

AIR CONDITIONING AND REFRIGERATION

Journal

The magazine of the Indian Society of Heating, Refrigerating and Air Conditioning Engineers

HVAC in Times of COVID-19

INSIDE:

- A Primer on HVAC Parameters, Filtration and UVGI in Healthcare Facilities
- Operation of Thermal Comfort Systems during COVID-19
- HVAC for Healthcare Facilities in Times of COVID-19
- Resilient and Future Proof HVAC Systems for Post COVID-19 Buildings
- Managing Healthcare by HVAC Post COVID-19
- Practical Approach to Design Challenges for COVID-19 Facilities
- Restarting HVAC Operations After a Prolonged Lockdown
- ISHRAE Releases COVID-19 Guidance Documents

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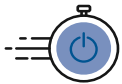
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This article addresses the challenge of providing thermal comfort and indoor air quality to patients and all others who need to be present in a healthcare facility, without compromising their well-being.

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Radiant cooling systems offer high indoor air quality, thermal comfort and energy efficiency while controlling the spread of virus by diluting the indoor air with 100% treated fresh air.

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COVID-19 is not merely contracted from large droplets but is virtually an airborne infection, as the virus can remain suspended in air long after it is expelled. Read on to know about HVAC design of quarantine, isolation and treatment facilities.

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By E. R. Muralikanth

HVAC systems would have been switched off during the total lockdown phase. What are the possible problems one can come across while the systems are restarted after a prolonged shut down?

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Kasturba Hospital in Mumbai has an isolation facility for COVID-19 patients



A view of National Cancer Institute, Nagpur



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"Be open, be impatient, be hopeful. If you can do that, history will remember the Class of 2020 not for what you lost, but for what you changed. You have the chance to change everything. I am optimistic you will... The long arc of history tells us we have every reason to be hopeful. So, be hopeful."

– Sundar Pichai

Google CEO, addressing the graduating class of 2020



The first COVID-19 case in India was detected on January 30 but it was a distant threat till March 15, when the number of patients crossed 100. Suddenly the nation realised it was staring at a human calamity of enormous proportions. Measures for prevention and mitigation needed to be, and were, introduced urgently.

Different states imposed restrictions on social interaction and movement of people to deal with the situation. Sanitisers, hand-washing and social distancing were promoted aggressively. A comprehensive lockdown was imposed in the country from March 25, permitting only essential services.

A typical feature of manufacturing operations in India is that they are heavily dependent on workers who have migrated from their villages that have no industries, to towns that have industries but a shortage of workers. These migrant workers, who lost their daily wages because of the lockdown, went back to their villages, sometimes trudging for hundreds of kilometres. Most of these workers did not return even after the lockdown was relaxed substantially. This is a challenge for the factories and their vendors in their bid to restart the supply chain

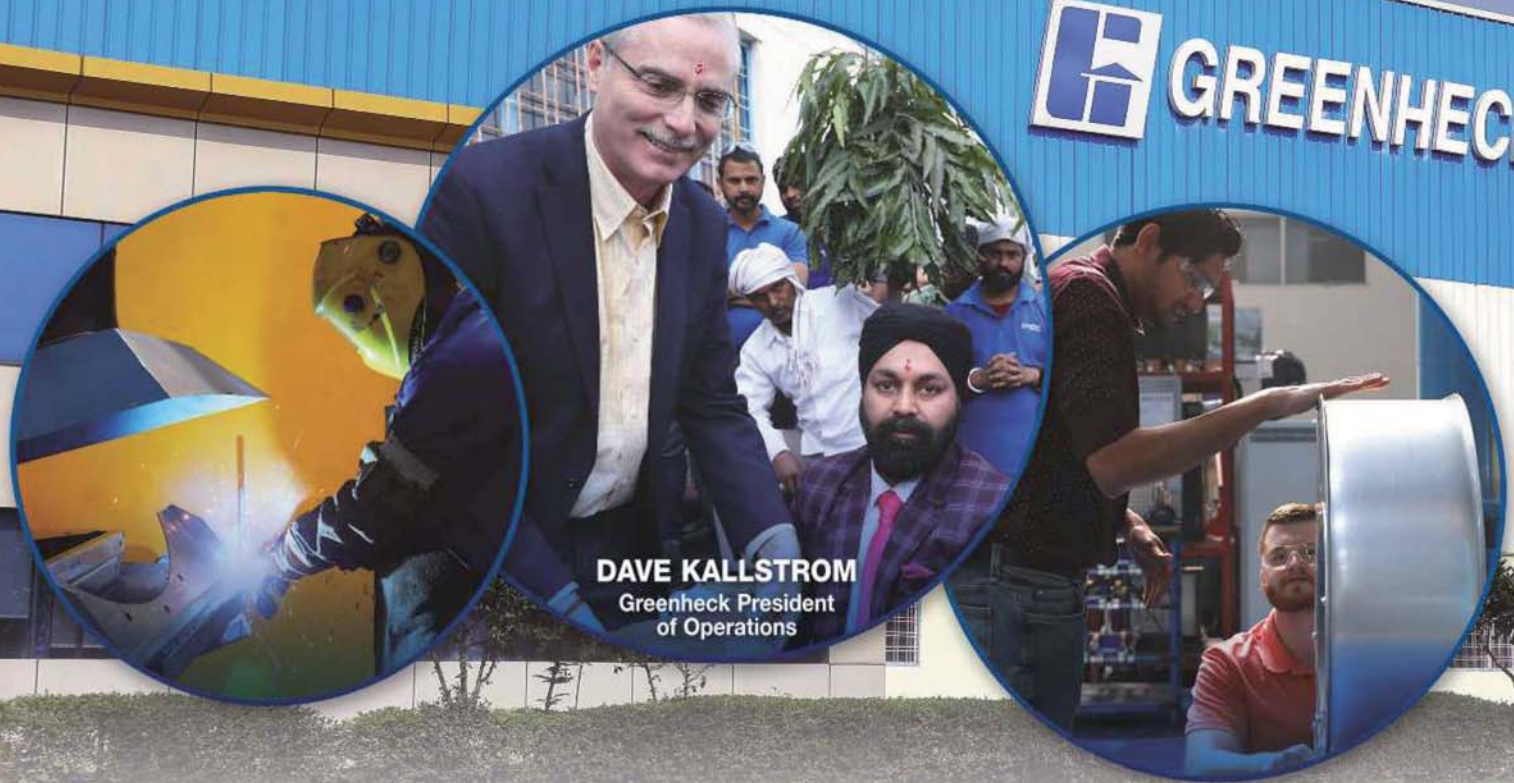
Production activity in factories outside the large metropolitan cities, which have been severely affected by COVID-19, was permitted from May 3 with safeguards regarding social distancing and sanitisation. However, room air conditioner factories were not able to commence production because of huge finished goods inventories and shortage of workers. Since outlets selling these products were not allowed to open yet, the inventories could not be sold and converted into the cash required to prime the supply chain.

Sales outlets for room air conditioners and other consumer durables were allowed to open in most areas from May 18. But customer footfall has been scanty. Manufacturers are expecting negative growth in sales this year after a dream run during the last six years. Most of the peak summer period has seen miniscule sales due to the lockdown. Like most other industries, the pandemic has taken a heavy toll of the HVAC industry. But "the long arc of history tells us we have every reason to be hopeful."

ISHRAE was one of the first professional associations in India to rise to the occasion, and quickly constituted a task force to steer the HVAC industry's response to the pandemic. The task force published a freely downloadable document, *ISHRAE COVID-19 Guidance Document for Air Conditioning and Ventilation*, as early as April 13. The document was adopted and is being recommended by the Central Public Works Department. It covers aspects related to residential, commercial, healthcare and all other types of buildings. It targets the whole gamut of HVAC systems from standalone RACs to centralised and ducted air conditioning systems. Later, on June 2, the ISHRAE task force rolled out another freely downloadable document, in association with Hospital Board of India – a wing of the Indian Medical Association – titled *IMA HBI-ISHRAE COVID-19 Guidance Document for Air-Conditioning and Ventilation in Healthcare Facilities*.

This issue of the *Journal* is dedicated to the response chalked out by the HVAC industry to one of the most formidable challenges ever faced by humanity. It is packed with information and insights from domain experts with decades of hands-on experience. We are sure it will serve as a valuable resource for our industry for a long time to come.

Rakesh Kumar, Managing Editor



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3M Unveils Electrostatic AC Filters

3M, a company engaged in science and innovation for air quality solutions, has launched two variants of electrostatic PM_{2.5} air conditioner filters to improve indoor air quality. These filters facilitate better air flow through the AC while trapping airborne particles and delivering cleaner, healthier air. They target specific challenges that users face including pollen, dust mites, debris and other allergens.



Electrostatic PM_{2.5} filter from 3M

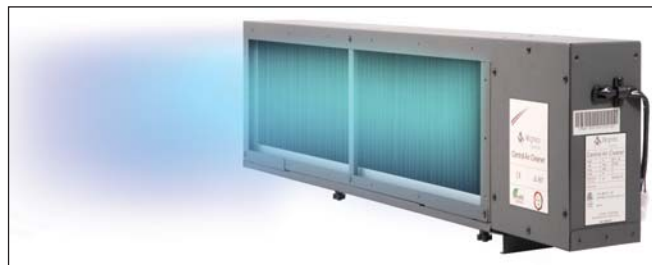
The new Household Dust variant of the filter can arrest up to approximately 90% of PM_{2.5} within two hours of use, whereas the Allergen variant, which is certified asthma- and allergy-friendly by Allergy Standards Limited (ASL), captures up to 93% in the same amount of time. Both variants are made with Filtrete brand 3-in-1 technology, which traps unwanted airborne particles without compromising on cooling.

