
Isolation Rooms:

Design, Assessment, and Upgrade



FRANCIS J. CURRY NATIONAL TUBERCULOSIS CENTER

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Abbreviations

Organizations

AIA	American Institute of Architects
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
Cal/OSHA	California Division of Occupational Safety and Health (California OSHA)
CDHS	California Department of Health Services
CDC	Centers for Disease Control and Prevention
CMC	California Mechanical Code
ICS	Institutional Consultation Services
OSHA	Occupational Safety and Health Administration (federal)
OSHPD	Office of Statewide Health Planning and Development (California)
UBC	Uniform Building Code

Terms

ACH	air changes per hour
CFM	cubic feet per minute
FPM	feet per minute
HEPA	high efficiency particulate air
HVAC	heating, ventilating, and air conditioning
" W.C.	inches of water column
<i>M. tb</i>	<i>Mycobacterium tuberculosis</i>
PIN	policy intent notice
TB	tuberculosis
UV	ultraviolet
UVGI	ultraviolet germicidal irradiation
VAV	variable air volume

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Preface

A Institutional Consultation Services

Institutional Consultation Services (ICS), a component of the Francis J. Curry National Tuberculosis Center, is funded by the Centers for Disease Control and Prevention (CDC) and the California Department of Health Services (CDHS). ICS staff have expertise and practical experience in infection control, occupational health, and mechanical engineering. Telephone and on-site consultations are provided to tuberculosis (TB) control staff of high-risk institutions, including health-care facilities, correctional facilities, and shelters.

B Background of the Isolation Room Guideline

During 1997 and 1998, ICS provided 24 on-site consultations to: 7 acute care hospital emergency departments, 14 public health clinics, and 3 community clinics. These consultations included evaluations of engineering control measures in rooms used to isolate or segregate known or suspected infectious TB patients. Consultations also included interviews with facility TB control personnel to determine their knowledge and skills regarding critical aspects of isolation room engineering controls.

C Key Findings from On-Site Consultations

Deficiencies in isolation room engineering controls identified by ICS were due primarily to a lack of available information and included the following observations:

- Known and suspected infectious TB patients were isolated in rooms with inadequate engineering controls such as: low air change rates, recirculation of isolation room air, and positive or neutral room pressurization.
- Most deficiencies in isolation room engineering controls could have easily been detected using simple assessment techniques, but expertise regarding such techniques was often not available.
- Monitoring and maintenance of isolation room engineering controls were often lacking. Design documents indicated that engineering controls in most rooms were probably adequate when first installed or upgraded. However, many had drifted out of compliance and were not routinely monitored. In one instance, a fan serving several isolation rooms was not working.

- Facility TB control personnel were often unaware of available guidelines and regulations governing engineering controls for isolation rooms.
- Facility personnel often lacked information regarding characteristics of a suitable room to isolate or segregate suspected or known infectious TB patients. Personnel often did not know how to select or assess a room for this purpose, or how to upgrade a room.
- Engineering Departments often did not share information with the Infection Control Department. For example, facility engineering staff installed isolation room monitors, but did not inform infection control staff how to use them.

D Identified Facility Needs

A consistent need was identified among facility TB control personnel for additional information about engineering control measures, in general, and their use in isolation rooms, in particular. The need for information and guidance pertaining to isolation room engineering controls in the following areas was compelling:

- Regulations and guidelines
- Assessment of isolation rooms
- Considerations for design of new isolation rooms
- Options for upgrade of existing isolation rooms
- Methods and techniques for monitoring

1 Introduction

A properly designed and operating isolation room can be an effective infection control measure. Infectious airborne particles are contained within the room, and the concentration of these particles inside the room is reduced.

However, a badly designed and/or incorrectly operating isolation room can place health-care workers and other patients at risk for TB infection and disease. In this situation, infectious particles may not be contained in the room, and/or their concentration inside the room may not be effectively reduced. Staff who rely on such an isolation room may have a false sense of security.

The mechanical elements that make an isolation room effective will deteriorate over time, which may make the controls ineffective. For example, fans can break and ducts can become clogged with dust and lint. People who have not been trained in engineering controls may inadvertently adjust or alter the controls. An isolation room that was successfully tested after construction may not be operating correctly a month later. Hence, periodic and ongoing assessment of negative pressure isolation rooms is important.

This guideline provides basic information about assessing and improving the design and operation of a negative pressure isolation room. It also includes options to convert an existing patient room into a negative pressure isolation room and information on guidelines and regulations covering isolation room engineering controls. In this guideline, the term “engineering controls” refers to the use of engineering concepts to help prevent the spread of infection.

TB control in high-risk settings is commonly organized in a **hierarchy**: **administrative (or work practice) controls** are the most important, followed by **engineering controls** and then **respiratory protection**. Although this guideline only addresses engineering controls, all three components should be in place for an effective TB control program.

Whenever an isolation room is used, written **policies and procedures** should be developed and implemented to address the administrative aspects of the isolation room. They should include: criteria for initiating and discontinuing isolation; who has authority for initiating and discontinuing isolation; isolation practices; and how often and by whom the policy and procedure is evaluated. Development and implementation of a written respiratory protection program is also required.

It is hoped that this document will prove useful to people responsible for engineering controls in health-care facilities. The target audience includes management, infection control, environmental health and safety, facilities management, and engineering staff in hospitals and clinics.

2 What Does Engineering Have to Do with Infection Control?

The Basics

A Transmission of *Mycobacterium tuberculosis*

TB infection and disease are caused by the bacterium, *Mycobacterium tuberculosis* (*M. tb*). *M. tb* is released in tiny particles when a person with TB disease of the lungs or larynx coughs, sings, talks, or breathes. These particles, called **droplet nuclei**, are approximately 1-5 microns in size. (A micron is one millionth of a meter.) If air containing these droplet nuclei is inhaled by another person, TB infection may result.

B Ventilation

Ventilation can reduce the overall risk of infection in a room in two ways: **dilution** and **removal**.

When clean air is supplied to a room, it **dilutes** the concentration of airborne contaminants in the room. Dilution reduces the likelihood that a person in the room will breathe air that may contain contaminants. In the case of *M. tb*, this effect means that a person will be less likely to inhale one or more droplet nuclei.

Ventilation helps reduce the risk of *M. tb* transmission in an isolation room, but significant risk remains. For this reason, a respiratory protection program is required even in state-of-the-art isolation rooms.

The **removal** effect occurs when air from a room is either:

- **discharged** outdoors to a safe place, or
- passed through a **HEPA¹ filter** to trap droplet nuclei before recirculation

¹ A HEPA (high efficiency particulate air) filter removes all airborne particles in the TB droplet nuclei size range from the air that is passed through it.

Air Change Rates

The amount of ventilation in an isolation room is usually expressed in **air changes per hour (ACH)**. By calculating the air change rate, the room ventilation can be compared to published standards, codes, and recommendations. It can also be used to estimate the length of time required to remove infectious particles.

One air change occurs in a room when a **volume of air** equal to the **volume of the room** is supplied and/or exhausted. The air change rate in ACH is the volume of air circulating every hour divided by the room volume. *Appendix A* describes how to calculate the air change rate of a room.

Diffusers, Grilles, and Registers

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

Ceiling supply outlets are called **diffusers**. Wall supply outlets are called **grilles** or **registers**. Exhaust (or return) outlets are also called grilles or registers, regardless of whether they are mounted on the ceiling or the wall.

The **neck** of the outlet is the point at which the outlet connects to the air duct. The neck size is selected to match the airflow quantity.

The **pattern** or style of an outlet is the physical configuration of its face as seen from the room. For example, outlets can have a louvered pattern or a perforated metal pattern.

Ⓒ Air Mixing, Stagnation, and Short-Circuiting

Ventilation air supplied to a room by a mechanical system will mix with air already in the room. This air mixture is removed by the exhaust. The effectiveness of dilution and removal depends on the effectiveness of the mixing process: the better the mixing, the better the dilution and removal. **Stagnation** and **short-circuiting** need to be avoided.

Stagnation occurs when part of the room does not benefit from the clean supply air. Infectious particles in a stagnant spot are not being diluted or removed.

Short-circuiting occurs when the exhaust is located too close to the supply; the clean air is removed from the room before it can effectively mix with and dilute contaminants in the room air.

Ⓓ Supply and Exhaust Location

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

The supply diffuser is an active device; it directs the flow of air in the room. For a given amount of air, the size of the diffuser neck determines how far this air will travel. The smaller the neck, the farther the air is directed. However, if the neck is too small, airflow is reduced and the diffuser will be noisy.

The pattern of the diffuser face determines the predominant direction of air movement, similar to how adjustable louvers direct air from a car's air conditioning system. If the diffuser face pattern consisted of parallel louvers at the same angle, then air would be "thrown" in only one direction. Most diffusers are designed to blow in all directions, but there are special models that blow in just two or three directions.

The supply diffuser should be sized and the discharge pattern selected so that supply air reaches all parts of the room. The best diffuser for directing air is a louvered blade, ceiling-mounted type. However, diffuser style is often selected based on esthetic, rather than engineering control, concerns. In general, perforated face diffusers are considered more pleasing to the eye, but they do not direct air as well as most other patterns.

The exhaust grille, in contrast to the supply diffuser, is a passive device; it simply gathers air that is near. To encourage air mixing, the exhaust grille should be located at a point remote from the supply. The grille should have a neck sufficiently large to easily draw in the required exhaust air quantity.

When the exhaust grille collects room air, dust and lint are deposited on the grille and on the exhaust ductwork. Over time, these deposits can clog up the grille and duct, reducing airflow. To compensate, exhaust grilles, ductwork, and fans should be slightly oversized.

E Directional Airflow

Ventilation can also reduce the **local** concentration of infectious particles at certain locations in a room. This is achieved by coordinating the location of the ventilation outlets with the probable positions of the people in the room. Simply stated, supply air should be introduced near staff, and exhaust air should be collected near patients.

For example, if an emergency department waiting room includes a reception area, the risk of *M. tb* transmission to staff can be reduced if clean air is supplied at the reception desk and removed at the patient area. This should result in a general air current away from staff and towards patients.

F Negative Pressure

Negative pressure is designed to contain infectious particles within a room by creating a continuous air current going into the room under the door. Therefore, when the room is used as designed, airborne particles generated in the room cannot escape to the corridor.

