CHAPTER 7

HEALTH CARE FACILITIES

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CONTINUAL advances in medicine and technology necessitate constant reevaluation of the air-conditioning needs of hospitals and medical facilities. Medical evidence has shown that proper air conditioning is helpful in preventing and treating many conditions, but the relatively high cost of air conditioning demands efficient design and operation to ensure economical energy management (Demling and Maly 1989; Fitzgerald 1989; Murray et al. 1988; Woods et al. 1986).

Health care occupancy classification, based on the latest occupancy guidelines from the National Fire Protection Association (NFPA) Life Safety Code®, should be considered early in project design. Health care occupancy is important for fire protection (smoke zones, smoke control) and for future adaptability of the HVAC system for a more restrictive occupancy.

Health care facilities are increasingly diversifying in response to a trend toward outpatient services. The term **clinic** may refer to any building from the ubiquitous residential doctor's office to a specialized cancer treatment center. Prepaid health maintenance provided by integrated regional health care organizations is becoming the model for medical care delivery. These organizations, as well as long-established hospitals, are constructing buildings that look less like hospitals and more like luxury hotels and office buildings.

For the purpose of this chapter, health care facilities are divided into the following categories:

- Hospital facilities
- Outpatient health care facilities
- Nursing facilities
- Dental care facilities

The specific environmental conditions required by a particular medical facility may vary from those in this chapter, depending on the agency responsible for the environmental standard. Among the agencies that may have standards and guidelines for medical facilities are state and local health agencies, the U.S. Department of Health and Human Services, Indian Health Service, Public Health Service, Medicare/Medicaid, U.S. Department of Defense, U.S. Department of Veterans Affairs, and Joint Commission on Accreditation of Healthcare Organizations (JCAHO). The American Institute of Architects (AIA 2006) requires the owner to provide an Infection Control Risk Assessment (ICRA) and prepare Infection Control Risk Mitigation Recommendations (ICRMR). The ICRMR and ICRA are then to be incorporated in the contract documents by the design professional. Therefore, it is advisable to discuss infection control objectives with the hospital's infection control committee.

The general hospital was selected as the basis for the fundamentals outlined in the first section, Hospital Facilities, because of the variety of services it provides. Environmental conditions and design criteria apply to comparable areas in other health facilities.

The general acute care hospital has a core of critical-care spaces, including operating rooms, emergency rooms, delivery rooms, and a nursery. Usually the functions of radiology, laboratory, central sterile, and pharmacy are located close to the critical care space. Inpatient nursing, including intensive care nursing, is in the complex. The facility also incorporates a kitchen, dining and food service, morgue, and central housekeeping support.

Criteria for outpatient facilities are given in the second section. Outpatient surgery is performed with the anticipation that the patient will not stay overnight. An outpatient facility may be part of an acute care facility, a freestanding unit, or part of another medical facility such as a medical office building.

Nursing facilities are addressed separately in the third section, because their fundamental requirements differ greatly from those of other medical facilities.

Dental facilities are briefly discussed in the fourth section. Requirements for these facilities differ from those of other health care facilities because many procedures generate aerosols, dusts, and particulates.

AIR CONDITIONING IN DISEASE PREVENTION AND TREATMENT

Hospital air conditioning plays a more important role than just the promotion of comfort. In many cases, proper air conditioning is a factor in patient therapy; in some instances, it is the major treatment.

Studies show that patients in controlled environments generally have more rapid physical improvement than do those in uncontrolled environments. Patients with thyrotoxicosis do not tolerate hot, humid conditions or heat waves very well. A cool, dry environment favors the loss of heat by radiation and evaporation from the skin and may save the patient's life.

Cardiac patients may be unable to maintain the circulation necessary to ensure normal heat loss. Therefore, air conditioning cardiac wards and rooms of cardiac patients, particularly those with congestive heart failure, is necessary and considered therapeutic (Burch and Pasquale 1962). 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. An important factor in recovery is an environment in which the patient can lose heat by radiation and evaporation: namely, a cool room with dehumidified air.

A hot, dry environment of 90°F db and 35% rh has been successfully used in treating patients with rheumatoid arthritis.

Dry conditions may be hazardous to the ill and debilitated by contributing to secondary infection or infection totally unrelated to the clinical condition causing hospitalization. Clinical areas devoted to upper respiratory disease treatment and acute care, as well as the general clinical areas of the entire hospital, should be maintained at 30 to 60% rh.

Patients with chronic pulmonary disease often have viscous respiratory tract secretions. As these secretions accumulate and increase in viscosity, the patient's exchange of heat and water dwin-

The preparation of this chapter is assigned to TC 9.6, Health Care Facilities.

dles. Under these circumstances, the inspiration of warm, humidified air is essential to prevent dehydration (Walker and Wells 1961).

Patients needing oxygen therapy and those with tracheotomies require special attention to ensure warm, humid supplies of inspired air. Cold, dry oxygen or bypassing the nasopharyngeal mucosa presents an extreme situation. Rebreathing techniques for anesthesia and enclosure in an incubator are special means of addressing impaired heat loss in therapeutic environments.

Burn patients need a hot environment and high relative humidity. A ward for severe burn victims should have temperature controls that permit adjusting the room temperature up to 90°F db and relative humidity up to 95%.

HOSPITAL FACILITIES

Although proper air conditioning is helpful in preventing and treating disease, application of air conditioning to health facilities presents many problems not encountered in usual comfort conditioning design.

The basic differences between air conditioning for hospitals (and related health facilities) and that for other building types stem from the (1) need to restrict air movement in and between the various departments; (2) specific requirements for ventilation and filtration to dilute and remove contamination (odor, airborne microorganisms and viruses, and hazardous chemical and radioactive substances); (3) different temperature and humidity requirements for various areas; and (4) design sophistication needed to permit accurate control of environmental conditions.

Infection Sources and Control Measures

Bacterial Infection. Examples of bacteria that are highly infectious and transported within air or air and water mixtures are *Mycobacterium tuberculosis* and *Legionella pneumophila* (Legionnaires' disease). Wells (1934) showed that droplets or infectious agents of 5 µm or less in size can remain airborne indefinitely. Isoard et al. (1980) and Luciano (1984) have shown that 99.9% of all bacteria present in a hospital are removed by 90 to 95% efficient filters (ASHRAE *Standard* 52.1), because bacteria are typically present in colony-forming units that are larger than 1 µm. Some authorities recommend the use of high-efficiency particulate air (HEPA) filters having dioctyl phthalate (DOP) test filtering efficiencies of 99.97% in certain areas.

Viral Infection. Examples of viruses that are transported by and virulent within air are *Varicella* (chicken pox/shingles), *Rubella* (German measles), and *Rubeola* (regular measles). Epidemiological evidence and other studies indicate that many of the airborne viruses that transmit infection are submicron in size; thus, there is no known method to effectively eliminate 100% of the viable particles. HEPA and/or ultralow-penetration (ULPA) filters provide the greatest efficiency currently available. Attempts to deactivate viruses with ultraviolet light and chemical sprays have not proven reliable or effective enough to be recommended by most codes as a primary infection control measure. Therefore, isolation rooms and isolation anterooms with appropriate ventilation-pressure relationships are the primary means used to prevent the spread of airborne viruses in the health care environment.

Molds. Evidence indicates that some molds such as *Aspergillis* can be fatal to advanced leukemia, bone marrow transplant, and other immunocompromised patients.

Outside Air Ventilation. If outside air intakes are properly located, and areas adjacent to the intakes are properly maintained, outside air, in comparison to room air, is virtually free of bacteria and viruses. Infection control problems frequently involve a bacterial or viral source within the hospital. Ventilation air dilutes viral and bacterial contamination within a hospital. If ventilation systems are properly designed, constructed, and maintained to preserve correct pressure relations between functional areas, they remove airborne infectious agents from the hospital environment.

Temperature and Humidity. These conditions can inhibit or promote the growth of bacteria and activate or deactivate viruses. Some bacteria such as *Legionella pneumophila* are basically waterborne and survive more readily in a humid environment. Codes and guidelines specify temperature and humidity range criteria in some hospital areas as a measure for infection control as well as comfort.

AIR QUALITY

Systems must also provide air virtually free of dust, dirt, odor, and chemical and radioactive pollutants. In some cases, outside air is hazardous to patients suffering from cardiopulmonary, respiratory, or pulmonary conditions. In such instances, systems that intermittently provide maximum allowable recirculated air should be considered.

Outside Air Intakes. These intakes should be located as far as practical (on directionally different exposures whenever possible), but not less than 25 ft, from combustion equipment stack exhaust outlets, ventilation exhaust outlets from the hospital or adjoining buildings, medical-surgical vacuum systems, cooling towers, plumbing vent stacks, smoke control exhaust outlets, and areas that may collect vehicular exhaust and other noxious fumes. The bottom of outside air intakes serving central systems should be located as high as practical (12 ft recommended) but not less than 6 ft above ground level or, if installed above the roof, 3 ft above the roof level.

Exhaust Outlets. These exhausts should be located a minimum of 10 ft above ground level and away from doors, occupied areas, and operable windows. Preferred location for exhaust outlets is at roof level projecting upward or horizontally away from outside intakes. Care must be taken in locating highly contaminated exhausts (e.g., from engines, fume hoods, biological safety cabinets, kitchen hoods, and paint booths). Prevailing winds, adjacent buildings, and discharge velocities must be taken into account (see Chapter 16 of the 2005 *ASHRAE Handbook—Fundamentals*). In critical or complicated applications, wind tunnel studies or computer modeling may be appropriate.

Air Filters. A number of methods are available for determining the efficiency of filters in removing particulates from an airstream (see Chapter 24 of the 2004 *ASHRAE Handbook—HVAC Systems and Equipment*). All central ventilation or air-conditioning systems should be equipped with filters having efficiencies no lower than those indicated in Table 1. Where two filter beds are indicated, Filter Bed No. 1 should be located upstream of air-conditioning equipment, and Filter Bed No. 2 should be downstream of the supply fan. Appropriate precautions should be observed to prevent wetting the filter media by free moisture from humidifiers. Where only one filter bed is indicated, it should be located upstream of air-conditioning equipment. All filter efficiencies are based on ASHRAE *Standard* 52.2.

The following are guidelines for filter installations:

- HEPA filters with Minimum Efficiency Reporting Values (MERV) of 17 should be used on air supplies serving protective-environment rooms for clinical treatment of patients with a high susceptibility to infection due to leukemia, burns, bone marrow transplant, organ transplant, or human immunodeficiency virus (HIV). HEPA filters should also be used on discharge air from fume hoods or safety cabinets in which infectious or highly toxic or radioactive materials are processed. The filter system should be designed and equipped to permit safe removal, disposal, and replacement of contaminated filters.
- Filters should be installed to prevent leakage between filter segments and between the filter bed and its supporting frame. A small leak that permits any contaminated air to escape through the filter can destroy the usefulness of the best air cleaner.

