member to keep cabin temperature regulated. As ships of this type are not pressurized, the heating system is still comparatively simple.

In one type, two 100,000 Btu heaters are placed in parallel positions and the ram air from an external scoop is passed through the heaters and discharged through a series of distributing outlets located in the cabin ceiling. The cabin air is discharged through grilles located in the bottom walls of the cabin. An auxiliary nose heater is used by the crew to obtain additional heat for the cockpit or for windshield defrosting.

The cabin is maintained at the desired temperature by means of an automatic control which operates both heaters simultaneously. This control consists of two duct thermostats, one being mounted in the air inlet duct between the air scoop and the heaters so that it is affected by outside ambient temperatures, and the other being mounted in the heater outlet duct so that it is affected by the discharge air temperatures. A thermostat in the cabin is so located that a continuous stream of cabin air passes through it. This type of control has been found to respond to a 1 deg temperature change in less than a second. Its theory of operation follows.

As the outside temperature starts to drop, the outside air duct thermostat decreases in resistance, unbalancing an electronic bridge. This unbalance is amplified by vacuum tubes and causes a power tube to close a relay, turning on the combustion heaters. The resulting increase in temperature is sensed by the warm air duct thermostat which increases in resistance, thus re-balancing the bridge and causing the relay to open. If there were no loss by radiation or convection from the aircraft cabin, these two duct thermostats would be sufficient for adequate control. However, the cabin thermostat is given approximately 30 times more influence than the duct thermostats and so acts as the master controller, and the duct thermostats prevent over-heating or under-heating and keep the discharge air from alternating between extreme cold and extreme heat.

In a slightly more elaborate system, two combustion heaters supply a plenum chamber which is maintained at a constant temperature. Air from the plenum chamber is then mixed with outside air to maintain desired cabin temperature. All of the warm air is discharged into the cabin through the walls. The discharge grilles are located on the floor under seats, and a modulating type controller varies proportions of heated and outside air necessary to maintain desired cabin temperature. The same type of control system as previously described is used, except that an amplifier operates a two-phase motor capable of positioning control dampers instead of operating a relay which would merely open and close the fuel valve. An auxiliary duct, running from the plenum chamber, is used by the pilot as a source of windshield defrosting air.

Pressurized Cabins

With the advent of the new high speed pressurized transport planes, and the addition of cabin cooling in addition to heating, the control problem becomes more complex. On all of these airplanes, the heat of compression from cabin supercharger must be controlled, the air cycle or expansion turbines must be turned on and also, the heat exchanger or combustion heaters, which are used in the system when cooling is required for additional heat, must be automatically controlled.

Assuming that one of these airplanes is operating in an extremely cold climate, the sequence of operation would be as follows:

The automatic controller for the supercharged-air inter-cooler would be in full closed position, so that none of the heat of compression would be removed, and the air would by-pass the expansion turbine and its compressor and the secondary after-cooler. An additional automatic controller would be operating the combustion heater and supplying the additional heat necessary to maintain the desired cabin temperature. If a heat exchanger were used as a supplemental source of heat, a modulating control operating a damper on this exchanger would run towards full heat position.

As the airplane enters a warm climate and heat requirements drop, the combustion heater would cease operation or the heat exchanger would go to full cold position, and the modulating control on the supercharger compressor would move towards the cold position. When the outside ambient temperature rises so high that cooling is desired, the cabin supercharger intercooler would be opened wide. If further cooling were required, the air would go into an air cycle turbine, which is modulated to deliver the required amount of cold air to maintain a comfortable cabin temperature.

Pressure in the cabin is maintained by providing a controlled, constant rate of air flow into the cabin sufficient to maintain ventilation, and adjusting the cabin-pressure relief valve setting, by means of a cabin pressure selector, to maintain the desired cabin pressure. Limits on maximum inside to outside pressure may be of the order of 4 or 5 psi, and safety controls should be provided to prevent exceeding this limit. There is a maximum rate at which the cabin can change to a newly selected value, this rate being in some cases also adjustable.

The requirements for controls of this nature are extremely rigid. It is commonplace for ships of this type to experience changes in outside ambient temperatures of as much as 100 deg in a space of 5 min. For this reason, speed of sensing a change and rapidity of response in the control system is essential if satisfactory control is to be accomplished. The older type thermostats cannot be used in airplanes, due to mass of the thermostat and to vibration experienced on all airplanes. All modern controls use some type of bridge system with temperature sensitive resistors as sensing elements. In some types of controls, the bridge system feeds a sensitive balanced relay, which in turn runs a modulating motor or controls an on-off power relay. A recent sensitive and quickly responding type uses an electronic amplifier, which in turn controls a two-phase motor, or, through relays, controls a d-c motor, or merely closes and opens a power relay for on-off applications.

In addition to extreme speed and accuracy which are required of all aircraft temperature controls, they must be able to operate under great extremes of temperature, pressure and humidity, and also withstand continuous extreme vibration. Heaters should have, in addition to control from thermostats, suitable limit controls to prevent over-heating due to failure of air supply, or any other cause. Also, there should be safety devices to shut off fuel in case of flame failure.

On the latest *high speed jet airplanes*, the temperature control problem is still more severe than on the latest transports; as in addition to the accuracy required, control response must be phenomenally fast. For example, on some, the air going to the cabin from the jet engine compressor can change the temperature at the rate of 150 deg per second. This, coupled with the fact that on smaller size pursuit ships air is changed in the cabin as much as four times per minute, makes the instantaneous sensing of change and an extremely rapid control movement essential. Also, in airplanes operating at Mach numbers in excess of 0.7, the control must react to the large adiabatic temperature rises encountered. Some of these problems are so new that controls still have not been developed to meet all of the desired conditions. However, present studies being made by control manufacturers should result in developments of such controls in the near future.