Negative pressure is created by setting (or balancing) a ventilation system so that more air is mechanically exhausted from a room than is mechanically supplied. This creates a ventilation imbalance, called an **offset**. The room makes up the offset by continually drawing in make-up air from outside the room.

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

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

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

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

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

Ⓒ Ultraviolet Germicidal Irradiation (UVGI)

UVGI, which has been shown to inactivate airborne droplet nuclei containing *M. tb*, may be used to supplement ventilation as an engineering control measure. Because UVGI can have negative short-term health effects on the skin and eyes, a safety plan should be implemented when it is used. UVGI has two applications: in-duct UVGI and upper room air UVGI.

In-duct UVGI is the installation of UV lamps in a return or exhaust air duct to kill any *M. tb* that may be in the airstream. This is useful as a supplemental engineering control in recirculating air systems, but is not recommended as an alternative to direct exhaust or HEPA filtration for isolation room exhaust.

Upper room air UVGI refers to the use of UV lamps directly in a room. Lamps are mounted high on walls or suspended from the ceiling. Radiation is directed into the upper portion of the room, where the air is disinfected. The ventilation system mixes this air with the air in the lower part of the room, resulting in dilution of potentially contaminated air.

Upper room air UVGI is a useful engineering control for crowded congregate settings, where susceptible people may have prolonged exposure to an unidentified infectious TB patient. Examples are homeless shelters, emergency department waiting rooms, and prison day rooms.

An isolation room has a different type of transmission risk than a congregate setting. In an isolation room, the infectious source (patient) and the individual at

risk (health-care worker) are known. Consequently, the health-care worker wears respiratory protection. The health-care worker is at greatest risk in close proximity to the patient. In general, this “near field” area contains the greatest concentration of infectious particles in the air. Although upper room air UVGI will help dilute the overall room concentration of *M. tb*, it will have little beneficial effect on this near field infection risk.

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

3 Guidelines and Regulations

A Introduction

There were several TB outbreaks in health-care facilities in the late 1980s and early 1990s. In response, guidelines and regulations were developed and implemented to help ensure safe TB control practices. Investigations of these outbreaks found lapses in administrative, engineering, and respiratory protection control measures. Even though engineering controls are secondary to administrative controls, they are still vital to a complete TB control program.

Highlights from national guidelines are included below.

B Centers for Disease Control and Prevention (CDC)

The most comprehensive TB control guideline for health-care facilities published to date is the CDC document, *Guidelines for Preventing the Transmission of Mycobacterium tuberculosis in Health-Care Facilities, 1994*, commonly referred to as the CDC Guidelines. This document includes *Supplement 3: Engineering Controls*, which contains recommended engineering controls for isolation rooms. Much of this ICS isolation room guideline is based on the CDC Guidelines.

Engineering control recommendations for the design of TB patient rooms include exhausting air to create negative pressure. For isolation room exhaust, the preferred practice is to directly exhaust to the outdoors. If recirculation is unavoidable, then high efficiency particulate air (HEPA) filters are recommended.

A minimum ventilation rate of 12 air changes per hour (ACH) is recommended for isolation rooms that are being renovated or newly constructed, and where HEPA filter units are used to supplement the central system ventilation.

For existing isolation rooms, the CDC Guidelines are less restrictive. Increasing the isolation room air change rate to 12 ACH is recommended where feasible, but a minimum of 6 ACH is allowed. The guidelines include the caveat that 6 ACH is “based on comfort- and odor-control considerations” rather than infection control concerns. Higher ventilation rates “are likely to produce an incrementally greater reduction in the concentration of bacteria.” In ICS’s experience, 12 ACH is usually feasible in existing isolation rooms.

The CDC Guidelines also include recommendations for testing and monitoring isolation rooms. The recommendations address testing methods and frequency of testing.

C American Institute of Architects (AIA)

The AIA has published a guideline titled *Guidelines for Design and Construction of Hospitals and Health Care Facilities*. These guidelines apply to the design and construction of new health-care facilities and major renovations in existing facilities.

Recommendations of the 1996-1997 AIA guidelines include the following: 12 ACH in isolation rooms, negative pressure, and daily confirmation of negative pressure when a room is used for isolation.

This guideline also recommends that air from isolation rooms be either exhausted outdoors or HEPA-filtered before recirculation.

A separation of 25 feet is recommended between exhaust from isolation rooms and other ventilation system intakes or occupied areas.

D Federal OSHA

The Occupational Safety and Health Administration, U.S. Department of Labor (federal OSHA) is preparing a new Occupational TB Control Standard.

Meanwhile, a 1996 compliance directive is in place: *CPL 2.106 – Enforcement Procedures and Scheduling Occupational Exposure to Tuberculosis*. The directive is based on the CDC Guidelines, but does not address air change rates.

Employers are required to maintain and test negative pressure in isolation and treatment rooms used by individuals with suspected or confirmed infectious TB disease.

E California Regulations and Guidelines

Appendix B contains highlights of the following California regulations and guidelines: *Interim Tuberculosis Control Enforcement Guidelines*, published and enforced by the California Division of Occupational Safety and Health (Cal/OSHA), and the *California Mechanical Code (CMC)*, enforced by the Office of Statewide Health Planning and Development (OSHDP).

F Comparison of Regulations and Guidelines

A table comparing selected engineering items of five prominent federal and California regulations and guidelines is included as *Appendix C*.

4 *Designing a New State-of-the-Art Isolation Room*

A Introduction, Planning

During the planning stages of a new construction or a remodel project, users often meet with architects to discuss various design elements. This enables the users to provide input to the design team. These discussions usually concentrate on the physical layout of the space. The mechanical elements are often left to the mechanical engineer's discretion.

Infection control coordinators and other appropriate managers should be included in this process. The infection control aspects of the mechanical system should be addressed so that this system is understood by the people relying on the controls.

Architects and mechanical engineers may not be aware of many infection control requirements. While engineers must comply with building codes to get approval for construction and occupancy, they may not be aware of CDC recommendations, or of federal or local OSHA requirements.

The mechanical design elements of a new hospital isolation room should, at a minimum, meet all local code requirements, as well as OSHA requirements and CDC recommendations.

B Architectural Considerations

Architecturally, an isolation room should meet all the detailed requirements for a single-patient room, including a dedicated adjacent bathroom.

Architectural design elements should also meet local code requirements. For example, California requirements include:

- code minimum clearance around the bed
- code minimum room area
- windows operable only by use of tools or keys

To increase the effectiveness of negative pressure, the architectural elements should ensure that the isolation room suite is sealed, except for a half-inch high air gap under the door. Towards this end, the ceiling should be plaster rather than

removable ceiling tiles, and lights should be surface-mounted. Gasketing should be provided at the sides and top of the door, and at ceiling and wall penetrations such as those around medical and electrical outlets.

The location of the proposed isolation room should also be considered: areas prone to strong drafts, such as those near elevator banks or doorways, should be avoided if possible.

Isolation room doors should be equipped with self-closing devices.

Ⓒ Ventilation Rate

When designing the heating, ventilating, and air-conditioning (HVAC) elements of a building, the amount of air supplied to each room is usually selected on the basis of comfort concerns. Unless there are governing code requirements, the engineer will provide ventilation air as required to keep the space comfortable. This air quantity is usually less than the amount required for effective dilution and removal of infectious particles.

For many spaces in health-care facilities, such as isolation rooms, infection control concerns are as important as comfort concerns. Engineers should increase the airflow rate accordingly.

ICS recommends that negative pressure isolation rooms have an exhaust air ventilation rate of at least 12 ACH.

This recommendation is consistent with the CDC Guidelines and meets all local requirements known to ICS.

The ACH is the airflow per hour divided by room volume (see *Appendix A*). For negative pressure rooms, the exhaust airflow should be calculated, rather than supply. The ACH of the dedicated bathroom or anteroom, when present, should be calculated separately from that of the isolation room proper. In other words, only include exhaust air that is exhausted in the isolation room.

Variable Air Volume Systems

Many mechanical systems do not provide a constant airflow rate. These are called variable air volume (VAV) systems. They are designed to continually vary the amount of cooling or heating air delivered to a room in response to the amount of cooling or heating required. Supply air varies between a fixed minimum and a fixed maximum using a VAV box installed in the ductwork. VAV systems are generally not found in hospitals, but are common in buildings that include clinics.

The volume of air supplied to an isolation room should not vary. Therefore, if an isolation room is to be included in a building served by a VAV system, the box supplying air to the isolation room should be set to deliver constant airflow. The mechanical engineer will need to address comfort control of this room separately.

D Supply and Exhaust Ductwork and Outlets

The supply and exhaust location should be chosen to maximize air mixing and to optimize directional airflow **from** the staff member **towards** the patient. Exhaust should be removed near the possible contamination source.

The best arrangement is to supply air at the ceiling above the foot of the bed, and to exhaust air on the wall near the floor at the head of the bed (where the patient's head is likely to be).

The supply diffuser should be the louvered blade type, rather than the perforated face type. The diffuser neck size and blow pattern should be selected so that air is directed to all parts of the room. The diffuser should be located where airflow is not obstructed by items such as surface-mounted light fixtures or a suspended television set.

The bottom of the exhaust grille should be located approximately 6 inches above the floor. Because the grille does not direct air, its face pattern is not as important as that of the diffuser. The vertical exhaust duct should be installed in the isolation room wall. An enlarged wall cavity will be required and should be coordinated with the architect. To reduce noise, dampers should be located at a point in the duct far from the outlet. The area in front of the exhaust grille should be kept clear of obstructions, such as furniture and supply carts.

The individual air ducts providing supply and exhaust air for the isolation room suite should have control dampers to adjust the airflow quantity. These dampers are usually manually operated, but may be automatic. Because of the hard ceiling, the handles for the dampers should not be above the isolation room ceiling. They should be either accessible from above the corridor ceiling, or remote, tamper-proof handles should be provided in the ceiling or wall of the isolation room.

E Negative Pressure

As described previously, negative pressure is achieved when exhaust exceeds supply and the room is well sealed except for a gap under the door.

