tremes 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.

SHIP AIR CONDITIONING

In air conditioning a ship, the designer is faced with all problems that would normally arise on shore installation plus additional factors. Mechanical ventilation is an absolute necessity for the comfort of passengers and ships' personnel, and for utility and preservation of cargo and stores. Ships are constructed with water-tight bulkheads dividing the vessel into several compartments. This complicates the running of duct work and results in a multiplicity of both supply and exhaust fans. Temperature and humidity requirements of various spaces aboard ship vary widely. Passenger staterooms and public spaces must have year-round air conditioning with is also being applied more and more to the quarters of the officers and crew. Boiler rooms, galleys, laundries, etc., must have ventilation, and some must have tempered air. Cargo spaces are quite likely to need dehumidification in addition to ventilation.

Inasmuch as ventilation is such a necessary factor aboard a ship, the majority of recently built vessels have been utilizing the air distribution system for heating purposes.

A ship is a self-contained structure quite likely to be away from repair ports for long periods. Adequate spare parts, therefore, form an integral part of equipment furnished. The same type of equipment should be used in as many places as possible throughout the ship, in order to reduce the number of spare parts to be carried.

Preliminary system design is simplified by uniformity of conditions which apply to most ships. Among such conditions are: (1) the necessity for the vessel to supply its own power, (2) the availability of an unlimited supply of low cost steam at suitable pressure, (3) limitations of available space and permissible weight.

The problem of heat transfer and insulation must be given careful consideration. The thermal conductivity of ship building material, such as steel, copper and brass, is many times the value of building material used ashore. The length of ducts between heat sources and fans necessitates extra duct insulation. Hull insulation must be of high quality, with

attention given to fireproofness, low density, low thermal conductivity, ruggedness, vermin resistance, and ease of application. Board types are most common.

Duct insulation must have the same characteristics as hull insulation. Semi-rigid and rigid board are most common. Corrugated asbestos is not used because in the presence of moisture, it tends to disintegrate. There is a growing use of natural cork on chilled air ducts because of great difficulty in applying an adequate vapor seal due to space limitations.

SHIP HEATING AND VENTILATING

It is usually most economical in weight and space to use steam duct heaters for heating spaces served by mechanical supply systems. Spaces which do not have mechanical supply, or do not require ventilation in cold weather, are heated by steam convectors or, where the load is large, by unit heaters. Ventilation air, except that supplied to auxiliary and main machinery spaces, is usually preheated to temperatures of 50 to 70 F. No recirculation is used in ventilation and heating systems, but a manual reduction (25 to 50 percent) of air quantity is made during the heating cycle. All heaters are automatically controlled, and preheaters are designed and installed to minimize possibility of freezing of condensate. Preheaters are frequently located close to the outside air intake in order to conserve insulation and, for the same reason, zone reheaters are located as close as possible to each zone. Where a reheater serves only one space, it is commonly located in the space.

TABLE 1. DESIGN CONDITIONS FOR SHIPS

AREA	OUTSIDE DESIGN TEMPERATURES			INSIDE CONDITIONS	
	Heating	Ventilating	Cooling	DB & R.H.	Effective Temp.
	F	F	F	F %	F
Living Quarters	0	95	95(DB) 80(WB)	80 50	73–74
Public Spaces	0	95	95(DB) 80(WB)	80 55	73½–74½
Naval Vessels	+10	88(DB) 80(WB)	88(DB) 80(WB)	85 50	75–78

Combinations or variations of duct type and convection or radiant heaters are used, depending upon basic design requirements, such as weight and space limitations, and the economic justification of the cost of the type selected.

Because of many different requirements of various spaces aboard ship, some design temperatures and humidities are given in Table 1. The resulting quantities of air should be checked against typical heating and ventilation practices for ships.*

Machinery Spaces

The prime purpose of machinery space ventilation is to maintain a habitable temperature for the operating personnel. It is more practicable to use *spot cooling* of personnel at working areas than to attempt to obtain uniform ambient temperature. The permissible temperature rise (above

* See Ventilation and Heating of Maritime Commission Ships, by J. W. Markert (*Heating and Ventilating*, Feb. 1943, p. 333).