IMPLEMENTING COVID-19 MECHANICAL SYSTEMS
LESSONS LEARNED FOR NEW HOSPITAL

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The current surge of patients caused COVID-19 pandemic will cause a paradigm shift in the design of new hospitals. Building codes and standards will be modified to address the need of patient surge due topandamics. Hospital need to be flexible, modular in design, patient flow, touchless highly used surfaces, physical infrastructure etc. In addition, preparedness of Alternate Care Sites where patients can remain and receive medical care for the duration of their isolation period. These are typically established in none-traditional environments, such as converted hotels or mobile field medical units to address the surge in response. It is critical to ensure these facilities support implementation of recommended infection prevention depending on the level of care that is needed.

Hospitals have generally reacted to major healthcare outbreaks likes of 1918 Spanish flu where shift away from wards to single patient bedroom to minimize spread of the disease. Many healthcare organizations and hospitals lacked the flexibility to accommodate sudden surges of patients with infectious respiratory viruses.

The purpose of this article is to prepare newly designed hospital infrastructure implementing lessons learned against an infectious respiratory virus for an improved mechanical, plumbing, medical gases systems without significantly increasing the capital cost.

MECHANICAL SYSTEMS

Hospital mechanical systems have stringent requirements to meet the environmental comfort, infection control, energy conservation, highest level of flexibility and now we are adding disaster planning. Best practices as per ASHRAE should apply in maintaining the desired temperature, humidity, room air exchange, and pressure requirements for various types of rooms inside the hospital.

Heating Ventilating and Air-Conditioning (HVAC):

Over the past decades as technologies developed the mechanical systems have drastically changed the industry to have the system be energy compliant moving towards net zero energy and carbon footprint, improving indoor air quality and the challenge in containing first and operational costs.

There are many variables in selecting the optimal mechanical system to achieve the above requirement. This can be achieved by running an energy model for different systems for the specific geographical location. Typical systems for a hospital to be considered are:

- Constant Volume Return Air System
- Constant Volume 100% Outside Air System

- Variable Air Volume 100% Outside Air System with Heat Recovery
- Variable Air Volume 100% Outside Air with Heat Recovery and Displacement Ventilation

The selected systems should consider first cost, indoor air quality, operational costs including maintenance and energy, flexibility for future remodel and adaptability to sudden surge of patients in case of an outbreak.

During the COVID 19 pandemic it has become apparent ventilation systems has been one of the key elements in controlling infection in the hospital. The 100% outside air, a once through, system is most effective in controlling the spread of infection in a hospital. It has been our experience the 100% outside air variable air volume with multi stage heat recovery mechanical system gives the best value for first cost, improved energy, flexibility, efficiency, better indoor air quality in controlling infection within the hospital.

Intakes to air handling unit to be upstream of prevailing winds and a minimum code required distance away from building exhaust air to avoid air entrapment into the supply air.

Variable Air Volume system:

Hospital building codes require a minimum outside air changes per hour in each type of room i.e. surgery, emergency, isolation rooms, patient rooms etc. The codes will not allow the use of variable air volume in a return air system since there is no way of assuring the minimum outside air into the space. Our energy programs have indicated significant savings using variable air volume. This lead us to the use 100% outside air system. The plus side of using variable air volume system, the patient room can easily be converted to negative pressure room in case of an outbreak.

Filtration:

Individual virus particle can be 0.1 micron or smaller. Particles and droplets generated by talking and respiration are typically much larger than 0.1 micron, making the virus easier to capture. Virus can remain active up to 3 hours in outdoor air and 2-3 days on room surfaces. The following filtration that capture range of different size particles:

MERV 11-12 Captures 65-80% of particles 1-3 microns in size (i.e., dust, vehicle emissions)

MERV 13-15 Captures 50-85% of particles 0.3-1.0 micron in size (i.e., smoke, exhalation droplets)

MERV 16 (N-95 respirator equivalent) captures 0.3-1.0 microns in size (i.e., smoke, exhalation droplets). Coronavirus is about 0.12 micron in diameter.

HEPA filter (P-100 respirator equivalent) captures 99.97-99.99% effective for 0.3 micron particles (i.e., bacteria, viruses). HEPA filtration is effective for contaminant removal.

If 100% outside air system is selected, the outside air can be treated with a MERV 10 pre-filters and MERV 16 final filters which is a typical filtration required for a hospital.

Humidification:

Ideal humidity should be between 40%-60% to reduce airborne transmission. Above 60% the microbe and virus growth is facilitated. If it goes below 40% the virus remains in the air for a longer time and spread more easily. Maintain code require range of humidification for the type of room i.e. operating room, isolation rooms, patient rooms etc.

Displacement Ventilation:

There are two fundament concepts in ventilating a patient room as an example. Once concepts which has been traditionally used is by supplying air at the ceiling and the other is by supplying air at lower level:

Supply air at ceiling: The supply air is generally supplied at 55F (13C) mixing with the warm ceiling air to maintain the desired room temperature of 72F (22C). Supplying air at the ceiling level mixing with the entire room air at the ceiling where there contaminants are concentrated in a warm layer near the ceiling.

Supplying air at lower level: this concept is called displacement ventilation where air is supplied at 65F (18C). The supply air at low level seeks warm objects such as occupants, equipment and/or outside windows where air is lifted towards to the ceiling by rising warm air. Compared to supplying air at the ceiling, this concept can improve indoor air quality and saves energy by supplying warmer at the lower level. We have also found this concept to be more comfortable on the occupant because the temperature gradient at the occupant zone is less gradual than supplying air at the ceiling level.

