

Environmental Controls

In this manual, the term “environmental controls” refers to the use of engineering technologies to help prevent the spread and reduce the concentration of infectious droplet nuclei in the air.

Due to funding and other restrictions, public health clinics, community health clinics, and homeless shelters frequently make use of locations that were not originally designed for use as clinics or shelters. As a result, if a location has an existing ventilation system, it may not have sufficient safeguards to prevent the spread of TB, or it may not be operational. Some settings have no ventilation system at all.

Additional risks faced by clinics, shelters, and hospital emergency departments, are deficiencies in AIIR environmental controls. When deficiencies occur, suspected or known TB patients may be placed in AIIRs that have inadequate environmental controls, such as low air change rates or positive pressure, placing others at risk of exposure.

This section outlines the environmental controls for designing, implementing, and maintaining an effective ventilation system at both a facility level and at an AIIR level. See part 2 for more specific information on different settings.

Using Ventilation to Reduce the Risk of Spreading TB

What is Ventilation?

Ventilation is the movement of air in a building and replacement of inside air with air from the outside. Two general types of ventilation are the subjects of this manual:

- Natural ventilation, which relies on open doors and windows to bring in air from the outside. Fans may also assist in this process and distribute the air
- Mechanical ventilation, which usually refers to the use of mechanical air-moving equipment that circulates air in a building and may also involve heating and/or cooling. Mechanical ventilation systems may or may not bring in air from the outside

How Ventilation Helps Reduce the Risk

Ventilation can reduce the risk of infection through dilution and removal.

When clean or fresh air enters a room, by either natural or mechanical ventilation, it dilutes the concentration of airborne particles, such as droplet nuclei, in room air. This is similar to opening doors and windows to dilute objectionable odors. Dilution reduces the likelihood that a person in the room will breathe air that may contain infectious droplet nuclei.

This removal effect occurs when potentially contaminated room air is either:

- Exhausted outdoors to a safe place (i.e., away from persons), or
- Filtered or irradiated to trap or inactivate droplet nuclei containing *M. tuberculosis*.

In any ventilated space, air is constantly entering (being supplied) and leaving (being exhausted). When air is introduced into a space, it will mix to a certain extent with the air already in the room. This will dilute any airborne pollutants to create an air mixture.

The more effective the mixing of air, the better the dilution of infectious particles.

Natural Ventilation and Fans

Note: *This information may not apply to certain settings, such as hospitals or AIRs. Natural ventilation should be implemented only when in compliance with your facility's regulations.*

In buildings without operational central forced-air heating and/or air conditioning systems, natural ventilation and fans should be used whenever possible to provide fresh outdoor air to all occupied rooms in the building. However, this may not be practical in extremely cold climates.

This section explains how fresh air and fans can be used to improve ventilation in a building. It includes information on:

- What to check and how to improve ventilation
- How to use exhaust and freestanding fans more effectively
- Advantages and disadvantages of natural ventilation.

A case study about how one homeless shelter director improved ventilation in her building is located at the end of this section.

About Natural Ventilation

Natural ventilation refers to fresh dilution air that enters and leaves a building through openings such as windows, doors, and skylights. All rooms where people congregate, such as waiting rooms or shelter dormitories (and that are not served by a central ventilation system) should have an operable window, door, or skylight that is kept open as often as possible.

Using Propeller Fans

Propeller fans can be an inexpensive way to increase the effectiveness of natural ventilation.

Types of Propeller Fans

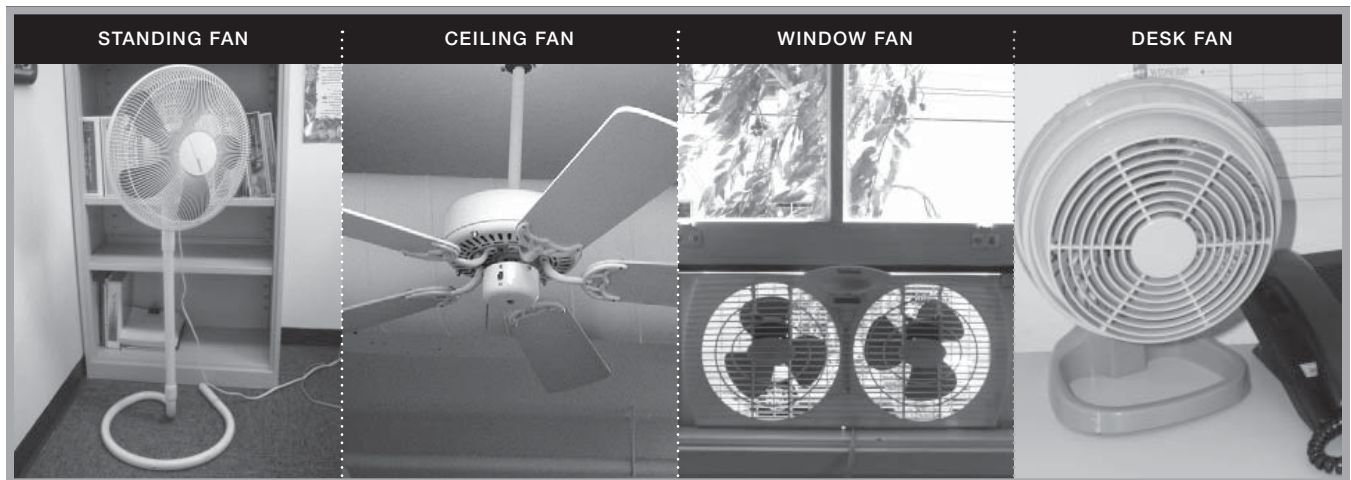
Ceiling fans are propeller fans that are suspended from the ceiling. They circulate air throughout a room but do not move it in any particular direction.

Propeller fans that move air in a particular direction include:

- Small fans that sit on a desk or other surface
- Fans that stand on the floor
- Fans mounted in a window opening

FIGURE 1.

Propeller Fans



Air Mixing and Removal

A propeller fan helps mix air in a room. This dilutes any infectious particles by spreading them throughout the room. The amount of particles near the source is reduced, but the amount in other parts of the room may increase.

If this dilution effect is combined with a way to replace room air with fresh air, such as an open window or door, the result will be fewer particles overall in the room.

A room with an open window and a fan will have less TB-transmission risk than an enclosed room with no fan, an enclosed room with a fan, or a room with an open window but no fan.

Using Directional Airflow to Reduce the Risk of Spreading TB

What is Directional Airflow?

Ventilation can also help reduce the local concentration of infectious particles in a room. This is done by matching the location of people in a room to the airflow. Simply stated, locate the people you are trying to protect from TB exposure near an air supply. Locate people who may be infectious near a place where air is exhausted from the space.

How Directional Airflow Helps Reduce the Risk

In the homeless shelter setting, this principle can help protect staff from an unidentified TB patient. For example, use of directional airflow can help reduce the chance that TB will spread from a client to a staff member doing intake interviews. If the air direction is known, the staff member should sit near the fresh air source, and the clients should sit near the exhaust location.

In a room in which large numbers of people may congregate, such as a dormitory or a waiting room, anyone could be a source of TB, and TB could spread to others in the room. Therefore, the direction of air movement is less critical. It is more important to achieve good air mixing in all locations so that particles are more quickly diluted and removed.

Directional Airflow and Staff Location

If placed in or near a wall opening, propeller fans can also be used to encourage air movement into and out of a room.

For example, fans installed in the windows on the back wall of a building exhaust air to the outside. If doors and windows in the front of the building are kept open, the overall effect should be to draw in fresh air through the front of the building and exhaust air through the rear.

With this arrangement, the risk that TB will be spread is greater near the back of the building. If this building is used as a homeless shelter, place the staff near the front of the building, and place people who are coughing or have other symptoms of airborne infectious diseases, including TB, near the exhaust fans.

Using Exhaust Fans

Clinics or shelters that do not have a central heating and/or air conditioning system often do have exhaust fans serving certain areas. Two common examples are bathroom exhaust fans and range hoods used over kitchen stoves. These fans increase ventilation by directly exhausting room air outdoors.

There is a wide variety of exhaust fan systems. A system can be as simple as a propeller fan installed in the wall, or it could include a ceiling grille, with a fan and a duct, leading to discharge on an outside wall or on the roof.

Over time, dust and lint accumulate on exhaust fans. The fans and ducts become clogged and less air is exhausted. For this reason, these systems should be cleaned regularly.

Locate the people you are trying to protect from TB exposure near an air supply.

Air Supply and Exhaust Locations

A ventilation system introduces and removes air by means of air outlets. In health-care applications, outlets are usually mounted on a ceiling or on a wall.

- Ceiling supply outlets are called *diffusers*. Wall supply outlets are called grilles or registers. Exhaust (or return) outlets are also called *grilles* or *registers*, regardless of whether they are mounted on the ceiling or the wall
- The neck of the outlet is the point at which the outlet connects to the air duct. The neck size is selected to match the airflow quantity
- The pattern or style of an outlet is the physical configuration of its face as seen from the room. For example, outlets can have a louvered pattern or a perforated metal pattern

Air provided to a room is always *supply* air. Air removed from a room, however, is either *return* or *exhaust* air, depending on the path it takes after it leaves the room.

- **Return air** is returned to the unit for recirculation
- **Exhaust air** is discharged outdoors

The effectiveness of any given ventilation rate in clearing a space of air contaminants depends on how well the air is mixed. In turn, air mixing depends largely on how and where air enters and leaves the space. The most common causes of poor air mixing are stagnation and short-circuiting. Both should be avoided because they reduce the benefits of ventilation.

