TB in Homeless Shelters:

Reducing the Risk through Ventilation, Filters, and UV

INSTITUTIONAL CONSULTATION SERVICES
effective TB solutions

FRANCIS J. CURRY NATIONAL TUBERCULOSIS CENTER
AND
CALIFORNIA DEPARTMENT OF HEALTH SERVICES

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Preface

A About Institutional Consultation Services

Institutional Consultation Services (ICS) is part of the Francis J. Curry National Tuberculosis Center (CNTC), funded by the Centers for Disease Control and Prevention (CDC) and the California Department of Health Services.

ICS staff has expertise and practical experience in the areas of mechanical engineering, infection control, and occupational health. ICS services include telephone and on-site consultations to tuberculosis (TB) control staff of institutions in which TB transmission is likely to occur. Facilities served include shelters, drug treatment centers, correctional facilities, hospitals, and clinics.

In addition to consultations, ICS staff develops products for use in institutions with an increased risk of TB transmission. These products include guidelines, such as this one; templates; a video module with accompanying viewer's guide; and a Frequently Asked Questions series. The latter is featured on the CNTC's Web site at www.nationaltbcenter.edu/ics.html.

B ICS Experience with Homeless Shelters

During 1996-98, an ICS mechanical engineer provided on-site consultations at 19 homeless shelters in California.

On-site consultations included an evaluation of how ventilation, filters, and UV, where present, helped control TB. Methods such as these that reduce the risk of TB transmission are called *TB control measures.* Consultations also included conversations with shelter managers and other staff to determine their knowledge and skills regarding their TB control measures.

Following each consultation, ICS provided the facility with a report recommending ways of reducing the likelihood that TB would spread in the shelter. Recommendations varied from immediate no-cost steps, such as opening windows and doors, to suggested modifications of the shelter's ventilation equipment.

There was considerable variation in the shelters visited:

- Some shelters provided food and shelter but no other services. Other facilities provided a range of services on-site, including case management and chemical dependency recovery services.
- Some shelters served a different group of clients every night on a first-come, first-served basis. Other shelters allowed clients to stay for up to 6 months.
- Buildings used as shelters varied from a converted warehouse sleeping 600 people to a self-contained trailer for 4 clients.
- Most shelters visited served only adult male clients. A smaller number served women, families, or teenagers.

Because of factors such as these, the likelihood that TB will spread varies considerably from shelter to shelter.

C Findings from ICS On-Site Consultations with Shelters

Problems with ventilation, filters, and ultraviolet germicidal irradiation (UVGI) at homeless shelters included:

- rooms without ventilation
- broken ventilation equipment
- ventilation systems operating below capacity because equipment needed cleaning or other routine upkeep
- inadequate air filters in central ventilation systems
- inappropriate design and installation of UVGI lamps

D Barriers Identified by ICS On-Site Consultations

Barriers to more effective use of ventilation, filters, and UVGI in homeless shelters included:

- limited knowledge about TB and how TB is spread
- limited knowledge of the role of ventilation, filters, and UVGI in reducing TB risk
- high staff turnover rate and overworked staff
- limited maintenance staff and budgets

- dilapidated buildings and mechanical ventilation systems
- limited funds to improve TB control through use of ventilation, filters, and UVGI

E Why This Guideline Was Developed

The primary goal of this guideline is to help homeless shelter operators and managers reduce the risk of TB transmission in their shelters by using ventilation, filters, and UVGI.

This guideline aims to help shelter directors, managers, and others to:

- understand how TB is spread in a shelter (see Introduction)
- understand how ventilation, filters, and UVGI can help reduce the risk that TB will spread in shelters (see Introduction)
- evaluate and improve ventilation in shelters (see Sections 1 and 2)
- use filters and UVGI to reduce the risk that TB will spread (see Sections 2 and 3)
- maintain TB control measures to ensure that they are effective (see Sections 1, 2, and 3)
- make informed decisions regarding planning, funding, and selection of ventilation equipment, filters, and UVGI (see Sections 1, 2, and 3)

F Who Should Use This Guideline

Directors and facility managers of homeless shelters are the primary audience for this guideline. Others with an interest in reducing the risk of TB in shelters will also find it useful, including:

- staff of homeless shelter funding sources, such as governmental agencies and community-based organizations
- homeless shelter designers, such as architects and engineers
- TB control program managers in public health departments
- public health nurses and community health nurses working in shelters
- others who work in, or may provide services to, homeless shelters, including:

- medical staff, such as on-site clinic and TB screening staff
- environmental health inspectors and occupational health inspectors
- building inspectors
- advocates and educators
- caseworkers

G How This Guideline Is Organized

The guideline begins with an introduction describing how TB is spread and how ventilation, filters, and UVGI can reduce the risk of TB transmission.

The body of the guideline is divided into three major sections:

Section 1 Natural Ventilation and Fans

Section 2 Central Ventilation Systems

Section 3 Upper-Room UVGI and HEPA Filter Units

Each of these sections contains the following:

- "How to Use This Section," which summarizes and describes the contents of the section
- a checklist to help you evaluate your TB control measures
- recommendations and stepwise instructions on how to improve your TB control measures if problems are found
- a case study to demonstrate how to use the information in the section
- a checklist to help you plan and complete routine upkeep
- advantages and disadvantages of this type of control measure

Following Section 3, two appendixes provide additional information to help you prevent the spread of TB in your shelter. A glossary and a list of resources are also included as appendixes.

See the table of contents for a listing of the sections by page number.

H How to Use This Guideline

- Review the table of contents to get an overview of the guideline. Note the titles of the appendixes for future reference.
- Read the introduction. This section contains information on how TB is spread and how ventilation, filters, and UVGI can reduce this risk in shelters. This section will make it easier to understand Sections 1, 2, and 3.
- Start with Section 1, “Natural Ventilation and Fans.”
- If your shelter has a central ventilation system, continue with Section 2, “Central Ventilation Systems.”
- If you do not know what type of system your shelter has, read the introductions of Sections 1 and 2 to find out.
- After working your way through Sections 1 and/or 2, if your facility has UVGI or HEPA filter units, or if you would like to find out more about how to use these control methods, read Section 3, “Upper-Room UVGI and HEPA Filter Units.”

This guideline is designed to be kept for future use as a manual or reference guide.

I Note on the Use of “TB” and “Mycobacterium tuberculosis” in This Document

In TB control, “TB” and “Mycobacterium tuberculosis (M. tb),” the germ that causes TB, are used in different ways. It is technically correct to use “TB” only in reference to the disease (i.e., TB disease). Likewise, it is correct to use *M. tb* with the words exposure, infection, and transmission (for example, “*M. tb* exposure,” “*M. tb* infection,” and “*M. tb* transmission”). To reflect common usage, this document uses “TB” with these words, instead of *M. tb* (for example, “TB exposure,” “TB infection,” “TB transmission”). *M. tb* is used only in describing particles that a person with TB disease of the lungs or larynx expels from the lungs.

Introduction

A Why TB Is a Problem in Homeless Shelters

TB is more likely to spread in shelters than in other settings. If a shelter client has TB in an infectious stage, it can spread throughout the shelter to other clients and staff. Shelters are especially vulnerable because:

- The shelter environment increases the chances that if a person with TB is present, TB will be spread.
- Homeless people are more likely to have TB than others in the general population.

