

Infection Control Guide on Heating, Ventilation and Air Conditioning (HVAC)

for Nurse Managers and Clinicians



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Introduction

A core principle of infection control in health care settings is that health care-associated infections are not inevitable. The heating, ventilation and air-conditioning (HVAC) system is a critical component of infection control in a health care facility.

The HVAC system is responsible for tempering the air, adjusting the relative humidity in a space, establishing pressurization relationships between spaces, filtering and diluting the air recirculated through the building, ventilating the building and flushing contaminants (i.e., substances that can make the air impure and hazardous to breathe) from spaces.¹ This document explores these concepts in the context of infection control from a clinical perspective.

Clinicians who understand the facility's HVAC system can maximize their essential contributions to infection control by preventing system misuse and unintended outcomes. Because building operation decisions are ultimately made by the building owner and operators, frequent and clear communication between clinical and facility teams is best practice to ensure that patient environmental and infection control needs are met.

Inpatient health care facilities have some of the cleanest air found in the built environment and must adhere to strict environmental regulation from organizations including The American National Standards Institute (ANSI), ASHRAE and the American Society for Health Care Engineering (ASHE). First produced in 2008, ANSI/ASHRAE/ASHE Standard 170, *Ventilation of Health Care Facilities* is a major standard that dictates requirements for HVAC design.²

The 2017 version of ANSI/ASHRAE/ASHE Standard 170 dramatically redefined outpatient space requirements, so outpatient facilities might not be designed or operate to the same standards as inpatient spaces. However, it is still common in outpatient spaces to perform aerosol-generating procedures (AGPs) and to house patients positive for airborne infectious diseases. The combination of less stringent HVAC standards and infectious diseases can potentially cause contamination issues.

Figure 1 details a basic ventilation schematic. Fresh outside air (OSA) is constantly taken into the system (blue ductwork) to a central station air-handling unit (AHU), which conditions and filters the air. That air flows to rooms as supply air (green ductwork). Once in a space, supply air can be either:

- Recirculated to the AHU (yellow ductwork) to be mixed with fresh OSA, reconditioned and resupplied to a space.
- Exhausted (red ductwork) and removed from the building.

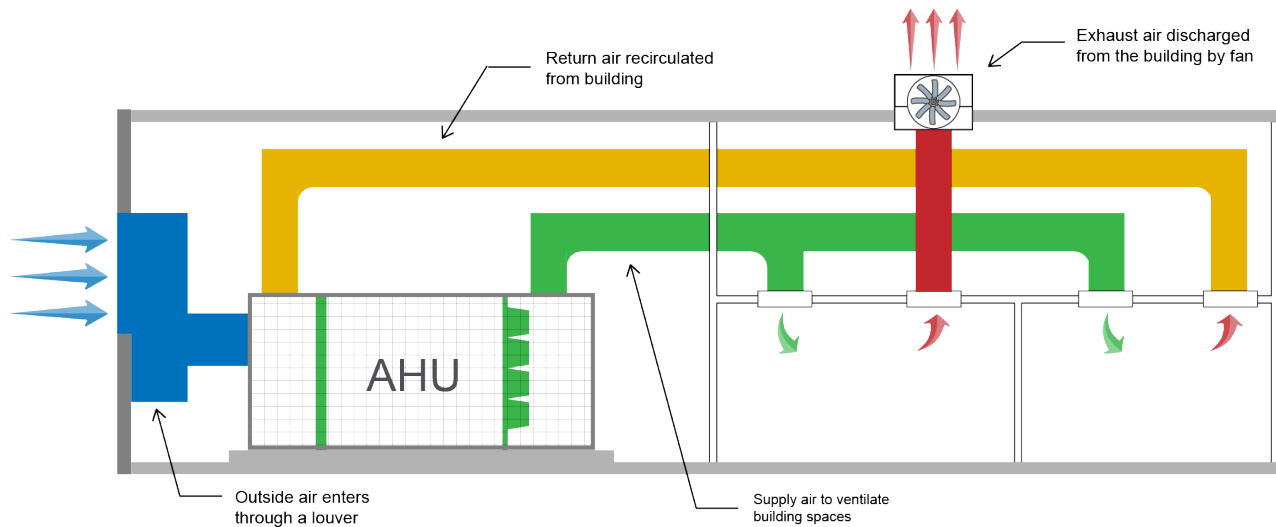


Figure 1. Ventilation system schematic.

Brief Literature Review

A building's heating, ventilation and air-conditioning (HVAC) design is driven by facility type as well as location, climate, building codes and available capital. While local and state code references and adoptions vary from location to location, the most pertinent guidance comes from the **Facilities Guideline Institute (FGI)**, which establishes guidelines dedicated to planning, design and construction, and **ASHRAE**, which produces standards dedicated to the built environment. Three of the most crucial standards for health care facilities from ASHRAE are:

- ANSI/ASHRAE Standard 52.2, *Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size*
- ANSI/ASHRAE Standard 62.1, *Ventilation for Acceptable Indoor Air Quality*
- ANSI/ASHRAE/ASHE Standard 170, *Ventilation of Health Care Facilities*

ANSI/ASHRAE Standard 52.2 establishes minimum efficiency reporting value (MERV) ratings for filters, which indicate how many particles filters absorb from the air. Based on the capture rate of particles at various sizes, the filters receive a MERV rating that allows consumers to compare products on a uniform scale.³

The amount of outside air delivered to a space is determined by **ANSI/ASHRAE Standard 62.1**⁴ and/or by **ANSI/ASHRAE/ASHE Standard 170** (for health care spaces specifically).⁵ Standard ANSI/ASHRAE 62.1 uses space type, occupancy levels and floor area to determine the quantity of outside air delivered to a space.⁶ ANSI/ASHRAE/ASHE Standard 170 also considers space type and additionally specifies the number of times air is changed in a space (air changes per hour [ACHs]).⁷ An HVAC designer will design non-health care spaces to ASHRAE Standard 62.1 minimum requirements and a health care space to whichever requirements are more stringent between ANSI/ASHRAE Standard 62.1 and ANSI/ASHRAE/ASHE Standard 170.⁸

In-Depth Review

Personal Protective Equipment

When working in or bringing materials to an infectious disease area, personal protective equipment (PPE) must always be worn, whether or not an individual is physically entering a patient room. This requirement applies to clinicians as well as HVAC technicians, environmental services (EVS) personnel or administrative workers in these areas.⁹ If not absolutely necessary, it is inadvisable to pass through a area housing an infected patient and building occupants should use alternate routes.

HVAC systems alone are incapable of protecting someone in the same room as an infectious patient. PPE is always required.¹⁰




Pressurization

Pressurization refers to directing airflow relationships between spaces. In a properly maintained HVAC system, pressurization reduces occupants' chances of exposure to contaminated air by flowing air from clean to less clean spaces.

