Recommendations and Lessons Learned

Makeshift Negative Pressure Patient Rooms In Response to COVID-19

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Everyone knows that installing new HVAC systems and equipment within an existing hospital requires extensive research, design, regulatory permits and, most importantly, time. But when you must create a large number of negative pressure hospital patient rooms in response to a pandemic, you don't have much time. Instead, you can create these rooms using appliances such as portable high-efficiency particulate air (HEPA) exhaust fan units, with guidance from relevant codes and standards and by following hospital licensing requirements.

Appliances move in and out of hospitals routinely. Although various codes and standards define appliances differently, they generally refer to units that are not hardwired, plumbed or directly attached to the building structure, floors, walls or ceilings. Through the use of appliances such as the portable HEPA exhaust fan unit, the authors were able to isolate infectious patients, while meeting or exceeding the requirements of applicable codes.

HVAC systems within a hospital, if designed properly, can help mitigate airborne transmission of diseases. Ventilation and filtration provided by HVAC systems can reduce the airborne concentration of SARS-CoV-2, the virus responsible for the coronavirus disease (COVID-19), and thus the risk of transmission through the air.[1] The "ASHRAE Position Document on Infectious Aerosols" states, "Some diseases are known to spread by infectious aerosols. The risk of pathogen spread, and therefore the number of people exposed, can be affected both positively and negatively by HVAC and local exhaust ventilation (LEV) systems."[2]

Building codes and health-care guidelines throughout the country require that hospitals have a minimum number of positive and negative pressure isolation rooms. A negative pressure isolation room isolates a patient to protect others in the hospital, while a positive pressure isolation room is designed to protect a patient

This peer-reviewed article does not represent official ASHRAE guidance. For more information on ASHRAE resources on COVID-19, visit ashrae.org/COVID19.

FIGURE 1 Conversion of a typical medical-surgical patient room to a temporary negative pressure patient room. (Left) A typical medical-surgical patient room may be quickly converted to a negative pressure room by placing portable HEPA exhaust fan units that are exhausted through windows directly by or via flexible duct through a fixed window panel. (Center) In this case, the return air grille is sealed. (Right) A digital pressure gage with audible alarm is placed outside the door.

with a compromised immune system from airborne contagions. Due to the recent COVID-19 pandemic, the focus of this article is on negative pressure isolation rooms.

Problem

Here is the problem: every hospital in the United States has only a limited number of negative pressure isolation rooms. During a pandemic, hospitals simply do not have enough of these rooms to handle the volume of patients. So, what can be done? We do not yet know if COVID-19 is an infectious disease spread through aerosols; however, placing COVID-19 patients in a typical medical-surgical or intensive care unit (ICU) room may contaminate sections of the hospital, possibly jeopardizing the health of others.

Recommendations

This article summarizes our recent approach to successfully converting a large number of ICU and medical-surgical patient rooms to makeshift negative pressure rooms at two large, acute care hospitals in California. These makeshift rooms were created in an incredibly short amount of time. The approach was so successful that it was shared among 15 other hospitals in California.

An important distinction exists between a well-planned negative pressure isolation room that meets all of the requirements of the applicable codes versus a makeshift negative pressure room that needs to become operational within hours. This distinction is the reason these makeshift rooms are identified as “negative pressure rooms” and not “isolation rooms.”

A typical emergency room may be quickly converted into a negative pressure room at the time of a pandemic (*Figure 1*). The guidance for temporary emergency response measures in hospitals varies between states and is impacted by hospital licensing. It is critical to perform any work in conjunction with the authorities having jurisdiction and to obtain approval before starting.

For example, in California, the Office of Statewide Health and Planning and Development (OSHPD) takes a more conservative approach than some of the national

Top Ten Lessons Learned

Be proactive, not reactive.

Place noisy, portable HEPA exhaust fan units outside whenever possible.

Use a pressure monitor with a digital display and alarm for each negative pressure room.

