also designed to discharge air to the outside to achieve negative pressure. These air cleaners must be designed specifically for this purpose.

Monitoring negative pressure. Negative pressure must be monitored to ensure that air is always flowing from the corridor (or surrounding area) into the AII room. Negative pressure can be monitored either continuously or periodically. Monitoring methods include chemical aerosols (e.g., smoke tube), differential pressure-sensing devices (e.g., manometer), and physical indicators (e.g., flutter strips).

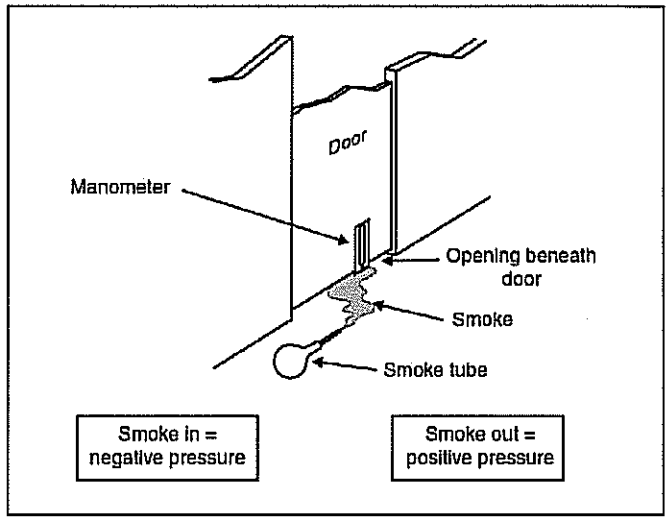
A chemical aerosol resembling smoke can be used to observe airflow between a room and the surrounding area, or within a room. Devices called smoke tubes generate the chemical aerosol resembling smoke, which follows the local air currents wherever it is released. To check the negative pressure in a room, hold a smoke tube approximately 2 inches in front of the base of the closed door of the AII room or in front of the air transfer grille, if the door has such a feature. Hold the smoke tube parallel to the door. A small amount of smoke should be generated slowly to ensure that the velocity of smoke emanating from the tube does not overpower the air velocity (Figure 5). If the room is under negative pressure, the smoke will travel into the room (from higher to lower pressure). If the room is not under negative pressure, the smoke will be blown outward or stay in front of the door. Room air cleaners in the room should be operating. Persons using smoke tubes should avoid inhaling the smoke, because direct inhalation of high concentrations of the smoke can be irritating (*391*) (Figure 5).

Manometers are used to monitor negative pressure. They provide either periodic (noncontinuous) pressure measurements or continuous pressure monitoring. A continuous monitoring indicator can simply be a visible or audible warning signal indicating that air pressure is positive. Both periodic and continuous pressure detectors generate a digital or analog signal that can be recorded for later verification or used to automatically adjust the room's ventilation control system.

Physical indicators (e.g., flutter strips) are occasionally used to provide a continuous visual sign that a room is under negative pressure. These simple and inexpensive devices are placed directly in the door and can be useful in identifying a pressure differential problem.

Pressure-measuring devices should sense the pressure just inside the airflow path into the AII room (e.g., at the base of the door). Unusual airflow patterns can cause pressure variations. For example, the air can be under negative pressure at the middle of a door and under positive pressure at the base of the same door. The ideal location of a pressure-measuring device has been illustrated (Figure 6). If the pressure-sensing ports of the device cannot be located directly across the airflow path, validating that the negative pressure at the sensing point is and remains the same as the negative pressure across the flow path might be necessary.

FIGURE 5. Smoke tube testing and manometer placement to determine the direction of airflow into and out of a room



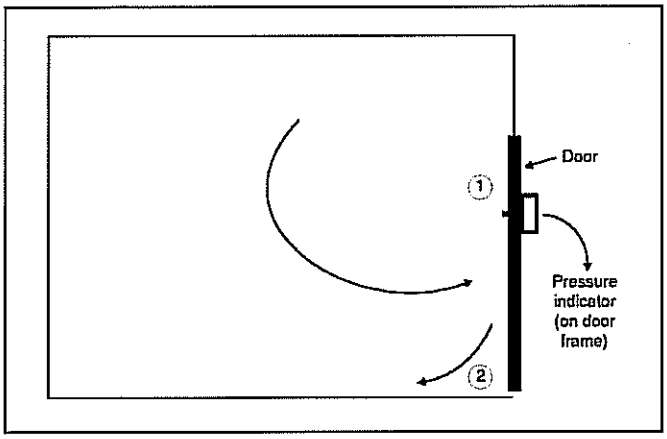
Pressure-sensing devices should incorporate an audible warning with a time delay to indicate an open door. When a door is open, the negative pressure cannot be maintained, but this situation should not generate an alarm unless the door is left open. Therefore, the time delay should allow adequate time for persons to enter or leave an AII room without activating the alarm.

The pressure differentials used to achieve low negative pressure (<0.005 inch) require the use of substantially sensitive mechanical devices, electronic devices, or pressure gauges to ensure accurate measurements. Pressure-measuring and monitoring devices can give false readings if the calibration has drifted. For example, a sensor might indicate that the room pressure is slightly negative compared with the corridor, but, because air current momentum effects or "drift" of the electrical signal, air might actually be flowing out of the AII room through the opening at the base of the door. In one study of 38 AII rooms with electrical or mechanical devices to continuously monitor air pressurization, one half had airflow at the door in the opposite direction of that indicated by the continuous monitors (*392*). The investigators attributed this problem to instrument limitations and device malfunction. A negative pressure differential of ≥0.01 inch of water gauge (compared with the previously recommended 0.001 inch of water gauge) might help to minimize this problem.

Periodic checks are required to maintain the desired negative pressure and the optimal operation of monitoring devices.

- AII rooms should be checked for negative pressure before occupancy.

FIGURE 6. Cross-sectional view of a room indicating the location of negative pressure measurement*



* Airflow pressure at location 1 might differ from that at location 2. Measure pressure at location 2 for correct indication of negative pressure.

- When occupied by a patient, an AII room should be checked daily with smoke tubes or other visual checks for negative pressure.
- If pressure-sensing devices are used in AII rooms occupied by patients with suspected or confirmed TB disease, negative pressure should be checked daily by using smoke tubes or other visual checks.
- If the AII rooms are not being used for patients who have suspected or confirmed TB disease but potentially could be used for such patients, the negative pressure should be checked monthly.
- Laboratories should be checked daily for negative pressure.

AII Rooms and Other Negative-Pressure Rooms

AII rooms are used to 1) separate patients who probably have infectious TB from other persons, 2) provide an environment in which environmental factors are controlled to reduce the concentration of droplet nuclei, and 3) prevent the escape of droplet nuclei from such rooms into adjacent areas using directional airflow. Other negative-pressure rooms include bronchoscopy suites, sputum induction rooms, selected examination and treatment rooms, autopsy suites, and clinical laboratories.

Preventing the escape of droplet nuclei. AII rooms used for TB isolation should be single-patient rooms with negative pressure, compared with the corridor or other areas connected to the room. Opening doors and windows can substantially affect the negative pressure in an AII room. Infection-control criteria require AII room windows and doors to remain closed, except when doors must be opened for persons to enter or leave the room. It might also be necessary to keep certain doors in the corridor outside the AII rooms closed to maintain the negative-pressure differential between an AII room and the corridor. The use of self-closing doors is recommended. The openings in the room (e.g., windows, and electrical and plumbing entries) should be sealed as much as possible, with the exception of a small gap (1/8–1/2 inch) at the base of the door to provide a controlled airflow path. Proper use of negative pressure will prevent contaminated air from escaping the room (*393,394*).

Reducing the concentration of droplet nuclei. AII rooms in existing health-care settings should have an air change rate of ≥6 mechanical ACH. Whenever feasible, this airflow rate should be increased to ≥12 mechanical ACH by adjusting or modifying the ventilation system or should be increased to ≥12 equivalent ACH by supplementing with air-cleaning technologies (e.g., fixed or portable room-air recirculation systems or UVGI systems). New construction or renovation of existing health-care settings should be designed so that AII rooms achieve a total air change rate of ≥12 mechanical ACH. These recommendations are consistent with guidelines by ASHRAE and AIA that recommend ≥12 mechanical ACH for AII rooms (*117,118*). Ventilation recommendations for other negative-pressure rooms in new or renovated health-care settings have been presented (see Risk Classification Examples).

To dilute the concentration of normal room air contaminants and minimize odors, a portion of the supply air should come from the outdoors. A minimum of 2 ACH of outdoor air should be provided to AII rooms and other negative-pressure rooms (*117,118*).

Exhaust from AII rooms and other negative-pressure rooms. Air from AII rooms and other negative-pressure rooms for patients with suspected or confirmed TB disease should be exhausted directly to the outside and away from air-intake vents, persons, and animals, in accordance with applicable federal, state, and local regulations on environmental discharges. Exhaust ducts should be located away from sidewalks or windows that can be opened. Ventilation system exhaust discharges and inlets should be designed to prevent the re-entry of exhausted air. Wind blowing over a building creates a substantially turbulent recirculation zone that can cause exhausted air to re-enter the building. Exhaust flow should be discharged above this zone. Design guidelines for proper placement of exhaust ducts have been published (*395*). 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.

Alternatives to negative-pressure rooms. AII can also be achieved by the use of negative-pressure enclosures (e.g., tents or booths). These enclosures can provide patient isolation in EDs and medical testing and treatment areas and can supplement AII in designated negative-pressure rooms.

Other Selected Settings

Operating rooms, autopsy suites, sputum-induction rooms, and aerosolized treatment rooms pose potential hazards from infectious aerosols generated during procedures on patients with TB disease (*72,90,396–398*). Recommended administrative, environmental, and respiratory-protection controls for these and other selected settings have been summarized (Appendix A). Additional or specialized TB infection controls that are applicable to special circumstances and types of health-care delivery settings have also been described (see Managing Patients Who Have Suspected or Confirmed TB Disease: Considerations for Special Circumstances and Settings). Ventilation recommendations for these settings in new or renovated health-care facilities have been included in this report (Table 2). Existing facilities might need to augment the current ventilation system or use the air-cleaning methods to increase the number of equivalent ACH.

Patients with TB disease who also require a PE room (e.g., severely immunocompromised patients) are special cases. These patients require protection from common airborne infectious microorganisms and must be placed in a room that has HEPA-filtered supply air and is under positive pressure compared with its surroundings (*118*). If an anteroom is not available, the use of other air-cleaning methods should be considered to increase the equivalent ACH. The air-cleaning systems can be placed in the room and in surrounding areas to minimize contamination of the surroundings. Similar controls can be used in ORs that are used for patients with TB disease because these rooms must be maintained under positive pressure, compared with their surroundings to maintain a sterile field.

Air-Cleaning Methods

HEPA Filtration

HEPA filtration can be used to supplement other recommended ventilation measures by providing a minimum removal efficiency of 99.97% of particles equal to 0.3 μm in diameter. This air-cleaning method is considered an adjunct to other ventilation measures. Used alone, this method neither provides outside air for occupant comfort nor satisfies other recommended ventilation measures (e.g., using source control whenever possible and minimizing the spread of contaminants in a setting through control of airflow patterns and pressure differentials).

HEPA filters have been demonstrated to reduce the concentration of *Aspergillus* spores (range in size: 5–6 μm) to below measurable levels (*399–401*). Because infective droplet nuclei generated by TB patients are believed to range from 1–5 μm in diameter (*300*) (comparable in size to Aspergillus spores) (*402*), HEPA filters will remove *M. tuberculosis*–containing infectious droplet nuclei from contaminated air. HEPA filters can be used to clean air before it is 1) exhausted to the outside, 2) recirculated to other areas of a health-care setting, or 3) recirculated in an AII room. Because electrostatic filters can degrade over time with exposure to humid environments and ambient aerosols (*403*), their use in systems that recirculate air back into the general ventilation system from AII rooms and treatment rooms should be avoided. If used, the filter manufacturer should be consulted regarding the performance of the filter to ensure that it maintains the desired filtration efficiency over time and with loading.

Use of HEPA filtration when exhausting air to the outside. HEPA filters can be used as an added safety measure to clean air from AII rooms and local exhaust devices (e.g., booths, tents, and hoods) before exhausting it to the outside. This added measure is not necessary, however, if the exhaust air cannot re-enter the ventilation system supply and does not pose a risk to persons and animals where it is exhausted.

Exhaust air frequently is not discharged directly to the outside; instead, the air is directed through heat-recovery devices (e.g., heat wheels or radiator-like devices). Heat wheels are frequently used to reduce the costs of operating ventilation systems (*404*). As the wheel rotates, energy is transferred into or removed from the supply inlet air stream. If a heat wheel is used with a system, a HEPA filter should also be used. 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 might be impacted on the wheel by the exhaust air and subsequently stripped off into the supply air.

Recirculation of HEPA-filtered air. Air from AII rooms and other negative-pressure rooms should be exhausted directly to the outside. In certain instances, however, recirculation of air into the general ventilation system from such rooms is unavoidable (e.g., settings in which the ventilation system or building configuration causes venting the exhaust to the outside impossible). In such cases, HEPA filters should be installed in the exhaust duct exiting the room to remove infectious organisms from the air before it is returned to the general ventilation system.

