Alternate Care Site HVAC Guidebook

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1. INTRODUCTION

1.1. History of the Development of the Guidebook

The Coronavirus pandemic created unprecedented challenges to the nation's healthcare system. USACE was tasked with the design and construction of Alternate Care Sites (ACS) to relieve the strain on the healthcare system. The ASHRAE Alternate Care Sites Task Force was convened upon the request to the ASHRAE Epidemic Task Force from the USACE Headquarters to provide engineering recommendations, solutions, and guidance to address the HVAC systems for ACS. ACS are temporary facilities that are used as flexible patient care space to limit the overload of hospitals and other urgent care facilities during the pandemic to allow them to treat the most severely ill patients.

1.2. Objectives

Coronavirus Disease 2019 (COVID-19) is a respiratory tract infection caused by a newly emergent coronavirus, SARS-CoV-2, that was first recognized in Wuhan, China, in December 2019. Genetic sequencing of the virus suggests that SARS-CoV-2 is a beta coronavirus closely linked to the SARS virus. While most people with COVID-19 develop mild or uncomplicated illness, a percentage develop severe illness requiring hospitalization and oxygen support, and some requiring admission to an intensive care unit and use of ventilators. In such severe cases, COVID-19 can be complicated by Acute Respiratory Disease Syndrome (ARDS), sepsis, and septic shock, multi-organ failure, including acute kidney failure as well as cardiac injury. Older age people with comorbid diseases appear to have greater risk factors for death due to additional complications.

This guide is being developed in response to a need for ACS to be deployed in locations where permanent hospital beds are insufficient for the number of COVID-19 positive patients needing care. The guidance included in the later sections is meant to apply specifically to COVID-19 patient care but would be generally applicable to similar viruses transmitted as airborne infectious aerosols and through droplets. Project teams for future ACS deployment would need to review the requirements shown in this guidebook to determine which may be applicable to epidemics or pandemics for similar viruses.

1.3. Scope

This guide will primarily be applicable to host sites with large open spaces as outlined in the table below. Most of the recommendations are suitable for Arena to Healthcare (A2HC) situations. Convention Centers and other "large spaces" are included in guidance for A2HC. Conversion of smaller large space facilities such as school gymnasiums would also be applicable to a high degree. These are several of the most robust types of ACS which may operate throughout the year while offering greater flexibility in approach to the design and construction of the overall ACS. Closed Hospital to Health Care (CH2HC) will also be applicable. Many of the requirements from ASHRAE Standard 170 and other references will be directly applicable to the CH2HC sites.

Hotel, dormitory, barracks, and tent ACS facilities will have the least applicability to this guide. Hotel sites are limited in the retrofit that may take place to return the facility back to hotel usage when the ACS is no longer required. Tent locations, due to the inability to maintain a tight envelope, are only suitable during temperate weather conditions which may limit their use depending on the local climate.

Based on these limitations the hotel, dormitory, barracks, and tent facilities may not holistically use this design guide although some of the reference material and principles contained in its sections may be useful.

Patients requiring protective isolation should be treated at hospital facilities that have patient rooms with anterooms to maintain positive pressure relative to the neighboring spaces.

Table 1-1: ACS facility types

Temporary Facility Type	**Level of Applicability**	**Comments**
Arena (A2HC)	High	Flexible location with outer "buffer" zone including convention centers
High School Gymnasium	High	Flexible location with smaller bed capacity used in rural areas
Closed Hospital (CH2HC)	Medium	Infrastructure may be existing with need for modifications
Hotel / Barracks / Dormitory (H2HC)	Low	Non-acute patients only to minimize disruption of host site
Tent	Low	Limited use due to climatic constraints

1.4. Participants

Technical experts have been convened to provide guidance for ACS HVAC systems to include the following topics: filtration, temperature, humidity, air distribution and exhaust systems. Thanks to members of the ASHRAE Epidemic Task Force (AETF) for their assistance in developing this document.

Table 1-2: ACS HVAC Guidebook Contributors

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1.5. Contaminant Control

Contaminant control through dilution by ventilation in buildings has been a topic of interest in the HVAC industry since 1973 when ANSI/ASHRAE Standard 62 was first published. In 1986, the World Health Organization reported a significant number of newly constructed western buildings were not properly ventilated, leading to the phrase “sick building syndrome” to be coined and used hence forth as a catalyst to increase awareness and drive change within commercial building ventilation requirements. In 2004, ASHRAE Standard 62 was split into commercial and residential sections (62.1 & 62.2) and is now the common building standard for ventilation requirements. Then, in 2008, ASHRAE Standard 170 was published to provide ventilation guidance that is specific for healthcare facilities. In conjunction with these standards and others related to the human environment and what we know about the mitigation of viral dispersion, the following approaches are minimum design requirements and optimal practices for temporary facilities used as wards for infected patients. The use of any facility for non-infected patients, as a spill-over facility, should utilize the existing system approach if it can meet or exceed the minimum requirements necessary for proper patient care.

This guidebook aims to provide recommendations in applying these standards which are used for permanent facilities to temporary sites under less than ideal conditions or with time, budget, and technical feasibility constraints.

1.6. Document Contents

The following sections are included in the guide. Each section is meant to elaborate on approaches used to satisfy a project work statement including motivation for using the approach and examples of its implementation.

1. Introduction – provides background on the development of the guide and clarifies its applicability to various types of ACS.
2. Requirements – outlines the technical basis of design for approaches recommended by this guide.
3. Airflow – describes the parameters for airflow in exhaust, supply, and return air systems included in the patient rooms or patient care areas as well as throughout the ACS supporting areas.
4. Filtration – elaboration on the use of filtration of ventilation and exhaust air to protect patients and staff.
5. Space conditions – description of recommended space conditions and how these may be provided for an ACS being deployed into an existing facility.
6. Prioritization – methodology for identifying which mechanical system approaches may be pursued to provide care to patients knowing that most ACS must prioritize certain features due to limited time, budget, and site characteristics.
7. Additional sections may be added as more material is developed for use in planning future ACS.

1.7. References

1. ANSI/ASHRAE/ASHE Standard 170-2017
2. ANSI/ASHRAE Standard 62.1-2019
3. ANSI/ASHRAE Standard 55-2017
4. ANSI/ASHRAE Standard 52.2-2017
5. ANSI/ASHRAE Standard 180-2018, Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems
6. ASHRAE Position Document on Infectious Aerosols updated in April 2020
7. Unified Facilities Criteria (UFC) 4-510-01 – Design: Military Medical Facilities
8. Patient Hood Study from CDC NIOSH
    a. https://www.cdc.gov/niosh/surveyreports/pdfs/301-05f.pdf
9. CDC--Interim Infection Prevention and Control Recommendations for Healthcare Personnel During the Coronavirus Disease 2019 (COVID-19) Pandemic
    a. https://www.cdc.gov/coronavirus/2019-ncov/hcp/infection-control-recommendations.html
10. CDC--Aerosol Generating Procedures
    a. https://www.cdc.gov/coronavirus/2019-ncov/hcp/faq.html?CDC_AA_refVal=https%3A%2F%2Fwww.cdc.gov%2Fcoronavirus%2F2019-ncov%2Fhcp%2Finfection-control-faq.html

11. Infectious Diseases Society of America (IDSA)- Aerosol-Generating Procedures—Guidelines table 3 on COVID-19

    a. https://www.idsociety.org/globalassets/idsa/practice-guidelines/covid-19/infection-prevention/table-3.pdf#Table3

12. Federal Healthcare Resilience Task Force Alternate Care Site Toolkit 3rd Edition

13. https://www.usace.army.mil/Coronavirus/Alternate-Care-Sites/

14. https://www.usace.army.mil/Coronavirus/Industry-Information-Re-COVID-19-Support/

15. Taylor and Tasi 2018

2. REQUIREMENTS AND RECOMMENDATIONS FOR MECHANICAL SYSTEMS

2.1. Definition of Case Types

The following requirements have been developed for Alternative Care Sites (ACS) listed in Table 2-1. The table describes the case type or acuity as well as the preferred type of patient room configuration.

An important distinction among the types of facility are the likelihood of aerosol generating procedures (AGP) that may take place. CDC defines AGP as "procedures that are more likely to generate higher concentrations of infectious aerosols than coughing, sneezing, talking, or breathing. These AGP potentially put healthcare personnel and others at an increased risk of pathogen exposure and infection."

Aerosols of various sizes and quantities are produced when people talk, cough, sneeze and even breath. Airborne transmission of diseases can occur when pathogens are present in small aerosols which remain suspended in air for prolonged periods of time. In healthcare settings, certain medical procedures are known or suspected to generate infectious aerosols resulting in increased risks of airborne disease transmission. Some of the most common procedures considered at risk for generating respiratory aerosols generating procedures (AGPs) could be performed at alternate care sites include:

- open suctioning of airways
- sputum induction
- cardiopulmonary resuscitation
- endotracheal intubation and extubation
- non-invasive ventilation (e.g., BiPAP, CPAP)
- bronchoscopy
- manual ventilation
- NG tube placement

Research is ongoing in regard to the current COVID-19 pandemic in regard to the degree of aerosol transmission, however the design practices used in this guidebook apply to protect staff, patients, and visitors from infectious aerosols that may be generated that include other pathogens in addition to exposure to SARS-CoV-2.

Table 2-1: Definition of Case Types

Cases	Patient Category*	Clinical Differentiation	Healthcare Classification	Space Type***	Examples of Applicable Facilities
(1) Acute, infectious disease positive, enclosed patient spaces	**ACUTE** (COVID-19 or other similar infectious disease, Positive)	On continuous ventilation therapy, infectious aerosols are present, AGPs more likely	Limited Critical Care** (Non-Ambulatory)	Enclosed Spaces (Single or Multiple Patient Occupancy)	Large open spaces (e.g. arenas, convention centers, gyms) with enclosed patient area/room (Figure 2-1)

Cases	Patient Category*	Clinical Differentiation	Healthcare Classification	Space Type***	Examples of Applicable Facilities
(2) Non-Acute, infectious disease positive, enclosed patient spaces	**NON-ACUTE** (COVID-19 or other similar infectious disease, Positive or assumed positive)	May require supplemental oxygen, infectious aerosols are present	Basic Care (Ambulatory)	Enclosed Spaces (Single or Multiple Patient Occupancy)	Large open spaces (arenas, gyms….) with enclosed patient area/room (Figure 2-1), Hotel Rooms (hotel rooms, dormitories, barracks….) (Figure 2-2)
(3) Non-Acute, infectious disease positive, open patient spaces / cubicles	**NON-ACUTE** (COVID-19 or other similar infectious disease, Positive or assumed positive)	May require supplemental oxygen, infectious aerosols are present	Basic Care (Ambulatory)	Open Space (Multiple Patient Occupancy)	Large open spaces (arenas, gyms….) with open cubicle patient area (no ceiling) (Figure 2-3) or large space with an open bay (Figure 2-4)

* This column is not intended to represent true clinically defined patient acuity but represents a general categorization
** Patients with critical medical conditions that require more than ventilator and/or oxygen support to be treated in hospitals
*** Combining patients within multi-occupancy patient space requires confirmed diagnosis of same infectious disease(s)

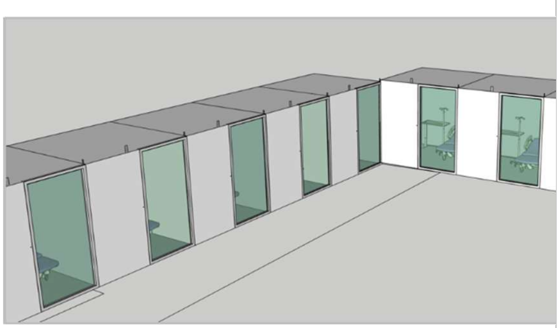


Figure 2-1: Large open spaces with enclosed patient rooms

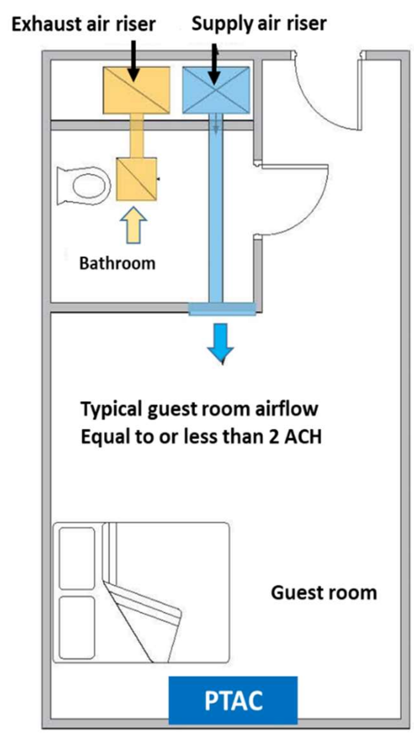
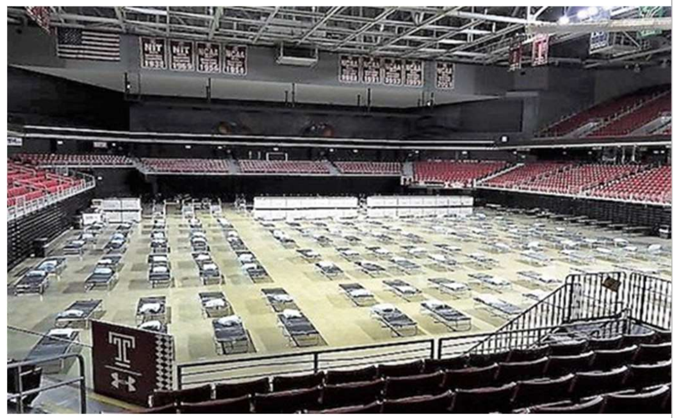


Figure 2-2: Diagram of converted hotel room

	
Figure 2-3: Large open space with open cubicle patient area	Figure 2-4: Open space with no partitions

2.2. Requirements for Environmental Conditions

Space temperature setpoints in the patient spaces listed in Figure 2-1 should meet the ASHRAE Standard 170 temperature range between 70F and 75F. Other spaces in the Alternate Care Site should follow ASHRAE Standard 170-2017 Table 7.1. However, for temporary usage in this application, slight deviation is allowed. When enclosed patient areas are ventilated and conditioned using air supplied through transfer grilles (See Figure 2-5) the project team will evaluate the capacity of the existing infrastructure to provide adequate conditions through transfer air or with supplemental conditioning to maintain the specified temperatures. Use of PPE within the ACS may also indicate the need for temperatures down to 68F. "WRT" defines pressurization "with respect to" neighboring spaces.