Where fire-rated walls are penetrated, a fire watch is required.

Use rooms with full height walls or solid ceiling, whenever possible, to prevent impact to adjacent rooms.

Do not use the existing return air duct system for exhaust.

Locate HEPA exhaust fan units to ensure all exhaust ductwork outside the room is under negative pressure.

Test, adjust and balance the affected patient rooms and adjacent areas upon return to their original conditions.

Keep exhaust at least 10 ft (3 m) away from any populated area and/or any OA intake that can return the exhaust air to the hospital.

Communicate requirements with hospital staff.

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guidelines or standards. ANSI/ASHRAE/ASHE Standard 170, *Ventilation of Health Care Facilities*, is also a great resource in the design of these types of rooms.

Typical requirements of a well-designed negative pressure isolation room located in an acute care hospital are as follows:

- Minimum of 12 air changes per hour;
- Minimum of 0.01 in. w.c. (2.5 Pa) of negative pressure to the adjacent corridor;
- A setpoint of 0.03 in. w.c. (7.5 Pa) of negative pressure to the adjacent corridor;
- Inclusion of an anteroom;
- Positive airflow from the corridor to the anteroom;
- Positive airflow from the anteroom to the isolation room;
- Minimum airflow difference of 150 cfm (71 L/s) into the space;
- Exhaust to the outside without mixing with the general exhaust;
- Ceiling supply air diffuser at the front of the patient's feet; and
- Lower wall-mounted exhaust air grille near the patient's head.

Does a makeshift negative pressure room meet all the requirements of a licensed isolation room? Absolutely not. Does it provide a possible temporary safeguard against the spread of infection? Yes. Our approach closely follows the OSHPD Policy Intent Notice PIN-4, "Review of Existing Facilities for Airborne Infection Isolation Rooms and Projects Related to Isolation of TB Patients."[3] PIN-4 was originally established in 1996 to address tuberculosis (TB) patients and was updated in 2011. The 2020 executive orders issued by OSHPD authorized the use of PIN-4 for implementing makeshift negative pressure rooms during the COVID-19 pandemic. Here is an excerpt from OSHPD PIN-4:

"Because of the expense of building new Airborne Infection Isolation Rooms, the increasing number of suspected and confirmed tuberculosis (TB) cases requiring isolation at public hospitals, the need to admit TB patients to different areas of the hospital at different times, and the need to use 'TB rooms' for non-isolation patients some of the time, many hospitals are turning to a variety of methods to isolate TB patients that are generally consistent with publications of the Centers for Disease Control and Prevention (CDC)."

TB is an airborne disease;[4] it is currently debated whether COVID-19 has the characteristics of an airborne disease. The CDC states that the virus is thought to spread through respiratory droplets.[5] The well-known 6 ft (2 m) guideline established for social distancing is simply to avoid the transmission of COVID-19 through droplets. Droplet particles are greater than 5 µm to 10 µm in diameter. Airborne transmission is different from droplet transmission, as it refers to the presence of microbes within droplet nuclei, which are generally considered to be particles less than 5 µm in diameter. Droplet nuclei can remain in the air for long periods of time.[6]

What if the COVID-19 virus is also transmitted through microbes within droplet nuclei? While unlikely, scientists do not know enough to make a conclusive recommendation at this time. Many health-care institutions are treating COVID-19 as an airborne disease and, as HVAC engineers, we should treat it similarly to TB until we know otherwise. An ASHRAE issued statement indicates that "transmission of SARS-CoV-2 through the air is sufficiently likely that airborne exposure to the virus should be controlled."[7] Below are some of the recommendations of PIN-4 that were successfully implemented in our approach:

- Provide a portable high-efficiency particulate air (HEPA) exhaust fan unit for each patient room. Each unit's HEPA filter shall have a minimum of 99.97% dioctyl phthalate efficiency or minimum efficiency reporting value (MERV) of 17.
- HEPA exhaust fan units are not hardwired, plumbed or directly attached to the building structure, floors, walls or ceilings.
- HEPA exhaust fan units are installed in existing intensive care rooms or existing medical-surgical nursing rooms.
- Exhaust is through windows, either directly or via duct through a fixed window panel.
- Monitor the room pressure. Gages shall be readable from the corridor and annunciate locally at the door when air balance is disrupted except for time delays for the normal opening of the doors.
- Close windows and seal doors to the extent practical for all air penetration leaks into the room.
- Ensure alterations do not compromise or alter fire protection systems.
- Verify that exhaust outlets of any portable unit exhausted to the building exterior is at least 10 ft (3 m) away from any opening. This may require securing some

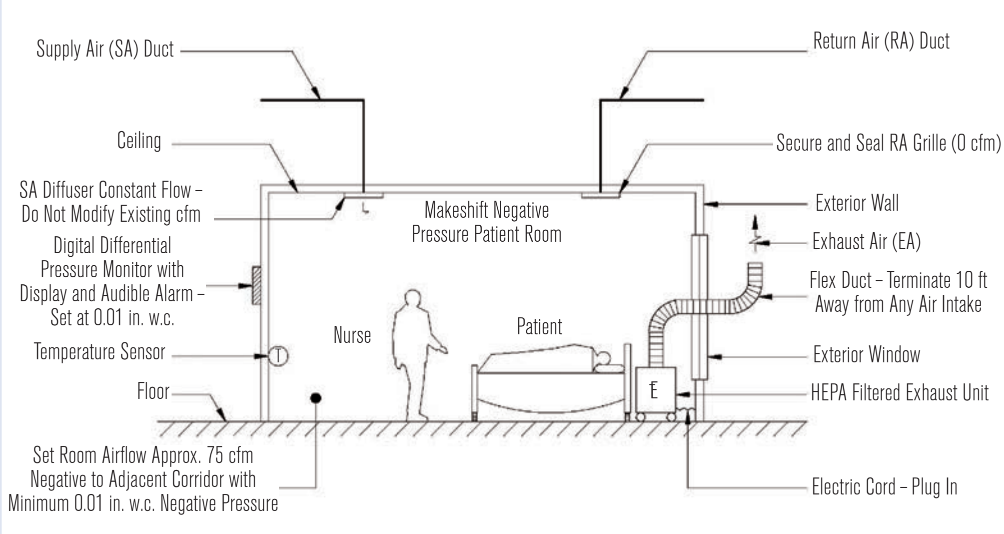
existing windows if they are operable. Note, the 10 ft (3 m) requirement is an OSHPD temporary measure and not reflective of Standard 170 requirements, which may be enforced in other jurisdictions.

- The maximum airflow rate from the corridor into the room is listed as 75 cfm (35 L/s) under PIN-4; however, in our experience, this is not always sufficient to maintain the required negative pressure. For some of the rooms, the required cfm was greater.
- Rebalancing the affected areas is recommended.

Figure 2 demonstrates the layout of a typical room.

Each modified space should be reviewed by a licensed engineer and a one-page report should be prepared for each space to document the modifications. Each report should be dated, signed and forwarded to the authority having jurisdiction and the hospital. The hospital's licensing personnel should file the report with the State Department of Public Health to obtain approval for use.

FIGURE 2 Layout of a typical makeshift negative pressure patient room.



Top Ten Lessons Learned

The Top Ten Lessons Learned from this experience are as follows:

Lesson 1: Be Proactive, Not Reactive

"Don't do something just to do something," said Joel Sanders, OSHPD Compliance Officer. Some of the facilities we visited went through a great deal of effort and made significant modifications that did not follow established guidelines and ended up making the situation worse.

Often, the hospital's maintenance staff was eager to act by modifying HVAC equipment control sequences or constructing infection barriers without a properly engineered action plan. Action without a plan and full understanding of the codes, regulations and hospital licensing requirements may result in undesirable outcomes.