Typically, rooms with known airborne contaminants are set at a negative relative air pressure, which brings air into the room rather than pushing it out. This contains contaminants to the space where they are generated. Negative pressure is established by removing (i.e., returning to the air-handling unit [AHU] or exhausting) more air from a space than is supplied. This imbalance pulls in additional air from adjacent spaces to make up for the air removed. In this way, the negative pressure relationship can mitigate the chances for dangerous contaminants to travel to clean areas. It is critically important to note that any pressure relationship relies on doors remaining closed, which will be discussed in the next section.

Conversely, a positive relative air pressure pushes air out of a room rather than pulling it in. This minimizes contaminants in spaces that may house an immunocompromised patient (e.g., operating room [OR] or protective environment [PE] room).¹¹ Positive pressure is established by returning less air than is supplied to a room, so air is constantly pushed out of the room into surrounding spaces. This keeps airborne contaminants from surrounding spaces out of the positively pressurized room.

Air will be induced to the room via small openings around the door frame when the door is closed. In signage, pressure is indicated by the following symbols inside a triangle:

- + for positive 
- 0 for neutral 
- — for negative 

Transfer air for negative or positive pressurization purposes is indicated by a broken arrow in the line through the door as seen in Figure 2.¹²

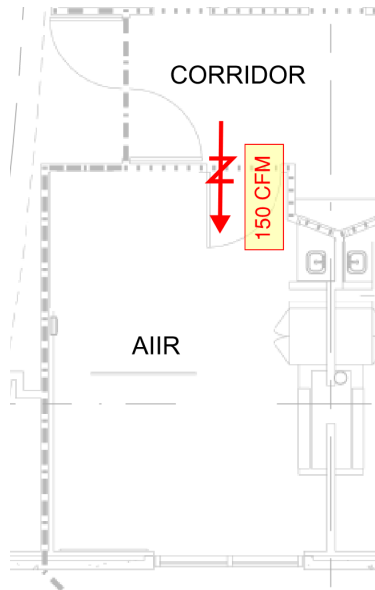


Figure 2. Transfer air symbol for negative pressurization.

Figure 3 and Figure 4 show interior perspectives of a negative room and positive room, respectively. In Figure 3 the tissue paper at the bottom of the door is being blown into the room as air comes in from the gaps around the closed door. In Figure 4, the tissue paper is forced tight to the closed door as air is sucked in around the gaps.



Figure 3. View from inside a negative pressure room.

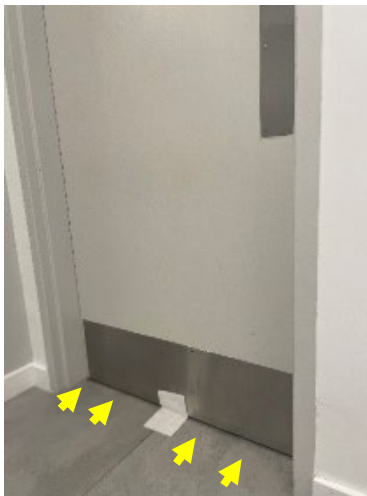


Figure 4. View from inside a positive pressure room.

Keeping the Door Closed

The infection control capabilities of all HVAC systems can be rendered useless by a single factor: human overrides. The most common opportunity for an unintentional human override is leaving a door open.

A space under negative pressure loses its pressure relationship when the door is opened because the HVAC system is designed to induce air through the cracks around the door frame with the door closed. Once the door is opened, the area of the opening through which air is induced becomes much larger than the design intends, and the HVAC system is incapable of maintaining the pressure relationship with the adjacent space. This allows for particles to migrate from the contaminated room to adjacent spaces.

Consider a scenario in which someone is smoking a cigarette in a room, as shown in Figure 5. If the individual keeps the door closed, the smoke particles will largely stay inside the room because there is no pressure relationship between the room and its adjacent spaces. Opening the door forces an exchange between the smoky and adjacent space air. Contaminated air contained by negative pressure migrates exactly this way when a patient room door is not closed.

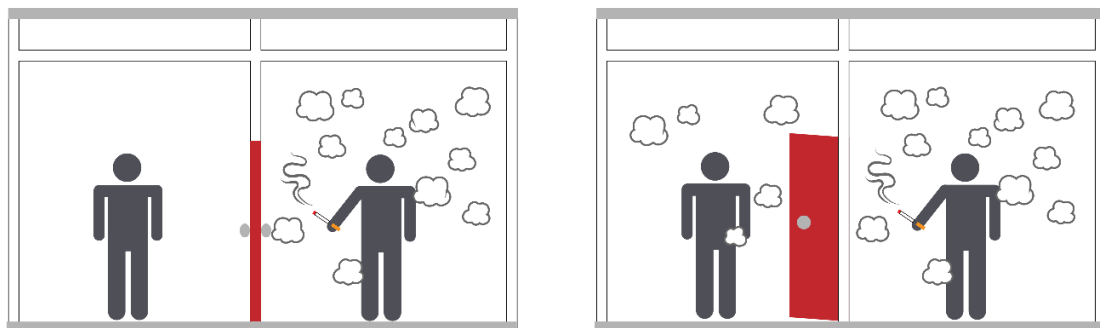


Figure 5. Smoke migrating indoors.

Filtration

Filtration refers to air passing through media that stop particles from continuing into supply airflow. Filtration is an important function of the HVAC system, and increasing filtration is a well-grounded strategy for air cleaning. Without proper filtration, both the building occupants and HVAC equipment could suffer adverse effects.

Filters (i.e., particle-trapping media) are rated on a minimum efficiency reporting value (MERV) system based on the ability to stop variously sized particles.¹³ As the MERV rating increases so does the filter's efficiency of capturing smaller particles.