These enclosed areas may be conditioned with transfer air or by using individual cooling units to deliver conditioned supply air into the patient space. Unidirectional flow is recommended for either transfer air concepts, cooling units, or both in parallel. Temporary AHUs may also supply multiple spaces in lieu of transfer air or individual A/C units.

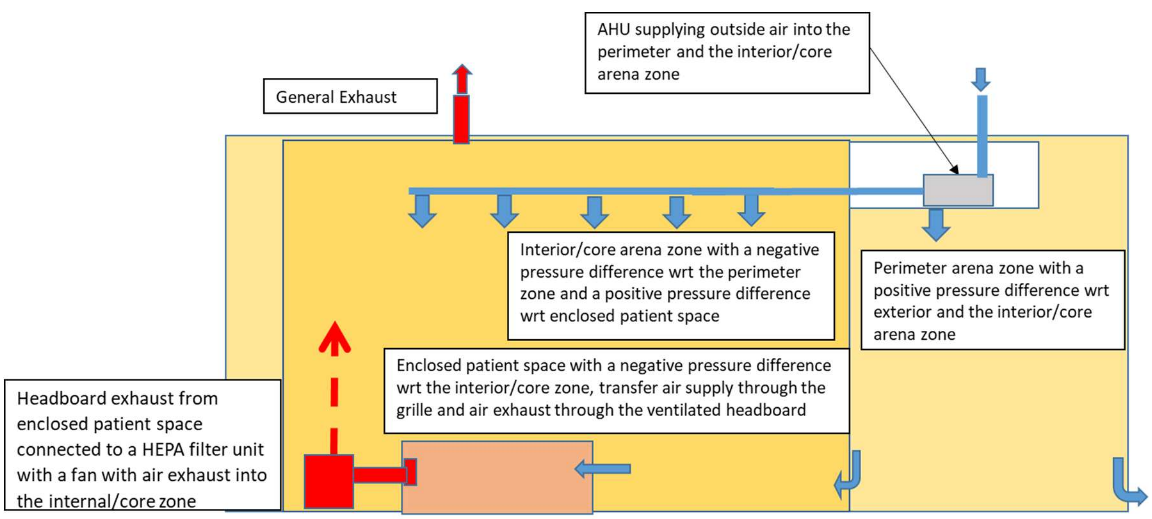


Figure 2-5: Schematic A of Enclosed Patient Room Ventilation

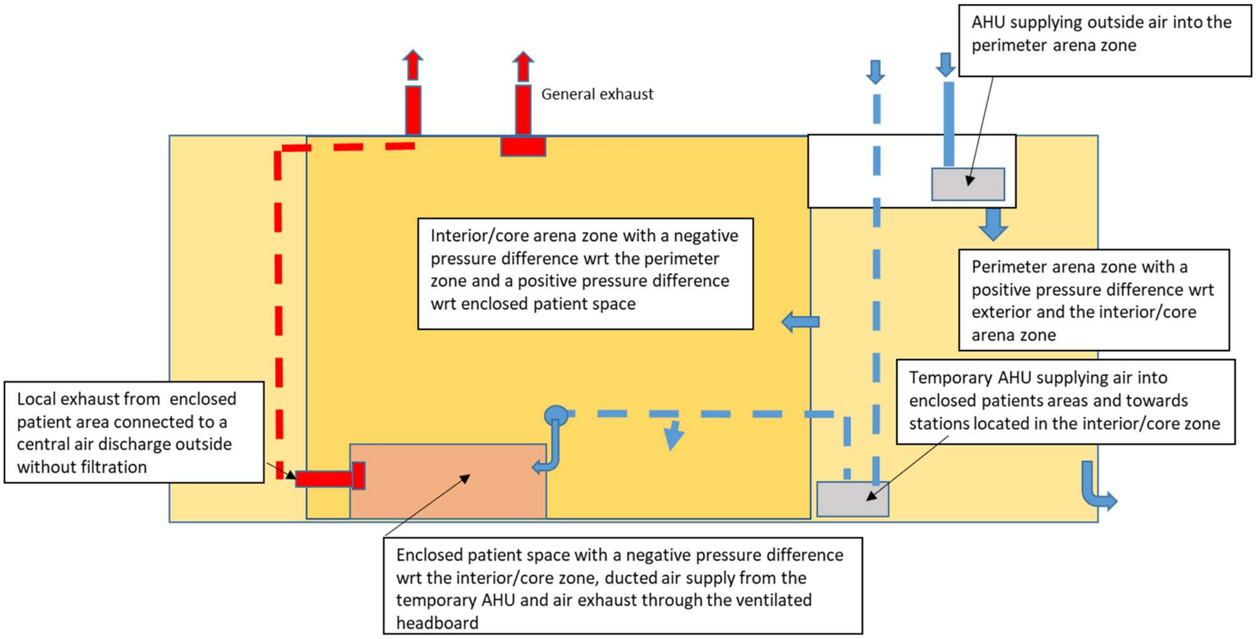


Figure 2-6: Schematic B of Enclosed Patient Room Ventilation

Figure 2-5 and Figure 2-6 show schematics A and B for air supply to and exhaust from the large open space with a perimeter zone and an enclosed patient rooms. Supply air is entering the patients' area via transfer grille (A), or from a temporary AHU ducted to the enclosed patients' area (B).

HVAC systems serving an ACS should be capable to maintain space relative humidity (RH) above 30% (especially important for cold and dry climate), and below 60%. RH above 40% has been reported to improve patient outcomes and reduce the spread of similar infections such as influenza (Taylor and Tasi 2018). ASHRAE's Position Document on Infectious Aerosols does not provide a specific relative humidity level to maintain but recommends "*Practitioners may use the information herein to make building design and operation decisions on a case-by-case basis*."

Building envelope construction may be a constraint in providing higher humidity levels even if HVAC systems are capable of providing humidified air. Many ACS will be limited in the ability to utilize humidified air due to the potential for condensation and the resulting risk of mold growth.

Exhaust/return air inlet must be located above or near the patient's head in the headwall to promote unidirectional flow to effectively remove contaminants. The use of an exhaust hood with an enclosure over the patient's upper body can greatly improve the capture rate and removal of aerosols generated by the patient.

Supply air outlets shall be sized, located, and installed to promote effective contaminant control via establishing proper airflow pattern (i.e. Supply air devices to be installed opposite of the patient's bed) while conditioning the space. Supply air velocities within 24 inches of the patient's head or entrance plane of a capture hood shall be 40 fpm or lower to limit interference with exhaust capture efficiency. Although ASHRAE Standard 170 provides some guidance on patient comfort through recommendations on temperature and relative humidity ranges, refer to ASHRAE Standard 55 for a more detailed analysis of thermal comfort beyond temperature and relative humidity such as air velocity, clothing insulation, metabolic rate and radiant temperature.

2.3. Requirements for Pressure Management

Patient treatment spaces or patient rooms in an ACS shall be negatively pressurized to limit transfer of airborne contaminants into adjacent spaces. Air pressurization within an ACS shall be coordinated with the clinical concept of operations to define clean and less-clean zones and account for staff donning and doffing areas, as well as clean patient room observation areas and staff respite areas. This guide is based on the premise that all patients are COVID-19 positive. The preferable solution is isolation of infected patients in single-occupancy, fully enclosed patient room as shown in Figure 2-7 provided with individual room temperature, relative humidity and pressurization controls. Enclosed rooms are recommended as the more reliable method to provide airflow in the desired quantities and maintain pressure relationships. Additionally, they may help protect staff and patients from non-COVID-19 illness or disease that patients may have. This approach improves mitigation efforts to slow the potential spread of additional infections between patients. ACS developed using this guide should include screening areas to prevent mixing of suspected COVID-19 patients with non-COVID-19 patients.

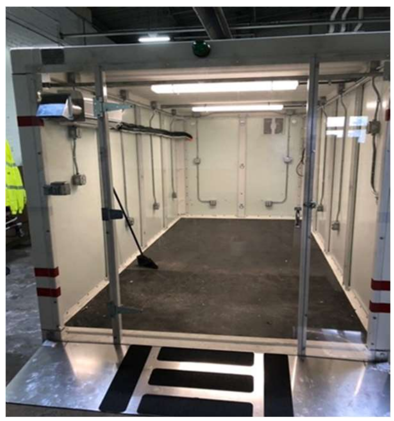


Figure 2-7: Photograph of enclosed patient room

The relative pressurization between the patient's room and adjacent spaces as shown in Figure 2-8 and Figure 2-9 should be negative whether the adjacent spaces are part of the ACS or are unmodified areas of the host facility.

Clean spaces within the ACS should be positively pressurized relative to the patient care area or other less-clean spaces to reduce the possibility of airborne pathogens contaminating personnel and clean supplies.

