come from the surgical team and as a result of their activities during an operation.[13]

During an operation most members of the surgical team are in the vicinity of the operating table which creates the undesirable situation of concentrating contamination in this highly sensitive area. Although some studies[14,15] have been conducted on the effectiveness of turbulent air movement and displacement air movement systems in the removal of contamination from the operating site, there is insufficient information at present upon which to base a preference for wall- or ceiling-mounted air inlets which produce turbulent air movement or perforated ceiling plenums which produce displacement or piston action. In addition, these studies have indicated that the use of more than one exhaust outlet located on individual walls will improve the removal rate of contamination.[14,15] A minimum of two exhaust outlets located on opposite walls at floor level is recommended. A minimum ventilation rate of 15 room volumes of air per hour is recommended to provide for dilution of the concentration of contamination and an acceptable rate of removal. Some investigators have recommended 20 room volumes of air for this purpose.[14,15]

Operating rooms. Because the operating rooms in the average hospital in the United States are not in use more than 8 hr per day, the air-conditioning or ventilating system may be designed to permit the recirculation of the air during the time when the operating rooms are not in use. Such systems will permit recirculation of the air without costly renovation if as a result of proposed research, it is determined that an acceptable quality of air with recirculation can be maintained during surgery.

Although dramatic results relative to air disinfection of operating rooms by irradiation have been reported,[16,17] this method of disinfection has not been generally applied. The reluctance to use irradiation may be accounted for by such factors as special designs required for installation, protective measures necessary for patients and personnel, constant vigilance relative to lamp efficiency, and the required maintenance.

The following conditions are recommended for operating, cystoscopic, and fracture rooms:

1. Temperatures of 70 to 76 F.
2. Relative humidity of 50 percent.
3. Ventilation rate of 15 room volumes of air per hour.
4. Recirculation of air not permitted during the time the operating rooms are in use.
5. Positive air pressure of 0.1 in. of water within the operating rooms relative to the pressure of any adjoining rooms.
6. Manometer installed at the surgical supervisor's desk to permit air pressure readings of all rooms.
7. Exhaust air removed from each room at several locations located near the floor.
8. Use of high-efficiency filters on the air supply to the rooms.
9. Entire installation to conform to the requirements of NFPA No. 56, *Code for the Use of Flammable Anesthetics*, which pertain to explosion hazards.

In order to provide maximum safety for the patient and to conform to the above recommendations, a separate fan-coil system will be required to serve the operating rooms. The controls governing the recirculation of the air of the operating rooms should be conveniently located for use by the surgical supervisor. These controls should have a visual signal to indicate whether the air of a room is being recirculated.

Recovery rooms. Post operative recovery rooms used in conjunction with the operating rooms should have approximately the same temperature and humidity as the operating rooms. As residual anesthesia odor and nausea resulting from anesthesia sometimes create an odor problem in recovery rooms, a ventilation rate of 4 room volumes of air per hour is recommended. A positive air pressure relative to the air pressure of adjoining areas should be provided.

Anesthesia storage room. The anesthesia storage room, in the surgery, should be located on an outside wall to facilitate gravity ventilation by means of openings located in the wall at floor and ceiling levels. Gravity ventilation at a rate of 2 room volumes of air per hour is required by NFPA No. 56, *Code for the Use of Flammable Anesthetics*.

Central sterilizing and supply. Used and contaminated utensils, instruments, and equipment are brought to this unit for cleaning and sterilization prior to reuse.

This unit usually consists of a cleaning area, a sterilizing area, and a storage area where supplies are kept until requisitioned. Where these areas are in one large room, it is desirable, in so far as possible, to maintain an air flow from the clean storage and sterilizing areas toward the contaminated cleaning area for exhaust.

Temperature and humidity should be within the comfort range, and a ventilation rate of 2 room volumes of air per hour with a balanced air pressure relative to the air pressure of adjoining areas.

The following features are important in the central sterilizing and supply unit:

1. Insulation of sterilizers in these areas will reduce heat load.
2. Sterilizer equipment closets should be amply ventilated to remove excess heat.
3. Air exhaust grilles or hoods, located immediately above sterilizer doors, will assist in voiding excess heat and steam and will protect wall and ceiling finishes.

Obstetrical Department

The systems designed for the delivery suite should conform in all respects to the requirements for surgical suites.

Emergency Department

This department, in most instances, will be the most highly contaminated area in the hospital, as a result of the soiled condition of many patients upon arrival and the relatively large numbers of persons accompanying them. The ventilation, temperature, and humidity requirements of the operating rooms in this department will be the same as those of the operating rooms in the surgical suites. Waiting rooms will require a minimum ventilation rate of 4 room volumes of air per hour. Temperatures and humidities of offices and waiting space should be within the comfort range.

Service Department

Service areas include dietary, housekeeping, mechanical, and employees' facilities. These areas are not usually cooled, but adequate ventilation is important to provide sanitation and a wholesome environment. Ventilation of these areas cannot be limited to exhaust systems only; provision for supply air must be incorporated in the design. The best designed exhaust system may prove ineffective without an adequate air supply. Experience has shown that reliance on open windows results only in dissatisfaction, particularly during the heating season. The incorporation of air- to air-heat exchangers in the general ventilation system offers possibilities for economical operation in these areas.[18]

Dietary facilities. In this area the main kitchen, bakery, dietitian's office, dishwashing room, and dining space will require care in design.

Kitchen ventilation should conform to local codes, but in the absence of such codes, a minimum of 20 room volumes of air per hour is recommended.