In 1998, 6.3% of reported TB cases in the United States were people who were homeless at some time during the year before their TB was diagnosed.

The homeless are more likely than the general population to have TB because risk factors for TB, including the following, are more common:

- contact with other homeless people who have TB
- poor nutrition
- poor access to health care
- poor adherence to follow-up visits and prescribed treatment for TB infection
- substance abuse, especially injection drug use and alcohol
- limited access to HIV education and prevention measures, increasing the risk of HIV infection among the homeless (HIV is the virus that causes AIDS)

TB disease develops more quickly among people who are infected with both TB and HIV. Because homeless persons may be at higher risk for HIV infection than the general population, TB can also develop among the homeless more quickly and spread to others before it is even suspected.

For homeless people, food, shelter, and personal safety are often higher priorities than TB and HIV prevention.

In addition to increased TB among the homeless, characteristics of shelter environments often increase the chances that TB will spread. For example:

- Building ventilation is often inadequate.
- Clients are crowded into close quarters, typically for 8 to 12 hours per night.

Other factors contribute to the high likelihood that TB will spread in shelters. Among these, the most important is that many shelters do not screen clients for TB symptoms. Without this screening, a client with symptoms of TB:

- will not be referred for medical care and treatment
- will not be separated from other clients or be using a face mask to lessen the chance that TB, if present, will spread

B How TB Is Spread

TB is caused by a bacterium (a type of germ) called *Mycobacterium tuberculosis (M. tb).* A person who has TB disease in his or her lungs or larynx (throat) can release tiny particles containing *M. tb* into the air by coughing, sneezing, singing, shouting, talking, or breathing. These tiny particles are called droplet nuclei.

These particles are invisible to the naked eye and are approximately 1 to 5 microns in size. (A micron is approximately one-millionth of a yard.) Droplet nuclei can remain airborne in room air for a long period of time, until they are removed by natural or mechanical ventilation.

In order for TB to spread, there must be a source that produces *M. tb* (person with TB) and others to inhale droplet nuclei containing *M. tb.* Anyone who shares air with a person with TB disease of the lungs or larynx in an infectious stage is at risk, although TB is not usually spread by brief contact. TB is spread when another person inhales one or more of these particles and becomes infected with TB, or, in other words, develops TB infection.

C The Difference between TB Infection and TB Disease

TB Infection

TB infection does not cause a person to feel sick, and there are no symptoms.

A tuberculin skin test is used to diagnose TB infection. A positive result means that TB infection is present.

Treatment for TB infection is very effective in preventing TB disease from developing.

Nine in ten people with TB infection will never develop TB disease. However, one in ten of those infected will develop TB disease at some time in their lives. About half of these will develop TB disease within the first 2 years after they become infected.

There is no way to know for sure which people with TB infection will later get sick with TB disease. But development of TB disease is more common among people who have TB infection along with other conditions, including:

- HIV infection and other diseases that weaken the immune system
- medical treatments, such as certain cancer treatments, that weaken the immune system

TB Disease

As described above, about 10% of people who have TB infection will develop TB disease at some time in their lives. Most TB disease occurs in the lungs, but about 15% occurs in other parts of the body. General symptoms of TB include:

- fever
- sweating at night
- loss of appetite
- weight loss
- fatigue

In addition to these symptoms, a person with active TB disease of the lungs or larynx usually has a cough and sometimes coughs up blood.

Without treatment, a client with TB will get sicker. A client with TB disease of the lungs or larynx will also become more contagious. Untreated TB can become a life-threatening disease. With effective and complete treatment, a cure is very likely.

A person with a cough lasting 3 or more weeks and one or more other symptoms of TB should be evaluated as soon as possible by a health-care provider. If TB disease is diagnosed or suspected, treatment will be prescribed.

D When TB Is Contagious

TB is only contagious when it occurs in the lungs or larynx. TB that occurs elsewhere in the body is not contagious, unless the person has TB in the lungs or larynx at the same time.

In general, a person with suspected or confirmed TB disease of the lungs or larynx should be considered contagious until the person:

- has had three consecutive negative acid-fast bacilli (AFB) sputum smears on 3 different days (an AFB sputum smear is a type of medical test used in the diagnosis of TB); *and*
- has completed at least 2 weeks of anti-TB therapy if the AFB sputum smears were ever positive, or 4 days of anti-TB therapy if the AFB sputum smears were always negative (anti-TB therapy should be consistent with CDC guidelines); *and*
- has improving symptoms; *and*
- has or has had continued close medical care.

A person who has met all four of the above conditions may reside in a shelter without placing other clients and staff at risk. However, unless the person is later found to have an illness other than TB, he or she must continue to take TB medications as prescribed and continue to receive medical care for TB.

E How Shelters Can Reduce the Risk of Spreading TB

Although the likelihood of spreading TB in shelters is high, shelter operators and others can take steps to significantly reduce this risk. There are three main ways in which shelters can reduce the chances that TB will spread:

1. administrative and work practice control measures
2. ventilation, filters, and UVGI
3. staff use of respiratory protection

In general, administrative and work practice control measures have the greatest impact on preventing TB transmission, followed by the use of ventilation, filtration, and UVGI. Use of respirators by shelter staff may be important in certain situations—for example, when transporting a client suspected of having TB of the lungs or larynx, or entering a room in which such a client has been placed temporarily to separate him or her from other clients and staff.

Administrative and Work Practice Control Measures

- *Identifying* clients with a cough and one or more other symptoms of TB disease of the lungs or larynx (see previous page)
- *Promptly referring* clients with one or more symptoms of TB disease for medical care
- *Promptly reporting* clients with suspected or confirmed TB disease to the public health department
- *Separating* clients with symptoms of TB from other clients and staff by placing them in rooms by themselves until they can be medically evaluated the next day (Clients may also be instructed to use masks over the nose and mouth to trap droplet nuclei and be monitored for use of masks.)
- *Making tissues readily available* to clients, instructing them to cover the nose and mouth with tissues when coughing and sneezing, and reinforcing this behavior with signs and verbal reminders
- *TB screening of shelter staff and clients,* such as TB symptom screening, tuberculin skin testing, chest x-ray, and medical follow-up, if indicated
- *Assisting the local public health department* in treating shelter clients for TB infection and disease
- *Educating staff and clients* about TB
- *Placing each bed as far from neighboring beds as possible,* with head-to-foot, instead of head-to-head, arrangement of beds

Note: *Shelters should not house clients who are being evaluated for, or known to have, TB disease of the lungs or larynx until the conditions listed in Section D, "When TB Is Contagious," have been met.* Consult with your local public health department for assistance with alternative housing.

Ventilation, Filters, and UVGI

These measures will reduce the chances that others will inhale air containing *M. tb,* and are the subject of this guideline.

Staff Use of Respiratory Protection

A respirator is a "mask" that fits over the nose and mouth of the user. In TB control, a respirator is designed to prevent the user from inhaling droplet nuclei containing *M. tb.*

The Occupational Safety and Health Administration (OSHA) has specific requirements for staff use of respirators. Contact OSHA for additional information.