Table 1, taken from ASHRAE Standard 52.2, *Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size*, shows the MERV and high efficiency

particulate air (HEPA) filter ratings by average particle size efficiency (PSE). A typical commercial building will have a MERV 8 filter, while an inpatient facility will have at least a MERV 14 filter.¹⁴

MERV rating	Average PSE 0.3-1.0 microns	Average PSE 1.0-3.0 microns	Average PSE 3.0-10.0 microns
1			< 20%
2			< 20%
3			< 20%
4			< 20%
5			20-34.9%
6			35-49.9%
7			50-69.9%
8			70-84.9%
9		< 50%	≥ 85%
10		50-64.9%	≥ 85%
11		65-79.9%	≥ 85%
12		80-89.9%	≥ 90%
13	< 70%	≥ 90%	≥ 90%
14	75-84.9%	≥ 90%	≥ 90%
15	85-94.9%	≥ 90%	≥ 90%
16	≥ 95%	≥ 95%	≥ 95%
HEPA	≥ 99.97%	≥ 99.97%	≥ 99.97%

Table 1. Filtration level by MERV rating. Source: ASHRAE Standard 52.2

The air discharged from a properly maintained and operated HEPA filter contains less particulate (including things like pollen, dust, and microbes) than fresh outdoor air. In fact, HEPA filters were designed to filter radioactive particles from the air by the U.S. Army during its development of nuclear weapons in World War II. These filters are still used in the nuclear power industry today.¹⁵

Dilution

Often, infectious particles are too small to follow the bulk airflow movement from a supply diffuser to an exhaust grille. The infectious particles will float and collide with and bounce off of other particles and around the enclosed space.¹⁶ The particles can be considered cleared from the room only after sufficient time has passed for the HVAC system to flush them while the room is unoccupied with the door closed. Consult Table 2 for the required decontamination times based on the air change per hour (ACH) rate of the space.¹⁷ It is important to note an ACH of one does not decontaminate the room; it takes many ACHs to occur before a room has been effectively decontaminated by an HVAC system. However, an HVAC system should not be

solely relied upon to decontaminate a room. For example, some particles will settle on exposed surfaces and require additional surface disinfection, typically by EVS.

ACH	99% Efficiency (minutes)	99.9% Efficiency (minutes)
2	138	207
4	69	104
6	46	69
7	35	52
10	28	41
12	23	35
15	18	28
20	14	21
50	6	8

Table 2. Decontamination times for varying ACH per CDC.¹⁸

HVAC Equipment

HVAC systems can receive air from either a central station AHU or smaller room recirculating units (e.g., fan coil units [FCUs]). Air temperature is regulated (i.e., tempered) by the same principles in both units, but the quality of air delivered differs greatly. Room recirculating units heat or cool the air but may not have higher levels of filtration. A central station AHU provides advanced filtration (MERV 14 or higher for inpatient facilities per ANSI/ASHRAE/ASHE Standard 170).¹⁹ Figure 6 indicates the pre-filter and final filter locations in an AHU. The pre-filter provides minimal if any dilution (see previous section); its primary function is to protect the AHU components from damage caused by large particles.²⁰ A final filter provides the filtration levels required to safely ventilate the building.²¹

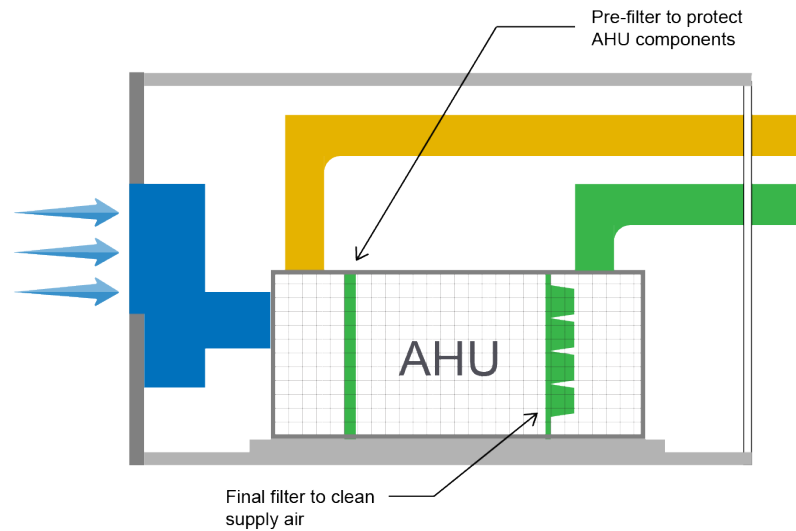


Figure 6. Pre-filter and final filter locations.

By contrast, in-room recirculating units have only pre-filters and no final filters as seen in Figure 7. The pre-filters are likely only MERV 8 rated and, as mentioned, will not provide adequate levels of infection control alone.²² Additional equipment such as portable HEPA filters will be required to pressurize and filter the air with an in-room recirculating unit to meet infection control requirements.²³

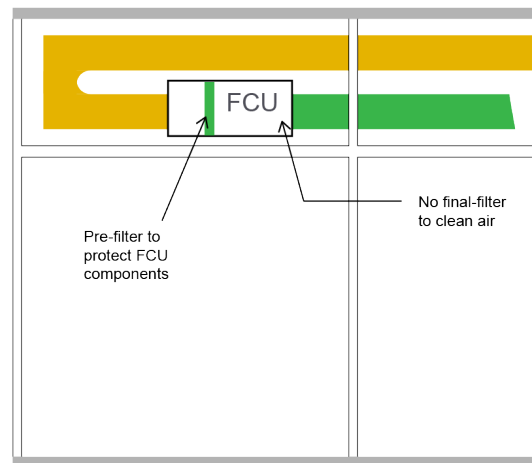


Figure 7. Pre-filter in a recirculating unit.

For some spaces, ANSI/ASHRAE/ASHE Standard 170 requires specific locations for the supply air source (aka inlet) and/or return/exhaust opening (aka outlet). For example, AIIR room exhaust outlets should be located directly above the head of the bed as shown in Figure 8.²⁴ In this arrangement, infectious output from a patient's coughing, sneezing, etc., will be directed away from health care staff²⁵ into the exhaust grille and discharged directly outside of the hospital.²⁶ For this reason, the placement of the patient in AIIR rooms should be maintained below the exhaust grill as much as possible.

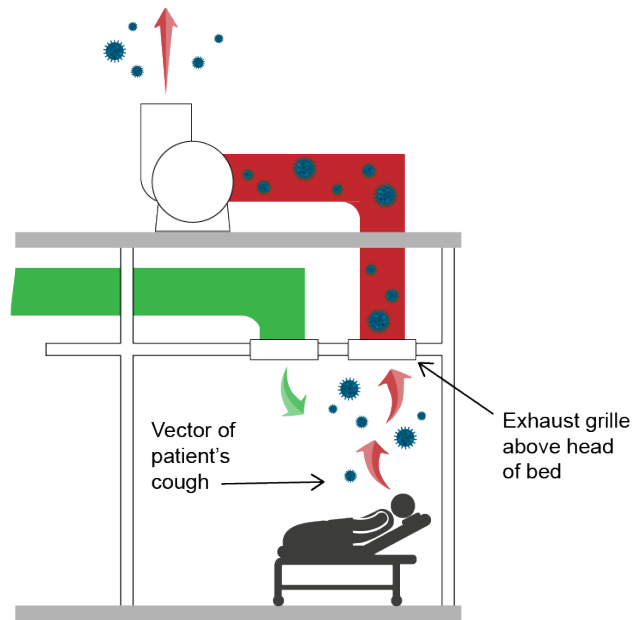


Figure 8. AIIR exhaust grille (outlet) location.