Table 1 Filter Efficiencies for Central Ventilation and Air-Conditioning Systems in General Hospitals

Minimum Number of Filter Beds	Area Designation	Filter Efficiencies, MERV[a]	
		Filter Bed	
		No. 1	No. 2
2	Orthopedic operating room Bone marrow transplant operating room Organ transplant operating room	8	17[b]
2	General procedure operating rooms Delivery rooms Nurseries Intensive care units Patient care rooms Treatment rooms Diagnostic and related areas	8	14
1	Laboratories Sterile storage	13	
1	Food preparation areas Laundries Administrative areas Bulk storage Soiled holding areas	8	

[a]MERV = Minimum Efficiency Reporting Value based on ASHRAE *Standard* 52.2-1999.
[b]HEPA filters at air outlets.

- At minimum, a manometer should be installed in the filter system to measure pressure drop across each filter bank. Visual observation is not accurate for determining filter loading.
- High-efficiency filters should be installed in the system, with adequate facilities provided for maintenance and in situ filtration performance testing without introducing contamination into the delivery system or the area served.
- Because high-efficiency filters are expensive, the hospital should project the filter bed life and replacement costs and incorporate these into the operating budget. Control sequences to monitor and alarm, including ability to normalize or benchmark pressure drops and associated airflows, can enhance indication of filter loading when air handlers operate at less than design flow.
- During construction, openings in ductwork and diffusers should be sealed to prevent intrusion of dust, dirt, and hazardous materials. Such contamination is often permanent and provides a medium for growth of infectious agents. Existing or new filters as well as coils may rapidly become contaminated by construction dust.

Air Movement

The data given in Table 2 illustrate the degree to which contamination can be dispersed into the air of the hospital environment by one of the many routine activities for normal patient care. The bacterial counts in the hallway clearly indicate the spread of this contamination.

Because of the dispersal of bacteria resulting from such necessary activities, air-handling systems should provide air movement patterns that minimize the spread of contamination. Undesirable airflow between rooms and floors is often difficult to control because of open doors, movement of staff and patients, temperature differentials, and stack effect, which is accentuated by vertical openings such as chutes, elevator shafts, stairwells, and mechanical shafts common to hospitals. Although some of these factors are beyond practical control, the effect of others may be minimized by terminating shaft openings in enclosed rooms and by designing and balancing air systems to create positive or negative air pressure within certain rooms and areas.

Systems serving highly contaminated areas, such as autopsy and airborne infectious isolation rooms, must maintain a negative air

Table 2 Influence of Bedmaking on Airborne Bacterial Count in Hospitals

Item	Count per Cubic Foot	
	Inside Patient Room	Hallway near Patient Room
Background	34	30
During bedmaking	140	64
10 min after	60	40
30 min after	36	27
Background	16	
Normal bedmaking	100	
Vigorous bedmaking	172	

Source: Greene et al. (1960).

pressure in these rooms relative to adjoining rooms or the corridor (Murray et al. 1988). The negative pressure difference is obtained by supplying less air to the area than is exhausted from it (CDC 1994). Protective-environment rooms exemplify positive or negative pressure conditions. Exceptions to normally established negative and positive pressure conditions include operating rooms where highly infectious patients may be treated (e.g., operating rooms in which bronchoscopy or lung surgery is performed) and infectious isolation rooms that house immunosuppressed patients with airborne infectious diseases such as tuberculosis (TB). These areas should include an anteroom between the operating or protective-environment room and the corridor or other contiguous space. The three common approaches to anteroom relative pressurization are (1) anteroom positive to both the room and contiguous space, (2) anteroom negative to both the room and contiguous space, and (3) anteroom positive to room, negative to contiguous space. Current thinking is that the anteroom should be always positive to corridor and surrounding space when used in a protective-environment setting. Any of these techniques minimizes cross-contamination between the patient area and surrounding areas, and may be used depending on local fire smoke management regulations.

Pressure differential causes air to flow in or out of a room through various leakage areas (e.g., perimeter of doors and windows, utility/fixture penetrations, cracks, etc.). A level of differential air pressure (0.01 in. of water) can be maintained only in a tightly sealed room. Therefore, it is important to obtain a reasonably close fit of all doors and seal all walls and floors, including penetrations between pressurized areas. Opening a door between two areas immediately reduces any existing pressure differential between them to such a degree that its effectiveness is nullified. When such openings occur, a natural interchange of air takes place between the two rooms because of turbulence created by the door opening and closing combined with personnel ingress/egress.

For critical areas requiring both the maintenance of pressure differentials to adjacent spaces and personnel movement between the critical area and adjacent spaces, the use of appropriate anterooms must be considered.

Figure 1 shows the bacterial count in a surgery room and its adjoining rooms during a normal surgical procedure. These bacterial counts were taken simultaneously. The relatively low bacterial counts in the surgery room, compared with those of the adjoining rooms, are attributable to the lower level of activity and higher air pressure in operating rooms.

In general, outlets supplying air to sensitive ultraclean areas should be located on the ceiling, and perimeter or several exhaust outlets should be near the floor. This arrangement provides downward movement of clean air through the breathing and working zones to the floor area for exhaust. There are two recognized approaches to infectious isolation room air distribution. One approach locates the supply air above and near the doorway, and exhaust air from near the floor behind the patient's bed. This arrangement has the intent of controlling the flow of clean air first to parts of the room

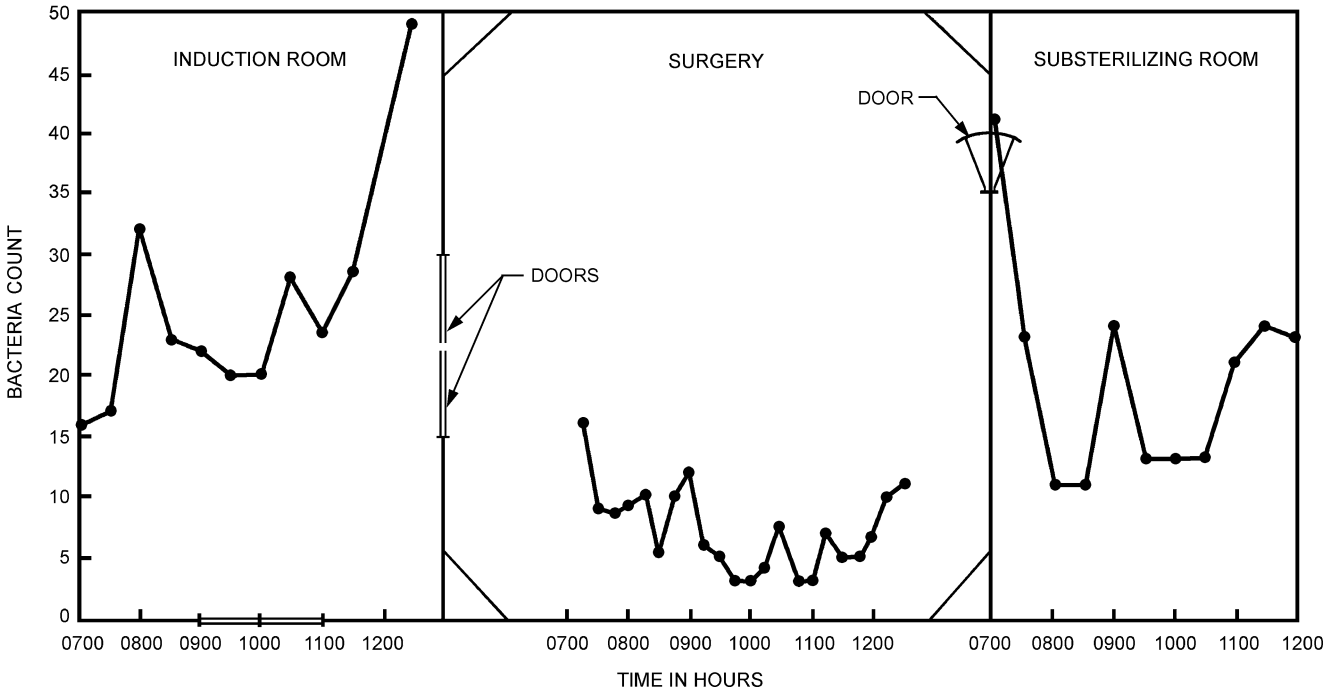

Fig. 1 Typical Airborne Contamination in Surgery and Adjacent Areas

where workers or visitors are likely to be, and across the infected source into the exhaust. The limited ability of this arrangement to achieve this directional airflow movement, in view of the relatively low air exchange rates involved and the minimal influence of the exhaust outlet, led others to advocate a second arrangement in which the supply diffuser and exhaust outlet are located to maximize room air mixing, and therefore contaminant removal, typically with ceiling-mounted supply and exhaust outlets over the patient bed or on the wall behind the bed. With this arrangement, the supply diffusers must be carefully selected and located such that primary air throw does not induce bedroom air to enter the anteroom.

The laminar airflow concept developed for industrial clean room use has attracted interest from some medical authorities. There are advocates of both vertical and horizontal laminar airflow systems, with and without fixed or movable walls around the surgical team (Pfost 1981). Some medical authorities do not advocate laminar airflow for surgeries but encourage air systems similar to those described in this chapter.

Laminar airflow in surgical operating rooms is predominantly unidirectional when not obstructed; this airflow pattern is commonly attained at a velocity of 90 ± 20 fpm. Laminar airflow has shown promise in rooms used for treating patients who are highly susceptible to infection (Michaelson et al. 1966).

Temperature and Humidity

Specific recommendations for design temperatures and humidities are given in the section on Specific Design Criteria. Temperature and humidity for other inpatient areas not covered should be 75°F or less and 30% to 60% rh.

Pressure Relationships and Ventilation

Table 3 covers ventilation recommendations for comfort, asepsis, and odor control in areas of acute care hospitals that directly affect patient care. If specific organizational criteria must be met, refer to that organization's literature. Ventilation in accordance with ASHRAE *Standard* 62.1, Ventilation for Acceptable Indoor Air Quality, should be used for areas where specific standards are not given. Where a higher outside air requirement is called for in ASHRAE *Standard* 62.1 than in Table 3, the higher value should be used. Specialized patient care areas, including organ transplant and burn units, should have additional ventilation provisions for air quality control as may be appropriate.

Ventilation system design must as much as possible provide air movement from clean to less clean areas. In critical-care areas, constant-volume systems should be used to ensure proper pressure relationships and ventilation. In noncritical patient care areas and staff rooms, variable air volume (VAV) systems may be considered for energy conservation. When using VAV systems in the hospital, special care should be taken to ensure that minimum ventilation rates (as required by codes) are maintained and that pressure relationships between various spaces are maintained. With VAV systems, a method such as air volume tracking between supply, return, and exhaust could be used to control pressure relationships (Lewis 1988).