The CDC Guidelines note that negative pressure can be established if exhaust exceeds supply by 50 cubic feet per minute (CFM) or by 10% of the supply air quantity, whichever is greater. These values are chosen to provide a negative pressure differential of at least 0.001 inches of water column (" W.C.).

In practice, an offset this small can be inadequate. Negative pressure may not be consistently maintained if there are other external factors, such as fluctuating air currents caused by elevators, doors, or windows to the outside.

When designing a new negative pressure isolation room, exhaust should exceed supply by at least 100 CFM. The actual pressure differential created at the door by the offset depends on how well the room is sealed and the size of the air gap under the door. In reality, no room can be perfectly sealed. It cannot be assumed that the total offset is being made up by air coming in under the door.

Because smoke may migrate into a room during a fire, building code officials are concerned with the amount of air drawn into a room under the door from a corridor. The amount of exhaust air offset from the corridor will need to comply with local codes, which may limit the maximum allowable offset. If the isolation room is equipped with an anteroom, this issue will not be as important.

ICS recommends that the negative pressure differential across the isolation room door be approximately 0.03" W.C. In practice, this may require that the airflow offset be adjusted to more than 100 CFM after the room is built, but before it is occupied. Engineers should allow for this possibility in their designs.

Isolation Room with Dedicated Bathroom

Some isolation rooms have a dedicated bathroom that is part of the isolation room suite and only for use by the isolated patient. Such isolation rooms are more likely to be found in hospitals than in clinics. The advantage of the bathroom is that the patient will not have to open and close the door as often to leave the suite.

To contain odors, the isolation room bathroom, where applicable, should be at negative pressure with respect to the isolation room. The bathroom ventilation should comply with local requirements. For example the *California Mechanical Code* (CMC) mandates an air change rate of 10 ACH, negative pressure, and direct exhaust to the outdoors for bathrooms. In general, an offset of 50 CFM is sufficient between the bathroom and the isolation room.

Both the isolation room and the combined isolation room and bathroom should be at negative pressure. In other words, not only must the total exhaust for the isolation room plus bathroom exceed the total supply for isolation room plus bathroom, but the isolation room exhaust should also exceed the isolation room supply. This can be illustrated with the following simple example.

Dedicated Bathroom Case Study

Background

Assume an isolation room with a dedicated bathroom. Supply air to the isolation room is measured and found to be 200 CFM.

The isolation room volume is approximately 1,000 cubic feet, so the supply air change rate is 12 ACH.

You are installing a new exhaust fan with a capacity of 300 CFM that will serve only the isolation room suite. Local codes mandate a minimum air change rate of 10 ACH in toilet rooms. The toilet room volume is approximately 240 cubic feet, so a minimum of 40 CFM exhaust is required.

The Options

How should the 300 CFM of exhaust air be split up between the bathroom and the isolation room?

- Should 250 CFM be exhausted in the isolation room and 50 CFM in the bathroom?
- Or should 200 CFM be exhausted in the isolation room and the remaining 100 CFM in the bathroom?

The Best Arrangement

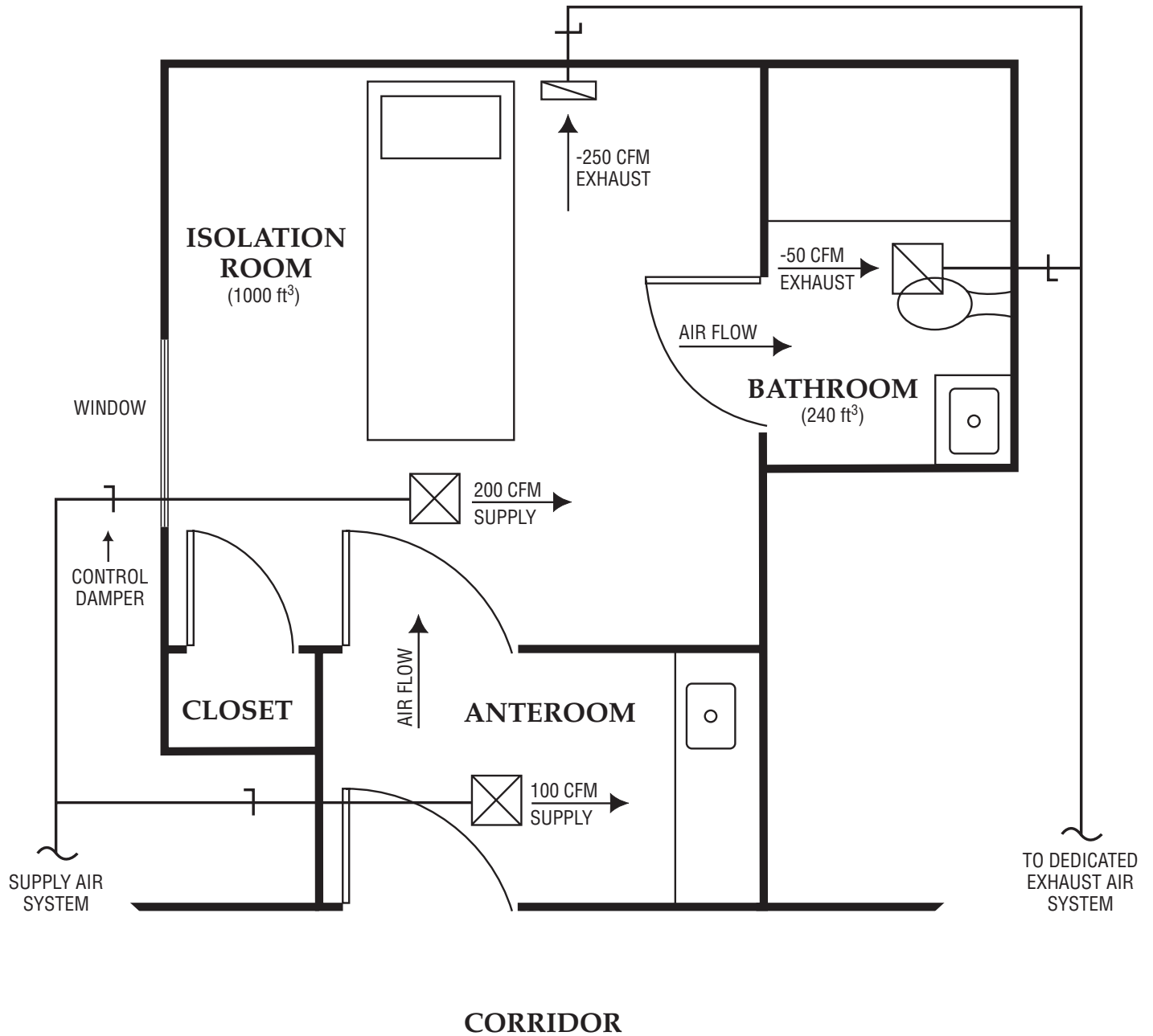
The preferred arrangement is to exhaust 250 CFM at the isolation room and 50 CFM at the bathroom (as shown in the diagram on the next page), rather than 200 CFM at the isolation room and 100 CFM at the bathroom.

The Reason

Each arrangement will result in both a 100 CFM offset across the isolation room door and an equal volume of air moving through the isolation room. But only the preferred option provides more exhaust than supply in the isolation room itself and increases airflow towards the head of the bed.

Also, code officials may require that direct exhaust from the isolation room exceed direct supply air. The latter option would result in a room with supply equal to exhaust.

Dedicated Bathroom Case Study



F Isolation Room Exhaust

Exhaust air removed from isolation rooms is likely to contain infectious particles. Consequently, this air should be discharged directly outside the building, where the particles can be diluted by outdoor air and killed by sunlight.

While not included as a minimum recommendation by the CDC Guidelines, the optimum type of exhaust system should serve only negative pressure isolation room suites, i.e., a dedicated exhaust system. Where applicable, this exhaust system should also serve the dedicated isolation room bathroom and anteroom.

Over time, dust and lint can collect at exhaust grilles and in exhaust ducts. Seals at duct joints also break down and leak. These two effects result in diminished exhaust airflow from the isolation room. To compensate, exhaust ducts should be oversized. **Isolation room exhaust ducts and fan systems should be sized for the expected airflow plus an extra 50%.**

Labeling

Maintenance personnel and contractors often re-route ducts to accommodate new services. To help protect these workers from potentially contaminated isolation room exhaust, the exhaust ductwork should be permanently labeled. The label should read, “*Caution – Negative Pressure Isolation Room Exhaust,*” or similar words to that effect. The labels should be attached at most 20 feet apart, and at all floor and wall penetrations.

Maintenance workers may also shut down the exhaust fan without realizing this will cause a loss of negative pressure. To avoid this possibility, a permanent warning sign should be posted on the fan at the electrical disconnect and at appropriate electrical panel breakers. The sign should read, “*Negative Pressure Isolation Room Exhaust Fan – Contact Infection Control Coordinator Before Turning Off Fan,*” or have similar wording. The sign should also include the telephone number of the infection control coordinator and the room number(s) of the isolation room(s) exhausted by the fan.

Exhaust Discharge

The exhaust fan discharge should be located and designed to minimize the possibility that this air is inhaled by people who are outdoors or inside the building. Exhaust air should be directed away from occupied areas (i.e., walkways) or openings into the building (i.e., windows or outside air intakes).

To promote dilution, the fan discharge should be directed vertically upward at a speed of at least 2000 feet per minute (FPM). The discharge location should be at least 25 feet away from public areas or openings into a building.

If a suitable discharge location is unavailable, then the exhaust can be disinfected using a HEPA filter. In this case, a HEPA filter must be installed in the discharge duct upstream of the exhaust fan. This is not a desirable option, however, because it will be considerably more expensive to install, maintain, and operate than a simple exhaust fan assembly.

ⓐ Permanent Room Pressure Monitor

After a new isolation room is constructed and before it is occupied, the mechanical contractor will adjust the airflow quantities as directed by the engineer to ensure that it operates as designed. However, mechanical systems do drift out of balance over time. It is important to regularly check that an isolation room is still operating under negative pressure; planning for this should be included in the initial design of the mechanical room.

The most reliable way to monitor negative pressure is to install a permanent electronic room pressure monitor as part of the construction project.

When properly selected and installed, a room pressure monitor can provide continuous qualitative and quantitative confirmation of negative pressure across a room boundary. This is in contrast to routine periodic smoke testing, which merely provides an indication of directional airflow at the moment of testing.