Spaces such as operating rooms (ORs), bronchoscopy, certain nuclear imaging, and medical gas storage are designed with outlets located low on the wall.²⁷ As shown in Figure 9, these low wall returns either exhaust denser gas from the lower area of the room or aid in creating an even (laminar) flow of air across a patient bed and away from health care staff.²⁸ These low wall exhaust or return points must be kept clear of any equipment or materials to function properly.

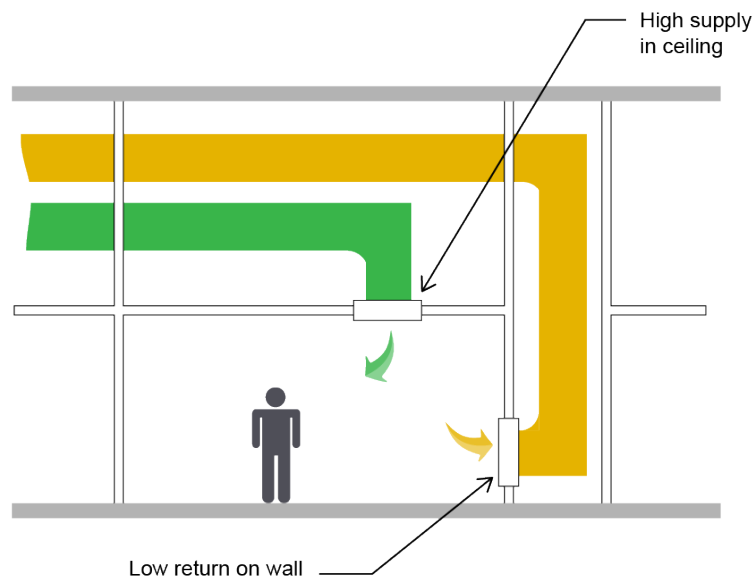


Figure 9. Low wall return diagram.

Critical spaces such as ORs for orthopedic procedures, transplants, neurosurgery and dedicated burn unit procedures, and pharmacy clean rooms and protective environment (PE) rooms will frequently have HEPA filters located within the ceiling supply inlet, which is an effective method for delivering the lowest particulate count to the space.²⁹

Airborne Infection Isolation Rooms (AIIRs)

An airborne infection isolation room (AIIR) is a space designed to house patients under investigation or confirmed positive for airborne infectious diseases³⁰ (e.g., influenza, tuberculosis, COVID-19, mumps, measles and pertussis).³¹ These spaces have an increased ACH to decontaminate the room. For example, an AIIR room should have 12 ACH (acute care patient room, 4 ACH; intensive care unit, 6 ACH).³² All of the air supplied to an AIIR is exhausted directly outdoors via a dedicated (and hazardous) exhaust system.

Review Table 2 for decontamination times for spaces with different ACH. When in use, the door should be closed at all times except as necessary for designated team members garbed in appropriate PPE.³³

Any time an aerosol-generating procedure (AGP) is taking place on an individual under investigation or confirmed positive for an airborne infectious disease, the procedure should be performed in an AIIR.³⁴ Figure 10 provides an airflow diagram of an AIIR during an AGP. The AIIR is negative to the corridor. Aerosolized particles will be flushed from the room due to the higher ACH via the exhaust grille above the head of the bed, and discharged from the hospital by an exhaust fan.³⁵

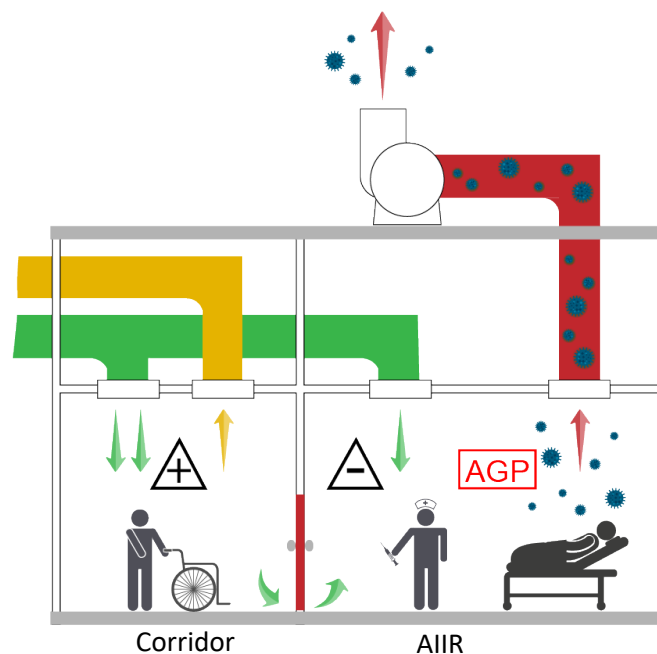


Figure 10. AGP taking place in an AIIR.

Protective Environment (PE) Rooms

Conversely to AIIRs, protective environment (PE) rooms are designed to hold immunocompromised patients and protect them from any potential contaminants in the air from adjacent spaces.³⁶ The PE room operates under the same principles as an AIIR: pressure relationships, a closed door and an increased ACH of 12.³⁷

However, PE rooms are distinct from AIIRs and must be used differently. A PE room will have a positive relationship to adjacent spaces to keep any airborne contaminants out for the immunocompromised individual's safety. Also dissimilarly to an AIIR, a PE room does not need to be exhausted to the outdoors because the susceptible individual does not produce particulates hazardous to other building occupants.³⁸

Best Practices and Recommendations

Many times building owners aim for a building that exceeds minimum code requirements in an effort to achieve higher resiliency, better operational performance and an enhanced occupant experience. The following are operational and design recommendations to achieve these targets as they pertain to infection control by heating, ventilation and air-conditioning (HVAC) systems.

Communication

Clinician leaders should be aware of HVAC system features and limitations to better understand which rooms are best suited for housing their patients (reading this document is an excellent start). It is also best practice to develop a reliable communication process with health care facilities management.

With a reliable communication process, facilities can and should alert the clinical team to HVAC system down time or temporary limitations, so the clinical team can respond effectively. By the same token, clinical team leaders can and should inform non-clinical staff about procedures and activities that are being performed in their clinical space, as well as areas that are housing individuals under investigation or confirmed positive for airborne infectious diseases.

Furthermore, HVAC systems are not perfect, and even with redundancy measures in place, machines can fail. These failures need to be communicated quickly and well. Clinicians also often face the unexpected and can partner with facilities to support rapid and effective solutions for patient care.