The number of air changes may be reduced to 25% of the indicated value when the room is unoccupied, if provisions are made to ensure that (1) the number of air changes indicated is reestablished whenever the space is occupied, and (2) the pressure relationship with the surrounding rooms is maintained when the air changes are reduced.

In areas requiring no continuous directional control (±), ventilation systems may be shut down when the space is unoccupied and ventilation is not otherwise needed.

Because of the cleaning difficulty and potential for buildup of contamination, recirculating room heating and/or cooling units must not be used in areas marked "No." Note that the standard recirculating room unit may also be impractical for primary control where exhaust to the outside is required.

In rooms with hoods, extra air must be supplied for hood exhaust so that the designated pressure relationship is maintained. Refer to Chapter 14, Laboratories, for further discussion of laboratory ventilation.

For maximum energy conservation, using recirculated air is preferred. If all-outside air is used, an efficient heat recovery method should be considered.

Smoke Control

As the ventilation design is developed, a proper smoke control strategy must be considered. Passive systems rely on fan shutdown and smoke and fire barriers. Proper treatment of duct penetrations must be observed.

Active smoke control systems use the ventilation system to create areas of positive and negative pressures that, along with fire and smoke partitions, limit the spread of smoke. The ventilation system may be used in a smoke removal mode in which combustion products are exhausted by mechanical means. As design of active smoke control systems evolves, the engineer and code authority should carefully plan system operation and configuration. Refer to Chapter 52 and NFPA *Standards* 90A, 92A, and 101.

SPECIFIC DESIGN CRITERIA

There are seven principal divisions of an acute care general hospital: (1) surgery and critical care, (2) nursing, (3) ancillary, (4) administration, (5) diagnostic and treatment, (6) sterilizing and supply, and (7) service. Environmental requirements of each department/space in these divisions differ according to their function and procedures carried out in them. This section describes the functions of these departments/spaces and covers details of design requirements. Close coordination with health care planners and medical equipment specialists in mechanical design and construction of health facilities is essential to achieve the desired conditions.

Surgery and Critical Care

No area of the hospital requires more careful control of the aseptic condition of the environment than the surgical suite. Systems serving operating rooms, including cystoscopic and fracture rooms, require careful design to minimize the concentration of airborne organisms.

The greatest amount of bacteria found in the operating room comes from the surgical team and is a result of their activities during surgery. During an operation, most members of the surgical team are near the operating table, creating the undesirable situation of concentrating contamination in this highly sensitive area. There are three distinct classifications for surgery care areas class A, B, and C (ACS 2000) that generally support invasive procedures as defined in (AIA 2006).

Operating Rooms. Past studies of operating-room air distribution devices and observation of installations in industrial clean rooms indicate that delivering air from the ceiling, with a downward movement to several exhaust/return openings located low on opposite walls, is probably the most effective air movement pattern for maintaining the contamination concentration at an acceptable level. Completely perforated ceilings, partially perforated ceilings, and ceiling-mounted diffusers have been applied successfully (Pfost 1981). A mixture of low and high exhaust opening locations may work better than either all low or all high locations, with supply air at face velocities of around 25 to 35 fpm from a unidirectional laminar-flow ceiling array.

Operating room suites are typically in use no more than 8 to 12 h per day (except trauma centers and emergency departments). For energy conservation, the air-conditioning system should allow a reduction in the air supplied to some or all of the operating rooms when possible. Positive space pressure must be maintained at reduced air volumes to ensure sterile conditions. The time required for an inactive room to become usable again must be considered. Consultation with the hospital surgical staff will determine the feasibility of this feature.

A separate air exhaust system or special vacuum system should be provided for the removal of anesthetic trace gases. Medical vacuum systems have been used to remove nonflammable anesthetic gases (NFPA *Standard* 99). One or more outlets may be located in each operating room to connect the anesthetic machine scavenger hose.

Although good results have been reported from air disinfection of operating rooms by irradiation, this method is seldom used. The reluctance to use irradiation may be attributed to the need for special designs for installation, protective measures for patients and personnel, constant monitoring of lamp efficiency, and maintenance.

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

- The temperature and relative humidity set points should be adjustable by surgical staff. Systems should be capable of maintaining the space temperature in the lower end of the range (62°F) for specialized procedures such as cardiac surgery. Table 3 lists tolerable temperature ranges; however, these are not intended to be dynamic control ranges. Special or supplemental cooling equipment should be considered if this lower temperature negatively affects energy use for surrounding areas.
- Air pressure should be kept positive with respect to any adjoining rooms by supplying excess air.
- A differential-pressure-indicating device should be installed to permit air pressure readings in the rooms. Thorough sealing of all wall, ceiling, and floor penetrations, and tight-fitting doors are essential to maintaining readable pressure.
- Humidity indicator and thermometers should be located for easy observation.
- Filter efficiencies should be in accordance with Table 1.
- The entire installation should conform to requirements of NFPA *Standard* 99, Health Care Facilities.
- Air should be supplied at the ceiling with exhaust/return from at least two locations near the floor, with consideration given to having at least two high exhaust/return openings opposite from the low outlets. Endoscopic, laparoscopic, or thoracoscopic surgery procedures aided by camera, and robotic or robot-assisted surgery procedures, require heat-producing equipment in the operating room. Exhaust/return openings located above this equipment can capture the more buoyant heated air and prevent it from being reentrained in the ceiling supply airstream. The bottom of low openings should be at least 3 in. above the floor. Supply diffusers should be unidirectional (laminar-flow). High-induction ceiling or sidewall diffusers should be avoided.
- Total air exchange rates should address lights and equipment (e.g., blanket and blood warmers, fiber-optic equipment, robotic consoles). Suites with a large amount of electronic equipment have been reported to require 30 to 35 air changes per hour using conventional air-conditioning systems with 18 to 20°F supply temperature differentials.
- Acoustical materials should not be used as duct linings unless terminal filters of at least MERV 14 efficiency are installed downstream of the linings. Internal insulation of terminal units may be encapsulated with approved materials. Duct-mounted sound traps should be of the packless type or have polyester film linings over acoustical fill.
- Any spray-applied insulation and fireproofing should be treated with fungi growth inhibitor.
- Sufficient lengths of watertight, drained stainless steel duct should be installed downstream of humidification equipment to ensure complete evaporation of water vapor before air is discharged into the room.

Control centers that monitor and allow adjustment of temperature, humidity, and air pressure may be located at the surgical supervisor's desk.

Obstetrical Areas. The pressure in the obstetrical department should be positive or equal to that in other areas.

Delivery Rooms. The delivery room design should conform to the requirements of operating rooms.

Table 3 Ventilation Requirements for Areas Affecting Patient Care in Hospitals and Outpatient Facilities

Function Space	Pressure Relationship to Adjacent Areas[a]	Minimum Air Changes of Outside Air per Hour[b]	Minimum Total Air Changes per Hour[c]	All Air Exhausted Directly to Outside[m]	Air Recirculated Within Room Units[d]	Relative Humidity,[n] %	Design Temperature,[o] °F
Surgery and Critical Care							
Operating room (class B and positive C surgical)	Positive	4	20	—	No	30 to 60	62 to 80
Operating/surgical cystoscopic rooms[e, p, q]	Positive	4	20	—	No	30 to 60	68 to 73[r]
Delivery room[p]	Positive	4	20	—	No	30 to 60	68 to 73
Recovery room[p]	—*	2	6	—	No	30 to 60	75 ± 2
Critical or intensive care (burn or intermediate)	Positive*	2	6	—	No	30 to 60	70 to 75
Newborn intensive care	Positive*	2	6	—	No	30 to 60	72 to 78
Treatment room[s]	—*	2	6	—	—	30 to 60	70 to 75
Nursery suite	Positive	5	12	—	No	30 to 60	75 to 80
Trauma room[f, s]	Positive	5	12	—	No	30 to 60	70 to 75
Trauma room (crisis or shock)	—	3	15	—	No	30 to 60	70 to 75
Anesthesia gas storage	Negative	—	8	Yes	—	—	—
GI endoscopy[ab]	—	2	6	—	No	30 to 60	68 to 73
Bronchoscopy[q]	Negative	2	12	Yes	No	30 to 60	68 to 73
Emergency waiting rooms	Negative	2	12	Yes	—	30 to 60	70 to 75
Triage areas	Negative	2	12	Yes	—	—	70 to 75
Radiology waiting rooms	Negative	2	12	Yes[t]	—	—	70 to 75
Procedure room (class A surgical)	Positive	3	15	—	No	30 to 60	70 to 75
Nursing							
Patient room	—*	2	6[v]	—	—	30 (W), 50 (S)	70 to 75
Toilet room[g]	Negative	Optional	10	Yes	No	—	—
Newborn nursery suite	—*	2	6	—	No	30 to 60	72 to 78
Protective environment room[i, q, w]	Positive	2	12	—	No	—	70 to 75
Airborne infection isolation room[h,q, x]	Negative	—	12	Yes[u]	No	30 to 60	70 to 75
Isolation alcove or anteroom[w, x]	Pos./Neg.	2	10	Yes	No	—	—
Labor/delivery/recovery/postpartum (LDRP)	—*	2	6[v]	—	—	30 (W), 50 (S)	70 to 75
Public corridor	Negative	2	2	—	—	—	—
Patient corridor	—*	2	4	—	—	—	—
Ancillary							
Radiology (diagnostic and treatment)	—	2	6	—	—	40 (W), 50 (S)	78 to 80
Radiology (surgery/critical care and catheterization)	Positive	3	15	—	No	30 to 60	70 to 75
Darkroom	Negative	2	10	Yes[j]	No	—	—
Laboratory, general[y]	Negative	2	6	Yes	No	30 to 60	70 to 75
Laboratory, bacteriology	Negative	2	6	Yes	No	30 to 60	70 to 75
Laboratory, biochemistry[y]	Positive	2	6	—	No	30 to 60	70 to 75
Laboratory, cytology	Negative	2	6	Yes	No	30 to 60	70 to 75
Laboratory, glasswashing	Negative	Optional	10	Yes	—	—	—
Laboratory, histology	Negative	2	6	Yes	No	30 to 60	70 to 75
Microbiology[y]	Negative	—	6	Yes	No	30 to 60	70 to 75
Laboratory, nuclear medicine	Negative	2	6	Yes	No	30 to 60	70 to 75
Laboratory, pathology	Negative	2	6	Yes	No	30 to 60	70 to 75
Laboratory, serology	Positive	2	6	Yes	No	30 to 60	70 to 75
Laboratory, sterilizing	Negative	Optional	10	Yes	No	30 to 60	70 to 75
Laboratory, media transfer	Positive	2	4	—	No	30 to 60	70 to 75
Autopsy room[q]	Negative	2	12	Yes	No	—	—
Nonrefrigerated body-holding room[k]	Negative	Optional	10	Yes	No	—	70 to 75
Pharmacy	Positive[aa]	2	4	—	—	30 to 60	70 to 75
Administration							
Admitting and Waiting Rooms	Negative	2	6	Yes	—	30 to 60	70 to 75
Diagnostic and Treatment							
Bronchoscopy, sputum collection, and pentamidine administration	Negative	2	12	Yes	—	30 to 60	70 to 75
Examination room	—*	2	6	—	—	30 to 60	70 to 75
Medication room	Positive	2	4	—	—	30 to 60	70 to 75
Treatment room	—*	2	6	—	—	30 (W), 50 (S)	75 ± 2
Physical therapy and hydrotherapy	Negative	2	6	—	—	30 to 60	72 to 78 up to 80
Soiled workroom or soiled holding	Negative	2	10	Yes	No	30 to 60	72 to 78
Clean workroom or clean holding	Positive	2	4	—	—	—	—
Sterilizing and Supply							
ETO-sterilizer room	Negative	—	10	Yes	No	30 to 60	72 to 78
Sterilizer equipment room	Negative	—	10	Yes	No	30 to 60	74 ± 2
Central medical and surgical supply							
Soiled or decontamination room	Negative	2	6	Yes	No	30 to 60	72 to 78
Clean workroom	Positive	2	4	—	No	30 to 60	72 to 78
Sterile storage	Positive	2	4	—	—	Under 50	74 ± 2
Endoscope cleaning room	Negative	2	10	Yes	No	—	—

