heat regulatory center may be temporarily deranged following an anesthetic, brain injury, or after an overdose of barbiturate. Loss of fluids and electrolytes is another influencing factor. In these circumstances there is great benefit from assisting the body in cooling, and this can best be done in a cool room of low relative humidity where conditions for heat loss are ideal. This measure is also valuable in controlling temperature of patients with various acute febrile diseases.

Frequently from 50 to 75 percent of personnel aboard naval vessels operating in tropical waters are afflicted with heat rash to a degree that interferes with rest and sleep. In carefully controlled experiments it was possible to produce a fulminating type of rash in all men living continuously at an effective temperature of 85 (90 F dry-bulb and 83 F wet-bulb). In the control group, 12 out of 24 hr were spent in a relatively cool atmosphere of 75 ET (80 F dry-bulb, and 70 F wet-bulb). These men either remained free from heat rash, or occasionally developed a mild form. Thus, intermittent cooling to a degree that prevented sweating in men at rest, eliminated a serious handicap to good performance of duty.

In both laboratory tests and aboard hospital ships a relatively cool living environment of 76 to 78 ET provided an atmosphere conducive to rest and sleep without excessive sweating. Berthing spaces tended to have extremely low odor levels. Motivation, initiative and alertness, in contrast to the usual irritability and lack of incentive incident to residence in tropical climate, were maintained.

Little has been done, however, to obtain practical methods for application of air conditioning under heavy heat loads and on the enormous scale that would be needed to modify life in the tropics. Part time cooling of personnel to promote rest and sleep in tropical areas would provide a prophylactic measure of great potential importance.

TREATMENT OF DISEASE

In the past few years considerable progress has been made in using air conditioning as an adjunct in the treatment of various diseases. Among the important applications are those in operating rooms, nurseries for premature infants, maternity and delivery rooms, children's wards, clinics for arthritic patients, heat therapy, cold therapy, oxygen therapy, X-ray rooms, and the control of allergic disorders.

Normal individuals may be subjected to considerable strain in adjusting to hot humid conditions. Heat loss by radiation is reduced, as is loss by evaporation of sweat. Individuals with certain disease processes are at a still greater disadvantage since they may also have difficulty in the transport of heat from the interior to the surface of the body via the circulation.

Patients with thyrotoxicosis tolerate hot humid conditions or *heat waves* very poorly. Their metabolism is high, and therefore their heat production is excessive. They may be unable to eliminate heat from the body surface as rapidly as it is produced and transported to the skin. They develop hyperthermia or fever, and a tachycardia or rapid heart rate. The demand on the circulation for transport of heat from the interior of the body to the skin surface is increased. The increased body temperature leads to increased cell metabolism, and in turn to still greater heat production. This vicious cycle may threaten life if the cardio-vascular or transport mechanism breaks down. A cool, dry environment favors the loss of heat by radiation and evaporation from the skin, and may save the life of the patient.

Cardiac patients may be unable to maintain the circulation necessary to insure normal heat loss. Recently the importance of air conditioning hospital wards and rooms of cardiac patients, particularly those with congestive heart failure, has been stressed as a therapeutic measure. It is more important in tropical or subtropical climates. Individuals with head injuries, those subjected to brain operations, and those with barbiturate poisoning may have hyperthermia, especially in a hot environment, due to a disturbance in the heat regulatory center of the brain. Obviously, one of the most important factors in recovery is an environment in which the patient can lose heat by radiation and evaporation, namely, a cool room with dehumidified air.

The patient in shock, or the patient who has had a severe hemorrhage, may have an inadequate volume of circulating blood and be unable to maintain an adequate skin circulation. This may result in heat storage or fever. Patients with extensive skin burns may be unable to lose heat adequately from the limited uninvolved skin surface, and thus develop a fever. They need adequate fluid replacement, saline solution, plasma or blood to expand the circulating blood volume and thereby improve peripheral circulation. A cool environment is valuable in aiding heat loss after adequate skin circulation is established.

A hot dry environment (89.6 F and 35 percent relative humidity) has been used over an extended period for the treatment of patients with rheumatoid arthritis, with reported improvement.

OPERATING ROOMS

The widest application of air conditioning in hospitals is in operating rooms. Complete air conditioning of operating wards is important because winter humidification helps reduce the danger incident to the use of anesthetic gases; summer cooling with some dehumidification tends to eliminate excessive fatigue and to protect the patient and operating personnel; and finally, filtering aids the removal of allergens from the operating room air.

Reducing Explosion Hazard

Explosion hazards in operating rooms increase with the introduction of anesthetic gases and apparatus. Ether administered by the old drop method gives rise to an explosive mixture, but in practice this method is still regarded as comparatively safe. When ether is mixed with pure oxygen, or nitrous oxide in certain concentrations, the explosion hazard may be as great as with ethylene-oxygen, or cyclopropane-oxygen mixtures.

Of the anesthetic gases nitrous oxide alone does not explode but supports combustion. Ether, vinyl ether, ethylene, and cyclopropane are as potentially dangerous as gasoline or illuminating gas in the home. Chloroform does not explode violently in contact with flame, but decomposes to liberate phosgene. All of the anesthetic gases and vapors, except ethylene, are heavier than air. Although the incidence of injury or death from explosion is negligible compared with other hazards in the operating room, the dramatic features surrounding an explosion justify continued investigation to eliminate the hazard.