Continuous monitoring can provide instant notification if the pressurization fails or fluctuates during the day.

Most monitors consist of two main components: a wall-mounted panel and a sensor. The panel is usually mounted on the corridor wall just outside the isolation room suite and displays the pressure difference in units of " W.C.

There are two common types of permanent pressure monitors: those that measure and display the actual air pressure difference between the isolation room and the reference space (direct type); and those that measure the velocity of air moving between the two spaces through a fixed opening and convert this to a pressure value (indirect). Both types require an electrical power connection at the wall panel. Either type is suitable for a negative pressure isolation room, but indirect monitors generally provide a more accurate pressure reading.

Pressure differentials across room boundaries can be very small, often in the range of thousandths of an inch. For example, the CDC Guidelines recommend that negative pressure be at least minus 0.001" W.C. Some devices that measure differential pressure are not accurate to this level. Before specifying or purchasing a room pressure monitor, make sure that the device is capable of accurately and reliably measuring a pressure difference this small.

Direct Room Pressure Monitor

To record a pressure differential directly, two readings are required: the air pressure in the room and the reference pressure in the corridor. A remote sensor to measure the room pressure is installed in the negative pressure room wall or ceiling. Another sensor measures the air pressure in the corridor. The difference in these two pressure values is the relative room pressurization, which is displayed on the panel.

If there is an anteroom between the isolation room and the corridor, the pressure differential to be measured is the one between the isolation room and the ante-

room. In this case, both measurement points are remote from the corridor panel. If there is no anteroom, the reference pressure can be measured right at the panel, and only one remote reading is required.

The location of the remote sensors will affect the accuracy of the measurement. They should be installed as close as possible to the isolation room door, but away from drafts.

Tubing will need to be run from the panel to the sensor(s). For new construction, this tubing will typically be run out of sight inside wall cavities and above the ceiling. Air tubing is usually rigid plastic, but can be made of copper.

Indirect Room Pressure Monitor

The sensing component of a velocity-reading room pressure monitor consists of an air tube with an interior velocity sensing element. The tube is installed in the wall between the isolation room and the anteroom or corridor. An electrical device measures the air velocity and direction. This signal is run back to the wall panel, where it is converted to a pressure readout.

Again, care should be taken when installing the sensor. It should be located above or next to the door, but away from the influence of drafts. To help shield the sensors, louvered cover plates are usually provided on both sides of the wall.

The signal between the sensor and the wall panel is a low voltage electrical signal instead of the air tubing used in direct pressure monitors.

Alarm(s) and Controls

In addition to providing a continuous readout of the pressure difference, the wall panel should include an audible and visual alarm to warn staff when pressurization is lost.

The alarm will sound when the measured room pressurization drifts to less than the monitor's **reference pressure** value. The reference pressure value is programmed by the user. It will be a value between the steady state pressure differential maintained by the room and zero (neutral pressure).

For example, in a room with a steady state pressure differential of minus 0.03" W.C., the alarm could be programmed to activate when the pressure differential falls to minus 0.001" W.C. Minus 0.001" W.C. is the reference pressure value.

The wall panel should also allow staff to program a built-in **time delay** between loss of pressurization and alarm activation. The time delay will allow staff a sufficient interval to routinely enter and leave the room without setting off the alarm. A typical time delay is 45 seconds.

The **audible alarm** is usually a beeping sound, which will stop when negative pressure is restored or when a "mute" button on the panel is pressed.

The **visual alarm** usually consists of a red warning light. Most wall panels also have a green “normal” or “safe” light, which indicates that the monitor is operating and negative pressure is within programmed parameters. Unlike the audible alarm, the visual alarm will not reset when the “mute” button is pressed. After negative pressure is restored, the lights will either automatically reset or the “reset” button must be pressed, depending on the brand of the monitor. In case no one was present, the latter option will indicate that negative pressure was temporarily lost.

Remote Alarm

In addition to the alarm included on the wall panel, most room pressure monitors include an extra identical signal that allows a “safe” or “alarm” signal to be connected from the wall panel to a remote location. Common locations for this remote alarm are the nurses’ station, the engineering department, and the central switchboard.

It is usually possible to connect the alarm signals from a number of isolation room monitors to a remote alarm panel. In California, for example, the hospital building codes require that negative pressure isolation rooms be equipped with an alarm that annunciates at the room and at a nurses’ station or other suitable location.

Other Optional Features

There are a number of room pressure monitors available with additional options. Examples of such options include: an amber “warning” light that illuminates during the time delay when negative pressure is lost; adjustment for use in positive pressure rooms; and control of a fan or damper to maintain negative pressure.

Commissioning and Staff Training

The monitor installer’s responsibilities should include verifying the operation of the sensor. A detailed checklist is included as *Appendix D*. The following should be completed before the room is used to isolate suspected or confirmed infectious TB patients:

1. **Verify that the alarm works.** Hold the room door open. After the time delay, the audible and visual alarm should annunciate. The alarm should reset after the “mute” or “reset” button is pressed and/or the door is closed again.
2. **Verify that the monitor is correctly reading the pressure.** While the door is held open, the pressure reading should be at or near 0" W.C.
3. **Instruct staff in monitor usage.** The floor staff who depend on the monitor for their safety should feel comfortable using it. They should receive detailed instructions on how the monitor works and how it is used.

The checklist should be completed for each isolation room monitor in the facility. A copy of the completed checklist should be kept in the Policies and Procedures binder for that department.

Ongoing Monitor Checks

To validate the continuous pressure monitor, negative pressure should be verified **monthly** with smoke trail or similar testing. The results should be recorded. Space for this is included in the checklist.

Most manufacturers recommend that each monitor be recalibrated **annually**. The recalibration procedure will depend on the monitor type and should be available from the manufacturer. ICS recommends that a new monitor checklist be completed at the same time.

H Anteroom

If space and budget permit, an anteroom should be provided between the negative pressure isolation room and the corridor. This will help prevent infectious particles in the isolation room from escaping to the corridor.

When an isolation room door is open, negative pressure is immediately lost. If there is an anteroom that is negative to the corridor, then the overall integrity of the suite is maintained. The anteroom provides an “air lock” between the isolation room and the rest of the facility.

An anteroom should be at positive pressure with respect to the isolation room, and at either neutral or negative pressure with respect to the corridor. Because smoke may migrate from the corridor if there is a fire, some codes and regulations mandate that the anteroom be neutral to the corridor, rather than negative. However, in practice this is very difficult to accomplish. It is not easy to balance airflow to a space so that it will be positive at one door and neutral at the other. Furthermore, air pressure in the corridor will vary due to external factors such as elevators and corridor doors to the outside.

Local codes should be consulted regarding other design elements of anterooms for isolation rooms. For example, California requirements include:

- provision of a sink, cabinets, and work counter
- provision of a view window in the door to the isolation room
- alignment of door to corridor with door to isolation room, or provision of a second locked and gasketed entry for gurney
- maximum of two isolation rooms per anteroom

5 Assessing an Existing Isolation Room

A Introduction

This section covers the steps that should be taken to evaluate the effectiveness of an existing negative pressure isolation room.

Failed engineering controls in negative pressure isolation rooms have been identified as factors in documented hospital TB outbreaks. Regularly scheduled assessment of engineering controls will identify and may help prevent such failures.

Items that should be checked include the exhaust and supply airflow rate, negative pressure, and exhaust duct termination location.

B Ventilation

To determine the ACH of a space, you will need to measure the airflow and calculate the room volume. See *Appendix A*.

The airflow measurements and calculations should be performed by a certified testing and balancing agency¹ or by in-house engineering staff.

Airflow Measurement

The airflow of a room is usually measured at the individual registers and diffusers using a balometer. This is a device that consists of a hood, a velocity sensor, and a microprocessor.

The hood is placed over a register or diffuser and should completely cover the air outlet. The top of the hood should have a foam gasket that establishes a good seal between the hood and the ceiling or wall around the outlet.

The hood directs all air entering or leaving the outlet past a velocity-sensing grid. The area of the grid is fixed. Therefore, the microprocessor can calculate and display the quantity of air being exhausted or supplied by the air outlet. Balometers usually provide an airflow reading in cubic feet of air per minute (CFM). If the outlet is an exhaust or return grille, a minus sign will appear in front of the CFM value. For example, a reading of **180 CFM** indicates a supply outlet, whereas **-180 CFM** indicates an exhaust or return.

¹ Testing and balancing firms should be members of the Associated Air Balance Council (AABC) or the National Environmental Balancing Bureau (NEBB).

The standard size of a balometer hood outlet is 24" X 24", although adapters are provided to adjust the hood size. This size hood can be used to measure the airflow of any outlet equal to or smaller than this (e.g., 12" X 24" or 18" X 18" diffuser). For other size outlets, such as a 36" X 6" slot diffuser, the hood size on the balometer may need to be changed.

There may not be sufficient space in front of some outlets to place the balometer. In this case, the airflow should be measured by a pitot traverse in the duct that serves the outlet.

A pitot traverse is a specialized measurement that requires access above the ceiling. Air velocity is measured at a number of sample locations inside the duct. Airflow is calculated based on these velocity readings and the area of the duct cross-section.

If a dedicated exhaust fan serves the isolation room suite, it may be possible to estimate the airflow at the room by measuring the airflow at this fan. Because of duct leakage, this measurement will not be as accurate as one taken at or near the outlet. Inadequately sealed duct joints can result in extra air being sucked into the duct between the isolation room exhaust grille and the fan, which would result in an overestimate of airflow at the room. To compensate for this, an allowance of at least 10% should be made. This allowance should be increased in the case of a long duct run.

If room airflow is found to be inadequate, i.e., less than 12 ACH, it should be increased. See Section 6, *Upgrading or Converting an Existing Room*.

© Air Mixing and Directional Airflow

After establishing the airflow, the next step is to evaluate how effectively this air is used in the isolation room. This assessment is not as straightforward as calculating the airflow rate because there is no clearly defined numerical standard to meet.

Smoke testing can be used to visualize the direction of room air and to estimate how well air is mixing. Consequently, ventilation problems can be identified, such as undesirable directional airflow patterns and poor mixing.