Stagnation occurs when part of the room does not benefit from the fresh supply air. It also occurs in a room that does not have any ventilation. People in a stagnant location would probably feel that the air is stuffy. Infectious particles in a stagnant area are not diluted or removed quickly.

Short-circuiting occurs when clean air is removed before it has mixed well with room air, such as when the exhaust is located right next to the supply of incoming air. A room must not only have a satisfactory amount of clean air supplied to it, but this air must also mix with the air already in the room.

Proper selection and location of the supply and exhaust outlets will help avoid stagnation and short-circuiting.

Checking Natural Ventilation and Fans

People can usually feel the presence or absence of air movement in a space. A ventilated space has a slight draft. In the absence of ventilation, air will feel stuffy and stale and odors will linger. Use the following checklist to assess natural ventilation in your facility:

- Check that all occupied rooms have a source of natural ventilation
- Check that windows and doors are easy to open and to keep open
- Check air mixing and determine directional air movement in all parts of occupied rooms. An inexpensive way to visualize air movement is to use incense sticks:

1. Hold two incense sticks together and light them. (CNTC recommends that two sticks be used side-by-side)
 2. As soon as the incense starts to burn, blow out the flame. Now the incense should produce a continuous stream of smoke.
 3. Observe the direction of the smoke.
 4. Observe how quickly the smoke dissipates. This is a subjective test that may require some practice. It does not give a definite result but is useful for comparing rooms to each other. For example, it may take 5 seconds for smoke to dissipate in one room but 10 seconds in another.
 5. Repeat smoke tests for different common conditions at your facility. For example, if doors are kept open during the day but closed at night, the tests should be done under both conditions.
- Check that all room fans are working and clean
 - Check that exhaust fans are working and clean. To check exhaust fans that have a grille, hold a tissue or a piece of paper against the grille. If the fan is working, the tissue or paper should be pulled against the grille.

Recommendations for Natural Ventilation and Fans

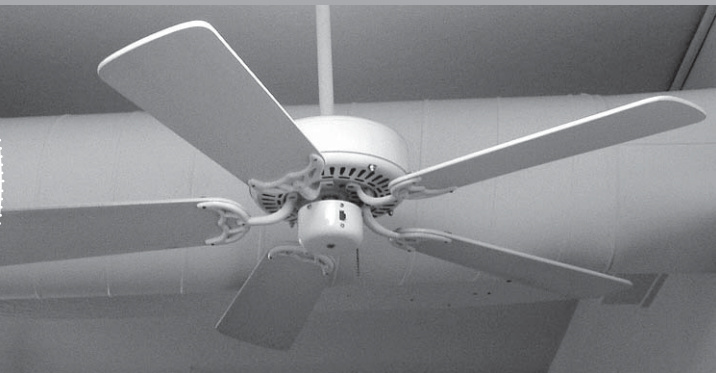
- Provide fresh outside air to all occupied rooms. Use natural ventilation and fans to provide this air where there is no central ventilation system
- Keep doors, windows, and skylights open as often as possible
- Check that doors, windows, and skylights are easy to open
- Add fans to increase air mixing and directional airflow
- Keep fans running as much as possible when the space is occupied
- Place fans so that air movement can be felt in all occupied parts of the room
- Room fans should be placed in locations where they will add to natural ventilation currents. For example, if a building experiences natural air currents from east to west, fans should be placed so that air is blown out the west windows
- Place fans so that air flows from clean to less clean areas. Place staff near fresh air sources
- In shelters, provide extra blankets to clients who complain of drafts so that ventilation can be used when the space is occupied
- If ventilation and fans cause objectionable noise or drafts and cannot be used when the space is occupied, consider increasing ventilation at times when the space is unoccupied. For example, many shelters are closed during part of the day, providing an opportunity to open windows and doors while running fans at high speed to “air out” dormitories
- Natural ventilation can be unpredictable and may not be practical in cold climates. If this is the case, you should consider adding a central ventilation system. See “Central Ventilation Systems” on page 24. If this is not feasible, consider the use of HEPA filter units or upper-air UVGI to provide clean air on a room-by-room basis. See “Upper-Air UVGI and HEPA Filter Units” on page 38

Routine Upkeep for Natural Ventilation and Fans

- Clean exhaust fan outlets and fans about once a month with a HEPA-filtered vacuum cleaner. Use a damp cloth or vacuum cleaner to remove dust and lint from fans, grilles, and ducts. Clean ducts behind grilles as far back as the vacuum cleaner can reach. This should not be done when patients are in the room
- Check natural ventilation at least once a year or whenever disruption/alteration is suspected
- Keep records of all routine upkeep activities and dates

Advantages and Disadvantages of Natural Ventilation and Fans

ADVANTAGES	DISADVANTAGES
<ul style="list-style-type: none">• Natural ventilation can be implemented immediately by opening doors, windows, and skylights• Bringing fresh air into a space not only reduces the risk of TB transmission, but also improves overall indoor air quality. Unwanted indoor pollutants and odors are reduced• Freestanding fans are relatively inexpensive to buy and operate• Freestanding fans can be moved wherever needed	<ul style="list-style-type: none">• Natural ventilation can be uncontrollable and unpredictable depending on wind conditions and other factors. For example, people may close windows and doors, or the wind direction outside may change• Air that is introduced directly from the outdoors, without the benefit of filters or ductwork, may bring in unwanted elements, such as traffic exhaust and noise, rain, dust, odors, pollen, and insects• Keeping windows and doors open may adversely affect security, comfort, and privacy. This is especially true at night and in the winter



Natural Ventilation & Fans

Lynn is the director of Welcome Home, a homeless shelter that serves approximately 100 people each night.

The building is a converted warehouse with a high ceiling. It is divided into men's and women's dormitories, each with a shower and toilet room, and a small office area.

Lynn is concerned about the spread of TB because of the high incidence of TB among the urban homeless population. Her facility does not screen clients for TB, and because it operates on a first-come, first-served basis, it generally houses a different group of clients each night, thereby possibly increasing the risk. While her facility has not had a TB outbreak, Lynn knows it could happen any time.

There is no central forced-air ventilation system. Each shower and toilet room has an exhaust fan.

Check Ventilation

Lynn wanted to improve ventilation in her building. Her first step was to check the existing ventilation.

Using incense, she noted that air mixing seemed satisfactory near doors and open windows as smoke seemed to disperse quickly. In the corners, away from doors and open windows, however, air movement seemed slow.

To match nighttime conditions, Lynn closed the doors and windows and repeated the tests. Air movement was slow throughout the facility.

During both sets of tests, Lynn noticed that most air moved upward and from the front of the building toward the back.

Lynn looked at the two exhaust fans. Both had a considerable buildup of lint and dust. She turned them on and held a piece of paper against each grille. In the men's room the paper was pulled against the grille. But in the women's room there was no pulling effect, and Lynn noticed that she could not hear the fan running.

Based on these simple checks, Lynn now had a good idea of the ventilation in her building:

- Air moved from the front of the building to the back
- During the day, when doors and windows were kept open, air movement was good except in the corners of the rooms
- At night, when doors and most windows were closed, air movement was slow
- Both exhaust fans needed cleaning
- The fan in the women's room was not operating.

How could Lynn improve the situation with her limited budget? She got out the vacuum cleaner and thoroughly cleaned the two exhaust grilles. She noticed an immediate improvement in airflow at the grille in the men's room, but the fan in the women's room still was not working.

Improvements

Near the corners on the back wall were two blocked-up windows. It occurred to Lynn that if she were to install a fan in each of these windows, it should produce an air current throughout the building, regardless of whether the doors and windows were open.

She measured the windows and bought a through-the-wall fan at her local hardware store for each window. Staff from an affiliated job-training program installed the fans in the windows as part of a training exercise. Lynn made sure that the window fans exhausted air out the back of the building.

While they were at her building, Lynn asked the crew to look at the exhaust fan in the women's room. They found the problem, a broken electrical wire, and repaired it.

The Results

Lynn did some final incense tests that night, with the fans on and the doors closed. Air movement was greatly improved throughout the facility. However, some clients complained about a slight draft and were provided with extra blankets.

She repeated the tests the next morning with the windows and doors open and was pleased to see that airflow was now satisfactory, even in the corners.

Feeling very proud of herself, Lynn wrote and posted a one-page policy summarizing her environmental control efforts:

- Keep doors and windows open during the day
- Keep all fans (toilet exhaust and through-the-wall fans) on at all times
- Clean fans on the first of every month.

The next month, Lynn was happy to share her experience, and her policy, with her peers at a meeting of the local homeless shelter directors' organization. The members agreed that, while TB transmission at Welcome Home could still occur, the risk had been reduced. Furthermore, the increased fresh air had improved the indoor environment for her staff and clients.

What else could be done to prevent the transmission of TB in homeless shelters?

Central Ventilation Systems

Facilities that do not already have a central ventilation system can improve air circulation and reduce TB transmission risk by adding one. Facilities that have existing central ventilation systems should make any necessary improvements to make sure the systems have adequate components in place and meet the applicable regulatory requirements. In all cases, environmental controls must be in place and followed to prevent the spread of contaminants.

This section describes a central ventilation system and methods to assess and improve a system. It should be useful to those responsible for an existing facility served by a mechanical system and to those considering the design of a central ventilation system for a new or an existing building. It includes information about:

- Configuration and components of a central ventilation system
- Checking a ventilation system
- Recommendations for existing systems
- Recommended routine upkeep
- Advantages and disadvantages of a central ventilation system.

