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Health Care Standards and Guidelines

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Health Care Standards and Guidelines

Health Care Standards and Guidelines Table of Contents

Health Care Standards and Guidelines

Contained herein is a compilation of excerpts from the Centers for Disease Control, the American Institute of Architects, and the American Society of Heating, Refrigerating and Air-Conditioning Engineers. The intent of this document is to provide the owner, engineer, architect, or health care worker an overview of those excerpts as they relate to the standards and guidelines that are applicable to the design and/or use of today's isolation room.

Individuals should consult all relevant local, state, and federal building codes to define what applicable standards or guidelines from this section might pertain to a particular health care facility.

Isolation Rooms

Federal Register — CDC

p.54259

"TB isolation rooms should be single-patient rooms with special ventilation characteristics appropriate for the purposes of isolation (Suppl.3.) The primary purposes of TB isolation rooms are to: (a) separate patients who are likely to have infectious TB from other persons; (b) provide an environment that will allow reduction of the concentration of droplet nuclei through various engineering methods; and (c) prevent the escape of droplet nuclei from the TB isolation room and treatment room, thus preventing entry of *M. tuberculosis* into the corridor and other areas of the facility."

AIA

p.14, section 7.2.C1.

"At least one airborne infection isolation room shall be provided. These rooms may be located within individual nursing units and used for normal acute care when not required for isolation cases, or they may be grouped as a separate isolation unit."

p.14, section 7.2.C6.

"Airborne infection isolation rooms may be used for noninfectious patients when not needed for patients with airborne infectious disease."

p.14, section 7.2.D.

"The differentiating factor between protective environment rooms and other patient rooms is the requirement for positive air pressure relative to adjoining spaces with all supply air passing through HEPA filters with 99.97 percent efficiency for particles >3 micron μm in size."

p.60

"The protective environment airflow design specifications protect the patient from common environmental airborne infectious microbes (i.e., Aspergillus spores). These special ventilation areas shall be designed to provide directed airflow from the cleanest patient care area to less clean areas."

"If the facility determines that airborne infection isolation is necessary for protective environment patients, an anteroom should be provided. Rooms with reversible airflow provisions for the purpose of switching between protective and airborne infection isolation functions are not acceptable."

ASHRAE Handbook

p.7.6

"**Protective Isolation Units.** Immunosuppressed patients (including bone marrow or organ transplant, leukemia, burn, and AIDS patients) are highly susceptible to diseases."

p.7.7

"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 relationship with respect to the adjacent area or anteroom. Alternatively, when it is permitted by the jurisdictional authority, such isolation rooms may be equipped with controls that enable the room to be positive, equal, or negative in relation to the adjacent area. However, in such instances, controls in the adjacent area or anteroom must maintain the correct pressure relationship with respect to the other adjacent room(s)."

"**Infectious Isolation Unit.** The infectious isolation room is used to protect the remainder of the hospital from the 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 1993). Temperatures and humidities should correspond to those specified for patient rooms."

"Some designers have provided isolation rooms that allow maximum space flexibility by using an approach that reverses the airflow direction by varying exhaust flow rate. This approach is useful only if appropriate adjustments can be ensured for different types of isolation procedures."

HVAC Systems

Federal Register — CDC

p.54279

"Two types of general ventilation systems can be used for dilution and removal of contaminated air: the single-pass system and the recirculating system. In a single-pass system, the supply air is either outside air that has been appropriately heated and cooled or air from a central system that supplies a number of areas. After air passes through the room (or area), 100% of that air is exhausted to the outside. The single-pass system is the preferred choice in areas where infectious airborne droplet nuclei are known to be present (e.g., TB isolation rooms or treatment rooms) because it prevents contaminated air from getting recirculated to other areas of the facility."

"In a recirculating system, a small portion of the exhaust air is discharged to the outside and is replaced with fresh outside air, which mixes with the portion of exhaust air that was not discharged to the outside. The resulting mixture, which can contain a large proportion of contaminated air, is then recirculated to the areas serviced by the system. This air mixture could be recirculated into the general ventilation in which case contaminants may be carried from contaminated areas to uncontaminated areas. Alternatively, the air mixture could also be recirculated within a specific room or area, in which case other areas of the facility will not be affected."

p.54260

"Air from TB isolation rooms and treatment rooms used to treat patients who have known or suspected infectious TB should be exhausted to the outside in accordance with applicable federal, state and local regulations. The air should not be recirculated into the general ventilation. In some instances, recirculation of air into the general ventilation system from such rooms is unavoidable (i.e., in existing facilities in which the ventilation system or facility configuration makes venting the exhaust to the outside impossible). In such case, HEPA filters should be installed in the exhaust duct leading from the room to the general ventilation system to remove infectious organisms and particulates the size of droplet nuclei from the air before it is returned to the general ventilation system."

p.54284

"Individual room-air recirculation can be used in areas where there is no general ventilation system, where an existing system is incapable of providing adequate airflow, or where an increase in ventilation is desired without affecting the fresh air supply or negative pressure system already in place. Recirculation of HEPA-filtered air within a room can be achieved in several ways: (a) by exhausting air from the room into a duct, filtering it through a HEPA filter installed in the duct, and returning it to the room...; (b) by filtering air through HEPA recirculation system mounted on the wall or ceiling of the room...; or (c) by filtering air through portable HEPA recirculation systems."

AIA

p.58–59 *excerpt from Table 2*

	All air exhausted directly to outdoors[5]	Recirculated by means of room units[6]
Protective environment room	–	no
Airborne infection isolation room	–	no
Isolation alcove or anteroom	yes	no

[5] "Air from areas with contamination and/or odor problems shall be exhausted to the outside and not recirculated to other areas. Note that individual circumstances may require special consideration for air exhaust to outside, e.g., in intensive care units in which patients with pulmonary infection are treated, and rooms for burn patients."

[6] "Because of cleaning difficulty and potential for buildup of contamination, recirculating room units shall not be used in areas marked "No." However, for airborne infection control, air may be recirculated within individual isolation rooms if HEPA filters are used. Isolation and intensive care unit rooms may be ventilated by reheat induction units in which only the primary air supplied from a central system passes through the reheat unit. Gravity-type heating or cooling units such as radiators or convectors shall not be used in operating rooms and other special care areas."

ASHRAE Handbook

p.7.5 *excerpt from Table 3*

	All air exhausted directly to outdoors	Air recirculated within room units
Infectious isolation	yes	no
Isolation alcove or anteroom	yes	no

p.7.4

"Because of the cleaning difficulty and potential for buildup of contamination, recirculating room 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 critical care areas, constant volume systems should be employed to assure proper pressure relationships and ventilation except in unoccupied rooms. In noncritical patient care areas and staff rooms, variable air volume (VAV) systems may be considered for energy conservation. When using VAV systems within 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 departments 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)."

p.7.7

"A separate, dedicated air-handling system to serve the protective isolation unit simplifies pressure control and quality (Murray 1988)."

Air Change Rates

Federal Register — CDC

p.54287

"To reduce the concentration of droplet nuclei, TB isolation rooms and treatment rooms in existing health-care facilities should have an airflow of ≥6 ACH. Where feasible, this airflow rate should be increased to ≥12 ACH by adjusting or modifying the ventilation system or by using auxiliary means (e.g. recirculation of air through fixed HEPA filtration units or portable air cleaners)... New construction or renovation of existing health-care facilities should be designed so that TB isolation rooms achieve an airflow of ≥12 ACH."

AIA

p.58 *excerpt from Table 2*

	Min. air changes of outdoor air per hour[3]	Min. total air changes per hour[4]
Toilet room	–	10
Protective environment room	2	12
Airborne infection isolation room	2	12
Isolation alcove or anteroom	–	10

[3] "To satisfy exhaust needs, replacement air from the outside is necessary. Distribution of the outside air, added to the system to balance required exhaust, shall be as required by good engineering practice. Minimum outside air quantities shall remain constant while the system is in operation."

[4] "Number of air changes may be reduced when the room is unoccupied if provisions are made to ensure that the number of air changes indicated is reestablished any time the space is being utilized. Adjustments shall include provisions so that the direction of air movement shall remain the same when the number of air changes is reduced."

ASHRAE Handbook

p.7.5 *excerpt from Table 3*

	Min. air changes of outdoor air per hour	Min. total air changes per hour
Toilet room	*optional*	10
Infectious isolation	2	6
Isolation alcove or anteroom	2	10

p.7.4

"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."

Room Airflow Patterns

Federal Register — CDC

p.54280

"General ventilation systems should be designed to provide optimal patterns of airflow within rooms and prevent air stagnation or short-circuiting of air from the supply to the exhaust (i.e., passage of air directly from the air supply to the air exhaust). To provide optimal airflow patterns, the air supply and exhaust should be located such that clean air first flows to parts of the room where HCWs are likely to work, and then flows across the infectious sources and into the exhaust. In this way, the HCW is not positioned between the infectious source and the exhaust location. Although this configuration may not always be possible, it should be used when feasible. One way to achieve this airflow pattern is to supply air at the side of the room opposite the patient and exhaust it from the side where the patient is located. Another method, which is most effective when the supply is cooler than the room air, is to supply air near the ceiling and exhaust it near the floor (Figure S3-2). Airflow patterns are affected by large air temperature differentials, the precise location of the supply and exhaust, the location of furniture, the movement of HCWs and patients, and the physical configuration of the space. Smoke tubes can be used to visualize airflow patterns in a manner similar to that described for estimating room air mixing."

AIA

p.50, section 7.31.D7.

"The bottoms of ventilation (supply/return) openings shall be at least 3 inches (7.62 centimeters) above the floor."

ASHRAE Handbook

p.7.3

"In general, outlets supplying air to sensitive ultraclean areas and highly contaminated areas should be located on the ceiling, with perimeter or several exhaust inlets near the floor. This arrangement provides a downward movement of clean air through the breathing and working zones to the contaminated floor area for exhaust. The bottoms of return or exhaust openings should be at least 3 in. above the floor."

Facility Airflow Direction

Federal Register — CDC

p.54281

"The general ventilation system should be designed and balanced so that air flows from less contaminated (i.e., more clean) to more contaminated (less clean) areas. For example, air should flow from corridors (clean areas) into TB isolation rooms (less clean areas) to prevent spread of contaminants to other areas. In some special treatment rooms in which operative and invasive proce-

dures are performed, the direction of airflow is from the room to the hallway to provide cleaner air during these procedures. Cough-inducing or aerosol-generating procedures (e.g., bronchoscopy or irrigating of turberculous abscesses) should not be performed in rooms with this type of airflow on patients who may have infectious TB."

"The direction of airflow is controlled by creating a lower (negative) pressure in the area into which the flow of air is desired. For air to flow from one area to another, the air pressure into the two areas must be different. Air will flow from a higher pressure area to a lower pressure. The lower pressure area is described as being at negative pressure relative to the higher pressure area. Negative pressure is attained by exhausting air from an area at a higher rate than air is being supplied. The level of negative pressure necessary to achieve the desired airflow will depend on the physical configuration of the ventilation system and area, including the airflow path and flow openings, and should be determined on an individual basis by an experienced ventilation engineer."

ASHRAE Handbook

p.7.3

"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 the vertical openings such as chutes, elevator shafts, stairwells, and mechanical shafts common to hospitals. While 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."

Room Pressurization/Anterooms

Federal Register — CDC

p.54281

"The minimum pressure difference necessary to achieve and maintain negative pressure that will result in airflow into the room is very small (0.001 inch of water). Higher pressures (≥ 0.001 inch of water) are satisfactory: however, these higher pressures may be difficult to achieve. The actual level of negative pressure achieved will depend on the difference in the ventilation exhaust and supply flows and the physical configuration of the room, including the airflow path and flow opening. If the room is well sealed, negative pressure greater than the minimum of 0.001 inch of water may be readily achieved. However, if rooms are not well sealed, as may be the case in many facilities (especially older facilities), achieving higher negative pressures may require exhaust/supply flow differentials beyond the capability of the ventilation system."

"To establish negative pressure in a room that has a normally functioning ventilation system, the room supply and exhaust airflows are first balanced to achieve an exhaust flow of either 10% or 50 cubic feet per minute (cfm) greater than supply (whichever is the greater). In most situations, this specification should achieve a negative pressure of at least 0.001 inch of water. If the minimum of 0.001 is not achieved and cannot be achieved by increasing the flow differential (within the limits of the ventilation system), the room should be inspected for leakage (e.g., through doors, windows, plumbing, and equipment wall penetrations), and corrective action should be taken to seal the leaks."

"Negative pressure in a room can be altered by changing the ventilation system operation or by opening and closing the room's doors, corridor doors, or windows. When an operating configuration has been established, it is essential that all doors and windows remain properly closed in the isolation room and other areas (e.g., doors in corridors that affect air pressure) except when persons need to enter or leave the room area."

"Although an anteroom is not a substitute for negative pressure in a room, it may be used to reduce escape of droplet nuclei during opening and closing of the isolation room door. Some anterooms have their own air supply duct but others do not. The TB isolation room should have negative pressure relative to the anteroom, but the air pressure in the anteroom relative to the corridor may vary depending on the building design. This should be determined, in accordance with applicable regulation, by a qualified ventilation engineer."

p.54282

"Differential pressure-sensing devices also can be used to monitor negative pressure; they can provide either periodic (noncontinuous) pressure measurements or continuous pressure monitoring. The continuous monitoring components may simply be a visible and/or audible warning signal that air pressure is low. In addition, it may also provide a pressure readout signal, which can be recorded for later verification or used to automatically adjust the facility's ventilation control system."

"Pressure-measuring devices should sense the room pressure just inside the airflow path into the room (e.g., at the bottom of the door). Unusual airflow patterns within the room can cause pressure variations; for example, air can be at negative pressure at the middle of a door and at positive pressure at the bottom of the door. If the pressure sensing ports of the device cannot be located directly across the airflow path, it will be necessary to validate that the negative pressure at the sensing point is and remains the same as the negative pressure across the flow path."