Such cooking equipment as broilers, ovens, ranges, kettles, and steamers are generally grouped for efficient utilization. The area serving this equipment should be vented through a hood to remove heat, odor, and vapors. The ventilation rate through the hood will vary according to design and mounting height,[19] but a rate of 100 cfm per sq ft of hood opening is very often used with conventional hoods mounted to provide a clearance of 6½ ft from the floor. Hoods over cooking equipment should be equipped with grease filters to remove any grease from the vapors before they enter the duct system. Condensed grease in duct systems is a potential fire hazard.

Safety measures should be incorporated in the design to protect the duct system against fires originating over the stove. Such protection can usually be provided by one or more of the following methods: an emergency steam line to the throat of the hood at the duct connection for smothering action, CO_2 outlets at the hood perimeter, or fusible link dampers in the duct.

The hood exhaust fan should be selected to provide the air volume required for the maximum recommended resistance of the filter. These resistances will increase greatly as the filters become fouled. The location of the kitchen air supply inlets relative to the hood exhaust is important to eliminate the possibility of short circuiting between supply and exhaust. Where dietary facilities are located within the hospital structure, exhaust ventilating air should be discharged above the roof.

The dietitian's office is often located within the main kitchen or immediately adjacent to it. It is usually completely enclosed to insure privacy and quiet and will therefore require an air supply inlet and an exhaust outlet in the room.

The dishwashing room should be enclosed and ventilated at the same rate as the kitchen, to reduce the noise level and to confine the contamination and the steam and heat liberated by equipment. Depending upon the size of the area, all or the greatest part of exhaust air may be taken off through the dishwasher hood. Exhaust ductwork should be noncorrosive and watertight to handle condensation of steam and should be graded to drip into a convenient drain.

Dining space. The ventilation of this space should conform to local codes. The reuse of dining space air for ventilation and cooling of food preparation areas in the hospital is not recommended. Where cafeteria service is provided, serving areas and steam tables are usually hooded. The air handling capacities of these hoods will be somewhat less than those required for the cooking area.

Housekeeping facilities. Of these facilities, the soiled linen rooms and laundry only will require special attention.

The soiled linen storage room, used as a storage space prior to laundering, is subject to odors from soiled linens and will require ventilation at a rate of not less than 8 room volumes of air per hour. A negative air pressure relative to adjoining areas should be maintained.

Laundry ventilation should conform to local codes, but in the absence of such codes, a minimum of 10 room volumes of air per hour is recommended.

The design of laundry ventilation systems seldom receives the study necessary to provide proper safeguards against the recontamination of linen by airborne organisms during the cleaning process.

The activities associated with sorting linen and loading washers are reported to add heavily to the contamination of the laundry air. This contaminated air is then drawn through extractors and tumblers where the linen acts as a filter and collects the organisms. It has been reported that many of these organisms survive the heat of the ironing process and are returned to the hospital on the clean linen.[20]

To reduce the contamination of the laundry air, it is recommended that the sorting of linen be done in an enclosed area separated from the main laundry. This area will require a ventilation rate of 8 room volumes of air per hour and should be maintained at a negative pressure relative to adjoining areas.

Of the various pieces of laundry equipment, the flatwork ironer produces the greatest amount of heat and vapor. A usual practice is to install a canopy over the ironer to concentrate and remove the heat immediately at this point. Most laundry layouts permits a large part of the exhaust to be discharged through the canopy, although some exhaust should also be provided over the washers to remove heat and vapors originating from this equipment. The exhaust from tumblers should be carried away by a system independent of the general exhaust system. This exhaust may require lint filters in addition to those on the tumbler. All laundry exhaust should be carried to a point above the roof or to an outlet where it will not be obnoxious to other areas of the hospital. It should not be in close proximity to fresh air ventilation intakes.

Fresh air supply is a requisite to good ventilation of this area and distribution designed to avoid short circuiting is important. The design may lend itself to the use of air-to-air heat exchangers for economy of operation.[18]

Mechanical facilities. Boiler rooms should be provided with proper ventilation. Exhaust ventilating fans which compete with the boilers and the chimney for an insufficient air supply are not uncommon. The air supply to boiler rooms should be computed on the basis of providing both comfortable working conditions and the air quantities required for maximum combustion rates of the particular fuel used. Boiler and burner ratings will establish maximum combustion rates, and the air quantities can thus be computed according to the type of fuel.

Maintenance shops, such as carpentry, machine, electrical, and plumbing shops present no particular ventilation difficulties. Proper ventilation of paint shops and paint storage areas is very important because of fire hazard, and should conform to all applicable codes.

Employees' facilities. These rooms should be treated to provide comfort and to conform to local codes.

REFERENCES

[1] S. M. Farrer and C. M. MacLeod: Staphylococcal infections in a general hospital (*The American Journal of Hygiene*, July 1960, p. 35).

[2] V. W. Greene *et al:* Air-handling systems must be planned to reduce the spread of infections (*Modern Hospital*, August 1960, p. 136).

[3] R. E. O. Williams *et al: Hospital Infections* (Lloyd-Luke Medical Books Ltd., London, 1950).

[4] U. S. Public Health Service, Communicable Disease Center: Hospital acquired staphylococcal disease (*Proceedings*, National Conference on the subject, sponsored also by National Academy of Sciences and National Research Council, Atlanta, Ga., September 1958).

[5] R. G. Bond and G. S. Michaelson: *Bacterial Contamination from Hospital Solid Waste* (*Progress Report*—National Institutes of Health Research Grant E 3019 (C1), January 1961).

[6] American Public Health Association, Committee on Research: The present status of the control of airborne infections (*American Journal of Public Health*, January 1947, p. 13).

[7] American Public Health Association, Committee on Research: Progress in the control of airborne infections (*American Journal of Public Health*, May 1950, p. 82).