A case study about how one homeless shelter director made immediate low-cost improvements to ventilation in his shelter is located at the end of this section on page 36.

Note: *Staff members who have little or no previous knowledge of mechanical systems can make many of the improvements described here. For example, replacing lint filters with pleated filters and cleaning outside air intakes are easy to do. Other improvements, such as the installation of in-duct UVGI, will require the services of an outside contractor.*

About Central Ventilation Systems

Central ventilation systems, also called forced-air systems, are mechanical systems that circulate air in a building. By providing fresh dilution air, a mechanical system can help prevent the spread of TB.

However, the same system can inadvertently spread particles containing *M. tuberculosis* beyond the room occupied by the TB patient because it recirculates air throughout a building. Ventilation systems have been responsible for TB transmission among people who were never in the same room but shared air through a ventilation system.

Using a Mechanical System to Improve TB Control

There are three general ways in which a central ventilation system can help interrupt the path of TB transmission:

- It can introduce fresh outside air to replace room air
- It can use filters to remove infectious particles from recirculated air
- It can use UVGI lamps to disinfect recirculated air.

These features can be incorporated into the design of a new system or can be added to an existing system.

Configurations

Forced-air systems come in many different configurations. A ventilation unit can be located in an attic, a basement, or a closet, or it can be suspended from the ceiling in the room itself. The basic components of the system are usually the same and may include some or all of the following:

- Filters to clean air before recirculation
- A fan to move the air through the unit
- A furnace for heating
- An air conditioning section for cooling

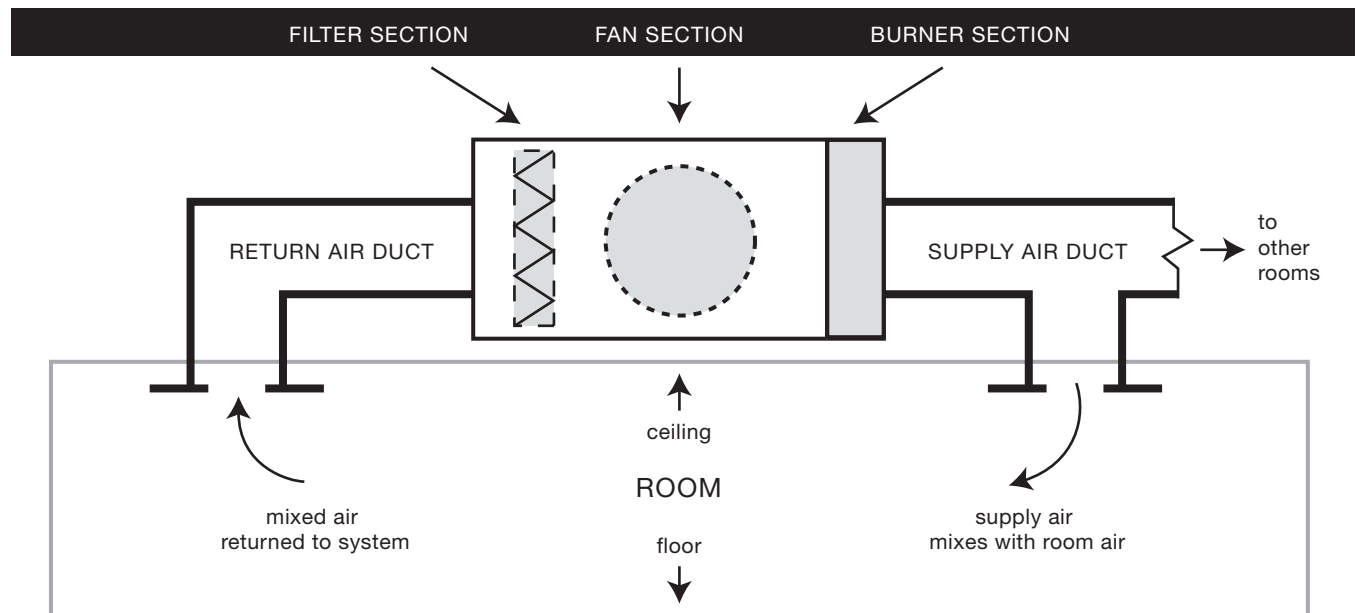
These components can be installed in a single unit or can be housed in separate sections.

A system may also include other parts, such as:

- A thermostat and controls to turn the fan on and off and to control the temperature
- Ductwork, diffusers, and/or grilles to distribute and collect air

FIGURE 2.

Recirculating Central Ventilation Unit



Recirculating Systems

Some buildings have a mechanical system that recirculates all air returned to the system—that is, 100% recirculation (See Figure 2).

In a 100% recirculating system, air is supplied to a room to provide ventilation and/or heating or air conditioning. This air mixes with room air and then is drawn back (returned) to the unit, where it is filtered and/or heated or cooled before being sent back to the room.

Even in a building with a recirculating air system, some rooms will exhaust rather than return air. Typically, bathrooms, shower rooms, institutional kitchens, and similar spaces will have a separate fan to exhaust air directly outdoors. See “Using Exhaust Fans” on page 18 for more information.

Negative pressure is created by exhausting more air from a room than is supplied to the room so infectious particles are contained within a room by a continuous air current being pulled into the room under the door.

Using Negative Pressure to Reduce the Risk of Spreading TB

What is Negative Pressure?

Negative pressure is created by exhausting more air from a room than is supplied to the room so infectious particles are contained within a room by a continuous air current being pulled into the room under the door. Therefore, when the negative pressure room is used as designed, airborne particles generated in the room cannot escape to the corridor.

Negative pressure is created by setting (or balancing) a ventilation system so that more air is mechanically exhausted from a room than is mechanically supplied. This creates a ventilation imbalance, called an offset. The room makes up the offset by continually drawing in air from outside the room. Probably the most common examples of negative pressure are residential bathrooms. Often a bathroom will have an exhaust fan but no supply.

How Negative Pressure Helps Reduce the Risk

A negative pressure room must be as air-tight as possible to prevent air from being pulled in through cracks and other gaps. This is called *sealing* a room. In a sealed room, the direction from which the make-up air enters the room and the speed with which it moves can be controlled. The smaller the make-up air opening, the faster the make-up air will move.

Ideally, the room should be well sealed except for a small (typically half-inch high) gap under the door. This should create a strong current under the door into the room.

Whenever the door is open, air movement at the doorway is uncertain. Although more air is being drawn into the room than is leaving because of the offset, the large door opening results in a free exchange of air occurring at the door. Air is coming into the room, but air is also leaving.

If the room has leaks, such as those around windows or around lights, control of the offset is lost. If the leaks allow in a greater amount of air than the negative pressure offset, this excess air will flow out of the room under the door. This can cause a room to operate under positive pressure even though the mechanical system is designed to create negative pressure.

In conclusion, the greater the offset and the tighter the room is sealed, the better.

Components: Air Filters

Filters are used to clean air. They remove particles from air that is passed through them. The cleaned air is then distributed. Many different levels of filters are available.

If a suitable filter is used, many particles containing *M. tuberculosis* will be removed and the risk of spreading TB by recirculation will be reduced.

Ventilation systems may have just one filter or they may have two or more. More than one filter is referred to as a *filter bank*.

What Type of Filter Should Be Used?

The most suitable type of filter for many recirculating air systems is a pleated filter. Pleated filters are so called because the filter inside the filter frame is folded into pleats. Lint filters are commonly flat.

The graph in Figure 3 compares the efficiency of three different types of filters:

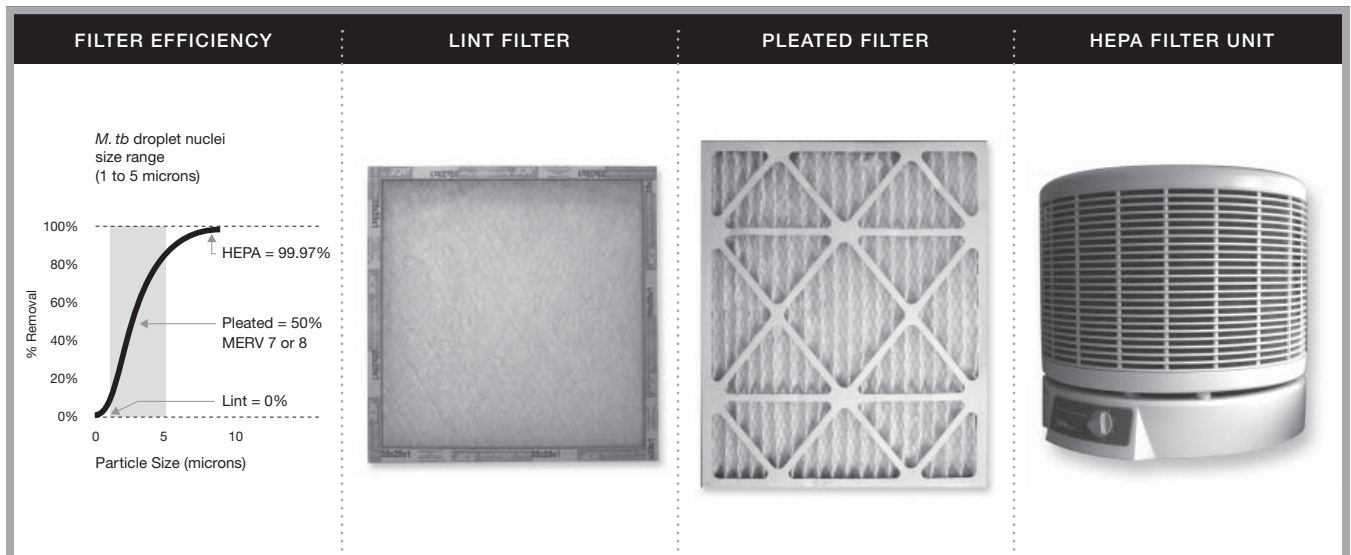
- High-efficiency particulate air (HEPA) filter
- Pleated ASHRAE 25% efficient filter (MERV 7 or 8)
- Lint filter

The shaded area in the figure represents the size range of TB droplet nuclei (1-5 μm). Each of the three filters will remove an amount of particles equivalent to the area under the line corresponding to that filter. The ASHRAE Minimum Efficiency Reporting Value, or MERV, rates the filtering efficiency of an air filter. The higher the MERV rating, the more efficient a filter is.