Table 3 Ventilation Requirements for Areas Affecting Patient Care in Hospitals and Outpatient Facilities (*Continued*)

Function Space	Pressure Relationship to Adjacent Areas[a]	Minimum Air Changes of Outside Air per Hour[b]	Minimum Total Air Changes per Hour[c]	All Air Exhausted Directly to Outside[m]	Air Recirculated Within Room Units[d]	Relative Humidity,[n] %	Design Temperature,[o] °F
Service							
Food preparation center[l]	—*	2	10	Yes	No	—	—
Warewashing	Negative	Optional	10	Yes	No	—	—
Dietary day storage	*	Optional	2	—	No	—	—
Laundry, general	Negative	2	10	Yes	No	—	—
Soiled linen sorting and storage	Negative	Optional	10	Yes	No	—	—
Clean linen storage	Positive	2 (Optional)	2	—	—	—	—
Linen and trash chute room	Negative	Optional	10	Yes	No	—	—
Bedpan room	Negative	Optional	10	Yes	No	—	—
Bathroom	Negative	Optional	10	Yes	No	—	72 to 78
Janitor's closet	Negative	Optional	10	Yes	No	—	—
Hazardous material storage	Negative	2	10	Yes	No	—	—

(W) = winter (S) = summer

* = Continuous directional control not required

[a] Where continuous directional control is not required, variations should be minimized; in no case should a lack of directional control allow spread of infection from one area to another. Boundaries between functional areas (wards or departments) should have directional control. Lewis (1988) describes ways to maintain directional control by applying air-tracking controls. Ventilation system design should provide air movement, generally from clean to less clean areas. If any VAV or load-shedding system is used for energy conservation, it must not compromise pressure-balancing relationships or minimum air changes required by the table. See note z for additional information.

[b] Ventilation rates in this table cover ventilation for comfort, as well as for asepsis and odor control in areas of acute-care hospitals that directly affect patient care. Ventilation rates in accordance with ASHRAE *Standard* 62, Ventilation for Acceptable Indoor Air Quality, should be used for areas for which specific ventilation rates are not given. Where a higher outside air requirement is called for in *Standard* 62 than here, use the higher value.

[c] Total air changes indicated should be either supplied or, where required, exhausted. Number of air changes can be reduced when the room is unoccupied, if the pressure relationship is maintained and the number of air changes indicated is reestablished any time the space is used. Air changes shown are minimum values. Higher values should be used when required to maintain room temperature and humidity conditions based on the cooling load of the space (lights, equipment, people, exterior walls and windows, etc.).

[d] Recirculating HEPA filter units used for infection control (without heating or cooling coils) are acceptable. Gravity-type heating or cooling units such as radiators or convectors should not be used in operating rooms and other special-care areas.

[e] For operating rooms, 100% outside air should be used only when codes require it and only if heat recovery devices are used.

[f] "Trauma room" here is a first-aid room and/or emergency room used for general initial treatment of accident victims. The operating room in the trauma center that is routinely used for emergency surgery should be treated as an operating room.

[g] See section on Patient Rooms for discussion of central toilet exhaust system design.

[h] "Airborne infectious isolation rooms" here are those that might be used for infectious patients in the average community hospital. The rooms are negatively pressurized. Some may have a separate anteroom. See the section on Infectious Isolation Unit for more information.

[i] Protective-environment rooms are those used for immunosuppressed patients, positively pressurized to protect the patient. Anterooms are generally required and should be negatively pressurized with respect to the patient room.

[j] All air need not be exhausted if darkroom equipment has scavenging exhaust duct attached and meets ventilation standards of NIOSH, OSHA, and local employee exposure limits.

[k] A nonrefrigerated body-holding room is only applicable to facilities that do not perform autopsies onsite and use the space for short periods while waiting for the body to be transferred.

[l] Food preparation centers should have an excess of air supply for positive pressurization when hoods are not in operation. The number of air changes may be reduced or varied for odor control when the space is not in use. Minimum total air changes per hour should be that required to provide proper makeup air to kitchen exhaust systems. (See Chapter 31, Kitchen Ventilation.) Also, exfiltration or infiltration to or from exit corridors must not compromise exit corridor restrictions of NFPA *Standard* 90A, pressure requirements of NFPA *Standard* 96, or the maximum defined in the table. The number of air changes may be reduced or varied as required for odor control when the space is not in use. See AIA (2006), Table 2.1.2.

[m] Areas with contamination and/or odor problems should be exhausted to the outside and not recirculated to other areas. Individual circumstances may require special consideration for air exhaust to the outside (e.g., intensive care units where patients with pulmonary infection are treated, rooms for burn patients). To satisfy exhaust needs, replacement air from the outside is necessary. Minimum outside air quantities should remain constant while the system is in operation.

[n] Relative humidity ranges listed are minimum and maximum limits where control is specifically needed. These limits are not intended to be independent of space temperature. For example, relative humidity is expected to be at the higher end of the range when the temperature is also at the higher end, and vice versa.

[o] For indicated temperature ranges, systems should be capable of maintaining the rooms at any point within the range during normal operation. A single figure indicates a heating or cooling capacity to at least meet the indicated temperature. This is usually applicable when patients may be undressed and require a warmer environment. Use of lower temperature is acceptable when patients' comfort and medical conditions require those conditions.

[p] NIOSH *Criteria Documents* 75-137 and 96-107 on waste anesthetic gases and nitrous oxide indicate a need for both local exhaust (scavenging) systems and general ventilation of areas in which these gases are used.

[q] Differential pressure between space and corridors should be a minimum of 0.01 in. of water. If monitoring device alarms are installed, allowances should be made to prevent nuisance alarms.

[r] Because some surgeons or surgical procedures may require room temperatures outside the indicated range, operating room design conditions should be developed in consort with all users, surgeons, anesthesiologists, and nursing staff.

[s] The first-aid and/or emergency room used for initial treatment of accident victims can be ventilated as for the treatment room. Treatment rooms used for cryosurgery with nitrous oxide should have provisions for exhausting waste gases.

[t] In a recirculating ventilation system, HEPA filters can be used instead of exhausting the air to the outside; return air should pass through the HEPA filters before being introduced to any other spaces.

[u] If exhausting air from an airborne-infection isolation room to the outside is not practical, the air may be returned through HEPA filters to the air-handling system exclusively serving the isolation room.

[v] Total air changes per room for patient rooms, and labor/delivery/recovery/postpartum rooms may be reduced to four when using supplemental heating and/or cooling systems (radiant heating and cooling, baseboard heating, etc.).

[w] Protective-environment airflow design specifications protect the patient from common environmental airborne infectious microbes (e.g., *Aspergillus* spores). They should provide directed airflow from the cleanest patient area to less clean areas. HEPA filters at 99.9% efficiency to 0.3 µm should be used in the supply airstream, to protect patient rooms from environmental microbes in ventilation system components. Recirculation HEPA filters can be used to increase equivalent room air exchanges. Constant-volume airflow is required for consistent ventilation. If design criteria indicate that airborne-infection isolation is necessary for protective-environment patients, an anteroom should be provided. Rooms with reversible airflow provisions (to allow switching between protective-environment and airborne-infection isolation) are not acceptable (AIA 2006).

[x] "Infectious disease isolation (AII) room" here is one used to isolate the airborne spread of infectious diseases, such as measles, varicella, or tuberculosis. Design should include provision for normal patient care during periods not requiring isolation. Supplemental recirculating devices may be used in the patient room to increase the equivalent room air exchanges; however, they do not provide outside air requirements. Air may be recirculated within individual isolation rooms if HEPA filters are used. Rooms with reversible airflow provisions (to allow switching between protective-environment and AII) are not acceptable (AIA 2006).

[y] When required, provide appropriate hoods and exhaust devices for noxious gases or vapors [AIA (2006), see Section 2.1-10.2.4.5(2), and NFPA *Standard* 99).

[z] Simple visual methods such as smoke trail, ball-in-tube, or flutterstrip can be used to verify airflow direction. These devices require a minimum differential air pressure to indicate airflow direction. Per AIA (2006) guidelines, recirculating devices with HEPA filters may be used in existing facilities as interim, supplemental environmental controls to meet requirements for airborne infectious agents control. Design limitations must be recognized. Either portable or fixed systems should prevent stagnation and short-circuiting of airflow. Supply and exhaust locations should direct clean air to work areas across the infectious source, and then to the exhaust, so that health care workers are not positioned between the infectious source and the exhaust. Systems design should also allow easy access for scheduled preventative maintenance and cleaning.

[aa] Some jurisdictions may require pharmacies that compound hazardous drugs to be maintained under negative pressure or use anterooms to reduce the potential migration of airborne drug contamination out of the pharmacy.

[ab] Consult user for standard of care expectation, because space could be also be considered negative or positive.

Recovery Rooms. Postoperative recovery rooms used in conjunction with operating rooms should be maintained at a relative humidity of 45 to 55%. Because the smell of residual anesthesia sometimes creates odor problems in recovery rooms, ventilation is important, and a balanced air pressure relative to that of adjoining areas should be provided.

Intensive Care Units. These units serve seriously ill patients, from postoperative to coronary patients. A variable-range temperature capability of 70 to 75°F, relative humidity of 30% minimum and 60% maximum, and positive air pressure are recommended.

