates malfunctioning of the topping or anticipator, or both, bridge circuits. Faults in these circuits may not be readily apparent since the operation of the cabin bridge will not be affected. The fault light is illuminated by either of two relays in the regulator.

Such things as evaporator inlet and outlet air, refrigerant, main cabin ambient, and duct air temperatures may be indicated by a gage with a multiposition selector on the flight engineer's panel.

A possible variation of this system eliminates the programmers and utilizes limit switches and relays on the various valves in the system to transfer the control signals from one component to another. In an air-cycle system all control may be accomplished through positioning an interconnected *gang* valve. Such a gang valve is shown schematically in Fig. 6. Signals from the temperature regulator drive an actuator which, through a linkage and gear arrangement, causes the air to bypass the air-cycle machines and primary heat exchangers, and imposes additional restriction on the turbocompressors if further heat is needed. The same type of control could be applied to a vapor-cycle refrigeration system where evaporator air bypass is used for modulation.

Another variation of temperature control eliminates the gang valve or air mix valves. This control modulates the cooling air supplied to the air conditioning system, and causes a portion of air to be recirculated through the turbocompressors for additional heat when needed.

The temperature control system may also be required to control electric heaters in the floors or side walls of the airplane. These may be installed only in local areas. The transport airplane cabin is essentially a long narrow room and there may be a considerable difference in the heating or cooling requirements of the extreme ends. This may be complicated by the installation of a partition which separates the cabin into two sections, first class and tourist. The passenger density may be considerably different in the two sections which will make a considerable difference in air conditioning requirements. The temperature control system should have



Main Cabin Air Mix Valves
1. Air Cycle Machine Bypass
2. Cold Air
3. Valve Motor
4. Hot Air
5. Turbocompressor Back Pressure

Control Cabin Air Mix Valves
6. Valve Motor
7. Cold Air
8. Hot Air

Fig. 6 .... Air-Cycle Temperature Control Valves

provisions for adjusting to these load variations, either automatically or manually.

CABIN PRESSURIZATION CONTROL SYSTEM

The cabin pressure control system must meter the exhaust cabin ventilating air to maintain a constant low altitude cabin pressure during high altitude flight, and must control any cabin pressure change to a rate which will not result in discomfort to the airplane occupants. The control system must respond to rapid ambient pressure changes which occur during climb and descent, and to abrupt changes in cabin air inflow which occur when an air source is turned on or off.

Positive pressure relief at some maximum pressure must be provided to protect the airplane in the event of a pressure control system failure. A negative (vacuum) pressure relief mechanism to let air in when outdoor pressure exceeds cabin pressure must also be provided.

Other desirable features are a barometric correction selector to help select the proper landing field altitude so that the pressure differential at landing may approach zero, and a limit control to maintain a maximum cabin altitude if other control components fail. An indicating system should be provided, including a rate of climb indicator, an altitude warning horn, an altimeter, and a differential pressure indicator.

The main components of a typical cabin pressure control system are the automatic controller, the manual controller, and the three outflow valves. This system is installed in an airplane in which the main passenger and control cabins, forward and aft cargo compartments, and the lower nose section are pressurized. Decompression panels, mounted in rubber extrusions, are provided in bulkheads and in the floor between pressurized sections to provide local structural protection should the airplane become rapidly depressurized at altitude.

This system is pneumatically operated by air from the ventilating system. The air is filtered to remove particulate matter before it is delivered to the control lines. The automatic controller has a rate chamber responding to the setting of the rate selector knob. A rate control diaphragm divides the rate chamber from a control chamber. Control flow is regulated by an isobaric control valve and isobaric bellows balanced against a spring connected to the cabin altitude selector. The selector can be set for cabin altitudes from 1000 ft below sea level to 10,000 ft altitude. The selector setting affects the outflow valves through the controller components and a pressure tight line to the outflow valve pneumatic relays.