Ideally, the clean supply air will be introduced near a health-care worker, while exhaust air will be removed near the patient. Good air mixing is confirmed by rapid dissipation of the test smoke in all parts of the room, which demonstrates that particles generated in the room are being diluted and removed.

If air mixing is not optimal due to short-circuiting or stagnation, the diffuser and/or register should be relocated or replaced. Either of these options will require the services of a consultant mechanical engineer. In the interim, a supplemental propeller-type fan can be placed in the isolation room to encourage air mixing. Such a fan is not recommended as a long-term solution because it may create uncomfortable drafts and be turned off by the patient.

D Exhaust Ductwork and Discharge

The engineering department staff at the facility should trace the path taken by the exhaust air duct after it leaves the isolation room. If applicable, they should also check the exhaust duct serving the bathroom and anteroom. For the record, a set of drawings should be generated (or an existing design set marked) to show the ductwork and fan.

The exhaust ductwork and fan should also be checked for optimum performance. Conditions that should be corrected include: excess air leakage at duct joints, damaged ductwork, incorrectly adjusted dampers, and fans in need of servicing.

Recirculating Air Systems

If air from an isolation room is returned to a recirculating ventilation system that does not include HEPA filtration, this room should no longer be used for isolation. Staff and patients in rooms served by this system may be exposed to *M. tb* from patients in isolation.

The risk of exposure from a recirculating mechanical system is affected by dilution of the return air with outside air and by the filter in the mechanical system. The risk is reduced as the percentage of outside air is increased and the efficiency of the filter is increased.

Filtration in hospital ventilation systems is usually better than in clinics because hospitals are typically covered by stricter building codes and have larger facilities and maintenance budgets.

Dedicated or Shared Exhaust System

The CDC Guidelines do not address the issue of dedicated exhaust air systems serving isolation rooms. However, in some jurisdictions this is mandated by the building code for new or renovated rooms. Because most building codes are not retroactive, it is usually acceptable for an existing isolation room to combine the exhaust air with other exhaust systems, such as those serving toilet rooms.

Duct and Fan Labeling

If the existing exhaust system is dedicated, make sure that the ductwork is labeled as recommended for a new isolation room (“*Caution – Negative Pressure Isolation Room Exhaust*”). For a shared system, only the ductwork between the isolation room and the main exhaust trunk needs to be labeled.

The exhaust fan, whether dedicated or shared, should have a warning label as recommended for a new system (“*Negative Pressure Isolation Room Exhaust Fan – Contact Infection Control Coordinator Before Turning Off Fan*”).

See Section 4.F, *Isolation Room Exhaust*, for additional information on labeling of exhaust ductwork and fans.

E Negative Pressure Verification

Negative pressure is the easiest characteristic of an isolation room to check. Several methods are available to qualitatively assess negative air pressure, including smoke trail testing and tissue testing.

If the isolation room is operating as intended, there will be an air current moving into the room under the door. The existence and direction of this current should be verified.

Smoke Trail Test

Smoke trail testing helps visualize the current near a room door. In this simple procedure, smoke is released near the air gap under an isolation room door. See *Appendix E* for more detailed instructions on smoke trail testing.

Commercially available smoke-generating kits produce a visible cloud, which usually consists of water and acid. The quantity of smoke typically issued from the tube is minimal and is undetectable at short distances from the tube. Because inhalation of this smoke in concentrated form can cause irritation, care should be taken not to expose workers or patients until the smoke has been diluted. The amount of smoke used should not be excessive.

There are many different types of easy-to-use smoke-generating kits available from safety supply companies. A typical design is the disposable self-contained puff bottle. Another common design is the disposable smoke tube, which attaches to a rubber bulb that acts like a bellows.

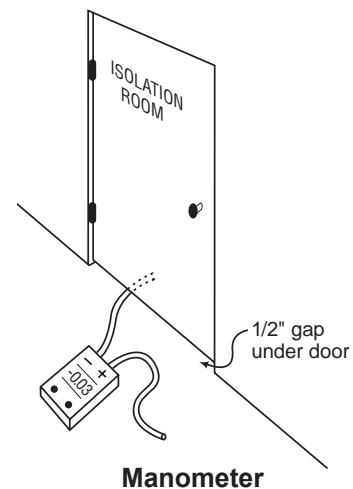
If commercial smoke-generating devices are not available, incense sticks can be used. ICS recommends that two sticks be used side-by-side to generate the smoke trail. However, incense smoke does have a strong odor, and is not as visible or controllable as commercial smoke.

Tissue Test

If smoke-generating devices are not available, or if the room is occupied by a patient who may be vulnerable to the irritant properties of smoke, a thin strip of tissue can be used to determine whether a room is at negative, neutral, or positive pressure. A thin strip of tissue should be held parallel to the door with one end of the tissue in front of the gap. The direction of the tissue's movement will indicate the direction of air movement.

Manometer

Relative room pressurization can also be verified using a handheld pressure gauge or manometer, which is similar to a direct room pressure monitor, except it is portable. A length of rubber tubing is attached to each of the two ports on the manometer. The manometer displays (in " W.C.) the pressure difference between the two spaces at the termination of the tubes. If one of the tubes is threaded under the



door into the isolation room and the other is in the hallway, the manometer will indicate the pressure difference between the two spaces. A negative symbol verifies that the room is at negative pressure.

Velometer

Air **speed** is measured by a velometer, usually in units of feet per minute (FPM). These devices can be placed near the gap under the isolation room door to measure the speed of the airstream. Velometers are available in a number of different configurations. Many only indicate air speed regardless of air direction. For instance, some velometers indicate how fast the air is moving, but not whether the air is entering or leaving the room. However, there are models available that can also be used to determine airflow direction.

Repeat Test

All of these tests to verify negative pressure should be conducted at least three times until the results are consistent.

Validate Existing Monitor

If the existing room is equipped with a permanent room pressure monitor, one of the above tests should be performed to confirm negative pressure and to validate the monitor. Also, the *Isolation Room Pressure Monitor Checklist (Appendix D)* should be completed for the monitor.

F Negative Pressure Measurement

After negative pressure has been verified, it should be measured. The table below summarizes three ways to quantify negative pressure. The corresponding units of measurement, the measuring device for each method, and the approximate costs are also shown.

PARAMETER	UNITS OF MEASUREMENT	MEASURING DEVICE (APPROXIMATE COST AS OF 1999)
pressure difference	inches of water column (" W.C.)	manometer (\$500)
speed of air under the door	feet per minute (FPM)	velometer (\$250 - \$1700)
exhaust air offset	cubic feet per minute (CFM)	balometer (\$2,600)

Repeat Test

Negative pressure measurements should be conducted at least three times until the results are consistent.

Existing Monitor

If the existing room is equipped with a permanent room pressure monitor, verify that it has been calibrated within the last 12 months.

Clinic Case Study: Episode 1

Background

Routine annual tuberculin skin testing revealed that two employees in a small, single-story county clinic converted their TB skin tests over the last year. Both employees were clerks in the billing department; neither had patient contact.

The clinic manager, Janet Abernathy, was concerned because the billing department shares a corridor with the room used to isolate TB patients. *M. tb* transmission may have occurred due to failed engineering controls at the isolation room.

Assessment

Janet tested pressurization of the isolation room with a piece of tissue. The room was clearly positive with respect to the corridor. She felt airflow from the supply grille. Even after wiping off the considerable amount of dust on the exhaust grille, there was no air movement. A tissue held against the grille was not pulled toward the grille as would be expected.

The county facilities department sent out a maintenance engineer, Cynthia Fine, to investigate further.

Cynthia remembered converting this room into an isolation room for TB patients about two years ago. She had sealed the room and installed a small dedicated rooftop exhaust fan. But now she found that dust and lint had accumulated on the fan motor, causing the motor to overheat and burn out. She cleaned the fan and ductwork and replaced the motor. Exhaust was now measured and found to be 150 CFM.

Room air supply was 130 CFM, which was 20 CFM less than exhaust. However, a series of smoke tests showed that the room was now at neutral pressure rather than negative pressure. Obviously, room air leakage exceeded the 20 CFM offset.

Calculate Air Change Rate

The room was square-shaped (15 feet each side), with a ceiling height of 8.5 feet. The exhaust air change rate was calculated as follows:

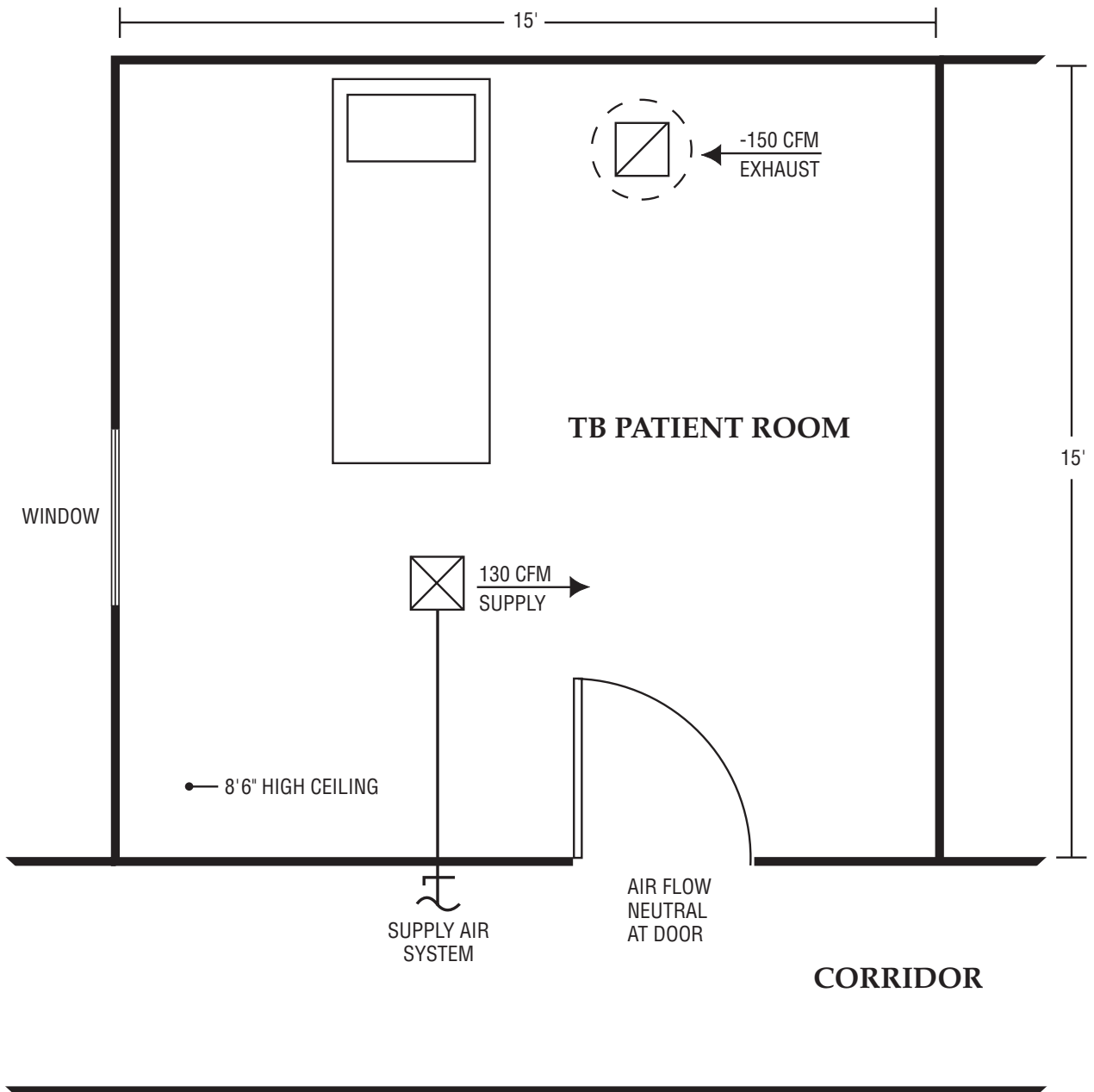
$$\text{room volume} = 15 \times 15 \times 8.5 = 1913 \text{ cubic feet}$$