Sanjit Satapathy, Head of Consumer Business Group for 3M India, said, "Our new AC filters are an ideal option to help improve air quality in Indian homes, offices and clinics, which rely on wall-mounted ACs and are backed by our proven track record in meeting the highest international standards of quality and performance."

Each pack of the new Household Dust and Allergen filters contains four filtration sheets that can be easily installed in split ACs as a do-it-yourself (DIY) installation, without any help from a technician or using any tools. The pack also contains two filter change indicators that help the user to understand when their installed filter needs to be replaced for best results in terms of air filtration and air flow.

Magneto Launches Advanced Central Air Cleaner

Magneto CleanTech has launched an enhanced version of Magneto Central Air Cleaner (MCAC), co-powered by Filterless Magnetic Air Purification (FMAP) and Ultraviolet Germicidal Irradiation (UVGI) technologies. This high efficiency air filtration system based on the 'trap and kill' process now combines with



Magneto Central Air Cleaner

anti-microbial UV-C rays, which thoroughly decontaminate the indoor air by killing over 90% of airborne viruses and infections instead of letting them grow.

The advanced unit of MCAC integrates with all types of air-conditioning systems to eliminate harmful PM_{2.5} particles, viruses, bacteria, air-borne pathogens and cancer-causing toxic gases that create indoor air pollution. It traps airborne viruses of even 0.1 microns (which is the size range of the SARS-CoV-2 virus) at the magnetic stage – through electron beaming, and the RNA of the virus is ruptured and destroyed by the photonic energy of the UVGI system.

Speaking during the launch, Himanshu Agarwal, Founder CEO, Magneto CleanTech said, "Magneto Central Air Cleaner incorporates the best-in-class technology to rid the air of any harmful viruses and other particles. It is a very proud moment for us as an Indian company to take the lead in providing the nation sanitised air. We're contributing to make India and the world a safer, better place."

Hero Group Introduces ZenShield

Zenatix, the Hero Group's venture into the technology space, has announced the launch of ZenShield, a comprehensive COVID-ready building HVAC monitoring and control solution. ZenShield, which helps in complying with ISHRAE's recommendations, enables commercial buildings and offices to protect their occupants from the spread of COVID-19.

With ZenShield, buildings can automate their HVAC settings in real time without manual intervention, and ensure ISHRAE safety standards, compliance and audit trails. It helps to automate temperature control, humidity control and exhaust operation, and ensures the circulation of fresh air in the building while monitoring the temperature and humidity in real time. Multiple buildings can be automatically monitored in real time to ensure the health and safety of the occupants via a centralised dashboard.

Nikhil Rajpal, CEO, Hero Electronix, said, "With ZenShield, we are expecting to empower businesses in India to safely rebuild themselves and safeguard the health of their employees in the coming months."

Rahul Bhalla, CEO and Co-founder, Zenatix remarks, "Our years of proven experience and expertise in IoT solutions for enterprises has translated into ZenShield solution, which will ensure compliance with ISHRAE guidelines." ❁

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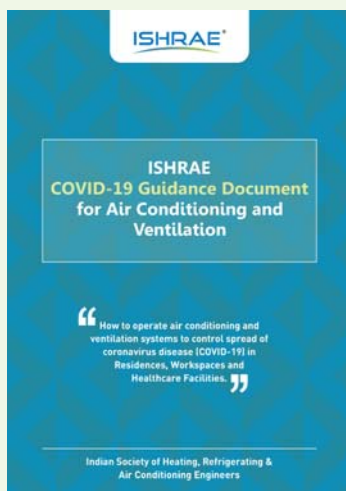
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ISHRAE Releases COVID-19 Guidance Document

Richie Mittal, National President, ISHRAE while announcing the release of *ISHRAE COVID-19 Guidance Document for Air Conditioning and Ventilation*, said, "While the world continues to fight this global pandemic of COVID-19, we at ISHRAE have launched a task force along with a set of guidelines that may help reduce the impact of the virus in our homes, offices and hospitals. At ISHRAE, we're dedicated to the safety and health of all citizens affected or not affected and would like to contribute in this global fight against this global enemy through our contribution as part of the largest body of HVAC&R industry. This is the primary reason why the guideline also includes a portion for service technicians and air conditioning system operation and maintenance."

ISHRAE had set up a COVID-19 Task Force comprising of thought leaders and experts from among its members to help carve out guidelines as an aid to humanity at large and to help fight the pandemic in buildings and complexes, in particular. For over a month, the task force mapped through studies and rolled out the guidelines for safe use of HVAC systems in residential houses, commercial buildings and hospitals on April 13. A copy of these guidelines is available at www.ishrae.in for free download. ISHRAE's Guidance Document has been adopted and is being recommended by the Central Public Works Department (CPWD).

These guidelines, in brief, cover aspects related to all types of buildings, be it residential, commercial or healthcare, and target from the simple, standalone air conditioning systems to the more complex, centralised and ducted air conditioning systems and address the concerns related to them, viz., filtration system, humidity, ventilation, etc.



ISHRAE's COVID-19 Guidance Document refers to studies conducted at various relative humidity levels showing that using viral culture methods, low temperatures (7-8°C) were optimal for airborne influenza survival, with virus survival decreasing progressively at moderate temperatures (20.5-24°C) and further decreasing at higher (greater than 30°C) temperatures. Hence ISHRAE recommends safe operation of air conditioning and cooling systems with indoor air temperature and humidity set between 24°C and 30°C and 40% and 70% respectively.

In commercial buildings, multiple occupancy and transient visitors necessitate precautions, especially in the operation of their air conditioning systems. Hence, it would be prudent for all commercial buildings to limit risk by ventilating the indoor environment with outdoor air as much as possible. The suggestive precaution, as mentioned in the guidelines, is the use of mechanical ventilation systems that improve the quality of the outdoor air through filtration. However, the document has also mapped out separate operating guidelines based on the category of indoor unit, which can be read here.

ISHRAE released a separate guidance document on June 2 in association with Indian Medical Association Hospital Board of India, titled *IMA HBI-ISHRAE COVID-19 Guidance Document for Air-Conditioning and Ventilation in Healthcare Facilities*. It has been rolled out by the same COVID-19 task force chaired by Vishal Kapur that had put together the earlier guidance document. It carries a message by Dr. Rajan Sharma, National President of IMA, commending ISHRAE's efforts. This document may also be downloaded from ISHRAE website.

Voltas Expands its Manufacturing Facilities

Voltas, a Tata Group company and a leader in the heating, ventilation air conditioning and refrigeration (HVACR) industry, has expanded its manufacturing capabilities with two large greenfield facilities at Waghodia and Sanand in Gujarat, with another unit mooted at Tirupati, Andhra Pradesh.

The company has announced commencement of its operations at the plant in Waghodia. This plant is spread over a 32-acre site with an investment of Rs 65 crore. It will manufacture a range of HVACR equipment between 2 and 2000 TR for commercial buildings, and public and industrial infrastructure. It also houses superior psychrometric laboratories and AHRI-certified test beds for chillers. Situated close to Vadodara, it will tap the existing market for specialty components, contributing



The new Voltas factory at Waghodia

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Voltas Continues Service Support During Lockdown

Pradeep Bakshi, Managing Director of Voltas, has emphasised the company's resolve to support various user segments by keeping afloat its service operations during the lockdown. "While the COVID-19 pandemic has led to a nationwide lockdown, we at Voltas have always strived to ensure that our services remain focussed towards our consumers and the nation's needs at large. We have been managing the upkeep of all essential services with the help of over 1,500 technicians and engineers of Voltas, who are currently working on the frontlines of this pandemic."

Describing the challenges faced by the personnel, he added, "One of the most common challenges faced during the lockdown would be that of transportation, especially since movement has been restricted at this time. Therefore, arranging safe travel to and from the site for our engineers and technicians has been challenging. The most common customer service request was the need for operational manpower for the essential sites and emergency breakdown calls for rectification. There is a need to keep essential services companies functioning uninterrupted at all times and we, at Voltas, are ensuring the same while keeping in mind the safety and security of our employees."

Panasonic Anticipates Change in Buying Behaviour Post COVID-19

Manish Sharma, President & CEO, Panasonic India and South Asia anticipates a change in buying behaviour, as extra-cautious consumers will either shift to online purchase from e-commerce platforms or make short visits to offline retailers after online research to pick up the product of choice.



Manish Sharma

Sharma says the safety of employees, consumers and all related stakeholders is the topmost priority. Even when the lockdown lifts, organisations will be wary about bringing in the full workforce immediately. The company is working on a staggered approach for its manufacturing plant, corporate office and branches.

On the manufacturing front, he emphasises, automation and digitisation will be key to driving production efficiencies. Even raw material and finished goods will need to go through a full sanitisation process to maintain safety standards. He rates after-sales service and installation as critical, since customers will be cautious and technicians too will need to follow the highest standard of hygiene for their own safety.

Sharma is optimistic about the revival of the overall economy and consumption. "In India too, very early signs are encouraging and wherever shops are opening, we are seeing consumers walk-in to buy products such as refrigerators and ACs," he adds.