- A HEPA filter will remove all particles in the size range of TB bacteria droplet nuclei. (However, a HEPA filter is a specialized device that will not fit in most central ventilation systems.)
- A common lint filter will remove no particles in the size range of TB droplet nuclei size
- Pleated filters (MERV 7 or 8) can remove approximately half of all particles in the size range of TB droplet nuclei, though the efficiency varies with the MERV rating

FIGURE 3.

Air Filtration



Pleated filters are readily available from hardware stores in sizes that fit most ventilation systems.

Pleated filters are slightly more expensive than lint filters. They also cause more of an obstruction, which will reduce airflow slightly.

How Often Should Filters Be Changed?

In the absence of a filter gauge, there should be a set schedule to change the filters. In addition, filters should be checked visually every month and replaced as needed when they are evenly coated with dust.

It is important to replace filters frequently. Pleated filters will load up with lint and dust more quickly than lint filters. The amount of time it takes for a filter bank to load up depends on:

- How many particles there are in the air (the dustier room air is, the quicker the filter will load up), and
- How often the ventilation system is operated (the more frequently the ventilation system is used, the quicker the filters will become dirty).

Fan energy is used to push or pull air through filters. This is because filters cause an obstruction in the air's path. Over time, as dust accumulates, the obstruction increases. Consequently, the amount of air that the fan can move through the filter decreases.

Less airflow means less air supply to dilute objectionable air particles and less return air to remove such particles.

Pressure Drop and Filter Gauge

The relative amount of obstruction caused by filters is called the pressure drop. It is measured in inches of water gauge (" W.G.).

A filter gauge installed across a filter bank shows the pressure drop across the filter in " W.G. This is the most effective way to track filter loading and to determine when it is time to change the filter.

A filter gauge assembly consists of:

- The gauge
- Two sensors installed inside the duct, one on each side of the filter
- Copper or rubber air tubing

Tubing connects each sensor to the gauge. The gauge reads the pressure difference between the front (upstream) and the back (downstream) of the filter.

The observed pressure drop when new filters are installed is called the *clean pressure drop*. For pleated filters, this is usually about 0.25" W.G. As the filter loads up, the pressure drop will increase. The filter is usually replaced when the pressure drop increases by roughly 0.20" W.G. to 0.45" W.G. This is called the *changeout pressure drop*.

Many filter banks do not include a filter gauge, and many smaller ventilation systems are not constructed to accommodate one. For example, residential-type recirculating heating systems do not have an obvious location for a filter gauge.

As a rule of thumb, you should install a filter gauge if you have a filter bank, as opposed to just a single filter. If you have a filter bank that does not include a filter gauge, a facilities engineer or mechanical contractor should install one.

Components: Outside Air

For TB control, the best type of system is one without recirculation—that is, a 100% outside air (single-pass or once-through) arrangement. In this case, all supply air is fresh outside air, which is filtered and then heated or cooled before it is supplied. All potentially contaminated room air is exhausted directly outside the building.

However, once-through systems are uncommon because it is expensive to continuously heat or cool air from outside to a comfortable room temperature. For example, if it is 40 degrees Fahrenheit (°F) outdoors and 70°F indoors, recirculating 70°F air is cheaper than heating outdoor air from 40° to 70°F.

Most commercial ventilation systems, such as those that serve office buildings, are a compromise between 100% recirculation and 100% outside air. They recirculate most, but not all, of the air returned by the system. The portion of outside air is usually somewhere between 10 and 30% of the total quantity of supply air.

Outside Air Intake

The outside air intake is where fresh air enters the ventilation system on the roof or an outside wall. It can be a duct opening or part of the unit, and it usually includes an adjustable damper. A damper is a device that can be opened to increase the amount of outside air drawn into the unit.

Existing 100% recirculating air systems should be modified to include an outside air intake. A facilities engineer or a mechanical contractor should do this work.

As air is drawn in, dirt and debris, such as pigeon feathers, accumulate around the opening. For this reason, intakes are usually easy to find. A wire mesh screen is often used to trap dirt and debris.

Outside air intakes should be kept fully opened and clean to allow in as much fresh outside air as possible.

Components: In-Duct UVGI

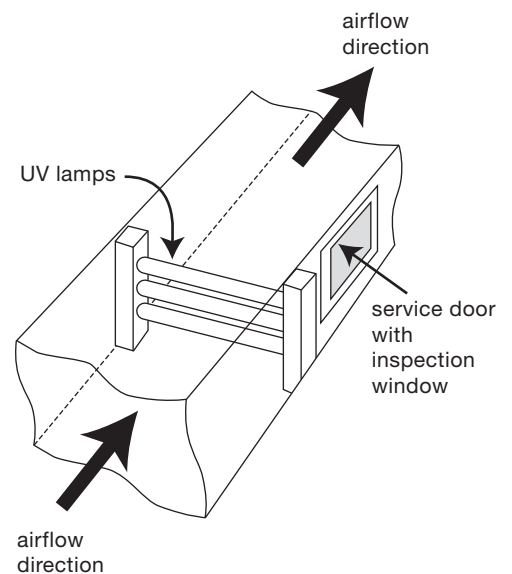
In a recirculating air system, pleated filters remove about half of all TB particles. The remaining TB particles are recirculated. This is why 100% outside air systems are ideal for high-risk settings. However, 100% outside air systems are expensive to install and operate. To provide increased protection, UVGI lamps can be installed in a recirculating system in conjunction with pleated filters to further clean the air.

An appropriately designed, installed, and maintained in-duct UVGI system should effectively disinfect most recirculated air and, therefore, significantly reduce the risk of TB exposure. For TB control purposes, such a system would be almost equivalent to a 100% outside air system.

In-duct UVGI is a useful option for a recirculating air system that serves areas at high risk for TB transmission as well as areas with lower risk.

FIGURE 4.

In-duct UVGI



Installation and Monitoring

A UVGI installation should be designed and installed by an experienced professional, such as a UVGI lamp manufacturer representative, a mechanical engineer, or a mechanical or an electrical contractor.

The expertise and equipment required to install, monitor, and maintain the lamps may be difficult and expensive to acquire.

Lamps are installed in a row at right angles to the airflow direction. The number and spacing of the lamps should be selected to ensure that all air is exposed to the radiation. Detailed calculations and measurements based on airflow and duct size will be required.

The UV intensities used inside a duct can be, and should be, greater than for upper-air UVGI because the lamps are mounted inside the ductwork, thereby reducing the risk of UV exposure to staff and others. The required intensity of the lamps will depend on air speed in the duct.

A duct access door, with a glass viewing window, should be provided so that the lamps can be cleaned, checked, and replaced. (UVGI does not penetrate glass.) The duct access door should be electrically linked to the lamps' power supply so the lamps are switched off when the access door is opened. This will protect maintenance staff from accidental exposure to UVGI. A warning sign alerting staff of the danger to the skin and eyes from direct exposure to the bulbs should be posted on, or adjacent to, the viewing window.

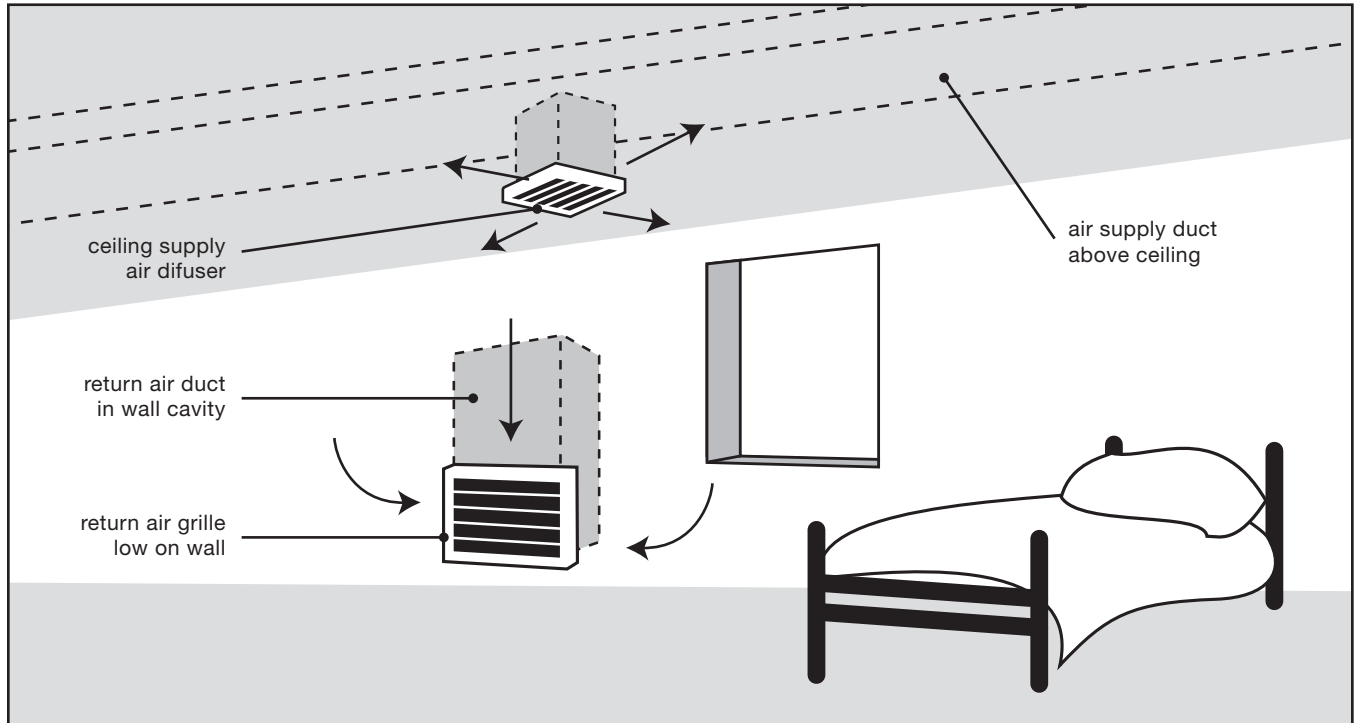
Monitoring and maintenance are crucial, because the intensity of lamps fades over time. See "Routine Upkeep of Existing Central Ventilation Systems" on page 3.