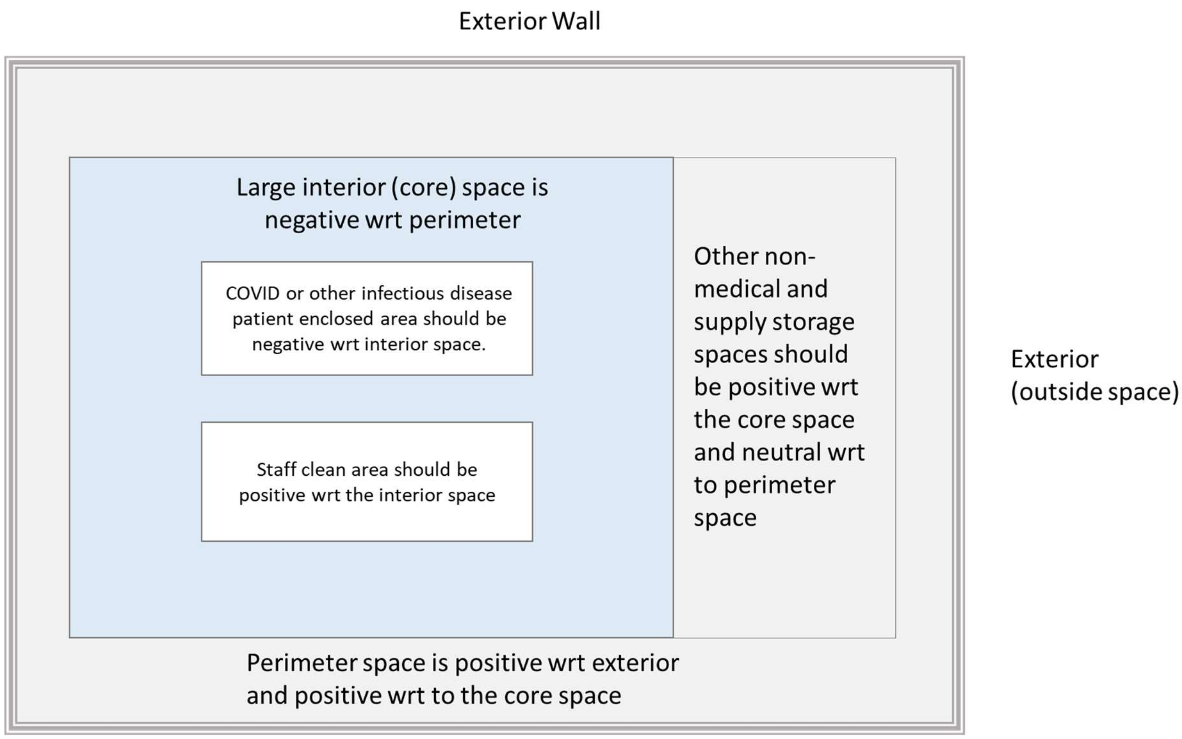


Figure 2-8: Interior / core arrangement with perimeter zone

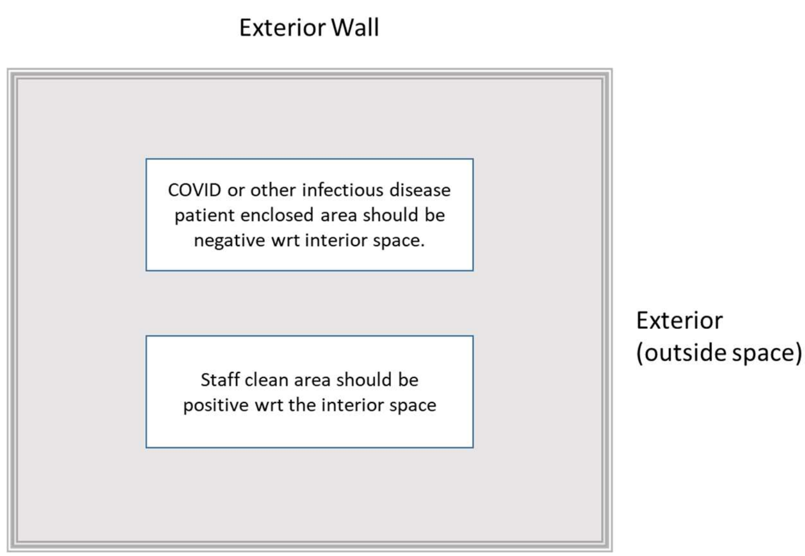


Figure 2-9: Interior zone without a perimeter zone

ASHRAE Standard 170 requires a minimum of 0.01 in (2.5 Pa) of water column to maintain proper negative or positive pressure between two adjacent spaces. Enclosed ACS patient rooms should attempt to achieve this relative pressure.

The overall building pressure should be maintained positive in relation to exterior to prevent unfiltered outside air entering the building. The uncontrolled infiltrating air can be cold and dry (DOE climate zones 6-9) or hot and humid (DOE climates zones 0a through 3a), which may cause significant impact on environmental control and patient comfort within the building.

2.4. Requirements for Exhaust and Supply Airflow and Air Change Rates

2.4.1. Exhaust Airflow

In acute and non-acute patient rooms intended for patients with a known/suspected infectious airborne, novel, or respiratory disease, airflow within the patient room should be primarily driven by the exhaust air exiting the room as this system will create the room negative static pressure and facilitate local source capture. Local source capture is prioritized due to its effectiveness while dilution ventilation may also be used alongside of local capture or as the sole approach in some cases. In addition, properly designed local source capture systems will also provide equivalent or greater air changes within the patient room as their dilution ventilation counterpart, thus providing the best of both aerosol control options.

To pursue the local source-control approach, place an exhaust hood (a.k.a. a Ventilated Headboard) of approximate 4' wide x 2' high directly behind the patient's head, with the hood bottom positioned roughly 6-inches above the horizontal mattress surface. A graphical representation of a ventilated headboard is shown in Figure 3-11. Ventilated headboards provide:

- a special inlet system designed to provide a high air capture rate into the exhaust or filtration system.
- a surge isolation capacity within alternate care site treatment rooms.
- near-instant capture of patient-generated aerosol.
- low effective capture velocities (30-35 fpm) without being interrupted by competing cross-currents.
- retraction feature that allows doctors, nursing staff, and technicians to conduct hands-on clinical procedures while still offering some degree of protection.
- continuous high volume air changes within the patient room and induces protective directional airflows when make-up/supply air locations are appropriately positioned.
- volumetric exhaust of 240-280 cfm which may provide the desired room ACH rate.
- Flexible configuration for patient's angle from horizontal.

In large spaces (arena, convention center, or tents) with open cubicle patient spaces (without a ceiling or one of sealed walls) holding infectious patients, exhaust cubicle air directly to the outdoors using grilles/hoods to control virus concentration and to prevent stagnant zones inside partitions. If direct exhaust to the outdoors is unfeasible, discharge through a HEPA filter before returning cubicle air to the arena space.

2.4.2. Supply Airflow

Outside air supply rate based on ASHRAE Standard 170 to be 2 ACH based on an individual patient room's volume with typical ceiling heights.

ASHRAE Standard 170 also requires 12 ACH for patient rooms which may be increased if necessary to maintain pressurization as described in Section 2.3. Airflow requirements are likely to be infeasible for conversion of hotel or barracks facilities to acute patient care areas without major modifications to the HVAC systems.

Outside supply airflow rate into large open spaces such as gyms or arenas with partitions are expected to be 0.3 cfm/ft2 based on ANSI/ASHRAE Standard 62.1 calculated for the net arena floor area.

When installation of local exhaust systems in open patient spaces with non-acute, COVID-19 positive patients is not feasible, supply air from a height less than fifteen feet towards the occupied zone using ASHRAE Group E diffusers to create a directional ventilation air distribution pattern.

2.5. Requirements for Air Discharge

Follow ASHRAE Standard 170 requirements for exhaust air. The standard allows air from exhaust hoods and from general exhaust to be discharged directly outdoors when:

- the discharge can be arranged in a vertical direction (with no rain cap or other device to impede the vertical momentum) and at least 10 ft. (3 m) above the adjoining roof level with a stack velocity of at least 2500 fpm (Figure 2-10a); and
- exhaust discharge outlets are located not less than 25 ft. (8 m) horizontally from outdoor air intakes, operable windows/doors, and areas that are normally accessible to the public

Patient room exhaust discharge outlet(s) and general exhaust from the ACS shall be configured to terminate into the atmosphere in a vertical direction (with no rain cap or other device to impede the vertical momentum) and at least 10 ft (3 m) above the ACS roof level with a stack velocity of at least 2500 fpm, and shall be located not less than 25 ft (8 m) horizontally from any outdoor air intakes, operable windows/doors, and areas that are normally accessible to the public as shown in Figure 2-11b. High-velocity nozzles and roof mounted exhaust fans may be utilized to introduce ambient outside air into the discharged airstream.

When air discharge from local exhaust systems outside the building are not technically feasible, recirculation HEPA filter units shall be permitted. In a high bay spaces with filtered exhaust into the large open space, exhaust air should be discharged in a vertical direction from a height of at least 15 ft. above the floor level when space height permits, with a discharge velocity less than 600 fpm to reduce disturbance to temperature and contaminant stratification along the space height.

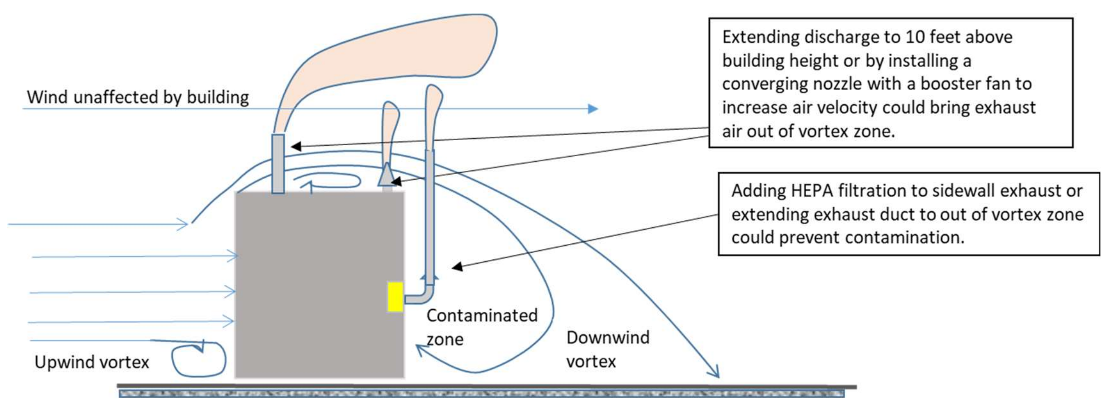


Figure 2-10: Air discharge without exhaust air filtration

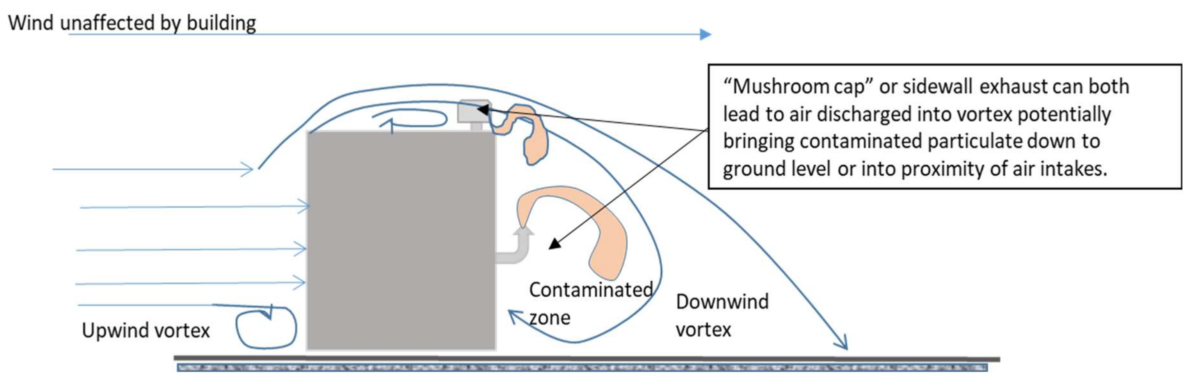


Figure 2-11: Air discharge with air filtration

2.6. Requirements for Filtration Efficiency for Supply and Exhaust Systems

2.6.1. Filtration of Supply Air

Air supply shall be cleaned by using MERV 8 pre-filters and MERV 14 final filters per ASHRAE Standard 170-2017 including Addendum P. A full description of filtration requirements is included in the standard as part of Table 7.1 including other applicable parameters.

2.6.2. Filtration of Exhaust Air

When local or general exhaust systems do not meet minimum requirements in Section 2.5 and shown in Figure 2-10, exhaust air shall be HEPA-filtered prior to discharge (pre-filter may be desired to extend HEPA filter longevity). If HEPA installation is not feasible, MERV 16 or 15/15A may be used as long as discharge location is not within 10’ of building entrainment or occupied zones or areas that are normally accessible to the public.

When air discharge from local exhaust systems outside the building is not technically feasible, air cleaning and recirculation using HEPA fan/filter units shall be permitted with air discharged internally in a vertical direction from a height of at least 15 ft. above the floor level, with a discharge velocity less than 600 fpm to reduce disturbance to temperature and contaminant stratification along the space height.

Induced draft fans may be provided to increase the effective stack height where conditions shown in Figure 2-11 are in effect.

Where existing equipment to be reused in the ACS don’t provide the required supply air filtration efficiency, an AHU shall be retrofitted to add MERV14 filter or a separate filter box shall be installed along the supply air distribution system, depending on the ability of the existing AHUs to overcome the additional pressure drop associated with higher MERV rated filters as shown in Figure 2-12. When static pressure created by existing fan is not sufficient to provide required airflow rate with an increase pressure drop over the additional filter, a supply air booster fan should be used.

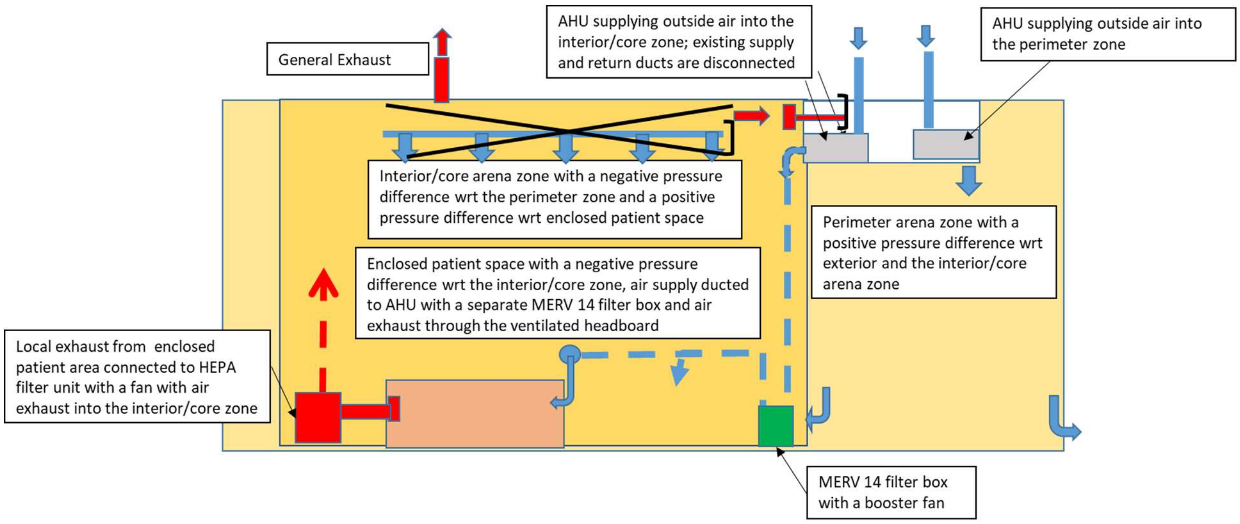


Figure 2-12: Retrofit for existing supply air system

2.6.3. Requirements for Filter Maintenance

Pre-filters and filters including HEPA filters should be inspected regularly to check for gaps, bowing of filters, excessive loading, etc. Filter banks with MERV ratings 12 and above should be provided with a manometer or differential pressure measuring device that is readily accessible and provides a reading of differential static pressure across the filter to indicate when the filter needs to be changed. Installations that may be in service for six months or longer are more likely to benefit from manometers. According to ANSI/ASHRAE Standard 180-2018 filters should be inspected at least quarterly and pre-filters may be inspected more frequently if environmental conditions are poor or according to manufacturer's recommendations. HEPA filter are typically replaced on the annual basis if used in continuous service which may exceed the duration of deployment for many ACS. Filtration technology shall be checked to meet specific application requirements regarding the airflow rate, static pressure and filtration effectiveness, logistic of filter replacement, etc.