F How Ventilation Can Reduce the Risk of Spreading TB

What Is Ventilation?

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

- *Natural ventilation* 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* 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 Likelihood That TB Will Spread

Ventilation can reduce the spread of TB through *dilution* and *removal*.

When clean or fresh air enters a room, by either natural or mechanical ventilation, the fresh air *dilutes* the concentration of particles, such as droplet nuclei, in room air. This is similar to opening doors and windows to dilute objectionable odors.

The *removal* effect occurs when potentially contaminated room air is either:

- exhausted outdoors to a safe place, or
- *filtered or irradiated* to trap or inactivate some or all droplet nuclei containing *M. tb.*

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 mixture is then exhausted.

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

Ventilation Rate of a Mechanical System

A straightforward way to increase the effectiveness of ventilation is to increase the amount of air moving through a space—in other words, to increase the *ventilation rate.*

A room's ventilation rate can be calculated if it has mechanical ventilation. The ventilation rate can then be compared to rates listed in published codes, standards, and recommendations.

The ventilation rate is usually expressed in *air changes per hour (ACH).* One *air change* occurs in a room when a *volume of air* equal to the *volume of the room* is supplied and/or exhausted.

Appendix A describes air change rates in more detail and demonstrates how to calculate the air change rate of a room that has mechanical ventilation and/or a HEPA filter unit.

Air Supply and Exhaust Locations

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.

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, people whom you are trying to protect from TB exposure should be located near supply air. Clients who may be infectious should be situated near where air is exhausted from the space.

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 shelter 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 clients may be found, such as a dormitory or a TV room, anyone could be a source of TB, and TB could spread to others in the room. Therefore, the direction of air movement does not matter. It is more important to achieve good air mixing in all locations so that particles are more quickly diluted and removed.

G How UVGI Can Reduce the Risk of Spreading TB

What Is UVGI?

UVGI, or ultraviolet germicidal irradiation (see the glossary in Appendix C), uses a type of radiation that has been shown to kill or inactivate *M. tb* in air. A specially designed light fixture with a bulb that often looks something like a florescent lamp generates a type of UV radiation (UV-C).

There are two ways that UVGI is used in TB control:

- *In-duct UVGI* is the use of UVGI lamps inside an air duct or air cleaner. In-duct UVGI works much like a filter. See Section 2 for a detailed discussion of in-duct UVGI.
- *Upper-room UVGI* is the mounting of UVGI lamps in a room where there is a risk of TB spreading. See Section 3 for a detailed discussion of upper-room UVGI.

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 fast 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 humidit*y (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.

When UVGI is used in a homeless shelter, precautions should be taken to alert and protect staff and clients. Staff should also receive appropriate education. UVGI is described in more detail in Sections 2 and 3.

1 Natural Ventilation and Fans

A Introduction

Many buildings that are used as homeless shelters do not have a central forced-air heating and/or air-conditioning system. For example, many unventilated warehouses have been converted for use as shelters. Or they may have such a system, but it may be broken or otherwise not operational.

In such buildings, 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.

B How to Use This Section

This section explains how fresh air and fans can be used to improve ventilation in a building.

- If rooms in your building are not served by a central ventilation system, you should read this section to learn how to check and improve natural ventilation. Learn what to check and how it can be improved.
- Use this section to learn how to use exhaust and freestanding fans more effectively.
- Read the case study to see how one homeless shelter director used the ideas in this section to improve ventilation in her building.
- Read the advantages and disadvantages of natural ventilation to compare natural ventilation and fans to other types of ventilation.

C Natural Ventilation

Natural ventilation refers to fresh dilution air that enters and leaves a building through openings such as windows, doors, and skylights. All dormitories, lounges, and other congregate rooms 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.

D 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 roof. 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

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 risk than an enclosed room with no fan, an enclosed room with a fan, or a room with an open window but no fan.

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.

Consider fans installed in the windows on the back wall of a building. The fans exhaust air 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, staff should be placed near the front of the building, and people who are coughing

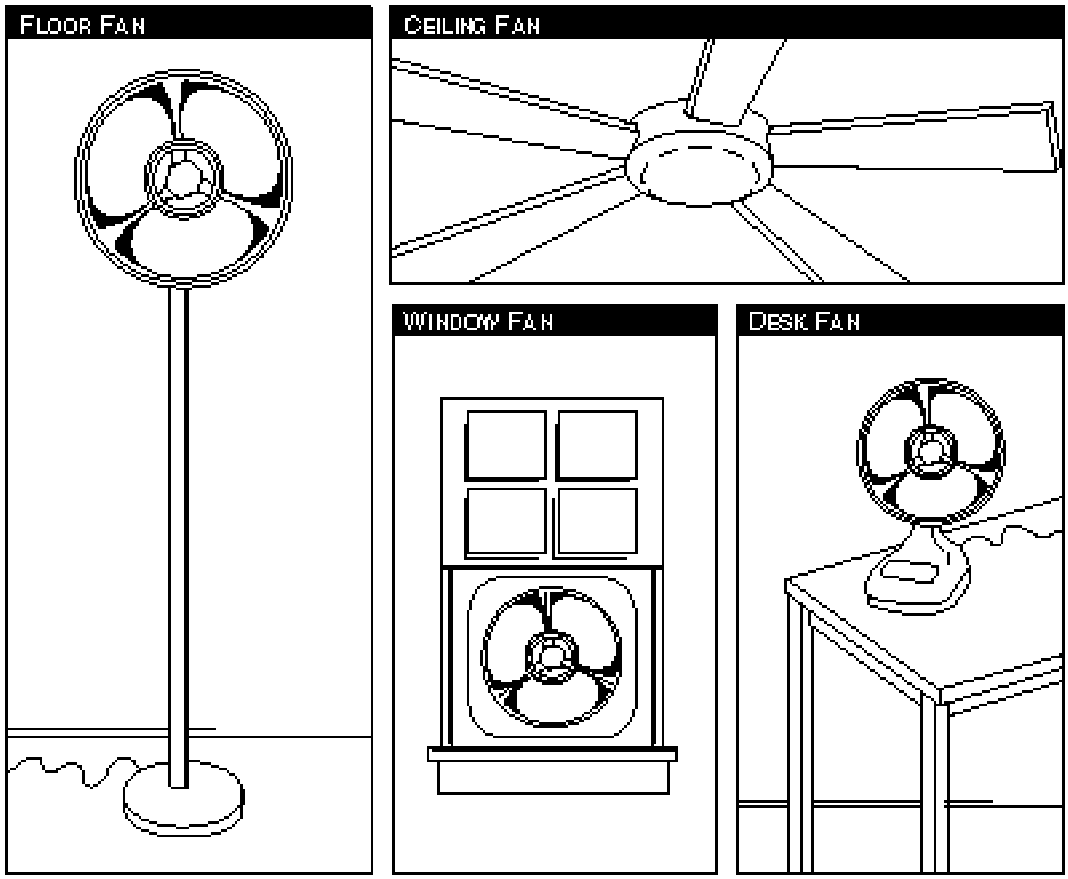


Figure 1. Propeller fans

or have other symptoms of airborne infectious diseases, including TB, should be placed near the exhaust fans.

E Exhaust Fans

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, 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.

