mum design safety factors, and this necessitates unusual attention to design details. Particular attention should be given also to the adjustment of a system after installation, because designed air quantities are usually close to the minimum acceptable and therefore, improper balance will result in unsatisfactory conditions in some spaces.

Each space aboard ship must be treated in accordance with the particular requirements of its use. The ventilation of most spaces is determined by empirical calculations. The quantity of air supplied must be not less than that which satisfies (1) maximum allowable temperature rise, (2) minimum allowable fresh air per person, and (3) permissible air change, named in order of importance.

The present practice of various ship designers may be to supply the quantity of air which satisfies only one of these requirements, but the most satisfactory ship ventilation will result from the use of that quantity which is large enough to satisfy all three.

When heating and cooling loads are estimated, the cooling effect of the water through which the vessel is sailing must be considered if the space is at or below the waterline. Maximum and minimum water temperatures of 85 and 35 F are usually used for such calculations. This factor is important enough to justify the omission of ventilation from certain spaces which have only small heat gains and do not require fresh air for other purposes.

The relation between supply and exhaust ventilation depends on the type of space, and the space's relation to the weather. In any case, it should be remembered that positive means for supply and exhaust must always be provided. Where natural ventilation is anticipated, infiltration and exfiltration via open doors, windows, etc., cannot always be considered adequate for this purpose.

In addition to the ventilation requirements, but closely related to and usually forming an integral part of the study, is the manner in which heating shall be furnished for cold weather conditions. In all spaces which are provided with mechanical supply ventilation, where heat is also required, the simpler method and most economical from standpoint of weight is that in which duct type or blast heaters are fitted in the ventilating systems. Where this type of heating is furnished, convectors or radiators should be provided for spaces requiring heat but not furnished with mechanical supply ventilation. The most satisfactory arrangement for this method of heating, except where individual space control is essential, is zone heating. To accomplish this, the ventilation supply system, with the fan operating at slow speed (usually about 50 to 70 per cent delivery) passes the air over a preheater which raises the air to a temperature of about 40 to 60 F. This preheated air is then passed through the system and thence through one or more reheaters which are located in the ducts and so arranged that each serves a group of spaces which possess the same or similar heating requirements. It may be necessary to slightly revise the individual space air quantities, which have been determined on the basis of summer cooling, in order to bring them in line with the reheat or delivery temperature. In some cases central heating is used. By this arrangement all the air needed for heating is passed through the preheater and reheater fitted in series. This system

has the disadvantage of affording poorer thermostatic control and cruder heating properties. In all installations of duct type heaters, however, care must be taken in the first stage of heating (preheater) to provide protection against freezing, either by heater design or compensating automatic valve control. Of course, many of the usual combinations or variations of duct type and convection or radiant heaters may be used with varying degrees of satisfaction, depending on basic design requirements such as weight and space limitations and economic justification for refinements.

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 preserving temperature conditions satisfactory for the successful operation of machinery, particularly of that designed for certain maximum ambient temperatures. High dissipation of heat, from high temperature steam equipment or from high powered electrical installations, make it more practicable to use *spot cooling* of working areas, rather than to attempt to obtain uniform ambient temperature. The permissible temperature rise at working stations is usually about 15 F while the overall temperature rise is usually between 30 and 50 F.

When the necessary quantity of air has been determined, the ventilation arrangements should be designed so that all of this air will be distributed to locations where the personnel are to be stationed under operating conditions, thus giving them the maximum benefit from the cool air so introduced. This consideration is of vital importance because it must be remembered that the physical well being and alertness of the crew are more important than the operating ambients of the machinery; and by such installation the personnel receives the air before it becomes heated to the temperatures satisfactory for the equipment.

In addition to the air supply, these spaces must be exhausted, preferably by mechanical means. Every attempt should be made to remove air at or close to heat sources so that the mixing of ambient air with that which has been heated to a higher temperature will be at a minimum. The quantity or capacity of the mechanical exhaust systems should take into consideration the expansion of the supply air because of heating and should be also sufficient to insure an indraft through access openings to the space. Generally, in order to accomplish this, the quantity of mechanical exhaust should be about 120 per cent of the supply. In many installations, the combustion air for diesel engines and boilers is taken directly from the machinery space and serves as a partial mechanical exhaust system.

Normally, heat is not required for machinery spaces except for those fitted with electrically operated equipment, which may remain inactive