"Pressure-sensing devices should incorporate an audible warning with time delay to indicate that a door is open. When the door to the room is opened, the negative pressure will decrease. The time-delayed signal should allow suffi-

cient time for persons to enter or leave the room without activating the audible warning."

p.54283

"A potential problem with using pressure-sensing devices is that the pressure differential used to achieve the low negative pressure necessitates the uses of very sensitive mechanical devices, electronic devices, or pressure gauges to ensure accurate measurements. Use of devices that cannot measure these low pressures (i.e., pressures as low as 0.001 inch of water) will require setting higher negative pressures that may be difficult and, in some instances, impractical to achieve."

"Periodic checks are required to ensure that the continuous monitoring devices, if used, are operating properly."

AIA

p.58 *excerpt from Table 2*

	Air movement relationship to adjacent areas[2]
Toilet room	In
Protective environment room	Out
Airborne infection isolation room	In
Isolation alcove or anteroom	In/Out

[2] "Design of the ventilation system shall provide air movement which is generally from clean to less clean areas. If any form of variable air volume or load shedding system is used for energy conservation, it must not compromise the corridor-to-room pressure balancing relationships or the minimum air changes required by the table."

p.133, section A7.2.D.

"Immunosuppressed Host Airborne Infection Isolation (Protective Environment/Airborne Infection Isolation). An anteroom is required for the special case in which an immunosuppressed patient requires airborne infection isolation. There is no prescribed method for anteroom ventilation—the room can be ventilated with either of the following airflow patterns: (a) airflows from the anteroom, to the patient room and the corridor, or (b) airflows from the patient room and the corridor, into the anteroom. The advantage of pattern (a) is the provision for a clean anteroom in which health care workers need not mask before entering the anteroom."

ASHRAE Handbook

p.7.7

"In cases where the patient is immunosuppressed but not contagious, a positive pressure should be maintained between the patient room and adjacent area. Some jurisdictions may require an anteroom, which maintains a negative pressure relationship with respect to the adjacent isolation room and an equal pressure relationship with respect to the corridor, nurses' station, or common area."

"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 relationship with respect to the adjacent area or anteroom. Alternatively, when it is permitted by the jurisdictional authority, such isolation rooms may be equipped with controls to enable the room to be positive, equal, or negative in relation to the adjacent area. However, in such instances, controls in the adjacent area or anteroom must maintain the correct pressure relationship with respect to the other adjacent room(s)."

"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 particulates from the patients' area reach adjacent areas."

p.7.5 *excerpt from Table 3*

	Pressure relationship
Toilet room	N
Isolation	+/–
Isolation alcove or anteroom	+/–

P = positive N = negative +/– = Continuous directional control not required.[E]

[E] "Although continuous directional control is not required, variations should be minimized and in no case should a lack of directional control allow the spread of infection from one area to another. Boundaries between functional areas (wards or departments) should have directional control. Lewis (1988) describes methods for maintaining directional control by applying air tracking controls."

Filtration

Federal Register — CDC

p.54283

"HEPA filtration can be used as a method of air cleaning that supplements other recommended ventilation measure. For the purposes of these guidelines, HEPA filters are designed as air-cleaning devices that have demonstrated and documented minimum removal efficiency of 99.97% of particles greater than or equal to 0.3 microns in diameter. HEPA filters have been shown to be effective in reducing the concentration of *Aspergillus* spores (which range in size from 1.5 microns to 6 microns) to below measurable levels (100 -102). The ability of HEPA filter to remove tubercle bacilli from the air has not been studied, but *M. tuberculosis* droplet nuclei probably range from 1 micron to 5 microns in diameter (i.e., approximately the same size as *Aspergillus* spores). Therefore, HEPA filters can be expected to remove infectious droplet nuclei from contaminated air. HEPA filters can be used to clean air before it is exhausted to the outside, recirculated to other areas of a facility, or recirculated within a room. If the device is not completely passive, (e.g., it utilizes techniques such as electrostatics) and the failure of the electrostatic components

permits loss of filtration efficiency to less than 99.97%, the device should not be used in systems that recirculate air back into the general facility ventilation system from TB isolation rooms and treatment rooms in which procedures are performed on patients who may have infectious TB."

"HEPA filters can be used in a number of ways to reduce or eliminate infectious droplet nuclei from room air or exhaust. These methods include placement of HEPA filters: (a) in exhaust ducts to remove droplet nuclei from air being discharged to the outside, either directly or through ventilation equipment; (b) in ducts discharging room air in to the general ventilation system; and (c) in fixed or portable room-air cleaners. The effectiveness of portable HEPA room-air cleaner units has not been evaluated adequately, and there is probably considerable variation in their effectiveness. HEPA filters can also be used in exhaust ducts or vents that discharge air from booths or enclosures into the surrounding room. In any application, HEPA filters should be installed carefully and maintained meticulously to ensure adequate function."

ASHRAE Handbook

p.7.2

"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 the air-conditioning equipment, and Filter Bed No. 2 should be downstream of the supply fan, any recirculating spray water systems, and water-reservoir type humidifiers."

"HEPA filters having DOP test efficiencies of 99.97% should be used on air supply systems serving rooms used for clinical treatment of patients with a high susceptibility to infection from leukemia, burns, bone marrow transplant, organ transplant, or acquired immunodeficiency syndrome (AIDS)."

p.7.3 *excerpt from Table 1*

Minimum Number of Filter Beds	Area Designation	Filter Efficiencies, % Filter Bed No. 1[a]	No. 2[a]	No. 3[b]
3	Orthopedic operating room Bone marrow transplant operating room Organ transplant operating room	25	90	99.97[c]
2	General procedure operating rooms Delivery rooms Nurseries Intensive care units Patient care rooms Treatment rooms Diagnostic and related areas	25	90	
1	Laboratories	1	80	–

[a] Based on ASHRAE *Standard* 52.1-1992. [b] Based on DOP test. [c] HEPA filters at air outlets.

AIA

p.50, section 7.31.D8.

"All central ventilation or air conditioning systems shall be equipped with filters with efficiencies equal to, or greater than, those specified in Table 3. Where two filter beds are required, filter bed no. 1 shall be located upstream of the air conditioning equipment and filter bed no. 2 shall be downstream of any fan or blowers."

p.60 *excerpt from Table 3*

Area designation	No. of filter beds	Filter bed no. 1 (%)	Filter bed no. 2 (%)
All areas for inpatient care, treatment, and diagnosis, and those areas providing direct service or clean supplies such as sterile and clean processing, etc.	2	30	90
Protective environment room	2	30	99.97
Laboratories	1	80	–

Sound Levels in Rooms

ASHRAE Handbook

p.43.5

"Table 2 lists normally accepted HVAC background sound levels for a variety of space uses. The acceptable sound levels in Table 2 are specified in terms of room criterion, which should be used whenever the quality of space use dictates the need for a neutral, unobtrusive background sound."

Table 2. (partial) Design Guidelines for HVAC System Noise in Unoccupied Spaces

Space	RC(N) Level[a,b]
Hospitals and clinics (private rooms)	25-35

[a] The values and ranges are based on judgment and experience, not on quantitative evaluations of human reactions. They represent general limits of acceptability for typical building occupancies. Higher or lower values may be appropriate and should be based on a careful analysis of economics, space usage, and user needs. They are not intended to serve by themselves as a basis for a contractual requirement.

[b] When the quality of sound in the space is important, specify criteria in terms of RC(N). If the quality of sound in the space is secondary concern, the criteria may be specified in terms of NC levels.

"Noise criterion (NC) levels...may be substituted when the quality of space use is not as demanding and rumbly, hissy, or tonal characteristics in the background sound can be tolerated as long as it is not too loud."

References

AIA 1996-97 – American Institute of Architects Academy of Architecture for Health with assistance from the U.S. Department of Health and Human Services. Chapter 7: General Hospital. In: Guidelines for Design and Construction of Hospital and Health Care Facilities. The American Institute of Architects Press, Washington, D.C., 1996.

ASHRAE 1995 – American Society of Heating, Refrigerating, and Air-Conditioning Engineers. Chapter 7: Health Facilities. In: 1995 Application Handbook. American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., Atlanta, Georgia, 1995.

CDC 1994 – CDC Guidelines for Preventing the Transmission of Mycobacterium Tuberculosis in Health-Care Facilities; U.S. Department of Health and Human Services, Public Health Services; Federal Register Vol. 59, No. 208.

Appendix

Following is a partial reprint of the Federal Register Vol. 59, No. 208 – Centers for Disease Control and Prevention – Guidelines for Preventing the Transmission of Mycobacterium Tuberculosis in Health-Care Facilities, 1994 with pertinent sections highlighted.

federal register

Friday
October 28, 1994

Part II

Department of Health and Human Services

Centers for Disease Control and Prevention

Guidelines for Preventing the Transmission of Mycobacterium Tuberculosis in Health-Care Facilities, 1994; Notice

Executive Summary

This document updates and replaces all previously published guidelines for the prevention of *Mycobacterium tuberculosis* transmission in health-care facilities. The purpose of this revision is to emphasize the importance of (a) the hierarchy of control measures, including administrative and engineering controls and personal respiratory protection; (b) the use of risk assessments for developing a written tuberculosis (TB) control plan; (c) early identification and management of persons who have TB; (d) TB screening programs for healthcare workers (HCWs); (e) HCW training and education; and (f) the evaluation of TB infection-control programs.

Transmission of *M. tuberculosis is* a recognized risk to patients and HCWs in health-care facilities. Transmission is most likely to occur from patients who have unrecognized pulmonary or laryngeal TB, are not on effective anti-TB therapy, and have not been placed in TB isolation. Several recent TB outbreaks in health-care facilities, including outbreaks of multidrug-resistant TB, have heightened concern about nosocomial transmission. Patients who have multidrug-resistant TB can remain infectious for prolonged periods, which increases the risk for nosocomial and/or occupational transmission of *M. tuberculosis.* Increases in the incidence of TB have been observed in some geographic areas; these increases are related partially to the high risk for TB among immunosuppressed persons, particularly those infected with human immunodeficiency virus (HIV). Transmission of *M. tuberculosis* to HIV-infected persons is of particular concern because these persons are at high risk for developing active TB if they become infected with the bacteria. Thus, healthcare facilities should be particularly alert to the need for preventing transmission of *M. tuberculosis* in settings in which HIV-infected persons work or receive care.

Supervisory responsibility for the TB infection-control program should be assigned to a designated person or group of persons who should be given the authority to implement and enforce TB infection-control policies. An effective TB infection-control program requires early identification, isolation, and treatment of persons who have active TB. The primary emphasis of TB infection-control plans in health-care facilities should be achieving these three goals by the application of a hierarchy of control measures, including (a) the use of administrative measures to reduce the risk for exposure to persons who have infectious TB, (b) the use of engineering controls to prevent the spread and reduce the concentration of infectious droplet nuclei, and (c) the use of personal respiratory protective equipment in areas where there is still a risk for exposure to *M. tuberculosis* (e.g., TB isolation rooms). Implementation of a TB infection-control program requires risk assessment and development of a TB infection-control plan; early identification, treatment, and isolation of infectious TB patients; effective engineering controls; an appropriate respiratory protection program; HCW TB training, education, counseling, and screening; and evaluation of the program's effectiveness.

Although completely eliminating the risk for transmission of *M. tuberculosis* in all health-care facilities may not be possible at the present time, adherence to these guidelines should reduce the risk to persons in these settings. Recently, nosocomial TB outbreaks have demonstrated the substantial morbidity and mortality among patients and HCWs that have been associated with incomplete implementation *of* CDC's *Guidelines for Preventing the Transmission of Tuberculosis in HealthCare Facilities, with Special Focus on HlV-Related Issues* published in 1990.* Follow-up investigations at some of these hospitals have documented that complete implementation of measures similar or identical to those in the *1990 TB Guidelines* significantly reduced or eliminated nosocomial transmission of *M. tuberculosis* to patients and/or HCWs.

1. Introduction

A. Purpose of Document

In April 1992, the National MDR-TB Task Force published the *National Action Plan to Combat Multidrug-Resistant Tuberculosis* (1). The publication was a response to reported nosocomial outbreaks of tuberculosis (TB), including outbreaks of multidrug-resistant TB (MDR-TB), and the increasing incidence of TB in some geographic areas. The plan called for the update and revision of the guidelines for preventing nosocomial transmission of *Mycobacterium tuberculosis* published December 7,1990 (2).

Public meetings were held in October 1992 and January 1993 to discuss revision of the *1990 TB Guidelines (2).* CDC received considerable input on various aspects of infection control, including health-care worker (HCW) education; administrative controls (e.g., having protocols for the early identification and management of patients who have TB); the need for more specific recommendations regarding ventilation; and clarification on the use of respiratory protection in health-care settings. On the basis of these events and the input received, on October 12,1993, CDC published in the **Federal Register** the *Draft Guidelines For* Preventing the *Transmission of Tuberculosis in Health-Care Facilities Second Edition (3).* During and after the 90-day comment period following publication of this draft CDC's TB Infection-Control Guidelines Work Group received and reviewed more than 2,500 comments.

The purpose of this document is to make recommendations for reducing the risk for transmitting *M. tuberculosis to* HCWs, patients, volunteers, visitors, and other persons in these settings. The information also may serve as a useful resource for educating HCWs about TB.

These recommendations update and replace all previously published CDC recommendations for TB infection control in health-care facilities (2, 4). The recommendations in this document are applicable primarily to inpatient facilities in which health care is provided (e.g., hospitals, medical wards in correctional facilities, nursing homes, and hospices).

* *CDC. Guidelines for Preventing the Transmission of Tuberculosis in Health-Care Facilities, with Special Focus on HIV-Related Issues.* MMWR 1990; 39 (No. RR-17).

Recommendations applicable to ambulatory care facilities, emergency departments, home-healthcare settings, emergency medical services, medical offices, dental settings, and other facilities or residential settings that provide medical care are provided in separate sections, with cross-references to other sections of the guidelines if appropriate.