Filter systems utilizing "bag in, bag out" method of filter changes are also recommended as design features to minimize exposure to operations staff. In the absence of bag in, bag out filters staff will need PPE storage areas to don protection during filter changes as described on ASHRAE's Epidemic Task Force website.

2.7. Requirements to Duct Systems

For A2HC situations, it can be anticipated that these spaces are designed to accommodate much bigger groups of people and greater cooling loads, and therefore the total supply airflow rate provided by existing HVAC system may be sufficient to control thermal load. It could also be possible that the exhaust rate provided by existing HVAC system would be sufficient for areas of the facility that do not have patients.

CH2HC scenarios may have existing systems with airflow capacities and other infrastructure sizes in a similar magnitude as size and capacity of systems that will be needed in an ACS.

General and local exhaust ductwork from the negative pressure spaces shall be designed so that all potentially contaminated ductwork within the building is under negative pressure. Ductwork downstream from a HEPA filter such as a HEPA fan filter unit or "clean air machine" is not considered to be contaminated.

ACS constructed in the past have used either 100% exhaust for the patient room air leaving the facility or HEPA filters for recirculated air where 100% exhaust air was not feasible. Providing 100% exhaust or HEPA filtration will be more important if research points towards COVID-19 being airborne or if this guide is being adapted to other airborne illnesses.

Locating fans on the roof or other building exterior location is a best practice method to provide negative pressure ductwork inside the facility as shown in Figure 2-11. HEPA filtration for air discharged inside the host facility may also be used.

Supply and return air distribution ductwork can spread bacteria and diseases, which can greatly affect patients with weak immune systems. When existing HVAC systems are used, interior surfaces of the air distribution system (i.e., AHU, ductwork, terminal units, air devices, etc.) exposed to airflow may need to be cleaned. Inspect existing air distribution system including supply and return ductwork to identify the presence of dirt and mold which can then be cleaned before the facility is occupied. Duct lining should be evaluated for risk of contamination if it is present in the existing system. Note that the primary location for contamination is the cooling coil and drain pan. These shall be inspected and cleaned.

3. AIRFLOW APPROACHES AND METHODS OF SUPPLY AND EXHAUST

3.1. Airflow Approaches and Methods of Supply and Exhaust

3.1.1. Introduction

Contaminant capture and removal effectiveness depends greatly upon supply and exhaust strategies. These strategies depend on the type of facility in which they are employed, and this document addresses the following two major categories, large open spaces such as arenas or convention space, and typical hotel style rooms. The versatility and availability of arenas and convention centers make them prime locations for alternate care sites. Large spaces should be targeted for acute and non-acute care patients. Confined spaces like hotels, barracks and dorms are more appropriate for non-acute care.

Supply systems used for treating airborne infectious disease should be designed as all outdoor air systems to avoid cross-contamination of air from different zones. Existing return ducts should be disconnected, and new ductwork sealed to allow the system to operate with 100% outside air. If the coil capacity of the existing system is not able maintain temperature and humidity in 100% outside air mode, a return air mode may be utilized if the return air ductwork is retrofitted to include a MERV 8 pre-filter and a HEPA filter complemented by a booster fan if needed to overcome additional pressure drop of the filter banks. This option will require additional time and resources and it may be more cost effective to discharge return air cleaned by a HEPA filter unit directly to the ACS interior space. Supply systems for fully enclosed pods do not require 100% outside air if the patient pod air is exhausted directly outside per Standard 170 requirements or HEPA filtered before being discharged to the ACS interior space. These scenarios allow designers to determine how they can provide the minimum required air changes to the patient spaces safely, effectively, and efficiently as possible.

All areas with potential viral loading, such as doffing areas, rooms with used PPE, or common areas that patients could access during their time at the facility, would be subject to the HEPA filtered exhaust requirement if exhaust air is not purged directly outside per ASHRAE Standard 170 requirements. Restrooms are also to be exhausted to the outside.

3.1.2. Supply Air System Selection air system selection.

Prioritization of system approach in order of preference:

1. Supply systems use 100% OA, all potentially viral loaded air is exhausted outside per ASHRAE Standard 170 requirements.
2. Supply systems uses return air from ACS interior spaces:
    a. Potentially viral loaded air is exhausted outside per ASHRAE Standard 170, return air is only from clean spaces in the facility (unused exhibit halls, admin areas, corridors, etc.)
    b. Potentially viral loaded air is exhausted through HEPA filters and returned to ACS interior
3. Supply systems use return air from ACS interior spaces, if potentially viral loaded air is in the general return, the AHU would have HEPA filters on the mixed air section. The increased pressure drop can be overcome by increasing the filter surface area, upgrading AHU fan size, or introducing booster fans. This would be most applicable to the open patient bed scenario where the viral loaded arena air does not utilize ducted exhaust.

Based on the desired system approach, to achieve the required minimum airflow requirements and maintain comfort conditions within the arena and patient spaces, there are three supply air delivery approaches that should be considered:

1. Existing AHU has the capacity/functionality to meet the minimum requirements (Figure 3-1).
2. Combination of existing AHU and temporary AHU to achieve minimum requirements (Figure 3-2).
3. Temporary AHU used in place of existing with capacity/functionality to meet minimum requirements (Figure 3-3).

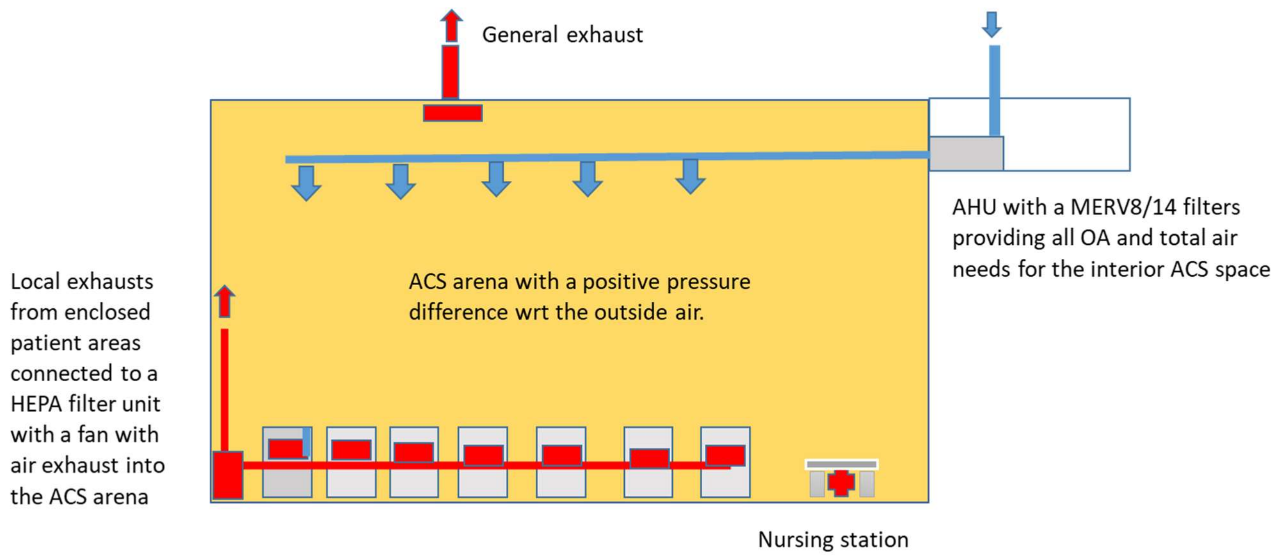


Figure 3-1: Diagram of scenario for existing AHU serving patient spaces

The figure above is an example of ventilation and conditioning of enclosed patient spaces located in the building without perimeter zone using existing DOAS AHU, air distribution, and general exhaust systems. AHU is upgraded with MERV 8 prefilters and MERV 14 final filters providing all outside air needs (including for enclosed patient areas, nursing stations, etc.) and a positive pressure difference in ACS with respect to outside. ACS air is forced into enclosed patient space via transfer grill under the negative pressure created by a headboard exhaust. A HEPA filter box with a fan is connected to a group of headboard exhausts. Cleaned air is discharged back into the upper zone of ACS.

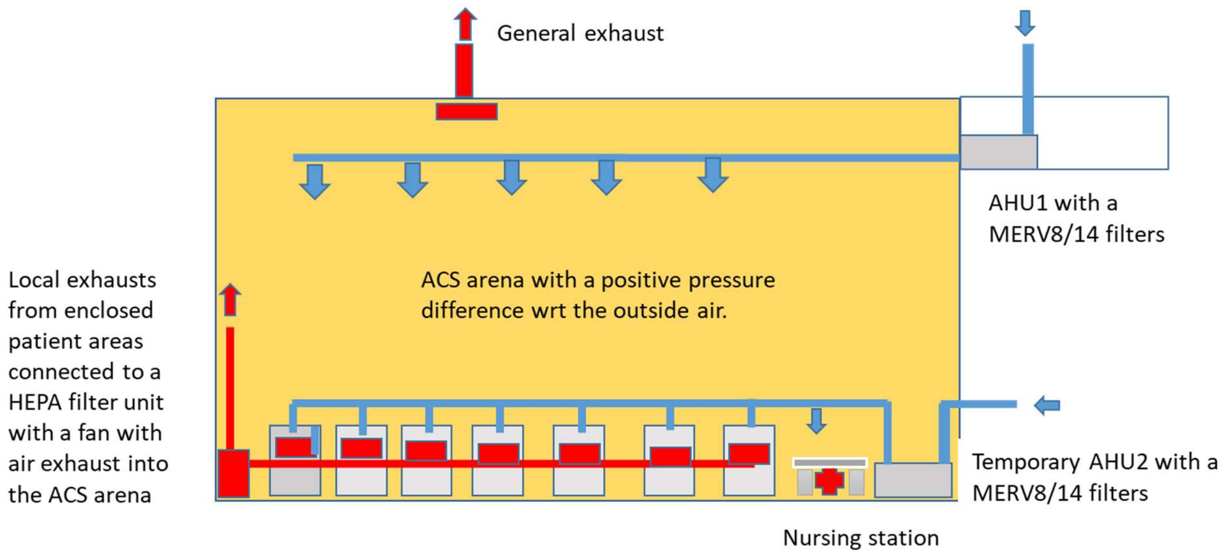


Figure 3-2: Diagram of scenario for existing and temporary AHUs for enclosed patient spaces

The figure above is an example of ventilation and conditioning of enclosed patient spaces located in the building without perimeter zone using existing DOAS AHU, air distribution and general exhaust systems. AHU is upgraded with MERV 8 prefilters and MERV 14 final filters and the airflow rate is adjusted to provide outside air needs of all ACS areas except for enclosed patient areas, and a positive pressure difference in ACS with respect to outside. Clean and conditioned outside air is supplied into enclosed patient space from the temporary AHU equipped with a MERV 8 prefilters and MERV 14 final filters and is exhausted using headboard exhaust at a higher rate to created negative pressure in the patient space with respect to the ACS space. A HEPA filter box with a fan is connected to a group of headboard exhausts. Cleaned air is discharged back into the upper zone of ACS.