He believes that in the worse-case scenario, the industry will see a 20-25% impact on annual demand, but is hopeful that recovery in demand will take place in some time.

Johnson Controls-Hitachi Launches Mobile Primary Health Centres

Johnson Controls-Hitachi Air Conditioning India Limited (JCH-IN) has introduced mobile primary health centres (PHCs) in rural areas of Gujarat to encourage the villagers to stay at home. This initiative will support the Gujarat Government in ensuring a successful lockdown.

As part of its CSR initiative, JCH-IN has equipped its PHCs with medical specialists, paramedics and 24x7 kitted ambulances to address the medical needs of villagers at their doorsteps. In addition, specially trained staff of the PHCs are educating villagers on the significance of sanitisation, social distancing, immunity boosting and other preventive measures to combat COVID-19.

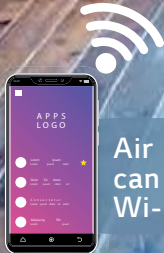


A JCH-IN mobile PHC

Gurmeet Singh, Chairman and Managing Director, JCH-IN said, "JCH-IN is committed to support India in fighting the COVID-19 disaster. The medical specialists provided by JCH-IN have been advising, guiding and encouraging the rural populace in Gujarat to stringently follow the various Central and State government guidelines issued on combating COVID-19. Also, timely and accurate diagnosis provided by the medical specialists for ailments is helping the State government medical authorities to mitigate the huge overload on the medical system caused by the pandemic."

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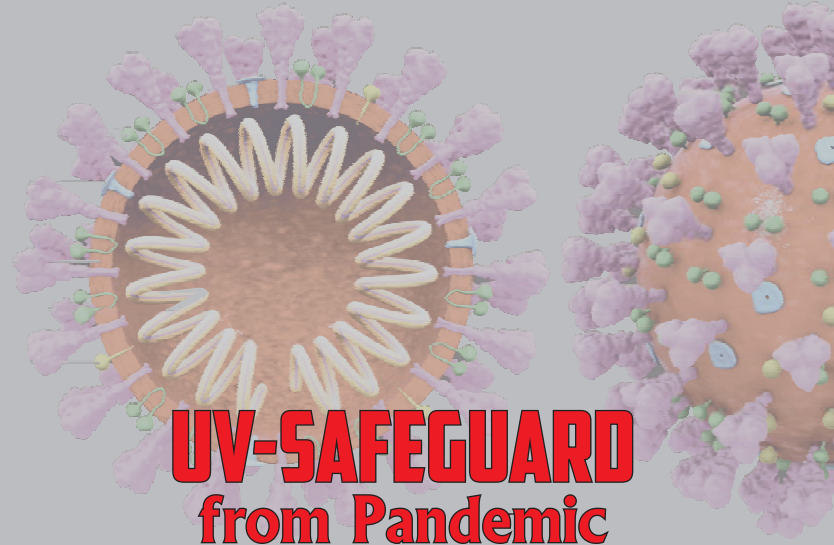
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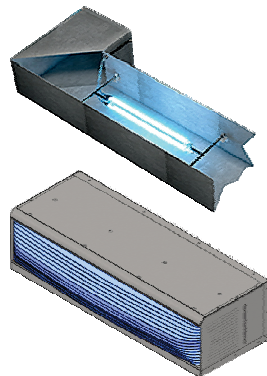
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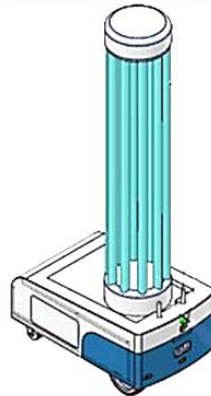
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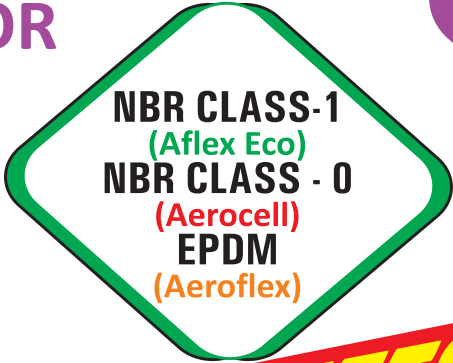
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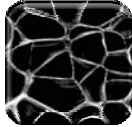
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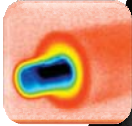
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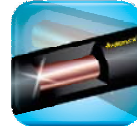


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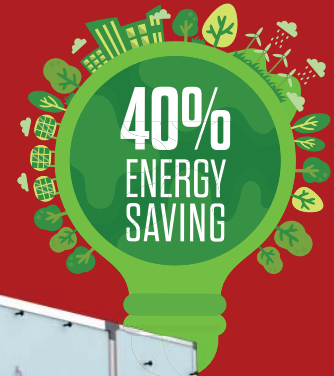
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Kasturba Hospital in Mumbai has an isolation facility for COVID-19 patients

A Primer on HVAC Parameters, Filtration and UVGI in Healthcare Facilities

B. Gautham Baliga Opal HVAC Engineers Pvt. Ltd., Design & Build Contractors, Mumbai

Introduction

As the realities of COVID-19 slowly dawn on us, it is becoming clear that its effects on the healthcare systems will go far beyond the disease that it produces. We would be naïve to believe that once the COVID-19 spectre recedes, 'the genie has gone back in the bottle'.

Many healthcare facilities have discovered to their dismay that their existing HVAC facilities, which were ignored all along, are not only deficient for the pandemic, but are faulty or in poor condition for use even in normal circumstances.

About the Author

Gautham Baliga is a graduate mechanical engineer from IIT Kharagpur and has been in the HVAC profession for the last 40 years. After his initial 8 years with Voltas Ltd., he has been director with Opal HVAC Engineers Pvt. Ltd. – a company engaged in specialised HVAC projects related to healthcare, pharmaceutical, industrial and comfort sectors. He is a Past President of ISHRAE Mumbai Chapter and an ISHRAE Distinguished Lecturer.

This article is not really about systems or how to design them. It is for getting to know the important considerations to be taken into account for proper design. Each one of these factors will need to be addressed to achieve a design for good patient outcomes and for the safety of the healthcare workers.

We will cover the following aspects:

- Indoor Air Quality [IAQ]
- Relative humidity
- Temperature
- Pressure gradient
- Air distribution
- Air changes
- Filtration
- Ultraviolet Germicidal Irradiation [UVGI]

Indoor Air Quality in Hospitals

The control of IAQ plays an important part in the prevention of infection in a hospital to protect the hospital staff and the patients, especially the immuno-suppressed and immuno-compromised patients who are highly susceptible to the adverse effects of various airborne chemicals and microbes. Poor IAQ in a hospital may result in outbreaks of sick hospital syndrome (SHS). They can cause headaches, fatigue, eye, skin irritations and other symptoms.

In commercial buildings and public places, the important IAQ parameters have been well identified. They include carbon dioxide (CO₂), carbon monoxide (CO), nitrogen dioxide (NO₂), ozone (O₃), formaldehyde (CH₂O), total volatile organic compounds (TVOC), respirable suspended particulates (RSP) and total bacterial count. They can adversely affect our health with various degrees of severity. They can result in sick building syndrome (SBS) or building-related illnesses (BRI), such as pneumonitis and cancers.

In addition to the above-mentioned airborne pollutants, there are some toxic chemicals that are used in hospitals and they can be found in the indoor space. Chemical contaminants that are of great concern for hospitals include glutaraldehyde (C₅H₈O₂), nitrous oxide (N₂O), and latex allergens.

- Glutaraldehyde is a toxic chemical. It is used as a cold sterilant to disinfect and clean heat-sensitive medical, surgical and dental equipment and equipment used in endoscopy. This chemical can cause skin irritation and large exposure can result in nausea, headache, and shortness of breath.
- Nitrous oxide is used widely in anesthesia. Exposure to this chemical can cause dizziness, fatigue, headache, excessive sweating or shivering, nausea, or vomiting.
- Latex allergens are released while wearing surgical and examination gloves or installing catheters and other tubing. Latex allergy can result in skin or mucous membranes (eyes, mouth, nose, or other moist areas) reacting when in contact with latex. A severe latex allergy can affect breathing and other serious problems.

Many of the pathogenic bacteria in hospitals are very small and range in size from less than 1 micron to 5 microns and are respirable. They can remain suspended in the air for a long time and this enables the disease to be transmitted easily. Some of these are mycobacterium tuberculosis (TB) bacteria, legionella bacteria, methicillin-resistant staphylococcus aureus, and aspergillus spores.

- TB bacteria: When an active TB patient coughs, sneezes or speaks, airborne TB droplets will be generated. These droplets, if respired by others, can lead to their being infected.
- Legionella bacteria: A common source of this bacterium in hospitals is the water mist plume discharged from cooling towers and then drawn into the indoor environment through the outdoor air intake. Other sources could be evaporative condensers, potable water systems, and hot water systems.

- Staphylococcus aureus: These bacteria are present on the skin and in the nose, blood, and urine of an infected patient. During some surgical procedures that require the use of power tools, such as oscillating bone saws and bone drills, microbial aerosols will be generated.
- Aspergillus spores: Hospital renovation or nearby construction work are major sources of aerosolized Aspergillus spores. The fungal spores from soil, plants, animals, and dust particles can attach themselves to the clothing of healthcare workers or visitors (Michael Leung & Alan H.S. Chan, Control and management of hospital indoor air quality).