Advantages and Disadvantages of In-Duct UVGI

ADVANTAGES	DISADVANTAGES
<p>in-duct UVGI lamps, unlike HEPA filters, do not cause a significant obstruction to airflow in the system. Therefore, they can remove most infectious particles from air but do not significantly reduce the amount of airflow.</p> <p>In-duct UVGI is usually less expensive to install and operate than a 100% outside air system.</p>	<p>UVGI lamps are a more specialized type of equipment than almost all other components of a mechanical system and require specialized expertise to install and maintain.</p>

FIGURE 5.

Examples of Diffusers and Grilles



Components: Diffuser and Grille Locations

Supply air provides the heating or cooling effect. It also reduces the concentration of infectious particles in a room. Generally, air is supplied by an individual diffuser in every room but returned through just one grille.

For example, a mechanical system may provide heating to two separate dormitories in a homeless shelter. Each dormitory may have three small diffusers in the ceiling to ensure that the heated air reaches everyone in both rooms. A single large grille in the hallway may return air to the heating unit. In this building, the general direction of air will be from the diffusers, throughout the dormitories, and into the hallway to be returned to the unit.

Components: Thermostats

Room thermostats are electrical devices that control ventilation systems. They are usually mounted on a wall near a return air grille.

Many different types of thermostats are available, ranging from the very simple to programmable units with many functions. Most designs include three basic components:

- A switch that allows the thermostat to control the unit
- A thermometer that measures and displays room temperature, and
- An adjustable set point that allows the user to input the desired room temperature.

More expensive thermostats allow the user to program the fan, furnace, and air conditioning individually and to have different set points for weekdays and weekends.

The simplest type of thermostat is a two-position switch that operates in response to room temperature. The two positions are OFF and AUTO. When set to OFF, the unit will not run no matter how cold or hot the room becomes. When set to AUTO, the thermostat will turn on the fan and furnace when the room temperature, as measured by the thermostat, drops below the heating set point or rises above the cooling set point. This type of control is not recommended for TB control because the system does not operate continuously.

Checking a Ventilation System

To improve TB control and general indoor air quality, make regular checks of all ventilation systems serving the facility. An N-95 mask should be worn in the area where AIR air is exhausted. Choose a staff person to be the in-house monitor for the ventilation system.

A useful tool is a list of basic information for all units in the building. The list should include information such as ventilation unit location, rooms served by the unit, the thermostat location, and the number and size of filters. See “Summary of Ventilation Units Worksheet” on page 152 for a sample checklist.

If engineering drawings are unavailable, it probably will be necessary to crawl around the attic to see where all the ducts lead in order to find the ventilation units and identify the areas they serve. For this task you will need a rough floor plan of the facility so you can draw the ductwork as well as a tape measure to measure the filter size. Ducts exhausting air from AIRs should be labeled.

Performing Checks at Ventilation Unit or Furnace

Check that:

- Unit is operating
- Unit has filters
- Filters are the pleated type
- Filters are clean

The filter bank should be located at the return grille (remove grille to check and replace the filters), in the return ductwork, or at the unit.

Check whether an outside air intake is provided at the ventilation units. If so, check that the damper is set to the fully open position and that the intake grille and ductwork are clean. If there is an outside air intake, it will be on the roof or an outside wall.

Performing Checks in Rooms

- Check that each ventilation unit is working by turning on the fan at the thermostat and observing airflow at all supply and return outlets. Hold a tissue against each outlet to check airflow
 - If the outlet is supply, the tissue will be blown away from the outlet
 - If the outlet is exhaust or return, the tissue will be drawn toward the outlet
 - If the tissue does not move, the outlet is not working. The cause should be investigated
- Check that the thermostat has a FAN ON or similar setting that allows continuous operation of the fan

- Check that a central ventilation unit serves all occupied rooms
- Check air mixing and determine directional air movement in all parts of occupied rooms. An inexpensive and reliable way to perform these tests is to use incense sticks to visualize air movement as described under “Checking Natural Ventilation and Fans,” on page 19
- Check that all outlets are clean
- Check the return and exhaust air ductwork for dust and lint buildup. Return and exhaust air often include dust and lint that become deposited and accumulate on grilles and ductwork upstream of (before) the filter bank
- Check that all exhaust fans in bathrooms and shower rooms are working

Recommendations for Existing Central Ventilation Systems

- Use pleated filters
- Provide outside air intakes
- Set outside air intakes to the fully open position
- Use thermostats that allow continuous fan operation
- Run ventilation systems continuously whenever the building is occupied
- Install, if one doesn’t already exist, a pressure gauge for ventilation units that have more than one filter
- Provide natural ventilation to occupied rooms not served by ventilation systems and to all occupied spaces at times when ventilation systems are broken or otherwise not operating
- Consider the use of in-duct UVGI as a supplement to filtration and outside air dilution

Routine Upkeep of Existing Central Ventilation Systems

- Check filters every month and replace when required. Make sure filters are installed correctly in the filter track, not jammed into position. When a new set of filters is installed, write the replacement date on the cardboard frame of the filter. Tracking the average life of the filters will help in planning maintenance
- Clean diffusers, grilles, and in-duct UVGI lamps every month
- Clean return air ductwork with a vacuum cleaner every year. Remove grille and clean as far back as the vacuum cleaner hose can reach
- Check ventilation units and thermostats every year. Make sure that thermostats start units and that units are running
- If you have in-duct UVGI:
 - Check that lamps are operating
 - Clean lamps every month
 - Replace lamps at least once a year or as recommended by the manufacturer. Dispose of used lamps as the manufacturer recommends
 - Keep records of all routine upkeep activities and dates

An appropriately designed, installed, and maintained in-duct UVGI system should effectively disinfect most recirculated air and, therefore, significantly reduce the risk of TB exposure from recirculated air.

Recommendations for the Design of New Central Ventilation Systems

Architects, engineers, and others designing mechanical systems for new or renovated facilities should consider the following recommendations:

Ventilation Rate

Provide a ventilation rate of at least 12 ACH in rooms frequented by patients or clients. Dilution ventilation is the most effective environmental control against TB transmission. Generally, the incremental cost of increasing ventilation capacity in a new ventilation system installation is not significant compared with the total cost of the installation's design and construction. 12 ACH is the minimum rate recommended by ASHRAE for waiting rooms in health facilities. Given the rates of TB among the homeless, a shelter has comparable risk to a hospital waiting room.

Once-Through System or Economizer Capability

Consider using a single-pass or once-through ventilation system. This type of system exhausts to the outside all air returned to the system, rather than recirculating a portion of the air. If it is decided that operation of this type of system would be too expensive, then consider providing a system that is capable of once-through operation—one that will automatically vary the amount of return air to be recirculated depending on the temperature outdoors. If it is temperate outdoors (about 65°F), no air will be recirculated. Rather, outdoor air will be continuously brought in to provide what is often referred to as free cooling, or the economizer cycle.

Minimum Outside Air Quantity

If a recirculating system is used, a fixed minimum proportion of the supply air should be fresh outside air. This value is usually called the *minimum outside air set point*. The CDC recommends a minimum outside air supply rate of 25 cubic feet per minute (CFM) per person for homeless shelters. ASHRAE recommends a minimum outside air change rate of 25 CFM per person in patient rooms, 15 CFM during medical procedures, and 12 ACH for waiting rooms in health facilities. The higher of the two airflow rates generated by means of these criteria should be used as the minimum outside air set point.