Individual room-air recirculation can be used in areas in which no general ventilation system exists, where an existing system is incapable of providing sufficient ACH, or where air-cleaning (particulate removal) is desired without affecting the fresh air supply or negative-pressure system. Recirculation of HEPA-filtered air in a room can be achieved by 1) exhausting air from the room into a duct, passing it through a HEPA filter installed in the duct, and returning it to the room (Figure 7); *2*) filtering air through HEPA recirculation systems installed

on the wall or ceiling of the room (Figure 8); or 3) filtering air through portable HEPA recirculation systems. In this report, the first two approaches are referred to as fixed room-air recirculation systems because the recirculation systems are not easily movable.

Fixed room-air recirculation systems. The preferred method of recirculating HEPA-filtered air is by using 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 7). This technique can add equivalent ACH in areas in which the recommended minimum ACH is difficult to meet with general ventilation. This equivalent ventilation concept compares particle removal by HEPA filtration of the recirculated air with particle clearance from exhaust ventilation. Because the air does not have to be conditioned, airflow rates that are higher than those produced by the general ventilation system can usually be achieved. An alternative is to install HEPA filtration units on the wall or ceiling (Figure 8).

Fixed recirculation systems are preferred to portable (free-standing) units because they can be installed with a higher degree of reliability. In addition, certain fixed systems have a higher airflow capacity than portable systems, and the potential for short-circuiting of air is reduced as the distance between the air intake and exhaust is increased.

Portable room-air recirculation systems. Portable room-air recirculation units with HEPA filters (also called portable air cleaners) can be considered when 1) a room has no general ventilation system, 2) the system cannot provide adequate ACH, or 3) increased effectiveness in airflow is needed. Effectiveness depends on the ability of the portable room-air recirculation unit to circulate as much of the air in the room as possible through the HEPA filter. Effectiveness can vary depending on the room's configuration, the furniture and persons in the room, the placement of the HEPA filtration unit compared with the supply diffusers and exhaust grilles, and the degree of mixing of air within the room.

Portable room-air recirculation units have been demonstrated to be effective in removing bioaerosols and aerosolized particles from room air (*405–410*). Findings indicate that various commercially available units are useful in reducing the concentration of airborne particles and are therefore helpful in reducing airborne disease transmission. The performance of 14 units was evaluated for volumetric airflow, airborne particle reduction, noise level, and other parameters (*406*). The range of volumetric airflow rates was 110 cfm–1,152 cfm, and the equivalent ACH range was an average of 8–22 in a standard-sized, substantially well-mixed, single-patient room. Recommendations were provided to make subsequent models safer, more effective, quieter, and easier to use and service. Purchasers should be aware that the majority of manufacturer specifications indicated flow rates of free-wheeling fans and not the fan under the load of a filter.

FIGURE 7. Fixed ducted room-air recirculation system using a high efficiency particulate air (HEPA) filter inside an air duct

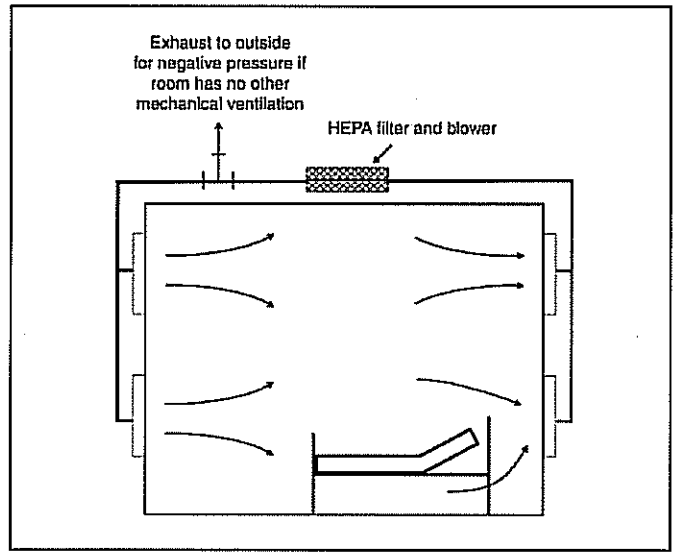
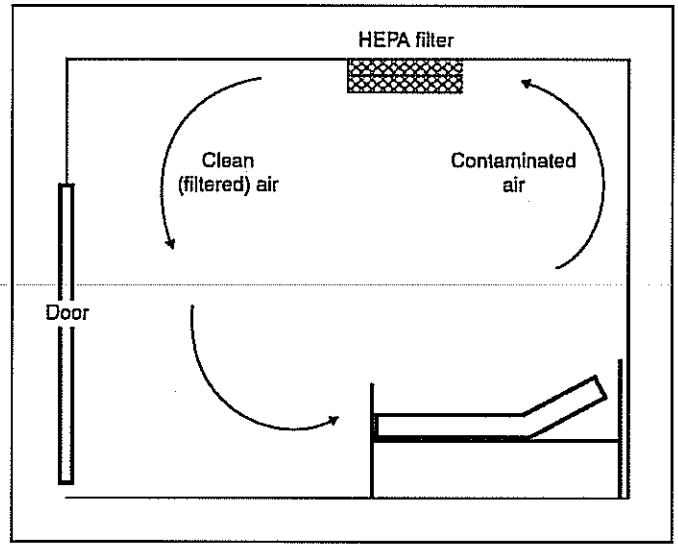


FIGURE 8. Fixed ceiling-mounted room-air recirculation system using a high efficiency particulate air (HEPA) filter



Portable HEPA filtration units should be designed to 1) achieve ≥12 equivalent ACH, 2) ensure adequate air mixing in all areas of the rooms, and 3) be compatible with the ventilation system. An estimate of the ability of the unit to circulate the air in a room can be made by visualizing airflow patterns (estimating room air mixing [see Supplements, Environmental Controls; and General Ventilation]). If the air movement is adequate in all areas of the room, the unit should be effective.

If portable devices are used, units with high volumetric airflow rates that provide maximum flow through the HEPA filter are preferred. Placement should be selected to optimize the recirculation of AII room air through the HEPA filter. Careful consideration must be given to obstacles (e.g., furnishings, medical equipment, and walls) that could disrupt airflow and to system specifications (e.g., physical dimensions, airflow capacity, locations of air inlet and exhaust, and noise) to maximize performance of the units, minimize short-circuiting of air, and reduce the probability that the units will be switched off by room occupants.

Installing, maintaining, and monitoring HEPA filters. The performance of HEPA filters depends on proper installation, testing, and meticulous maintenance (*411*), especially if the system recirculates air to other parts of the health-care setting. Improper design, installation, or maintenance could allow infectious particles to circumvent filtration and escape into the general ventilation system (*117*). These failures also could impede proper ventilation performance.

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 filters for possible leakage and filter loading. A quantitative filter performance test (e.g., the dioctyl phthalate penetration test [*412,413*]) should be performed at the initial installation and each time the filter is changed. Records should be maintained for all filter changes and testing. A leakage test using a particle counter or photometer should be performed every 6–12 months for filters in general-use areas and in areas with systems that will probably be contaminated with *M. tuberculosis* (e.g., AII 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. 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 avoid jarring or dropping 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 and only while the ventilation system or room-air recirculation unit is not being operated.

Laboratory studies indicate that re-aerosolization of viable mycobacteria from filter material (HEPA filters and N95 disposable respirator filter media) is not probable under normal conditions (*414–416*). Although these studies indicate that *M. tuberculosis* becoming an airborne hazard is not probable after it is removed by a HEPA filter (or other high efficiency filter material), the risks associated with handling loaded HEPA filters in ventilation systems under field-use conditions have not been evaluated. Therefore, persons performing maintenance and replacing filters on any ventilation system that is probably contaminated with *M. tuberculosis* should wear a respirator (see Respiratory Protection) in addition to eye protection and gloves. When feasible, HEPA filters can be disinfected in 10% bleach solution or other appropriate mycobacteriacide before removal (*417*). In addition, filter housing and ducts leading to the housing should be labeled clearly with the words "TB-Contaminated Air" or other similar warnings. Disposal of filters and other potentially contaminated materials should be in accordance with applicable local or state regulations.

One or more lower-efficiency disposable pre-filters installed upstream can extend the life of a HEPA filter by at least 25%. If the disposable filter is replaced by a 90% extended surface filter, the life of the HEPA filter can be extended by approximately 900% (*178*). Pre-filters should be handled and disposed of in the same manner as the HEPA filter.

UVGI

Ultraviolet germicidal irradiation (UVGI) is a form of electromagnetic radiation with wavelengths between the blue region of the visible spectrum and the radiograph region. UV-C radiation (short wavelengths; range: 100–280 nm) (*418*) can be produced by various artificial sources (e.g., arc lamps and metal halide lamps). The majority of commercially available UV lamps used for germicidal purposes are low-pressure mercury vapor lamps that emit radiant energy in the UV-C range, predominantly at a wavelength of 253.7 nm (*418*).

Research has demonstrated that UVGI is effective in killing or inactivating *M. tuberculosis* under experimental conditions (*292,385,419–423*) and in reducing transmission of other infectious agents in hospitals (*424*), military housing (*425*), and classrooms (*426–428*). Because of the results of multiple studies (*384,429–432*) and the experiences of clinicians and mycobacteriologists during the preceding decades, UVGI has been recommended as a supplement or adjunct to other TB infection-control and ventilation measures in settings in which the need to kill or inactivate *M. tuberculosis* is essential (*6,7,196,433,434*). UVGI alone does not provide outside air or circulate interior air, both of which are essential in achieving acceptable air quality in occupied spaces.

Applications of UVGI. UVGI is considered a method of air cleaning because it can kill or inactivate microorganisms so that they are no longer able to replicate and form colonies. UVGI is not a substitute for HEPA filtration before exhausting the air from AII rooms back into the general circulation.

UVGI lamps can be placed in ducts, fixed or portable room air-recirculation units, or upper-air irradiation systems. The use of this air-cleaning technique has increased, particularly in substantial open areas in which unsuspected or undiagnosed patients with TB disease might be present (e.g., ED waiting rooms, shelters, and correctional facilities), and the costs of conditioning substantial volumes of outdoor air are prohibitive.

For each UVGI system, guidelines should be followed to maximize effectiveness. Effectiveness can be expressed in terms of an equivalent air change rate (*427,435–437*), comparing the ability of UVGI to inactivate organisms with removal through general ventilation. Initially, understanding and characterizing the application for which UVGI will be used is vital. Because the effectiveness of UVGI systems will vary, the use of UVGI must be carefully evaluated and the level of efficacy clearly defined and monitored.

The effective use of UVGI is associated with exposure of *M. tuberculosis*, as contained in an infectious droplet, to a sufficient dose of UV-C radiation at 253.7 nm to ensure inactivation. Because dose is a function of irradiance and time, the effectiveness of any application is determined by its ability to deliver sufficient irradiance for enough time to result in inactivation of the organism within the infectious droplet. Achieving a sufficient dose can be difficult with airborne inactivation because the exposure time can be substantially limited; therefore, attaining sufficient irradiance is essential.

The number of persons who are properly trained in the design and installation of UVGI systems is limited. One critical recommendation is that health-care facility managers consult a UVGI system designer to address safety and efficacy considerations before such a system is procured and installed. Experts who can be consulted include industrial hygienists, engineers, and health physicists.

Duct irradiation. Duct irradiation is designed to kill or inactivate *M. tuberculosis* without exposing persons to UVGI. In duct irradiation systems, UVGI lamps are placed inside ducts to disinfect the exhaust air from AII rooms or other areas in which *M. tuberculosis* might be present before it is recirculated to the same room (desirable) or to other areas served by the system (less desirable). When UVGI duct systems are not properly designed, installed, and maintained, high levels of UVGI can be produced in the duct that can potentially cause high UVGI exposures during maintenance operations.

Duct-irradiation systems depend on the circulation of as much of the room air as possible through the duct. Velocity profiles and mixing are important factors in determining the UVGI dose received by airborne particles. Design velocity for a typical UVGI unit is approximately 400 fpm (*438*). The particle residence time must be sufficient for inactivation of the microorganisms.

Duct irradiation can be used in three ways.

- Ventilation systems serving AII rooms to recirculate air from the room, through a duct containing UV lamps, and back into the same room. UVGI duct systems should not be used either in place of HEPA filters, if air from AII rooms must be recirculated to other areas of a setting, or as a substitute for HEPA filtration of air from booths, tents, or hoods used for cough-inducing or aerosol-generating procedures.
- Return air ducts serving patient rooms, waiting rooms, EDs, and general-use areas in which patients with undiagnosed TB disease could potentially contaminate the recirculated air.
- Recirculating ventilation systems serving rooms or areas in which ceiling heights are too low for the safe and effective use of upper-air UVGI.

Upper-air irradiation. In upper-air irradiation, UVGI lamp fixtures are suspended from the ceiling and installed on walls. The base of the lamps are shielded to direct the radiation upward and outward to create an intense zone of UVGI in the upper air while minimizing the levels of UVGI in the lower part of the room where the occupants are located. The system depends on air mixing to move the air from the lower part of the room to the upper part where microbial-contaminated air can be irradiated.