For example, if an AIIR is not available for a suspected or confirmed infectious patient but temporary or procedure space is required, alternatives are available. As previously discussed, ANSI/ASHRAE/ASHE Standard 170 requires air from certain areas to be exhausted directly outdoors. Radiology waiting rooms, emergency waiting rooms, triages, endoscopy, and bronchoscopy are examples of these areas that could be considered.³⁹ Additionally, areas such as operating rooms are feasible alternatives, with a high ACH rate for dilution and a design specifically to prevent cross contamination.⁴⁰

If any of these temporary solutions are pursued, the decision must be communicated to both clinical and facilities staff as decontamination (see Table 2) and cleaning would be required in the room before the room may be used again. Of course, after the individual has left the room, the necessary timeframe for space decontamination must elapse (Table 2) before the room is used again.

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It is recommended to have a detailed plan in place for moving individuals around the hospital. Designing this plan with input from your facilities department could be mutually beneficial and safest for your patients. For example, consider the proper process for moving an infectious patient from the emergency department to an AIIR. The amount of time the patient is outside the AIIR should be minimized and the route should not pass through any densely occupied spaces. The plan should be updated to reflect any temporary provisions or construction at the facility, which facilities management should communicate to you.

Relative Humidity

Relative humidity is a ratio expressing how much water content is currently in the air to how much water the air is capable of holding, which plays a large role in infection control. For example, an RH of 50% means the air is half as moist as is physically possible. An RH of 100% means the air is holding as much moisture as it can; any more moisture will result in fogging of the air. Figure 11 demonstrates the optimal relative humidity ranges to prevent bacteria, viruses,

fungi, mites, respiratory infections, allergic rhinitis, chemical interactions and ozone production. The 40% to 60% relative humidity range is ideal to mitigate these contaminants. Spaces housing airborne infectious patients (if not all spaces housing patients) should be kept within these levels.⁴¹

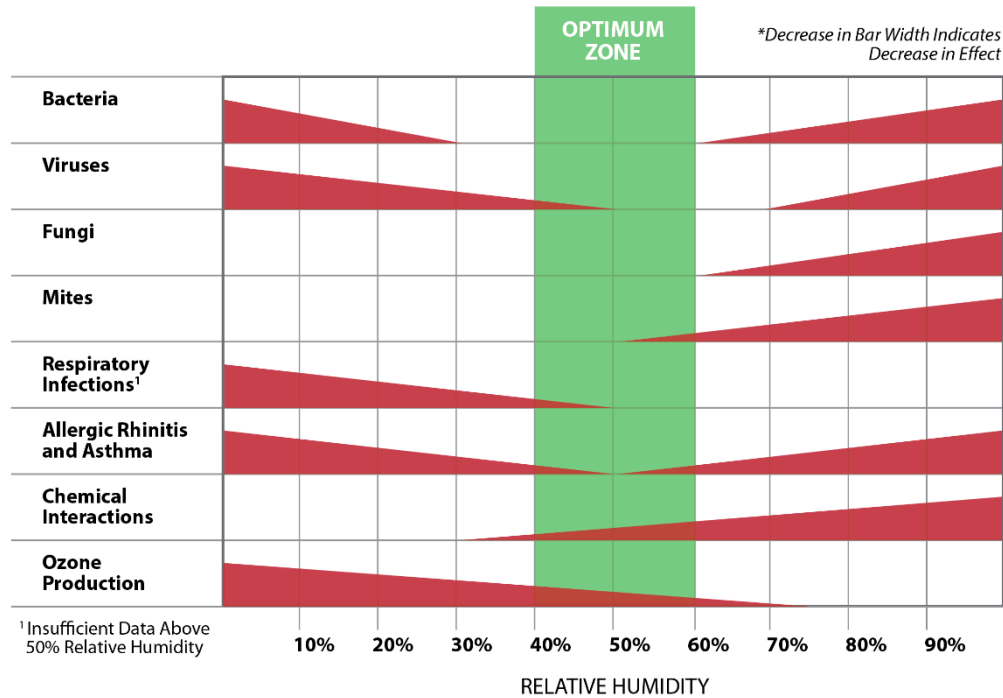


Figure 11. Sterling Risk Chart for Relative Humidity.

Anterooms

An anteroom establishes a buffer between an isolation space and its adjacent spaces.⁴² Highlighted in Figure 12, the anteroom functions so an individual can enter or exit the isolation space without compromising the pressure relationship inside. When the isolation room is in use, the anteroom door should be closed with managed access (similar to an AIIR door). The anteroom should not be used for storage, except as dictated by the clinical team for hand-washing and donning/doffing protective equipment. Note that isolation rooms not equipped with an anteroom will require adequate space in the corridor for hand-washing and donning/doffing protective equipment.⁴³

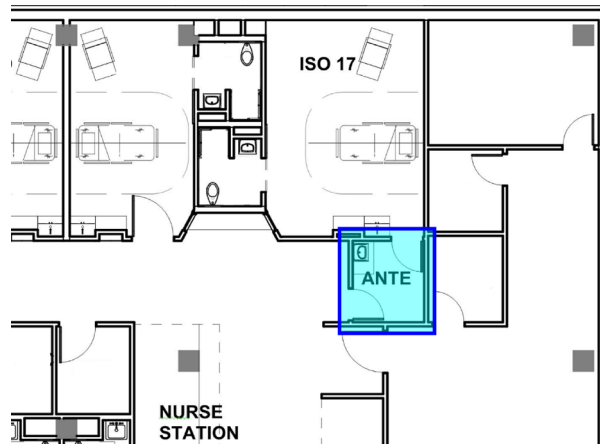


Figure 12. Anteroom for an isolation room.

Figure 13 demonstrates the clean-to-less-clean airflow for an AIIR with an anteroom: air is drawn into the anteroom from the corridor, then into the AIIR from the anteroom. Remember, opening doors compromises pressure relationships. With an anteroom in place, this means that the anteroom door and AIIR door will not be open at the same time, so there will always be a closed door between the individual who is infectious and building occupants in adjacent spaces.⁴⁴

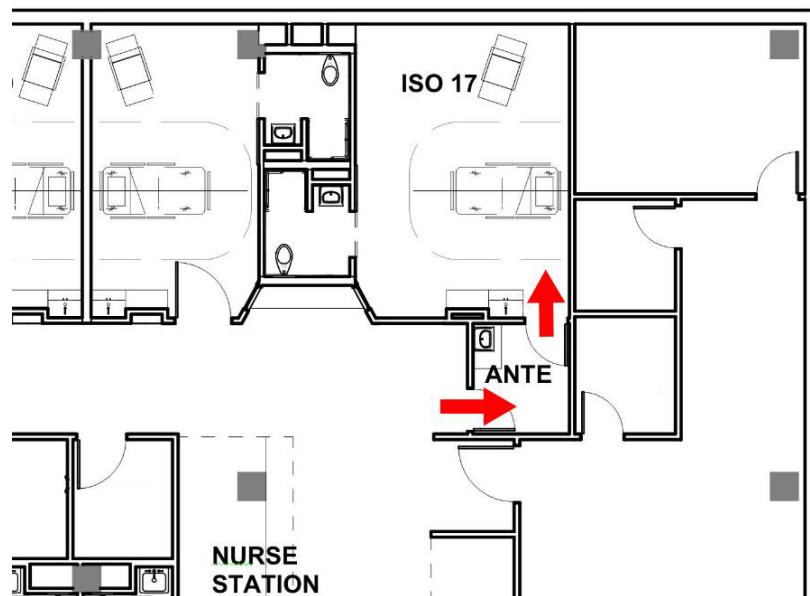


Figure 13. Anteroom pressurization diagram.