Relative Humidity

Relative humidity affects human comfort, respiratory system and healthcare spaces in a variety of ways.

How Humidity Affects Comfort

The temperature boundaries of the comfort zone are well defined in terms of laboratory and field observations. However, how humidity affects comfort is less certain, particularly the upper humidity levels.

Low humidity leads to complaints about dry nose, throat, eyes and skin. Low humidity can lead to drying of the skin and mucous membrane surfaces leading to increasing susceptibility to respiratory disease as well as discomfort.

High humidity levels reduce comfort. It leads to sweating. Prolonged sweating leads to accumulation of salts on the skin, which in turn leads to discomfort. With high humidity, clothes pick up moisture. This causes increased friction between skin and fibres and creates uncomfortable sensation.

How Humidity Affects the Respiratory System

The normal human body has excellent protection systems to prevent respiratory infections. There are several layers of filters starting with the mouth and the wind pipe. The moist surfaces having mucous layer collect the larger particles before they enter the trachea and pharynx in the upper respiratory tract. In the lower respiratory tract, the bronchi and alveoli can trap smaller particles to various degrees of efficiency.

Moisture in the air is the first arm of our immune system and we now know that our body cannot fight off foreign particles or invaders as adequately when we are in a dry environment. Further, the infectivity of the bacteria too increases with low humidity. Relative humidity of at least 40% is considered the threshold. (Dr. Stephanie Taylor, Presenter, "Optimize Occupant Health, Building Energy Performance and Revenue through Indoor-Air Hydration", ASHRAE).

All microorganisms need water to grow initially. Too much humidity leads to higher levels of dust mites and fungi, two of the worst culprits for indoor allergy sufferers. Mold and fungi are known to exacerbate respiratory conditions such as upper respiratory (nasal and throat) symptoms, cough, wheeze and asthma. Immuno-suppressed or Immuno-compromised patients are at increased risk.

Effect of Humidity on Airborne Transmission of Cough Aerosol

Small particles get generated during the course of coughing and sneezing and to a lesser extent by even talking and breathing. Particle size distributions of coughed materials encompass a broad spectrum of diameters, from very small to large droplets. It is known that most of the viable particles ranging from 0.65 to 3.3µm in the cough-generated aerosols are immediately respirable (K. P. Fennelly *et al.*, "Cough-generated Aerosols of Mycobacterium tuberculosis: A New Method to Study Infectiousness," American Journal of Respiratory and Critical Care Medicine).

While big particles and droplets from cough promptly fall to the ground and surfaces, the smaller ones float in the air for a long time. Small particles <5 micron (droplet nuclei or residue) are formed from droplets (usually within milliseconds) in the air, and shrink in size due to the process of evaporation and desiccation in low humidity and remain suspended in air for several hours.

How Humidity Affects the Virulence of Bacteria

Organisms that have been exposed to dry environment have increased virulence and increased rates of antibiotic resistance even in the absence of antibiotics. It has been observed that bacteria that have become resistant to medication can pass that genetic material back and forth when they are in the airborne state. In a low humidity environment in a hospital, when cough droplets containing bacteria become airborne, those bacteria can share their antibiotic resistant genes while in the airborne state. This is known as horizontal gene transfer and it is very rapid.

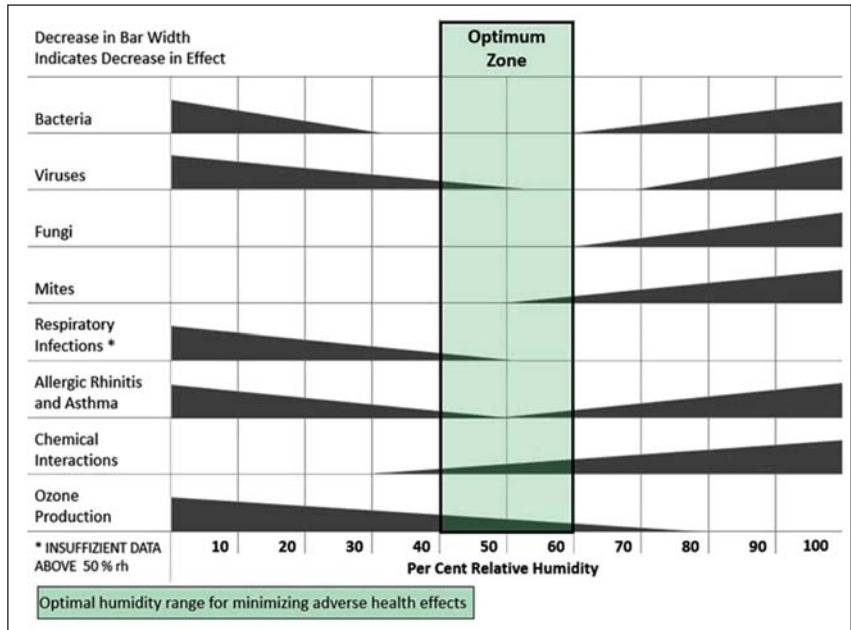


Figure 2: 'Criteria for Human Exposure to Humidity in Occupied Buildings', E.M. Sterling, 1985 ASHRAE Transactions CH85-13-1

Apart from virus, there is a correlation of humidity with the growth of various pathogens as given in the Sterling Chart (Figure 2).

All things considered, the humidity level of 40% ~ 60% is considered to be the most suitable environment for humans and decreases problems from pathogens.

How Humidity Affects the Hospital Building

Apart from human beings, the building habitat too is not wholesome when there is high humidity. Of all the conditions needed for the growth of mold, moisture is the simplest and most universal requirement for fungal growth. Preventing moisture from getting into the food sources is a good way to prevent fungal growth from becoming established. Actual condensation of moisture leads to the growth of some of the most hazardous species of mold. However, there are thousands of varieties of fungi that do not require liquid water to germinate. When humidity rises every day, the air slowly permeates moisture into the food sources. When moisture content and temperature remain high for long periods of time periods when the air conditioning is turned off, the extra moisture needed to support fungus gets added to paper, organic materials and other food sources in the rooms.

In addition to creating health problems, moisture can damage the

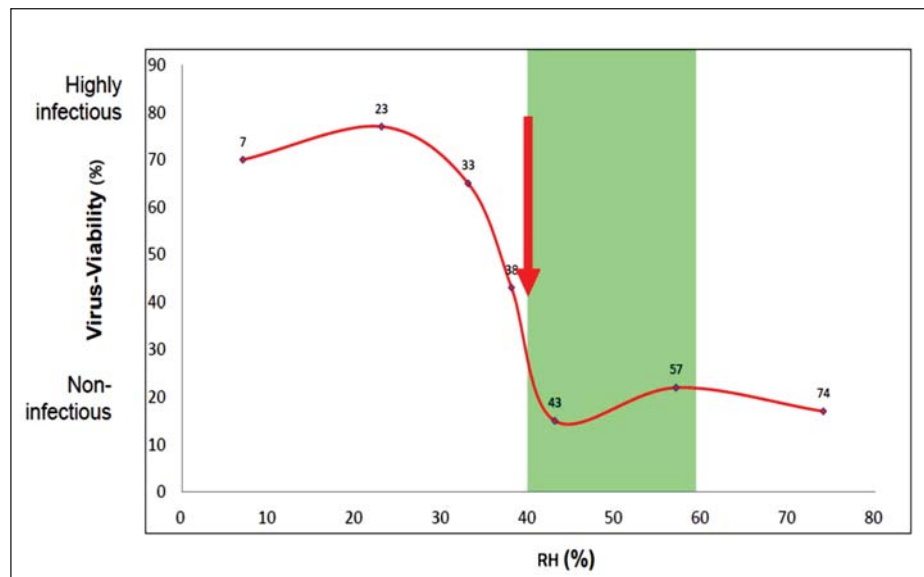


Figure 1: Stephanie Taylor, presenter, 'Optimize Occupant Health, Building Energy Performance and Revenue through Indoor-Air Hydration', ASHRAE

hospital building materials and components. Some examples are given below:

- Wooden materials, varnishes and paints get damaged and adhesives fail.
- Insulations deteriorate and the thermal coefficient of resistance reduces as moisture pervades the insulation material cells of the space between materials.
- Anchor fasteners, structural members and air conditioning ducts corrode.
- Prolonged damp conditions can lead to mold, bacteria and insect pests colonizing the building material.

It is thus important that there is humidity control in hospitals to protect the patients and other inhabitants as well as to protect the hospital building itself.

Temperature

The patient’s thermal wellbeing is largely a function of temperature, not humidity. This fact alone makes temperature a very important parameter. The normal comfort temperature range for patient rooms is considered 21~24°C. Depending on the clothes worn and the air velocity, ISHRAE IEQ standards indicate that people can be comfortable between 24°C and 30°C.

Patients in both clinical and inpatient facilities may be very scantily dressed or without clothes and sometimes for long periods of time. The temperatures should be controllable so that the patient can have higher temperature for comfort.

In a variety of disease or injury, patient metabolism or fever can interfere with body’s ability to regulate heat. Burn units in general will be required to have capability of heating the space to 32.2°C.

Operation theatre and emergency department healthcare workers often wear layers of clothing, mostly un-permeable, and will feel very hot inside. They may require temperatures as low as 18°C.