A major consideration is the placement of UVGI fixtures to achieve sufficient irradiance of the upper-air space. The ceiling should be high enough (≥8 feet) for a substantial volume of upper air to be irradiated without overexposing occupants in the lower part of the room to UVGI. System designers must consider the mechanical ventilation system, room geometry, and emission characteristics of the entire fixture.

Upper-air UVGI can be used in various settings.

- AII rooms and rooms in which aerosol-generating or aerosol-producing procedures (e.g., bronchoscopy, sputum induction, and administration of aerosolized medications) are performed.
- Patient rooms, waiting rooms, EDs, corridors, central areas, and other substantial areas in which patients with undiagnosed TB disease could potentially contaminate the air.
- Operating rooms and adjacent corridors where procedures are performed on patients with TB disease.
- Medical settings in correctional facilities.

Portable room air recirculation systems. In portable room air-recirculation units containing UVGI, a fan moves a volume of room air across UVGI lamps to disinfect the air before it is recirculated back to the room. Some portable units contain both a HEPA filter (or other high efficiency filter) and UVGI lamps.

In addition to the guidelines described for the use of portable room air-recirculation systems containing HEPA filtration, consideration must be given to the volume of room air that passes through the unit, the UVGI levels, particle residence time, and filtration efficiency (for devices with a filter). One study in which a bioaerosol chamber was used demonstrated that portable room air cleaners with UVGI lamps as the primary air-cleaning mechanism are effective (>99%) in inactivating or killing airborne vegetative bacteria (*439*). Additional studies need to be performed in rooms with portable air cleaners that rely only on UVGI for air cleaning.

Portable room air cleaners with UVGI can be used in 1) AII rooms as an adjunct method of air cleaning and 2) waiting rooms, EDs, corridors, central areas, or other substantial areas in which patients with undiagnosed TB disease could potentially contaminate the air.

Effectiveness of UVGI. Air mixing, air velocity, relative humidity, UVGI intensity, and lamp configuration affect the efficacy of all UVGI applications. For example, with upper-air systems, airborne microorganisms in the lower, occupied areas of the room must move to the upper part of the room to be killed or inactivated by upper-air UVGI. Air mixing can occur through convection caused by temperature differences, fans, location of supply and exhaust ducts, or movement of persons.

Air-mixing. UVGI has been demonstrated to be effective in killing bacteria in the upper-air applications under conditions in which air mixing was accomplished primarily by convection. In a 1976 study on aerosolization of *M. bovis* BCG (a surrogate for *M. tuberculosis*) in a room without mechanical ventilation that relied primarily on convection and infiltration resulted in 10–25 equivalent ACH, depending on the number of UVGI fixtures used (*384*). Other early studies examined the effect of air-mixing on UVGI efficacy (*440,441*). These studies indicated that the efficacy of UVGI was substantially increased if cold supply air relative to the lower portion of the room entered through diffusers in the ceiling. The findings indicated that substantial temperature gradients between the upper and lower portions of the room favored (cold air in the upper portion of the room) or inhibited (hot air in the upper portion of the room) vertical mixing of air between the two zones.

When large-bladed ceiling fans were used to promote mixing in the experimental room, the ability of UVGI to inactivate *Serratia marcescens*, an organism known to be highly sensitive to UVGI, was doubled (*442,443*). Similar effects were reported in studies conducted during 2000–2002 in which louvered UVGI fixtures were used. One study documented an increase in UVGI effectiveness of 16% at 2 ACH and 33% at 6 ACH when a mixing fan was used (*444*). Another study conducted in a simulated health-care room determined that 1) at 0 ACH, a high degree of efficacy of upper-air UVGI was achieved in the absence or presence of mixing fans when no temperature gradient was created; and 2) at 6 ACH, bringing in warm air at the ceiling resulted in a temperature gradient with cooler room air near the floor and a UVGI efficacy of only 9% (*422*). Turning on box fans under these winter conditions increased UVGI efficacy nearly 10-fold (to 89%) (*445*).

To reduce variability in upper-air UVGI efficacy caused by temperature gradients in the room, a fan should be routinely used to continually mix the air, unless the room has been determined to be well mixed under various conditions of operation. Use of a fan would also reduce or remove the variable winter versus summer ACH requirements for optimal upper-air UVGI efficacy (*446*).

Relative humidity. In studies conducted in bioaerosol chambers, the ability of UVGI to kill or inactivate microorganisms declined substantially when the relative humidity exceeded 60% (*447–450*). In room studies, declines in the ability of upper-air UVGI to kill or inactivate microorganisms at high relative humidity (65%, 75%, and 100%) (*384,422*) have also been reported. The exact mechanism responsible for the reduced effectiveness of UVGI at these higher levels of relative humidity is unknown but does not appear to be related to changes in UV irradiance levels. Relative humidity changes from 55%–90% resulted in no corresponding changes in measured UVGI levels (*437*). In another study, an increase in relative humidity from 25%–67% did not reduce UVGI levels (*422*). Bacteria have been demonstrated to absorb substantial amounts of water from the air as the relative humidity increases. At high humidity, the UV irradiance levels required to inactivate bacteria might approach the higher levels that are needed for liquid suspensions of bacteria (*448*). The ability of bacteria to repair UVGI damage to their DNA through photoreactivation has also been reported to increase as relative humidity increases (*422,448*).

For optimal efficacy of upper-air UVGI, relative humidity should be maintained at ≤60%, a level that is consistent with recommendations for providing acceptable indoor air quality and minimizing environmental microbial contamination in indoor environments (*386,451*).

Ventilation rates. The relation between ventilation and UVGI has also been evaluated. Certain predicted inactivation rates have been calculated and published for varying flow rates, UV intensity, and distances from the lamp, based on radiative heat transfer theory (*438*). In room studies with substantially well-mixed air, ventilation rates (0 ACH, 3 ACH, and 6 ACH) were combined with various irradiation levels of upper-air UVGI. All experiments were conducted at 50% relative humidity and 70° F (21.2° C). When *M. parafortuitum* was used as a surrogate for *M. tuberculosis*, ventilation rates usually had no adverse effect on the efficiency of upper-air UVGI. The

combined effect of both environmental controls was primarily additive in this artificial environment, with possibly a small loss of upper-air UVGI efficiency at 6 ACH (*422*). Therefore, ventilation rates of up to 6 ACH in a substantially well-mixed room might achieve ≥12 ACH (mechanical ACH plus equivalent ACH) by combining these rates with the appropriate level of upper-air irradiation (*422*). Higher ventilation rates (>6 ACH) might, however, decrease the time the air is irradiated and, therefore, decrease the killing of bacteria (*429,452*).

Ventilation rates up to six mechanical ACH do not appear to adversely affect the performance of upper-air UVGI in a substantially well-mixed room. Additional studies are needed to examine the combined effects of mechanical ventilation and UVGI at higher room-air exchange rates.

UVGI intensity. UVGI intensity field plays a primary role in the performance of upper-air UVGI systems. The UVGI dose received by microorganisms is a function of UVGI times duration of exposure. Intensity is influenced by the lamp wattage, distance from the lamp, surface area, and presence of reflective surfaces. The number of lamps, location, and UVGI level needed in a room depends on the room's geometry, area, and volume, and the location of supply air diffusers (*422,436*). UVGI fixtures should be spaced to reduce overlap while maintaining an even irradiance zone in the upper air.

The emission profile of a fixture is a vital determinant of UVGI effectiveness. Information regarding total UVGI output for a given fixture (lamp plus housing and louvers) should be requested from the manufacturer and used for comparison when selecting UVGI systems. Information concerning only the UVGI output of the lamp is inadequate; the lamp output will be higher than the output for the fixture because of losses from reflectors and nonreflecting surfaces and the presence of louvers and other obstructions (*436,437*). In addition, information provided by the manufacturer reflects ideal laboratory conditions; damage to fixtures or improper installation will affect UV radiation output. Because old or dust-covered UVGI lamps are less effective, routine maintenance and cleaning of UVGI lamps and fixtures is essential. UVGI system designers should consider room geometry, fixture output, room ventilation, and the desired level of equivalent ACH in determining the types, numbers, and placement of UVGI fixtures in a room to achieve target irradiance levels in the upper air.

Health and safety issues. Short-term overexposure to UV radiation can cause erythema (i.e., abnormal redness of the skin), photokeratitis (inflammation of the cornea), and conjunctivitis (i.e., inflammation of the conjunctiva) (*453*). Symptoms of photokeratitis and conjunctivitis include a feeling of sand in the eyes, tearing, and sensitivity to light. Photokeratitis and conjunctivitis are reversible conditions, but they can be debilitating while they run their course. Because the health effects of UVGI are usually not evident until after exposure has ended (typically 6–12 hours later), HCWs might not recognize them as occupational injuries.

In 1992, UV-C (100–280 nm) radiation was classified by the International Agency for Research on Cancer as "probably carcinogenic to humans (Group 2A)" (*454*). This classification was based on studies indicating that UV-C radiation can induce skin cancers in animals and create DNA damage, chromosomal aberrations, and sister chromatid exchange and transformation in human cells in vitro. In addition, DNA damage in mammalian skin cells in vivo can be caused. In the animal studies, a contribution of UV-C radiation to the tumor effects could not be excluded, but the effects were higher than expected for UV-B radiation alone (*454*). Certain studies have demonstrated that UV radiation can activate HIV gene promoters (i.e., genes in HIV that prompt replication of the virus) in laboratory samples of human cells (*455–460*). The potential for UV-C radiation to cause cancer and promote HIV in humans is unknown, but skin penetration might be an important factor. According to certain reports, only 20% of incident 250 nm UV penetrates the stratum corneum, compared with approximately 30–60% of 300 nm UV (UV-B) radiation (*461*).

In upper-air UVGI systems, fixtures must be designed and installed to ensure that UVGI exposures to occupants are below current safe exposure levels. Health-hazard evaluations have identified potential problems at some settings using UVGI systems. These problems include overexposure of HCWs to UVGI and inadequate maintenance, training, labeling, and use of personal protective equipment (PPE) (*398,462,463*).

An improperly maintained (unshielded) germicidal lamp was believed to be the cause of dermatosis or photokeratitis in five HCWs in an ED (*464*) and three HCWs who were inadvertently exposed to an unshielded UVGI lamp in a room that had been converted from a sputum induction room to an office (*465*). These case reports highlight the importance of posting warning signs to identify the presence of UVGI (see Supplement, Labeling and Posting) and are reminders that shielding should be used to minimize UVGI exposures to occupants in the lower room. In the majority of applications, properly designed, installed, and maintained UVGI fixtures provide protection from the majority of, if not all, the direct UVGI in the lower room. 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 UVGI fixture 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.

Although more studies need to be conducted, lightweight clothing made of tightly woven fabric and UV-absorbing sunscreens with solar-protection factors (SPFs) of ≥15 might help

protect photosensitive persons. Plastic eyewear containing a UV inhibitor that prevents the transmission of ≥95% of UV radiation in the 210–405 nm range is commercially available. HCWs should be advised that any eye or skin irritation that develops after UVGI exposure should be evaluated by an occupational health professional.

Exposure criteria. In 1972, CDC published a recommended exposure limit (REL) for occupational exposure to UV radiation (*453*). REL is intended to protect HCWs from the acute effects of UV light exposure. Photosensitive persons and those exposed concomitantly to photoactive chemicals might not be protected by the recommended standard.

The CDC/NIOSH REL for UV radiation is wavelength dependent because different wavelengths have different adverse effects on the skin and eyes (*453*). At 254 nm, the predominant wavelength for germicidal UV lamps, the CDC/NIOSH REL is 0.006 joules per square centimeter (J/cm^2) for a daily 8-hour work shift. ACGIH has a Threshold Limit Value® for UV radiation that is identical to the REL for this spectral region (*466*). HCWs frequently do not stay in one place in the setting during the course of their work and, therefore, are not exposed to UV irradiance levels for 8 hours. Permissible exposure times (PET) for HCWs with unprotected eyes and skin can be calculated for various irradiance levels as follows:

$$\text{PET (seconds)} = \frac{0.006\ \text{J/cm2 (CDC/NIOSH REL at 254 nm)}}{\text{Measured irradiance level (at 254 nm) in W/cm}^2}$$

Exposures exceeding the CDC/NIOSH REL require the use of PPE to protect the skin and eyes.

Labeling, Maintenance, and Monitoring

Labeling and posting. Health-care settings should post warning signs on UV lamps and wherever high-intensity (i.e., UVGI exposure greater than the REL) UVGI irradiation is present to alert maintenance staff, HCWs, and the general public of the hazard. The warning signs should be written in the languages of the affected persons (Box 6).

Maintenance. Because the UVGI output of the lamps declines with age, a schedule for replacing the lamps should be developed in accordance with manufacturer recommendations. The schedule can be determined from a time-use log, a system based on cumulative time, or routinely (e.g., at least annually). UVGI lamps should be checked monthly for dust build-up, which lessens radiation output. A dirty UVGI lamp should be allowed to cool and then should be cleaned in accordance with the manufacturer recommendations so that no residue remains.