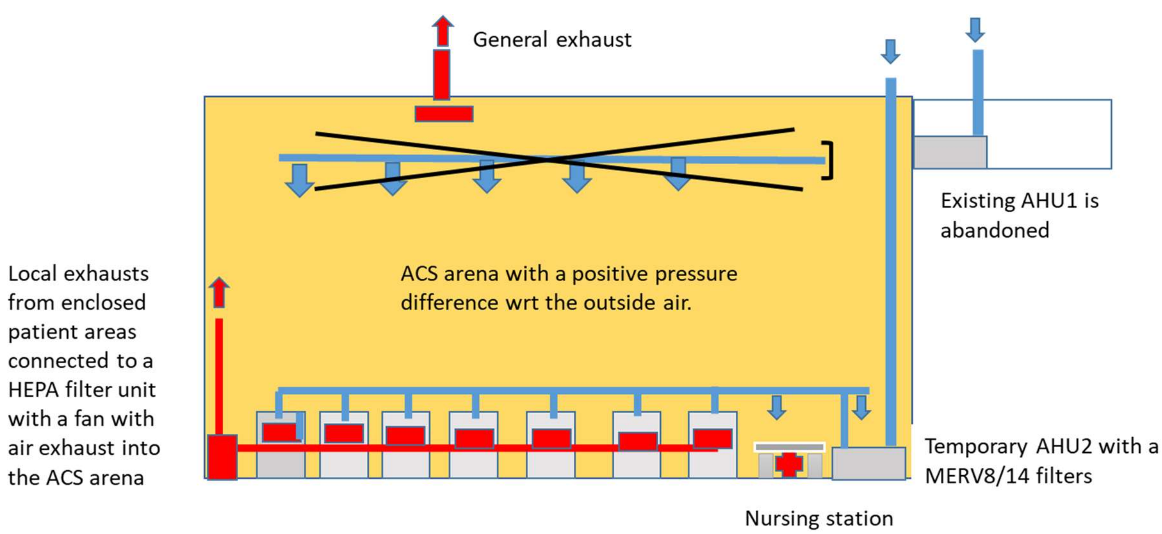


Figure 3-3: Diagram of scenario for temporary AHU servingb enclosed patient spaces

The figure above is an example of ventilation and conditioning of enclosed patient spaces located in the building without perimeter zone using temporary DOAS AHU, new air distribution and existing general exhaust systems. Existing AHU and air distribution system are abandoned. Clean and conditioned outside air is supplied into all ACS spaces and into enclosed patient spaces from the temporary AHU2 equipped with a MERV 8 prefilter and MERV 14 final filter and is exhausted using headboard exhaust at a higher rate to created negative pressure in the patient space with respect to the ACS space. A HEPA filter box with a fan is connected to a group of headboard exhausts. Cleaned air is discharged back into the upper zone of ACS. Existing general exhaust is adjusted to maintain positive pressure in ACS with respect to the outside air.

In order for the large space to be considered, the existing AHU should be capable of incorporating the minimum filtration requirements described in this document and still achieve space conditioning and ventilation supply requirements for the ACS. In most cases, systems designed for large meeting spaces/arenas with the potential for high occupancy levels will have sufficient airflow to meet intended volumetric requirements for ACS. In cases where the existing AHU is not capable or the building owner doesn't want modifications to the existing system, a temporary AHU shall be employed to either manage all requirements or supplement the existing AHU to achieve all requirements. The temporary AHU can be installed outside of the facility and provide 100% outdoor air to the space. It can also be installed inside the facility, considering the indoor environmental impact, and be ducted outside to pull outdoor air to mix with re-circulated open space air to achieve total air changes in the patient areas. If the temporary AHU is handling any outdoor airflow, it should meet the minimum filtration requirements. In these applications, units with higher static capability make the most sense, such as units with backward inclined blowers. Fan arrays can be utilized to add redundancy.

A temporary AHU option is to use an indoor only re-circulating unit within the arena space to supplement the existing AHU. In this case, the existing AHU would handle the outdoor air changes to the entire space at minimum and the temporary unit would be located within the facility, outside the patient spaces, pulling in conditioned and filtered arena air. Applying necessary supplemental conditioning, the temporary AHU would supply the adequate total air changes to the patient spaces. Because the unit is located inside, there is no filtration requirement, unless there is a wetted coil, where minimum MERV 8 shall be required. In this application, smaller units such as blower coils, fan coils, fan powered chilled water terminals and ducted split systems could be utilized to simply section out wards, while adding redundancy and flexibility to the design. This approach assumes the arena air is uncompromised by the infectious aerosol and that patients are in fully enclosed and negatively pressurized pods with filtered or externally ducted local exhaust. Recirculated air should be HEPA filtered.

3.1.3. General Exhaust

The existing general exhausts can be used for ACS either as a general exhaust or be connected to local exhaust from patient areas. The existing general exhaust system may require enhancement to maintain building pressure requirements. Additional control dampers and/or variable frequency drives can be utilized to accomplish these requirements. The Requirements section describes exhaust requirements for filtered and non-filtered applications. However, most of existing exhausts servicing facilities that can be temporarily transferred to ACS are not designed for discharging air contaminated by infectious aerosols. Therefore, they need to be either converted to meet those requirements or air must undergo filtration in HEPA filters prior to discharge.

3.1.4. Airflow in the Fully Enclosed Patient Spaces

In the fully enclosed patient space, negative pressure is created by the exhaust system with ventilation air supplied directly or transferred into the patient space. Transfer supply air comes from arena through pressure relationships through a transfer grille, supply air from the building AHU as shown in Figure 3-4 or through the use of a supplemental A/C unit to supply conditioned air to the patient space from the arena using a supply grille as shown in Figure 3-5. A supplemental A/C unit or conditioning device would only be necessary if the thermal loads exceed the capability of the main supply system capacity.

Supply air diffusers for enclosed patient spaces shall be located so that supply air jet does not interfere with performance of local exhaust and promote thermal comfort. Supply air will preferably be introduced into the patient space on the wall opposite of the patient exhaust hood at a targeted maximum velocity of 100 fpm. Under all scenarios, velocities within 24” of the patient head or the entrance plane of the local exhaust system shall not exceed 40 fpm. Mechanically delivered supply air volumes should be at least 10% to 25% smaller than the exhaust hood exhaust volume to maintain the patient space under negative pressure.

The preferable methods of air supply are transfer grilles or connecting supply ducts directly to air diffuser/supply plenum on individual enclosed pods. Supply remaining airflow rate using existing air diffusers in the building, preferably the ones located close to the occupied zone, to support nursing stations and other required spaces. The supply outlets can be typical louvered grilles, directional linear diffusers, or perforated fabric duct.

In large open spaces, there are three typical patient space categories:

1. Fully enclosed patient space (Figure 2-1)
2. Partitioned, partially open patient space (not fully enclosed) (Figure 2-3)
3. Fully open patient space (Figure 2-4)

Using local exhaust system near the patient head to provide efficient contaminant removal, the make-up air supply outlet should be located on the opposing wall to promote uni-directional or single pass airflow. When utilizing transfer air and supplemental A/C unit air together, make sure the two supply jets are parallel to one another to avoid disturbances to the airflow (Figure 3-5 and Figure 3-6). Supply air velocity into patient space should be minimized (target 100 fpm discharge velocity) to reduce turbulent eddy flow within the patient space.

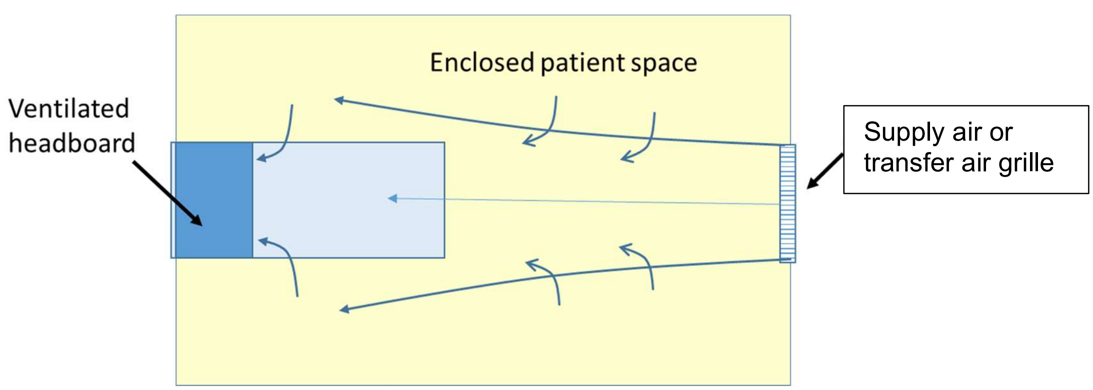


Figure 3-4: Airflow pattern diagram with air supply grille or transfer air grille

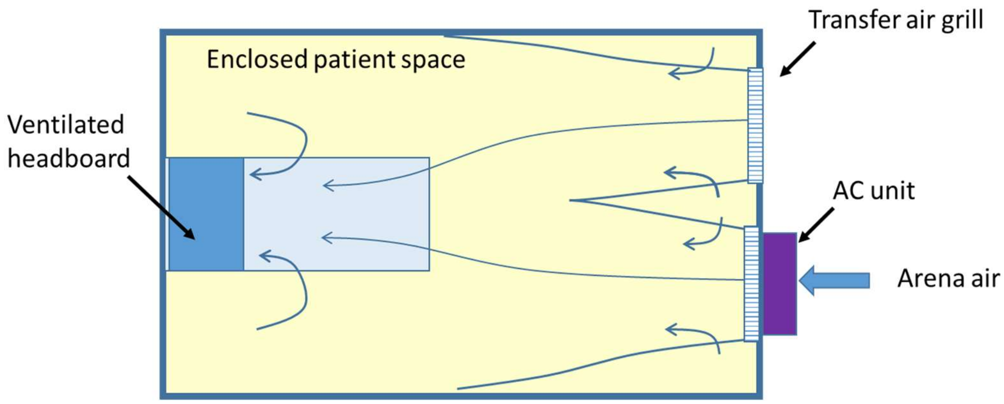


Figure 3-5: Airflow pattern diagram with transfer grill and supplemental AC unit

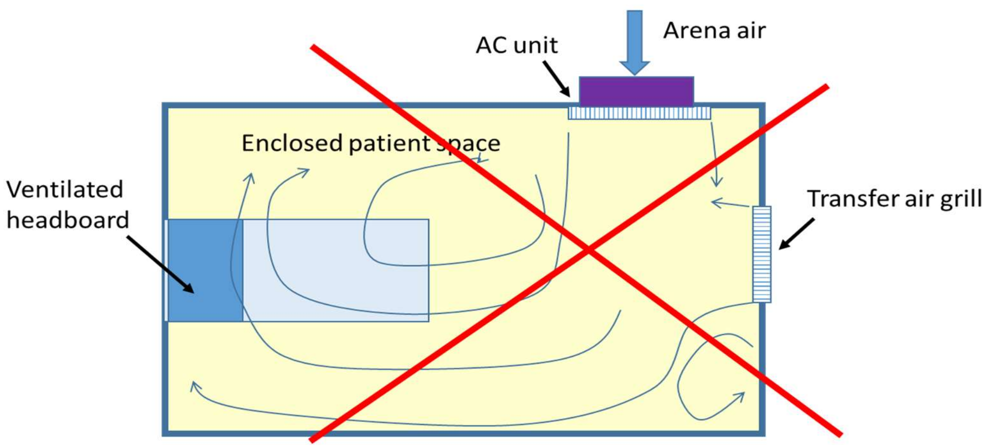


Figure 3-6: Airflow pattern diagram showing vortex created by impingement of opposing supply jets

3.2. Airflow in Partitioned, Partially Open Patient Spaces.

There are three methods of supplying airflow to the partitioned spaces:

1. Recommended: Use of local, high efficiency exhaust means, such as a ventilated headboard.
2. Acceptable: Use of local exhaust grille in the sidewall above the patient headboard.
3. Not recommended: No local exhaust provided.

With the ventilated headboard, contaminant removal efficiency and clean to less clean airflow is enhanced within the partitioned space as air is drawn from the arena into the patient space by utilizing this local exhaust means (Figure 3-7). The hood of the ventilated headboard creates a uniform negative pressure region over the patient's entire head, significantly increasing patient generated aerosol removal efficacy compared to other local exhaust options. A similar effect will happen by utilizing a local exhaust grille in the sidewall or ceiling above the patient headboard, but only contaminants that propagate to within a few inches of the grille face will be drawn into the exhaust effectively (Figure 3-8). Partially enclosed pods use of existing air diffusers supplying high velocity air into the upper zone typically found in large spaces, is less effective as it will likely create poorly ventilated/stagnant zones in patient's pods (Figure 3-9).

Because the partitioned spaces are open to the arena space, air distribution effectiveness can be improved further by using directional ventilation supplied into the occupied zone. This high velocity, cool ventilated supply air can be introduced within the occupied space or from above from a height up to 15 ft using prefabricated perforated AHSRAE Group E diffusers or porous fabric duct.