Nursery Suites. Air conditioning in nurseries provides the constant temperature and humidity conditions essential to care of the newborn in a hospital environment. Air movement patterns in nurseries should be carefully designed to reduce the possibility of drafts.

Some codes or jurisdictions require that air be removed near floor level, with the bottoms of exhaust openings at least 3 in. above the floor; the relative efficacy of this exhaust arrangement has been questioned by some experts, because exhaust air outlets have a minimal effect on room air movement at the relatively low air exchange rates involved. Air system filter efficiencies should conform to Table 1. Finned tube radiation and other forms of convection heating should not be used in nurseries.

Full-Term Nurseries. A relative humidity of 30 to 60% is recommended for full-term nurseries, examination rooms, and work spaces. The maternity nursing section should be controlled similarly to protect the infant during visits with the mother. The nursery should have a positive air pressure relative to the work space and examination room, and any rooms located between the nurseries and the corridor should be similarly pressurized relative to the corridor. This prevents infiltration of contaminated air from outside areas.

Special-Care Nurseries. These nurseries require a variable range temperature capability of 75 to 80°F and a relative humidity of 30 to 60%. This type of nursery is usually equipped with individual incubators to regulate temperature and humidity. It is desirable to maintain these same conditions within the nursery proper to accommodate both infants removed from the incubators and those not placed in incubators. Pressurization of special-care nurseries should correspond to that of full-term nurseries.

Observation Nurseries. Temperature and humidity requirements for observation nurseries are similar to those for full-term nurseries. Because infants in these nurseries have unusual clinical symptoms, the air from this area should not enter other nurseries. A negative air pressure relative to that of the workroom should be maintained in the nursery. The workroom, usually located between the nursery and the corridor, should be pressurized relative to the corridor.

Emergency Rooms. Emergency rooms are typically the most highly contaminated areas in the hospital because of the soiled condition of many arriving patients and the relatively large number of persons accompanying them. Temperatures and humidities of offices and waiting spaces should be within the normal comfort range.

Trauma Rooms. Trauma rooms should be ventilated in accordance with requirements in Table 3. Emergency operating rooms located near the emergency department should have the same temperature, humidity, and ventilation requirements as those of operating rooms.

Anesthesia Storage Rooms. Anesthesia storage rooms must be ventilated in conformance with NFPA *Standard* 99. However, mechanical ventilation only is recommended.

Nursing

Patient Rooms. When central systems are used to condition patient rooms, recommendations in Tables 1 and 3 should be followed to reduce cross-infection and control odor. Each patient room should have individual temperature control. Air pressure in patient suites should be neutral in relation to other areas.

Most governmental design criteria and codes require that all air from toilet rooms be exhausted directly outside. The requirement appears to be based on odor control.

Where room unit systems are used, it is common practice to exhaust through the adjoining toilet room an amount of air equal to the amount of outside air brought in for ventilation. Ventilation of toilets, bedpan closets, bathrooms, and all interior rooms should conform to applicable codes.

Protective Isolation Units. Immunosuppressed patients (including bone marrow or organ transplant, leukemia, burn, and AIDS patients) are highly susceptible to diseases. Some physicians prefer an isolated laminar airflow unit to protect the patient; others are of the opinion that the conditions of the laminar cell have a psychologically harmful effect on the patient and prefer flushing out the room and reducing spores in the air. An air distribution of 15 air changes per hour supplied through a nonaspirating diffuser is often recommended. With this arrangement, the sterile air is drawn across the patient and returned near the floor, at or near the door to the room.

In cases where the patient is immunosuppressed but not contagious, positive pressure should be maintained between the patient room and adjacent area. Some jurisdictions may require an anteroom, which maintains a negative pressure relative to the adjacent isolation room and an equal pressure to the corridor, nurses' station, or common area. Exam and treatment rooms should be controlled in the same manner. Positive pressure should also be maintained between the entire unit and adjacent areas to preserve sterile conditions.

When a patient is both immunosuppressed and contagious, isolation rooms within the unit may be designed and balanced to provide a permanent equal or negative pressure relative to the adjacent area or anteroom. Pressure controls in the adjacent area or anteroom must maintain the correct pressure relationship relative to the other adjacent room(s). A separate, dedicated air-handling system to serve the protective isolation unit simplifies pressure control and quality (Murray et al. 1988).

Infectious Isolation Unit. The infectious isolation room protects the rest of the hospital from patients' infectious diseases. Recent multidrug-resistant strains of tuberculosis have increased the importance of pressurization, air change rates, filtration, and air distribution design in these rooms (Rousseau and Rhodes 1993). Temperatures and humidities should correspond to those specified for patient rooms.

The designer should work closely with health care planners and the code authority to determine the appropriate isolation room design. It may be desirable to provide more complete control, with a separate anteroom used as an air lock to minimize the potential that airborne particles from the patients' area reach adjacent areas. Design approaches to airborne infectious isolation may also be found in CDC (2005).

Switchable isolation rooms (rooms that can be set to function with either positive or negative pressure) have been installed in many facilities. AIA (2006) and CDC (1994) have, respectively, prohibited and recommend against this approach. The two difficulties of this approach are (1) maintaining the mechanical dampers and controls required to accurately provide the required pressures, and (2) that it provides a false sense of security to staff who think that this provision is all that is required to change a room between protective isolation and infectious isolation, to the exclusion of other sanitizing procedures.

Floor Pantry. Ventilation requirements for this area depend on the type of food service adopted by the hospital. Where bulk food is dispensed and dishwashing facilities are provided in the pantry, using hoods above equipment, with exhaust to the outside, is recommended. Small pantries used for between-meal feedings require no special ventilation. The air pressure of the pantry should be in balance with that of adjoining areas to reduce the movement of air into or out of it.

Labor/Delivery/Recovery/Postpartum (LDRP). The procedures for normal childbirth are considered noninvasive, and rooms are controlled similarly to patient rooms. Some jurisdictions may require higher air change rates than in a typical patient room. It is expected that invasive procedures such as cesarean section are performed in a nearby delivery or operating room.

Ancillary

Radiology Department. Among the factors affecting ventilation system design in these areas are odors from certain clinical treatments and the special construction designed to prevent radiation leakage. Fluoroscopic, radiographic, therapy, and darkroom areas require special attention.

Fluoroscopic, Radiographic, and Deep Therapy Rooms. These rooms require a temperature from 78 to 80°F and a relative humidity from 40 to 50%. This relative humidity range control often requires dedicated room equipment and control. Depending on the location of air supply outlets and exhaust intakes, lead lining may be required in supply and return ducts at points of entry to various clinical areas to prevent radiation leakage to other occupied areas.

Darkroom. The darkroom is normally in use for longer periods than x-ray rooms, and should have an independent system to exhaust air to the outside. Exhaust from the film processor may be connected into the darkroom exhaust.

Laboratories. Air conditioning is necessary in laboratories for the comfort and safety of the technicians (Degenhardt and Pfost 1983). Chemical fumes, odors, vapors, heat from equipment, and the undesirability of open windows all contribute to this need.

Particular attention should be given to the size and type of equipment used in the various laboratories, as equipment heat gain usually constitutes a major portion of the cooling load.

The general air distribution and exhaust systems should be constructed of conventional materials following standard designs for the type of systems used. Exhaust systems serving hoods in which radioactive materials, volatile solvents, and strong oxidizing agents such as perchloric acid are used should be made of stainless steel. Washdown facilities and dedicated exhaust fans should be provided for hoods and ducts handling perchloric acid.

Hood use may dictate other duct materials. Hoods in which radioactive or infectious materials are to be used must be equipped with ultrahigh-efficiency filters at the exhaust outlet and have a procedure and equipment for safe removal and replacement of contaminated filters. Exhaust duct routing should be as short as possible with minimal horizontal offsets. This applies especially to perchloric acid hoods because of the extremely hazardous, explosive nature of this material.

Determining the most effective, economical, and safe system of laboratory ventilation requires considerable study. Where laboratory space ventilation air quantities approximate the air quantities required for ventilating the hoods, the hood exhaust system may be used to exhaust all ventilation air from the laboratory areas. Where hood exhaust exceeds air supplied, a supplementary air supply may be used for hood makeup. VAV supply/exhaust systems in the laboratory have gained acceptance but require special care in design and installation.

Supplementary air supply, which need not be completely conditioned, should be provided by a system independent of the normal ventilating system. The individual hood exhaust system should be interlocked with the supplementary air system. However, the hood exhaust system should not shut off if the supplementary air system fails. Chemical storage rooms must have a constantly operating exhaust air system with a terminal fan.

Hood exhaust fans should be located at the discharge end of the duct system to prevent exhaust products entering the building. For further information on laboratory air conditioning and hood exhaust systems, see NFPA *Standard* 99, Hagopian and Hoyle (1984), and Chapter 14 of this volume.

Exhaust air from hoods in biochemistry, histology, cytology, pathology, glass washing/sterilizing, and serology-bacteriology units should be discharged to the outside with no recirculation. Use care in designing the exhaust outlet locations and arrangements: exhaust should not be re-entrained in the building via outside air intakes or other building openings. Separation from outside air intake sources, wind direction and velocity, building geometry, and exhaust outlet height and velocity are important. In some laboratory exhaust systems, exhaust fans discharge vertically at a minimum of 7 ft above the roof at velocities up to 4000 fpm. The serology-bacteriology unit should be positively pressured relative to adjoining areas to reduce the possibility of infiltration of aerosols that could contaminate the specimens being processed. The entire laboratory area should be under slight negative pressure to reduce the spread of odors or contamination to other hospital areas. Temperatures and humidities should be within the comfort range.

Bacteriology Laboratories. These units should not have undue air movement, so care should be exercised to limit air velocities to a minimum. The sterile transfer room, which may be within or adjoining the bacteriology laboratory, is where sterile media are distributed and where specimens are transferred to culture media. To maintain a sterile environment, an ultrahigh-efficiency HEPA filter should be installed in the supply air duct near the point of entry to the room. The media room, essentially a kitchen, should be ventilated to remove odors and steam.

Infectious Disease and Virus Laboratories. These laboratories, found only in large hospitals, require special treatment. A minimum ventilation rate of 6 air changes per hour or makeup equal to hood exhaust volume is recommended for these laboratories, which should have a negative air pressure relative to any other area nearby to prevent exfiltration of any airborne contaminants. Exhaust air from fume hoods or safety cabinets must be sterilized before being exhausted to the outside. This may be accomplished by using electric or gas-fired heaters placed in series in the exhaust systems and designed to heat the exhaust air to 600°F. A more common and less expensive method of sterilizing the exhaust is to use HEPA filters in the system.