UVGI lamps should be replaced if they stop glowing, if they flicker, or if the measured irradiance (see Supplement, Environmental Controls) drops below the performance criteria or minimum design criterion set forth by the design engineers. Maintenance personnel must switch off all UVGI lamps before entering the upper part of the room or before accessing ducts for any purpose. Only limited seconds of direct exposure to the intense UVGI in the upper-air space or in ducts can cause dermatosis or photokeratitis. Protective clothing and equipment (e.g., gloves, goggles, face shield, and sunscreen) should be worn if exposure greater than the recommended levels is possible or if UVGI radiation levels are unknown.

Banks of UVGI lamps can be installed in ventilation system ducts. Safety devices and lock-out or tag-out protocols should be used on access doors to eliminate exposures of 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 to ensure that they are functioning properly. The access door should have a warning sign written in appropriate languages to alert maintenance personnel to the health hazard of looking directly at bare UV lamps. The lock for this door should have an automatic electric switch or other device that turns off the lamps when the door is opened.

Types of fixtures used in upper-air irradiation include wall-mounted, corner-mounted, and ceiling-mounted fixtures that have louvers or baffles to block downward radiation and ceiling-mounted fixtures that have baffles to block radiation below the horizontal plane of the fixtures. If possible, light switches that can be locked should be used to prevent injury to persons who might unintentionally turn the lamps on during

BOX 6. Examples of ultraviolet germicidal irradiation (UVGI) signs

- Wall sign for upper-air UVGI

CAUTION
ULTRAVIOLET ENERGY
SWITCH OFF LAMPS BEFORE
ENTERING UPPER ROOM

- General warning posted near UVGI lamps

CAUTION
ULTRAVIOLET ENERGY
PROTECT EYES AND SKIN

- Warning posted on the door of air handlers where UVGI is present in ductwork

CAUTION
ULTRAVIOLET ENERGY IN DUCT
DO NOT SWITCH OFF SAFETY BUTTON
OR ACTIVATE LAMPS WITH DOOR OPEN

maintenance procedures. Because lamps must be discarded after use, consideration should be given to selecting germicidal lamps that are manufactured with relatively low amounts (i.e., ≤5 mg) of mercury. UVGI products should be listed with the Underwriters Laboratories (UL) or Electrical Testing Laboratories (ETL) for their specific application and installed in accordance with the National Electric Code.

Monitoring. UVGI intensity should be measured by an industrial hygienist or other person knowledgeable in the use of UV radiometers with a detector designed to be most sensitive at 254 nm. Equipment used to measure UVGI should be maintained and calibrated on a regular schedule, as recommended by the manufacturer.

UVGI should be measured in the lower room to ensure that exposures to occupants are below levels that could result in acute skin and eye effects. The monitoring should consider typical duties and locations of the HCWs and should be done at eye level. At a minimum, UVGI levels should be measured at the time of initial installation and whenever fixtures are moved or other changes are made to the system that could affect UVGI. Changes to the room include those that might result in higher exposures to occupants (e.g., addition of UV-reflecting materials or painting of walls and ceiling). UVGI monitoring information, lamp maintenance, meter calibration, and lamp and fixture change-outs should be recorded.

UVGI measurements should also be made in the upper air to define the area that is being irradiated and determine if target irradiance levels are met (*467*). Measurements can be made using UVGI radiometers or other techniques (e.g., spherical actinometry), which measures the UVGI in an omnidirectional manner to estimate the energy to which microorganisms would be exposed (*468*). Because high levels of UVGI can be measured in the upper air, persons making the measurements should use adequate skin and eye protection. UVGI radiation levels close to the fixture source can have permissible exposure times on the order of seconds or minutes for HCWs with unprotected eyes and skin. Therefore, overexposures can occur with brief UVGI exposures in the upper air (or in ventilation system ducts where banks of unshielded UV lamps are placed) in HCWs who are not adequately protected.

Upper-air UVGI systems and portable room-air recirculation units. A study in 2002 examined the relation between three portable room-air recirculation units with different capture or inactivation mechanisms and an upper-air UVGI system in a simulated health-care room (*409*). The study determined that the equivalent ACH produced by the recirculation units and produced by the upper-air UVGI system were approximately additive. For example, one test using aerosolized *M. parafortuitum* provided an equivalent ACH for UVGI of 17 and an equivalent ACH for the recirculation unit of 11; the total experimentally measured equivalent ACH for the two systems was 27. Therefore, the use of portable room-air recirculation units in conjunction with upper-air UVGI systems might increase the overall removal of *M. tuberculosis* droplet nuclei from room air.

Environmental Controls: Program Concerns

To be most effective, environmental controls must be installed, operated, and maintained correctly. Ongoing maintenance is a critical part of infection control that should be addressed in the written TB infection-control plan. The plan should outline the responsibility and authority for maintenance and address staff training needs. At one hospital, improperly functioning ventilation controls were believed to be an important factor in the transmission of MDR TB disease to three patients and a correctional officer, three of whom died (*469*). In three other multihospital studies evaluating the performance of AII rooms, failure to routinely monitor air-pressure differentials or a failure of the continuous monitoring devices installed in the AII rooms resulted in a substantial percentage of the rooms being under positive pressure (*57,392,470,471*).

Routine preventive maintenance should be scheduled and should include all components of the ventilation systems (e.g., fans, filters, ducts, supply diffusers, and exhaust grilles) and any air-cleaning devices in use. Performance monitoring should be conducted to verify that environmental controls are operating as designed. Performance monitoring can include 1) directional airflow assessments using smoke tubes and use of pressure monitoring devices that are sensitive to pressures as low as approximately 0.005 inch of water gauge and 2) measurement of supply and exhaust airflows to compare with recommended air change rates for the respective areas of the setting. Records should be kept to document all preventive maintenance and repairs.

Standard procedures should be established to ensure that maintenance staff notifies infection-control personnel before performing maintenance on ventilation systems servicing patient-care areas. Similarly, infection-control staff should request assistance from maintenance personnel in checking the operational status of AII rooms and local exhaust devices (e.g., booths, hoods, and tents) before use. A protocol that is well-written and followed will help to prevent unnecessary exposures of HCWs and patients to infectious aerosols. Proper labeling of ventilation system components (e.g., ducts, fans, and filters) will help identify air-flow paths. Clearly labeling which fan services a given area will help to prevent accidental shutdowns (*472*).

In addition, provisions should be made for emergency power to avoid interruptions in the performance of essential environmental controls during a power failure.

Respiratory Protection

Considerations for Selection of Respirators

The overall effectiveness of respiratory protection is affected by 1) the level of respiratory protection selected (e.g., the assigned protection factor), 2) the fit characteristics of the respirator model, 3) the care in donning the respirator, and 4) the adequacy of the fit-testing program. Although data on the effectiveness of respiratory protection from various hazardous airborne materials have been collected, the precise level of effectiveness in protecting HCWs from *M. tuberculosis* transmission in health-care settings has not been determined.

Information on the transmission parameters of *M. tuberculosis* is also incomplete. Neither the smallest infectious dose of *M. tuberculosis* nor the highest level of exposure to *M. tuberculosis* at which transmission will not occur has been defined conclusively (*159,473,474*). In addition, the size distribution of droplet nuclei and the number of particles containing viable *M. tuberculosis* organisms that are expelled by patients with infectious TB disease have not been adequately defined, and accurate methods of measuring the concentration of infectious droplet nuclei in a room have not been developed. Nonetheless, in certain settings (e.g., AII rooms and ambulances during the transport of persons with suspected or confirmed infectious TB disease), administrative and environmental controls alone might not adequately protect HCWs from infectious airborne droplet nuclei.

On October 17, 1997, OSHA published a proposed standard for occupational exposure to *M. tuberculosis* (*267*). On December 31, 2003, OSHA announced the termination of rulemaking for a TB standard (*268*). Previous OSHA policy permitted the use of any Part 84 particulate filter respirator for protection against infection with *M. tuberculosis* (*269*). Respirator usage for TB had been regulated by OSHA under CFR Title 29, Part 1910.139 (29 CFR 1910.139) (*270*) and compliance policy directive (CPL) 2.106 (Enforcement Procedures and Scheduling for Occupational Exposure to Tuberculosis). Respirator usage for TB is now regulated under the general industry standard for respiratory protection (29 CFR 1910.134) (*271*). General information on respiratory protection for aerosols, including *M. tuberculosis*, has been published (*272–274*).

Performance Criteria for Respirators

Performance criteria for respirators are derived from data on 1) effectiveness of respiratory protection against noninfectious hazardous materials in workplaces other than health-care settings and an interpretation of how these data can be applied to respiratory protection against *M. tuberculosis*, 2) efficiency of respirator filters in filtering biologic aerosols, 3) face-seal leakage, and 4) characteristics of respirators used in conjunction with administrative and environmental controls in outbreak settings to stop transmission of *M. tuberculosis* to HCWs and patients.

Particulate filter respirators certified by CDC/NIOSH, either nonpowered respirators with N95, N99, N100, R95, R99, R100, P95, P99, and P100 filters (including disposable respirators), or PAPRs with high efficiency filters can be used for protection against airborne *M. tuberculosis*.

The most essential attribute of a respirator is the ability to fit the different facial sizes and characteristics of HCWs. Studies have demonstrated that fitting characteristics vary substantially among respirator models. The fit of filtering facepiece respirators varies because of different facial types and respirator characteristics (*10,280–289*). Selection of respirators can be done through consultation with respirator fit-testing experts, CDC, occupational health and infection-control professional organizations, peer-reviewed research, respirator manufacturers, and from advanced respirator training courses. Data have determined that fit characteristics cannot be determined solely by physical appearance of the respirator (*282*).

Types of Respiratory Protection for TB

Respirators encompass a range of devices that vary in complexity from flexible masks covering only the nose and mouth, to units that cover the user's head (e.g., loose-fitting or hooded PAPRs), and to those that have independent air supplies (e.g., airline respirators). Respirators must be selected from those approved by CDC/NIOSH under the provisions of 42 CFR, Part 84 (*475*).

Nonpowered air-purifying respirators. Nine classes of nonpowered, air-purifying, particulate-filter respirators are certified under 42 CFR 84. These include N-, R-, and P-series respirators of 95%, 99%, and 100% (99.7%) filtration efficiency when challenged with 0.3 μm particles (filters are generally least efficient at this size) (Table 4). The N, R, and P classifications are based on the capacity of the filter to withstand exposure to oil. All of these respirators meet or exceed CDC's filtration efficiency performance criteria during the service life of the filter (*1,272,273*).

Nonpowered air-purifying respirators work by drawing ambient air through the filter during inhalation. Inhalation causes negative pressure to develop in the tight-fitting facepiece and allows air to enter while the particles are captured on the filter. Air leaves the facepiece during exhalation because positive pressure develops in the facepiece and forces air out of the

mask through the filter (disposable) or through an exhalation valve (replaceable and certain ones are disposable).

The classes of certified nonpowered air-purifying respirators include both filtering facepiece (disposable) respirators and elastomeric (rubber-like) respirators with filter cartridges. The certification test for filtering facepieces and filter cartridges consists only of a filter performance test. It does not address respirator fit. Although all N-, R-, and P-series respirators are recommended for protection against *M. tuberculosis* infection in health-care settings and other workplaces that are usually free of oil aerosols that could degrade filter efficiency, well-fitting N-series respirators are usually less expensive than R- and P-series respirators (*272,273*). All respirators should be replaced as needed, based on hygiene considerations, increased breathing resistance, time-use limitations specified in the CDC/NIOSH approval guidelines, respirator damage, and in accordance with manufacturer user's instructions.

PAPRs. PAPRs use a blower that draws air through the filters into the facepiece. PAPRs can be equipped with a tight-fitting or loose-fitting facepiece, a helmet, or a hood. PAPR filters are classified as high efficiency and are different from those presented in this report (Table 4). A PAPR high efficiency filter meets the N100, R100, and P100 criteria at the beginning of their service life. No loading tests using 0.3 μm particles are conducted as part of certification. PAPRs can be useful for persons with facial hair or other conditions that prevent an adequate face to facepiece seal (*476*).

Atmosphere-supplying respirators. Positive-pressure airline (supplied-air) respirators are provided with air from a stationary source (compressor) or an air tank.

Effectiveness of Respiratory-Protection Devices

Data on the effectiveness of respiratory protection against hazardous airborne materials are based on experience in the industrial setting; data on protection against transmission of *M. tuberculosis* in health-care settings are not available. The parameters used to determine the effectiveness of a respiratory protective device are face-seal efficacy and filter efficiency.

Face-seal leakage. Face-seal leakage is the weak link that limits a respirator's protective ability. Excessive face-seal leakage compromises the ability of particulate respirators to protect HCWs from airborne materials (*477*). A proper seal between the respirator's sealing surface and the face of the person wearing the respirator is essential for the effective and reliable performance of any tight-fitting, negative-pressure respirator.