F Checking Natural Ventilation and Fans

People can usually feel the existence or lack 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 shelter:

- 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.
    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 shelter. 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 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.

G Recommendations for Natural Ventilation and Fans

- Provide fresh outside air to all occupied rooms in homeless shelters. 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.
- Place fans so that air movement can be felt in all occupied parts of the room.
- Room fans should be placed in locations so they 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.
- 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. Many shelters are closed during part of the day, for example. This provides 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 Section 2, "Central Ventilation Systems." If this is not feasible, consider the use of HEPA filter units or upper-room UVGI to provide clean air on a room-by-room basis. See Section 3, "Upper-Room UVGI and HEPA Filter Units."

H Routine Upkeep of Natural Ventilation and Fans

- Clean exhaust fan outlets and fans about once a month with a vacuum cleaner. Use a 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.
- Check natural ventilation about once a year.
- Keep records of all routine upkeep activities and dates.

Natural Ventilation and Fans Case Study

Lynn Vail 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 Los Angeles homeless. 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.

Lynn decided to reduce the TB risk by screening clients for symptoms of TB. She contacted her local TB control program to find out how to do this.

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—that is, 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 upwards and from the front of the building toward the back.

Lynn had a look 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 to be cleaned.
- The fan in the women's room was not operating.

How could Lynn improve the situation with her limited budget? She gave herself a week to think about it. In the meantime, 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 for each at her local hardware store. 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 wall.

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 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 up 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.

J Advantages and Disadvantages of Natural Ventilation and Fans

Advantages

- 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.

Disadvantages

- Natural ventilation can be uncontrollable and unpredictable depending on wind conditions and other factors. For example, clients 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 winter.

2 Central Ventilation Systems

A Introduction

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 spread particles containing *M. tb* 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.

B How to Use This Section

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

- Read this section to learn about the various parts of your central ventilation system and how they help control the spread of TB. Learn what to check and how to make improvements. Topics covered include:

- which type of air filter you should use
- increasing the amount of fresh air brought in from outside
- the use of in-duct UVGI
- which type of thermostat you should use

Staff members who have little or no previous knowledge of mechanical systems can make many of the improvements described below. 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.

- Read the case study to see how one homeless shelter director used the ideas in this section to make immediate low-cost improvements to ventilation in his shelter.
- Architects, engineers, and others planning the design of new ventilation systems for an existing or a new shelter should read the recommendations for the design of new central ventilation systems.
- Read the advantages and disadvantages of central ventilation to compare a central ventilation system to other types of ventilation.

C Ventilation Systems

What Is a Ventilation System?

Forced-air systems come in many different configurations. A 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, however, 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)

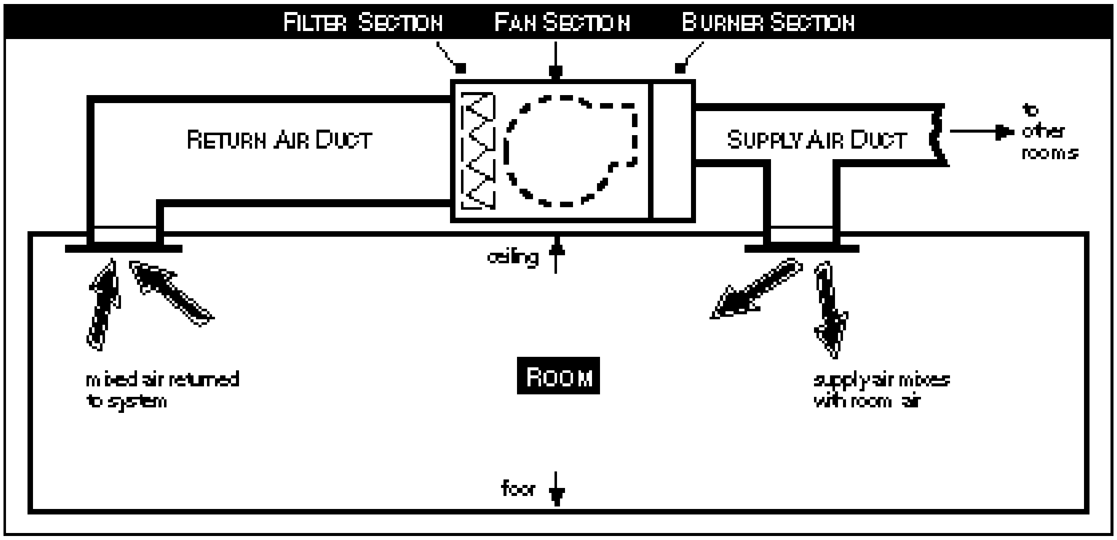


Figure 2. Central ventilation unit

These components may all be installed in a single unit or may be 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)

Recirculating Systems

Many homeless shelters have a mechanical system that recirculates all air returned to the system—that is, 100% recirculation.

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.

Return Air and Exhaust Air

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.

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. Exhaust fans are discussed in Section 1.

TB Transmission and a Central Ventilation System

A central ventilation system should help reduce the spread of TB in two ways:

- by reducing the amount of TB particles in the supply air stream
- by effectively using this supply air to dilute infectious particles in the building

Recirculating air can both help and hinder the spread of airborne infection.

- When air is supplied and removed at a room in which particles are being generated, it displaces the contaminated air in that particular room.
- However, the air taken from this room is circulated to other rooms. This increases the number of areas in which people are at risk.

In other words, the ventilation system can spread the risk throughout the rest of the building while it reduces the risk in the room occupied by an infectious person.

D 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. tb* 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, such as those in homeless shelters, is a *pleated filter.* Pleated filters are so called because the filter inside the filter frame is folded into pleats. More common lint filters are flat.

The graph in Figure 3 compares the efficiency of three different types of filters: a high-efficiency particulate air (HEPA) filter; a pleated ASHRAE 25% efficient filter; and a lint filter. (ASHRAE 25% filter is an industry term for a type of pleated filter; ASHRAE is the American Society of Heating, Refrigeration, and Air-Conditioning Engineers.) The shaded area represents the size range of TB droplet nuclei. Each of the three filters will remove an amount of particles equivalent to the area under the line corresponding to that filter.

- 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 can remove approximately half of all particles in the size range of TB droplet nuclei.*

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, *filters should be checked visually every month and replaced 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)