Temporary Conditions

For infection control purposes, facilities sometimes introduces temporary conditions to a space. It is critically important to be aware of and support those provisions. If a portable HEPA machine is placed in the room, the machine must not be turned off because it provides a pressurization relationship between the contaminated area and adjacent spaces, as well as to increase dilution of contaminants. If the HEPA machine is turned off, the pressure relationship is compromised.⁴⁵

Modes of Transmission

Airborne infections in susceptible hosts are brought indoors to a health care facility by people, air currents, construction materials, etc. Harmful microorganisms can proliferate in certain indoor conditions and can serve as a source for health care-associated infections if they enter the HVAC system. There are two types of transmission for airborne infectious diseases: short and long range.

Short range refers to diseases (e.g., pertussis and meningococcal infection) where the microorganisms can remain active and infect individuals via droplets released by an infected individual.³ Short-range modes of transmission include coughing, sneezing or talking.

Long-range modes of transmission are indirect via droplet nuclei aerosolized in the air (e.g., wind, HVAC systems or building drafts). Examples of diseases caused by long-range transmission are tuberculosis and measles.⁹

New and Emerging Technology

New and emerging technology is a constant, especially in health care, whether upgrading the physical environment or operational processes. When the facility incorporates new and emerging technologies, a careful assessment is necessary to determine that they are proven safe and effective. Any claims should be verified by a reputable third party agency (e.g., Air-Conditioning, Heating, and Refrigeration Institute [AHRI], International Organization for Standards [ISO], Underwriters Laboratories [UL], etc.).⁴⁶

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Conclusion

An HVAC system is an important part of a health care facility's infection control system, and when any part of a system is not operating as intended, the entire system's success may be compromised. While it is not the clinical team's responsibility to monitor and maintain the HVAC system, the team should understand its purpose and basic function related to infection control. This knowledge allows the clinical team to optimize the system's outcomes (e.g., ensuring low wall grilles are not blocked or performing an aerosol-generating procedure in an airborne infection isolation room) and reduce human overrides (e.g., leaving the door open to a pressurized room). An informed clinical team supports a robust infection control system for a health care facility.

Case Studies

Case Study A: FGI 2021

The Facilities Guideline Institute (FGI) released a document in March 2021 titled "Guidance for Designing Health and Residential Care Facilities that Respond and Adapt to Emergency Conditions," within which is a case study highlighting an academic medical center in the mid-Atlantic region of the United States and its facilities' response to the COVID-19 pandemic.⁴⁷

The case study includes helpful guidance for managing patients admitted for infectious diseases, and specifically discusses how to address patients with varying levels of condition severity. The document also provides a thorough risk assessment table for infectious diseases that aligns with the Centers for Disease Control and Prevention (CDC) recommendations, listed in Table 3 below.⁴⁸

Facility Design Consideration	Hazard Being Addressed?	Priority	Risk	Other Notes, Specific Solutions
Surge capacity (ED)	Exponential spread of disease	High	High	Converted the emergency department conference room to additional treatment stations
Surge capacity (ICU)	Exponential spread of disease	High	High	As elective surgeries were canceled, the perioperative suite was used for COVID-19 patients with an ICRA tent vestibule in the positive pressure, HEPA-filtered OR's. Air volumes were turned back to decrease pressure across the threshold, and freestanding HEPA filters supplemented OR ventilation for air scrubbing.
Surge capacity (morgue)		Medium	High	Rented morgue containers (refrigerated sea boxes) and racks, temporary power, and plywood ramps were added.
Separation of patient populations (inpatient)	Transmission (all types)	High	High	In accordance with the clear emergency operations plan outlined, non-positive, positive, and PUI (patient under investigation) patients were immediately separated. This was critical to the outcome of no known cross-transmission of disease to patients as a result of being in the hospital.
				Designated COVID-19 units were identified in areas/floors that would be easy to isolate in accordance with the emergency operation plan.
				PACU and pre-op bays (which have headwall infrastructure and services in place) were used as additional ICU beds for non-infectious patients, facilitating separation of patient populations.
Surfaces (cleaning)	Contact transmission (cross-contamination between patients/caregivers)	High	Medium-High	Operationally, all known and potential areas where known and unknown positive individuals may have been located in the facilities were deep cleaned. EVS immediately validated cleaning protocols with the infection prevention department and refreshed education of staff in cleaning techniques.
				From a future design perspective, surfaces would be considered in the ICRA with respect to how well finishes would hold up to cleaning agents to ensure surfaces would remain clean and not degrade due to caustic chemicals. How does this affect design of the room, wardrobe, headwall, etc.?
Hand hygiene		High	Medium-High	Added numerous hand sanitation stations.
PPE donning/doffing space	Droplet/contact	High	High	Temporary ICRA barriers (negative pressure) were set up at unit entrances, primarily for donning and doffing PPE. ICRA vestibules were temporarily installed at the entry door of the OR (surge capacity use).
Convenient access to PPE	Droplet	High	High	Added numerous stations for mask distribution
				Storage of high volumes of PPE was provided on mobile covered racks that were kept in hallways where volumes were greatest. Where feasible offices and conference rooms were converted to storage rooms for more localized distribution. Enough PPE for 72 hours was maintained on hand. A storage room for these supplies was created to validate expirations.
				For future designs, storage should be considered. What is required for just-in-time delivery of supplies? What is stored on-site at a centralized warehouse? What scale is needed?