The HVAC Design Manual for Hospitals and Clinics [ASHRAE] gives the following chart, which includes special temperature requirements for Operation Theatres:

| Operation Room Type | Requirements |
|---------------------|--|
| Heart | Low temperature, fist reheat, large room |
| Orthopedic | Low temperature, larger room, extra filtration |
| Cystoscopic | Medium temperature |
| General | Medium temperature |
| Pediatric | High temperature |
| Neurological | Low temperature, large room |
| Trauma | High temperature |
| Burn | High temperature |

Figure 3: Special temperature requirements for operation theatres (The HVAC Design Manual for Hospitals and Clinics [ASHRAE])

Pressurization

While the quantity of air distributed to the space is important, from an air-quality standpoint, space pressurization is perhaps even more important. The air quantities of supply, return, fresh air and exhaust should be balanced so that air travels from the cleanest spaces (such as operating rooms) to the dirtiest spaces (such as soiled utility or decontamination rooms).

In healthcare facilities, the convention is to have the differential pressure at least 2.5 Pa so that any interference due to door opening, elevator movement and other normal activities will not change the positive or negative nature of the pressure or the airflow direction.

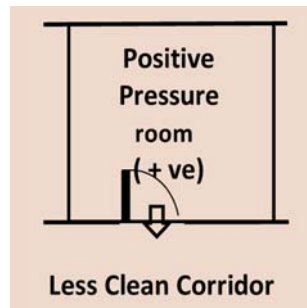


Figure 4: Positive Pressurization; when a product/person has to be protected from airborne contamination coming in from adjoining spaces, the room is kept at a higher pressure (positive) with respect to the surroundings – in this situation, air ex-filtrates from the room

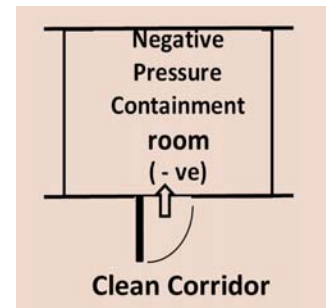


Figure 5: Negative pressurization; when adjoining spaces need to be protected from product or person in the room, the room has to be contained – the room is kept at a lower pressure (negative) with respect to the surroundings; air infiltrates into room, and not vice versa

The pressure differentials recommended for the isolation rooms, as per the CDC, are as follows:

Protective Environment Isolation Rooms [P.E] (Positive Pressure Rooms): Minimum 2.5Pa and ideally >8Pa.

Airborne Infectious Isolation Rooms (A.I.I.): Minimum > -2.5Pa.

A pressure differential of 2.5 Pa is recommended by NABH for Operation Theatres. Such a low pressure is difficult to monitor and it would be prudent to design and maintain the differential pressure at >8Pa.

The ASHRAE Standard 170-2017 has a recommendation for the pressure gradient for the various rooms in a hospital, which indicates whether they should be positive, negative or neutral with respect to the surroundings.

It is very important to understand that in addition to the pressure differential, which can force a desired airflow path carrying particles, the particle concentration differential can also create an air exchange due to mass diffusion between two areas with a significant particle concentration difference to allow the concentrations in both rooms to reach equilibrium.

This means that, even if there is a pressure differential between adjoining areas separated by a door, if the less clean area is significantly dirty, there will be a mass diffusion of particles from

continued on page 30



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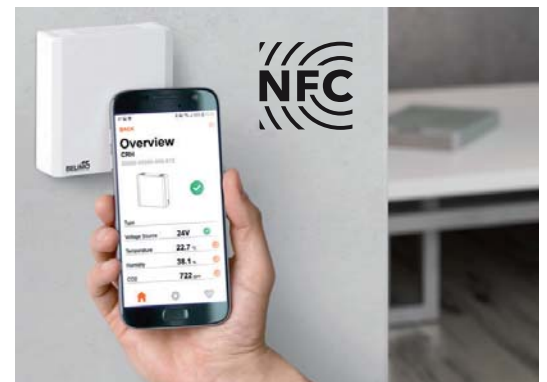
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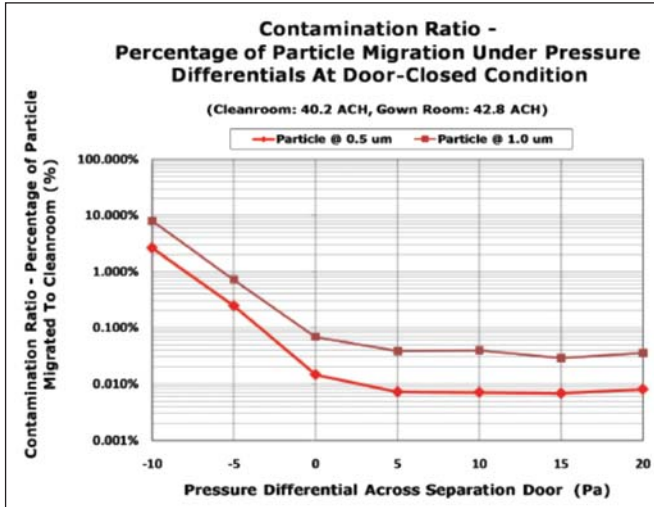


Figure 6: CR values across a closed door under pressure differential (ASHRAE Design Guide for Cleanrooms)

the dirty area into the clean area in spite of the latter area being at a higher pressure.

The risk level of particle contamination can be expressed as *contamination rate* (CR) (Sun *et al.*, 2011). CR is defined as the airborne particle concentration gain above the initial concentration in a clean space over the particle concentration in the adjoining less clean space that is the source of the contamination. CR is a criterion to quantify the effectiveness of a cleanroom barrier in preventing particle migration into the clean space. The lower the CR level, the better the performance of the barrier's effectiveness. A typical contamination ratio study is given in Figure 6.

It is thus important that clean spaces open into adjacent areas that are not significantly less clean.

Introduction of an airlock (also called ante-room) outside a clean space to be protected can significantly improve the barrier effectiveness. This illustration from ASHRAE Design Guide for Cleanrooms (Figure 7) makes the concept clear.

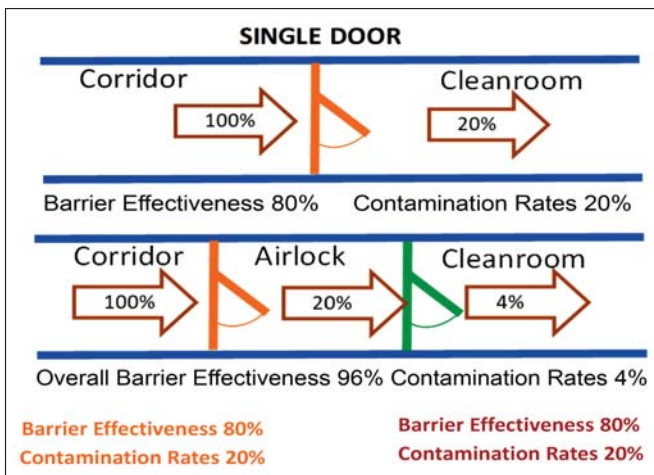


Figure 7: Barrier effectiveness of airlocks (ASHRAE Design Guide for Cleanrooms)

It is common to have a clean corridor acting as an airlock for a number of operation theatres. Especially for negative isolation rooms, airlock is recommended. The use of airlock enhances the contamination barrier protection offered by pressure differentials.

When there is an airlock, the two doors are interlocked so that both the doors do not open simultaneously.

For pressurization it is important that the rooms should be of tight construction and the doors should be of good quality with minimum possible gap between the door frame and the door gasket.

It should be noted that when a door is of the swing type, there is a piston effect on the air when it is opened. This effect brings in its wake a surge of outside contaminated air into the clean space. Especially for operation theatres it is a good idea to have sliding doors as opening and closing these doors does not create the piston effect.

Air Distribution

For infection control, it is not only about air filtration and differential pressure. How the air is introduced into the room and then how it sweeps away the contaminants is important. A few examples will make the concept clear.

- In an Airborne Infectious Isolation (A.I.I.) room, the people in the outside corridor and the healthcare workers will need to be protected from the patient. The room is thus kept under negative pressure. The healthcare worker should be safe when attending to the patient and the latter's respiration should be directly exhausted. The air pattern shown in Figure 8 does just that. The clean air from the supply air duct comes first on the healthcare worker and thence to the patient and then exhausted from the nearby exhaust grille.

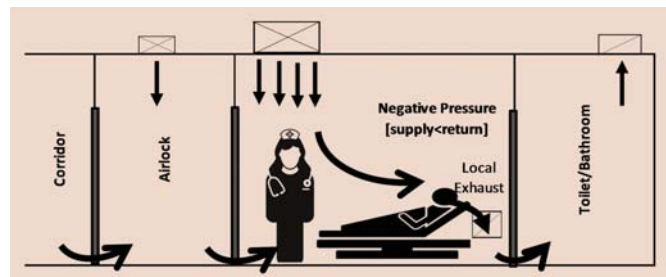


Figure 8: Air Pattern for a negative pressure A.I.I. Room

- In a Protective Environment Isolation (P.E.) room, the people in the outside corridor and the healthcare workers should not infect the patient, who is immuno-compromised or immuno-suppressed. The room is thus kept under positive pressure. The healthcare worker's respiration when attending to the patient should be directly exhausted. The air pattern shown in Figure 9 tries to achieve this. The clean air from the supply air duct comes first on the patient and thence to healthcare worker and then exhausted from the nearby exhaust grille.