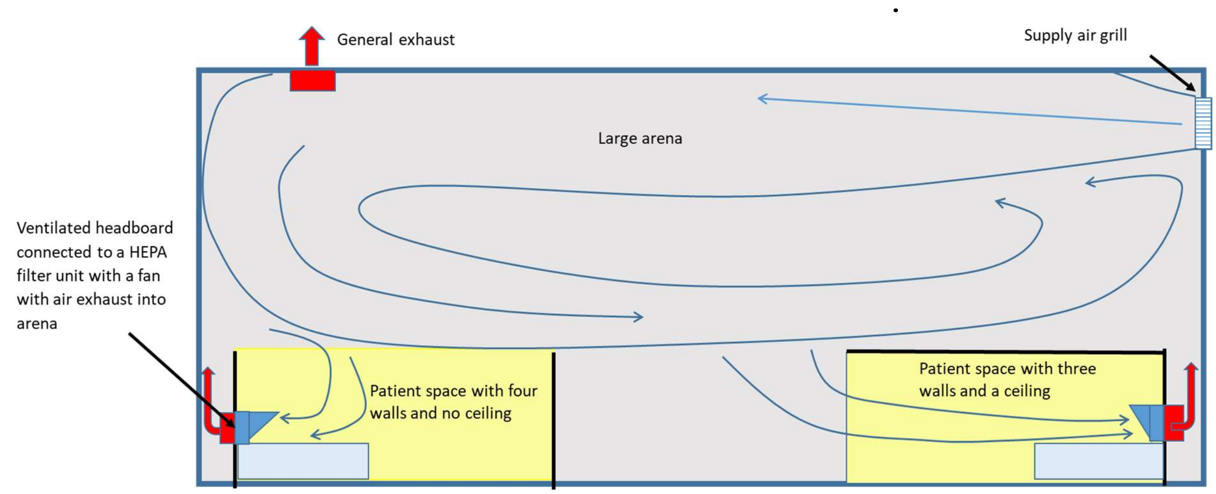


Figure 3-7: Airflow pattern diagram with partitioned patient spaces and ventilated headboard.

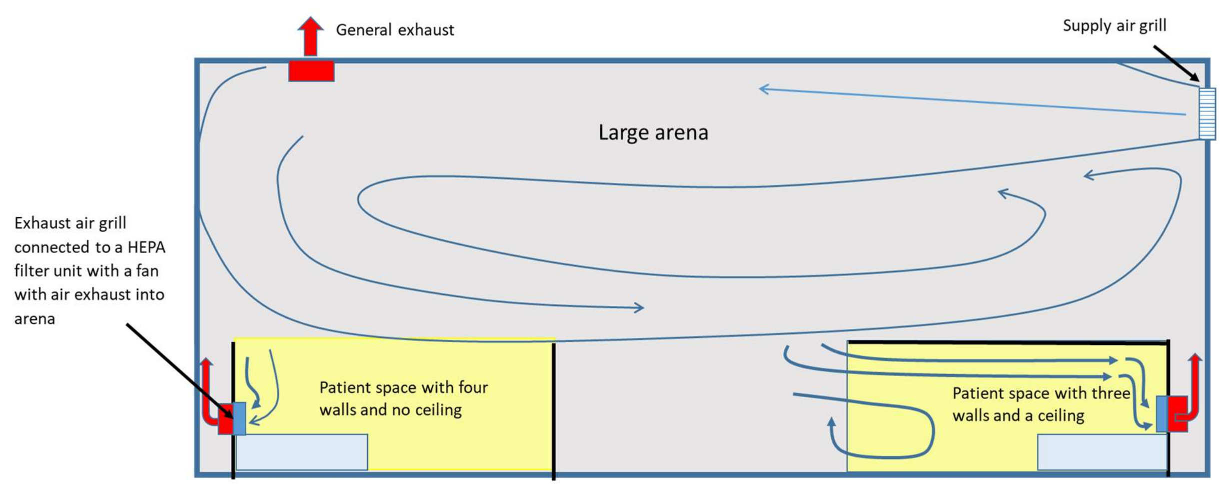


Figure 3-8: Airflow pattern diagram with partitioned patient spaces and exhaust grille.

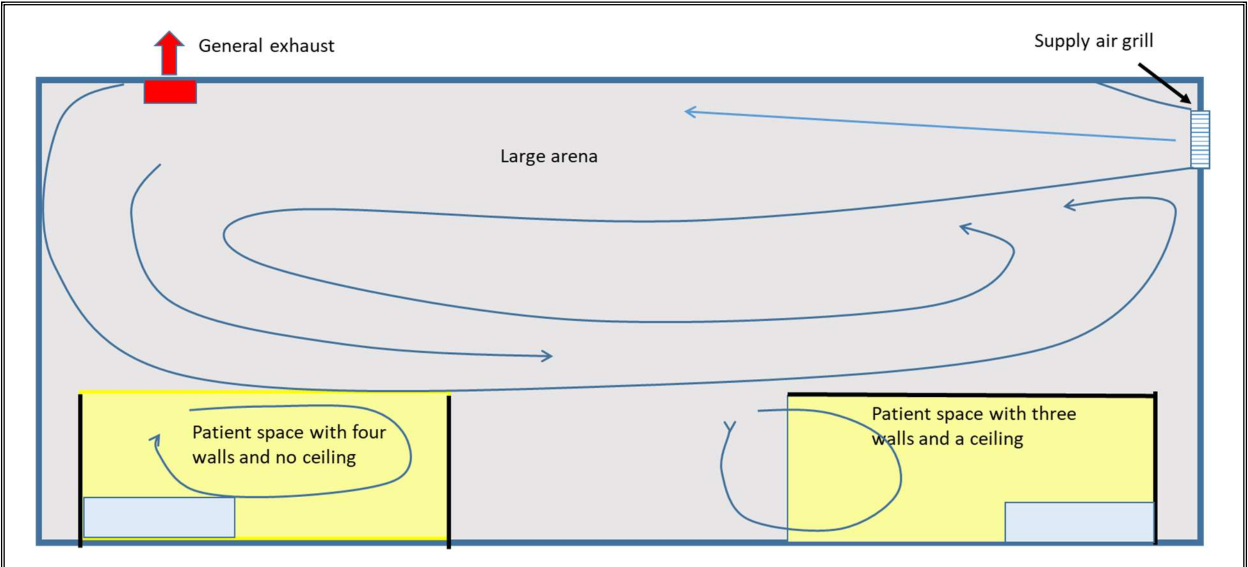


Figure 3-9: Airflow pattern diagram with partitioned patient spaces without local exhaust.

3.3. Airflow in Fully Open Patient Spaces

Use existing supply and exhaust systems. This patient space type will lead to well mixed conditions with uniform temperature throughout the arena height, but in doing so will spread aerosols throughout the entirety of the arena as well (Figure 3-10) as the arena air is constantly mixed. This approach also eliminates the ability to promote clean-to-less-clean airflow in the greater arena space, creating a higher level of viral exposure potential to healthcare and facility maintenance personnel. It is not recommended that fully open spaces be used for COVID-19 positive patients.

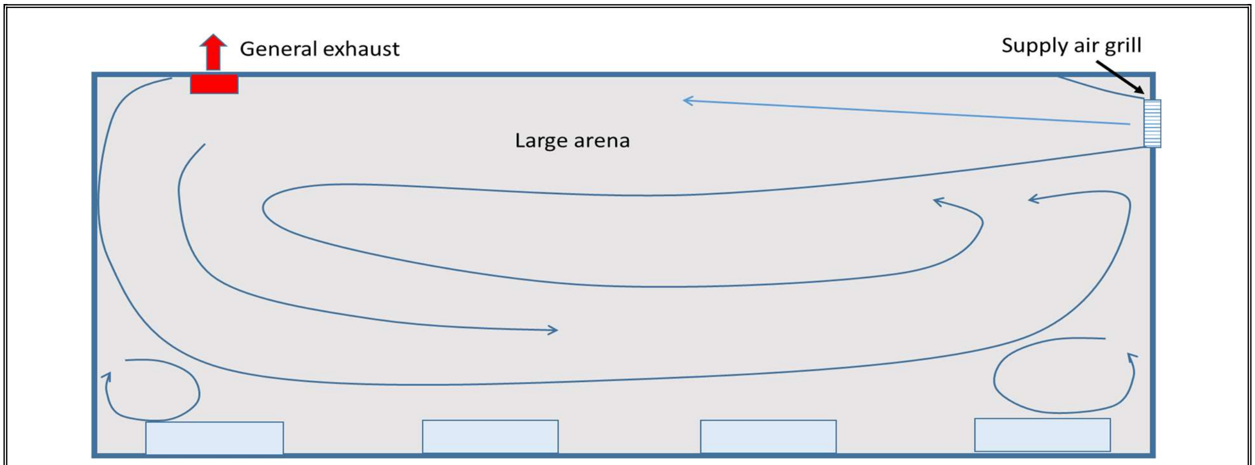


Figure 3-10: Airflow pattern diagram in large arena with fully open patient beds.

3.4. Local Exhaust in acute and non-acute patient rooms.

In Acute and Non-Acute patient rooms intended for patients with a known/suspected infectious airborne, novel, or respiratory disease, local exhaust effectively captures infectious aerosol generated by the patient, promotes protection to attending healthcare personnel and creates the room negative pressure, while the airflow pattern within the patient room is primarily driven by supply air louvers. Strategically placed and appropriately sized supply air outlets create the protective directional airflow without creating excessive discharge velocities or disturbing hood performance and uncomfortable drafts near the patient.

Traditional patient isolation room designs often utilize return air louvers located over the patient either in the ceiling or above the headboard. This is typically partnered with a mixing diffuser with space dilution being the approach utilized in contaminant control. Though this is typically effective in terms of providing dilution ventilation, localized capture of patient-source aerosol, such as that provided by a ventilated headboard (Figure 3-11), can provide significant efficiency gains on contaminant control. Research has shown local source capture design techniques to be a more-effective approach than traditional dilution ventilation concepts. In addition, properly designed local source capture systems will also provide equivalent or greater air changes within the patient room as their dilution ventilation counterpart, thus providing the best of both aerosol control options.

Figure 3-11: NIOSH Ventilated Headboard.

Supporting efficacy research as well as detailed instructions on the design, construction, and deployment of the Ventilated Headboard can be found in the references section https://www.cdc.gov/niosh/surveyreports/pdfs/301-05f.pdf.

Those instructions are centered around HEPA fan/filter recirculation systems, however unfiltered exhaust systems, if appropriately designed and discharged, could also be applied. While there are likely to be other hood design approaches that might work similarly, they will likely share most of the Ventilated Headboard design principles described below in order to be effective at quickly capturing and removing infectious aerosols while reducing exposure hazards to attending Health Care Professionals (HCP).

Ventilated Headboard Design Principles:

- Size: 2’ x 4’ hood face with minimum 6” hood plenum depth (accommodates up to regular patient bed plus induces wider path of protective unidirectional room airflow into hood)
- Extendable canopy extends 36” (75% of largest size dimension) out from hood face and over patient pillow area

- Face velocities of 30-35 fpm across entire hood face results in volumetric exhaust requirements of 240-280 cfm. This equates to 14.4-16.8 ACH of dilution ventilation.
- At 240 cfm, the ventilated headboard requires an approximate hood negative static pressure of two tenths of an inch water column.
- Make-up/supply air into patient room should be on the opposite wall at or above the entry door in order to support clean-to-(less-clean) protective directional airflows. [Hotel/barracks configurations may require ventilated headboard to be driven by portable HEPA fan/filter unit if directional airflows cannot be established with the existing HVAC system design.]
- Supply air discharge velocity into patient space should be sufficiently low as to minimize turbulent eddy formations or reverse airflow within the patient space.
- The Ventilated Headboard should have sufficient back-pressure across the face to provide even airflow distribution across the entire 8-square feet. In research reported by CDC/NIOSH achieved this backpressure requirement through the use of common MERV 7 filters installed at the hood face, though other techniques may be feasible.

3.5. Nursing Stations, Corridors and Other Non-Patient Care Perimeter Areas

As part of the greater arena space, the existing supply system can be utilized to condition and ventilate this space. Supplemental supply air can be provided as required. The nursing stations shall not have local exhaust, supporting clean-to-less-clean airflow. The supply air volumes must be sufficient to provide make-up air for the patient spaces and condition the entire arena (Figure 3-12 and Figure 3-13).

Corridors and other non-patient care perimeter areas that are not subject to viral loading should be positively pressurized with respect to the larger arena area and the outdoor atmosphere (Figure 3-12 and Figure 3-13). This allows these spaces to maintain existing system functionality without additional filtration or other infectious aerosol transmission mitigation practices.