For tight-fitting, negative-pressure respirators (e.g., N95 disposable respirators), the amount of face-seal leakage is determined by 1) the fit characteristics of the respirator, 2) the care in donning the respirator, and 3) the adequacy of the fit-testing program. Studies indicate that a well-fitting respirator and a fit test produces better results than a well-fitting respirator without a fit test or a poor-fitting respirator with a fit test. Increased face-seal leakage can result from additional factors, including incorrect facepiece size, failure to follow the manufacturer's instructions at each use, beard growth, perspiration or facial oils that can cause facepiece slippage, improper maintenance, physiological changes of the HCW, and respirator damage.

Face-seal leakage is inherent in tight-fitting negative-pressure respirators. Each time a person wearing a nonpowered particulate respirator inhales, negative pressure (relative to the workplace air) is created inside the facepiece. Because of this negative pressure, air containing contaminants can leak into the respirator through openings at the face-seal interface and avoid the higher-resistance filter material. A half-facepiece respirator, including an N95 disposable respirator, should have <10% leakage. Full facepiece, nonpowered respirators have the same leakage (<2%) as PAPRs with tight-fitting full-facepieces.

The more complex PAPRs and positive-pressure airline respirators reduce or eliminate this negative facepiece pressure and, therefore, reduce leakage into the respirator and enhance protection. A PAPR is equipped with a blower that forcibly draws ambient air through high efficiency filters and then delivers the filtered air to the facepiece. This air is blown into the facepiece at flow rates that generally exceed the expected inhalation flow rates. The pressure inside the facepiece reduces face-seal leakage to low levels, particularly during the relatively low inhalation rates expected in health-care settings. PAPRs with a tight-fitting facepiece have <2% face-seal leakage under routine conditions (*278*). PAPRs with loose-fitting facepieces, hoods, or helmets have <4% inward leakage under routine conditions (*278*). Therefore, a PAPR might offer lower levels of face-seal leakage than nonpowered, half-mask respirators.

Filter penetration. Aerosol penetration through respirator filters depends on at least five independent variables: 1) filtration characteristics for each type of filter, 2) size distribution of the droplets in the aerosol, 3) linear velocity through the filtering material, 4) filter loading (i.e., amount of contaminant

TABLE 4. Nonpowered air-purifying respirator filter classes certified in 42 CFR* 84

Resistance to efficiency filter degradation	Filter efficiencies†		
	95 (95%)	99 (99%)	100 (99.97%)
N (Not resistant to oil)	N95	N99	N100
R (Resistant to oil)	R95	R99	R100
P (Oil proof)	P95	P99	P100

* Code of Federal Regulations.
† The percentages in parenthesis indicate the minimum allowable laboratory filter efficiency value when challenged with 0.3 μm particles.

deposited on the filter), and 5) electrostatic charges on the filter and on the droplets in the aerosol (*284*).

When N95 disposable respirators are used, filter penetration might approach 5% (50% of the allowable leakage of 10% for an N95 disposable respirator). When high efficiency filters are used in PAPRs or for half-facepiece respirators, filter efficiency is high (effectively 100%), and filter penetration is less of a consideration. Therefore, for high efficiency or 100-series filter respirators, the majority of inward leakage of droplet nuclei occurs at the respirator's faceseal or exhalation valve.

Implementing a Respiratory-Protection Program

If respirators are used in a health-care setting, OSHA requires the development, implementation, administration, and periodic reevaluation of a respiratory-protection program (*271,277,278*). The most critical elements of a respiratory-protection program include 1) assigning of responsibility, 2) training, and 3) fit testing (*1*). All HCWs who use respirators for protection against infection with *M. tuberculosis* should be included in the respiratory-protection program.

Visitors to AII rooms and other areas with patients who have suspected or confirmed infectious TB disease may be offered respirators (e.g., N95 disposable respirators) and should be instructed by an HCW on the use of the respirator before entering an AII room (see Respiratory Protection section for User-Seal Check FAQs). The health-care setting should develop a policy on use of respirators by visitors.

The number of HCWs included in the respiratory- protection program will vary depending on the 1) number of persons who have suspected or confirmed TB disease examined in a setting, 2) number of rooms or areas in which patients with suspected or confirmed infectious TB disease stay or are encountered, and 3) number of HCWs needed to staff these rooms or areas. In settings in which respiratory-protection programs are required, enough HCWs should be included to provide adequate care for patients with suspected or confirmed TB disease. However, administrative measures should be used to limit the number of HCWs exposed to *M. tuberculosis* (see Prompt Triage).

Information on the development and management of a respiratory-protection program is available in technical training courses that cover the basics of respiratory protection. Such courses are offered by OSHA, the American Industrial Hygiene Association, universities, manufacturers, and private contractors. To be effective and reliable, respiratory-protection programs must include at least the following elements (*274,277,278*).

Assignment of Responsibility

One person (the program administrator) must be in charge of the respiratory-protection program and be given the authority and responsibility to manage all aspects of the program. The administrator must have sufficient knowledge (obtained by training or experience) to develop and implement a respiratory-protection program. Preferably, the administrator should have a background in industrial hygiene, safety, health care, or engineering. The administrator should report to the highest official possible (e.g., manager of the safety department, supervisor of nurses, HCWs' health manager, or infection-control manager) and should be allocated sufficient time to administer the respiratory-protection program in addition to other assigned duties.

Standard Operating Procedures

The effectiveness of a respiratory-protection program requires the development of written standard procedures. These procedures should include information and guidance for the proper selection, use, and care of respirators (*274*).

Screening

HCWs should not be assigned a task requiring use of respirators unless they are physically able to perform job duties while wearing the respirator. HCWs who might need to use a respirator should be screened by a physician or other licensed health-care professional for pertinent medical conditions at the time they are hired and then re-screened periodically (*274*). The screening process should begin with a screening questionnaire for pertinent medical conditions, the results of which should be used to identify HCWs who need further evaluation (Appendix G). Unless prescribed by the screening physician, serial physical examination or testing with chest radiographs or spirometry is neither necessary nor required (*287*).

Training

HCWs should be provided annual training on multiple topics.

- Nature, extent, and hazards of TB disease in the health-care setting. This training can be conducted in conjunction with other related training on infectious disease associated with airborne transmission (e.g., severe acute respiratory syndrome [SARS]-coronavirus [CoV] and measles) and with serial TB screening.
- The risk assessment process and its relation to the respirator program.
- Signs and symbols used to demonstrate that respirators are required in an area.
- Reasons for using respirators.
- Environmental controls used to prevent the spread and reduce the concentration of infectious droplet nuclei.

- Reasons for selecting a particular respirator for a given hazard (see Selection of Respirators; and Respirator Options: Special Circumstances).
- Operation, capabilities, and limitations of respirators.
- Respirator care.
- Cautions regarding facial hair and respirator use.
- Applicable federal, state, and local regulations regarding respirators, including assessment of employees' knowledge.

Trainees should be provided resources as an adjunct to the respiratory-protection program.

- Opportunities to handle and wear a respirator until they are proficient (see Supplement, Fit Testing).
- Educational material for use as references.
- Instructions to refer all respirator problems immediately to the respirator program administrator.

Selection

Filtering facepiece respirators used for protection against *M. tuberculosis* must be selected from those approved by CDC/NIOSH under the provisions of 42 CFR 84 (http://www.cdc.gov/niosh/celintro.html). A listing of CDC/NIOSH-approved disposable particulate respirators (filtering facepieces) is available at http://www.cdc.gov/niosh/npptl/topics/respirators/disp_part. If a health-care setting uses respirators for protection against other regulated hazards (e.g., formaldehyde and ethylene oxide), then these potential exposures should be specifically addressed in the program. Combination product surgical mask/N95 disposable respirators (respirator portion certified by CDC/NIOSH and surgical mask portion listed by FDA) are available that provide both respiratory protection and bloodborne pathogen protection. Selection of respirators can be chosen through consultation with respirator fit-testing experts, CDC, occupational health and infection-control professional organizations, peer-reviewed research, respirator manufacturers, and advanced respirator training courses (*10,280–289*).

Fit Testing

A fit test is used to determine which respirator fits the user adequately and to ensure that the user knows when the respirator fits properly. After a risk assessment is conducted to validate the need for respiratory protection, perform fit testing during the initial respiratory-protection program training and periodically thereafter, in accordance with federal, state, and local regulations.

Fit testing provides a method to determine which respirator model and size fits the wearer best and to confirm that the wearer can properly fit the respirator. Periodic fit testing for respirators used in environments where a risk for *M. tuberculosis* transmission exists can serve as an effective training tool in conjunction with the content included in employee training and retraining. The frequency of periodic fit testing should be determined by the occurrence of 1) a risk for transmission of *M. tuberculosis*, 2) a change in facial features of the wearer, 3) a medical condition that would affect respiratory function, 4) physical characteristics of respirator (despite the same model number), or 5) a change in the model or size of the assigned respirator (*281*).

Inspection and Maintenance

Respirator maintenance should be an integral part of an overall respirator program. Maintenance applies both to respirators with replaceable filters and to respirators that are classified as disposable but are reused. Manufacturer instructions for inspecting, cleaning, maintaining, and using (or reuse) respirators should be followed to ensure that the respirator continues to function properly (*278*).

When respirators are used for protection against noninfectious aerosols (e.g., wood dust) that might be present in the air in heavy concentrations, the filter can become obstructed with airborne material. This obstruction in the filter material can result in increased resistance, causing breathing to be uncomfortable. In health-care settings in which respirators are used for protection against biologic aerosols, the concentration of infectious particles in the air is probably low. Thus, the filter in a respirator is unlikely to become obstructed with airborne material. In addition, no evidence exists to indicate that particles that affect the filter material in a respirator are reaerosolized easily. Therefore, the filter material used in respirators in health-care settings might remain functional for weeks. Because electrostatic filter media can degrade, the manufacturer should be contacted for the product's established service life to confirm filter performance.

Respirators with replaceable filters are reusable, and a respirator classified as disposable can be reused by the same HCW as long as it remains functional and is used in accordance with local infection-control procedures. Respirators with replaceable filters and filtering facepiece respirators can be reused by HCWs as long as they have been inspected before each use and are within the specified service life of the manufacturer. If the filter material is physically damaged or soiled or if the manufacturer's service life criterion has been exceeded, the filter (in respirators with replaceable filters) should be changed or the disposable respirator should be discarded according to local regulations. Infection-control personnel should develop standard procedures for storing, reusing, and disposing of respirators that have been designated for disposal.

Evaluation

The respirator program must be evaluated periodically to ensure its continued effectiveness.

Cleaning, Disinfecting, and Sterilizing Patient-Care Equipment and Rooms

General

Medical instruments and equipment, including medical waste, used on patients who have TB disease are usually not involved in the transmission of *M. tuberculosis* (*478–480*). However, transmission of *M. tuberculosis* and pseudo-outbreaks (e.g., contamination of clinical specimens) have been linked to inadequately disinfected bronchoscopes contaminated with *M. tuberculosis* (*80,81,160,163,164,166*). Guidelines for cleaning, disinfecting, and sterilizing flexible endoscopic instruments have been published (*481–485*).

The rationale for cleaning, disinfecting, or sterilizing patient-care instruments and equipment can be understood more readily if medical devices, equipment, and surgical materials are divided into three general categories (*486*). The categories are critical, semicritical, and noncritical and are based on the potential risk for infection if an item remains contaminated at the time of use.

Critical Medical Instruments

Instruments that are introduced directly into the bloodstream or other normally sterile areas of the body (e.g., needles, surgical instruments, cardiac catheters, and implants) are critical medical instruments. These items should be sterile at the time of use.

Semicritical Medical Instruments

Instruments that might come into contact with mucous membranes but do not ordinarily penetrate body surfaces (e.g., noninvasive flexible and rigid fiberoptic endoscopes or bronchoscopes, endotracheal tubes, and anesthesia breathing circuits) are semicritical medical instruments. Although sterilization is preferred for these instruments, high-level disinfection that destroys vegetative microorganisms, the majority of fungal spores, mycobacteria (including tubercle bacilli), and small nonlipid viruses can be used. Meticulous cleaning of such items before sterilization or high-level disinfection is essential (*481*). When an automated washer is used to clean endoscopes and bronchoscopes, the washer must be compatible with the instruments to be cleaned (*481,487*). High-level disinfection can be accomplished with either manual procedures alone or use of an automated endoscope reprocessor with manual cleaning (*80,481*). In all cases, manual cleaning is an essential first-step in the process to remove debris from the instrument.

Noncritical Medical Instruments or Devices

Instruments or devices that either do not ordinarily touch the patient or touch only the patient's intact skin (e.g., crutches, bed boards, and blood pressure cuffs) are noncritical medical instruments. These items are not associated with transmission of *M. tuberculosis*. When noncritical instruments or equipment are contaminated with blood or body substances, they should be cleaned and then disinfected with a hospital-grade, Environmental Protection Agency (EPA)-registered germicide disinfectant with a label claim for tuberculocidal activity (i.e., an intermediate-level disinfectant). Tuberculocidal activity is not necessary for cleaning agents or low-level disinfectants that are used to clean or disinfect minimally soiled noncritical items and environmental surfaces (e.g., floors, walls, tabletops, and surfaces with minimal hand contact).