$$\text{exhaust air change rate} = 150 \text{ CFM} \times 60 \text{ minutes} / 1913 \text{ cubic feet} = 5 \text{ ACH}$$

Therefore, even with the exhaust fan fixed, the room was unsuitable for isolation because it was at neutral pressure with a low air change rate.

Clearly, something had to be done. See Section 6 for conclusion.

Clinic Case Study: Episode 1



6 *Upgrading or Converting an Existing Room*

A Introduction

This section covers methods of improving the ventilation characteristics of an existing room to make it more effective for negative pressure isolation.

Previous sections have outlined recommendations for a new state-of-the-art negative pressure isolation room and shown how to assess an existing room to see how it compares with these recommendations. This section describes how to correct deficiencies found during the assessment.

The methods outlined below could also be used to convert an existing patient room into an isolation room.

Disconnect Recirculating Air System

The first step is to ensure that air from the room is not inadequately filtered and recirculated to other areas. The air removed from the room must either be exhausted outdoors to a safe location or HEPA-filtered. If room exhaust is currently connected to a recirculating air system that does not include a HEPA filter, it should be disconnected from this system.

Install HEPA Filter in Existing Return Air System

Theoretically, another safe option for correcting a recirculating system is to replace the existing filter with a HEPA filter. However, ICS does not recommend this. A HEPA filter is a specialized piece of equipment that should only be used in a ventilation system specifically designed to accommodate it. HEPA filters are physically larger than most filters and require larger fans to overcome increased resistance to airflow.

Two Upgrade/Conversion Options

There are two basic approaches to upgrading or creating a negative pressure room. The preferred option is to adjust the building ventilation system to create a permanent negative pressure room. A temporary solution is to add a recirculating HEPA filter unit to supplement, or even replace, the building ventilation system.

Regardless of the upgrade option selected, steps must be taken to reduce unwanted air leakage from the room, i.e., the room must be sealed.

Negative Pressure

As explained previously, the negative pressure value will depend on two factors: how much more air is exhausted than supplied (i.e., the offset); and how well the room is sealed. In general, when converting or upgrading a room, the negative pressure value will not be as high as that attainable for new construction because there is less control over the architectural elements.

ICS recommends that the negative pressure value should be at least minus 0.006" W.C. for upgraded or converted negative pressure rooms.

This is more stringent than the CDC Guidelines, which recommend minus 0.001" W.C. as a minimum negative pressure value. In our experience, a pressure difference of 0.001" W.C. will not be consistently maintained if there are other external factors, such as drafts created by elevators and doors that open to the outside.

B Sealing the Room

A room in which exhaust exceeds supply will not necessarily be at negative pressure with respect to the corridor; it is not unusual to have such a room at positive pressure.

For example, a room could have exhaust air from the central system exceeding supply by 100 CFM. Assume this room has leaky windows and some holes in the ceiling tiles. If it is windy outdoors, 75 CFM could enter through the leaks around the windows, and another 75 CFM could enter through the ceiling. Now the air being introduced to the room exceeds exhaust by 50 CFM. Smoke testing at the door would probably indicate positive pressurization.

When upgrading an existing isolation room or converting an existing room to operate at negative pressure, it is important to make the best use of the excess exhaust by sealing the room as tightly as possible. For a given exhaust air offset, the better the room is sealed, the more air is made up under the door and the greater the negative pressure.

The following are some examples of steps that can be taken to improve a room's air tightness:

- Apply gasketing at sides and top of room door
- Caulk around windowpanes and around window frames
- Apply gasketing at the connection of the ceiling and the walls
- Apply gasketing around electrical boxes
- Replace acoustic ceiling tiles with non-porous vinyl tiles and apply gasketing at tile connection to ceiling grid
- Replace recessed light fixtures with surface-mounted fixtures

Ⓒ Adjust Ventilation System

If the room is not currently connected to an exhaust system, it should be either connected to an existing exhaust system or a new system should be installed. Consult with the building facilities department staff, who will probably hire a mechanical engineering consultant to design this work and oversee the construction.

Connect to Existing or Add New Exhaust System

If there is an accessible exhaust air system nearby, such as a toilet exhaust system, with sufficient capacity, it may be possible to make a new exhaust connection to the existing return register. Otherwise, a new exhaust air fan and ductwork system should be installed. See Section 4.F for new isolation room exhaust recommendations.

New exhaust ducts, and new or existing exhaust fans serving isolation rooms, should have the same warning labels used for new isolation rooms. See Section 4.F.

Rebalance Existing Mechanical System

To increase room airflow and/or create, or increase, negative pressure, the existing ventilation system needs to be adjusted to exhaust more air. The supply air quantity may also need to be increased. Airflow is varied using dampers.

Adjust Dampers

Dampers are devices that control the flow of air in ducts, similar to the way valves control the flow of fluids in pipes. Dampers, usually located above the ceiling, should only be adjusted by a facility engineer or certified air balance contractor. To increase airflow, the dampers in the ducts serving the room should be opened wider. It usually takes an air balancer two or three iterations to obtain the desired airflow.

The exhaust airflow rate should be at least 12 ACH. For existing rooms, this recommendation is more restrictive than the CDC Guidelines, which accept an air change rate of 6 ACH. However, 6 ACH will not satisfy some local regulatory agencies, including Cal/OSHA and the Office of Statewide Health Planning and Development (OSHPD) in California. Twelve ACH, which meets all local requirements known to ICS, is readily achievable using HEPA filter units.

The supply should be approximately 100 CFM less than exhaust. Depending on how well the room is sealed, more air may need to be exhausted in order to achieve a larger pressure differential.

Most rooms do not have a dedicated ventilation system. They are connected to a fan system that serves other rooms in the building. Before and after adjusting the isolation room airflow, the air balancer should measure the airflow in some of these other spaces to make sure that the isolation room adjustments do not have an adverse effect on ventilation elsewhere.

D Add Recirculating HEPA Filter Unit

It may not be possible or practical to connect to an existing exhaust air system, or to install a new one. It is possible to create a temporary and less expensive isolation room. This can be done using a recirculating HEPA filter unit. There are two basic ways to use these units in isolation rooms. They can be used to increase only the ventilation rate of a room without affecting room pressurization. Or they can be used to simultaneously:

- Increase the ventilation rate,
- Create or increase negative pressure, and
- Replace the need for additional exhaust.

HEPA Filter Units

HEPA filter units are readily available electrical devices that consist primarily of a fan, a HEPA filter, and a prefilter.¹ They also include controls, such as a three-speed switch, and possibly an indicator light to indicate when the filter needs to be changed.

HEPA filter units are available in a number of different physical configurations, including wall- and ceiling-mounted types. The most popular configuration is the floor-standing, portable type.

Wall- or ceiling-mounted units are less obtrusive and do not take up floor space. They are also less likely to be tampered with by staff and patients. However, floor-mounted units are more portable and are easier to service. Regulatory bodies, such as OSHPD in California, may require that a structural engineer oversee the design and construction of the support system for a wall-mounted or ceiling-mounted HEPA filter unit.

Increase Ventilation Rate

If negative pressure in the isolation room is satisfactory, but the ventilation rate is low, a HEPA filter can be used to supplement the room airflow rate. The effective ventilation rate of the room is the sum of the central system airflow and the HEPA filter unit airflow.

Sizing HEPA Filter Units

The size of the unit selected should be based on the **additional airflow** (in CFM) required to achieve the desired air change rate (in ACH) in your room.

To determine the additional airflow:

1. **Measure** the actual CFM exhausted from the room, and
2. **Calculate** the CFM required to achieve the desired ACH.

The HEPA filter unit should be sized to make up the difference.

¹ The prefilter traps relatively large particles and therefore helps to extend the life of the HEPA filter.

Most HEPA filter units allow staff to adjust the amount of air delivered by means of a switch. Common examples of switches include those with three fixed settings and those that allow any setting between the maximum and minimum. Manufacturers' catalogs generally list a CFM delivered by the unit at each of the three speeds, or at the high and low setting.

In practice, ICS has found that people usually turn down the HEPA filter unit switch and operate the units at or near the low setting. This is because the units can be very noisy and/or drafty when the fan is at, or near, full speed.

ICS recommends that HEPA filter units be selected based on the airflow at or near the low speed.