The cabin rate of change selector controls the rate of change of cabin pressure and can be set for rates from 50 to 1600 fpm. The selector setting affects an orifice which regulates rate of air flow between control chamber and rate chamber. Cabin pressure follows control chamber pressure via outflow valve activity. Therefore, the rate of cabin pressure change will follow the rate of control chamber change. Generally, the maximum comfortable rate of cabin altitude change for most people is about 300 fpm, but rates as high as 1600 fpm can be tolerated briefly so long as the net cabin altitude change does not exceed 100 ft.

The 8.6 psi pressure differential control maintains that maximum differential between cabin and ambient, overriding cabin altitude selections which would result in a differential higher than 8.6 psi.

A manual cabin pressure control is provided for use when the automatic control is inoperative.

The jet pump consists of a venturi which uses engine bleed air to provide a vacuum source for the control and outflow valve components, acting on the valve heads to assist in depressurizing the cabin at landing and to minimize pressure bumps when cabin inflow air is turned on.

Three cabin pressure outflow valves are provided in this system, but one or two can be used on smaller airplanes. Enough valves must be provided to assure proper flow distribution from the upper cabin to, or around, the lower cargo areas. Dirt accumulation on these valves is a problem since a large percentage of all air that flows into the cabin goes out there. Tobacco tars are particularly troublesome and periodic cleaning is required. The valve assembly includes a pneumatically balanced poppet valve with a vacuum relief diaphragm, a control chamber, a cabin air port and filter, a positive pressure relief valve, a pneumatic relay, a jet pump, an atmosphere port, and a cabin altitude limit control. The poppet valve is moved to pass air from the cabin as pneumatic signals are received from the automatic or manual control through the pneumatic relay to the control chamber, thus maintaining a selected pressure or effecting a change at a selected rate.

A variation of this system is one in which the pneumatic components of the controller vary an electrical circuit to position the outflow valves, which are driven by an electrical actuator.

CARGO COMPARTMENTS

Revenue from air cargo has become a substantial portion of the total air transport market and is constantly growing. Much of the cargo that is shipped by air is either live or perishable goods and requires air conditioning, although not as exacting as the passenger considerations. Cargo compartments are classified by the Civil Air Regulations according to the provisions for fire prevention, extinction, or both. Essentially, two main classifications are created: (1) ventilated and (2) unventilated. There is some small inflow into the unventilated compartment because of leakage, but it is low enough that a fire would be self-extinguishing.

The ventilated compartments have greater versatility with respect to the types of cargo that can be carried. Live animals can be carried in unventilated compartments, but the loading density and time of trip should be such that the CO_2 content of the air does not build up above safe limits. The control of temperature in the ventilated compartments can be nearly as good as in the passenger cabin. Cabin air may be exhausted through the cargo compartment, or supplemental conditioned air can be added directly. Electric heat may be added separately or in conjunction with these methods. The control of the supplemental air or electric heat would be separated from the passenger cabin temperature control.

Generally the only attempt in the unventilated compartment is to maintain a temperature above freezing by insulation, but electric heat may be added, or cabin exhaust air may be circulated through a shell around the compartment by means of a blower, or both methods may be used. Animals will add heat to the compartment from their bodies, and proper packaging and loading will produce a temperature compatible with their well being.

The optimum temperature for all confined livestock is 70 to 75 F, except 80 to 85 F for reptiles, and lower than 70 F for some heavy coated fur bearing animals. The recommended minimum temperatures are: 65 F for monkeys, apes, small birds, jungle cats, and other tropical animals; 55 F for cattle, horses, swine, hamsters, domesticated cats, short haired dogs; 45 F for long haired dogs, foxes, adult poultry; and 70 F for baby chicks in cardboard cartons, and non-hibernating reptiles. The recommended maximum temperatures are 95 F, except 85 F for small birds and heavy coated fur bearing animals, and 100 F for reptiles.

Animals are not tolerant of drafts or noise so these items should also be given consideration. The rate of CO_2 production by livestock varies considerably with the species, but can