portholes, windows, and skylights is greatly restricted because they must be fitted with light-excluding devices.

Much of the cooling and ventilation that is accomplished by natural means ashore must be handled by mechanical means afloat. Space does not exist for the large ventilation trunks required for natural ventilation. Also, because of the restricted space and shipbuilding materials the heat quantities that must be dissipated by ventilation air are often greater than would be required for a similar shore installation. Mechanical ventilation is not merely desirable, but is absolutely necessary in many shipboard spaces to enable the crew to operate the vessel. Furthermore there are numerous spaces which must be ventilated to prevent the accumulation of objectionable, combustible and toxic gases. Shipboard equipment must also be reliable inasmuch as specialized servicing facilities are not available at sea, and failure during an emergency may jeopardize the vessel's safety. Experience has demonstrated that *simple* and *foolproof* heating and ventilating arrangements are essential for satisfactory service. Ventilation systems on ships must be designed to operate in heavy weather with little or no attention, and to resist the efforts of unauthorized personnel to readjust the heat or air distribution. Also, they must be laid out in such a manner that the watertight and fireproof integrity of the vessel is not impaired.

Contrary to the impression among some engineers and designers, that there is a basic difference between marine and shore installations in the application of heating, ventilating and air conditioning arrangements, the same fundamentals apply to both shore and shipboard applications. The air capacity handled by a system ashore will equal the capacity that an identical system will deliver afloat. The same laws of heat transfer apply, and the same heat balance must be maintained in the human body. The only variation between ship and shore applications is that emphasis is placed on different practical aspects of the design.

SHIP CONSTRUCTION FEATURES

The seaworthiness of the vessel is increased by subdividing the main watertight hull space into a number of watertight compartments. This is usually done by providing transverse watertight structures (bulkheads) so located along the ship's length that the vessel will not sink even when the shell is pierced in one or more watertight compartments, by collision, torpedoing, or other causes. It is obvious that the watertightness of these bulkheads is very important, particularly under war conditions. Every effort is made to lead ventilation ducts so that they do not pass through such structures. Where openings must be cut for ventilation or other purposes, special watertight closures are fitted to protect the watertightness of the bulkheads.

In addition to the obstructions caused by the main transverse bulkheads, the ship's interior is fitted with decks and flats (partial decks) that are spaced to suit the use to which the space is put. The deck height (floor height) in cargo spaces generally varies from 9 to 30 ft. This height in living quarters varies 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 the equipment.

Bulkheads, shell, and decks are designed to suit structural as well as watertight requirements of the vessel, and consequently, the designer must always contend with beams, stiffeners, stanchions and brackets.

Fig. 1 indicates the arrangement of a typical cargo vessel, and shows the main transverse watertight bulkheads, decks, structural members, and many other pertinent characteristics. Living quarters are usually located on and above the weather deck, this custom being based on the assumption that better natural air and light are available in this location. It is obvious that the upper 'tween deck and other spaces can be conveniently used for additional living and working spaces, but that natural ventilation is far less effective in this case.

The foregoing description mentions some of the limits and natural boundaries which affect the design and layout of ship ventilation and heating systems. It should be added that there are also equipment, wireways, and miscellaneous piping which must be considered. Since there is very little unassigned space, fan rooms are usually quite congested 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 often causes poor aspect ratios, inaccessibility, and other undesirable conditions. It therefore follows that the design of a ship's heating and ventilating system is far more than a theoretical calculation. A good designer must be familiar with all phases of ship construction and operation in order to provide sufficient and efficient ventilation and heating, and to locate the equipment where it will interfere least with basic arrangements, major equipment, stability, and other important factors.

FACTORS AFFECTING DESIGN

A ship may be favorably compared to a *floating hotel*. Its make-up includes living accommodations, dining rooms, shops, power plants, commissary spaces, etc., all of which must be so arranged and maintained as to make it self-sustaining for long periods of time. In contrast to a hotel, however, a ship may, on a single cruise, move from artic to tropical climates. On the other hand, it may be built to operate only in one single locality. It is therefore necessary to assume maximum and minimum design air temperature condition based on the intended use of the vessel so that adequate cooling and heating may be provided. For vessels designed to operate generally in all parts of the world, a maximum summer temperature may be taken as 88 F and a minimum winter temperature as 10 F. For other ships, those which spend long periods in port or in inland waters, the maximum and minimum temperatures may be taken as 90 and 0 F respectively.

Preliminary design of heating and ventilating installations aboard ship is simplified by the uniformity of the conditions which apply to all ships. Among such conditions are (1) the necessity for the vessel to supply its own power, (2) the availability of an unlimited supply of sea water, (3) the drastic restriction of shipbuilding materials because of strength requirements, corrosion resistance and fire hazard, and (4) the limitation of available space and permissible weight. On the other hand, shipboard space, weight, and power limitations require precise layouts with mini-