Designated personnel at health-care facilities should conduct a risk assessment for the entire facility and for each area* and occupational group, determine the risk for nosocomial or occupational transmission of M. *tuberculosis*, and implement an appropriate TB infection-control program. The extent of the TB infection-control program may range from a simple program emphasizing administrative controls in settings where there is minimal risk for exposure to M. *tuberculosis*, to a comprehensive program that includes administrative controls, engineering controls, and respiratory protection in settings where the risk for exposure is high. In all settings, administrative measures should be used to minimize the number of HCWs exposed to *M. tuberculosis* while still providing optimal care for TB patients. HCWs providing care to patients who have TB should be informed about the level of risk for transmission of *M. tuberculosis* and the appropriate control measures to minimize that risk.

In this document, the term "HCWs" refers to all the paid and unpaid persons working in health-care settings who have the potential for exposure to *M. tuberculosis.* This may include, but is not limited to, physicians; nurses; aides; dental workers; technicians; workers in laboratories and morgues; emergency medical service (EMS} personnel; students; part-time personnel; temporary staff not employed by the health-care facility; and persons not involved directly in patient care but who are potentially at risk for occupational exposure to *M. tuberculosis* (e.g., volunteer workers and dietary, housekeeping, maintenance, clerical, and janitorial staff).

Although the purpose of this document is to make recommendations for reducing the risk for transmission of *M. tuberculosis* in health-care facilities, the process of implementing these recommendations must safeguard, in accordance with applicable state and federal laws, the confidentiality and civil rights of persons who have TB.

B. Epidemiology, Transmission, and Pathogenesis of TB

The prevalence of TB is not distributed evenly throughout all segments of the U.S. population. Some subgroups or persons have a higher risk for TB either because they are more likely than other persons in the general population to have been exposed to and infected with *M. tuberculosis* or because their infection is more likely to progress to active TB after they have been infected (5). In some cases, both of these factors may be present. Groups of persons known to have a higher prevalence of TB infection include contacts of persons who have active TB, foreign-born persons from areas of the world with a high prevalence of TB (e.g., Asia, Africa, the Caribbean, and Latin America), medically underserved populations (e.g., some African-Americans, Hispanics, Asians and Pacific Islanders, American Indians, and Alaskan Natives), homeless persons, current or former correctional-facility inmates, alcoholics, injecting-drug users, and the elderly. Groups with a higher risk for progression from latent TB infection to active disease include persons who have been infected recently (i.e., within the previous 2 years), children less than <4 years of age, persons with fibrotic lesions on chest radiographs, and persons with certain medical conditions (i.e., human immunodeficiency virus [HlV] infection, silicosis, gastrectomy or jejuno-ileal bypass, being ≥10% below ideal body weight, chronic renal failure with renal dialysis, diabetes mellitus, immunosuppression resulting from receipt of high-dose corticosteroid or other immunosuppressive therapy, and some malignancies) (5).

M. tuberculosis is carried in airborne particles, or droplet nuclei, that can be generated when persons who have pulmonary or laryngeal TB sneeze, cough, speak, or sing (6). The particles are an estimated 1-5 μm in size, and normal air currents can keep them airborne for prolonged time periods and spread them throughout a room or building (7). Infection occurs when a susceptible person inhales droplet nuclei containing *M. tuberculosis,* and these droplet nuclei traverse the mouth or nasal passages, upper respiratory tract, and bronchi to reach the alveoli of the lungs. Once in the alveoli, the organisms are taken up by alveolar macrophages and spread throughout the body. Usually within 2-10 weeks after initial infection with *M. tuberculosis,* the immune response limits further multiplication and spread of the tubercle bacilli; however, some of the bacilli remain dormant and viable for many years. This condition is referred to as latent TB infection. Persons with latent TB infection usually have positive purified protein derivative (PPD) tuberculin skin-test results, but they do not have symptoms of active TB, and they are not infectious.

In general, persons who become infected with *M. tuberculosis* have approximately a 10% risk for developing active TB during their lifetimes. This risk is greatest during the first 2 years after infection. Immunocompromised persons have a greater risk for the progression of latent TB infection to active TB disease; HIV infection is the strongest known risk factor for this progression. Persons with latent TB infection who become coinfected with HIV have approximately an 8%-10% risk per year for developing active TB (8). HIV-infected persons who are already severely immunosuppressed and who become newly infected with *M. tuberculosis* have an even greater risk for developing active TB (9-12).

The probability that a person who is exposed to *M. tuberculosis* will become infected depends primarily on the concentration of infectious droplet nuclei in the air and the duration of exposure. Characteristics of the TB patient that enhance transmission include (a) disease in the lungs, airways, or larynx; (b) presence of cough or other forceful expiratory measures; (c) presence of acid-fast bacilli [AFB] in the sputum; (d) failure of the patient to cover the mouth and nose when coughing or sneezing; (e) presence of cavitation on chest radiograph; (f) inappropriate or short duration of chemotherapy; and (g) administration of procedures that can induce coughing or cause aerosolization of *M. tuberculosis* (e.g., sputum induction). Environmental factors that enhance the likelihood of transmission include (a) exposure in relatively small, enclosed spaces; (b) inadequate local or general ventilation that results in insufficient dilution and/ or removal of infectious droplet nuclei; and (c) recirculation of air containing infectious droplet nuclei. Characteristics of the persons exposed to *M. tuberculosis* that may affect the risk for becoming infected are not as well defined. In general, persons who have been infected previously with *M. tuberculosis* may be less susceptible to subsequent infection. However, reinfection can occur among previously infected persons, especially if they are severely immunocompromised. Vaccination with Bacille of Calmette and Guérin (BCG) probably does not affect the risk for infection; rather, it decreases the risk for progressing from latent TB infection to active TB (13). Finally, although it is well established that HIV infection increases the

* Area: a structural unit (e.g., a hospital ward or laboratory) or functional unit (e.g., an internal medicine service) in which HCWs provide services to and share air with a specific patient population or work with clinical specimens that may contain viable *M. tuberculosis* organisms The risk tar exposure to *M. tuberculosis in* a given area depends on the prevalence of TB In the population served and the characteristics of the environment.

likelihood of progressing from latent TB infection to active TB, it is unknown whether HIV infection increases the risk for becoming infected if exposed to *M. tuberculosis.*

C. Risk for Nosocomial Transmission of *M. Tuberculosis*

Transmission of *M. tuberculosis is* a recognized risk in health-care facilities (14-22). The magnitude of the risk varies considerably by the type of health-care facility, the prevalence of TB in the community, the patient population served, the HCW s occupational group, the area of the health-care facility in which the HCW works, and the effectiveness of TB infection-control interventions. The risk may be higher in areas where patients with TB are provided care before diagnosis and initiation of TB treatment and isolation precautions (e.g., in clinic waiting areas and emergency departments) or where diagnostic or treatment procedures that stimulate coughing are performed. Nosocomial transmission of *M. tuberculosis* has been associated with close contact with persons who have infectious TB and with the performance of certain procedures (e.g., bronchoscopy [17], endotracheal intubation and suctioning [18], open abscess irrigation [20], and autopsy [21,22]). Sputum induction and aerosol treatments that induce coughing may also increase the potential for transmission of *M. tuberculosis* (23,24). Personnel of health-care facilities should be particularly alert to the need for preventing transmission of *M. tuberculosis* in those facilities in which immunocompromised persons (e.g., HIV-infected persons) work or receive care–especially if cough-inducing procedures, such as sputum induction and aerosolized pentamidine treatments, are being performed.

Several TB outbreaks among persons in health-care facilities have been reported recently (11,24-*28;* CDC, unpublished data). Many of these outbreaks involved transmission of multidrug-resistant strains of *M. tuberculosis* to both patients and HCWs. Most of the patients and some of the HCWs were HIV-infected persons in whom new infection progressed rapidly to active disease. Mortality associated with those outbreaks was high (range: 43%-93%). Furthermore, the interval between diagnosis and death was brief (range of median intervals: 4-16 weeks). Factors contributing to these outbreaks included delayed diagnosis of TB, delayed recognition of drug resistance, and delayed initiation of effective therapy—all of which resulted in prolonged infectiousness, delayed initiation and inadequate duration of TB isolation, inadequate ventilation in TB isolation rooms, lapses in TB isolation practices and inadequate precautions for cough-inducing procedures, and lack of adequate respiratory protection. Analysis of data collected from three of the health-care facilities involved in the outbreaks indicates that transmission of *M. tuberculosis* decreased significantly or ceased entirely in areas where measures similar to those in the *1990 TB Guidelines* were implemented (2,29-32). However, several interventions were implemented simultaneously, and the effectiveness of the separate interventions could not be determined.

D. Fundamentals of TB Infection Control

An effective TB infection-control program requires early identification, isolation, and effective treatment of persons who have active TB. The primary emphasis of the TB infection-control plan should be on achieving these three goals. In all health-care facilities, particularly those in which persons who are at high risk for TB work or receive care, policies and procedures for TB control should be developed, reviewed periodically, and evaluated for effectiveness to determine the actions necessary to minimize the risk for transmission of *M. tuberculosis.*

The TB infection-control program should be based on a hierarchy of control measures. The first level of the hierarchy, and that which affects the largest number of persons, is using administrative measures intended primarily to reduce the risk for exposing uninfected persons to persons who have infectious TB These measures include (a) developing and implementing effective written policies and protocols to ensure the rapid identification, isolation, diagnostic evaluation, and treatment of persons likely to have TB; (b) implementing effective work practices among HCWs in the health-care facility (e.g., correctly wearing respiratory protection and keeping doors to isolation rooms closed); (c) educating, training, and counseling HCWs about TB; and (d) screening HCWs for TB infection and disease.

The second level of the hierarchy is the use of engineering controls to prevent the spread and reduce the concentration of infectious droplet nuclei. These controls include (a) direct source control using local exhaust ventilation, (b) controlling direction of airflow to prevent contamination of air in areas adjacent to the infectious source, (c) diluting and removing contaminated air via general ventilation, and (d) air cleaning via air filtration or ultraviolet germicidal irradiation (UVGI).

The first two levels of the hierarchy minimize the number of areas in the health-care facility where exposure to infectious TB may occur, and they reduce, but do not eliminate, the risk in those few areas where exposure to *M. tuberculosis* can still occur (e.g., rooms in which patients with known or suspected infectious TB are being isolated and treatment rooms in which cough-inducing or aerosol-generating procedures are performed on such patients). Because persons entering such rooms may be exposed to *M. tuberculosis,* the third level of the hierarchy is the use of personal respiratory protective equipment in these and certain other situations in which the risk for infection with *M. tuberculosis* may be relatively higher.

Specific measures to reduce the risk for transmission of *M. tuberculosis* include the following:

· Assigning to specific persons in the health-care facility the supervisory responsibility for designing, implementing, evaluating, and maintaining the TB infection-control program (Section II.A).

· Conducting a risk assessment to evaluate the risk for transmission of *M. tuberculosis* in all areas of the healthcare facility, developing a written TB infection-control program based on the risk assessment, and periodically repeating the risk assessment to evaluate the effectiveness of the TB infection control program (Section II.B).

· Developing, implementing, and enforcing policies and protocols to ensure early identification, diagnostic evaluation, and effective treatment of patients who may have infectious TB (Section II.C; Suppl. 2).

· Providing prompt triage for and appropriate management of patients in the outpatient setting who may have infectious TB (Section II.D).

· Promptly initiating and maintaining TB isolation for persons who may have infectious TB and who are admitted to the inpatient setting (Section II.E; Suppl. I).

· Effectively planning arrangements for discharge (Section II.E).

· Developing, installing, maintaining, and evaluating ventilation and other engineering controls to reduce the practices, and (f) the criteria for discontinuing isolation.

· In rare circumstances, placing more than one TB patient together in the same room may be acceptable. This practice is sometimes referred to as "cohorting." Because of the risk for patients becoming superinfected with drug-resistant organisms, patients with TB should be placed in the same room only if all patients involved (a) have culture confirmed TB, (b) have drug susceptibility test results available on a current specimen obtained during the present hospitalization, (c) have identical drug-susceptibility patterns on these specimens, and (d) are on effective therapy. Having isolates with identical DNA fingerprint patterns is not adequate evidence for placing two TB patients together in the

same room, because isolates with the same DNA fingerprint pattern can have different drug-susceptibility patterns.

· Pediatric patients with suspected or confirmed TB should be evaluated for potential infectiousness according to the same criteria as are adults (i.e., on the basis of symptoms, sputum AFB smears, radiologic findings, and other criteria) (Suppl. 1). Children who may be infectious should be placed in isolation until they are determined to be noninfectious. Pediatric patients who may be infectious include those who have laryngeal or extensive pulmonary involvement, pronounced cough positive sputum AFB smears, or cavitary TB or those for whom cough-inducing procedures are performed (44).

· The source of infection for a child with TB is often a member of the child's family (45). Therefore, parents and other visitors of all pediatric TB patients should be evaluated for TB as soon as possible. Until they have been evaluated, or the source case is identified, they should wear surgical masks when in areas of the facility outside of the child's room, and they should refrain from visiting common areas in the facility (e.g., the cafeteria or lounge areas).

· TB patients in intensive-care units should be treated the same as patients in noncritical-care settings. They should be placed in TB isolation and have respiratory secretions submitted for AFB smear and culture if they have undiagnosed pulmonary symptoms suggestive of TB.

· If readmitted to a health-care facility, patients who are known to have active TB and who have not completed therapy should have TB precautions applied until a determination has been made that they are noninfectious (Suppl. 1).

2. TB Isolation Practices

· Patients who are placed in TB isolation should be educated about the mechanisms of *M. tuberculosis* transmission and the reasons for their being placed in isolation. They should be taught to cover their mouths and noses with a tissue when coughing or sneezing, even while in the isolation room, to contain liquid drops and droplets before they are expelled into the air (46).

· Efforts should be made to facilitate patient adherence to isolation measures (e.g., staying in the TB isolation room). Such efforts might include the use of incentives (e.g., providing them with telephones, televisions, or radios in their rooms or allowing special dietary requests). Efforts should also be made to address other problems that could interfere with adherence to isolation (e.g., management of the patient's withdrawal from addictive substances [including tobacco]).