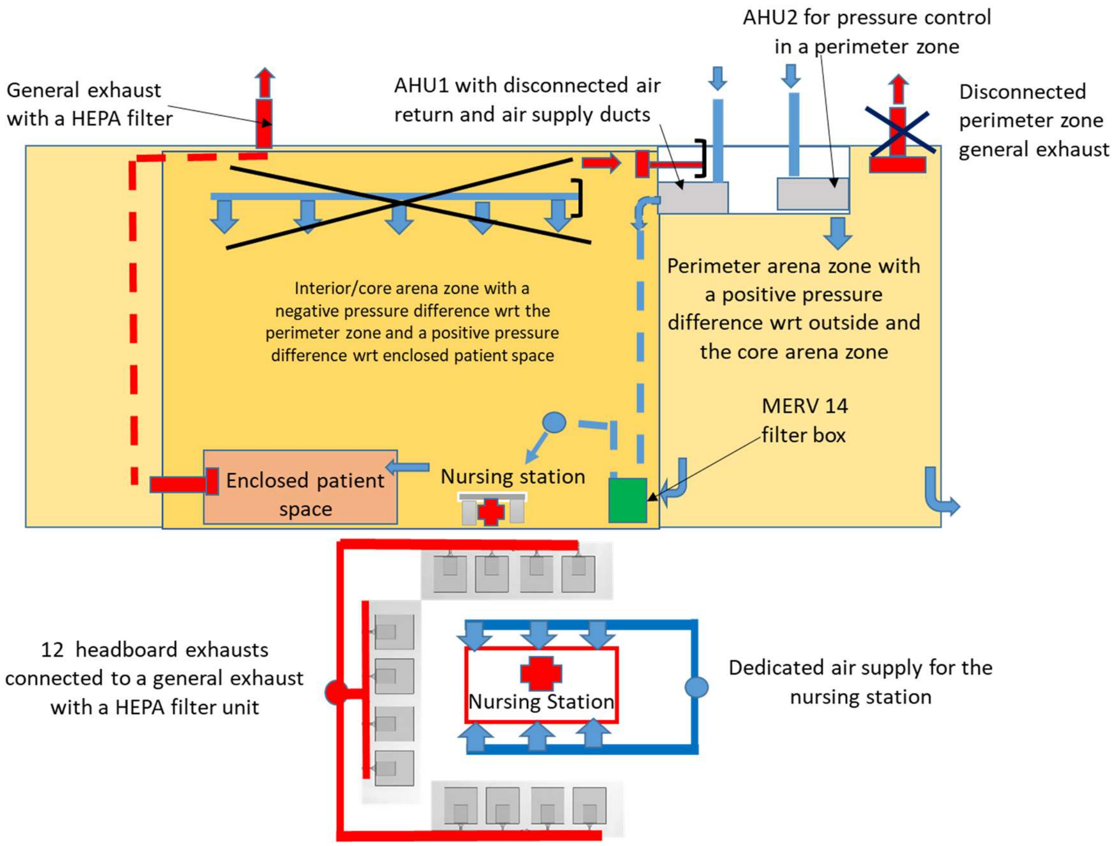


Figure 3-12: System diagram with air supply into enclosed patient's space via transfer grill.

One configuration as shown in Figure 3-12 provides enclosed patient spaces that are located in the building with an internal core zone and a perimeter arena zone. Perimeter zones are ventilated and pressurized using existing AHU1 with the original supply air filter and the airflow rate adjusted to create a positive pressure difference in the perimeter zone with respect to outside and the core zone. Perimeter zone exhaust fan is deactivated. In this case the return air duct is disconnected from the AHU serving the core zone and there is no possibility to upgrade original filter in this AHU1 to a MERV 14 filter. Therefore, a separate MERV14 filter box with a booster fan is installed on the floor (it could be installed in the mechanical room given space is available). Temporary fabric duct connected to AHU2 is installed to supply air directly into the occupied zone to allow for high efficiency ventilation and conditioning of the space including nursing stations. Conditioned air is forced into enclosed patient's space via transfer grill under the negative pressure created by a headboard exhaust. Existing general exhaust is connected to a group of 12 headboard exhausts. Since this general exhaust is not designed to meet requirements set for air discharge without filtration, this exhaust system is equipped with a HEPA filter.

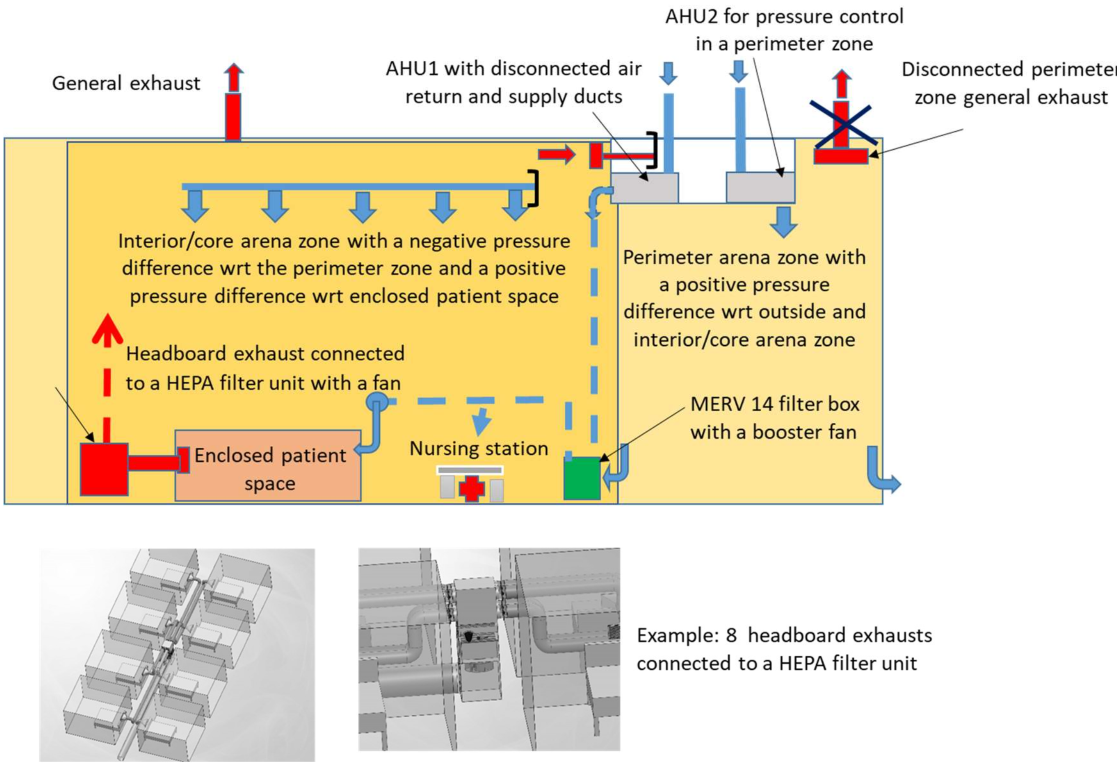


Figure 3-13: System diagram of air supply directly into enclosed patient's space.

The other primary configuration as shown in Figure 3-13 uses a similar configuration as described above except that the enclosed patient spaces may be exhausted through a HEPA fan filter unit with the outlet in the arena's core zone. an enclosed patient space located in the core space of a building that has an internal core zone and a perimeter zone. In this example headboard exhausts are shown connected to the HEPA filter unit to increase source control effectiveness inside the enclosed patient spaces. The patient spaces are negatively pressurized to the area core space by the HEPA fan filter box. Cleaned air is discharged back into the upper zone of ACS. Existing general exhaust is adjusted to maintain positive pressure in ACS with respect to the perimeter zone.

3.6. Airflow in Hotel or Equivalent Spaces

These spaces are typically enclosed spaces that can be utilized as a temporary hospital wing to house infected patients. Patients that require minimal clinical care or non-acute care can be treated and observed in this space type. The existing supply and exhaust system should be utilized where possible. In the event the exhaust system is inadequate, a temporary system such as a fan filter unit with HEPA filtration can be employed in each space. If ducted exhaust is required, either duct the HEPA unit directly outside using part of the perimeter glazing or duct to the HVAC system return outlet. Because the fan filter unit has HEPA filtration removing 99.97% of viral particles it does not need to be ducted directly outside. Another option is to utilize the ventilated headboard to increase capture efficiency.

When hotel rooms are larger than required for the patient care, the inlet and discharge points of the HEPA can be positioned (augmented with duct when necessary) to create negative static pressure within the patient space with a protective, HEPA filtered positive pressure space surrounding the HEPA discharge. Ideally, the room return air will be co-located within the HEPA filtered clean space. The result of this approach provides protective negative pressure patient space without impacting overall HAVC balance or design. The same approach can also be adopted in use with the ventilated headboard, providing an even greater level of contaminant control and worker safety.

3.7. Filtration System Solutions

3.7.1. Supply air systems

Per ASHRAE Standard 170, air handling units (AHU) shall include a pre-filter with a minimum filter efficiency of MERV 8 and a final filter rated at MERV 14 (e.g., Figure 3-14)

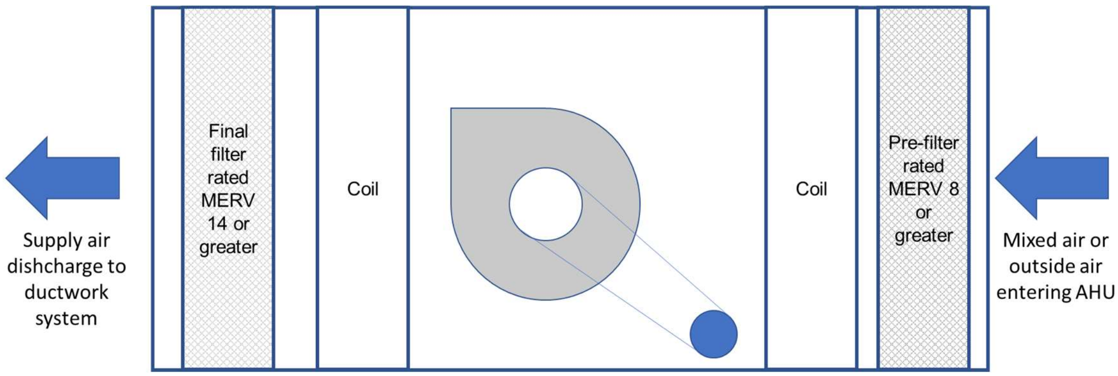
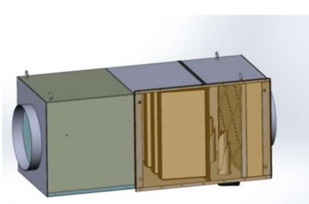


Figure 3-14: Basic diagram of AHU filter banks

3.7.2. Enhanced filtration systems

A combination of a pre-filter and a HEPA filter used in filter units can be supplemented by other technologies. The relative value of adding ultraviolet or other technologies increases if HEPA filters are determined not to be feasible for the specific requirements of the ACS being constructed. UV lamps and a sample of other emerging technologies are listed in Figure 3-15.

Isolation Air filter and temperature control unit with HEPA filtration and UV light sterilizing of airborne viruses and bacteria trapped on the HEPA.



Fan filter unit with MERV8 pre-filter, near HEPA (particle removal efficiency of 99.9%) filter and air purifier

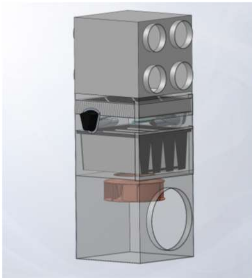


Figure 3-15: Examples HEPA filter units

3.8. Duct Systems

Dirty air distribution ductwork and components, like coils and drain pans, can spread bacteria and diseases, which can greatly affect patients with weak immune systems. When existing HVAC systems are used, interior surfaces of the air distribution system (i.e., AHU, ductwork, water coils, drain pans, terminal units, air devices, etc.) exposed to airflow may need to be cleaned or taken offline following use for sufficient time duration to allow for natural deactivation of infectious contaminants. Inspect existing air distribution system to identify contamination by dirt and mold before the facility is occupied to allow time for cleaning.

Coil and in-duct mitigation systems including ultraviolet lamps and other emerging technologies may be evaluated for use on projects in conjunction with local authorities.

Ductwork that is under negative pressure shall be constructed of metal or made of industrial quality non-metal ductwork systems. Ductwork that is positively pressurized can be metal or fabric. Fabric duct must be non-porous unless the purpose is to use the fabric duct as a supply air source for the space it is applied. Temporary duct can be supported independently in the space using temporary support structures or the pod structures themselves. From these structures, hanger wire or metal straps can be used to position the duct in the vertical plane, as necessary. The supply duct should be located minimum of 10 feet off the floor. Ductwork should be sized to limit velocities to less than or equal to 1000 fpm and capable of withstanding pressures up to 3”-w.c.

Air exhausted from infected patient spaces shall be ducted and negatively pressurized to prevent viral transmission to clean spaces. In the event this is not possible, seal any positively pressurized exhaust duct per SMACNA Leakage Seal Class A requirements. Exception, if the exhaust air is treated with HEPA filtration before becoming positively pressurized, there is no leakage seal or negative pressure requirement.

4. ENVIRONMENTAL SPACE CONDITIONS

4.1. Space Temperature

Existing reference material describes space temperatures thoroughly including ASHRAE Standard 170, local AHJ codes that apply to patient care, USACE project work statements, and other guidance. Overall the requirements in this section will be more flexible than pressurization or filtration requirements.