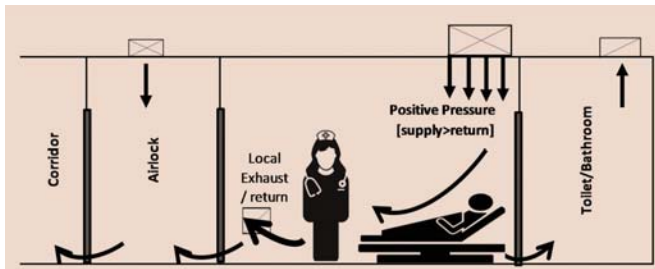


Figure 9: Air pattern for a positive pressure PE. Room

- In an operation theatre (OT), the room is kept under positive pressure to protect the space from the less clean outside corridor or airlock. Inside the OT, there are a lot of contaminants that get released from the surgical procedures. The unidirectional airflow from the HEPA filters covering the patient and the surgical staff provides clean air in operating table zone, which includes the patient as well as the surgical staff. The key to prevent surgical site infection is to sweep the contaminants released away from the wound and into the return air risers.

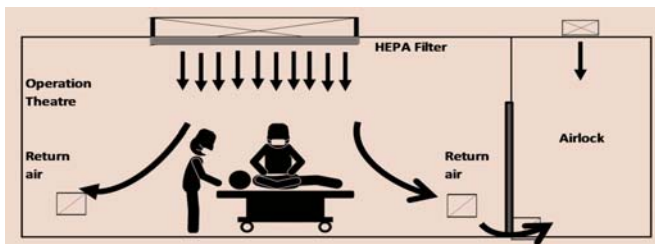


Figure 10: Air pattern for an operation theatre

Air Flow Patterns in Other Areas

The air patterns in rooms dealing with emergency waiting rooms, nuclear medicine, chemical decontamination rooms and TB patient waiting rooms are important and need to be a part of design deliberations as this will impact transmission of disease.

Air Change Rates

Air change rate represents the number of times the entire volume of air in the room is replaced each hour.

One of the methods to reduce the exposure of the person to the concentration of toxic chemicals and the number of microbes is by providing ventilation, i.e. introducing clean fresh air into the area. Higher number of air changes of ventilation per hour reduces the exposure of the patients and the healthcare workers to toxic chemicals and microbes.

Similarly, certain quantity of air is recirculated in the space through the air filtration system of the air handling unit. The number of times the air gets churned through the filtration system results in more of the particulate matter and the microbes getting filtered out of the air. This recirculation of air is also expressed in air changes per hour.

The chart given in Figure 11 is from the CDC and it shows the time required for airborne-contaminant removal efficiencies of 99% and 99.9% through air change rates. The chart assumes perfect mixing of the air within the space (i.e., mixing factor = 1). However, perfect mixing usually does not occur. Removal times will be longer in rooms or areas with imperfect mixing or air stagnation.

| ACH+ §¶ | Time (mins.) required for removal | |
|---------|-----------------------------------|------------------|
| | 99% efficiency | 99.9% efficiency |
| 2 | 138 | 207 |
| 4 | 69 | 104 |
| 6 | 46 | 69 |
| 8 | 35 | 52 |
| 10 | 28 | 41 |
| 12 | 23 | 35 |
| 15 | 18 | 28 |
| 20 | 14 | 21 |
| 50 | 6 | 8 |

Figure 11: Air change efficiency chart (CDC) – air changes/hour (ACH) and time required for airborne-contaminant removal efficiencies of 99% and 99.9%*

§ Values were derived from the formula:

$$t_2 - t_1 = - [\ln(C_2 / C_1) / (Q / V)] \times 60, \text{ with } t_1 = 0 \text{ and where}$$

t₁ = initial timepoint in minutes

t₂ = final timepoint in minutes

C₁ = initial concentration of contaminant

C₂ = final concentration of contaminant

C₂ / C₁ = 1 - (removal efficiency / 100)

Q = air flow in cubic feet/hour

V = room volume in cubic feet

Q / V = ACH

A typical air change rate of 12 ACH would indicate that the microbes generated in the room will be resident in the room for 23 minutes before being removed.

For the OTs, NABH requires a minimum of 20 ACH of air recirculation and 4 ACH of outside air make up.

Filtration

Air filtration has a huge role to play to protect humans in healthcare facilities whether it is hospitals, out-patient facilities, doctor’s office or clinics. In many of these places the occupants are

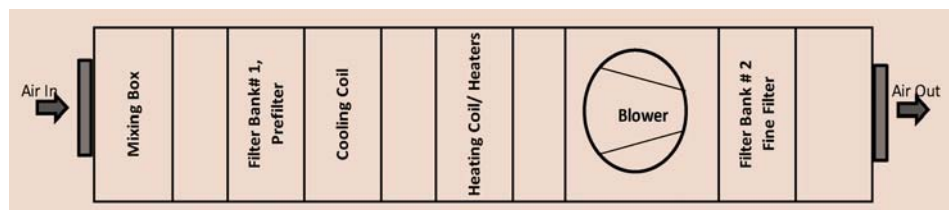


Figure 12: Two stage filtration in an air handling unit

| Standard 52.2 Minimum Efficiency Reporting Value (MERV) | Composite Average Particle Size Efficiency, % In Size Range, μm | | | Average Arrestance, % |
|---|---|----------------------|-----------------------|-------------------------------|
| | Range 1 (0.3-1.0) | Range 2 (1.0-3.0) | Range 3 (3.0-10.0) | |
| 1 | n/a | n/a | E3 < 20 | $A_{\text{avg}} < 65$ |
| 2 | n/a | n/a | E3 < 20 | $65 \leq A_{\text{avg}} < 70$ |
| 3 | n/a | n/a | E3 < 20 | $70 \leq A_{\text{avg}} < 75$ |
| 4 | n/a | n/a | E3 < 20 | $75 \leq A_{\text{avg}}$ |
| 5 | n/a | n/a | $20 \leq E3$ | n/a |
| 6 | n/a | n/a | $35 \leq E3$ | n/a |
| 7 | n/a | n/a | $50 \leq E3$ | n/a |
| 8 | n/a | $20 \leq E_2$ | $70 \leq E3$ | n/a |
| 9 | n/a | $35 \leq E_2$ | $75 \leq E3$ | n/a |
| 10 | n/a | $50 \leq E_2$ | $80 \leq E3$ | n/a |
| 11 | $20 \leq E_1$ | $65 \leq E_2$ | $85 \leq E3$ | n/a |
| 12 | $35 \leq E_1$ | $80 \leq E_2$ | $90 \leq E3$ | n/a |
| 13 | $50 \leq E_1$ | $85 \leq E_2$ | $90 \leq E3$ | n/a |
| 14 | $75 \leq E_1$ | $90 \leq E_2$ | $95 \leq E3$ | n/a |
| 15 | $85 \leq E_1$ | $90 \leq E_2$ | $95 \leq E3$ | n/a |
| 16 | $95 \leq E_1$ | $95 \leq E_2$ | $95 \leq E3$ | n/a |

Figure 13: Minimum Efficiency Reporting Values (MERVs) and filter efficiencies by particle size

already immuno-compromised or immuno-suppressed and are thus more susceptible to airborne contaminants than normal healthy people.

Filters can effectively trap particulate contaminants, including microbiological pathogens, and remove them from the circulating air. Various grades of filters can be used to achieve different degrees of cleanliness. For a healthcare facility, a proper filtration system generally consists of a pre-filter and a final filter in the air handling unit (AHU). The pre-filter should be placed upstream, ahead of the cooling/ heating coil, to remove large particles for a clean heat transfer medium. More importantly, the pre-filter can prolong the life of the final filter placed downstream of the AHU, resulting in a cost-effective operation.

Filter Classifications

The ASHRAE Standard 52.2 classifies filters used in HVAC application by their Minimum Efficiency Reporting Values (MERV). The standard takes into consideration the fractional efficiencies of filters for particles in the size range of 0.3 to 10 microns. The

test not only provides the initial efficiencies, but also the minimum efficiencies for different particle sizes in a loading test. Filters are given their MERV numbers based on their 'average minimum particle size efficiencies' for the three size range groups, namely E1 for 0.3 to 1 micron, E2 for 1 to 3 microns and E3 for 3 to 10 microns. For coarse filters, the standard also provides a methodology for measuring the Gravimetric Arrestance.

Air filters of MERV 13 and above have the potential to remove microbes and other particles ranging from 0.3 to 10.0 microns.

HEPA Filters

High Efficiency Particulate Air (HEPA) filters trap a vast majority of very small particulate contaminants from an air stream.

The three main mechanisms by which HEPA filters achieve filtration are: interception, inertial impaction and diffusion.