· Patients placed in isolation should remain in their isolation rooms with the door closed. If possible, diagnostic and treatment procedures should be performed in the isolation rooms to avoid transporting patients through other areas of the facility. If patients who may have infectious TB must be transported outside their isolation rooms for medically essential procedures that cannot be performed in the isolation rooms, they should wear surgical masks that cover their mouths and noses during transport. Persons transporting the patients do not need to wear respiratory protection outside the TB isolation rooms. Procedures for these patients should be scheduled at times when they can be performed rapidly and when waiting areas are less crowded.

· Treatment and procedure rooms in which patients who have infectious TB or who have an undiagnosed pulmonary disease and are at high risk for active TB receive care should meet the ventilation recommendations for isolation rooms (Section II.E.3; Suppl. 3). Ideally, facilities in which TB patients are frequently treated should have an area in the radiology department that is ventilated separately for TB patients. If this is not possible, TB patients should wear surgical masks and should stay in the radiology suite the minimum amount of time possible, then be returned promptly to their isolation rooms.

· The number of persons entering an isolation room should be minimal. All persons who enter an isolation room should wear respiratory protection (Section II.G; Suppl. 4). The patient's visitors should be given respirators to wear while in the isolation room, and they should be given general instructions on how to use their respirators.

· Disposable items contaminated with respiratory secretions are not associated with transmission of *M. tuberculosis.* However, for general infection-control purposes, these items should be handled and transported in a manner that reduces the risk for transmitting other microorganisms to patients, HCWs, and visitors and that decreases environ-mental contamination in the health-care facility. Such items should be disposed of in accordance with hospital policy and applicable regulations (Suppl. 5).

3. The TB Isolation Room

· TB isolation rooms should be single-patient rooms with special ventilation characteristics appropriate for the purposes of isolation (Suppl. 3). The primary purposes of TB isolation rooms are to (a) separate patients who are likely to have infectious TB from other persons; (b) provide an environment that will allow reduction of the concentration of droplet nuclei through various engineering methods and (c) prevent the escape of droplet nuclei from the TB isolation room and treatment room, thus preventing entry of *M. tuberculosis* into the corridor and other areas of the facility.

· To prevent the escape of droplet nuclei, the TB isolation room should be maintained under negative pressure (Suppl. 3). Doors to isolation rooms should be kept closed, except when patients or personnel must enter or exit the room, so that negative pressure can be maintained.

· Negative pressure in the room should be monitored daily while the room is being used for TB isolation.

· The American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) (47), the American Institute of Architects (AIA) (48), and the Health Resources and Services Administration (49) recommend a minimum of 6 air changes per hour (ACM) for TB isolation and treatment rooms. This ventilation rate is based on comfort and odor control considerations. The effectiveness of this level of airflow in reducing the concentration of droplet nuclei in the room, thus reducing the transmission of airborne pathogens has not been evaluated directly or adequately.

Ventilation rates of >6 ACH are likely to produce an incrementally greater reduction in the concentration of bacteria in a room than are lower rates (5-52). However, accurate quantitation of decreases in risk that would result from specific increases in general ventilation levels has not been performed and may not be possible.

For the purposes of reducing the concentration of droplet nuclei, TB isolation and treatment rooms in existing health care facilities should have an airflow of ≥6 ACH. Where feasible, this airflow rate should be increased to ≥12 ACH by adjusting or modifying the ventilation system or by using auxiliary means (e.g., recirculation of air through fixed HEPA filtration systems or portable air cleaners) (Suppl. 3, Section II.B.5.a) (53). New construction or renovation of existing health care facilities should be designed so that TB isolation rooms achieve an airflow of ≥12 ACH.

· Air from TB isolation rooms and treatment rooms used to treat patients who have known or suspected infectious TB should be exhausted to the outside in accordance with applicable federal, state, and local regulations. The air should not be recirculated into the general ventilation. In some instances, recirculation of air into the general ventilation system from such rooms is unavoidable (i.e., in existing facilities in which the ventilation system or facility configuration makes venting the exhaust to the outside impossible). In such cases,

HEPA filters should be installed in the exhaust duct leading from the room to the general ventilation system to remove infectious organisms and particulates the size of droplet nuclei from the air before it is returned to the general ventilation system (Section II.F; Suppl. 3). Air from TB isolation and treatment rooms in new or renovated facilities should not be recirculated into the general ventilation system.

· Although not required, an anteroom may increase the effectiveness of the isolation room by minimizing the potential escape of droplet nuclei into the corridor when the door is opened. To work effectively, the anteroom should have positive air pressure in relation to the isolation room. The pressure relationship between the anteroom and the corridor may vary according to ventilation design.

· Upper-room air UVGI may be used as an adjunct to general ventilation in the isolation room (Section II.F; Suppl. 3). Air in the isolation room may be recirculated within the room through HEPA filters or UVGI devices to increase the effective ACH and to increase thermal efficiency.

· Health-care facilities should have enough isolation roomy to appropriately isolate all patients who have suspected or confirmed active TB. This number

should be estimated using the results of the risk assessment of the health-care facility. Except for minimal-and very: low-risk health care facilities, all acute-care inpatient facilities should have at least one TB isolation room (Section U.B).

· Grouping isolation rooms together in one area-of the facility may reduce the possibility of transmitting *M. tuberculosis* to other patients and may facilitate care of TB patients and the installation and maintenance of optimal engineering (particularly ventilation) controls.

4. Discontinuation of TB Isolation

· TB isolation can be discontinued if the diagnosis of TB is ruled out. For some patients, TB can be ruled out when another diagnosis is confirmed. If a diagnosis of TB cannot be ruled out, the patient should remain in isolation until a determination has been made that the patient is noninfectious. However, patients can be discharged from the health-care facility while still potentially infectious if appropriate postdischarge arrangements can be ensured (Section II.E.5).

· The length of time required for a TB patient to become noninfectious after starting anti-TB therapy varies considerably (Suppl. 1). Isolation should be discontinued only when the patient is on effective therapy, is improving clinically, and has had three consecutive negative sputum AFB smears collected on different days.

· Hospitalized patients who have active TB should he monitored for relapse by having sputum AFB smears examined regularly (e.g., every 2 weeks). Nonadherence to therapy (i.e., failure to take medications as prescribed and the presence of drug-resistant organisms are the two most common reasons why patients remain infectious despite treatment. These reasons should be considered if a patient does not respond clinically to therapy within 2-3 weeks.

· Continued isolation throughout the hospitalization should be strongly considered for patients who have MDR-TB because of the tendency for treatment failure or relapse (i.e., difficulty in maintaining noninfectiousness3 that has been observed in such cases.

5. Discharge Planning

· Before a TB patient is discharged from the health care facility, the facility's staff and public health authorities should collaborate to ensure continuation of therapy. Discharge planning in the healthcare facility should include, at a minimum, (a) a confirmed outpatient appointment with the provider who will manage the patient until the patient is cured, (b) sufficient medication to take until the outpatient appointment, and (c) placement into case management (e.g., DOT) or outreach programs of the public health department. These plans should be initiated and in place before the patient's discharge.

· Patients who may be infectious at the time of discharge should only be discharged to facilities that have isolation capability or to their homes. Plans for discharging a patient who will return home must consider whether all the household members were infected previously and whether any uninfected household members are at very high risk for active TB if infected (e.g., children <4 years of age or persons infected with HIV or otherwise severely immunocompromised). If the household does include such persons arrangements should be made to prevent them from being exposed to the TB patient until a determination has been made that the patient is noninfectious.

F. Engineering Control Recommendations

1. General Ventilation

This section deals only with engineering controls for general-use areas of health-care facilities (e.g., waiting-room areas and emergency departments). Recommendations for engineering controls for specific areas of the facility (e.g., TB isolation rooms) are contained in the sections encompassing those areas. Details regarding ventilation design, evaluation, and supplemental approaches are described in Supplement 3.

· Health-care facilities should either (a) include as part of their staff an engineer or other professional with expertise in ventilation or (b) have this expertise available from a consultant who is an expert in ventilation engineering and who also has hospital experience. These persons should work closely with infection-control staff to assist in controlling airborne infections.

· Ventilation system designs in health-care facilities should meet any applicable federal, state, and local requirements.

· The direction of airflow in healthcare facilities should be designed, constructed, and maintained so that air flows from clean areas to less-clean areas.

· Health-care facilities serving populations that have a high prevalence of TB may need to supplement the general ventilation or use additional engineering approaches (i.e., HEPA filtration or UVGI) in general-use areas where TB patients are likely to go (e.g., waiting-room areas, emergency departments, and radiology suites). A single-pass, non recirculating that exhausts air to the outside, a recirculation system that passes air through HEPA filters before recirculating it to the general ventilation system, or upper air UVGI may be used in such areas.

2. Additional Engineering Control Approaches

a. HEPA filtration.

HEPA filters may be used in a number of ways to reduce or eliminate infectious droplet nuclei from room air or exhaust (Suppl. 3). These methods include placement of HEPA filters (a) in exhaust ducts discharging air from booths or enclosures into the surrounding room; (b) in ducts or in ceiling- or wall-mounted units, for recirculation of air within an individual room (fixed recirculation systems); (c) in portable air cleaners; (d) in exhaust ducts to remove droplet nuclei from air being discharged to the outside, either directly or through ventilation equipment; and (e) in ducts discharging air from the TB isolation room into the general ventilation system. In any application, HEPA filters should be installed carefully and maintained meticulously to ensure adequate functioning.

The manufacturers of in-room air cleaning equipment should provide documentation of the HEPA filter efficiency and the efficiency of the device in lowering room air contaminant levels.

b. UVGI.

For general-use areas in which the risk for transmission of *M. tuberculosis* is

relatively high, UVGI lamps may be used as an adjunct to ventilation for reducing the concentration of infectious droplet nuclei (Suppl. 3), although the effectiveness of such units has not been evaluated adequately. Ultraviolet (UV) units con be installed in a room or corridor to irradiate the air in the upper portion of the room (i.e., upper-room air irradiation), or they can be installed in ducts to irradiate air passing through the ducts. UV units installed in ducts should not be substituted for HEPA filters in ducts that discharge air from TB isolation rooms into the general ventilation system. However, UV units can be used in ducts that recirculate air back into the same room.

To function properly and decrease hazards to HCWs and others in the health-care facility, UV lamps should be installed properly and maintained adequately, which includes the monitoring of irradiance levels. UV tubes should be changed according to the manufacturer's instructions or when meter readings indicate tube failure. An employee trained in the use and handling of UV lamps should be responsible for these measures and for keeping maintenance records. Applicable safety guidelines should be followed. Caution should be exercised to protect HCWs, patients, visitors, and others from excessive exposure to UV radiation.

G. Respiratory Protection

· Personal respiratory protection should be used by (a) persons entering rooms in which patients with known or suspected infectious TB are being isolated, (b) persons present during cough-inducing or aerosol-generating procedures performed on such patients, and (c) persons in other settings where administrative and engineering controls are not likely to protect them from inhaling infectious airborne droplet nuclei (Suppl. 4). These other settings include transporting patients who may have infectious TB in emergency transport vehicles and providing urgent surgical or dental care to patients who may have infectious TB before a determination has been made that the patient is noninfectious (Suppl. 1).

· Respiratory protective devices used in health-care settings for protection against *M. tuberculosis* should meet the following standard performance criteria:

1. The ability to filter particles 1 μm in size in the unloaded* state with a filter efficiency of ≥95% (i.e., filter leakage of ≤5%), given flow rates of up to 50 L per minute.

2. The ability to be qualitatively or quantitatively fit tested in a reliable way to obtain a face-seal leakage of ≤10% (54,55).

3. The ability to fit the different facial sizes and characteristics of HCWs, which can usually be met by making the respirators available in at least three sizes.

4. The ability to be checked for facepiece fit, in accordance with standards established by the Occupational Safety and Health Administration (OSHA) and good industrial hygiene practice, by HCWs each time they put on their respirators (54,55).

· The facility's risk assessment may identify a limited number of selected settings (e.g., bronchoscopy performed on patients suspected of having TB or autopsy performed on deceased persons suspected of having had active TB at the time of death) where the estimated risk for transmission of *M. tuberculosis* may be such that a level of respiratory protection exceeding the standard performance criteria is appropriate. In such circumstances, a level of respiratory protection exceeding the standard criteria and compatible with patient-care delivery (e.g., more protective negative-pressure respirators; powered air-purifying particulate respirators [PAPRs]; or positive-pressure air-line, half-mask respirators) should be provided by employers to HCWs who are exposed to *M. tuberculosis.* Information on these and other respirators is in the *NIOSH Guide to Industrial Respiratory Protection* (55) and in Supplement 4 of this document.

· In some settings, HCWs may be at risk for two types of exposure: (a) inhalation of *M. tuberculosis* and (b) mucous membrane exposure to fluids that may contain bloodborne pathogens. In these settings, protection against both types of exposure should be used.

· When operative procedures (or other procedures requiring a sterile field) are performed on patients who may have infectious TB, respiratory protection worn by the HCW should serve two functions: (a) It should protect the surgical field from the respiratory secretions of the HCW, and (b) it should protect the HCW from infectious droplet nuclei that may be expelled by the patient or generated by the procedure. Respirators with exhalation valves and most positive-pressure respirators do not protect the sterile field.

· Health-care facilities in which respiratory protection is used to prevent inhalation of *M. tuberculosis* are required by OSHA to develop, implement, and maintain a respiratory protection program (Suppl. 4). All HCWs who use respiratory protection should be included in this program. Visitors to TB patients should be given respirators to wear while in isolation rooms, and they should be given general instructions on how to use their respirators.

· Facilities that do not have isolation rooms and do not perform cough-inducing procedures on patients who may have TB may not need to have a respiratory protection program for TB. However, such facilities should have written protocols for the early identification of patients who have signs or symptoms of TB and procedures for referring these patients to a facility where they can be evaluated and managed appropriately. These protocols should be evaluated regularly and revised as needed.