Nuclear Medicine Laboratories. Such laboratories administer radioisotopes to patients orally, intravenously, or by inhalation to facilitate diagnosis and treatment of disease. There is little opportunity in most cases for airborne contamination of the internal environment, but exceptions warrant special consideration.

One important exception involves the use of iodine-131 solution in capsules or vials to diagnose thyroid disorders. Another involves use of xenon-133 gas via inhalation to study patients with reduced lung function.

Capsules of iodine-131 occasionally leak part of their contents prior to use. Vials emit airborne contaminants when opened for preparation of a dose. It is common practice for vials to be opened and handled in a standard laboratory fume hood. A minimum face velocity of 100 fpm should be adequate for this purpose. This recommendation applies only where small quantities are handled in simple operations. Other circumstances may warrant provision of a glove box or similar confinement.

Use of xenon-133 for patient study involves a special instrument that permits the patient to inhale the gas and to exhale back into the instrument. The exhaled gas is passed through a charcoal trap mounted in lead and is often vented outside. The process suggests some potential for escape of the gas into the internal environment.

Because of the uniqueness of this operation and the specialized equipment involved, it is recommended that system designers determine the specific instrument to be used and contact the manufacturer for guidance. Other guidance is available in U.S. Nuclear Regulatory Commission *Regulatory Guide* 10.8 (NRC 1980). In particular, emergency procedures in case of accidental release of

xenon-133 should include temporary evacuation of the area and/or increasing the ventilation rate of the area.

Recommendations for pressure relationships, supply air filtration, supply air volume, recirculation, and other attributes of supply and discharge systems for histology, pathology, and cytology laboratories are also relevant to nuclear medicine laboratories. There are, however, some special ventilation system requirements imposed by the NRC where radioactive materials are used. For example, NRC (1980) provides a computational procedure to estimate the airflow necessary to maintain xenon-133 gas concentration at or below specified levels. It also contains specific requirements as to the amount of radioactivity that may be vented to the atmosphere; the disposal method of choice is adsorption onto charcoal traps.

Autopsy Rooms. Susceptible to heavy bacterial contamination (e.g., tuberculosis) and odor, autopsy rooms, which are part of the hospital's pathology department, require special attention. Exhaust intakes should be located both at the ceiling and in the low sidewall. The exhaust system should discharge the air above the roof of the hospital, away from points of potential reentrainment, such as outside air intakes and building openings. The autopsy room should be negatively pressured relative to adjoining areas to prevent the spread of contamination. Where large quantities of formaldehyde are used, special exhaust systems can effectively control concentrations below legal exposure limits. A combination of localized exhaust and ventilation systems with downdraft or side-draft tables can also effectively control concentrations while using smaller exhaust volumes than those required by dilution ventilation.

In smaller hospitals where the autopsy room is used infrequently, local control of the ventilation system and an odor control system with either activated charcoal or potassium permanganate-impregnated activated alumina may be desirable.

Animal Quarters. Principally because of odor, animal quarters (found only in larger hospitals) require a mechanical exhaust system that discharges contaminated air above the hospital roof. To prevent the spread of odor or other contaminants from the animal quarters to other areas, a negative air pressure of at least 0.1 in. of water relative to adjoining areas must be maintained. Chapter 14 has further information on animal room air conditioning.

Pharmacies. Design and ventilation requirements for pharmacies can vary greatly according to the type of compounding done there. Pharmacies handling hazardous drugs and/or involved in sterile compounding activities have special ventilation requirements such as, for example, horizontal or vertical laminar-airflow workbenches (LAFW), biological safety cabinets (BSC), and compounding (barrier) isolators. Room air distribution and filtration must be coordinated with any laminar airflow benches, cabinets, and isolators that may be needed. See Chapters 14 and 16 for more information.

Sterile Compounding. Sterile pharmaceutical compounding requirements are prescribed by the U.S. Pharmacopeia (USP 2003). This chapter is enforceable under the U.S. Food and Drug Administration, is adopted in whole or in part by many state boards of pharmacy, and may be incorporated into the inspection programs of health care accreditation organizations such as the Joint Commission on Accreditation of Healthcare Organization (JCAHO). End users, owners, architects, and engineers should consult the most recent release of USP 797, which is under continuous maintenance, as well as design guidance adopted by their state boards of pharmacy.

USP 797 prescribes that all sterile pharmaceutical preparations be compounded entirely within a critical work zone of ISO class 5 (former class 100 under Federal Standard 209E) or better air quality. This class 5 environment is generally provided using a primary engineering control. USP 797 also requires that the ISO class 5 critical work zone be placed in a buffer zone (also called a buffer room or cleanroom) whose air quality must meet a minimum of ISO class 8 and contain air-conditioning and humidity controls. [*Note*: In late 2004, USP announced its intention to increase the minimum air quality in the buffer zone to ISO class 7 (Newton 2004).] Lastly, adjacent to the buffer area, the sterile compounding pharmacy design must incorporate an anteroom for storage, hand washing, non-sterile preparation activities, donning and doffing of protective overgarments, etc. The air cleanliness in the anteroom must be ". . . demonstrably better than that of ambient air to reduce the risk of contaminants being blown, dragged or otherwise introduced into the filtered unidirectional airflow environment" (USP 2003).

Beyond air quality requirements, the physical design features separating the buffer area from the anteroom are based on the pharmacy's compounded sterile preparation (CSP) risk level (low, medium, or high) for microbial, chemical, and physical contamination. USP 797 instructs pharmacy professionals on determination of their pharmacy's CSP risk level based on purity and packaging of source materials, quantity and type of pharmaceutical, time until its administration, and various other factors. The desired CSP risk level capability should be identified before initiating the pharmacy design layout. Pharmacies intended for compounding high-risk-level CSPs require a physical barrier with a door to separate the buffer room from the anteroom. For medium- and low-risk level CSPs, the buffer area and anteroom can be in the same room, with an obvious line of demarcation separating the two areas (USP 2003).

Hazardous Drugs. In addition to defining and listing hazardous drugs, the NIOSH Alert provides protective recommendations, several of which can affect the ventilation design and physical layout of the pharmacy. These recommendations include the following:

- Prepare hazardous drugs in an area devoted to that purpose alone and restricted to authorized personnel.
- Prepare hazardous drugs inside a ventilated cabinet designed to prevent hazardous drugs from being released into the work environment.
- Use a high-efficiency particulate air (HEPA) filter for exhaust from ventilated cabinets and, where feasible, exhaust 100% of the filtered air to the outside, away from outside air intakes or other points of entry.
- Place fans downstream of HEPA filters so that contaminated ducts and plenums are maintained under negative pressure.
- Do not use ventilated cabinets that recirculate air inside the cabinet or that exhaust air back into the pharmacy unless the hazardous drug(s) in use will not volatilize (evaporate or sublimate) while they are being handled or after they are captured by the HEPA filter. (*Note*: This recommendation is a shift from traditional pharmacy design practice and involves knowledge of the physical properties of drugs within the current drug formulary as well as future new drugs that might be compounded within the cabinet.)
- Store hazardous drugs separately from other drugs, in an area with sufficient general exhaust ventilation to dilute and remove any airborne contaminants. Depending on the physical nature and quantity of the stored drugs, consider installing a dedicated emergency exhaust fan capable of quickly purging airborne contaminants from the storage room in the event of a spill, to prevent airborne migration into adjacent areas.

In December 2005, the American Society of Health Systems Pharmacists (ASHP) released a prepublication version of their *ASHP Guidelines on Handling Hazardous Drugs*. In addition to adopting the protective equipment recommendations presented in the NIOSH Alert, the ASHP *Guidelines* recommend that hazardous drug compounding be done in a contained, negative-pressure environment or one that is protected by an airlock or anteroom (ASHP 2005).

Often, the hazardous drugs previously discussed also require sterile compounding. If so, pharmacies must have an environment suitable for both product sterility and worker protection. Both the NIOSH Alert and ASHP *Guidelines on Hazardous Drugs* address

Table 4 Minimum Environmental Control Requirements for Pharmacies

Compounding Scenario	Hazardous Drug (HD) (Requires separate area)	Nonhazardous Drug
Sterile compounding (Requires particle-controlled environment)	If no particle-controlled environment, needs ISO 5 compounding aseptic containment isolator or If ISO 8* or better environment, needs ISO 5 compounding aseptic containment isolator, Class II BSC or Class III BSC. [Physically-separated buffer (clean) room required if CSP risk level is rated high]	If no particle-controlled environment, needs ISO 5 compounding aseptic isolator or If ISO 8* or better environment, needs ISO 5 laminar airflow workbench or Class II BSC [Physically-separated buffer (clean) room required if CSP risk level is rated high]
Nonsterile compounding	Needs compounding containment isolator or BSC	No sterility or occupational exposure controls required

*The USP Sterile Compounding Committee has indicated its intention to increase the minimum air particle count classification for the buffer area to ISO Class 7.

these dual objectives by recommending the use of class II or class III BSCs or compounding aseptic containment isolators. The precautionary recommendations regarding in-cabinet recirculation and cabinet-to-room recirculation of air potentially contaminated with hazardous drugs still apply. In addition, the USP's Sterile Compounding Committee, responsible for maintaining USP 797, has announced its intent to address the issue of hazardous drug sterile compounding in an updated release of USP 797, partially through reference to the NIOSH Alert (Newton 2004).

Table 4 provides a matrix of design and equipment decision logic based on USP 797 and the NIOSH Alert on Hazardous Drugs.

Administration

This department includes the main lobby and admitting, medical records, and business offices. Admissions and waiting rooms harbor potential risks of transmitting of undiagnosed airborne infectious diseases. Local exhaust systems that move air toward the admitting patient should be considered. A separate air-handling system is considered desirable to segregate this area from the hospital proper because it is usually unoccupied at night. When interior architectural open-water features are proposed, water treatment to protect occupants from infectious or irritating aerosols should be provided.

Diagnostic and Treatment

Bronchoscopy, Sputum Collection, and Pentamidine Administration Areas. These spaces are remarkable due to the high potential for large discharges of possibly infectious water droplet nuclei into the room air. Although the procedures performed may indicate the use of a patient hood, the general room ventilation should be increased under the assumption that higher than normal levels of airborne infectious contaminants will be generated.

Magnetic Resonance Imaging (MRI) Rooms. These rooms should be treated as exam rooms in terms of temperature, humidity, and ventilation. However, special attention is required in the control room because of the high heat release of computer equipment; in the exam room, because of the cryogens used to cool the magnet.

Treatment Rooms. Patients are brought to these rooms for special treatments that cannot be conveniently administered in the patients' rooms. To accommodate the patient, who may be brought from bed, the rooms should have individual temperature and humidity control. Temperatures and humidities should correspond to those specified for patients' rooms.

Physical Therapy Department. The cooling load of the electrotherapy section is affected by the shortwave diathermy, infrared, and ultraviolet equipment used in this area.