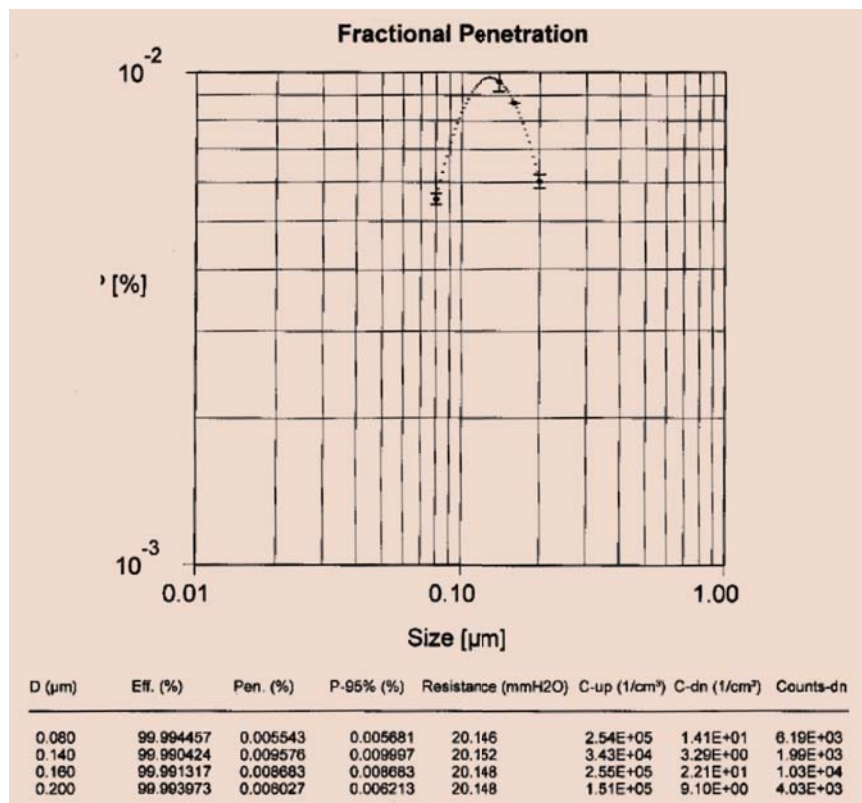


Figure 14: Typical HEPA fractional efficiency test report showing MPPS at 0.11m

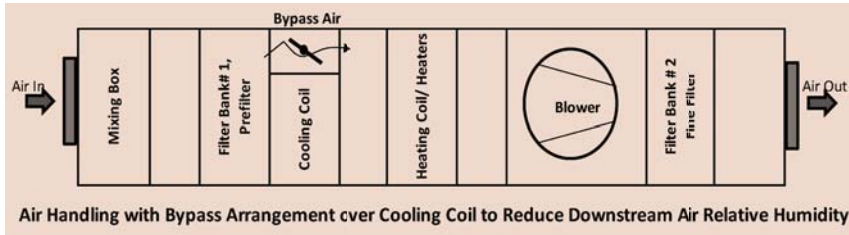


Figure 17: Cooling coil bypass arrangement

How Humidity Affects Filters

An important aspect with the above methods of filtration is that the dust, bacteria and other pathogens get collected in the filter. Some of these could act as nutrient substrate for growth of micro-organisms. High humidity can create a suitable environment for the growth of micro-organisms. Humidity levels above 85% escalate the problem. Especially when we locate Filter Bank#2 after the cooling coil, the filters will be subjected to high humidity, typically as high as 90% to 95%. With the use of higher air quantity through the air handling unit and bypassing the extra return air, which could be typically at 60% relative humidity, around the cooling coil and not passing through it, it is possible to reduce the humidity to below 85%.

Outdoor Air Intake and Filtration Requirement

The outside air quality varies greatly with the location of the healthcare facility. PM_{2.5} levels can be inordinately high in certain places or localities. It is recommended to use MERV13 or better grade of filters for outdoor air intake.

We have to be concerned where the outdoor air comes from as it can be a source of disease. These intakes have to be far away from cooling tower mist plumes that may carry Legionella bacteria, which can cause Legionnaire's Disease. Similarly care has to be taken that the outdoor air does not breathe in chimney exhausts from diesel generator sets, kitchen exhaust and other exhausts from the vicinity.

Air intakes are accumulation sites for dirt and debris, including rotting botanical materials like leaves, which are growth sites for fungi such as Aspergillus fumigatus. All intakes shall be designed to prevent entrainment of wind driven rain, shall have features to drain away rain water and have bird screens (HVAC Design Manual for Hospitals and Clinics).

Room Exhausts and Filtration Requirements

Hospital exhausts can have inordinate load of pathogens and we have to be careful where we exhaust the air. The exhaust air must be protected for containment by at least MERV10 grade filters [HVAC Design Manual for Hospitals and Clinics]. Certain exhausts such as those for A.I.I. Rooms will need HEPA filters. Another way to exhaust is to take a chimney and disperse high up into the air for dispersion. This may need studies to determine that the exhausts do not harm the neighborhood.

Ultraviolet Germicidal Irradiation (UVGI)

In HVAC systems, UVGI is being increasingly used for surface sterilization of cooling coils and condensate drain

pans and as a supplement to filters for air purification.

UVC Germicidal Ultraviolet wavelength (254nm) is effective in penetrating the cell membrane breaking the DNA structure of a micro-organism. DNA sterilization inhibits reproduction. Micro-organisms such as mold, bacteria and viruses will be destroyed with the required concentrations of germicidal irradiation.

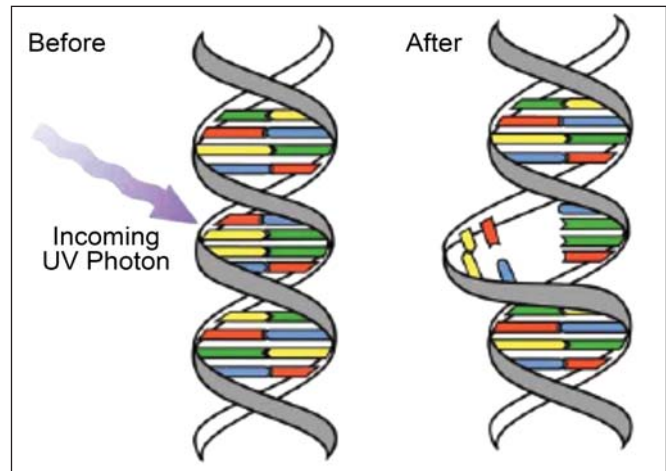


Figure 18: Ultraviolet radiation can damage DNA by distorting its structure (Credit: NASA's Earth Observatory/David Herring)

All viruses and almost all bacteria (excluding spores) are vulnerable to moderate levels of UVGI exposure, but the magnitude of the effect is species-dependent.

Out of the ultraviolet spectrum, it is the UV-C that has the maximum capability to destroy the microorganisms.

| Ultraviolet | Wavelength |
|-------------|---------------|
| UV-A | 315 to 400 nm |
| UV-B | 280 to 315 nm |
| UV-C | 200 to 280 nm |
| UV-V | 100 to 200 nm |

There are a number of factors to be considered that affect the deployment of UVC.

Residence Time

Greater the exposure time (contact time between the contaminant and the UV source), more the UV energy being delivered to the contaminant, resulting in a greater Kill Rate.

Intensity

Greater intensity results in more UV energy being delivered to the contaminant, resulting in a greater Kill Rate.

Reflection

Reflection of the UV rays using reflectors and the inside surfaces of the AHU or duct can be a helpful tool to considerably increase the effectiveness of the UV rays produced.

Relative Humidity

RH affects the susceptibility of microorganisms in the AHU as well as the duct where it is used. The susceptibility factor for the viruses was higher at 55% RH than that at 85% RH, possibly because

under high RH (Tseng *et al.*, Inactivation of virus-containing aerosols by ultraviolet germicidal irradiation, *Aerosol Sci Technol* 2005), microbial susceptibility to UVGI may increase or decrease, depending on the organism.

Temperature

Temperature affects the UV output of the lamp. Temperatures inside the AHU and duct can be below 13.3°C [56°F] and the output would be lower than 50% of the full output.

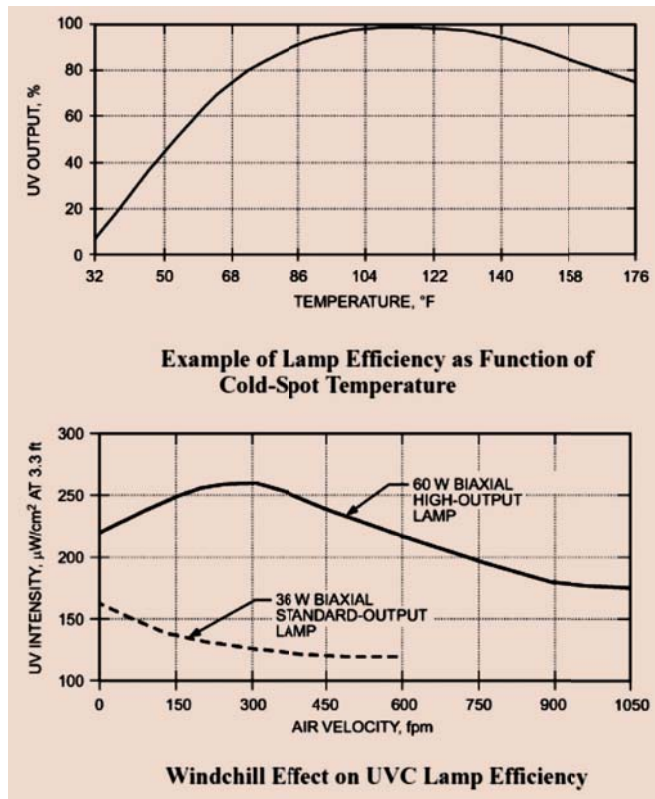


Figure 19: Output of UVGI lamps at various temperatures as a percentage of the peak output, and wind-chill effect on UVC lamp efficiency (ASHRAE 2012 *Systems and Equipment Handbook*, Chapter 17)

This brings us to the question about the right location of the UVGI lamp in the AHU. UV systems may be installed either upstream (return side) or downstream (supply side) of the evaporator coil. Either installation will keep the evaporator coil clean (2008 ASHRAE Handbook HVAC Systems and Equipment, Chapter 16). The selection of the lamp wattage has to be appropriately considered.