2. Exterior Devices

The exterior type of local exhaust ventilation device is usually a hood very near, but not enclosing, the infectious patient. The airflow produced by these devices should be sufficient to prevent cross-currents of air near the patient's face from causing escape of droplet nuclei. Whenever possible, the patient should face directly into the hood opening so that any coughing or sneezing is directed into the hood, where the droplet nuclei are captured. The device should maintain an air velocity ≥ 200 feet per minute at the patient's breathing zone to ensure capture of droplet nuclei.

3. Discharge Exhaust from Booths, Tents, and Hoods

Air from booths, tents, and hoods may be discharged into the room in which the device is located or it may be exhausted to the outside. If the air is discharged into the room, a HEPA filter should be incorporated at the discharge duct or vent of the device. The exhaust fan should be located on the discharge side of the HEPA filter to ensure that the air pressure in the filter housing and booth is negative with respect to adjacent areas. Uncontaminated air from the room will flow into the booth through all openings, thus preventing infectious droplet nuclei in the booth from escaping into the room. Most commercially available booths, tents, and hoods are fitted with HEPA filters, in which case additional HEPA filtration is not needed.

If the device does not incorporate a HEPA filter, the air from the device should be exhausted to the outside in accordance with recommendations for isolation room exhaust (Suppl. 3, Section II.B.5). (See Supplement 3, Section II.C, for information regarding recirculation of exhaust air.)

* Some filters become more efficient as they become loaded with dust. Health-care settings do not have enough dust in the air to load a filter on a respirator. Therefore, the filter efficiency for respirators used in health-care settings must be determined in the unloaded state.

TABLE S3 - 1.– Air Changes Per Hour (ACH) And Time in Minutes Required for Removal Efficiencies of 90%, 99%, and 99.9% of Airborne Contaminants.*

ACH	Minutes required for a removal efficiency of:		
	90%	99%	99.9%
1	138	276	414
2	69	138	207
3	46	92	138
4	35	69	104
5	28	55	83
6	23	46	69
7	20	39	59
8	17	35	52
9	15	31	46
10	14	28	41
11	13	25	38
12	12	23	35
13	11	21	32
14	10	20	30
15	9	18	28
16	9	17	26
17	8	16	24
18	8	15	23
19	7	15	22
20	7	14	21
25	6	11	17
30	5	9	14
35	4	8	12
40	3	7	10
45	3	6	9
50	3	6	8

B. General Ventilation

General ventilation can be used for several purposes, including diluting and removing contaminated air, controlling airflow patterns within rooms, and controlling the direction of airflow throughout a facility. Information on these topics is contained in the following sections.

1. Dilution and Removal

Purpose: To reduce the concentration of contaminants in the air.

General ventilation maintains air quality by two processes: dilution and removal of airborne contaminants. Uncontaminated supply (i.e., incoming) air mixes with the contaminated room air (i.e., dilution), which is subsequently removed from the room by the exhaust system (i.e., removal). These processes reduce the concentration of droplet nuclei in the room air.

a. Types of general ventilation systems.

Two types of general ventilation systems can be used for dilution and removal of contaminated air: the singlepass system and the recirculating system. In a single-pass system, the supply air is either outside air that has been appropriately heated and cooled or air from a central system that supplies a number of areas. After air passes through the room (or area), 100% of that air is exhausted to the outside. The single-pass system is the preferred choice in areas where infectious airborne droplet nuclei are known to be present (e.g., TB isolation rooms or treatment rooms) because it prevents contaminated air from being recirculated to other areas of the facility.

In a recirculating system, a small portion of the exhaust air is discharged to the outside and is replaced with fresh outside air, which mixes with the portion of exhaust air that was not discharged to the outside. The resulting mixture, which can contain a large proportion of contaminated air, is then recirculated to the areas serviced by the system. This air mixture could be recirculated into the general ventilation, in which case contaminants may be carried from contaminated areas to uncontaminated areas. Alternatively, the air mixture could also be recirculated within a specific room or area in which case other areas of the facility will not be affected (Suppl. 3, Section II.C.3).

b. Ventilation rates.

Recommended general ventilation rates for health-care facilities are usually expressed in number of ACH. This number is the ratio of the volume of air entering the room per hour to the room volume and is equal to the exhaust airflow (Q [cubic feet per minute]) divided by the room volume (V [cubic feet]) multiplied by 60 (i.e., ACH = Q ÷ V x 60).

The feasibility of achieving specific ventilation rates depends on the construction and operational requirements of the ventilation system (e.g., the energy requirements to move and to heat or cool the air). The feasibility of achieving specific ventilation rates may also be different for retrofitted facilities and newly constructed facilities. The expense and effort of achieving specific higher ventilation rates for new construction may be reasonable, whereas retrofitting an existing facility to achieve similar ventilation rates may be more difficult. However, achieving higher ventilation rates by using auxiliary methods (e.g., room-air recirculation) in addition to exhaust ventilation may be feasible in existing facilities (Suppl. 3, Section II.C).

2. Airflow Patterns Within Rooms (Air Mixing)

Purpose: To provide optimum airflow patterns and prevent both stagnation and short-circuiting of air.

General ventilation systems should be designed to provide optimal patterns of airflow within rooms and prevent air stagnation or short-circuiting of air from the supply to the exhaust (i.e., passage of air directly from the air supply to the air exhaust). To provide optimal airflow patterns, the air supply and exhaust should be located such that clean air first flows to parts of the room where HCWs are likely to work, and then flows across the infectious source and into the exhaust. In this way, the HCW is not positioned between the infectious source and the exhaust location. Although this configuration may not always be possible, it should be used whenever feasible. One way to achieve this airflow pattern is to supply air at the side of the room opposite the patient and exhaust it from the side where the patient is located. Another method, which is most effective when the supply air is cooler than the room air, is to supply air near the ceiling and exhaust it near the floor (Figure S3-2). Airflow patterns are affected by large air temperature differentials, the precise location of the supply and exhausts, the location of furniture, the movement of HCWs and patients, and the physical configuration of the space. Smoke tubes can be used to visualize airflow patterns in a manner similar to that described for estimating room air mixing.

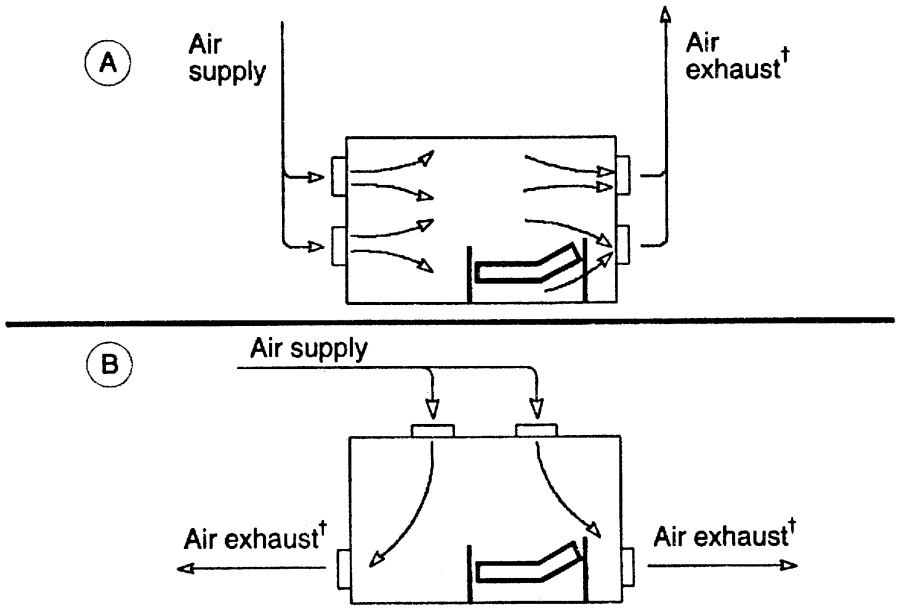
Adequate air mixing, which requires that an adequate number of ACH be provided to a room (Suppl. 3, Section II.B.l), must be ensured to prevent air stagnation within the room. However, the air will not usually be changed the calculated number of times per hour because the airflow patterns in the room may not permit complete mixing of the supply and room air in all parts of the room. This results in an "effective" airflow rate in which the supplied airflow may be less than required for proper ventilation. To account for this variation, a mixing factor (which ranges from 1 for perfect mixing to 10 for poor mixing) is applied as a multiplier to determine the actual supply airflow (i.e., the recommended ACH multiplied by the mixing factor equals the actual required ACH) (51,98). The room air supply and exhaust system should be designed to achieve the lowest mixing factor

* This table has been adapted from the formula for the rate of purging airborne contaminants (99). Values have been derived from the formula t_1, = [ln $C_2 \div C_1$) ÷ (Q ÷ V)] x 60, with $T_1 = 0$ and $C_2 + C_1$ – (removal efficiency ÷ 100), and where:

t_1 = initial timepoint
C_1 = initial concentration of contaminant
C_2 = final concentration of contaminants
Q = air flow rate (cubic feet per hour)
V = room volume (cubic feet)
Q ÷ V = ACH

The times given assume perfect mixing of the air within the space (i.e., mixing factor = 1). However, perfect mixing usually does not occur, and the mixing factor could be as high as 10 if air distribution is very poor (98). The required time is derived by multiplying the appropriate time from the table by the mixing factor that has been determined for the booth or room. The factor and required time should be included in the operating instructions provided by the manufacturer of the booth or enclosure, and these instructions should be followed.

FIGURE S3-2. Room airflow patterns designed to provide mixing of air and prevent passage of air directly from the air supply to the exhaust*



* Short circuiting of air.
† Air should be exhausted to the outside (or through high-efficiency particulate air [HEPA] filters, if recirculated).

possible. The mixing factor is determined most accurately by experimentally testing each space configuration, but this procedure is complex and time-consuming. A reasonably good qualitative measure of mixing can be estimated by an experienced ventilation engineer who releases smoke from smoke tubes at a number of locations in the room and observes the movement of the smoke. Smoke movement in all areas of the room indicates good mixing. Stagnation of air in some areas of the room indicates poor mixing, and movement of the supply and exhaust openings or redirection of the supply air is necessary.

3. Airflow Direction in the Facility

Purpose: To contain contaminated air in localized areas in a facility and prevent its spread to uncontaminated areas.

a. Directional airflow.

The general ventilation system should be designed and balanced so that air flows from less contaminated (i.e., more clean) to more contaminated (less clean) areas (47,48). For example, air should flow from corridors (cleaner areas) into TB isolation rooms (less clean areas) to prevent spread of contaminants to other areas. In some special treatment rooms in which operative and invasive procedures are performed, the direction of airflow is from the room to the hallway to provide cleaner air during these procedures. Cough-inducing or aerosol-generating procedures (e.g., bronchoscopy and irrigation of tuberculous abscesses) should not be performed in rooms with this type of airflow on patients who may have infectious TB.

b. Negative pressure for achieving directional airflow.

The direction of airflow is controlled by creating a lower (negative) pressure in the area into which the flow of air is desired. For air to flow from one area to another, the air pressure in the two areas must be different. Air will flow from a higher pressure area to a lower pressure area. The lower pressure area is described as being at negative* pressure relative to the higher pressure area. Negative pressure is attained by exhausting air from an area at a higher rate than air is being supplied. The level of negative pressure necessary to achieve the desired airflow will depend on the physical configuration of the ventilation system and area, including the airflow path and flow openings, and should be determined on an individual basis by an experienced ventilation engineer.

4. Achieving Negative Pressure in a Room

Purpose. To control the direction of airflow between the room and adjacent areas, thereby preventing contaminated air from escaping from the room into other areas of the facility.

a. Pressure differential.

The minimum pressure difference necessary to achieve and maintain negative pressure that will result in airflow into the room is very small (0.001 inch of water). Higher pressures (≥ 0.001 inch of water) are satisfactory; however, these higher pressures may be difficult to achieve. The actual level of negative pressure achieved will depend on the difference in the ventilation exhaust and supply flows and the physical configuration of the room including the airflow path and flow openings. If the room is well sealed, negative pressures greater than the minimum of 0.001 inch of water may be readily achieved. However, if rooms are not well-sealed, as may be the case in many facilities (especially older facilities), achieving higher negative pressures may require exhaust/supply flow differentials beyond the capability of the ventilation system.

To establish negative pressure in a room that has a normally functioning ventilation system, the room supply and exhaust airflows are first balanced to achieve an exhaust flow of either 10% or 50 cubic feet per minute (cfm) greater than the supply (whichever is the greater). In most situations, this specification should achieve a negative pressure of at least 0.001 inch of water. If the minimum 0.001 inch of water is not achieved and cannot be achieved by increasing the flow differential (within the limits of the ventilation system), the room should be inspected for leakage (e.g., through doors, windows, plumbing, and equipment wall penetrations), and

* Negative is defined relative to the air pressure in the area from which air is to flow.

corrective action should be taken to seal the leaks.

Negative pressure in a room can be altered by changing the ventilation system operation or by the opening and closing of the room's doors, corridor doors, or windows. When an operating configuration has been established, it is essential that all doors and windows remain properly closed in the isolation room and other areas (e.g., doors in corridors that affect air pressure) except when persons need to enter or leave the room or area.

b. Alternate methods for achieving negative pressure.

Although an anteroom is not a substitute for negative pressure in a room, it may be used to reduce escape of droplet nuclei during opening and closing of the isolation room door. Some anterooms have their own air supply duct, but others do not. The TB isolation room should have negative pressure relative to the anteroom, but the air pressure in the anteroom relative to the corridor may vary depending on the building design. This should be determined, in accordance with applicable regulations, by a qualified ventilation engineer.

If the existing ventilation system is incapable of achieving the desired negative pressure because the room lacks a separate ventilation system or the room's system cannot provide the proper airflow, steps should be taken to provide a means to discharge air from the room. The amount of air to be exhausted will be the same as discussed previously (Suppl. 3, Section II.B.4.a).