Hydrotherapy Section. This section, with its various water treatment baths, is generally maintained at temperatures up to 80°F. The potential latent heat buildup in this area should not be overlooked. The exercise section requires no special treatment; temperatures and humidities should be within the comfort zone. The air may be recirculated within the areas, and an odor control system is suggested.

Occupational Therapy Department. In this department, spaces for activities such as weaving, braiding, artwork, and sewing require no special ventilation treatment. Air recirculation in these areas using medium-grade filters in the system is permissible.

Larger hospitals and those specializing in rehabilitation may offer patients a greater diversity of skills to learn and craft activities, including carpentry, metalwork, plastics, photography, ceramics, and painting. The air-conditioning and ventilation requirements of the various sections should conform to normal practice for such areas and to the codes relating to them. Temperatures and humidities should be maintained in the comfort zone.

Inhalation Therapy Department. This department treats pulmonary and other respiratory disorders. The air must be very clean, and the area should have a positive pressure relative to adjacent areas.

Workrooms. Clean workrooms serve as storage and distribution centers for clean supplies and should be maintained at a positive pressure relative to the corridor.

Soiled workrooms serve primarily as collection points for soiled utensils and materials. They are considered contaminated rooms and should have a negative air pressure relative to adjoining areas. Temperatures and humidities should be in the comfort range.

Sterilizing and Supply

Used and contaminated utensils, instruments, and equipment are brought to this unit for cleaning and sterilization before reuse. The unit usually consists of a cleaning area, a sterilizing area, and a storage area where supplies are kept until requisitioned. If these areas are in one large room, air should flow from the clean storage and sterilizing areas toward the contaminated cleaning area. The air pressure relationships should conform to those indicated in Table 3. Temperature and humidity should be within the comfort range.

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

- Insulate sterilizers to reduce heat load.
- Amply ventilate sterilizer equipment closets to remove excess heat.
- Where ethylene oxide (ETO) gas sterilizers are used, provide a separate exhaust system with terminal fan (Samuals and Eastin 1980). Provide adequate exhaust capture velocity in the vicinity of sources of ETO leakage. Install an exhaust at sterilizer doors and over the sterilizer drain. Exhaust aerator and service rooms. ETO concentration sensors, exhaust flow sensors, and alarms should also be provided. ETO sterilizers should be located in dedicated unoccupied rooms that have a highly negative pressure relative to adjacent spaces and 10 air changes per hour. Many jurisdictions require that ETO exhaust systems have equipment to remove ETO from exhaust air. See OSHA 29 CFR, Part 1910.
- Maintain storage areas for sterile supplies at a relative humidity of no more than 50%.

Service

Service areas include dietary, housekeeping, mechanical, and employee facilities. Whether these areas are conditioned or not, 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 into the design. Such air must be filtered and delivered at controlled temperatures. 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. Air-to-air heat exchangers in the general ventilation system offer possibilities for economical operation in these areas.

Supply connections for water-using equipment (e.g., ice machines) should be copper rather than plastic tubing and should be provided with floor drains or floor sinks. Avoid designs that may include dead-end risers or branches without fixtures; in renovation projects, dead-end piping should be removed. Empty or upsized risers or branches are viable options.

Dietary Facilities. These areas usually include the main kitchen, bakery, dietitian's office, dishwashing room, and dining space. Because of the various conditions encountered (i.e., high heat and moisture production and cooking odors), special attention in design is needed to provide an acceptable environment. Refer to Chapter 31 for information on kitchen facilities.

The dietitian's office is often located within the main kitchen or immediately adjacent to it. It is usually completely enclosed for privacy and noise reduction. Air conditioning is recommended for maintaining normal comfort conditions.

The dishwashing room should be enclosed and minimally ventilated to equal the dishwasher hood exhaust. It is not uncommon for the dishwashing area to be divided into a soiled area and a clean area. In such cases, the soiled area should be kept at a negative pressure relative to the clean area.

Ventilation of the dining space should conform to local codes. The reuse of dining space air for ventilation and cooling of food preparation areas in the hospital is suggested, provided the reused air is passed through filters with a filtration efficiency of MERV 13 or better. Where cafeteria service is provided, serving areas and steam tables are usually hooded. The air-handling capacities of these hoods should be sized to accommodate exhaust flow rates (see Table 2 in Chapter 31). Ventilation systems for food preparation and adjacent areas should include an interface with hood exhaust controls to assist in maintaining pressure relationships.

Kitchen Compressor/Condenser Spaces. Ventilation of these spaces should conform to all codes, with the following additional considerations: (1) 350 cfm of ventilating air per compressor horsepower should be used for units located within the kitchen; (2) condensing units should operate optimally at 90°F maximum ambient temperature; and (3) where air temperature or air circulation is marginal, combination air- and water-cooled condensing units should be specified. It is often worthwhile to use condenser water coolers or remote condensers. Heat recovery from water-cooled condensers should be considered.

Laundry and Linen Facilities. Of these facilities, only the soiled linen storage room, the soiled linen sorting room, the soiled utility room, and the laundry processing area require special attention.

The room for storing soiled linen before pickup by commercial laundry is odorous and contaminated, and should be well ventilated and maintained at a negative air pressure.

The soiled utility room is provided for inpatient services and is normally contaminated with noxious odors. This room should be exhausted directly outside by mechanical means.

In the laundry processing area, equipment such as washers, flatwork ironers, and tumblers should have direct overhead exhaust to reduce humidity. Such equipment should be insulated or shielded whenever possible to reduce the high radiant heat effects. A canopy over the flatwork ironer and exhaust air outlets near other heat-producing equipment capture and remove heat best. Air supply inlets should be located to move air through the processing area toward the heat-producing equipment. The exhaust system from flatwork ironers and tumblers should be independent of the general exhaust system and equipped with lint filters. Air should exhaust above the roof or where it will not be obnoxious to occupants of other areas. Heat reclamation from the laundry exhaust air may be desirable and practicable.

Where air conditioning is contemplated, a separate supplementary air supply, similar to that recommended for kitchen hoods, may be located near the exhaust canopy over the ironer. Alternatively, spot cooling may be considered for personnel confined to specific areas.

Mechanical Facilities. The air supply to boiler rooms should provide both comfortable working conditions and the air quantities required for maximum combustion of the particular fuel used. Boiler and burner ratings establish maximum combustion rates, so the air quantities can be computed according to the type of fuel. Sufficient air must be supplied to the boiler room to supply the exhaust fans as well as the boilers.

At workstations, the ventilation system should limit temperatures to 90°F effective temperature. When ambient outside air temperature is higher, indoor temperature may be that of the outside air up to a maximum of 97°F to protect motors from excessive heat.

Maintenance Shops. Carpentry, machine, electrical, and plumbing shops present no unusual ventilation requirements. Proper ventilation of paint shops and paint storage areas is important because of fire hazard and should conform to all applicable codes. Maintenance shops where welding occurs should have exhaust ventilation.

CONTINUITY OF SERVICE AND ENERGY CONCEPTS

Zoning

Zoning (using separate air systems for different departments) may be indicated to (1) compensate for exposures because of orientation or for other conditions imposed by a particular building configuration, (2) minimize recirculation between departments, (3) provide flexibility of operation, (4) simplify provisions for operation on emergency power, and (5) conserve energy.

By ducting the air supply from several air-handling units into a manifold, central systems can achieve a measure of standby capacity. When one unit is shut down, air is diverted from noncritical or intermittently operated areas to accommodate critical areas, which must operate continuously. This or other means of standby protection is essential if the air supply is not to be interrupted by routine maintenance or component failure.

Separating supply, return, and exhaust systems by department is often desirable, particularly for surgical, obstetrical, pathological, and laboratory departments. The desired relative balance in critical areas should be maintained by interlocking supply and exhaust fans. Thus, exhaust should cease when supply airflow is stopped in areas otherwise maintained at positive or neutral pressure relative to adjacent spaces. Likewise, supply air should be deactivated when exhaust airflow is stopped in spaces maintained at a negative pressure.

Heating and Hot-Water Standby Service

The number and arrangement of boilers should be such that when one boiler breaks down or is temporarily taken out of service for routine maintenance, the capacity of the remaining boilers is sufficient to provide hot-water service for clinical, dietary, and patient use; steam for sterilization and dietary purposes; and heating for operating, delivery, birthing, labor, recovery, intensive care, nursery, and general patient rooms. However, reserve capacity may not be required in warmer climates, depending on individual facility building systems characteristics and operational requirements. Some codes or authorities do not require reserve capacity in climates where a design dry-bulb temperature of 25°F is equaled or

exceeded for 99.6% of the total hours in any one heating period as noted in the tables in Chapter 28 of the 2005 *ASHRAE Handbook—Fundamentals*.

Boiler feed, heat circulation, condensate return, and fuel oil pumps should be connected and installed to provide both normal and standby service. Supply and return mains and risers for cooling, heating, and process steam systems should be valved to isolate the various sections. Each piece of equipment should be valved at the supply and return ends.

Some supply and exhaust systems for delivery and operating room suites should be designed to be independent of other fan systems and to operate from the hospital emergency power system in the event of power failure. Operating and delivery room suites should be ventilated such that the hospital retains some surgical and delivery capability in cases of ventilating system failure.

Boiler steam is often treated with chemicals that cannot be released in the air-handling units serving critical areas. In this case, a clean steam system should be considered for humidification.

Mechanical Cooling

The source of mechanical cooling for clinical and patient areas in a hospital should be carefully considered. The preferred method is to use an indirect refrigerating system using chilled water or antifreeze solutions. When using direct refrigerating systems, consult codes for specific limitations and prohibitions. Refer to ASHRAE *Standard* 15, Safety Code for Mechanical Refrigeration.

Insulation

All exposed hot piping, ducts, and equipment should be insulated to maintain energy efficiency of all systems and protect building occupants. To prevent condensation, ducts, casings, piping, and equipment with outside surface temperature below ambient dew point should be covered with insulation having an external vapor barrier. Insulation, including finishes and adhesives on the exterior surfaces of ducts, pipes, and equipment, should have a flame spread rating of 25 or less and a smoke-developed rating of 50 or less, as determined by an independent testing laboratory in accordance with NFPA *Standard* 255, as required by NFPA 90A. The smoke-developed rating for pipe insulation should not exceed 150 (DHHS 1984).

Linings in air ducts and equipment should meet the erosion test method described in Underwriters Laboratories *Standard* 181. These linings, including coatings, adhesives, and insulation on exterior surfaces of pipes and ducts in building spaces used as air supply plenums, should have a flame spread rating of 25 or less and a smoke developed rating of 50 or less, as determined by an independent testing laboratory per ASTM *Standard* E84.