Air handling	Airborne	Low	Medium	All negative pressure rooms were not possible. Because CDC recommendations did not require every ICU to be in a negative pressure space, this was a lower priority. Alternatively solutions were pursued, and portable HEPA air scrubbers were added to ICU rooms that were not negative pressure.
		High	Medium	A "viral mode" was created to revise the air-handling system to increase the air changes by maximizing supply and return air. HEPA air scrubbers were used where patients were cohorted.
				All PUIs were considered to be on airborne precautions so spaces for these patients and the highest level of modification to existing AHU systems. Freestanding HEPA filtration units were installed in those areas as well.
High	High risk of transmission during certain procedures	Intubation spaces (closed door) with temporary negative (slightly negative) rooms were created in trauma bays and triage spaces using existing HVAC and added mobile HEPA recirculation units.		
Airborne Infection Isolation (All) rooms	Airborne	Medium	Low (negative rooms required only for certain procedures)	The quantity of negative pressure rooms was derived from the air balance report. Although staff thought they needed additional negative rooms, the CDC only recommended them for aerosolization procedures. Due to existing mechanical limitations, alternate solutions had equally acceptable outcomes.
				Procedures were performed in "viral mode" non-negative rooms with air scrubbers.
				Patients who tested negative for COVID-19 but required medically necessary All rooms were positioned in All rooms on non-COVID-19 and non-PUI units.

Table 3. Risk Assessment Table for Airborne Transmission.⁴⁹ Courtesy of FGI.

Case Study B: Shobha Subhash 2013

An article titled "Isolation anterooms: Important components of airborne infection control" emphasizes the value of isolation anterooms and provides examples, including an instance where infection control measures were compromised and its ramifications.⁵⁰

The document describes the case of a nurse working in an ICU contracted chickenpox from a patient housed in an AIIR, despite never entering the AIIR. It is important to note that this individual was not wearing personal protective equipment (PPE), which may have prevented transmission. Even though the nurse never entered the AIIR, the nurse did walk past the AIIR while the door was open and handed medical instruments to colleagues through the open door while the colleague was standing in the AIIR.

If the AIIR had been designed with an anteroom to provide a pressure differential between the AIIR and the corridor while the nurse handed instruments to a colleague, or while colleagues were entering or leaving the room, this case of transmission may not have happened.⁵¹

Tools

- Project Firstline Quick Guide on HVAC’s Role in Infection Control for Nurse Managers and Clinicians (2022)
- Project Firstline Professional Development Slides on HVAC’s Role in Infection Control for Nurse Managers and Clinicians (2022)
- Project Firstline Infection Control Guide on Heating, Ventilation and Air Condition (HVAC) for Health Care Facilities Managers (2022)
- Project Firstline Infection Control Guide on Heating, Ventilation and Air Condition (HVAC) for HVAC Technicians (2022)
- CDC “Guidelines for Environmental Infection Control in Health-Care Facilities” (July 2019)
- [CDC Project Firstline](#)
- Minnesota Department of Health Office of Emergency Preparedness Program. “Airborne Infectious Disease Management, Methods for Temporary Negative Pressure Isolation” (February 2020)
- ANSI/ASHRAE/ASHE Standard 170, *Ventilation of Health Care Facilities* (2021)
- FGI *Guidelines for Design and Construction of Healthcare Facilities* (2008)
- *American Journal of Infection Control*, “Isolation anterooms: important components of airborne infection control” (2013)

Glossary

ACH – Air changes per hour – The number of times the air is replaced per hour in the room. Replacing the air volume in the room once DOES NOT mean the room is decontaminated. See Table 2 on ACH decontamination times for recommended timeline to entering a hazardous room.

AGP – Aerosol-generating procedure – A medical procedure that produces airborne particles or respiratory droplets.

AHRI – Air-Conditioning, Heating, and Refrigeration Institute

AHU – Air-handling unit – HVAC component responsible for filtering, conditioning, and moving the air around a building. See also **central station AHU**.

AIR – Airborne infection isolation room – A room designed to the requirements of ANSI/ASHRAE/ASHE Standard 170 that is intended to provide airborne infection isolation.

ANSI – American National Standards Institute – U.S. governmental organization responsible for overseeing development of voluntary consensus standards for products, services, processes, systems, and personnel. Involved in the publication of ANSI/ASHRAE Standard 62.1, *Ventilation for Acceptable Indoor Air Quality* and ANSI/ASHRAE/ASHE Standard 170, *Ventilation of Health Care Facilities*.

ASHE – American Society for Health Care Engineering – An association of professionals who design, build, maintain and operate hospitals and other health care facilities, a trusted resource that provides education, regulatory guidance, advocacy representation and professional development. Involved in the publication of ANSI/ASHRAE/ASHE Standard 170, *Ventilation of Health Care Facilities*.

ASHRAE – An international society of engineers responsible for producing standards for and performing research of HVAC systems. Previously known as the American Society of Heating, Refrigerating and Air-Conditioning Engineers. Involved in the publication of:

- ASHRAE Standard 52.2, *Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size*
- ANSI/ASHRAE Standard 62.1, *Ventilation for Acceptable Indoor Air Quality*
- ANSI/ASHRAE/ASHE Standard 170, *Ventilation of Health Care Facilities*

Central station air-handling unit – A large piece of HVAC equipment typically in its own room or on the roof, responsible for heating, cooling, filtering, mixing and blowing the air around the facility.

Contaminant - A polluting substance that causes an impurity considered to be undesirable

EVS – Environmental services – Hospital workers responsible for cleaning and disinfecting the building. A hospital's first line of defense for infection prevention.

FCU – Fan coil unit – A piece of HVAC equipment responsible for cooling or heating air only. Similar to an AHU but typically only serves one space and does not have infection control capabilities.

FGI – Facilities Guidelines Institute – Organization working to develop guidelines dedicated to designing and building hospitals and other health care facilities. Relevant publications include:

- *FGI Guidelines for Design and Construction of Hospitals*
- *FGI Guidelines for Design and Construction of Outpatient Facilities*
- *FGI Guidelines for Design and Construction of Residential Health, Care, and Support Facilities*

Final filter– An air filter designed to be the final level of filtration before air leaves a piece of equipment. Intended to remove very fine particles from the air.

HEPA – High efficiency particulate air (filter) – A mechanical air filter capable of filtering at least 99.97% of airborne particles.

HVAC – Heating, ventilation and air-conditioning (system) – Building system responsible for tempering, pressurizing, and ventilating the building.

ICU – Intensive care unit – A patient room dedicated to housing patients in a more severe condition, or released from a demanding medical procedure. Can also be referred to as a critical care unit (CCU).

ISO – International Organization for Standardization – An international organization dedicated to producing standards across many products and companies.

MERV – Minimum efficiency reporting value – Rating value developed by ASHRAE to report a filter's ability to capture particles at varying size. A higher MERV rating indicates a higher performing filter.

Occupancy levels – Amount of people inside of a space at any time. Typically, HVAC systems are designed to supply sufficient fresh OSA (as determined by ANSI/ASHRAE 62.1) at a space's anticipated peak occupancy.