Air Distribution

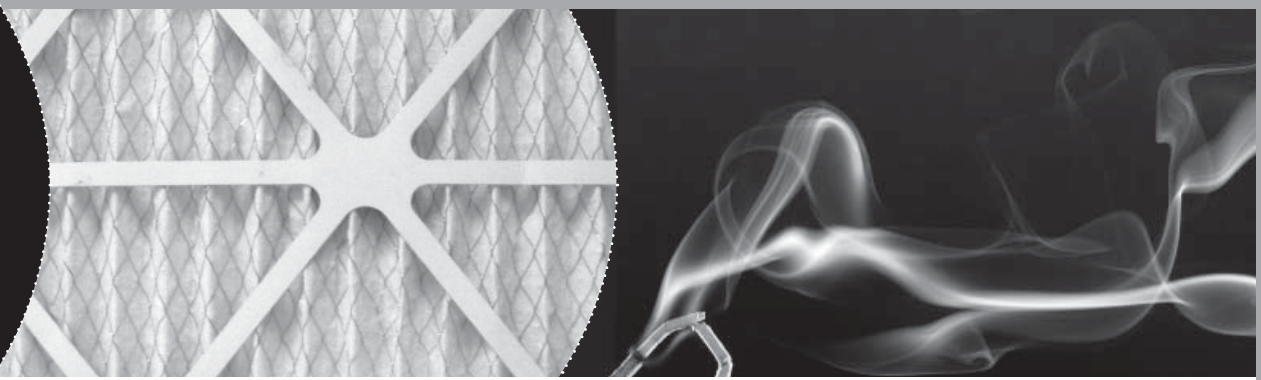
- Provide supply and return air in each room, rather than collecting air from several rooms at a single location. This will reduce the possibility of air currents carrying infectious particles to other areas
- Design the ventilation system for good air mixing. Adequate air supply and air mixing will greatly reduce the risk of TB transmission by diluting and removing infectious particles. Diffuser characteristics, such as size and air diffusion pattern, should be selected to suit the room in which diffusers are installed and the individual diffuser location within the room
- If the system will include ceiling diffusers, you can enhance air mixing by using the louvered face type, rather than the perforated face type
- If sidewall air supply grilles are used, the diffusers should be the double deflection type, with two sets of air deflection blades. The front set of blades is vertical; the second set behind these is horizontal. The louvers should be adjusted to provide even airflow patterns in each room
- Return registers should be located in the same room and as far away as possible from supply diffusers so that supply air can fully mix with room air

In-Duct UVGI

In-duct (or return-duct) UVGI may be used in a ventilation system to disinfect air removed from a group setting before recirculation.

Advantages and Disadvantages of Central Ventilation Systems

ADVANTAGES	DISADVANTAGES
<ul style="list-style-type: none">• Can be effective 24 hours a day, year-round• Controllable, adjustable, and predictable• Helps prevent transmission of airborne infectious diseases, including TB• Helps control temperature, odor, and indoor air pollutants	<ul style="list-style-type: none">• Expensive to plan, install, operate, and repair• May be drafty and/or noisy• Maintenance required



Central Ventilation System

Dan has been running an inner-city homeless shelter called You're Welcome for the last 4 years. The shelter is in the converted basement of a church. When he started working there, Dan noticed that it felt stuffy most of the time.

The shelter screens clients for TB symptoms at intake and regularly tests staff for TB infection. After several negative annual TSTs, Dan just converted his test to positive. This meant that he had acquired TB infection sometime over the last year. He thought that he had probably become infected at work.

This prompted Dan to implement some environmental control measures, something he had been thinking about since his first day on the job. He decided to start by taking a look at the ventilation system.

Dan made the following assessments and improvements in a few hours, without having to call in the service company, and equipped only with incense sticks, a screwdriver, and a tape measure.

- The existing forced-air heating system consisted of a furnace in a janitor's closet, a single return grille on the wall outside the closet, six ceiling supply grilles, and a thermostat
- The return grille and duct were extremely dusty. Dan removed the grille and cleaned out the dust with a vacuum cleaner
- He opened the filter section. The filter was a flat lint-type. It was also extremely dusty and was incorrectly installed in the filter track. Dan measured the lint filter (25" x 14" x 1") and discarded it. He bought three replacement pleated filters from a nearby hardware store. They cost about \$5 each. He wrote the date on one of the filters and placed it in the furnace
- The thermostat had an adjustable temperature setting and three fan settings: OFF, AUTO, and FAN ON. It was set to AUTO so the fan would come on only when the temperature dropped below 68°F. Dan set the controls to FAN ON, and the fan in the unit came on immediately. The improvement in ventilation was obvious
- The furnace had no outside air intake and there was no obvious way to connect one because the unit was not close to an outside wall. To let in natural ventilation, Dan decided to keep at least two windows open whenever the building was occupied
- Dan used some incense sticks to evaluate air movement. He was happy to see that air movement was brisk throughout the shelter. He also confirmed airflow at each diffuser and at the grille

What steps should Dan take to ensure that routine maintenance is done for the Central Ventilation System?

Using UVGI to Reduce the Risk of Spreading TB

What is UVGI?

Ultraviolet germicidal irradiation (UVGI) uses a type of radiation that has been shown to kill or inactivate *M. tuberculosis* in air. UVGI may be used to supplement ventilation as an environmental control measure. Because UVGI can have negative short-term health effects on the skin and eyes, a safety plan should be implemented when it is used. UVGI has two applications: in-duct UVGI and upper-air UVGI.

- In-duct UVGI is the installation of UV lamps in a return or exhaust air duct to kill any *M. tuberculosis* that may be in the airstream. This is useful as a supplemental environmental control in recirculating air systems, but is not recommended as an alternative to direct exhaust or HEPA filtration for AIIR exhaust. See “Components: In-Duct UVGI” on page 29 for a detailed discussion
- Upper-air UVGI refers to the use of UV lamps directly in a room. Lamps are mounted high on walls or suspended from the ceiling. Radiation is directed into the upper portion of the room, where the air is disinfected. The ventilation system mixes this air with the air in the lower part of the room, resulting in dilution of potentially contaminated air
- Upper-air UVGI is a useful environmental control for crowded congregate settings, where susceptible people may have prolonged exposure to an unidentified infectious TB patient. Examples are homeless shelters, emergency department waiting rooms, and prison day rooms. See “Upper-Air UVGI” on page 38 for detailed discussion of upper-air UVGI

An AIIR has a different type of transmission risk than a congregate setting. In an AIIR, the infectious source (patient) and the individual at risk (HCW) are known. Consequently, the HCW wears respiratory protection. The HCW is at greatest risk in close proximity to the patient. In general, this “near field” area contains the greatest concentration of infectious particles in the air. Although upper-air UVGI will help dilute the overall room concentration of *M. tuberculosis*, it will have little beneficial effect on this near field infection risk.

If used in an AIIR, UVGI will lower the concentration of infectious particles. However, given that staff in the AIIR wear respirators and the room air is exhausted or HEPA-filtered, the added benefit of upper-air UVGI in an AIIR will probably not be significant.

Effectiveness of UVGI

UVGI’s effectiveness increases with:

- **Intensity of the radiation**—depends on the wattage, condition, and age of the lamp (the intensity of a lamp fades over time and also, to a lesser extent, as dust accumulates on the lamp)
- **Length of exposure time**—depends on how quickly air containing infectious particles moves past the lamp
- **Proximity of infectious particles to the UVGI lamp**—depends on the placement and number of lamps used

UVGI’s effectiveness decreases with:

- **Relative humidity**—UVGI is not recommended for rooms in which the relative humidity of the air is greater than 70%

Hazards of UVGI

Although UVGI can cause temporary harm to the eyes and skin, newer fixture designs and compliance with guidelines on the use of UVGI should make it possible to use this control measure safely and effectively.

Precautions should be taken to alert and protect the people using the room(s) in which the UVGI is used. Facility staff should also receive appropriate education.

Upper-Air UVGI and HEPA Filter Units

Previous sections described how to improve natural ventilation in a building without a central ventilation system and how to improve and design a central ventilation system.

In addition to ventilation, upper-air UVGI lamps and HEPA filter units can be used on a room-by-room basis to help reduce the risk of TB transmission in a facility.

This section provides an introduction to upper-air UVGI and HEPA filters. The UVGI material is written to help individuals working with a contracted installer to achieve a better installation. The HEPA filter unit information is provided to help individuals select and use HEPA filter units.

Upper-Air UVGI

Upper-air UVGI is a specialized technology that can only be used in certain rooms. It uses UVGI lamps and room air currents to help stop the spread of TB. It is a unique infection control measure because the air is disinfected in the upper part of the room. It can be added on a room-by-room basis without affecting the existing building ventilation system. Upper-air UVGI should be considered to supplement the ventilation system in high-risk public areas, including emergency department (ED) waiting rooms and homeless shelters.

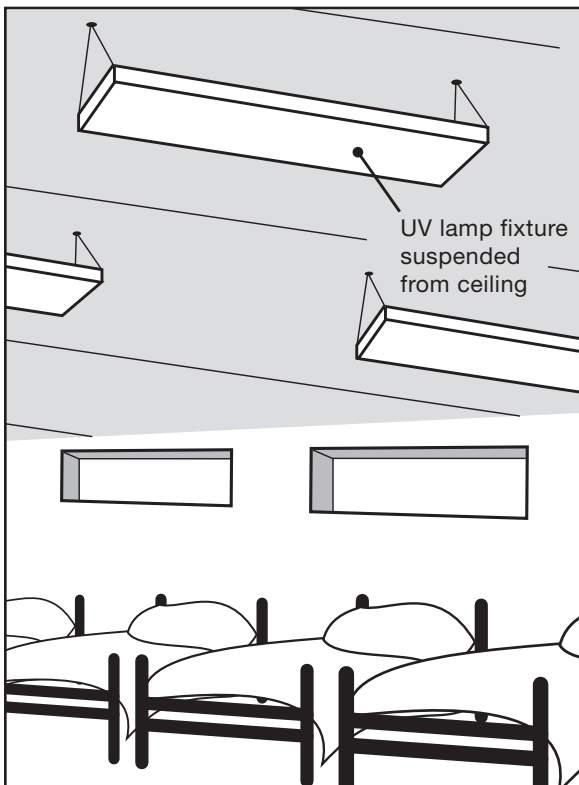
This section provides an overview of upper-air UVGI. Use this section to determine whether it can be used in your facility, and if appropriate, for advice on finding an installer and working with the installer to plan and install the fixtures so they are safe and effective.