Duct linings should not be used in systems supplying operating rooms, delivery rooms, recovery rooms, nurseries, burn care units, or intensive care units, unless terminal filters of at least MERV 14 efficiency are installed downstream of linings. Duct lining should be used only for acoustical improvement; for thermal purposes, external insulation should be used.

When existing systems are modified, asbestos materials should be handled and disposed of per applicable regulations.

Energy

Health care is an energy-intensive, energy-dependent enterprise. Hospital facilities are different from other structures in that they operate 24 h/day year-round, require sophisticated back-up systems in case of utility shutdowns, use large quantities of outside air to combat odors and to dilute microorganisms, and must deal with problems of infection and solid waste disposal. Similarly, large quantities of energy are required to power diagnostic, therapeutic, and monitoring equipment; and support services such as food storage, preparation, and service and laundry facilities. Control strategies such as supply air temperature reset on variable-air-volume systems and hydronic reheat supply water temperature reset on variable pumping systems can often be applied with good results.

Hospitals conserve energy in various ways, such as by using larger energy storage tanks and by using energy conversion devices that transfer energy from hot or cold building exhaust air to heat or cool incoming air. Heat pipes, runaround loops, and other forms of heat recovery are receiving increased attention. Solid waste incinerators, which generate exhaust heat to develop steam for laundries and hot water for patient care, are becoming increasingly common. Large health care campuses use central plant systems, which may include thermal storage, hydronic economizers, primary/secondary pumping, cogeneration, heat recovery boilers, and heat recovery incinerators.

The construction design of new facilities, including alterations of and additions to existing buildings, strongly influences the amount of energy required to provide services such as heating, cooling, and lighting. Selecting building and system components for effective energy use requires careful planning and design. Integrating building waste heat into systems and using renewable energy sources (e.g., solar under some climatic conditions) will provide substantial savings (Setty 1976).

Testing, Adjusting, and Balancing (TAB)

For existing systems, testing before the start of construction, preferably during design, can be a good investment. This early effort provides the designer with information on actual system performance and whether components are suitable for intended modifications, as well as disclosing additional modifications.

The importance of TAB for modified and new systems before patient occupancy cannot be overemphasized. Health care facilities require validation and documentation of system performance characteristics. Often, a combination of TAB with commissioning satisfies this requirement. See Chapters 37 and 42 for information on TAB and commissioning.

OUTPATIENT HEALTH CARE FACILITIES

An outpatient health care facility may be a free-standing unit, part of an acute care facility, or part of a medical facility such as a medical office building (clinic). Any surgery is performed without anticipation of overnight stay by patients (i.e., the facility operates 8 to 10 h per day).

If physically connected to a hospital and served by the hospital's HVAC systems, spaces within the outpatient health care facility should conform to requirements in the section on Hospital Facilities. Outpatient health care facilities that are totally detached and have their own HVAC systems may be categorized as diagnostic clinics, treatment clinics, or both.

DIAGNOSTIC CLINICS

A diagnostic clinic is a facility where patients are regularly seen on an ambulatory basis for diagnostic services or minor treatment, but where major treatment requiring general anesthesia or surgery is not performed. Diagnostic clinic facilities should be designed according to criteria shown in Tables 4 and 5 (see the section on Nursing Home Facilities).

TREATMENT CLINICS

A treatment clinic is a facility where major or minor procedures are performed on an outpatient basis. These procedures may render patients incapable of taking action for self-preservation under emergency conditions without assistance from others (NFPA *Standard* 101).

Design Criteria

The system designer should refer to the following paragraphs from the section on Hospital Facilities:

- Infection Sources and Control Measures
- Air Quality
- Air Movement
- Temperature and Humidity
- Pressure Relationships and Ventilation
- Smoke Control

Air-cleaning requirements correspond to those in Table 1 for operating rooms. A recovery area need not be considered a sensitive area. Infection control concerns are the same as in an acute care hospital. Minimum ventilation rates, desired pressure relationships and relative humidity, and design temperature ranges are similar to the requirements for hospitals shown in Table 3.

The following departments in a treatment clinic have design criteria similar to those in hospitals:

- Surgical: operating, recovery, and anesthesia storage rooms
- Ancillary
- Diagnostic and Treatment
- Sterilizing and Supply
- Service: soiled workrooms, mechanical facilities, and locker rooms

Continuity of Service and Energy Concepts

Some owners may desire standby or emergency service capability for the heating, air-conditioning, and service hot water systems and that these systems be able to function after a natural disaster.

To reduce utility costs, use energy-conserving measures such as recovery devices, variable air volume, load shedding, or devices to shut down or reduce ventilation of certain areas when unoccupied. Mechanical ventilation should take advantage of outside air by using an economizer cycle, when appropriate, to reduce heating and cooling loads.

The subsection on Continuity of Service and Energy Concepts in the section on Hospital Facilities includes information on zoning and insulation that applies to outpatient facilities as well.

NURSING FACILITIES

Nursing facilities may be classified as follows:

Extended care facilities are for recuperation of hospital patients who no longer require hospital facilities but do require the therapeutic and rehabilitative services of skilled nurses. This type of facility is either a direct hospital adjunct or a separate facility having close ties with the hospital. Clientele may be of any age, usually stay from 35 to 40 days, and usually have only one diagnostic problem.

Skilled nursing homes care for people who require assistance in daily activities; many of them are incontinent and nonambulatory, and some are disoriented. Residents may come directly from their homes or from residential care homes, are generally elderly (with an average age of 80), stay an average of 47 months, and frequently have multiple diagnostic problems.

Residential care homes are generally for elderly people who are unable to cope with regular housekeeping chores but have no acute ailments and are able to care for all their personal needs, lead normal lives, and move freely in and out of the home and the community. These homes may or may not offer skilled nursing care. The average length of stay is four years or more.

Functionally, these buildings have five types of areas that are of concern to the HVAC designer: (1) administrative and support areas inhabited by the staff, (2) patient areas that provide direct normal daily services, (3) treatment areas that provide special medical services, (4) clean workrooms for storing and distributing clean supplies, and (5) soiled workrooms for collecting soiled and contaminated supplies and for sanitizing nonlaundry items.

Table 5 Filter Efficiencies for Central Ventilation and Air-Conditioning Systems in Nursing Facilities

Area Designation	Minimum Number of Filter Beds	Filter Efficiency of Main Filter Bed, MERV*
Resident care, treatment, diagnostic, and related areas	1	15
Food preparation areas and laundries	1	8
Administrative, bulk storage, and soiled holding areas	1	6

*Ratings based on ASHRAE *Standard* 52.2; MERV = Minimum Efficiency Reporting Value

DESIGN CONCEPTS AND CRITERIA

Controlling bacteria levels in nursing homes is not as critical as it is in acute care hospitals. Nevertheless, the designer should be aware of the necessity for odor control, filtration, and airflow control between certain areas.

Table 5 lists recommended filter efficiencies for air systems serving specific nursing home areas. Table 6 lists recommended minimum ventilation rates and desired pressure relationships for certain areas in nursing homes.

Recommended interior winter design temperature is 75°F for areas occupied by patients and 70°F for nonpatient areas. Provisions for maintenance of minimum humidity levels in winter depend on the severity of the climate and are best left to the judgment of the designer. Where air conditioning is provided, the recommended interior summer design temperature and humidity is 75°F and 50% rh.

The general design criteria in the sections on Heating and Hot-Water Standby Service, Insulation, and Energy for hospital facilities apply to nursing home facilities as well.

APPLICABILITY OF SYSTEMS

Nursing homes occupants are usually frail, and many are incontinent. Though some occupants are ambulatory, others are bedridden, suffering from the advanced stages of illnesses. The selected HVAC system must dilute and control odors and should not cause drafts. Local climatic conditions, costs, and designer judgment determine the extent and degree of air conditioning and humidification. Odor may be controlled with large volumes of outside air and some form of heat recovery. To conserve energy, odor may be controlled with activated carbon or potassium permanganate-impregnated activated alumina filters instead.

Temperature control should be on an individual-room basis. In geographical areas with severe climates, patients' rooms should have supplementary heat along exposed walls. In moderate climates (i.e., where outside winter design conditions are 30°F or above), heating from overhead may be used.

DENTAL CARE FACILITIES

Institutional dental facilities include reception and waiting areas, treatment rooms (called operatories), and workrooms where supplies are stored and instruments are cleaned and sterilized; they may include laboratories where restorations are fabricated or repaired.

Many common dental procedures generate aerosols, dusts, and particulates (Ninomura and Byrns 1998). The aerosols/dusts may contain microorganisms (both pathogenic and benign), metals (such as mercury fumes), and other substances (e.g., silicone dusts, latex allergens, etc.). Some measurements indicate that levels of bioaerosols during and immediately following a procedure can be extremely

Table 6 Pressure Relationships and Ventilation of Certain Areas of Nursing Facilities

Function Area	Pressure Relationship to Adjacent Areas	Minimum Air Changes of Outside Air per Hour Supplied to Room	Minimum Total Air Changes per Hour Supplied to Room	All Air Exhausted Directly to Outside	Air Recirculated Within Room Units
Resident Care					
Resident room (holding room)	*	2	4	Optional	Optional
Resident corridor	*	Optional	2	Optional	Optional
Toilet room	Negative	Optional	10	Yes	No
Resident gathering (dining, activity)	*	2	4	Optional	Optional
Diagnostic and Treatment					
Examination room	*	2	6	Optional	Optional
Physical therapy	Negative	2	6	Optional	Optional
Occupational therapy	Negative	2	6	Optional	Optional
Soiled workroom or soiled holding	Negative	2	10	Yes	No
Clean workroom or clean holding	Positive	2	4	Optional	Optional
Sterilizing and Supply					
Sterilizer exhaust room	Negative	Optional	10	Yes	No
Linen and trash chute room	Negative	Optional	10	Yes	No
Laundry, general	*	2	10	Yes	No
Soiled linen sorting and storage	Negative	Optional	10	Yes	No
Clean linen storage	Positive	Optional	2	Yes	No
Service					
Food preparation center	*	2	10	Yes	Yes
Warewashing room	Negative	Optional	10	Yes	Yes
Dietary day storage	*	Optional	2	Yes	No
Janitor closet	Negative	Optional	10	Yes	No
Bathroom	Negative	Optional	10	Yes	No
Personal services (barber/salon)	Negative	2	10	Yes	No

*Continuous directional control not required

high (Earnest and Loesche 1991). Lab procedures have been shown to generate dusts and aerosols containing metals. At this time, only limited information and research are available on the level, nature, or persistence of bioaerosol and particulate contamination in dental facilities.

Nitrous oxide is used as an analgesic/anesthetic gas in many facilities. The design for controlling nitrous oxide should consider that nitrous oxide (1) is heavier than air and may accumulate near the floor if air mixing is inefficient, and (2) should be exhausted directly outside. NIOSH (1996) includes recommendations for the ventilation/exhaust system.

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