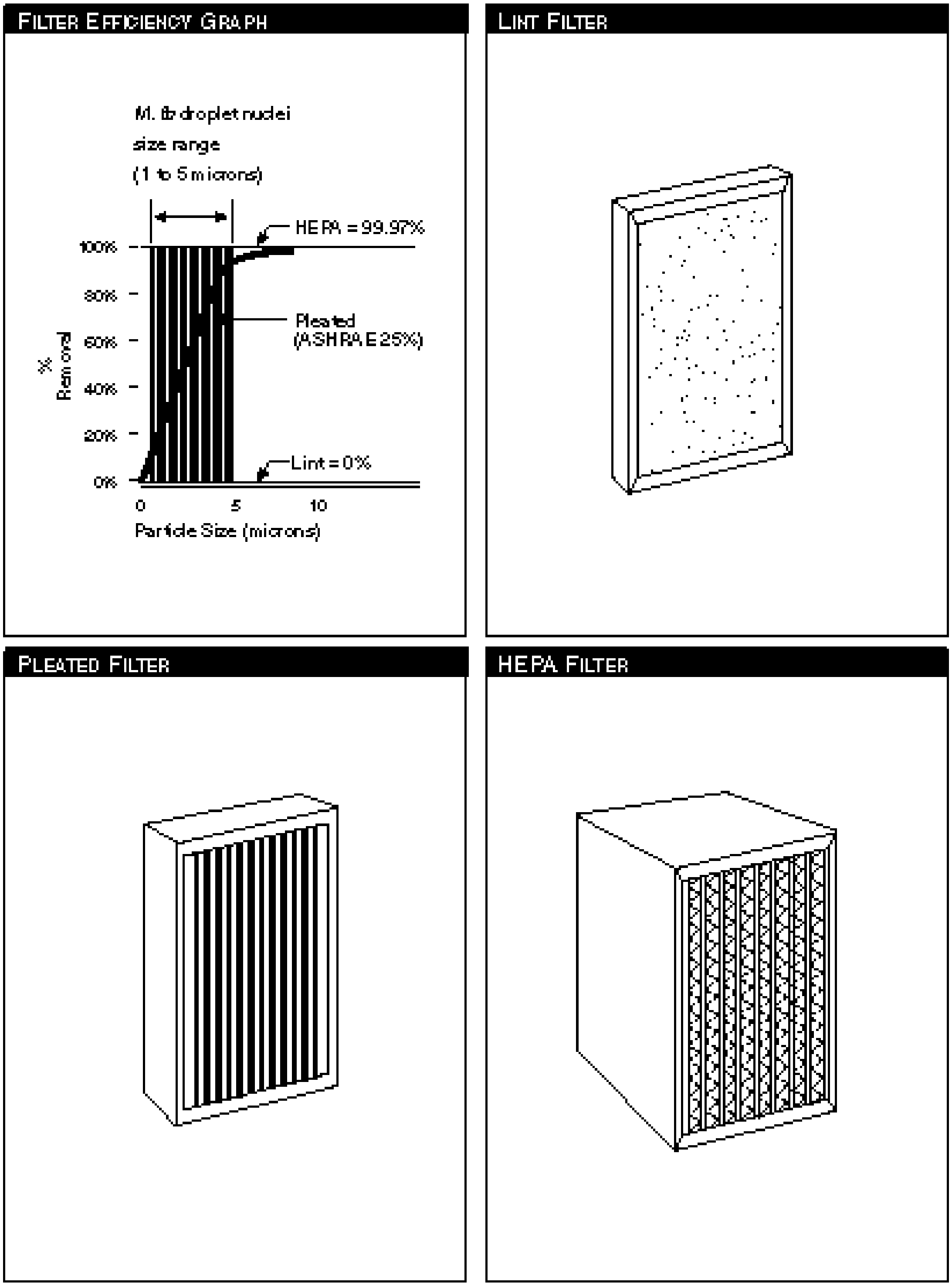


Figure 3. Air filters

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.

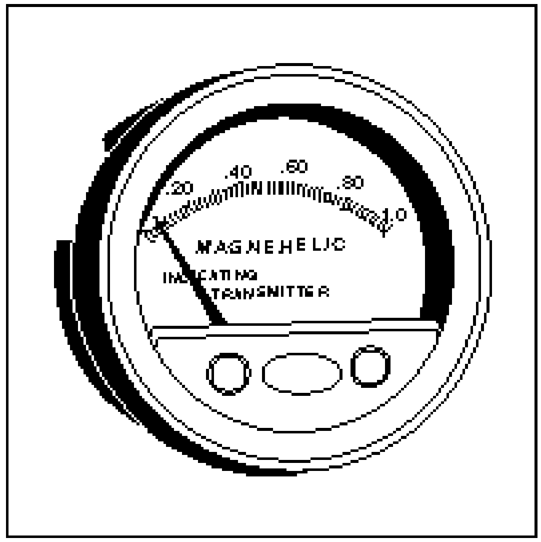


Figure 4. Air filter gauge

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 column ("W.C.).

A *filter gauge* installed across a filter bank shows the pressure drop across the filter in "W.C. This is the most effective way to track filter loading and to tell 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 therefore 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.C. As the filter loads up, the pressure drop will increase. The filter is usually replaced when the pressure drop increases by about 0.20" W.C. to about 0.45" W.C. 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, a filter gauge should be installed if the system includes more than one filter—that is, you should install a filter gauge if you have a filter bank rather than 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.

E Outside Air

For TB control, the best type of system is one without recirculation—that is, a 100% outside air, 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.

But 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.

For homeless shelters, 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 provided 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.

F In-Duct UVGI

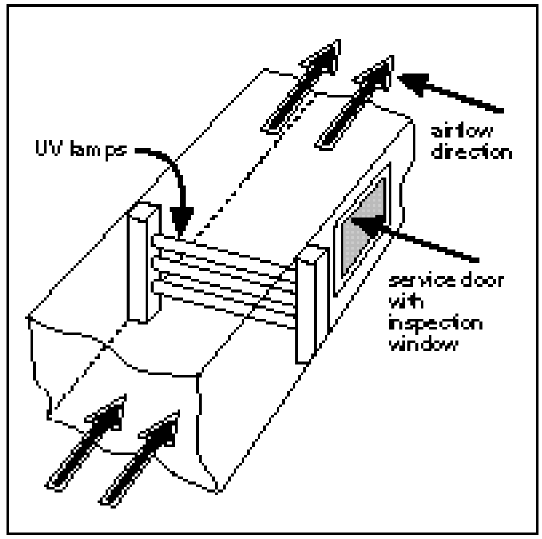


Figure 5. In-duct UVGI

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 from recirculated air. 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 both areas at high risk for TB transmission and areas without this risk.

Installation and Monitoring

A UVGI installation should be designed and installed by an experienced professional, such as a UVGI lamp manufacturer, 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, especially in the homeless shelter setting.

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-room UVGI because the lamps are mounted inside the ductwork, thereby reducing the risk of UV exposure to staff and clients. 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 of direct exposure to the bulbs should be posted on, or adjacent to, the viewing window.

Monitoring and maintenance is crucial, because the intensity of lamps fades over time. See Section K, “Routine Upkeep of Existing Central Ventilation Systems.”

Advantages and Disadvantages of In-Duct UVGI

An advantage of in-duct UVGI as an upgrade to an existing system is that, unlike HEPA filters, lamps 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.

In-duct UVGI is usually less expensive to operate than a 100% outside air system.

A disadvantage is that 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.

G Diffusers and Grilles

Ducts convey the *supply* air to the rooms and draw *return* or *exhaust* air back to the unit.

Air *outlets* deliver or remove air at the room ceiling, wall, or floor.

There are two types of outlets: diffusers and grilles.

- *Diffusers* deliver only supply air and are used only on a ceiling. They can be square, rectangular, or round in shape.
- *Grilles* (also called *registers*) are more flexible. A grille may be used for either supply or return in a system. A grille may supply air high on a wall. Grilles or registers also exhaust air on a ceiling, high or low on a wall, or at the floor.

A single system may include any combination of these outlet types. For example, both ceiling diffusers and grilles high on the wall could supply air in different rooms. The same system could return air by means of a grille on a wall.