These units may deliver less than the manufacturers' listed airflow, and output of the units may decrease as the filters load up. To compensate for this, ICS recommends **that the unit selected have a listed capacity that is 25% more than required**. The marginal cost of selecting a unit with more capacity is usually not significant, compared to the first cost of the unit.

To summarize, ICS recommends the selection of a unit listed to deliver 25% more CFM than required at or near the low speed fan setting.

For example, if 150 CFM is measured, and 220 CFM is required to achieve 12 ACH, then the required additional airflow is 70 CFM. If a HEPA filter unit is used to increase airflow, then 25% should be added to 70 CFM for a total of approximately 90 CFM. Therefore, a unit with a listed capacity of at least 90 CFM at or near the low fan speed setting should be selected.

Increase Ventilation Rate and Create or Increase Negative Pressure

If a sufficient portion of the discharge from a HEPA filter unit is ducted somewhere outside of the room, then the HEPA filter unit can create negative pressure and replace the need for any extra exhaust.

A HEPA filter unit supplements ventilation as follows:

1. The effective **exhaust air quantity is increased** by an amount equal to the airflow of the HEPA filter unit (because this air is now being removed and droplet nuclei are removed by the filter).
2. The effective **supply is increased** by an amount equal to the returned air quantity (HEPA unit airflow minus the amount discharged outside the room).
3. The effective **negative pressure offset is increased** by an amount equal to the HEPA unit airflow discharged outside the room.

Theoretically, the technique described above could also be used to create negative pressure in a room that had no ventilation system. However, this is not recommended because the room would then have no outside air at all, only recirculated, HEPA-filtered air. Building codes mandate that fresh outdoor air be supplied to all occupied spaces that do not have an operable window.

The following continuation of the Clinic Case Study illustrates the selection of a portable HEPA filter unit.

Clinic Case Study: Episode 2

Calculate Additional Airflow

Although Janet, the clinic manager, wanted to bring the isolation room into compliance with CDC engineering control recommendations, she thought her budget was too limited to accomplish this.

Cynthia, the engineer, suggested a portable HEPA filter unit as an affordable upgrade option. A HEPA filter unit would provide additional airflow. If a portion of the discharge were ducted outside, it would also create negative pressure.

The first step was to calculate the additional airflow required:

$$\begin{aligned} \text{Airflow required for 12 ACH} &= 1913 \text{ cubic feet} \times 12 \text{ ACH}/60 \text{ minutes} \\ &= \text{approximately } \mathbf{400 \text{ CFM}} \end{aligned}$$

$$\text{Additional airflow required} = 400 \text{ CFM} - 150 \text{ CFM} = \mathbf{250 \text{ CFM}}$$

Sizing and Installing a Portable HEPA Filter Unit

A HEPA filter unit that produced at least this much airflow was required. Cynthia contacted a mechanical equipment supplier. Two units were available: a small \$2000 unit rated for 150 to 300 CFM; and a large \$2800 unit rated for 250 to 750 CFM. Each unit had a variable speed switch and an optional connection that could be used to duct some of the discharge air outdoors.

Janet suggested buying the small unit to save money. If run at high speed, it would provide more than enough airflow. However, Cynthia explained that most people turn down the fan speed switch because the units can be noisy. The units may also produce less airflow than the catalog claims. She suggested adding a 25% safety factor, then buying a unit listed for this airflow at low or medium speed.

$$\text{Additional airflow plus safety factor} = 250 \text{ CFM} + 25\% = \text{approximately } \mathbf{310 \text{ CFM}}$$

Based on this, the larger unit was selected and placed in the room. Cynthia replaced a window pane with a sheet metal panel. She connected a flexible duct from the HEPA unit discharge to a hole in the sheet metal panel, set the unit to about 300 CFM, and diverted about a third of the discharge air to the outdoors.

The Happy Ending

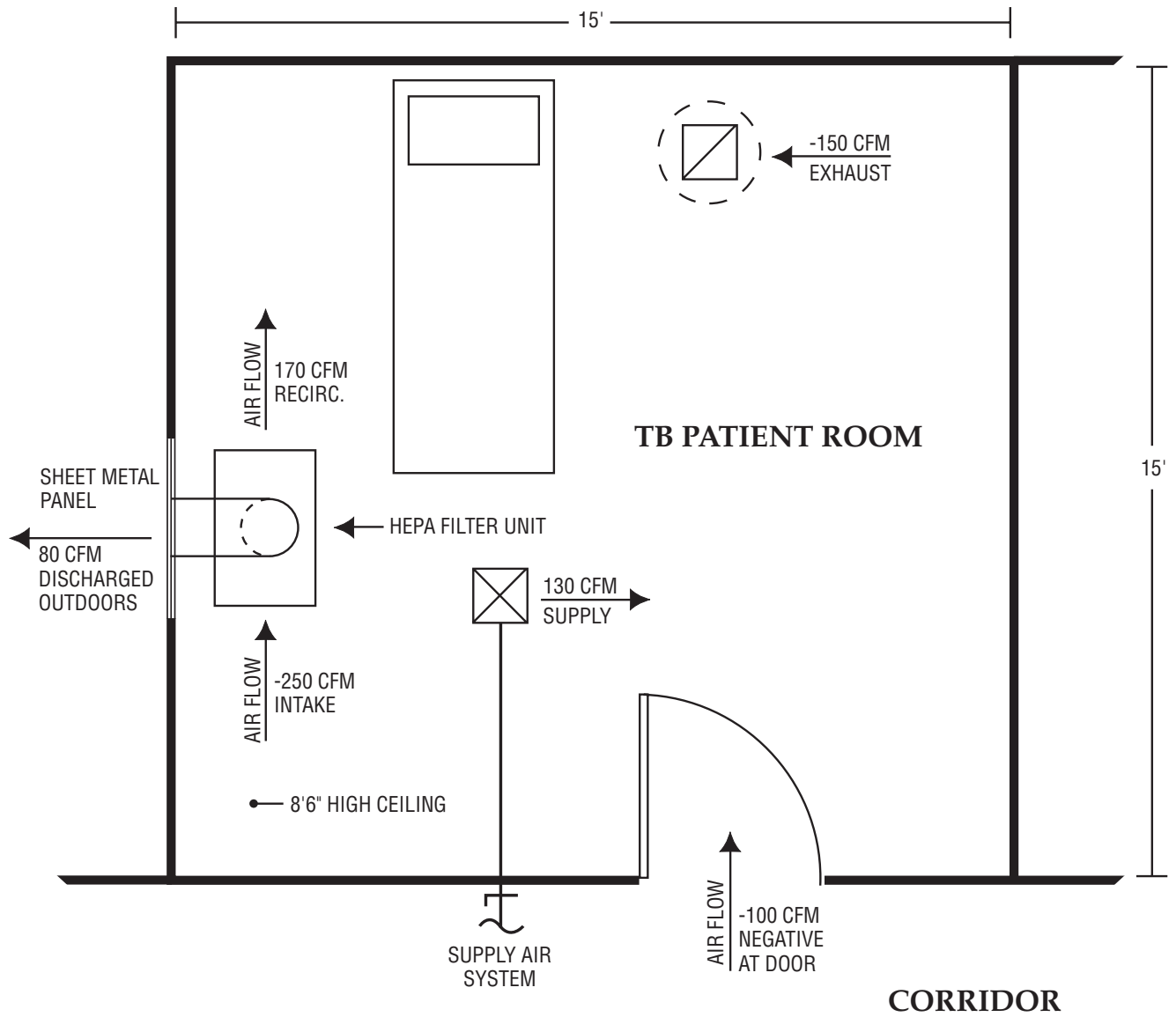
The room was now clearly at negative pressure, the airflow was improved, and the noise from the HEPA filter unit was acceptable.

Cynthia's final measurements showed that the HEPA filter was returning approximately 250 CFM, with 80 CFM of this discharged outside and the remaining 170 CFM recirculating in the room.

Effective supply:	$130 \text{ CFM} + 170 \text{ CFM} = 300 \text{ CFM}$
Effective exhaust:	$150 \text{ CFM} + 250 \text{ CFM} = 400 \text{ CFM}$
Effective offset:	$400 \text{ CFM} - 300 \text{ CFM} = 100 \text{ CFM}$

Clinic Case Study: Episode 2

<u>EFFECTIVE SUPPLY</u>	<u>EFFECTIVE EXHAUST</u>	<u>EFFECTIVE OFFSET</u>
130	-150	-400
170	-250	+300
<u>+300 CFM</u>	<u>-400 CFM</u>	<u>-100 CFM</u>



E Monitoring of Engineering Controls

Once the isolation room upgrade has been completed, procedures to monitor the engineering controls must be implemented. This is essential to ensure that staff will be alerted if the controls fail.

The two items that need to be monitored are the airflow rates and the room pressurization.

Airflow Rate Monitoring

The airflow rates are monitored by measuring with a balometer to ensure that the rates have not deviated more than about 5% from the initial values.

ICS recommends that airflow rates be measured and air change rates calculated at least once a year.

Room Pressurization Monitoring

Room pressurization should be continuously monitored to ensure that the room remains under negative pressure.

The CDC Guidelines recommend that room pressurization be confirmed daily while the room is occupied by a known or suspected infectious TB patient, and at least once a month at other times.

These tests can be done with smoke or a telltale device, such as a tissue. However, ICS recommends that each isolation room be equipped with a permanent room pressure monitor. See Section 4.G.

Documentation

Records should be kept of all isolation room engineering control tests and measurements. Local regulatory agencies may require that these tests be kept for a number of years. For example, Cal/OSHA requires that records be kept for a minimum of five years.

Resources

Web Sites

- American Society for Healthcare Engineering of the American Hospital Association: <http://www.ashe.org>
- Centers for Disease Control and Prevention: <http://www.cdc.gov/nchstp/tb>
- Francis J. Curry National Tuberculosis Center: <http://www.nationaltbcenter.edu>
- Occupational Health and Safety Administration: <http://www.osha.gov>

Additional Information

- Centers for Disease Control and Prevention. Guidelines for preventing the transmission of *Mycobacterium tuberculosis* in health-care facilities, 1994. *MMWR* 1994;(No. RR-13).
- Francis J. Curry National Tuberculosis Center, Institutional Consultation Services. Instructional video and viewer's guide titled: *How You Can Assess Engineering Controls for Tuberculosis in Your Health-Care Facility: You Don't Need a Weatherman to Know Which Way the Wind Blows*. 1998.