Room pressurization:

Room pressure differential shall be maintained as required by ASHRAE Standards. If a room is to be used for infectious patients such a regular patient rooms, the building automatic controls can change the setting to make the room negative pressure.

MEDICAL GASES

COVID 19 being a respiratory virus, there was a big demand for ventilators. Ventilators can consume 100% medical compressed air and no oxygen all the way up to 0% medical compressed air to 100% oxygen depending on the ability of lungs to exchange gasses in the blood.

Oxygen

ICU rooms are typically fitted with three outlets for a total flow of about 1.0 scfm plus ventilator demand. COVID 19 patient gross oxygen demand adds up to a range of 2.0-2.5 scfm.

Medical-surgical patient rooms have insufficient number of oxygen outlets, in addition the main supply piping systems is design for 20% of total ventilation being operational.

A need to increase the infrastructure by adding an additional oxygen tank or provide an auxiliary source connection at bulk oxygen tanks and upsizing the piping system.

Medical Compressed air

ICU rooms are typically fitted out with one outlet with a total flow of 1.0 scfm plus ventilator demand. Covid 19 patient gross medical compress air demand adds up to a range of 2.0-3.0 scfm.

Medical-surgical patient rooms have insufficient number of medical compressed air outlets, in addition the main supply piping system is designed for 20% of total ventilation being operational.

A need to increase the infrastructure by providing additional medical air compressors and upsizing the piping system.

PATIENT SURGE DUE TO AN OUTBREAK

The hospital should make plans to quickly mobilize to receive surge of patients in a pandemic outbreak.

There are two categories first is to receive infected patients within the hospital and if the hospital is at its full capacity, Alternate Care Sites to be considered as described below.

Modification to existing hospital:

Hospital mechanical systems shall be sized and be flexible to adapt to the air-change requirement and room air pressure requirement. As an example, modification to a patient room make it COVID 19 ready is by quickly converting to negative air pressure room as described below.

a. Utilize portable ante room isolation tent at the entry door
b. Install protectable portable isolation tent with HEPA around patient bed.
c. Keep door to patient room closed
d. Supply and exhaust air controlled by terminal units. The controls can easily be adjusted to make the room negative pressure.
e. Provide sufficient oxygen and medical air outlets and infrastructure to meet the capacity of the ventilators.

Alternate Care Sites (ACS)

Alternate Care Sies are typically established in non-traditional environments. A patient in need of medical care might require jurisdictions to establish Alternate Care Sites where patients with COVID-19 can remain and receive medical care for the duration of their isolation period.

Alternate Care Units could provide three levels of care:

1. Non-Acute Care for mildly to moderately: These patients may require oxygen but not require extensive nursing care.
2. Mid-Level care for moderately symptoms patients. These patients require oxygen, nursing care, and assistance with daily activities.
3. Acute Care: High acuity care patients requiring ventilator support with intensive nursing care.

General parameters for selecting an Alternate Care Site should have a minimum outside air changes per hour, temperature, filtration, and relative humidity. Medical gases such as oxygen and medical compressed air can be provided on temporary basis. The Alternate Care Sites clinical goals will dictate infrastructure needed.

High level of applicability: Gymnasiums and convention centers would have high level of applicability due to open conditioned space in applying the three levels of care. Modify existing space as follows:

1. Modify the existing air-handling unit with a MERV8 prefilters and MERV14 final filters and set the economizer to provide minimum outside air requirements. During mild weather, the economizer will provide up to 100% outside air.

2. Provide new temporary air-handling unit with 100% outside air fitted with MERV8 prefilters and MERV14 final filters. The supply air is ducted to each enclosed patient area.

3. Provide new temporary exhaust air fan with ductwork connected to each enclosed patient areas at the head of the patient. Exhaust fan without HEPA filters to be placed outdoors discharging at the highest point downstream of prevailing winds and far away from any building openings and breathing zones.

4. Patient area shall be negative pressure created by a headboard exhaust.

5. Patient are desired temperature to be 70-74F range with a minimum recommended relative humidity of 40%.

6. Temporary oxygen cylinders or bulk oxygen tank on a trailer and medical air compressors piped to each patient bed for the ventilators.

Medium level of applicability: Hotels and dormitories would have medium level of applicability housing none-acute patients only to minimize disruption of host site.

1. Protect mattress with waterproof wrap, carpet protection film remove none-essential furniture.

2. Utilize existing HVAC system if recirculating within single guest/patient room.

3. Consider local recirculating HEPA filter units for increased air exchanges.

4. Confirm exhaust discharges away from air intakes and occupied areas.

5. Confirm existing HVAC systems serving common areas do not recirculate air between patient and staff. Hotel guest rooms generally are served with a dedicated fan coil unit.

Low level of Applicability: Garages and tents would have a low level of applicability due to the lack of infrastructure of conditioned space.

Medical Field Units could also be an alternative if they can be mobilized in a timely manner.

CONCLUSIONS

There are many speculations of the potential future of COVID 19 Pandemic if it will become recurrent seasonal infections from previous infection from one variant protect individuals from reinfection with some new variants. one variant protect individual . There are studies been conducted as to what recurrence of future pandemics.

It is advisable to have a hospital be ready for such event as COVID 19 where hospitals did not have the capacity to deal with surge of infected patients.

The design and construction industry implemented changes to existing healthcare system to accommodate the surge of infected patients. There will be codes and standards changes based on lessons learned.

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