Diffuser and Grille Locations

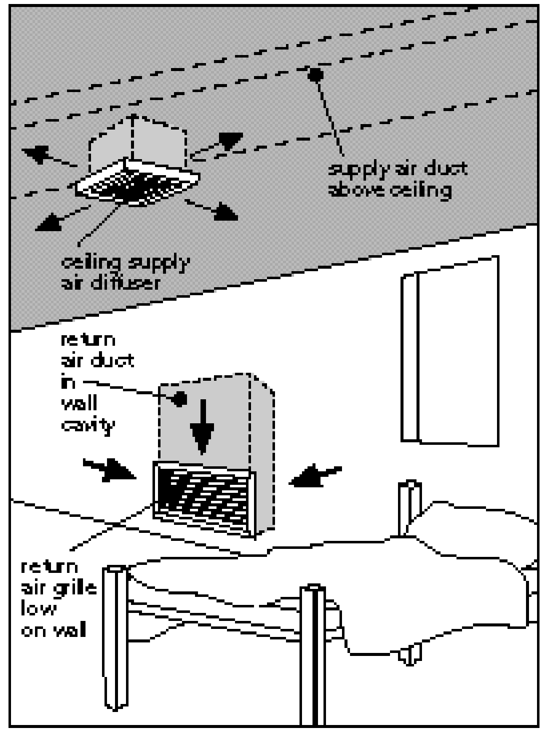


Figure 6. Examples of diffusers and grilles

Supply air provides the heating or cooling effect. It also reduces the concentration of infectious particles in a room. Therefore, supply is more important than return. In ICS experience, in most buildings used as homeless shelters, 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.

H Thermostat

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
- an *adjustable setpoint* 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 setpoints for weekdays and weekends.

The simplest type of thermostat is a two-position switch that switches 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 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 setpoint. This type of control is not recommended for TB control because the system does not operate continuously.

A central ventilation system will help stop the spread of TB only when the ventilation system is operating. The thermostat should be adjusted or replaced to make sure that air is circulated continuously whenever the building is occupied.

For a homeless shelter with a forced-air ventilation system, use a thermostat that, at a minimum, allows the fan to operate even when heating or cooling is not required. Such a thermostat will have at least three settings, OFF, AUTO, and FAN ON. The thermostat should be set to FAN ON whenever the building is occupied.

Checking a Central Ventilation System

To improve TB control and general indoor air quality, *make regular checks of all ventilation systems serving homeless shelters. 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 unit location, rooms served by the unit, the thermostat location, and the number and size of filters.

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.

A blank list is provided for your use in Appendix B. Also included is an example of a completed table.

Other assessment activities include the following:

Checks at Ventilation Unit or Furnace

- Check that:
    - the unit is operating
    - the unit has filters

  - the filters are the pleated type
  - the 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 to see if 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.

Checks at Rooms

- Check that each 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 all occupied rooms are served by a central ventilation unit.
- 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:
  1. Hold two incense sticks together and light them.
  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 shelter. 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 outlets are clean.
- Check return and exhaust air ductwork for dust and lint buildup.
  Return and exhaust air often includes 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.

J 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.
- Provide 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.

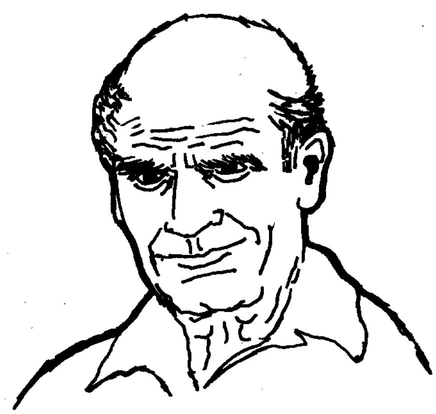
K Routine Upkeep of Existing Central Ventilation Systems

- 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 can reach.
- Check ventilation units and thermostats every year. Make sure that thermostats turn on 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.

L Central Ventilation System Case Study

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



The shelter screens clients for TB symptoms at intake and regularly screens staff for TB infection. After several negative annual tuberculin skin tests, James 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 James 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.

James 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. James 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. James 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. James 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, James decided to keep at least two windows open whenever the building was occupied.
- James 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.

M Recommendations for the Design of New Central Ventilation Systems

Architects, engineers, and others designing mechanical systems for new or renovated homeless shelters should consider the following recommendations.

Ventilation Rate

- Provide a ventilation rate of at least 6 ACH in rooms frequented by clients. Dilution ventilation is the most effective engineering 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. At least 6 ACH is the minimum rate recommended by

ASHRAE for waiting rooms in health facilities. Given the risk of TB among the homeless, a shelter is comparable to a hospital waiting room.

Once-Through System or Economizer Capability

- Consider using a 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 setpoint.* 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 2 ACH for waiting rooms in health facilities. (This is 33% of the recommended total air change rate mentioned above.) The higher of the two airflow rates generated by means of these criteria should be used as the minimum outside air setpoint.

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 they 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.

N Advantages and Disadvantages of a Central Ventilation System

Advantages

- Can be effective 24 hours a day, year-round
- Controllable, adjustable, and predictable
- Helps prevent transmission of airborne infectious diseases
- Helps control temperature, odor, and indoor air pollutants

Disadvantages

- Expensive to plan, install, operate, and repair
- May be drafty and/or noisy
- Maintenance required

A Introduction

3 Upper-Room UVGI and HEPA Filter Units

Previous sections have shown 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-room 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 homeless shelter.

B How to Use This Section

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

Upper-Room UVGI

Upper-room UVGI is a specialized technology that is particularly appropriate for homeless shelters but can only be used in certain rooms.

- You should first use this section to get an overview of upper-room UVGI and determine if it can be used in your shelter.
- If UVGI is appropriate, you should use this section for advice on finding an installer and working with the installer to plan and install the fixtures so they are safe and effective.
- You should also use this section on an ongoing basis to evaluate an existing installation and to help make sure that staff and clients are protected from the hazards of overexposure to UV radiation.

HEPA Filter Units

HEPA filter units are readily available machines that can be used anywhere to provide clean air.

- You should use this section to get an overview of HEPA filter units and to learn how to use them effectively.
- If you are considering the purchase of a HEPA filter unit, you should use this section to determine what type and size of unit is suitable.
- This section can also be used to help plan routine upkeep of HEPA filter units.

C Upper-Room UVGI

Introduction to Upper-Room UVGI

Upper-room UVGI uses UVGI lamps and room air currents to help stop the spread of TB. It is often recommended to supplement ventilation in crowded, group settings like homeless shelters.

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-room UVGI to supplement ventilation should be considered.

What Is Upper-Room UVGI?

Upper-room 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-room 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.

At no location should the measured UVGI intensity be more than the NIOSH REL.

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.

