will not sink even when the hull is pierced in one or more places, by collision, torpedoing, or other causes. Every effort is made to avoid penetration of watertight subdivisions and, where openings must be cut, special closures are fitted.

The ship's interior is fitted with decks and flats (partial decks). The deck heights (floor heights) in cargo spaces generally vary from 9 to 30 ft and in living quarters from 7½ to 9 ft. Usually in main machinery spaces, the entire depth is subdivided only by a few flats, with gratings provided where necessary to service equipment.

There is very little unassigned space on a ship, and many studies must be made to ascertain the arrangement of equipment which will best suit the conditions. Cuts in structural members must be limited in number and size. Lack of headroom and floor space often causes unsatisfactory drainage, inaccessibility, and other undesirable conditions. Air conditioning equipment must be located where it will interfere least with basic arrangements of major equipment and construction, and with ship stability.

FACTORS AFFECTING DESIGN

A ship is a self-contained structure capable of operating in a wide range of climates. The ventilation of most ships is designed on the basis of an 88 F outside dry-bulb temperature. Heating facilities on merchant vessels are invariably selected for an outside temperature of 0 F dry-bulb, although ships encountering only moderately cold weather in normal service are designed for higher outside temperatures. Designers of naval vessels commonly use 10 F outside dry-bulb temperature for estimating heating loads.

Cooling loads for most comfort systems are based on 95 F dry-bulb and 80 F wet-bulb temperatures. Inside conditions equivalent to from 73 to 75 effective temperature are used. An 81 F dry-bulb temperature and 50 per cent relative humidity are generally used for the design of comfort systems, except those serving public spaces having relatively large latent loads. These are designed for 80 F dry-bulb and approximately 55 per cent relative humidity. Bracket fans are supplied in many instances. Systems on naval vessels are designed for higher effective temperatures, and outside design temperatures of 88 F dry-bulb and 80 F wet-bulb are used.

Preliminary design is simplified by the uniformity of the 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 cooling water, (3) the all-year-round supply of low cost steam at suitable pressure, (4) the drastic restriction of shipbuilding materials because of strength requirements, corrosion resistance, and fire hazard, and (5) the limitation of available space and permissible weight. These limitations require precise layouts, with minimum design safety factor, and unusual attention to design details and to means for balancing systems.

The relation between supply and exhaust ventilation depends on the type of space, and the relation of the space to the weather. Positive means for supply and exhaust must be provided. Ventilation through doors, windows, hatches, etc., should not be considered in the basic design.

It is usually most economical to heat spaces served by mechanical supply systems with steam duct heaters, in order to save weight and space. Spaces which do not have mechanical supply or do not require

ventilation in cold weather are heated by steam convectors, or unit heaters where the load is large. Ventilation air, except that supplied to auxiliary and main machinery spaces, is usually preheated (50 to 70 deg). In addition, where blast heating is used, zone reheaters are provided. No recirculation is used on combined ventilation and heating systems, but manual speed reduction (25 to 50 per cent) is provided during the heating cycle. All heaters are automatically controlled, and preheaters are designed and installed to minimize the possibility of freezing of condensate.

The usual combinations or variations of duct type and convection or radiant heaters are used, depending on basic design requirements, such as weight and space limitations, and economic justification for refinements.

VENTILATION REQUIREMENT FOR VARIOUS TYPES OF SPACE

In the paragraphs which follow the most important considerations are given for the treatment of the various spaces, but the resulting quantities of air should in all cases be checked with those shown in Table 1.

Machinery Spaces

The prime purpose of machinery space ventilation is to maintain a habitable temperature for the operating personnel. Of secondary importance is the necessity for maintaining temperature conditions satisfactory for the successful operation of machinery. 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 at working stations is usually about 15 deg while the over-all temperature rise is usually between 30 and 50 deg.

These spaces must be exhausted adequately, preferably by mechanical means. Every attempt should be made to remove air at or close to heat sources. The capacity of the mechanical exhaust systems should take into consideration the expansion of the supply air, and should be sufficient to insure an indraft through access openings to the space.

Normally, heat is not required for machinery spaces except for those fitted with electrically operated equipment, which may remain inactive during periods while in port. Such spaces should be equipped so as to be heated to about 50 F during such periods.

Living Spaces

The minimum quantity of air required for any space which is fitted for sleeping or office work, including hospital space, should be that which will limit the temperature rise over the outside air conditions to not more than 10 deg (a rise of 7 deg is more satisfactory if practicable), or a minimum of 30 cfm per person, whichever is the greater. For spaces fitted for eating, recreation, or manual work the rise may be taken at 10 deg with not less than 20 cfm per person. The same requirement applies to mechanical exhaust, although natural exhaust may be used where only a short run of duct exists.

Heat should be furnished to maintain the following temperatures:

Staterooms, Berthing, Messing and Office Spaces	70 F
Working Spaces and Shops	60 F
Hospital Spaces	75 to 78 F