Due to the temporary and emergency nature of the ACS, it is suggested that a wider range 70F to 74F may be allowable for patient areas. Temperatures in the lower end of the range may be used where staff will have PPE on for extended periods of time.

Issues to address:

- Survival of the virus aerosol
- Patient symptoms: fever
- Care giver PPE as a clo value – may favor lower temperatures
- Patient sheets and/or blankets
- Surrounding T and H: Arena vs Hotel: “Ambient” conditions
- Recommend 72F +/- 2F and 40-60% RH, 30% RH may be achieved where 40% is not feasible. Humidification should only be supplied where it is known that the building envelope can sustain higher relative humidity levels inside the facility without condensation occurring.

4.2. Description of Technical Approaches

A2HC: Ambient conditions are determined by the arena HVAC system. To achieve a patient room condition of 70F +/- 2F and 40-60% RH make up air to the room/space may need to be reconditioned via mechanical system. Such a system may be air cooled and use the arena air as a heat sink/source.

Humidification should only be supplied where it is known that the building envelope can sustain higher relative humidity levels inside the facility without condensation occurring.

H2HC: Room HVAC is usually minimal with little or no outdoor air. Yet these simple systems should be designed to achieve a temperature in the 70-74F range assuming a typical hotel room heating and cooling load.

Therefore, for strictly temperature and humidity control, it may be possible to reach of 72F plus or minus 2F and 40-60% relative humidity with only the addition of portable humidifiers, or 30% relative humidity where achievable. Humidification should only be supplied where it is known that the building envelope can sustain higher relative humidity levels inside the facility without condensation occurring.

A2HC may have excess cooling capacity and ability to subcool the general space where transfer air could be used to cool enclosed patient rooms. For non-acute facilities with open patient beds in partitions the arena air-handling system may be able to provide suitable airflow, but the design should include provisions to get air in and around partitioned areas.

4.3. Humidity

Minimum relative humidity of 40% is recommended as a best practice for control of similar respiratory infections such as influenza. Taylor and Tasi (2018) and ASHRAE Position Document on Infectious Aerosols suggests that at higher relative humidity rates up to 40% RH patient outcomes are improved.

This is through three mechanisms. First, the patient and staff airways are able to provide a stronger natural defense with moisture in the mucus membranes. Second, the droplets from infected people will tend to fall to the ground due to their size in environments with proper humidity levels. When relative humidity is low, the moisture from the droplets evaporates, resulting in smaller particles that can remain airborne for longer periods of time and be carried for longer distances. Thirdly, some organisms increase in viability as relative humidity is lower.

30% is an acceptable value and matches requirements from the VA and Army design requirements. Humidification should only be supplied where it is known that the building envelope can sustain higher relative humidity levels inside the facility without condensation occurring.

Most ACS are not likely to have the necessary humidification capacity for the base building air-handling units. In that case supplemental units will be provided by project teams for buildings with adequate building envelope construction. Fabric duct would typically not be allowed for humidified supply air.

Additional considerations may be considered pertaining to humidification levels:

- Avoid condensation.
- Practical approaches for temporary units.
- Dehumidification in humid climates.
- Electric drainable reservoir type humidifiers in lieu of routing steam through the facility, allowing stagnant water, etc.
- PPE expected to be used by the staff may favor a lower range of humidity setpoints.

4.4. Heating

Temporary patient rooms installed in existing arenas will not be subjected to the variations of an outdoor environment.

Rooms in hotels converted into patient rooms need only be heated using the existing hotel HVAC. The internal heat gains in patient rooms exceeds that of a typical hotel bedroom due to health care equipment.

Methods of implementing facility systems to achieve the goals of the topic

A2HC: Space heating can be accomplished using electric duct coils in the supplemental ventilation system. The arena space conditions can be adjusted upward in the event that the facility cannot supply adequate electric power.

H2HC: Existing hotel room HVAC can provide enough heating to achieve the heating set point as long as the system is not taxed with outdoor air volumes beyond the design load.

5. PRIORITIZATION

5.1. Background

Prioritization is the methodology for identifying which mechanical system approaches may be pursued to provide care to patients knowing that most ACS must prioritize certain features due to limited time, budget, and site characteristics.

The Alternate Care Sites (ACS) have been developed with multiple concepts (A2HC, H2HC, CH2HC) with a variety of capacities, services, and needs. There are optimal and minimal methods to meet the requirements for a safe environment. The time to design and construct these facilities is impacted by the existing systems and requirements for the various levels of care needed. Construction supplies such as exhaust fans, HEPA filters, UV lights, etc., may limit the speed of opening a facility. Simple or complex controls with the testing and commissioning add time and cost. How will it be decided which systems should be installed?

This section is intended to take the requirements and system options presented throughout this document and provide guidance for applying the mechanical systems to each situation. There are subjective "in the field" issues to be accounted for along with the objective standards issued in this guidance document. The documents already produced, Project Work Statements for example, and the lessons learned provide direction and feedback on successful actions, things to be improved, and scenarios that did not work. There are minimum requirements for each type of space with more stringent requirements for acute or critical conditions.

5.2. Requirements and System Options

The selection guidance is based on the case types as defined in Section 2. All of the ACS scenarios indicate a positive or assumed positive COVID-19 or infectious disease, thus, mechanical systems considered must have containment control for protection of patients and staff and air cleaning to the maximum extent possible. Two of the three case types are defined as "enclosed" spaces and the third is "open" spaces defined as no ceiling or open bay. The third open type has different design conditions as measurable pressure is not achievable and directional airflow is the criteria.

The optimal system selections are based on:

- Once through airflow of 100% outside air and 100% exhaust air
- Use of existing air systems
- MERV 8 Pre-Filters and MERV 14 Final Filters in Supply
- Exhaust air discharged outdoors at highest point and does not require HEPA filters
- Measurable negative pressure in fully contained spaces
- Directional airflow in open spaces
- Use of Ventilated Headboards

Acceptable system selections are made when the optimal systems are not available. Examples are:

- Use of recirculated HEPA filtered air
- Provide new equipment (AHUs, FFUs, etc.) independent or combined with existing air systems
- HEPA filters on exhaust discharge which may be returned to the larger space

- Exhaust and supply grilles at specific locations in lieu of Ventilated Headboards

5.3. Mechanical Systems Selection Guidance

The following steps can be applied to determine the system selection: Determine the Application, Review the System Options, and Evaluate the Factors Impacting System Selection.

1. **Determine the Application**

   a. <u>Type of facility:</u>

- Arena, Hotel, or Hospital
  - Size and capacity
  - Utility capacity
- Open or Enclosed PODS,
  - Enclosed Patient Spaces
  - Open Patient Spaces
- Patient Category
  - Acute Infectious Disease Positive or Assumed Positive
  - Non-Acute Infectious Disease Positive or Assumed Positive

2. **Factors Impacting System Selection**

   a. <u>Design Standards/Criteria:</u>

      i. Recirculation or Exhaust Only
      ii. Exhaust with or without pressurization
      iii. Filtration level
      iv. Minimum or better air exchange rates
      v. Temperature and Humidity Control

   b. <u>Situational Criteria</u>

      i. Schedule

         (A) How fast is the space needed
         (B) Availability of equipment
         (C) Contractor/Procurement process

      ii. Cost

         (A) Budget and Cost Control

      iii. Equipment Availability

         (A) Off the Shelf or Long Lead
         (B) Pre-Positioned for Immediate Use

      iv. AHJ Approval

         (A) Differentiate between licensure for a hospital site vs ACS which needs to refer to standards and guidelines but may not be subject to the same regulatory AHJ's.

3. **Evaluate the System Options**

a. <u>General Ventilation:</u>

i. Existing Building Systems

(A) The building assessment provides the information for the design team to determine if use of the existing building ventilation is feasible.

ii. Stand Alone Systems

(A) Patient Bed Ventilation Hood
(B) Fan filter units with or w/o UV

iii. Combination of Building and Stand-Alone Systems

b. <u>Environmental Condition Control:</u>

i. Filtration

(A) Use building filtration, no additional filtration
(B) Use FFUs for PODs and/or non-patient spaces
(C) Use supplemental Fan powered boxes, fan coils, or AHUs

ii. UV Lights

(A) High wall mounted
(B) Fan filter units
(C) Robot or mobile cleaning units

iii. Temperature and Humidity

c. <u>Equipment</u>

i. Exhaust Fans
ii. Unitary Equipment

(A) Patient Bed Ventilator Hoods
(B) FFU w/UV lights
(C) UV lights, robots, mobile cleaning equipment

iii. Air Handling Units
iv. Air Distribution System (Duct, diffusers)
v. Air Pressure Monitoring Equipment

4. **Summary**

The mechanical system selections providing the optimal conditions are most desirable. The design criteria are defined with minimum requirements. The challenge is evaluating the existing space conditions and applying the situational criteria. The goal is to provide a safe environment for patients and staff in the time available most efficiently. The systems must be reliable, sustainable, and maintainable.

A chart is provided as a guide.

Mechanical System Application/System Selection for COVID-19 Alternate Care Site

Patient Diagnosis				COVID Positive or Presumed Positive	COVID Positive or Presumed Positive (pending test)	COVID Positive or Presumed Positive (pending test)
DETERMINE THE APPLICATION	ACUITY			ACUTE	NON-ACUTE	NON-ACUTE
	POD TYPE			ENCLOSED	ENCLOSED	OPEN
	CLINICAL DIFFERENTIATION		INFECTIOUS AEROSAL	Yes	Possible	Possible
			VENTILATION TREATMENT	Yes	None	None
			OXYGEN	Yes	Supplemental	Supplemental
	HEALTHCARE CLASSIFICATION			Critical Care Non-Ambulatory	Basic Care Ambulatory	Basic Care Ambulatory
FACTORS IMPACING SYSTEM SELECTION	STANDARDS	HOTEL (H2HC)	SINGLE PATIENT	Yes	Yes	No
			NEGATIVE PRESSURE ROOM	Yes	Yes	No
			ASHRAE 170	Yes	Yes	Yes
		ARENA (A2HC)	SINGLE PATIENT	Yes	Yes	No
			NEGATIVE PRESSURE ROOM	Yes	Yes	No
			ASHRAE 170	Yes	Yes	No
	FIXED DESIGN CRITERIA	RECIRCULATION ALLOWED		Not permitted	Not Permitted	Acceptable with HEPA
		FILTRATION REQUIRED		MERV 14	MERV 14	MERV 14
		MINIMUM AIR CHANGES		12	12	12
		INDIVIDUAL TEMPERATURE CONTROL		Acceptable	Acceptable	Not Applicable
		STRICT HUMIDITY CONTROL		Minimum 40%	Minimum 40%	Minimum 30%
	SITUATIONAL DESIGN CRITERIA	SCHEDULE		TBD LOCALLY	TBD LOCALLY	TBD LOCALLY
		BUDGET		TBD LOCALLY	TBD LOCALLY	TBD LOCALLY
		EQUIPMENT AVAILABILITY		TBD LOCALLY	TBD LOCALLY	TBD LOCALLY
		AUTHORITY HAVING JURISDICTION		TBD LOCALLY	TBD LOCALLY	TBD LOCALLY
EVALUATE SYSTEM OPTIONS	SUPPLY	EXISTING BUILDING SYSTEM		Preferred	Preferred	Preferred
		TEMPORARY AHU		Acceptable	Acceptable	Acceptable
		BOTH EB AND TEMP		Acceptable	Acceptable	Acceptable
		HEPA FILTER BOX AND BOOSTER FAN		Acceptable	Acceptable	Acceptable
		TRANSFER GRILLE		Acceptable	Acceptable	Acceptable
	EXHAUST	EXHAUST OUTDOORS WITH NEW FANS		Preferred	Preferred	Preferred
		VENTILATED HEADBOARDS W/EXHAUST SYSTEM		Preferred	Preferred	Preferred
		LOCAL EXHAUST GRILLES		Acceptable	Acceptable	Acceptable
		RECIRCULATION WITH HEPA FILTERS		Acceptable	Acceptable	Acceptable
	OTHER	(OTHER ITEMS)				

6. CONCLUSIONS AND NEXT STEPS

The task force committee hopes that this guidebook may be useful in development of future Alternative Care Sites if they become necessary due to rising level of hospitalizations of COVID-19 patients.

Several next steps remain for this guidebook.

1. Incorporate additional guidance based on feedback from existing sites. Previous project teams are encouraged to submit "lessons learned" so that this guidebook may help future projects provide a high level of performance with fast project delivery and reduced project budgets.
2. Develop case studies to demonstrate the approaches contained in the guidebook.
3. Review findings from ongoing efforts fighting the pandemic and update guidance where applicable based on new information and innovative approaches in industry.

The chairs would like to thank the participants for their contributions to this guide including many ASHRAE members from TC 9.6 Health Care Facilities, the United States Army Corps of Engineers, Veterans Administration, and participants from branches of the military and American Society of Healthcare Engineering.

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