Lesson Learned 2: Place Noisy, Portable HEPA Exhaust Fan Units Outside Whenever Possible

OSHPD PIN-4 recommends placing HEPA exhaust fan units inside the patient room. Initially, we did this, but soon realized it may not be a good idea due to the noise levels generated by some of the HEPA exhaust fan units.

These units have a control knob, which patients may feel inclined to adjust to lower the speed or turn off the unit altogether to reduce noise levels. Building codes and regulations recommend sound levels of 30 dB(A) to 35 dB(A) for patient rooms. Higher sound levels in patient rooms interfere with the healing process and activities of hospital staff.

PHOTO 1 Place noisy, portable HEPA exhaust fan units outside, whenever possible (Lesson 2).

Joel Sanders, OSHPD Compliance Officer, recommends that "whenever possible, locate HEPA exhaust fan units outside and protect them from the weather." The option of placing HEPA exhaust fan units outside (*Photo 1*) is more conducive to certain climates and may not be possible in all regions of the country or world. Protecting them from the weather can be as simple as providing a small tent.

Lesson Learned 3: Use a Pressure Monitor With A Digital Display and Alarm for Each Negative Pressure Room

During a pandemic, shortages of equipment and supplies may exist. If manometer alarms are not available, routine checks for negative pressure are required. That means assigning a qualified person to check each of them every 15 minutes.

Lesson Learned 4: Where Fire-Rated Walls are Penetrated, a Fire Watch is Required

Avoid penetrating fire-rated walls with temporary, flexible ductwork whenever possible. Anytime we penetrate a fire-rated wall with a duct or anytime we have an opening in a fire-rated wall, we need to install a fire damper or a combination of a fire/smoke damper. Obviously, during an emergency installation of temporary, flexible ductwork, there is not adequate time for such installation. Most code and authorities having jurisdiction allow such installations without fire/smoke dampers as long as the hospital assigns a full-time, qualified professional as a "fire watch."

Lesson Learned 5: Use Rooms With Full-Height Walls or a Solid Ceiling, Whenever Possible, to Prevent Impact To Adjacent Rooms

T-bar ceilings often do not allow proper pressure control and can experience excessive air leakage or adversely affect the pressure in adjacent rooms. Remember, these are temporary setups and the room pressurization could easily be affected by an accessible control knob that can be adjusted by a patient or hospital staff. Manual adjustment of the HEPA exhaust fan speed may result in fluctuation of the differential pressure to the corridor by over 90% (from 0.01 in. w.c. to 0.10 in. w.c. [2.5 Pa to 25 Pa] or above) depending upon the size of the HEPA exhaust fan. We learned this the hard way!

Lesson Learned 6: Do Not Use the Existing Return Air Duct System For Exhaust

Using the existing return air duct (*Photo 2*) may contaminate existing ductwork, spread infection and create significant challenges for infection control. In one case, the facilities maintenance staff used the direct digital control (DDC) system and temporarily closed the mixed air dampers of an existing economizer to provide 100% outside air (OA) to the space. They then used the return air duct to exhaust the air from a temporary negative pressure room. This may be a costly mistake due to the following three inherent problems:

1. The system is not designed for 100% OA, and temperature control of the entire hospital may be affected.

2. 100% OA on an economizer is not really 100%. Economizer dampers often have massive leakage rates and contaminated return air will likely mix with supply air and contaminate the entire hospital.

3. Let's assume everything works out well for now. What happens when we return to normal operation? We now have return air ductwork that is contaminated. We all have heard that when it comes to HVAC, DDC is your best friend. In this case, it could become your worst enemy. "Do not do it," said Joel Sanders, OSHPD Compliance Officer.

PHOTO 2 Don't use the existing return air duct system for exhaust (Lesson 6).