Fixed room-air recirculation systems (i.e., systems that recirculate the air in an entire room) may be designed to achieve negative pressure by discharging air outside the room (Suppl. 3, Section II.C.3)

Some portable room-air recirculation units (Suppl. 3, Section II.C.3.b.) are designed to discharge air to the outside to achieve negative pressure. Air cleaners that can accomplish this must be designed specifically for this purpose.

A small centrifugal blower (i.e., exhaust fan) can be used to exhaust air to the outside through a window or outside wall. This approach may be used as an interim measure to achieve negative pressure, but it provides no fresh air and suboptimal dilution.

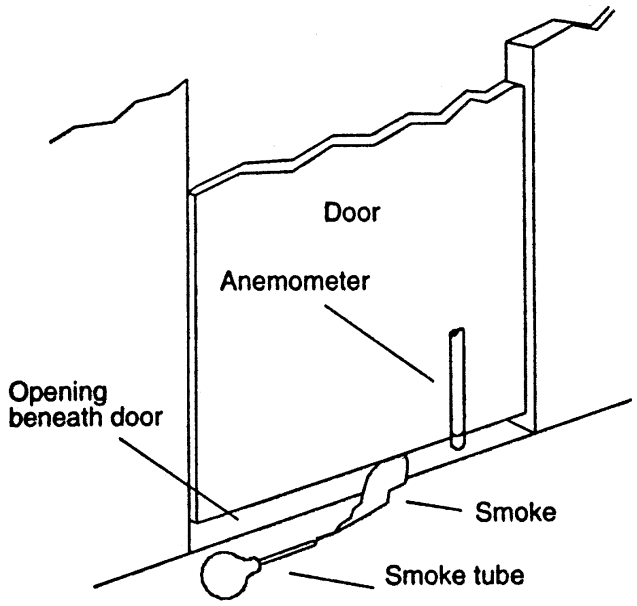
Another approach to achieving the required pressure difference is to pressurize the corridor. Using this method, the corridor's general ventilation system is balanced to create a higher air pressure in the corridor than in the isolation room; the type of balancing necessary depends on the configuration of the ventilation system. Ideally, the corridor air supply rate should be increased while the corridor exhaust rate is not increased. If this is not possible, the exhaust rate should be decreased by resetting appropriate exhaust dampers. Caution should be exercised, however, to ensure that the exhaust rate is not reduced below acceptable levels. This approach requires that all settings used to achieve the pressure balance, including doors be maintained. This method may not be desirable if the corridor being pressurized has rooms in which negative pressure is not desired. In many situations, this system is difficult to achieve, and it should be considered only after careful review by ventilation personnel.

c. Monitoring negative pressure.

The negative pressure in a room can be monitored by visually observing the direction of airflow (e.g., using smoke tubes) or by measuring the differential pressure between the room and its surrounding area.

Smoke from a smoke tube can be used to observe airflow between areas or airflow patterns within an area. To check the negative pressure in a room by using a smoke tube, hold the smoke tube near the bottom of the door and approximately 2 inches in front of the door, or at the face of a grille or other opening if the door has such a feature, and generate a small amount of smoke by gently squeezing the bulb (Figure S3-3). The smoke tube should be held parallel to the door, and the smoke should be issued from the tube slowly to ensure the velocity of the smoke from the tube does not overpower the air velocity. The smoke will travel in the direction of airflow. If the room is at negative pressure, the smoke will

Figure S3-3 Smoke-tube testing and anemometer placement to determine the direction of airflow into and out of a room*



* Smoke flowing into the room indicates the room is at negative pressure relative to the corridor and smoke flowing out of the room indicates the room is at positive pressure relative to the corridor. The anemometer, if used, is placed with the sensor in the airflow path at the bottom of the door.

travel under the door and into the room (e.g., from higher to lower pressure). If the room is not at negative pressure, the smoke will be blown outward or will stay stationary. This test must be performed while the door is closed. If room air cleaners are being used in the room, they should be running. The smoke is irritating if inhaled, and care should be taken not to inhale it directly from the smoke tube. However, the quantity of smoke issued from the tube is minimal and is not detectable at short distances from the tube.

Differential pressure-sensing devices also can be used to monitor negative pressure; they can provide either periodic (noncontinuous) pressure measurements or continuous pressure monitoring. The continuous monitoring component may simply be a visible and/or audible warning signal that air pressure is low. In addition, it may also provide a pressure readout signal, which can be recorded for later verification or used to automatically adjust the facility's ventilation control system.

Pressure-measuring devices should sense the room pressure just inside the airflow path into the room (e.g., at the bottom of the door). Unusual airflow patterns within the room can cause pressure variations; for example, the air can be at negative pressure at the middle of a door and at positive pressure at the bottom of the same door (Figure S3-4). If the pressure-sensing ports of the device cannot be located directly across the airflow path, it will be necessary to validate that the negative pressure at the sensing point is and remains the one as the negative pressure across the flow path.

Pressure-sensing devices should incorporate an audible warning with a time delay to indicate that a door is open. When the door to the room is opened, the negative pressure will decrease. The time-delayed signal should allow sufficient time for persons to enter or leave the room without activating the audible warning.

A potential problem with using pressure-sensing devices is that the pressure differentials used to achieve the low negative pressure necessitate the use of very sensitive mechanical devices, electronic devices or pressure gauges to ensure accurate measurements. Use of devices that cannot measure these low pressures (i.e., pressures as low as 0.001 inch of water) will require setting higher negative pressures that may be difficult and, in some instances, impractical to achieve (Suppl. 3, Section II.B.4).

Periodic checks are required to ensure that the desired negative pressure is present and that the continuous monitoring devices, if used, are operating properly. If smoke tubes or other visual checks are used, TB isolation rooms and treatment rooms should be checked frequently for negative pressure. Rooms undergoing changes to the ventilation system should be checked daily. TB isolation rooms should be checked daily for negative pressure while being used for TB isolation. If these rooms are not being used for patients who have suspected or confirmed TB but potentially could be used for such patients, the negative pressure in the rooms should be checked monthly. If pressure-sensing devices are used, negative pressure should be verified at least once a month by using smoke tubes or taking pressure measurements.

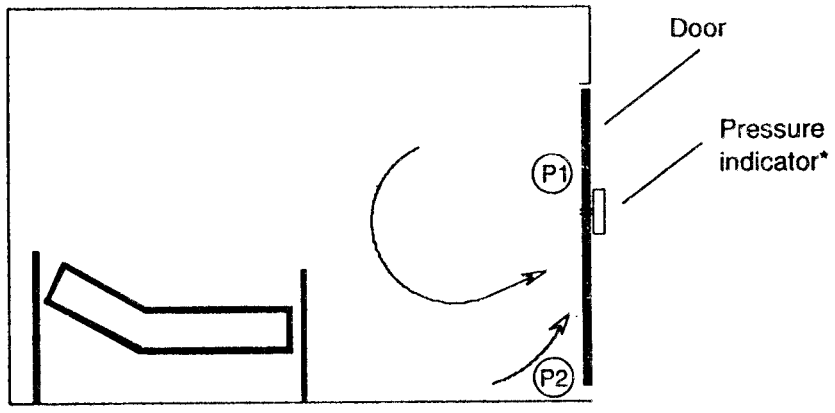
C. HEPA Filtration

Purpose: To remove contaminants from the air.

HEPA filtration can be used as a method of air cleaning that supplements other recommended ventilation measures. For the purposes of these guidelines, HEPA filters are defined as air-cleaning devices that have a demonstrated and documented minimum removal efficiency of 99.97% of particles greater than or equal to 0.3 μm in diameter. HEPA filters have been shown to be effective in reducing the concentration of *Aspergillus* spores (which range in size from 1.5 μm to 6 μm) to below measurable levels (100-102). The ability of HEPA filters to remove tubercle bacilli from the air has not been studied, but *M. tuberculosis* droplet nuclei probably range from 1 μm to 5 μm in diameter (i.e., approximately the same size as *Aspergillus* spores). Therefore, HEPA filters can be expected to remove infectious droplet nuclei from contaminated air. HEPA filters can be used to clean air before it is exhausted to the outside, recirculated to other areas of a facility, or recirculated within a room. If the device is not completely passive (e.g., it utilizes techniques such as electrostatics) and the failure of the electrostatic components permits loss of filtration efficiency to less than 99.97%, the device should not be used in systems that recirculate air back into the general facility ventilation system from TB isolation rooms and treatment rooms in which procedures are performed on patients who may have infectious TB (Suppl. 3, Section II.C.2).

HEPA filters can be used in a number of ways to reduce or eliminate infectious droplet nuclei from room air or exhaust. These methods include placement of HEPA filters (a) in exhaust ducts to remove droplet

Figure S3-4 Cross-sectional view of a room showing the location of negative pressure measurement



Airflow pressure at Position 1 may differ from Position 2.
Measure pressure at Position 2 to correctly identify negative pressure.
*Located on door frame

nuclei from air being discharged to the outside, either directly or through ventilation equipment; (b) in ducts discharging room air into file general ventilation system; and (c) in fixed or portable room-air cleaners. The effectiveness of portable HEPA room-air cleaning units has not been evaluated adequately, and there is probably considerable variation in their effectiveness. HEPA filters can also be used in exhaust ducts or vents that discharge air from booths or enclosures into the surrounding room (Suppl. 3, Section II.A.3). In any application, HEPA filters should be installed carefully and maintained meticulously to ensure adequate function.

Manufacturers of room-air cleaning equipment should provide documentation of the HEPA filter efficiency and the efficiency of the installed device in lowering room-air contaminant levels.

1. Use of HEPA Filtration when Exhausting to the Outside

HEPA filters can be used as an added safety measure to clean air from isolation rooms and local exhaust devices (i.e., booths, tents, or hoods used for cough-inducing procedures) before exhausting it directly to the outside, but such use is unnecessary if the exhaust air cannot re-enter the ventilation system supply. The use of HEPA filters should be considered wherever exhaust air could possibly reenter the system.

In many instances, exhaust air is not discharged directly to the outside; rather, the air is directed through heat-recovery devices (e.g., heat wheels). Heat wheels are often used to reduce the costs of operating ventilation systems (103). If such units are used with the system, a HEPA filter should also be used. As the wheel rotates, energy is transferred into or removed from the supply inlet air stream. The HEPA filter should be placed upstream from the heat wheel because of the potential for leakage across the seals separating the inlet and exhaust chambers and the theoretical possibility that droplet nuclei could be impacted on the wheel by the exhaust air and subsequently stripped off into the supply air.

2. Recirculation of HEPA-Filtered Air to Other Areas of a Facility

Air from TB isolation rooms and treatment rooms used to treat patients who have confirmed or suspected infectious TB should be exhausted to the outside in accordance with applicable Federal, state, and local regulations. The air should not be recirculated into the general ventilation. In some instances, recirculation of air into the general ventilation system from such rooms is unavoidable (i.e., in existing facilities in which the ventilation system or facility configuration makes venting the exhaust to the outside impossible). In such cases, HEPA filters should be installed in the exhaust duct leading from the room to the general ventilation system to remove infectious organisms and particulates the size of droplet nuclei from the air before it is returned to the general ventilation system (Section II.F; Suppl. 3). Air from TB isolation rooms and treatment rooms in new or renovated facilities should not be recirculated into the general ventilation system.

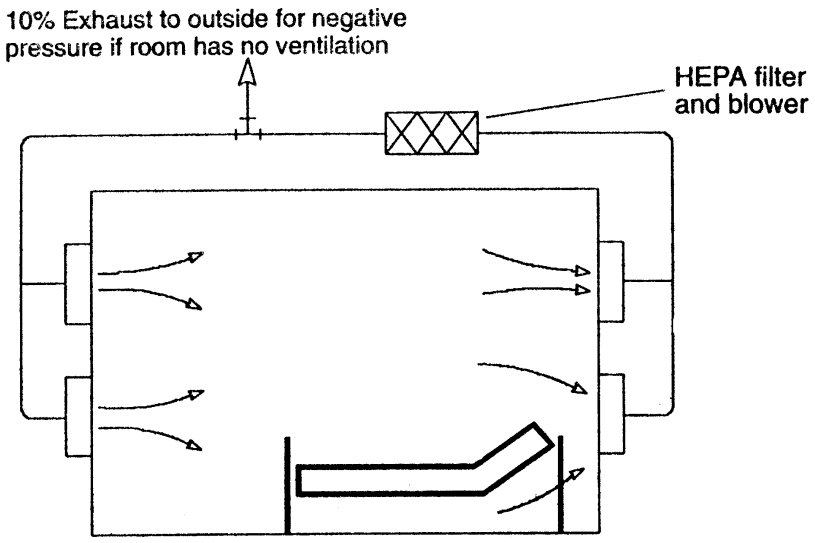
3. Recirculation of HEPA-Filtered Air within a Room

Individual room-air recirculation can be used in areas where there is no general ventilation system, where an existing system is incapable of providing adequate airflow, or where an increase in ventilation is desired without affecting the fresh air supply or negative pressure system already in place. Recirculation of HEPA-filtered air within a room can be achieved in several ways: (a) by exhausting air from the room into a duct, filtering it through a HEPA filter installed in the duct, and returning it to the room (Figure S3-5); (b) by filtering air through HEPA recirculation systems mounted on the wall or ceiling of the room (Figure S3-6); or (c) by filtering air through portable HEPA recirculation systems. In this document, the first two of these approaches are referred to as fixed room-air recirculation systems, because the HEPA filter devices are fixed in place and are not easily movable.

a. Fixed room-air recirculation systems.