Additional ICS Guidelines

The following guidelines were also developed by ICS:

- A Guideline for Establishing Effective Practices: Identifying Persons with Infectious TB in the Emergency Department
- Conducting Sputum Induction Safely
- Policy and Procedures for Tuberculosis Screening of Health-Care Workers
- Tuberculosis Exposure Control Plan: Template for the Clinic Setting

An order form for these guidelines can be obtained by calling (415) 502-4600. These guidelines are also available on the Francis J. Curry National Tuberculosis Center Web site: <http://www.nationaltbcenter.edu/ics.html>

Appendices

Appendix A

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.

Air changes per hour (ACH) is the most common unit used. 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 minutes** to determine the **volume** of air delivered per hour (in cubic feet).

To calculate **room volume** (in cubic feet), multiply room height (in feet) by the room area (in square feet). Room area is the room width (in feet) times the room length (in feet).

$$\text{ACH} = \frac{\text{airflow per hour}}{\text{room volume}} = \frac{\text{CFM} \times 60 \text{ minutes}}{\text{cubic feet}}$$

A room may have two airflow values, one for supply and another for exhaust. (The airflow difference between these two values is called the offset.) To calculate the air change rate, use the greater of the two airflow values. For negative pressure isolation rooms, the exhaust should be greater than the supply.

Example of Air Change per Hour Calculation

An isolation room is 200 square feet in area and has a ceiling height of 9 feet. Airflow measurements indicate a supply airflow of 360 CFM and an exhaust airflow of 480 CFM. Does this room comply with the CDC recommendation that isolation rooms have a minimum airflow rate of 12 ACH for new construction?

$$\text{Air change rate: } \frac{480 \text{ CFM} \times 60}{200 \text{ ft}^2 \times 9 \text{ ft}} = 16 \text{ ACH}$$

$$\text{Exhaust air offset: } 480 \text{ CFM} - 360 \text{ CFM} = 120 \text{ CFM}$$

In conclusion, this room exceeds the CDC minimum requirement. The offset of 120 CFM is made up by air from outside the room.

Appendix B

California Regulations and Guidelines

Interim Tuberculosis Control Enforcement Guidelines

Cal/OSHA has published and enforces *Interim Tuberculosis Control Enforcement Guidelines*. These were published in 1992 and have been updated periodically. The most recent update was in March 1997.

Engineering controls mandated for isolation rooms include negative pressure and an air change rate of 12 ACH, which can be achieved by a combination of building ventilation and HEPA filtration. The agency also mandates that ventilation systems be tested at least annually and that records of each test be kept for at least five years.

The California Mechanical Code

The *California Mechanical Code* (CMC) regulates the construction of *new* isolation rooms in California hospitals. The current version is the 1995 CMC and consists of the 1994 Uniform Building Code (UBC) combined with amendments specific to California. The CMC is enforced by the Office of Statewide Health Planning and Development (OSHPD).

The California amendments include detailed requirements for the mechanical design of many hospital spaces, including negative pressure isolation rooms. Requirements for isolation rooms include negative pressure and a minimum ventilation rate of 10 ACH. OSHPD also mandates that each negative pressure isolation room be equipped with an anteroom and a permanent room pressure monitor.

In response to the resurgence of TB, and recognizing the expense of constructing a new CMC-compliant negative pressure isolation room, OSHPD provides a less expensive option for the isolation of TB patients in *existing isolation rooms or patient rooms*. These requirements were published as *Policy Intent Notice (PIN) Number 4* in 1996. *PIN Number 4* allows the use of portable HEPA filter units to create negative pressure and increase the effective ventilation rate in TB isolation rooms. The requirements for such rooms include negative pressure, a minimum ventilation air change rate of 12 ACH to match Cal/OSHA requirements, and provision of a permanent room pressure monitor.

Appendix C

Comparison of Guidelines and Recommendations

		REGULATIONS			GUIDELINES		
	OSHPD ¹	Cal/OSHA ²	CDC ³	ASHRAE ⁴	AIA ⁵		
Room designation	negative-pressure isolation room	atmospheric isolation	TB isolation rooms and treatment rooms	infectious isolation room	airborne infection isolation room		
Applies to	new & remodel	all	all	new & remodel	new & remodel		
Total air changes per hour (ACH)	≥10	≥12	prefer ≥12 minimum ≥6	≥6	≥12		
In-room HEPA recirculation allowed?	only for remodel under PIN 4, dated 2/16/96	yes	yes, if used to achieve 12 ACH	no	yes		
Total ACH can include HEPA recirculation?	no	yes	yes	no	yes		
HEPA-filtered recirculation to other areas?	no	yes	only if unavoidable	no	yes		
Dedicated exhaust required?	yes	no	no	no	no		
Exhaust discharge location	on roof 25' from openings, and minimum 7' high, or HEPA filtered	sufficiently separated from fresh air intakes	to prevent reentry of air into building unless HEPA-filtered	on roof, minimum 10' high, away from openings	on roof, 25' from fresh air intakes		
Minimum outside air change rate (OSA ACH)	2	not addressed	not addressed	2	2		
Minimum exhaust air excess airflow (offset)	75 CFM	not addressed	10% of supply or 50 CFM, whichever is greater	not addressed	50 CFM		

	REGULATIONS			GUIDELINES		
	OSHPD ¹	Cal/OSHA ²	CDC ³	ASHRAE ⁴	AIA ⁵	
Minimum room pressure differential	0.001" W.G.	not addressed	0.001" W.G.	not addressed	not addressed	
Minimum air velocity under door	100 FPM	not addressed	not addressed	not addressed	not addressed	
Air distribution	supply high, exhaust low, specific arrangement	not addressed	see figure S3-2 on page 75 of CDC Guidelines	from clean (ceiling) to less clean (floor) areas	from clean to less clean areas	
Upper room or in-duct UVGI allowed?	not addressed	yes, but not in lieu of ventilation	yes, but not in lieu of ventilation	not addressed	yes, but not in lieu of ventilation	
Variable air volume ventilation allowed	no	not addressed	not addressed	yes, but maintain minimum code ACH and pressurization	yes, but maintain minimum code ACH and pressurization	
Anteroom required?	yes	no	no	"may be desirable"	no	
Minimum anteroom ACH	10	not addressed	not addressed	10	10	
Minimum anteroom outside air change rate (OSA ACH)	2	not addressed	not addressed	2	no recommendation	
Anteroom pressurization?	positive to isolation room, neutral to corridor	not addressed	positive to isolation room, may vary to corridor	not addressed	positive to isolation room, negative to corridor	
Monitoring of negative pressure	continuous, alarmed	test annually	check daily while being used for isolation	not addressed	not addressed	

References

1. 1995 California Mechanical Code. Title 24, Part 4, Chapter 4: Ventilation Air Supply.
2. California Division of Occupational Safety and Health (Cal/OSHA). Interim Tuberculosis Control Enforcement Guidelines, revised March 1, 1997. Policy and Procedure C-47.
3. Centers for Disease Control and Prevention. Guidelines for preventing the transmission of *Mycobacterium tuberculosis* in health-care facilities, 1994. *MMWR* 1994;43(No. RR-13).
4. American Society of Heating, Refrigerating and Air Conditioning Engineers. Chapter 7: Health Care Facilities. In: 1995 HVAC Applications handbook. Atlanta: American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., 1995.
5. American Institute of Architects, 1996-1997 Guidelines for Design and Construction of Hospitals and Health Care Facilities published by the American Institute of Architects Academy of Architecture for Health, with assistance from the Department of Health and Human Services (DHHS).

Appendix D

Isolation Room

Pressure Monitor Checklist

ISOLATION ROOM PRESSURE MONITOR CHECKLIST

ROOM NAME AND NUMBER _____

MONITOR MANUFACTURER AND MODEL NUMBER _____

This form should be completed **annually** and updated **monthly** for each room pressure monitor. Negative pressure should be verified **monthly** to validate the monitor. A copy of the completed form should be kept in the Policies and Procedure binder for the department.

MONITOR SETTINGS

Normal pressure reading (monitor reading with door closed) _____ " W.C.

Alarm will sound if pressure differential drops to _____ " W.C.

Time delay _____ seconds

Remote alarm location(s) _____

ANNUAL MONITOR CHECKS

TASK	DATE COMPLETED	SIGNED OFF BY
Monitor calibrated in accordance with manufacturer's requirements		
Confirmed negative pressure using smoke trail testing (this test should be repeated monthly and signed off below)		
Verified alarm operation (by holding door open or blocking off exhaust grille)		
Alarm sounded after _____ seconds		
Pressure reading at alarm _____ " W.C.		
Monitor use and functions demonstrated to all floor staff		

MONTHLY NEGATIVE PRESSURE CHECK

date/initials _____ date/initials _____ date/initials _____

date/initials _____ date/initials _____ date/initials _____

date/initials _____ date/initials _____ date/initials _____

date/initials _____ date/initials _____ date/initials _____

Appendix E

Smoke Trail Testing Method for Negative Pressure Isolation Rooms

Smoke from a smoke tube can be used to observe airflow between areas or airflow patterns within an area.

To check the negative pressure in a room, hold the smoke tube near the bottom of the door and approximately 2 inches in front of the door, or at the face of a grille or other door opening. Generate a small amount of smoke by gently squeezing the bulb.

This test must be performed outside the room with the door closed.

The smoke tube should be held parallel to the door, and the smoke should be issued slowly from the tube to ensure that the velocity of the smoke does not overpower the air velocity. The smoke will travel in the direction of airflow.

If the room is at negative pressure, the smoke will travel under the door and into the room (e.g., from higher to lower pressure). If the room is not at negative pressure, the smoke will be blown outward or will remain stationary.

If there is an anteroom, release smoke at the inner door undercut, with both anteroom doors shut.

In addition to a pedestrian entry, some isolation rooms or areas are accessed through a wider wheeled-bed stretcher door. Release smoke at all door entrances to isolation rooms or areas.

If room air cleaners are being used in the room, they should be running during the test.

Because the smoke is irritating if inhaled, care should be taken to prevent direct inhalation from the smoke tube. However, the quantity of smoke issued from the tube is minimal and is not detectable at short distances from the tube.