Disinfection

The rationale for use of a disinfectant with tuberculocidal activity is to ensure that other potential pathogens with less intrinsic resistance than that of mycobacteria are killed. A common misconception in the use of surface disinfectants in health care relates to the underlying purpose of products labeled as tuberculocidal germicides. Such products will not interrupt and prevent transmission of *M. tuberculosis* in health-care settings, because TB is not acquired from environmental surfaces. The tuberculocidal claim is used as a benchmark by which to measure germicidal potency. Because mycobacteria have the highest intrinsic level of resistance among the vegetative bacteria, viruses, and fungi, any germicide with a tuberculocidal claim on the label (i.e., an intermediate-level disinfectant) is considered capable of inactivating many pathogens, including much less resistant organisms such as the bloodborne pathogens (e.g., hepatitis B virus, hepatitis C virus, and HIV). Rather than the product's specific potency against mycobacteria, a germicide that can inactivate many pathogens is the basis for protocols and regulations indicating the appropriateness of tuberculocidal chemicals for surface disinfection.

Policies of health-care settings should specify whether cleaning, disinfecting, or sterilizing an item is necessary to decrease the risk for infection. Decisions regarding decontamination processes should be based on the intended use of the item, not on the diagnosis of the condition of the patient for whom the item is used. Selection of chemical disinfectants depends on the intended use, the level of disinfection required, and the structure and material of the item to be disinfected.

The same cleaning procedures used in other rooms in the health-care setting should be used to clean AII rooms. However, personnel should follow airborne precautions while cleaning these rooms when they are still in use. Personal protective equipment is not necessary during the final cleaning of an AII room after a patient has been discharged if the room has been ventilated for the appropriate amount of time (Table 1).

Frequently Asked Questions (FAQs)

The following are FAQs regarding TST, QFT-G, BAMT, treatment for LTBI, risk assessment, environmental controls, respiratory protection, and cough-inducing and aerosol-generating procedures.

TST and QFT-G

- **Does having more than one TST placed in 1 year pose any risk?** No risk exists for having TSTs placed multiple times per year.
- **Can repeated TSTs, by themselves, cause the TST result to convert from negative to positive?** No, the TST itself does not cause false-positive results. Exposure to other mycobacteria or BCG vaccination can cause false-positive TST results.
- **What defines a negative TST result?** A TST result of 0 mm or a measurement below the defined cut point for each criteria category is considered a negative TST result (Box 3).
- **What defines a positive TST result?** A TST result of any millimeter reading above or at the defined cut point for each criteria category is considered a positive TST result (Box 3). The cut point (5 mm, 10 mm, and 15 mm) varies according to the purpose of the test (e.g., infection-control surveillance or medical and diagnostic evaluation, or contact investigation versus baseline testing).
- **What defines a false-negative result?** A false-negative TST or QFT-G result is one that is interpreted as negative for a particular purpose (i.e., infection-control surveillance versus medical and diagnostic evaluation) in a person who is actually infected with *M. tuberculosis*. False-negative TST results might be caused by incorrect TST placement (too deeply or too shallow), incorrect reading of the TST result, use of an incorrect antigen, or if the person being tested is anergic (i.e., unable to respond to the TST because of an immunocompromising condition) or sick with TB disease.
- **What defines a false-positive result?** A false-positive TST or QFT-G result is one that is interpreted as positive for a particular purpose (i.e., infection-control surveillance versus medical and diagnostic evaluation) in a person who is actually not infected with *M. tuberculosis*. False-positive TST results are more likely to occur in persons who have been vaccinated with BCG or who are infected with NTM, also known as mycobacteria other than TB (MOTT). A false-positive TST result might also be caused by incorrect reading of the TST result (reading erythema rather than induration) or use of incorrect antigen (e.g., tetanus toxoid).
- **Is placing a TST on a nursing mother safe?** Yes, placing a TST on a nursing mother is safe.
- **A pregnant HCW in a setting is reluctant to get a TST. Should she be encouraged to have the test administered?** Yes, placing a TST on a pregnant woman is safe. The HCW should be encouraged to have a TST or offered BAMT. The HCW should receive education that 1) pregnancy is not a contraindication to having a TST administered and 2) skin testing does not affect the fetus or the mother. Tens of thousands of pregnant women have received TST since the test was developed, and no documented episodes of TST-related fetal harm have been reported. Guidelines issued by ACOG emphasize that postponement of the application of a TST as indicated and postponement of the diagnosis of infection with *M. tuberculosis* during pregnancy is unacceptable.
- **A pregnant HCW in a setting has a positive TST result and is reluctant to get a chest radiograph. Should she be encouraged to have the chest radiograph performed?** Pregnant women with positive TST results or who are suspected of having TB disease should not be exempted from recommended medical evaluations and radiography. Shielding consistent with safety guidelines should be used even during the first trimester of pregnancy.
- **Are periodic chest radiographs recommended for HCWs (or staff or residents of LTCFs) who have positive TST or BAMT results?** No, persons with positive TST or BAMT results should receive one baseline chest radiograph to exclude a diagnosis of TB disease. Further chest radiographs are not needed unless the patient has symptoms or signs of TB disease or unless ordered by a physician for a specific diagnostic examination. Instead of participating in serial skin testing, HCWs with positive TST results should receive a medical evaluation and a symptom screen. The frequency of this medical evaluation should be determined by the risk assessment for the setting. HCWs who have a previously positive TST result and who change jobs should carry documentation of the TST result and the results of the baseline chest radiograph (and documentation of treatment history for LTBI or TB disease, if applicable) to their new employers.
- **What is boosting?** Boosting is a phenomenon in which a person has a negative TST (i.e., false-negative) result years after infection with *M. tuberculosis* and then a positive subsequent TST result. The positive TST result is caused by a boosted immune response of previous sensitivity rather than by a new infection (false-positive TST conversion). Two-step testing reduces the likelihood of mistaking a boosted reaction for a new infection.
- **What procedure should be followed for a newly hired HCW who had a documented negative TST result 3 months ago at their previous job?** This person should

receive one baseline TST upon hire (ideally before the HCW begins assigned duties). The negative TST result from the 3 months preceding new employment (or a documented negative TST result anytime within the previous 12 months) should be considered the first step of the baseline two-step TST. If the HCW does not have documentation of any TST result, the HCW should be tested with baseline two-step TST (one TST upon hire and one TST placed 1–3 weeks after the first TST result was read).

- **Why are two-step TSTs important for the baseline (the beginning of an HCW's employment)?** If TST is used for TB screening (rather than BAMT), performing two-step TST at baseline minimizes the possibility that boosting will lead to suspicion of transmission of *M. tuberculosis* in the setting during a later contact investigation or during serial testing (false-positive TST conversions). HCWs who do not have documentation of a positive TST result or who have not been previously treated for LTBI or TB disease should receive baseline two-step TST.
- **If a person does not return for a TST reading within 48–72 hours, when can a TST be placed on them again?** A TST can be administered again as soon as possible. If the second step of a two-step TST is not read within 48–72 hours, administer a third test as soon as possible (even if several months have elapsed), and ensure that the result is read within 48–72 hours.
- **Should a TST reading of ≥10 mm be accepted 7 days after the TST was placed?** If the TST was not read between 48–72 hours, another TST should be placed as soon as possible and read within 48–72 hours. However, certain studies indicate that positive TST reactions might still be measurable 4–7 days after the TST was placed. If the TST reaction is read as ≥15 mm 7 days after placement, the millimeter result can be recorded and considered to be a positive result.
- **Do health-care settings or areas in the United States exist for which baseline two-step TST for newly hired HCWs is not needed?** Ideally, all newly hired HCWs who might share air space with patients should receive baseline two-step TST (or one-step BAMT) before starting duties. In certain settings, a choice might be offered not to perform baseline TST on HCWs who will never be in contact with or share air space with patients who have TB disease, or who will never be in contact with clinical specimens (e.g., telephone operators in a separate building from patients).
- **In our setting, workers are hired to provide health care in homes, and they are not medically trained. Two-step skin testing is difficult because of the requirement to return for testing and reading multiple times. Can the two-step TST be omitted?** No, ideally, all HCWs who do not have a previously documented positive TST result or treated LTBI or TB disease should receive two-step baseline skin testing in settings that have elected to use TST for screening. BAMT is a single test procedure. Baseline testing for *M. tuberculosis* infection will ensure that TB disease or LTBI is detected before employment begins and treatment for LTBI or TB disease is offered, if indicated.
- **When performing two-step skin testing, what should be done if the second-step TST is not placed in 1–3 weeks?** Perform the second-step TST as soon as possible, even if several months have passed.
- **Should gloves be worn when placing TST?** Specific CDC recommendations do not exist regarding this topic. If your local area indicates that universal precautions should be practiced with skin testing, the local areas should determine what precautions should be followed in their setting.
- **Is TST QC important?** Yes, performing QC for HCWs during training and retraining of placing and reading TST is important to avoid false-negative and false-positive TST results, and to ensure appropriate treatment decisions.
- **If the longitudinal reading of the induration of the TST result is 12 mm and the horizontal reading is 8 mm, what should be recorded?** The correct TST reading should be recorded as 8 mm (not 12 mm or 8 x 12 mm). For purposes of standardization, only record the millimeters of induration, which should be measured transversely (i.e., perpendicular), to the long axis of the forearm. Erythema (redness) around the TST site should not be read as part of the TST result. Consideration should be given to retesting if the selected area for placement was on or near a muscle margin, scar, heavy hair, veins, or tattoos, which could be barriers to reading the TST result, or consider offering a BAMT. BAMT results should be recorded in detail. The details should include date of blood draw, result in specific units, and the laboratory interpretation (positive, negative, or indeterminate—and the concentration of cytokine measured, e.g., IFN-γ).
- **Should HCWs who report upon hire that they have had a positive TST result or have been previously treated for LTBI or TB disease receive baseline two-step TST when beginning work at a new health-care setting?** Unless the HCW has documentation of a positive TST result or previously treated LTBI or TB disease, they should usually receive baseline two-step testing before starting duties. If documentation is available of a positive TST result, that

result can be considered as the baseline TST result for the HCW at the new setting, and additional testing is not needed. Recommendations for testing HCWs who transfer from one setting to another where the risk assessment might be different are presented (see Use of Risk Classification to Determine Need for TB Screening and Frequency of Screening HCWs).

- **If an HCW has a baseline first-step TST result between 0–9 mm, does a second-step TST need to be placed?** Yes, if the baseline first-step TST result is <10 mm, a second-step TST should be applied 1–3 weeks after the first TST result was read. HCWs who are immunocompromised are still subject to the 10 mm cutoff for baseline two-step testing for surveillance purposes but would be referred for medical evaluation for LTBI using the 5 mm cutoff.
- **An HCW in a medium-risk setting who had a two-step baseline TST result of 8 mm is retested 1 year later for serial TB screening and had a TST result of 16 mm. No known exposure to *M. tuberculosis* had occurred. Although the TST is now >10 mm, a ≥10 mm increase did not occur in the TST result to meet the criteria for a TST conversion. How should this reading be interpreted?** The TST result needs to be interpreted from two perspectives: 1) administrative and 2) individual medical interpretation. Because an increase by ≥10 mm did not occur, the result would not be classified as a TST conversion for administrative purposes. However, this HCW should be referred for a medical evaluation. The following criteria are used to determine whether a TST result is positive or negative, considering individual clinical grounds: 1) absolute measured induration (i.e., ≥5, ≥10, or ≥15 mm induration, depending on the level of risk and purpose of testing); 2) the change in the size of the TST result; 3) time frame of the change; 4) risk for exposure, if any; and 5) occurrence of other documented TST conversions in the setting. For HCWs at low risk for LTBI, TST results of 10–14 mm can be considered negative from a clinical standpoint, and these HCWs should not have repeat TST, because an additional increase in induration of ≥10 mm will not be useful in determining the likelihood of LTBI.
- **Are baseline two-step TSTs needed for HCWs who begin jobs that involve limited contact with patients (e.g., medical records staff)?** Yes, all HCWs who might share air space with patients should receive baseline two-step TST (or one-time BAMT) before starting duties. However, in certain settings, a choice might be offered not to perform baseline TST on HCWs who will never be in contact with or share air space with patients who have TB disease, or who will never be in contact with clinical specimens (e.g., telephone operators in a separate building from patients).
- **A setting conducts skin testing annually on the anniversary of each HCW's employment. Last year, multiple TST conversions occurred in April; therefore, all HCWs received a TST during that month. In the future, do all HCWs need to be tested annually in April?** No, after a contact investigation is performed, the best and preferred schedule for annual TB screening is on the anniversary of the HCW's employment date or on their birthday (rather than testing all HCWs at the same time each year), because it increases the opportunity for early recognition of infection-control problems that can lead to TST conversions.
- **An HCW who has been vaccinated with BCG is being hired. She states that BCG will make her TST result positive and that she should not have a TST. Should this HCW be exempted from baseline two-step TST?** Unless she has documentation of a positive TST result or previously treated LTBI or TB disease, she should receive baseline two-step TST or one BAMT. Some persons who received BCG never have a positive TST result. For others, the positive reaction wanes after 5 years. U.S. guidelines state that a positive TST result in a person who received BCG should be interpreted as indicating LTBI.
- **Does BCG affect TST results and interpretations?** BCG is the most commonly used vaccine in the world. BCG might cause a positive TST (i.e., false-positive) result initially; however, tuberculin reactivity caused by BCG vaccination typically wanes after 5 years but can be boosted by subsequent TST. No reliable skin test method has been developed to distinguish tuberculin reactions caused by vaccination with BCG from reactions caused by natural mycobacterial infections, although TST reactions of ≥20 mm of induration are not usually caused by BCG.
- **What steps should be taken when an HCW has had a recent BCG vaccination? When should the TST be placed?** A TST may be placed anytime after a BCG vaccination, but a positive TST result after a recent BCG vaccination can be a false-positive result. QFT-G should be used, because the assay test avoids cross reactivity with BCG.
- **A hospital HCW has not had a TST in 18 months because she was on maternity leave and missed her annual TST. She has been employed at the hospital for the previous 5 years. Is two-step testing necessary on her next skin test date?** No, two-step TSTs are needed only to establish a baseline for a specific setting for newly hired HCWs and others who will receive serial TST (e.g., residents or staff of correctional facilities or LTCFs). The

HCW should have a single TST or BAMT upon returning to work and should then resume a routine testing schedule on the next normal TST anniversary date.