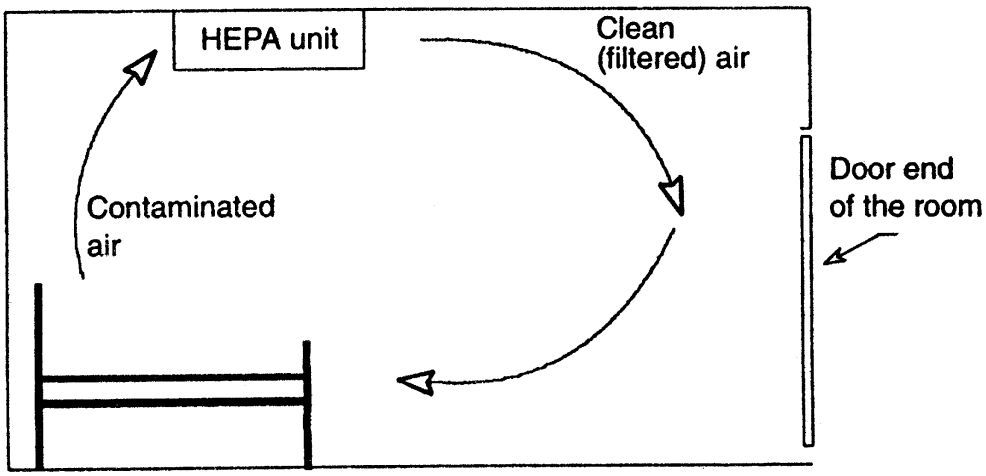
The preferred method of recirculating HEPA-filtered air within a room is a built-in system, in which air is exhausted from the room into a duct, filtered through a HEPA filter, and returned to the room (Figure S3-5). This technique may be used to add air changes in areas where there is a recommended minimum ACH that is difficult to meet with general ventilation alone. The air does not have to be conditioned, other than by the filtration, and this permits higher airflow

Figure S3-5. Fixed, ducted room-air recirculation system using a high-efficiency particulates air (HEPA) filter inside an ir duct*



* Such a system can be used to increase the room ventilation rate.

Figure S3-6. Fixed, ceiling-mounted room-air recirculation system using a high-efficiency particulates air (HEPA) filter*



* Such a system can be used to increase the room ventilation rate. Position the HEPA unit one third of the room's length from the patient's end of the room.

rates than the general ventilation system can usually achieve. An alternative is the use of HEPA filtration units that are mounted on the wall or ceiling of the room {Figure S3-7). Fixed recirculation systems are preferred over portable (free-standing) units because they can be installed and maintained with a greater degree of reliability.

b. Portable room-air recirculation units.

Portable HEPA filtration units may be considered for recirculating air within rooms in which there is no general ventilation system, where the system is incapable of providing adequate airflow, or where increased effectiveness in room airflow is desired. Effectiveness depends on circulating as much of the air in the room as possible through the HEPA filter, which may be difficult to achieve and evaluate. The effectiveness of a particular unit can vary depending on the room's configuration, the furniture and persons in the room, and placement of the HEPA filtration unit and the supply and exhaust grilles. Therefore, the effectiveness of the portable unit may vary considerably in rooms with different configurations or in the same room if moved from one location to another in the room. If portable units are used, caution should be exercised to ensure they can recirculate all or nearly all of the room air through the HEPA filter. Some commercially available units may not be able to meet this requirement because of design limitations or insufficient airflow capacity. In addition, units should be designed and operated to ensure that persons in the room cannot interfere with or otherwise compromise the functioning of the unit. Portable HEPA filtration units have not been evaluated adequately to determine their role in TB infection-control programs.

Portable HEPA filtration units should be designed to achieve the equivalent of ≥12 ACH. They should also be designed to ensure adequate air mixing in all areas of the hospital rooms in which they are used, and they should not interfere with the current ventilation system.

Some HEPA filtration units employ UVGI for disinfecting air after HEPA filtration. However, whether exposing the HEPA-filtered air to UV irradiation further decreases the concentration of contaminants is not known.

c. Evaluation of room-air recirculation systems and units.

Detailed and accurate evaluations of room-air recirculation systems and units require the use of sophisticated test equipment and lengthy test procedures that are not practical. However, an estimate of the unit's ability to circulate the air in the room can be made by visualizing airflow patterns as was described previously for estimating room air mixing (Suppl. 3, Section II.B.1). If the air movement is good in all areas of the room, the unit should be effective.

4. Installing. Maintaining, and Monitoring HEPA Filters

Proper installation and testing and meticulous maintenance are critical if a HEPA filtration system is used (104), especially if the system used recirculates air to other parts of the facility. Improper design, installation, or maintenance could allow infectious particles to circumvent filtration and escape into the general ventilation system (47). HEPA filters should be installed to prevent leakage between filter segments and between the filter bed and its frame. A regularly scheduled maintenance program is required to monitor the HEPA filter for possible leakage and for filter loading. A quantitative leakage and filter performance test (e.g., the dioctal phthalate [DOP] penetration test [105]) should be performed at the initial installation and every time the filter is changed or moved. The test should be repeated every 6 months for filters in general-use areas and in areas with systems that exhaust air that is likely to be contaminated with *M. tuberculosis* (e.g. TB isolation rooms).

A manometer or other pressure-sensing device should be installed in the filter system to provide an accurate and objective means of determining the need for filter replacement. Pressure drop characteristics of the filter are supplied by the manufacturer of the filter. Installation of the filter should allow for maintenance that will not contaminate the delivery system or the area served. For general infection-control purposes, special care should be taken to not jar or drop the filter element during or after removal. The scheduled maintenance program should include procedures for installation, removal, and disposal of filter elements. HEPA filter maintenance should be performed only by adequately trained personnel. Appropriate respiratory protection should be worn while performing maintenance and testing procedures. In addition, filter housing and ducts leading to the housing should be labeled clearly with

the words "Contaminated Air" (or a similar warning).

When a HEPA filter is used, one or more lower efficiency disposable prefilters installed upstream will extend the useful life of the HEPA filter. A disposable filter can increase the life of a HEPA filter by 25%. If the disposable filter is followed by a 90% extended surface filter, the life of the HEPA filter can be extended almost 900% (98). These prefilters should be handled and disposed of in the same manner as the HEPA filter.

D. TB Isolation Rooms and Treatment Rooms

Purpose: To separate patients who are likely to have infectious TB from other persons, to provide an environment that will allow reduction of the concentration of droplet nuclei through various engineering methods, and to prevent the escape of droplet nuclei from such rooms into the corridor and other areas of the facility using directional airflow.

A hierarchy of ventilation methods used to achieve a reduction in the concentration of droplet nuclei and to achieve directional airflow using negative pressure has been developed (Table S3-2). The methods are listed in order from the most desirable to the least desirable. The method selected will depend on the configuration of the isolation room and the ventilation system in the facility; the determination should be made in consultation with a ventilation engineer.

TABLE S3-2.– Hierarchy of Ventilation Methods for Tuberculosis (TB) Isolation Rooms and Treatment Rooms

Reducing concentration of airborne tubercle bacilli*	Achieving directional airflow using negative pressure♦
1. Facility heating, ventilation, and air-conditioning (HVAC) system.	1. Facility HVAC system.
2. Fixed room-air high-efficiency particulate air (HEPA) recirculation system	2. Bleed air★ from fixed room-air HEPA recirculation system.
3. Wall- or ceiling-mounted room-air HEPA recirculation system.	3. Bleed air from wall - or ceiling-mounted room-air HEPA recirculation system
4. Portable room-air HEPA	4. Bleed air from portable room-air HEPA recirculation unit✚ 5. Exhaust air from room through window-mounted fan.°

* Ventilation methods are used to reduce the concentration of airborne tubercle bacilli. If the facility HVAC system cannot achieve the recommended ventilation rate, auxiliary room-air recirculation methods may be used. These methods are listed in order from the most desirable to the least desirable. Ultraviolet germicidal irradiation may be used as a supplement to any of the ventilation methods for air cleaning.

♦ Directional airflow using negative pressure can be achieved with the facility HVAC system and/or the auxiliary air-recirculation-cleaning systems. These methods are listed in order from the most desirable to the least desirable.

★ To remove the amount of return air necessary to achieve negative pressure.

✚ The effectiveness of portable room-air HEPA recirculation units can vary depending on the room's configuration, the furniture and persons in the room, the placement of the unit, the supply and exhaust grilles, and the achievable ventilation rates and air mixing. Units should be designed and operated to ensure that persons in the room cannot interfere with or otherwise compromise the function of the unit. Fixed recirculating systems are preferred over portable units in TB isolation rooms of facilities in which services are provided regularly to TB patients.

° This method simply achieves negative pressure and should be used only as a temporary measure.

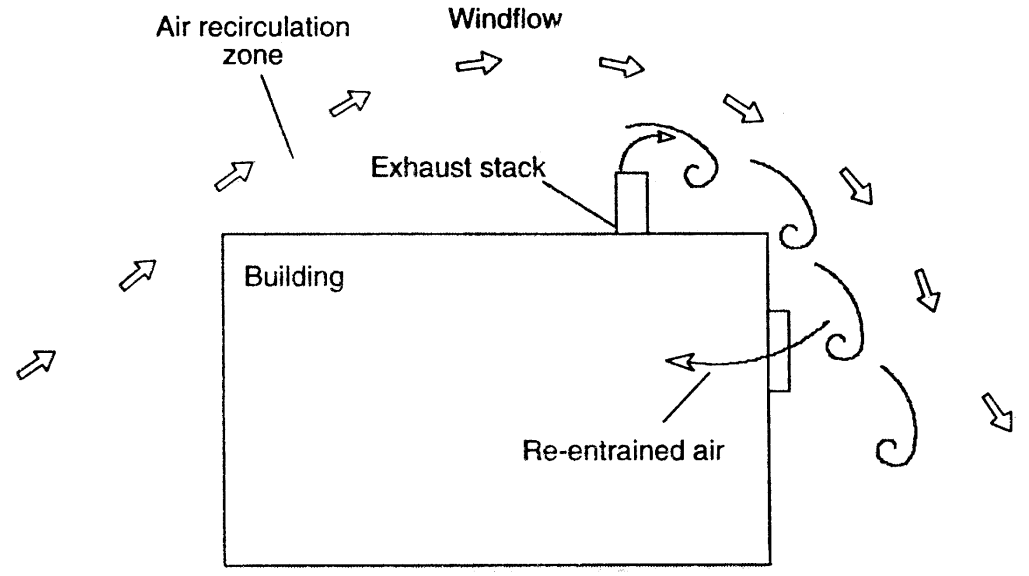
1. Preventing the Escape of Droplet Nuclei from the Room

Rooms used for TB isolation should be single-patient rooms with negative pressure relative to the corridor or other areas connected to the room. Doors between the isolation room and other areas should remain closed except for entry into or exit from the room. The room's openings (e.g., windows and electrical and plumbing entries) should be sealed as much as possible. However, a small gap of to 1/8 to 1/2 inch should be at the bottom of the door to provide a controlled airflow path. Proper use of negative pressure will prevent contaminated air from escaping the room.

2. Reducing the Concentration of Droplet Nuclei in the Room

ASHRAE (47), AIA (48), and the Health Resources and Services Administration (49) recommend a minimum of 6 ACH for TB isolation rooms and treatment rooms. This ventilation rate is based on comfort- and odor-control considerations. The

Figure S3-7 Air recirculation zone* created by wind blowing over a building



* Height of air recurclation zone may be variable. Air should be exhausted above this zone to prevent re-entrainment.

effectiveness of this level of airflow in reducing the concentration of droplet nuclei in the room, thus reducing the transmission of airborne pathogens, has not been evaluated directly or adequately.

Ventilation rates >6 ACH are likely to produce an incrementally greater reduction in the concentration of bacteria in a room than are lower rates (50-52). However, accurate quantitation of decreases in risk that would result from specific increases in general ventilation levels has not been performed and may not be possible.

To reduce the concentration of droplet nuclei, TB isolation rooms and treatment rooms in existing health-care facilities should have an airflow of ≥6 ACH. Where feasible, this airflow rate should be increased to ≥12 ACH by adjusting or modifying the ventilation system or by using auxiliary means (e.g. recirculation of air through fixed HEPA filtration units or portable air cleaners) (Suppl. 3, Section II.C) (53). New construction or renovation of existing health-care facilities should be designed so that TB isolation rooms achieve an airflow of ≥12 ACH.

3. Exhaust From TB Isolation Rooms and Treatment Rooms

Air from TB isolation rooms and treatment rooms in which patients with infectious TB may be examined should be exhausted directly to the outside of the building and away from air-intake vents, persons, and animals in accordance with federal, state, and local regulations concerning environmental discharges. (See Suppl. 3, Section II.C, for information regarding recirculation of exhaust air.) Exhaust ducts should not be located near areas that may be populated (e.g., near sidewalks or windows that could be opened). Ventilation system exhaust discharges and inlets should be designed to prevent reentry of exhausted air. Wind blowing over a building creates a highly turbulent recirculation zone, which can cause exhausted air to reenter the building (Figure S3-7). Exhaust flow should be discharged above this zone (Suppl. 3, Section II.C.l). Design guidelines for proper placement of exhaust ducts can be found in the 1989 *ASHRAE Fundamentals Handbook* (106). If recirculation of air from such rooms into the general ventilation system is unavoidable, the air should be passed through a HEPA filter before recirculation (Suppl. 3, Section II.C.2).

4. Alternatives to TB Isolation Rooms

Isolation can also be achieved by use of negative-pressure enclosures (e.g. tents or booths) (Suppl. 3, Section II.A.1). These can be used to provide impatient isolation in areas such as emergency rooms and medical testing and treatment areas and to supplement isolation in designated isolation rooms.

III. UVGI

Purpose: To kill or inactivate airborne tubercle bacilli.

Research has demonstrated that UVGI is effective in killing or inactivating tubercle bacilli under experimental conditions (66,107-110) and in reducing transmission of other infections in hospitals (111), military housing (112*)*, and classrooms (113-l l5). Because of the results of numerous studies (116-120) and the experiences of TB clinicians and mycobacteriologists during the past several decades, the use of UVGI has been recommended as a supplement to other TB infection-control measures in settings where the need for killing or inactivating tubercle bacilli is important (2,4,121-125).

UV radiation is defined as that portion of the electromagnetic spectrum described by wavelengths from 100 to 400 nm. For convenience of classification, the UV spectrum has been separated into three different wavelength bands: UV-A (long wavelengths, range: 320-400 nm), UV-B (midrange wavelengths, range: 290-320 nm), and UV-C (short wavelengths, range, 100-290 nm) (126). Commercially available UV lamps used for germicidal purposes are low-pressure mercury vapor lamps (127) that emit radiant energy in the UV-C range, predominantly at a wavelength of 253.7 nm (128).