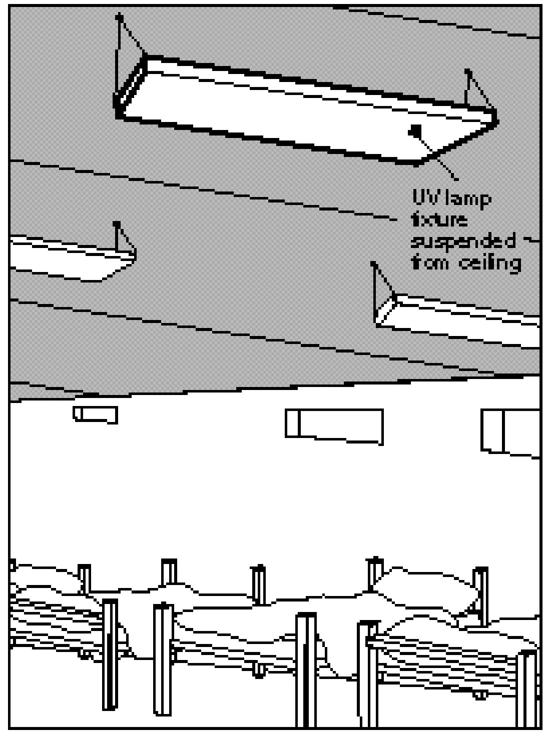


Figure 7. Upper-room UVGI in a dormitory

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-room 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:

- the type of lamps used
- the effectiveness of the fixture baffles at preventing radiation from reaching occupied areas
- the locations of the fixtures
- the 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.

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.*

UVGI Radiometer

Radiation levels are measured with a device called a *radiometer.* The radiometer should be calibrated specifically to measure UVGI radiation. These meters cost approximately $1,400 in 1999.

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-Room UVGI Is Suitable for a Particular Room

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

- *Upper-room 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.
- Unless a dormitory has a very high ceiling, *bunkbeds should not be used in dormitories.* A client who is sitting on the top bunk of a bunkbed 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-room with the potentially contaminated air below. The fans or ventilation system should be operating continuously when the building is occupied.

Preparing for an Upper-Room UVGI Installation

- *Find a suitable consultant and contractor.* A poorly installed upper-room UVGI system could result in:
    - harmful radiation levels in the occupied space, and
    - ineffective radiation levels in the upper-room bacterial kill zone

Upper-room UVGI requires specialized expertise and equipment. Only a qualified contractor, working closely with a lamp manufacturer's representative, should attempt the design, installation, and testing of an upper-room 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 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-room UVGI.
4. Talk to the contractor about the possibility of arranging a service contract for monitoring and replacement of the lamps after the installation.

Planning an Installation

The following items should be addressed before installing UVGI fixtures:

- *UVGI fixtures should be located so that radiation in the upper-room is uniform, continuous, and complete.*
- *The installation contract should include measurements of radiation levels* after installation. These measurements should be taken before the job is accepted and payment is made. A written report should be submitted to the owner.
    - The installation is not complete, and the lamps should not be used, until readings have been taken in the occupied zone to ensure that radiation levels are below the NIOSH REL. Readings should be taken in a number of locations corresponding to where people will be exposed.
    - Radiometer readings should be taken at each lamp to ensure that the radiation intensity meets the manufacturer's specifications.
- *Nonreflective 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 nonreflective paint. This should be included in the budget for the planned installation. Paint containing titanium dioxide is recommended for reducing reflection from surfaces.

- *Warning signs,* in all appropriate languages, should be posted on the UVGI fixtures and on the walls. The signs should carry the following or a similar message:
- Staff and clients may have concerns regarding health hazards from UVGI. To address these concerns, provide *education* on the purpose, benefits, and risks associated with upper-room UVGI. (The federal

> CAUTION
>
> High-Intensity 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.)

  Occupational Health and Safety Administration [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 individuals may turn off the fixtures.

D Checking Upper-Room UVGI

- Check radiation levels in parts of the room where people are likely to be exposed. A radiometer should be used. 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 nonreflective 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.

E Routine Upkeep of Upper-Room UVGI

- 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.
- Check and clean lamps and fixtures every 3 months. Use a cloth dampened with water or alcohol. Turn off the lamps before they are cleaned.
- 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 radiome ter readings and dates. This will help determine the average life of the lamps. Lamps should be purchased close to your planned replacement time because prolonged storage may result in a loss of radiation intensity.

F Advantages and Disadvantages of Upper-Room UVGI

Advantages

- Inexpensive to buy and operate compared to a central ventilation system
- Can be implemented room by room
- Limited impact on structure and mechanical systems
- Does not cause noise or drafts

Disadvantages

- Potentially hazardous to staff and clients

- 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 clients who are trying to sleep
- Staff and clients may have unwarranted fear of radiation

G HEPA Filter Units

Introduction to 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 homeless shelters that may have inadequate or no ventilation and limited funds for upgrades.

What Is a HEPA Filter Unit?

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 (for example, on/off switch and fan speed control)

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.

HEPA filter units are sized based on the amount of air they deliver, usually expressed in cubic feet per minute (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. In the homeless shelter setting, small units are useful for case manager 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.

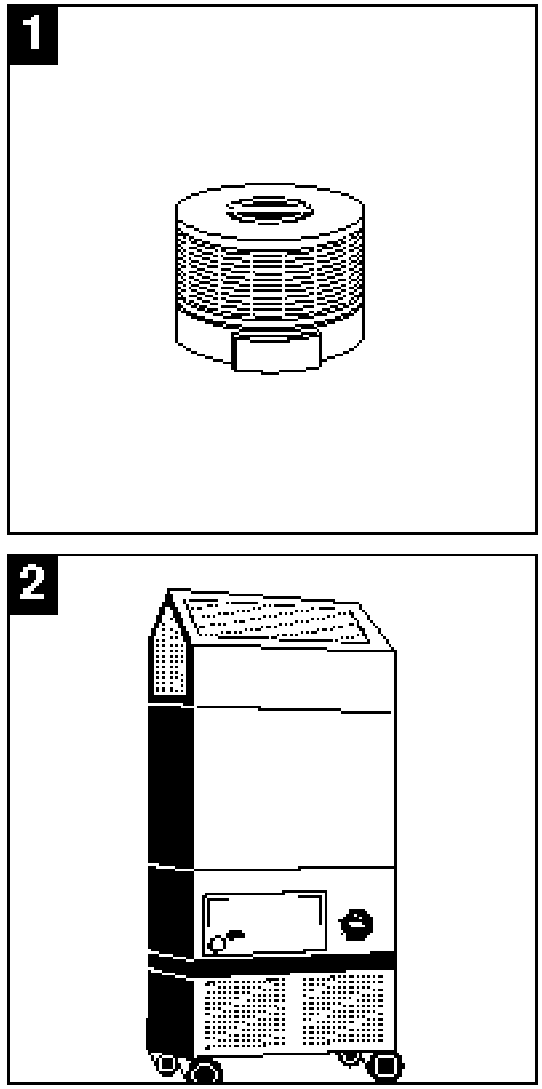


Figure 8. Small (1) and large (2) HEPA filter units

These units are readily available from hardware stores and similar retail outlets and cost around $100 in 1999.

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.

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 and in 1999 usually cost from $2,000 to $3,500.