During the course of ethylene anesthesia, the mixture, usually 80 percent ethylene and 20 percent oxygen, is so rich that the danger of explosion is slight in the immediate vicinity of the face mask, but leakage of ethylene into the

air may result in lower concentrations, and thus introduce a serious hazard. The most dangerous period is at the end of the operation when the patient's lungs and the anesthesia apparatus are customarily *washed out* with oxygen with or without the addition of carbon dioxide. Even when this procedure is omitted, it is difficult in practice to avoid dilution of the anesthetic gas with air during the normal course of breathing following the administration. In either case the mixture would pass through the explosion range and extraordinary precaution is necessary for the safety of the patient and operating personnel.

In a study of 230 anesthetic explosions and fires, 70 percent of the explosions and 60 percent of the deaths were caused by igniting agents other than static sparks. The National Fire Protection Association made certain recommendations for safe practice based on available information in NFPA No. 56, *Code of the use of Flammable Anesthetics* (Safe Practices for Hospital Operating Rooms, June 1959). This code outlines ways and means for eliminating or correcting hazardous conditions which experience and investigation have shown to contribute to the hazards in question. They are divided into four parts: Part I, General, deals with the nature of the hazards; Part II, Construction and Equipment, deals with physical standards for features incorporated into the construction and equipment of the surgical suite; Part III, Administration and Maintenance, contains requirements for administration and maintenance; and Appendix A, contains explanatory statements to assist in understanding this code. The requirements and recommendations are interdependent and each will be ineffective unless coordinated with the other. To approach complete success in the prevention of anesthetic explosions, all persons—the surgical staff, the nursing staff, the maintenance staff and administrative personnel—must be educated and periodically reminded of the explosive nature of combustible anesthetic agents.

Experience has shown that neither high humidity nor intercoupling devices have eliminated the danger from static electric discharge. The removal of gas concentrations from the operating table area, by means of specially devised exhaust ventilation, should be thoroughly tested. Portable duct systems as installed aboard ship should be acceptable. Serious explosions can occur in a closed system, but proper precautions will reduce this hazard to a minimum.

A comprehensive study of the explosion problem and of the general causes and prevention of operating room hazards, by the University of Pittsburgh, the ASHAE Research Laboratory, and the U. S. Bureau of Mines has led to a fruitful attempt to eliminate the explosive range of cyclopropane, one of the best but most difficult gases to handle. The use of helium as a diluent in the total gaseous mixture controls the oxygen concentration by displacement and, because of its flame quenching properties, it is the ideal gas for this purpose. In addition, a gaseous mixture containing helium is more difficult to ignite by electric discharges, and this quality increases the safety factor of anesthetic administration.

Operating Room Conditions

Little is known about optimum air conditions for maintaining normal body temperatures during anesthesia and the immediate post-operative period. An anesthetized patient displays dilation of blood vessels in the skin resulting in profuse sweating and (it has been believed) inability to regulate body temperature. From this it was concluded that all anesthetized patients suffered considerable heat loss, although there may be little more than 0.8 F deg variation in the rectal temperature during the course of the operation. The severe physiological effects, such as excessive sweating and rapid pulse, of high operating room temperatures on attendants and patients during the hot months signify the need for proper cooling. Statements of surgeons who operate in both air-conditioned and non-air-conditioned rooms strongly indicate that the recuperative power of the patient is greater when operated upon in air-conditioned rooms.

Although the comfortable air conditions for the operators are not identical with those for the patient, it is usually not difficult to compromise within a range of 50 to 60 percent relative humidity and 72 to 80 F temperature. It is generally reported that dry-bulb temperatures of 76 to 78 F with 55 percent relative humidity not only furnished comfort for the operating room workers, but apparently prevented exhaustion of patients as evidenced by rapid convalescence in the recovery ward. Additional heat may be furnished to patients locally or by suitable covering, according to body temperature in individual cases.

In the control of airborne infection in the operating room, the prevention of dispersal of infectious materials into the air, control of dust, and proper ventilation supersede attempts to remove or kill pathogenic organisms. The bacterial content of conditioned operating rooms is generally lower than that of non-conditioned rooms.

Bacterial counts aboard an air-conditioned submarine were found to be exceptionally low and not cumulative with time, although all of the air was recirculated for more than 12 hours without replenishment. The removal of bacteria by the process of air cooling and condensation of moisture out of air, merits further study.

The degree of air contamination can be reduced by proper ventilation if velocity of air over the floor does not exceed 50 fpm. Research is in progress on the use of filtered air flowing through a system of mechanical cleaners which protect the patient against infection from attendants, and from bacteria-containing air in the corridor or ward.

Operations are frequently postponed on allergic patients during asthmatic manifestations through fear of complications. The removal of airborne allergens, therefore, is in some cases an important function of the air-conditioning system in preparing patients for operation.

The best practice in air conditioning hospital operating rooms is the use of all outdoor air with arrangements for preheat, reheat, and the control of humidity, coupled with a mechanical exhaust system that removes the air from both the high and low levels of the operating room. However, there is some evidence of lack of any cumulative effect on bacteria count due to recirculation of air through an air conditioning unit in operating rooms. This consideration and the fact that relief cooling frequently provides improved, if not ideal conditions, has led to the use of central systems employing 50 percent recirculated air. Also, perhaps as a recognition of practice, the NFPA No. 56 outlines the conditions under which room air conditioners may be used in operating rooms. These conditions are so written in the pamphlet that the recommendation of separate mechanical ventilation of such rooms is clearly inferred.

The use of room air conditioners for relief cooling of mechanically ventilated rooms is now considered permissible when used with the necessary precautions. These precautions generally involve costly modification of standard room air conditioners. The use of larger systems employing 50 percent