- **Should two-step testing be performed in a contact investigation for HCWs who have not had a TST within the preceding 12 months?** No, two-step testing should only be used for baseline TST screening and has no role in a contact investigation. In a contact investigation, a follow-up TST should be placed 8–10 weeks after an initial negative TST result is read.
- **What length of time should a person who has had contact with someone with TB disease be included in a contact investigation?** This decision can best be made in consultation with the local TB program, which frequently has experience responding to similar situations. A minimum exposure time has not been established, but the minimum length of contact time with a person who has TB disease necessary for transmission will depend on multiple factors. Begin by estimating the duration of the infectious period (see Supplement, Contact Investigations). The highest priority for evaluation should be given to 1) persons with a medical risk factor for TB disease (e.g., HIV infection or immunosuppressive therapy); 2) infants and children <4 years; 3) household or congregate setting contacts; and 4) persons present during medical procedures (e.g., bronchoscopies, sputum induction, or autopsies). In addition, offer TB screening to all persons named by the patient as work or social contacts during the infectious period. Determining whether to broaden the investigation will depend on whether evidence of transmission to any of the above contacts exists (positive TST or BAMT results or conversions), the duration of the potential exposure, and the intensity of the exposure (e.g., in a poorly ventilated environment versus outdoors). If the exposure was to pulmonary TB that was cavitary on chest radiograph or if the patient had positive AFB sputum smear results, usually the minimum exposure duration for a person to be considered a contact would be shorter. Nonetheless, infection with *M. tuberculosis* requires some degree of prolonged or regular exposure (i.e., days to weeks, not just a few hours).
- **If an HCW in a setting has a latex allergy, should this person receive a TST?** A person with a latex allergy can receive a TST when latex-free products are used. Latex allergy can be a contraindication to skin testing if the allergy is severe and the products used to perform the test (e.g., syringe plungers, PPD antigen bottle stopper, and gloves) contain latex. Latex-free products are, however, usually available. If a person with a latex allergy does have a TST performed using products or equipment that contain latex, interpretation of the TST results can be difficult, because the TST reaction might be the result of the latex allergy, reaction to PPD, or a combination of both. Consider repeating the TST using latex-free products or use BAMT.
- **Should the TST site be covered with an adhesive bandage?** No, avoid covering the TST site with anything that might interfere with reading the TST result (e.g., adhesive bandages, cream, ointment, lotion, liquids, and medication).
- **When can a TST be placed if other vaccines are also being administered (e.g., measles, varicella, yellow fever, and smallpox)?** A TST should be administered either on the same day as vaccination with live virus or 4–6 weeks later. Vaccines that might cause a false-negative TST result are measles, varicella, yellow fever, smallpox, BCG, mumps, rubella, oral polio, oral typhoid, and live-attenuated influenza.
- **How frequently should persons in the general public receive TST?** Testing for LTBI in the general public is not necessary unless the person is at risk for exposure to *M. tuberculosis* (e.g., someone who had contact with a person with TB disease) or at increased risk for progression to TB disease (e.g., someone infected with HIV).
- **Should we use a multiple puncture (Tine®) skin test to perform a TST?** No, in the United States, the Mantoux method of skin testing is the preferred method because it is more accurate than Tine® skin tests. BAMT (currently QFT-G) is also now recommended as a test for *M. tuberculosis* infection.
- **What steps should be taken if an HCW has a baseline TST result of 16 mm and 1 year later the TST result was read as 0 mm?** If documentation existed for the 16 mm result, administering another TST to the HCW subsequently was not necessary. One or both of these TST results could be false results. The first result might have been documented as 16 mm, but perhaps 16 mm of erythema was measured and no induration was present. The second result of 0 mm might have been caused by incorrect administration of the TST (i.e., too deeply or too shallow), or was read and recorded incorrectly (if it was actually positive). In this instance, another TST should be placed, or a BAMT should be offered, or if TB disease is suspected, a chest radiograph should be performed.
- **What steps should be taken if the TST is administered intramuscularly instead of intradermally?** QC for administering TST is critical. If the TST is administered intramuscularly (too deeply), repeat the skin test immediately, or offer BAMT.

- **How are annual TST conversion rates for HCWs calculated?** A TST conversion is a change in the result of a test for *M. tuberculosis* infection wherein the condition is interpreted as having progressed from uninfected to infected. Annual TST conversion rates are calculated for a given year by dividing the number of test conversions among HCWs in the setting that year (numerator) by the total number of HCWs who received tests in the setting that year (denominator) multiplied by 100. By calculating annual TST conversion rates, year-to-year comparisons can be used to identify transmission of *M. tuberculosis* that was not previously detected.
- **Where can PPD be obtained?** Local and state health departments can provide PPD antigen for TST without charge to selected targeted testing and treatment programs. Purchase of the antigen and supplies is regulated by local and state laws related to professional licensure.
- **Where can millimeter rulers be obtained to measure TST results?** A TST training kit, which includes a TST training video, guide for facilitators, and a TST millimeter ruler is available free of charge from CDC (https://www2.cdc.gov/nchstp_od/PIWeb/TBorderform.asp). In addition, check with your local or state health department and TST antigen manufacturers.
- **Where can materials be obtained for educating HCWs regarding TB?** A list of TB websites and resources is available (Appendix E). Local or state health departments should have additional materials and access to resources and might be able to help develop a setting-specific TB education program.
- **Where can self-reading TST cards be obtained that allow HCWs to report their own results?** HCWs and patients should not be allowed to read and report their own TST results; therefore, self-reading cards for reporting TST results are not recommended. All TST results should be read and recorded by a trained TST reader other than the person on whom the TST was placed.

Treatment for LTBI

- **Who should be treated for LTBI?** Persons with LTBI who are at increased risk for developing TB disease should be offered treatment for LTBI regardless of age, if they have no contraindication to the medicine.
- **What are contraindications to treatment of LTBI?** Active hepatitis and ESLD are contraindications to the use of INH for treatment of LTBI. Persons who have these conditions might be eligible for rifampin for 4 months for treatment of LTBI. Because of the substantial and complex drug-drug interactions between rifamycins and HIV protease inhibitors (PI) and nonnucleoside reverse transcriptase inhibitors (NNRTI), clinicians are encouraged to seek expert advice if the concurrent use of these drugs is being considered in persons infected with HIV. Information regarding use of these drugs is available at http://www.cdc.gov/nchstp/tb/tb_hiv_drugs/toc.htm.
- **Do persons need to be in a specific age range to be eligible for treatment of LTBI?** No age restriction for eligibility of treatment for LTBI currently exists. Targeted TST programs should be conducted for persons at high risk, and these programs are discouraged for persons or settings considered to be low risk. However, for infection-control programs that conduct TB screening that includes HCWs who are frequently at low risk, proper medical evaluation needs to be conducted when an HCW with a positive TST result is identified. In this context, age might be a factor in the decision to administer treatment, because older persons are at increased risk for hepatic toxicity caused by INH.
- **What is the preferred regimen for treatment of LTBI?** Nine months of daily INH is the preferred treatment regimen for patients who have LTBI. The 6-month regimen of INH or the 4-month regimen of rifampin are also acceptable alternatives.
- **Why is the 2-month regimen of RZ generally not offered for treatment of LTBI?** Although the 2-month regimen of RZ was previously recommended as an option for the treatment of LTBI, reports of severe liver injury and death prompted the American Thoracic Society and CDC to revise recommendations to indicate that this regimen should generally not be offered for treatment of LTBI.
- **Can sputum specimens collected over a 2-day period that are reported as negative for AFB be used to exclude a diagnosis of TB disease?** Yes, airborne precautions can be discontinued when infectious TB disease is considered unlikely and either 1) another diagnosis is made that explains the clinical syndrome or 2) the patient has three negative AFB sputum smear results (*109–112*). Each of the three consecutive sputum specimens should be collected 8–24 hours apart (*124*), and at least one specimen should be an early morning specimen, because respiratory secretions pool overnight. Generally, this method will allow patients with negative sputum smear results to be released from airborne precautions in 2 days.
- **When does an infectious TB patient become noninfectious?** Historically, health-care professionals have believed that the effect of antituberculosis treatment to reduce infectiousness was virtually immediate; older texts state that patients on antituberculosis treatment are not infectious. Surrogates that are used for noninfectiousness include conversion of positive sputum AFB results to negative AFB results and clinical response to antituberculosis

treatment (i.e., improvement of symptoms and chest radiograph result).

Risk Assessment

- **In certain health-care settings (e.g., outpatient clinics or emergency medical settings) where patients are evaluated before a hospitalization during which TB disease is diagnosed, determining the number of TB patients who were encountered can be difficult. How should the risk classification be assigned?** These situations underscore the importance of obtaining an accurate patient history, completing contact investigations for all persons with suspected or confirmed TB disease, and ensuring effective communication to all settings in which persons with TB disease are encountered before diagnosis. Collaboration between infection-control personnel at the setting and the TB-control program staff at the local health department can help with this estimation.
- **At a pediatric hospital, the parents are normally with the child at the time of the TB diagnosis, and the parents can be diagnosed with TB disease at the same time as the child. To determine the number of patients diagnosed at the health-care setting, should the parents with TB disease who are visiting also be included in the total TB patient count?** Only patients with TB disease who were evaluated or treated in the health-care setting count, not visitors who have TB (unless they were diagnosed at the same setting).
- **In a 160-bed hospital, three HCWs have had TST conversions during a 2-month period, which is usually the number of TST conversions detected in the hospital in 1 year. Should the setting be classified as potential ongoing transmission?** If the HCWs with TST conversions can be linked together in some way, either through a job type, location of work, or DNA fingerprinting, then the classification of potential ongoing transmission might apply to one group of HCWs or one part of the setting. Evidence of ongoing transmission in this setting appears to exist, and a problem evaluation should be conducted to ascertain the reason for the TST conversions (see Problem Evaluation). Reasons could range from an undiagnosed case of TB in the setting to incorrect placement or reading of TST. Early consultation with the local health department and an expert in TB infection control might be helpful in identifying and resolving the problem.
- **If a health-care setting has a risk classification of potential ongoing transmission, how long should that classification be applied?** The classification of potential ongoing transmission should be assigned only on a temporary basis and always warrants a problem evaluation (see Problem Evaluation). After resolution of problems, settings with a classification of potential ongoing transmission should be reclassified as a medium-risk classification for at least 1 year.

Environmental Controls

- **What is the difference between environmental controls and engineering controls?** "Environmental controls" is a more inclusive term than "engineering controls". Examples of environmental controls are UVGI, HEPA filters and AII rooms. Examples of engineering controls are local exhaust ventilation (e.g., booths, hoods, and tents) and general ventilation (including directional airflow and negative pressure).
- **Is an AII room the same as a negative-pressure isolation room?** "AII room" is an accepted term and is used in the AIA guidelines that describe the purpose for and details of ventilation of AII rooms. An AII room is a special negative-pressure room for the specific purpose of isolating persons who might have suspected or confirmed infectious TB disease from other parts of the setting. Not all negative-pressure rooms are AII rooms, because they might not have the required air flow or differential pressure of an AII room.
- **Our TB clinic only treats persons with LTBI. Do we need an AII room and a respiratory-protection program?** Ideally, yes, because persons with LTBI are at risk for developing TB disease. TB clinics usually should have at least one AII room and a respiratory-protection program. An AII room and a respiratory-protection program might not be needed if 1) each person treated in the clinic will be adequately screened before admission and are determined to not have TB disease, 2) a system exists to promptly detect and triage persons who have symptoms or signs of TB disease, and 3) no cough-inducing procedures will ever be performed in the clinic.
- **Can airborne precautions be discontinued for a patient with suspected TB disease who has positive AFB sputum smear results but has a negative NAA for *M. tuberculosis*?** Yes, if the NAA test result is negative and dual infection with *M. tuberculosis* and another mycobacterial species is not clinically suspected, the patient may be released from airborne precautions. An NAA test is highly sensitive and specific for the identification of *M. tuberculosis* when performed properly on a patient who has a positive AFB sputum smear result.
- **During the winter months at a hospital, inadequate numbers of AII rooms are available for all patients with suspected or confirmed infectious TB disease. Can only two negative sputum smear results be obtained for AFB**

before releasing patients from airborne precautions? In general, the criterion for the release of a patient with suspected infectious TB disease from airborne precautions is that infectious TB disease is considered unlikely and either 1) another diagnosis is made that explains the clinical syndrome or 2) the patient has three negative AFB sputum smear results (*109–112*). Each of the three consecutive sputum specimens should be collected 8–24 hours apart (*124*), and at least one specimen should be an early morning specimen. Generally, this method will allow patients with negative sputum smear results to be released from airborne precautions in 2 days. If the number of AII rooms in the setting is inadequate, consider adding one or more AII rooms. Before undertaking this expense, however, ensure that the criteria for placing patients in AII rooms are correct and that the available rooms are not being used for patients in whom infectious TB disease is not suspected. In addition, the following intervals should be reviewed to identify any delays that could be corrected and decrease time for patients in AII rooms: 1) time between admission and ordering of sputum specimens for AFB examination, 2) time between ordering and collecting specimens, and 3) time between collection of specimens and receipt of results from the laboratory.