A. Applications

UVGI can be used as a method of air disinfection to supplement other engineering controls. Two systems of UVGI can be used for this purpose: duct irradiation and upper-room air irradiation.

1. Duct Irradiation

Purpose: To inactivate tubercle bacilli without exposing persons to UVGI.

In duct irradiation systems, UV lamps are placed inside ducts that remove air from rooms to disinfect the air before it is recirculated. When UVGI duct systems are properly designed, installed, and maintained, high levels of UV radiation may be produced in the ductwork. The only potential for human exposure to this radiation occurs during maintenance operations.

Duct irradiation may be used:

· In a TB isolation room or treatment room to recirculate air from the room, through a duct containing UV lamps, and back into the room. This recirculation method can increase the overall room airflow but does not increase the supply of fresh outside air to the room.

· In other patients' rooms and in waiting rooms, emergency rooms, and other general-use areas of a facility where patients with undiagnosed TB could potentially contaminate the air, to recirculate air back into the general ventilation. Duct-irradiation systems are dependent on airflow patterns within a room that ensure that all or nearly all of the room air circulates through the duct.

2. Upper-Room Air Irradiation

Purpose. To inactivate tubercle bacilli in the upper part of the room, while minimizing radiation exposure to persons in the lower part of the room.

In upper-room air irradiation, UVGI lamps are suspended from the ceiling or mounted on the wall. The bottom of the lamp is shielded to direct the radiation upward but not downward. The system depends on air mixing to take irradiated air from the upper to the lower part of the room, and nonirradiated air from the lower to the upper part. The irradiated air space is much larger than that in a duct system.

UVGI has been effective in killing bacteria under conditions where air mixing was accomplished mainly by convection. For example, BCG was atomized in a room that did not have supplemental ventilation (120), and in another study a surrogate bacteria, *Serratia marcesens*, was aerosolized in a room with a ventilation rate of 6 ACH (129). These reports estimated the effect of UVGI to be equivalent to 10 and 39 ACH, respectively, for the organisms tested, which are less resistant to UVGI than *M. tuberculosis* (120). The addition of fans or some heating/air conditioning arrangements may double the effective-ness of UVGI lamps (130-132). Greater rates of ventilation, however, may decrease the length of time the air is irradiated, thus decreasing the killing of bacteria (117,129). The optimal relation-ship between ventilation and UVGI is not known. Air irradiation lamps used in corridors have been effective in killing atomized *S. marcesens* (133). Use of UVGI lamps in an outpatient room has reduced culturable airborne bacteria by 14%-19%. However, the irradiation did not reduce the concentration of gram-positive, rod-shaped bacteria; although fast-growing mycobacteria were cultured, *M. tuberculosis* could not be recovered from the room's air samples because of fungal overgrowth of media plates (134).

Upper-room air UVGI irradiation may be used:

· In isolation or treatment rooms as a supplemental method of air cleaning.

· In other patients' rooms and in waiting rooms, emergency rooms, corridors, and other central areas of a facility where patients with undiagnosed TB could potentially contaminate the air.

Determinants of UVGI effectiveness include room configuration, UV lamp placement, and the adequacy of airflow patterns in bringing contaminated air into contact with the irradiated upper-room space. Air mixing may be facilitated by supplying cool air near the ceiling in rooms where warmer air (or a heating device) is present below. The ceiling should be high enough for a large volume of upper-room air to be irradiated without HCWs and patients being overexposed to UV radiation.

B. Limitations

Because the clinical effectiveness of UV systems varies, and because of the risk for transmission of *M. tuberculosis* if a system malfunctions or is maintained improperly, UVGI is not recommended for the following specific applications:

1. Duct systems using UVGI are not recommended as a substitute for HEPA filters if air from isolation rooms must be recirculated to other areas of a facility.

2. UVGI alone is not recommended as a substitute for HEPA filtration or local exhaust of air to the outside from booths, tents, or hoods used for cough-inducing procedures.

3. UVGI is not a substitute for negative pressure.

The use of UV lamps and HEPA filtration in a single unit would not be expected to have any infection-control benefits not provided by use of the HEPA filter alone.

The effectiveness of UVGI in killing airborne tubercle bacilli depends on the intensity of UVGI, the duration of contact the organism has with the irradiation, and the relative humidity (66,108,111). Humidity can have an adverse effect on UVGI effectiveness at levels >70% relative humidity for *S. marcescens* (135). The interaction of these factors has not been fully defined, however, making precise recommendations for individual UVGI installations difficult to develop.

Old lamps or dust-covered UV lamps are less effective; therefore, regular maintenance of UVGI systems is crucial.

C. Safety Issues

Short-term overexposure to UV radiation can cause erythema and keratoconjunctivitis (136,137*).* Broad-spectrum UV radiation has been associated with increased risk for squamous and basal cell carcinomas of the skin (138). UV-C was recently classified by the International Agency for Research on Cancer as "probably carcinogenic to humans (Group 2A)" (138). This classification is based on studies suggesting that UV-C radiation can induce skin cancers in animals; DNA damage, chromosomal aberrations and sister chromatid exchange and transformation in human cells in vitro; and DNA damage in mammalian skin cells in vivo. In the animal studies, a contribution of UV-B to the tumor effects could not be excluded, but the effects were greater than expected for UV-B alone (138). Although some recent studies have demonstrated that UV radiation can activate HIV gene promoters (i.e., the genes in HIV that prompt replication of the virus) in laboratory samples of human cells (139-144), the implications of these in vitro findings for humans are unknown.

In 1972, the National Institute for Occupational Safety and Health

(NIOSH) published a recommended exposure limit (REL) for occupational exposure to UV radiation (136). The REL is intended to protect workers from the acute effects of UV exposure (e.g., erythema and photokeratoconjunctivitis). However, photosensitive persons and those exposed concomitantly to photoactive chemicals may not be protected by the recommended standard. If proper procedures are not followed, HCWs performing maintenance on such fixtures are at risk for exposure, to UV radiation. Because UV fixtures used for upper-room air irradiation are present in rooms, rather than hidden in ducts safety may be much more difficult to achieve and maintain. Fixtures must be designed and installed to ensure that UV exposure to persons in the room (including HCWs and inpatients) are below current safe exposure levels. Recent health hazard evaluations conducted by CDC have noted problems with overexposure of HCWs to UVGI and with inadequate maintenance, training, labeling, and use of personal protective equipment (145-147).

The current number of persons who are properly trained in UVGI system design and installation is limited. CDC strongly recommends that a competent UVGI system designer be consulted to address safety considerations before such a system is procured and installed. Experts who might be consulted include industrial hygienists, engineers, and health physicists. Principles for the safe installation of UV lamp fixtures have been developed and can be used as guidelines (148,149).

If UV lamps are being used in a facility, the general TB education of HCWs should include:

1. The basic principles of UVGI systems (i.e., how they work and ``hat their limitations are).

2. The potential hazardous effects of UVGI if overexposure occurs.

3. The potential for photosensitivity associated with certain medical conditions or use of some medications.

4. The importance of general maintenance procedures for UVGI fixtures.

Exposure to UV intensities above the REL should be avoided. Lightweight clothing made of tightly woven fabric and UV-absorbing sunscreens with solar-protection factors (SPFs) ≥15 may help protect photosensitive persons. HCWs should be advised that any eye or skin irritation that develops after UV exposure should be examined by occupational health staff.

The NIOSH REL for UV radiation is wavelength dependent because different wavelengths of UV radiation have different adverse effects on the skin and eyes (l36). **Relative** spectral effectiveness (Sλ) is used to compare various UV sources with a source producing UV radiation at 270 nm, the wavelength of maximum ocular sensitivity. For example, the Sλ at 254 nm is 0.5; therefore, twice as much energy is required at 254 nm to produce an identical biologic effect at 270 nm (136). Thus, at 254 nm, the NIOSH REL is 0.006 joules per square centimeter (J/cm^2); and at 270 nm, it is 0.003 J/cm2.

For germicidal lamps that emit radiant energy predominantly at a wavelength of 254 nm, proper use of the REL requires that the measured irradiance level (E) in microwatts per square centimeter ($\mu W/cm^2$) be multiplied by the relative spectral effectiveness at 254 nm (0.5) to obtain the effective irradiance (E_{eff}). The maximum permissible exposure time can then be determined for selected values of E_{eff} (Table S3-3), or it can be calculated (in seconds) by dividing 0.003 J/cm^2 (the NIOSH REL at 270 nm) by E_{eff} in $\mu W/cm^2$ (136,150).

To protect HCWs who are exposed to germicidal UV radiation for 8 hours per workday, the measured irradiance (E) should be ≤0.2 $\mu W/cm^2$. This is calculated by obtaining E_{eff} (0.1 $\mu W/cm^2$) (Table S3-3) and then dividing this value by Sλ (0.5).

TABLE S3-3.—Maximum Permissible Exposure Times* for Selected Values of Effective Irradiance

Permissible exposure time per day	Effective irradiance (E_{eff})♦ ($\mu W/cm^2$)
8 hrs	0.1
4 hrs	0.2
2 hrs	0.4
1 hrs	0.8
30 min	1.7
15 min	3.3
10 min	5.0
5 min	10.0
1 min	50.0
30 sec	100.0

* Permissible exposure times are designed to prevent acute effects of irradiation to skin and eyes (136). These recommended limits are wavelength dependent because different wavelengths of

ultraviolet (UV) radiation have different adverse effects on these organs

♦ Relative spectral effectiveness (Sλ) is used to compare various UV sources with a source producing UV radiation at 270 nm, the wavelength of maximum ocular sensitivity. For example, the relative spectral effectiveness at 254 nm is 0.5; therefore, twice as much energy is required at 254 nm to produce an identical biologic effect at 270 nm. At 254 nm, the NIOSH REL is 0.006 joules per square centimeter (J/cm^2), and at 270 nm, it Is 0.003 J/cm^2. For germicidal lamps that emit radiant energy predominantly at a wavelength of 254 nm, proper use of the REL requires that the measured irradiance level (E) in microwatts per square centimeter ($\mu W/cm^2$) be multiplied by the relative spectral effectiveness at 254 nm (0.5) to obtain E_{eff}. The maximum permissible exposure time can be calculated (in seconds) by dividing 0.003 J/cm^2 (the NIOSH REL at 270 nm) by E_{eff} in $\mu W/cm^2$ (136,150). To protect health-care workers who are exposed to germicidal UV radiation for 8 hours per work day, the measured irradiance (E) should be ≤ 0.2 $\mu W/cm^2$, which is calculated by obtaining E_{eff} (0.1 $\mu W/cm^2$), then dividing this value by Sλ (0.5).

E. Maintenance and Monitoring

1. Labeling and Posting

Warning signs should be posted on UV lamps and wherever high-intensity (i.e., UV exposure greater than the REL) germicidal UV irradiation is present (e.g., upper-room air space and accesses to ducts [if duct irradiation is used]) to alert maintenance staff or other HCWs of the hazard. Some examples are shown below:

CAUTION
ULTRAVIOLET ENERGY: TURN OFF LAMPS BEFORE ENTERING UPPER ROOM

CAUTION
ULTRAVIOLET ENERGY: PROTECT EYES & SKIN

2. Maintenance

Because the intensity of UV lamps fluctuates as they age, a schedule for replacing the lamps should be developed. The schedule can be determined from either a time/use log or a system based on cumulative time. The tube should be checked periodically for dust build-up, which lessens the output of UVGI. If the tube is dirty, it should be allowed to cool, then cleaned with a damp cloth. Tubes should be replaced if they stop glowing or if they flicker to an objectionable extent. Maintenance personnel must turn off all UV tubes before entering the upper part of the room or before accessing ducts for any purpose. Only a few seconds of direct exposure to the intense UV radiation in the upper-room air space or in ducts can cause burns. Protective equipment (e.g., gloves and goggles [and/or face shields]) should be worn if exposure greater than the recommended standard is anticipated.

Banks of UVGI tubes can be installed in ventilating ducts. Safety devices should be used on access doors to eliminate hazard to maintenance personnel. For duct irradiation systems, the access door for servicing the lamps should have an inspection window* through which the lamps are checked periodically for dust build-up and malfunctioning. The access door should have a warning sign written in languages appropriate for maintenance personnel to alert them to the health hazard of looking directly at bare tubes. The lock for this door should have an automatic electric so itch or other device that turns off the lamps when the door is opened.

Two types of fixtures are used in upper-room air irradiation wall-mounted fixtures that have louvers to block downward radiation and ceiling-mounted fixtures that have baffles to block radiation below the horizontal plane of the UV tube. The actual UV tube in either type of fixture must not be visible from any normal position in the room. Light switches that can be locked should be used, if possible, to prevent injury to personnel who might unintentionally turn the lamps on during maintenance procedures. In most applications, properly shielding the UV lamps to provide protection from most, if not all, of the direct UV radiation is not difficult. However, radiation reflected from glass, polished metal, and high-gloss ceramic paints can be harmful to persons in the room, particularly if more than one UV lamp is in use. Surfaces in irradiated rooms that can reflect UVGI into occupied areas of the room should be covered with non-UV reflecting material.

3. Monitoring

A regularly scheduled evaluation of the UV intensity to which HCWs, patients, and others are exposed should be conducted.

UV measurements should be made in various locations within a room using a detector designed to be most sensitive at 254 nm. Equipment used to measure germicidal UV radiation should be maintained and calibrated on a regular schedule.

A new UV installation must be carefully checked for hot spots (i.e., areas of the room where the REL is exceeded) by an industrial hygienist or other person knowledgeable in making UV measurements. UV radiation levels should not exceed those in the recommended guidelines.

* Ordinary glass (not quartz) is sufficient to filter out UV radiation

Phoenix Controls
Corporation

55 Chapel Street, Newton MA 02458
Telephone 617-964-6670
Fax 617-965-4503
www.phoenixcontrols.com