Standard 170 allows recirculation with HEPA filtration for specific spaces including waiting rooms and triage. For infection isolation rooms, which is the intent of these negative pressure rooms, Standard 170 does not have the same allowance for recirculation. All air from infection isolation rooms must be exhausted to the outdoors per Table 7.1, Design Parameters—Hospital Spaces, of this standard.[8]

Lesson Learned 7: Locate HEPA Exhaust Fan Units to Ensure All Exhaust Ductwork Outside The Room is Under Negative Pressure

Any temporary, flexible ductwork installed in the corridor must be under negative pressure in accordance with state and international codes and the Uniform Mechanical Code. By placing the HEPA exhaust fan units outside to put the duct under negative pressure, you can prevent the contamination of the corridor if there is a leak in the duct. In addition, the ductwork should be run to avoid fire sprinklers and alarms in the corridor.

Lesson Learned 8: Test, Adjust and Balance the Affected Patient Rooms And Adjacent Areas Upon Return to Their Original Conditions

So, what happens when this pandemic comes to an end and we must return these makeshift patient rooms to their original conditions? Testing, adjusting and balancing of the affected patient rooms and adjacent areas will be required. The real question is what are the affected areas? The standard of care as well as many health-care regulatory agencies require complete testing, adjusting and balancing of the area served by an air-handling unit when at least 10% of the supply air associated with that unit is affected. Often, that means the entire department, which is an expensive proposition.

Lesson Learned 9: Keep Exhaust at Least 10 ft (3 m) Away from Any Populated Area and/or Any OA Intake that Can Return the Exhaust Air to The Hospital

As a temporary OSHPD measure, exhaust of the outlet of any portable unit must be 10 ft (3 m) away from an opening air intake or populated area. This is sometimes easier said than done because many of the portable units have limited static pressure capabilities. Lengthy flex duct will adversely affect the available unit airflow. In one case, we had no option other than to extend the flexible duct for more than 50 ft (15 m) outside. An awkward look.

Lesson Learned 10: Communicate Requirements With Hospital Staff

Audible alarms are great; however, if no one knows what to do when they go off, they serve no purpose. Hospital staff should be trained on what to look for on a pressure monitor and understand the importance of monitoring, as they will be the first to know if the patient has turned off the unit. Simple instruction and explanation go a long way.

Conclusion

A pandemic brings to light the importance of HVAC systems within a hospital. Without them, it would be impossible to contain the spread of airborne infectious diseases. Makeshift negative pressure patient rooms allow for a hospital to properly care for and ensure the safety of their patients. Although designed by a licensed engineer, collaboration with the hospital staff and regulatory agency representatives is critical to expeditiously address and maintain the requirements of these negative pressure rooms.

References

1. ASHRAE. 2020. COVID-19 (Coronavirus) Preparedness Resources. “Message from ASHRAE President Darryl Boyce.” ashrae.org/covid-19.

2. ASHRAE. 2020. “ASHRAE Position Document on Infectious Aerosols,” p. 1. Atlanta: ASHRAE. https://tinyurl.com/y8meg96z.

3. Office of Statewide Health Planning and Development. 2011. “Policy Intent Notice (PIN) 4 Review of Existing Facilities for Airborne Infection Isolation Rooms and Projects Related to Isolation of TB Patients,” pp. 1-3.

4. CDC. 2013. “Core Curriculum on Tuberculosis: What the Clinician Should Know,” p. 21. Center for Disease Control and Prevention.

5. CDC. 2020. “How to Protect Yourself and Others.” Centers for Disease Control and Prevention.” https://tinyurl.com/y9rst97g.

6. WHO. 2020. “Modes of Transmission of Virus Causing COVID-19: implications for IPC Precaution Recommendations.” World Health Organization.

7. ASHRAE. 2020 “ASHRAE Issues Statements on Relationship Between COVID-19 and HVAC in Buildings.” https://tinyurl.com/yaqpykb3.

8. ANSI/ASHRAE/ASHE Standard 170-2017, *Ventilation of Health Care Facilities*, pp. 8-14. ■

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