- **How many AII rooms are required in a 120-bed hospital?** For a hospital with 120 beds, a minimum of one AII room is needed. Although no available data exist to quantify the number of rooms needed for a given number of cases of suspected or confirmed TB disease, a reasonable choice is one additional AII room for every 200 patient-days of cases of suspected or confirmed TB disease. The setting's risk assessment will help determine the number of AII rooms needed.
- **Who is responsible for ensuring that negative pressure is achieved in AII rooms?** Ensuring that negative pressure is achieved in AII rooms is a function of the infection-control program at each health-care setting. This responsibility may be delegated to engineering, maintenance, or other appropriate staff to perform the actual negative pressure tests. AII rooms should be checked for negative pressure before occupation by a patient with suspected or confirmed infectious TB disease, and when in use by a person with TB disease, negative pressure should be checked daily with smoke tubes or other visual checks.
- **What is the difference between VAV and CAV? How do I determine which settings need them?** VAV is variable air volume, and CAV is constant air volume. These terms refer to how the ventilation system is designed to deliver air to and maintain temperature and relative humidity control within a room. CAV systems usually are best for AII rooms and other negative-pressure rooms, because the negative-pressure differential is easier to maintain. VAV systems are acceptable if provisions are made to maintain the minimum total and outside ACH and a negative pressure ≥0.01 inch of water gauge relative to adjacent areas at all times.
- **Why was the differential pressure requirement for an AII room increased from 0.001 inch of water gauge to ≥0.01 inch of water gauge?** In an ideal, controlled environment, 0.001 inches of water gauge has been demonstrated to ensure negative pressure in AII rooms. However, AIA and other organizations have demonstrated that a minimum of 0.01 inches of water gauge is needed in certain installations to ensure that negative pressure is consistently achieved.
- **How can a portable HEPA filter unit help control TB?** Portable HEPA filtration units recirculate room air, and the HEPA filters effectively remove all particles from the air in the size range of droplet nuclei, resulting in a dilution of the concentration of infectious particles in the room.

Respiratory Protection

- **What is the difference between a CDC/NIOSH-certified respirator and a surgical or procedure mask?** Respirators are designed to help reduce the wearer's (i.e., HCW's) exposure to airborne particles. The primary purpose of a surgical or procedure mask is to help prevent biologic particles from being expelled into the air by the wearer (i.e., patient).
- **How important is the fit of the respirator?** This step is critical. The fit of a respirator is substantially important. If a respirator does not fit tightly on the face, airborne hazards can penetrate or enter underneath the facepiece seal and into the breathing zone. Before each use, the wearer of a respirator should perform a user-seal check on themselves to minimize contaminant leakage into the facepiece (http://www.cdc.gov/niosh/topics/respirators).
- **How do I perform a respirator user-seal check?** Performing a user-seal check (formerly called "fit check") after redonning the respirator each time is critical to ensure adequate respiratory protection. The seal checks for respirators are described in the respirator user instructions and should be consulted before the respirator is used. The two types of user-seal checks usually are positive-pressure and negative-pressure checks.

  To check positive pressure seal after donning the respirator, the wearer should cover the surface of the respirator with their hands or with a piece of household plastic film and exhale gently. If air is felt escaping around the facepiece, the respirator should be repositioned, and the

user-seal check should be performed again. If the wearer does not feel air escaping around the facepiece, the positive pressure user-seal check was successful.

To check the negative pressure seal after donning the respirator, the wearer should cover the surface of the respirator and gently inhale, which should create a vacuum, causing the respirator to be drawn in toward the face. If the respirator is not drawn in toward the face or if the wearer feels air leaking around the face seal, the respirator should be removed and examined for any defects (e.g., a small hole or poor molding of the respirator to the face [especially around the nose area]). If no holes are found, the respirator should be repositioned and readjusted, and a second attempt at negative pressure user-seal check should be made. If the check is not successful, try a new respirator.

- **Is performing a user-seal check (formerly called "fit check") on a respirator before each use always necessary?** Yes, performing a user-seal check on respirators before each use is essential to minimize contaminant leakage into the facepiece. Each respirator manufacturer has a recommended user-seal check procedure that should be followed by the user each time the respirator is worn.
- **What is a respirator fit test and who does fit testing?** A fit test is used to determine which respirator does or does not fit the user adequately and to ensure that the user knows when the respirator fits properly. Fit testing must be performed by a qualified health professional. Fit testing should be performed during the initial respiratory-protection program training and periodically thereafter, based on the risk assessment for the setting and in accordance with applicable federal, state, or local regulations.

  Periodic fit testing for respirators used in TB environments can serve as an effective training tool in conjunction with the content included in employee training and retraining. The frequency of fit testing should be determined by a change in the 1) risk for transmission of *M. tuberculosis*, 2) facial features of the wearer, 3) medical condition that would affect respiratory function, 4) physical characteristics of the respirator (despite the same model number), or 5) model or size of the assigned respirator.
- **What kind of respiratory protection should HCWs use when providing care to persons with suspected or confirmed infectious TB disease in the home?** The recommended respiratory protection for HCWs who provide care in the homes of patients with suspected or confirmed infectious TB disease is at least an N95 respirator.
- **What kind of respiratory protection should HCWs use when transporting patients with suspected or confirmed infectious TB disease?** The risk assessment for the setting should consider the potential for shared air. Drivers, HCWs and other staff who are transporting patients with suspected or confirmed infectious TB disease in an enclosed vehicle should consider wearing an N95 disposable respirator. If the patient has symptoms or signs of infectious TB disease (e.g., productive cough or positive AFB sputum smear result), the patient should wear a surgical or procedure mask, if possible, during transport, in waiting areas, or when other persons are present. Patients who cannot tolerate masks because of medical conditions should observe strict respiratory hygiene and cough etiquette procedures.
- **What type of respiratory protection should be used in the operating room (OR) by HCWs with facial hair or other factors that preclude proper fitting of an N95 respirator? Will wearing a surgical or procedure mask underneath a PAPR solve this problem?** HCWs with facial hair should not wear negative pressure respirators (e.g., N95 disposable respirators that require a tight face-seal). In the OR, HCWs with facial hair who are caring for a person with suspected or confirmed infectious TB disease should consult their infection-control committee and respirator manufactures regarding optimal respiratory protection and adequate infection-control measures. The HCW in this case might wear a surgical or procedure mask to protect the surgical field underneath a loose-fitting PAPR. However, the user cannot be assured of proper operation unless the PAPR's manufacturer tested the PAPR over a surgical or procedure mask or N95 respirator. All respiratory-protection equipment should be used in accordance with the manufacturer's instructions.
- **Should bacterial filters be used routinely on the breathing circuits of all ventilators and anesthesia equipment on patients with suspected or confirmed infectious TB disease?** Yes, bacterial filters should be used routinely on the exhalation breathing circuits of patients with suspected or confirmed infectious TB disease to prevent exhaled air containing infectious droplet nuclei from contaminating the room air. Filters should be used on mechanical ventilators and also on hand-held ventilating bags (i.e., manual resuscitators [e.g., ambu-bags®]). The bacterial filter should be specified by the manufacturer to filter particles 0.3 μm in both the unloaded and the loaded states, with a filter efficiency of ≥95% (i.e., filter penetration of <5%) at the maximum design flow rates of the ventilator.
- **Who should not wear an N95 respirator?** Any HCW who is restricted from using a respirator because of medical reasons should not wear one nor should persons who cannot pass a fit test because of the presence of facial hair

or other condition that interferes with the seal of the respirator to the face.

- **How long can I use my respirator for TB exposures before I discard it?** Disposable respirators can be functional for weeks to months and reused by the same HCW. Reuse is limited by hygiene, damage, and breathing resistance, and manufacturer instructions should be considered.
- **Should persons who perform maintenance on and replace filters on any ventilation system that is likely to be contaminated with *M. tuberculosis* wear a respirator?** Laboratory studies indicate that re-aerosolization of viable mycobacteria from HEPA filters and N95 disposable respirator filter media is unlikely under normal conditions; however, the risks associated with handling loaded HEPA filters in ventilation systems under field-use conditions have not been evaluated. Therefore, persons performing maintenance and replacing filters on any ventilation system that is likely to be contaminated with *M. tuberculosis* should wear a respirator (see Respiratory Protection) and adhere to local recommendations for eye protection and gloves.

Cough-Inducing and Aerosol-Generating Procedures

- **Should a bronchoscopic procedure be performed on a patient with TB disease?** If possible, bronchoscopic procedures should be avoided for patients with 1) a clinical syndrome consistent with infectious pulmonary or laryngeal TB disease and 2) in persons with positive AFB sputum smear results, because bronchoscopic procedures substantially increase the risk for transmission either through an airborne route or a contaminated bronchoscope. If the diagnosis of TB is suspected, consideration should be given to empiric antituberculosis treatment, but a bronchoscopic procedure might have the advantage of confirmation of the diagnosis with histologic specimens; collection of additional specimens, including post bronchoscopy sputum, can increase the diagnostic yield and increase the opportunity to confirm an alternate diagnosis. Microscopic examination of three consecutive sputum specimens obtained at least 8 hours apart is recommended instead of bronchoscopy.
- **For ORs without an AII room, postoperative recovery is usually in the OR suite. Is this location acceptable?** If the OR has an anteroom, this location is acceptable. Reversible flow rooms (OR or isolation) are not recommended by CDC, AIA, or ASHRAE.

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Terms and Abbreviations Used in this Report

ACET	Advisory Council for the Elimination of Tuberculosis
ACGIH	American Conference of Governmental Industrial Hygienists
ACH	Air changes per hour
ACOG	American College of Obstetricians and Gynecologists
AERS	Adverse event reporting system
AFB	Acid-fast bacilli
AIA	American Institute of Architects
AIDS	Acquired immunodeficiency syndrome
AII	Airborne infection isolation
ALA	American Lung Association
ALT	Alanine aminotransferase
ANSI	American National Standards Institute
APF	Assigned protection factor
APIC	Association for Professionals in Infection Control and Epidemiology, Inc.
ART	Antiretroviral therapy
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.
AST	Aspartate aminotransferase
ATS	American Thoracic Society
BAMT	Blood assay for *Mycobacterium tuberculosis*
BCG	Bacille Calmette-Guérin
BIDR	Blinded independent duplicate reading
BMBL	Biosafety in Microbiological and Biomedical Laboratories
BSL	Biosafety level
BSC	Biological safety cabinet
CAV	Constant air volume
CDC	Centers for Disease Control and Prevention
CEL	Certified equipment list
CFM	Cubic feet per minute
CFR	Code of Federal Regulations
CoV	Coronavirus
CPL	Compliance policy directive

CT	Computed tomography
DHHS	U.S. Department of Health and Human Services
DNA	Deoxyribonucleic acid
DTBE	Division of Tuberculosis Elimination
DOT	Directly observed therapy
DTH	Delayed-type hypersensitivity
ED	Emergency department
EMS	Emergency medical service
EPA	Environmental Protection Agency
ESRD	End-stage renal disease
ETL	Electrical Testing Laboratories
FDA	U.S. Food and Drug Administration
FGI	Facility Guideline Institute
FPM	Feet per minute
HAART	Highly active antiretroviral therapy
HCW	Health-care worker
HEPA	High-efficiency particulate air
HIV	Human immunodeficiency virus
HMO	Health maintenance organization
HPLC	High-pressure liquid chromatograph
HVAC	Heating, ventilation, air conditioning
ICU	Intensive care unit
IDSA	Infectious Diseases Society of America
IFN-γ	Inteferon-gamma
IGRA	Interferon gamma release assay
INH	Isoniazid
IUATLD	International Union Against Tuberculosis and Lung Disease
JCAHO	Joint Commission on Accreditation of Healthcare Organizations
LTBI	Latent tuberculosis infection
MDR TB	Multidrug-resistant tuberculosis
MOTT	Mycobacterium other than tuberculosis
NAA	Nucleic acid amplification
NCID	National Center for Infectious Diseases