were generally gradual enough so that manual readjustment of controls could maintain reasonably comfortable cabin conditions. Nearly all of these heating systems were marginal in respect to heat available and the main problem was lack of heat, rather than inadequate control.

Non-Pressurized Cabins

With the advent of the combustion type heater, and use of larger and faster planes, use of manual controls became impracticable. The combustion type heaters reach full rating in less than a minute after being turned on, and as they are rated at 100,000 Btu per hr and up, and since several heaters are generally used, it would take full time of one crew 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 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 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 bridge and causing 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 master controller, and the duct thermostats prevent over-heating or under-heating and keep 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 cabin through walls. The discharge grilles are located on 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 merely opens and closes fuel valve. An auxiliary duct, running from plenum chamber, is used by pilot as a source of windshield defrosting air.

Pressurized Cabins

With the advent of new high speed pressurized transport planes and 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, air cycle or expansion turbines must be turned on and also, heat exchanger or combustion heaters, which are used in 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 supercharged air inter-cooler would be in full closed position, so that none of heat of compression would be removed, and air would bypass expansion turbine and its compressor and secondary after-cooler. An additional automatic controller would be operating the combustion heater and supplying additional heat necessary to maintain 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 airplane enters a warm climate and heat requirements drop, the combustion heater would cease operation or heat exchanger would go to full cold position, and modulating control on supercharge compressor would move towards cold position. When outside ambient temperature rises so high that cooling is desired, 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 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 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. There is a maximum rate at which 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 space of 5 minutes. 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 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, 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 is 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 for any reason. Also, there should be safety devices to shut off fuel in case of flame failure.

On latest *high speed jet airplanes*, the temperature control problem is still more severe than on latest transports; as in addition to accuracy re-