You can also find information about evaluating an existing UVGI installation and helping to keep staff and patients protected from the hazards of overexposure to UV radiation.

It may take an hour or more for TB particles to be removed by ventilation even in a room with a comfortable ventilation rate. Adding even more ventilation will help reduce the amount of time required to remove these particles. However, it may also be expensive to install and operate and may cause objectionable noise and drafts. In this case, using upper-air UVGI to supplement ventilation should be considered.

FIGURE 6.

Upper-air UVGI in a dormitory



- Upper-air UVGI lamps are mounted high on walls or hung from the ceiling
- Metal baffles on the fixtures are needed to ensure that the radiation is directed only outward and upward, away from where people are in the room below
- Upper-room air is irradiated and disinfected. Cleaned air mixes with the air in the lower part of the room and dilutes infectious particles

The clinical effectiveness of upper-air UVGI as a means to reduce the risk of TB transmission is uncertain and can't be measured. It varies depending on many factors, including the age of the lamps, placement of the lamps, room configuration, and room airflow patterns.

Care must be taken in the design, installation, and maintenance of UVGI because of safety concerns, because effectiveness can vary, and because every installation is unique.

Ensuring Safe Radiation Levels

Radiation can reach the lower occupied part of the room through reflection from the ceilings and walls and perhaps directly from the fixtures.

The actual radiation levels of an upper-air UVGI installation are difficult to predict. For a given fixture, final radiation levels will vary for every room and for different parts of the same room. Factors that affect each installation include:

- Type of lamps used
- Effectiveness of the fixture baffles at preventing radiation from reaching occupied areas
- Locations of the fixtures
- Reflectivity of the walls and ceilings.

The only way to tell if an installation is safe is to measure radiation levels in the occupied part of the room.

Measurements should be made at numerous locations and elevations where people may be exposed for long time periods. For example, in a dormitory room, readings should be taken at the heads of beds as well as the center and corners of the room.

Recommended Exposure Limit

The National Institute for Occupational Safety and Health (NIOSH) has published a recommended exposure limit (REL) for ultraviolet energy at the UVGI wavelength, approximately 254 nanometers. The REL depends on the intensity of the radiation and the exposure time. For an exposure time of 8 hours, the REL is 0.2 microwatt per square centimeter. *If the exposure time is longer or shorter than 8 hours, the REL is proportionally lower or higher.*

The measured UVGI intensity should be no more than the NIOSH REL at any location.

UVGI Radiometer

Radiation levels are measured with a device called a radiometer. The radiometer should be calibrated specifically to measure UVGI radiation.

Radiation levels at the lamps should be much greater than radiation levels in the occupied room. Because of the difference in radiation levels, two separate meters may be required, one to verify that the radiation levels at the lamps are high, and another to verify that radiation levels in the occupied room are low.

Determining If Upper-Air UVGI Is Suitable for a Particular Room

A room must meet the following criteria if upper-air UVGI is to be used:

- Upper-air UVGI is not recommended in rooms with ceilings less than 8 feet high. The lamps must be installed at a height of about 7 feet, sufficiently high so that people cannot look into the lamps or bump into them
- In homeless shelters using UVGI, bunk beds should not be used in dormitory rooms unless they have very high ceilings. A client who is sitting on the top bunk of a bunk bed may be exposed to radiation in the upper, radiated, part of the room
- Room fans or a ventilation system are recommended to help mix the disinfected air in the upper-air with the potentially contaminated air below. The fans or ventilation system should operate continuously when the building is occupied.

Preparing for an Upper-Air UVGI Installation

Find a suitable consultant and contractor. A poorly installed upper-air UVGI system could result in:

- Harmful radiation levels in the occupied space, and
- Ineffective radiation levels in the upper-air bacterial kill zone.

Specialized expertise and equipment are required to establish effective upper-air UVGI. Only a qualified contractor, working closely with a lamp manufacturer's representative, should attempt the design, installation, and testing of an upper-air UVGI system.

1. Start by contacting a number of UVGI lamp manufacturers. Ask each for the names and addresses of some local experienced consultants and contractors.
2. The next step is to contact the suggested consultant companies or individuals. Interview them about their experiences with previous installations.
3. Ask the consultant to arrange a visit to a successful installation. This will provide an opportunity to see an existing installation and to talk with another person about his or her experience with upper-air UVGI.
4. Talk to the contractor about the possibility of arranging a service contract for system monitoring and replacement of the lamps after the installation.

Planning an Installation

Before installing UVGI fixtures, address the following items:

- Locate UVGI fixtures so that radiation in the upper-air is uniform, continuous, and complete
- In the installation contract, include measurements of radiation levels after installation
- Take these measurements before the job is accepted and payment is made. Submit a written report to the owner
 - Until readings have been taken in the occupied zone to ensure that radiation levels are below the NIOSH REL, the installation is not complete, and the lamps should not be used. Readings should be taken in a number of locations corresponding to where people will be exposed
 - Take radiometer readings at each lamp to ensure that the radiation intensity meets the manufacturer's specifications

- Non-reflective paint may need to be added to ceilings and walls. Some ceiling paints can reflect too much radiation down to the occupied room below. If meter readings indicate excessive radiation in the occupied area, the ceiling may need to be painted with non-reflective paint. This should be included in the budget for the planned installation. Paint containing titanium dioxide is recommended for reducing reflection from surfaces
- Post warning signs, in all appropriate languages, on the UVGI fixtures and on the walls. The signs should carry the following or a similar message:

CAUTION

Ultraviolet Energy

Turn off lamps before entering the upper part of the room.
(The upper part of the room is the space above the UVGI fixtures.)

- Staff, patients, or shelter clients may have concerns regarding health hazards from UVGI. To address these concerns, provide education on the purpose, benefits, and risks associated with upper-air UVGI. (OSHA requires staff training.) Also, consider posting an information sheet on the wall of the room
- The on/off switch for the lamps should be accessible to appropriate staff members but not located where patients or clients may turn off the fixtures

Checking Upper-Air UVGI

- Check radiation levels in parts of the room where people are likely to be exposed using a radiometer. Radiation levels should be below the NIOSH REL
- If radiation levels are too high in any location, turn off the lamp or lamps causing the high radiation levels. To correct the problem, it may be necessary to add non-reflective paint to the ceiling and/or wall and/or to relocate or replace the fixtures
- Check that lamps are not burned out or broken. If lamps are working, they emit a visible violet blue glow that can be seen from below
- Turn off lamps and check that lamps and fixtures are free of dust and lint
- Check that the radiation level at each fixture meets the lamp manufacturer's recommendation. Protective clothing or special equipment may be required to take these readings without overexposing the skin or eyes to the radiation. Bulbs should be replaced if the radiation levels are below the manufacturer's recommended minimum levels

Routine Upkeep

- Designate a staff member to be the in-house monitor for UVGI fixtures. This person should be trained in the basic principles of UVGI operation and safety and should be responsible for cleaning, maintaining, and replacing the lamps. This may include regular maintenance by the engineering department, but a record should be kept of this work
- Check and clean lamps and fixtures every 3 months. Turn off the lamps before they are cleaned; clean with a cloth dampened with water or alcohol

- Replace lamps once a year or as recommended by the manufacturer. The violet blue glow emitted by a lamp is not an indicator of the lamp's effectiveness. Take radiometer readings at each new lamp to ensure that radiation levels meet the manufacturer's recommendations. Dispose of used lamps as recommended by the lamp manufacturer
- Keep a record of all maintenance and monitoring, including radiometer readings and dates. This will help determine the average life of the lamps. Lamps should be purchased close to your planned replacement time, as prolonged storage may result in a loss of radiation intensity

Advantages and Disadvantages of UVGI Systems

ADVANTAGES	DISADVANTAGES
<ul style="list-style-type: none"> • Inexpensive to buy and operate compared to a central ventilation system • Can be implemented room by room • Limited impact on structure and mechanical systems • Do not cause noise or drafts 	<ul style="list-style-type: none"> • Potentially hazardous to staff and people who use the rooms in which they are located • Effectiveness uncertain • Requires specialized expertise to install and monitor • Each installation is site-specific • Only addresses TB; does not remove dust and other particles • Hard to tell if working • Not as effective in humid rooms • Glow from lamps may bother individuals who are trying to sleep • Staff, patients, or shelter clients may have unwarranted fear of radiation

High Efficiency Particulate Air (HEPA) filter units

HEPA filter units are readily available machines that can be used anywhere to provide clean air. Use this section to get an overview of HEPA filter units and to learn how to use them effectively, to determine what type and size of unit is suitable for your facility, and to help plan routine upkeep of HEPA filter units.

HEPA filter units allow anyone to improve air quality in any room almost immediately. No detailed engineering knowledge is required to install or maintain HEPA units. These units are especially useful in settings that may have inadequate or no ventilation and limited funds for upgrades.

High efficiency filters, such as HEPA filters, remove essentially all particles in the size range of droplet nuclei from the air that passes through them. These filters are used in self-contained units to provide a source of clean air. A HEPA filter unit will provide cleaned air to dilute infectious particles and will also remove airborne particles.

HEPA filter units are available in a variety of sizes and configurations, but all consist primarily of:

- A HEPA filter to remove small particles from the air
- A prefilter to remove coarser particles and thereby prolong the life of the HEPA filter
- A fan to circulate air past the HEPA filter and into the room
- Controls, such as an on/off switch and fan speed control

HEPA filter units allow anyone to improve air quality in any room almost immediately.