H Recommendations for HEPA Filter Units

HEPA Filter Operation

- Provide portable HEPA filter units for all unventilated rooms frequented by 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 they generate is delivered close to the faces of the people that they are used to protect. An ideal location is on a desk or on a file cabinet adjacent to a staff member. 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 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 Appendix A, "What Does Air Change Mean?," for a more detailed description of room air change rates. ASHRAE recommends the minimum air change rate of 6 ACH for both waiting rooms and 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 rates 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 table on the next page lists recommended airflow and minimum HEPA filter unit sizes for some sample room volumes.

I HEPA Filter Unit Selection Table

This table can be used to select a HEPA filter unit based on measured room volume. The recommended safety factor is included.

Room Volume (cubic feet)	Airflow Required for 6 ACH (CFM)	Listed Minimum Airflow (CFM)
800 or less	80	100
1,000	100	130
1,500	150	190
2,000	200	250
4,000	400	500
8,000	800	1,000

- *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 air changes per hour (6 ACH)* (second column) is the ICS's minimum recommended air change rate for occupied rooms in homeless shelters.

  The required airflow in cubic feet per minute (CFM) to achieve this air change rate is calculated as follows:

  (*room volume* x 6 ACH)/60 minutes per hour = *airflow* in cubic feet per minute
- 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.

J Routine Upkeep of HEPA Filter Units

- 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, the prefilters should be replaced every 6 months, and the HEPA filters should be replaced 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.

K HEPA Filter Unit Case Study

Catherine Cao 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 air changes per hour (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:

room volume = ***width*** **x** ***length*** **x** ***height***

= **8 x 10 x 9.5**

= **760 cubic feet**

Next, she calculates the required airflow for a ventilation rate of 6 ACH:

airflow required for 6 ACH	**=**	***room volume* x 6 ACH**
	=	**760 x 6**
	=	**4,560 cubic feet per hour**
	=	**4,560/60 cubic feet per minute**
	=	**76 CFM**

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 CFM x 1.25 = 95 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.

L Advantages and Disadvantages of HEPA Filter Units

Advantages

- 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
- Does not require costly equipment to evaluate

Disadvantages

- Unpredictable because, if controls are accessible, clients and staff may turn them down or off; also, clients may move or unplug them
- Can be drafty and noisy
- Do not bring in outside air
- Do not filter out odors

Appendices

A What Does *Air Change* Mean?

What Does Air Change Mean?

One air change occurs in a room when a quantity of air equal to the volume of the room is supplied and/or exhausted.

Air change rates are units of ventilation that compare the amount of air moving through a space to the volume of the space. Air change rates are calculated to determine how well a space is ventilated compared to published standards, codes, or recommendations.

The most common unit used is *air changes per hour (ACH).* This is the volume of air (usually expressed in cubic feet) exhausted or supplied every hour divided by the room volume (also usually expressed in cubic feet).

Airflow is usually measured in cubic feet per minute (CFM). This is multiplied by 60 to give the volume of air delivered per hour in cubic feet.

$$ACH = \frac{\text{airflow per hour}}{\text{room volume}}$$

$$= \frac{\textbf{CFM x 60 minutes}}{\textbf{cubic feet}}$$

ACH is air changes per hour

60 is a constant (60 minutes per hour)

Airflow (usually in cubic feet per minute)

Room volume (usually in cubic feet) is *room width* (ft) x *room length* (ft) x *room height* (ft)

B Summary of Ventilation Units Worksheet

The following form should be completed to create a handy summary of information on the ventilation units in a building.

A sample of the completed form is also included.

Summary of Ventilation Units

Home at Last

Unit Location	Rooms Served by Unit	Thermostat Location	Filters (Number) and Size
Attic above men's dorm	Women's and men's dorms	Large men's dorm	(1) 15" x 27" x 2"
Notes: Filter is behind return grille in large men's dorm. Spare filters are stored in janitor's closet. Access to unit is through ceiling hatch in men's dorm.			
Janitor's closet in kitchen	Kitchen, meeting room, dining room, women's bathroom	Dining room	(1) 24 1/2" x 19 1/2" x 2"
Notes: Filter is at unit; undo four screws to change. Spare filters are stored in janitor's closet.			
Roof above director's office	Offices, women's dorm, small men's dorm, men's bathroom	Women's dorm	(1) 24 1/2" x 19 1/2" x 2"
Notes: Filter is near unit on roof; ladder to get to roof is in shed. Spare filters are stored in janitor's closet.			

SUMMARY OF VENTILATION UNITS

UNIT LOCATION	ROOMS SERVED BY UNIT	THERMOSTAT LOCATION	FILTERS (NUMBER) AND SIZE
NOTES:			
NOTES:			
NOTES:			

C Glossary

ACH: Air changes per hour. This is a measurement commonly used to express the ventilation rate of a space. ACH is the number of times an amount of air equal to the volume of the space is exhausted or supplied every hour.

ASHRAE: American Society of Heating, Refrigeration, and Air-Conditioning Engineers.

CDC: Centers for Disease Control and Prevention, a federal agency.

CFM: Cubic feet per minute. This is a measurement commonly used to express an airflow quantity. Airflow hoods usually provide readouts in CFM.

Diffuser: Mechanical device, installed on a ceiling, that supplies air to a room.

Droplet nuclei: Microscopic particles (1–5 microns in size) that can become airborne when a person coughs, sneezes, shouts, sings, breathes, or talks. Droplet nuclei produced by a person who has TB disease of the lungs or larynx in an infectious state can remain airborne for a long time and can spread TB to others.

Exhaust air: Air that is removed from a building by a fan system, as opposed to air that is removed from a space and then recirculated or returned.

Grille: Mechanical device that usually removes exhaust or return air from a room. Grilles are usually on the ceiling but can be on the wall or floor. If a grille is on a ceiling or floor or low on a wall, it is usually for exhaust or return air. However, if a grille is high on a wall, it can be exhaust, return, or supply.

HEPA filter: High-Efficiency Particulate Air filter. This is a filter that is capable of removing 99.97% of particles 0.3 micron in diameter or greater. HEPA filters remove all particles in the size range of TB droplet nuclei.

HEPA filter unit: Self-contained device consisting mainly of a HEPA filter, a prefilter, and a fan. These units can be used to provide clean air to supplement a building ventilation system.

OSHA: Occupational Safety and Health Administration, a federal agency.

Recirculation: Ventilation system in which supply air includes air that has been previously removed from an interior space.

Return air: Air that is removed from a space by a mechanical system, but not all of it is discharged directly outdoors. This air is usually returned to the mechanical system, where a portion of it is exhausted. The remainder is diluted with some outdoor air, filtered, conditioned (or heated), and then distributed.

Supply air: Air that is introduced into a space by a mechanical system.

TB control measures: Steps taken to reduce the risk of TB transmission. TB control measures are usually divided into a hierarchy: (1) administra tive (work practice) controls, (2) engineering controls, and (3) respiratory protection.

UVGI: UltraViolet Germicidal Irradiation. The use of ultraviolet radiation to kill or inactivate microorganisms.

UVGI lamps: Lamps that kill or inactivate microorganisms by emitting ultraviolet germicidal irradiation, predominantly at a wavelength of 254 nanometers. UVGI lamps are used in ceiling or wall fixtures for upper-room UVGI and inside air ducts or air cleaners for in-duct UVGI.

Ventilation rate: Quantity of air that is removed from or supplied to a room. It is usually expressed in air changes per hour (ACH).