OR – Operating room – A surgical room where medical operations and surgeries occur.

OSA – Outside air – Air from the outside that is brought in to establish pressure relationships, bring breathing air into the building, and dilute recirculated return air from the building.

PE – Protective environment – A room designed to hold immunocompromised patients and protect them from any potential contaminants in the air in adjacent spaces.

Positive air pressure – Pressurization in which air is pushed out of a space in order to prevent airborne contaminants from entering a room from adjacent spaces.

PPE – Personal protective equipment – protective clothing or equipment to be worn by an individual as a defense against acquiring an infection or illness.

Pre-filter– An air filter placed at the inlet of HVAC equipment designed to capture dust and large particles that could damage components inside the equipment.

Space type – Classification of a room depending on its function. A room’s space type and function will dictate which sections of specific HVAC design codes should be followed, and what provisions must be included in the HVAC system.

UL – Underwriters Laboratories – An organization dedicated to advancing public safety. Provides a certification of marketed products.

Endnotes

- ¹ ANSI/ASHRAE/ASHE. "Standard 170, Ventilation of Health Care Facilities" Feb. 2021
- ² See note 1.
- ³ ANSI/ASHRAE. "Standard 52.2, Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size" 2017
- ⁴ ANSI/ASHRAE. "Standard 62.1, Ventilation for Acceptable Indoor Air Quality" November 2019
- ⁵ ANSI/ASHRAE/ASHE. "Standard 170, Ventilation of Health Care Facilities" Feb. 2021
- ⁶ ANSI/ASHRAE. "Standard 62.1, Ventilation for Acceptable Indoor Air Quality" November 2019
- ⁷ ANSI/ASHRAE/ASHE. "Standard 170, Ventilation of Health Care Facilities" Feb. 2021
- ⁸ ANSI/ASHRAE/ASHE. "Standard 170, Ventilation of Health Care Facilities" Feb. 2021; ANSI/ASHRAE. "Standard 62.1, Ventilation for Acceptable Indoor Air Quality" November 2019
- ⁹ AHA/ASHE et al., "Using the Health Care Physical Environment to Prevent and Control Infection" 2018
- ¹⁰ CDC. "Ventilation in Buildings" 09 Feb. 2021. <https://www.cdc.gov/coronavirus/2019-ncov/community/ventilation.html>
- ¹¹ ANSI/ASHRAE/ASHE. "Standard 170, Ventilation of Health Care Facilities" Feb. 2021
- ¹² ASHRAE. "2020 ASHRAE Handbook – HVAC Systems and Equipment" 2020
- ¹³ ANSI/ASHRAE. "Standard 52.2, Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size" 2017
- ¹⁴ ANSI/ASHRAE/ASHE. "Standard 170, Ventilation of Health Care Facilities" Feb. 2021; ANSI/ASHRAE. "Standard 62.1, Ventilation for Acceptable Indoor Air Quality" November 2019
- ¹⁵ United States Department of Energy. "DOE Handbook Nuclear Air Cleaning Handbook" Nov 2003
- ¹⁶ Imani, R.J., et al. "The influence of air flow velocity and particle size on the collection efficiency of passive electrostatic aerosol samplers." *Aerosol and Air Quality Research* 19, no. 2 (2019): 195-203. <https://aaqr.org/articles/aaqr-18-06-0a-0211>
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- ¹⁹ ANSI/ASHRAE/ASHE. "Standard 170, Ventilation of Health Care Facilities" Feb. 2021
- ²⁰ ASHRAE. "2020 ASHRAE Handbook – HVAC Systems and Equipment" 2020
- ²¹ See note 18.
- ²² See note 18.
- ²³ ANSI/ASHRAE/ASHE. "Standard 170, Ventilation of Health Care Facilities" Feb. 2021
- ²⁴ See note 21.
- ²⁵ Hermans, R.D. "The Search for Minimum Protection, How Safe Do Healthcare Facilities Need to Be" 25 Jun. 2019
- ²⁶ Memarzadeh, F. "Factors to Consider in the Design of Isolation Rooms, Analysis of Particle Distribution after Coughing." Presentation, National Institute of Health.
- ²⁷ ANSI/ASHRAE/ASHE. "Standard 170, Ventilation of Health Care Facilities" Feb. 2021
- ²⁸ See note 25.
- ²⁹ See note 25.
- ³⁰ See note 25.
- ³¹ CDC. "Guidelines for Environmental Infection Control in Health-Care Facilities" Jul. 2019. <https://www.cdc.gov/infectioncontrol/pdf/guidelines/environmental-guidelines-P.pdf>
- ³² ANSI/ASHRAE/ASHE. "Standard 170, Ventilation of Health Care Facilities" Feb. 2021
- ³³ CDC. "Guidelines for Environmental Infection Control in Health-Care Facilities" Jul. 2019. <https://www.cdc.gov/infectioncontrol/pdf/guidelines/environmental-guidelines-P.pdf>
- ³⁴ CDC. "Interim Infection Prevention and Control Recommendations for Healthcare Personnel During the Coronavirus Disease 2019 (COVID-19) Pandemic" Sep. 2021. <https://www.cdc.gov/coronavirus/2019-ncov/hcp/infection-control-recommendations.html>
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- ³⁶ See note 33.
- ³⁷ See note 33.
- ³⁸ See note 33.
- ³⁹ See note 33.
- ⁴⁰ See note 33.
- ⁴¹ Arundel, A.V., et al. "Indirect Health Effects of Relative Humidity in Indoor Environments" Mar. 1986. <https://ehp.niehs.nih.gov/doi/abs/10.1289/ehp.8665351>
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- ⁴³ See note 40.
- ⁴⁴ ASHRAE. "HVAC Design Manual for Hospitals and Clinics"
- ⁴⁵ Minnesota Department of Health, Office of Emergency Preparedness. "Airborne Infectious Disease Management, Methods for Temporary Negative Pressure Isolation" 2007. <https://www.health.state.mn.us/communities/ep/surge/infectious/airbornenegative.pdf>
- ⁴⁶ CDC. "Ventilation in Buildings" 09 Feb. 2021. <https://www.cdc.gov/coronavirus/2019-ncov/community/ventilation.html>
- ⁴⁷ FGI. "Guidance for Designing Health and Residential Care Facilities that Respond and Adapt to Emergency Conditions" March 2021
- ⁴⁸ See note 45.
- ⁴⁹ See note 45.
- ⁵⁰ Subhash, S.S., et al. "Isolation anterooms: important components of airborne infection control." *American journal of infection control* vol. 41.5 (2013): 452-455.

⁵¹ See note 48.

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