The most common types of units are portable, freestanding devices. Ceiling-mounted and wall-mounted units are also available. Portable units have the advantage of greater flexibility and ease of installation and service. Permanent units are less vulnerable to tampering and theft, less likely to be in the way, and can't be easily moved to a location where they will be less effective.

The size of HEPA filter units is based on the amount of air they deliver, usually expressed in CFM. Most units include a switch that can be used to vary the airflow.

Small, Portable HEPA filter units

Small, portable units deliver 150 to 250 CFM. Most units include a three-position fan speed switch but no other controls. Small units are useful for offices, on-site clinic rooms, and other smaller areas.

Small units are light enough to be easily carried around and placed on a desktop or other surface. These units are readily available from hardware stores and similar retail outlets.

Some small units may use high efficiency filters that do not meet the precise requirements for HEPA filters. (A HEPA filter must remove 99.97% of particles equal to or greater than 0.3 micron in diameter.) However, TB droplet nuclei are significantly larger than particles used to test HEPA filters, so "near-HEPA" filters will remove the majority of particles in the size range of TB droplet nuclei.

Large HEPA filter units

Larger units can deliver from 300 to 1,000 CFM and can be used in rooms in which groups of people may spend time, such as TV lounges or waiting rooms.

These units usually have wheels so they can be moved from room to room. Controls include a fan speed switch and often a warning light to indicate when filter replacement is recommended.

Options may include a lockable cover for the controls to prevent tampering and an internal UVGI lamp. Because the HEPA filter removes all infectious particles in the TB droplet nuclei size range, the UVGI offers no added benefit.

Larger units are available from specialized medical equipment suppliers.

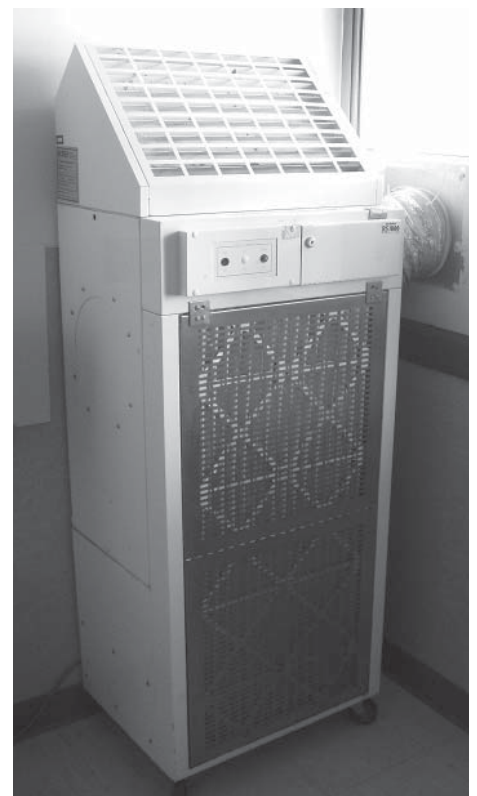
FIGURE 7A.

Small HEPA filter unit



FIGURE 7B.

Large HEPA filter unit



Recommendations for HEPA Filter Unit Selection

- **HEPA Filter Operation**

- Provide portable HEPA filter units for all unventilated rooms frequented by patients or shelter clients unless the rooms have an operable window or door that is usually kept open
- Place small units off the floor and next to staff so that the purified air generated by the filter units is delivered close to the faces of the people that they are used to protect. Consider the HEPA filter unit primarily as a source of clean air and secondly as a removal device for contaminated air
- Place units evenly throughout crowded rooms so that air movement can be felt in all parts of the room
- Select each unit based on the airflow it produces when it is running at or near the low-speed setting. HEPA filter units can be noisy when running at the higher speed settings. For this reason, people tend to operate them at low or medium speeds in small rooms during interviews. However, at lower speeds, the dilution effect is reduced because the units do not provide as much purified air
- Operate HEPA filter units continuously while rooms are occupied by patients or shelter clients and for approximately 1 hour after they leave

- **HEPA Filter Unit Selection**

- Select HEPA filter units to provide an air change rate of at least 6 ACH. See “What Does Air Change Mean?” in Appendix K on page 156 for a more detailed description of room air change rates. ASHRAE recommends the minimum air change rate of 12 ACH for waiting rooms and 6 ACH for exam rooms in health facilities. Given the rate of TB among the homeless, a group room is comparable to a hospital waiting room, and an interview room is comparable to an exam room
- Make unit selection based on the HEPA filter unit’s published airflow at low speed. For example, if the manufacturer’s data rate a unit’s three speeds as 100, 150, and 200 CFM, select the unit based on 100 CFM
- Units may deliver less than the manufacturers’ listed airflow, and output may decrease as the filters load up. To compensate for this, add a safety factor of 25% to the required airflow. The additional cost of buying a unit with more capacity is usually not significant compared to the cost of the unit

The “HEPA Filter Selection” table below lists recommended airflow and minimum HEPA filter unit sizes for some sample room volumes.

TABLE 2.

HEPA Filter Selection Table

Use this table to select a HEPA filter unit based on measured room volume. The recommended safety factor is included.

ROOM VOLUME	AIRFLOW REQUIRED FOR 6 ACH	LISTED MINIMUM AIRFLOW
800 ft ³	80 CFM	100 CFM
1,000 ft ³	100 CFM	130 CFM
1,500 ft ³	150 CFM	190 CFM
2,000 ft ³	200 CFM	250 CFM
4,000 ft ³	400 CFM	500 CFM
8,000 ft ³	800 CFM	1,000 CFM

- Room volume (first column) is room length times width times ceiling height. For example, a room that is 8 feet wide by 8 feet long with a 10-foot-high ceiling will have a volume of 640 cubic feet. A tape measure is required to measure room dimensions
- Six (6) ACH (second column) is the minimum recommended air change rate
 - The required airflow in CFM to achieve this air change rate is calculated as follows:
(Room volume x 6 ACH) / 60 minutes per hour = airflow in CFM
- The listed minimum airflow (third column) is the minimum rated airflow of a HEPA filter unit. The recommended 25% safety factor is included. Most HEPA filters include a switch that adjusts the airflow from a fixed minimum (low setting) to a fixed maximum (high setting). Because of the increased noise, people tend to use the units at the low setting. Therefore, the low setting should be the basis for unit selection
 - Example: Assume an 800-cubic-foot room volume. A unit that lists airflows as 100/150/200 CFM would be preferable to a unit that lists airflows of 50/100/150 CFM because it will provide the recommended airflow at the low (quieter) setting

Routine Upkeep of HEPA Filters

- Designate a staff person to be the in-house monitor of the HEPA filter units. This person should be aware of the basic principles of HEPA filter unit operation, including effective placement and maintenance. This person should also implement a written schedule for changing the prefilters and HEPA filters
- Maintenance consists of replacing the prefilter and the HEPA filter at regular intervals. The manufacturer's data should explain how this is done. In general, replace the prefilters every 6 months, and replace the HEPA filters every 1 or 2 years. Actual replacement time will depend mainly on how often the units are used and how dusty the room air is

Advantages and Disadvantages of HEPA Filter Units

ADVANTAGES	DISADVANTAGES
<ul style="list-style-type: none"> • Can be implemented almost immediately • Can be implemented room by room • Relatively inexpensive to plan, install, and maintain • Have adjustable airflow rate • Can be portable • Remove other indoor air pollutants, such as dust and allergens • Do not require costly equipment to evaluate 	<ul style="list-style-type: none"> • Unpredictable because, if controls are accessible, patients, shelter clients, or staff members may turn them down or off; also, they may move or unplug the units • Can be drafty and noisy • Do not bring in outside air • Do not filter out odors

HEPA Filter Unit

Catherine is a case manager in an inner-city homeless shelter. As part of her work she interviews about six new clients every week. Her office has no ventilation and no window to the outdoors. Because clients have not been medically screened and because of the lack of ventilation, she is concerned about TB transmission. The clinic manager has set aside \$150 to buy a HEPA filter unit for the office once Catherine can tell her what size of unit she would like.

Catherine wants a unit that will provide an air change rate of at least 6 ACH. She gets out a tape measure and a calculator so she can estimate a suitable HEPA filter unit airflow based on the room's volume.

She measures the room. It is 8 feet wide by 10 feet long. The ceiling is 9 1/2 feet high. She then calculates the room volume:

$$\begin{aligned} \text{Room volume} &= \text{width} \times \text{length} \times \text{height} \\ &= 8 \times 10 \times 9.5 \\ &= 760 \text{ cubic feet} \end{aligned}$$

$$\begin{aligned} \text{Airflow required for 6 ACH} &= \text{room volume} \times 6 \text{ ACH} \\ &= 760 \times 6 \\ &= 4,560 \text{ cubic feet per hour} \\ &= \frac{4,560}{60 \text{ cubic feet per minute (CFM)}} \\ &= 76 \text{ CFM} \end{aligned}$$

The actual airflow may be less than advertised. To compensate, Catherine adds a 25% safety factor to get a required airflow of 95 CFM.

$$76 \text{ CFM} \times 1.25 = \mathbf{95 \text{ CFM}}$$

Most units have an adjustable speed setting. They become noisier at the higher speeds. Catherine plans on running the unit at low speeds during interviews, so she decides to select a HEPA filter unit with a low-speed setting of at least 95 CFM.

Should Catherine aim to achieve 6 ACH or a higher rate? Why?