Another consideration for lamp selection is the lamp fouling factor. There is an advantage of locating the lamps downstream of high efficiency filters to protect them from dust accumulation. Otherwise, the lamps will need to be cleaned from time to time.

A point to note is that UVC can disinfect a pathogen only if it can reach it either directly or through reflection. In general, reducing the total number of pathogens reduces the risk of transmission.

UVGI is increasingly used as the concerns about indoor air quality are growing. UVGI is being used as an engineering control to interrupt the transmission of pathogenic organisms, such as

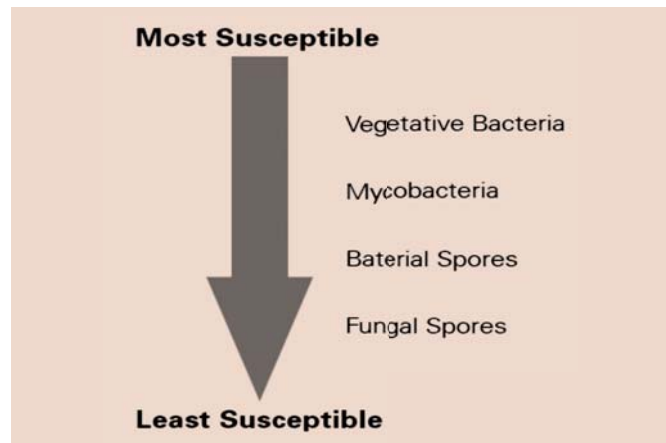


Figure 20: Susceptibility of microorganisms to UVGI (Reference: ASHRAE (2008c))

Mycobacterium tuberculosis (TB), influenza viruses, mold, and possible bioterrorism agents (Brickner 2003; CDC 2002, 2005; General Services Administration 2003).

Fungal spores are larger than most bacteria and are more resistant to UVGI than most bacteria. For spores, UVC exposure is postulated to result in the formation of lethal photoactive products (Memarzadeh *et al.*, *American Journal of Infection Control*, June 2010). For removal of spores, high efficiency air filtration, viz. MERV14 or superior would be a better choice. Using a combination of UVGI and high efficiency filters can be an effective solution in certain situations.

UVGI is used in two formats in the air conditioning systems:

In AHUs

UVGI directed at environmental surfaces can damage microorganisms present or growing on the surface. Lower-intensity UVGI is effective for surface inactivation because irradiation is applied continuously. UVGI from lamps in AHU plenums has been used successfully to inactivate microorganisms present on airstream surfaces such as on cooling coils and drain pans (Menzies *et al.*, 1999, 2003). This helps in keeping the cooling coils and drain pans clean. Since the bio films that normally develop on the heat exchanger surface get eliminated, studies have indicated better heat transfer because of the UVGI radiation.

Menzies *et al.*, found a significant decline in building-related symptoms associated with use of UVGI in AHUs though significant declines in airborne levels of fungi and bacteria as well as endotoxins were not detected in the workplace.

In Ducts

UV lamps placed in ductwork have been used to inactivate *Mycobacterium* species and other microorganisms. The residence time of the microbe under UVGI illumination is an important factor while considering the UVGI lamp design inside the duct. This is achieved by installing the UV lamps parallel to the airflow inside the ducts.

Safety Requirements

Inadvertent exposure to UVC can be dangerous for humans. Doors, covers and lamp mounting brackets that give direct access to Ultraviolet (UV) radiation lamp systems shall be equipped with

an interlocking mechanism that removes power from the ultraviolet (UV) radiation lamp system when the door is open or cover removed.

Further, polymeric cabinet, structural, and current carrying parts and wiring, which are subjected to irradiance from a UV lamp system, will need to be shielded from the UVC light or be constructed of a material that is capable of withstanding UVC exposure levels expected in the product without degrading.

In Conclusion

The importance of HVAC parameters that need to be controlled has been elaborated together with the requirements of filtration. UVGI can be used as an augmentation to filtration to provide further air purification. All these have to find their place in the room design for the various areas of the facility. This has to be followed up with efficient system design and its implementation to make the healthcare facility safe for the patients, healthcare workers and the visitors.

The cost of ownership of a facility includes operation and maintenance and revalidation of the installed parameters on a regular basis. Maintaining all the air handling systems together with ducts, filters and all the equipment coming in contact with air is of paramount importance and cannot be over-emphasized.


The ultimate indicator of the success of the HVAC systems will be the patient outcomes and the low cases of Hospital Acquired Infections (HAI) and Surgical Site Infections (SSI) that are ascribed to airborne infections.

This article comes in the milieu of the COVID-19. It has exposed the malaise in the HVAC systems of many of the healthcare facilities. Some of the glaring issues that need to be addressed are:

- Meeting the ventilation requirements.
- Use of unitary re-circulatory air conditioning equipment like cassettes and hi-wall units in critical areas like ICUs and emergency waiting rooms without meeting the required ventilation, filtration and pressure gradient.
- Use of false ceiling return instead of ducted return. False ceiling return will carry with it all the pathogens from the false ceiling plenum which is not accessible for cleaning.
- Inability of the infrastructure to induct extra ventilation required during pandemic.
- Inadequate isolation rooms or for that matter having a provision to convert some of the patient rooms quickly into isolation rooms to address surge in patients during pandemic.
- Engineers and technicians who have gone into a limbo due to inadequate training to handle pandemics.

All the mentioned shortcomings will need to be addressed before it is business as usual. It is sincerely believed that we will put things right in earnest post COVID-19. ❄

The author acknowledges inputs from Shankar Rajasekaran, Director at Impec Filters Ltd. and an expert in the domain of filters and filtration, for the section on Filtration.



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Figure 1: Unprotected surface






Figure 2: Surface protected with Microban





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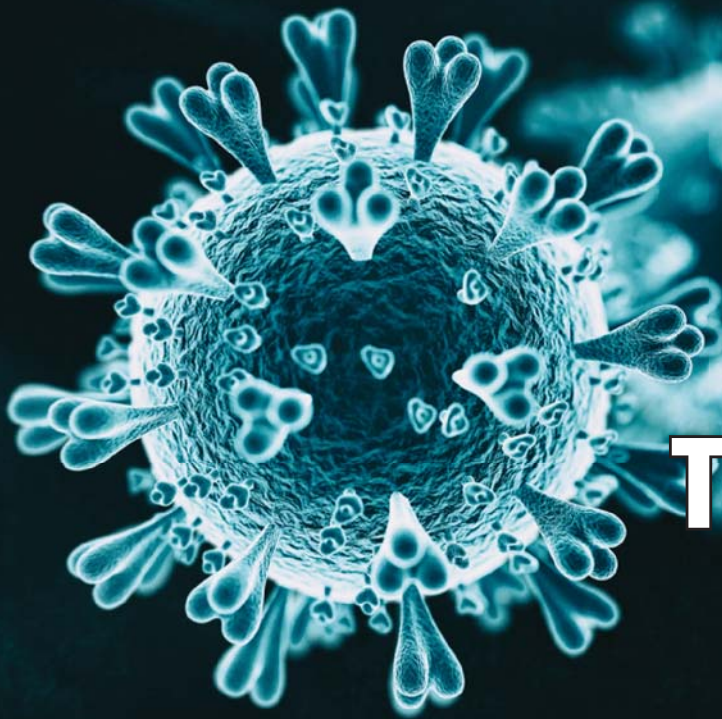
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Operation of Thermal Comfort Systems during COVID-19

By Gian Modgil Fellow ASHRAE, Past National President ISHRAE (2004-2005), New Delhi

Introduction

The outbreak of COVID-19 in India started towards the end of 2019 and it has been almost seven months that we have been struggling with rapid spread of this disease all over the world. Despite various agencies, institutes, virologists and scientists working over it, there is widespread confusion about how the virus is transmitted, as a lot of knowledge gaps persist about the transmission route of this virus within the community. This article is an attempt to present a clear picture about the role of air conditioning, if at all it exists, in the spread of this virus. Moreover, this article intends to explore the source and possible routes of spread in air conditioning.

About the Author

G. C. Modgil founded Sterling India Consulting Engineers in 1990 to provide environment-friendly Green solutions to the fast-developing construction industry. He has designed many institutional buildings, hotels, hospitals, airports, SEZs, IT parks, corporate offices, diplomatic missions and residential complexes. He has worked in association with reputed architects and has exposure to difficult architectural requirements of engineering services. He has a bachelor's in mechanical engineering from Thapar Institute of Engineering and Technology. He is a member of several professional groups such as the Working Group Committee for BEE on Revision of Energy Conservation Building Code (ECBC-2017); Indo-Swiss team for Building Energy Efficiency Project (BEEP); Technical Committee for Chiller Standard and Star Labeling of BEE; and Expert Panel for Space Conditioning under FLCTD by UNIDO and BEE.

Transmission Route of the Virus

Before understanding the role of HVAC in spreading the virus, it is important to review the studies that have been carried out on this topic. According to the US Centre for Disease Control and Prevention (CDC), respiratory droplets causing COVID-19 are too heavy to remain suspended in the air; direct person-to-person transmission normally only happens when people are in close contact – within about six feet of each other. It could also occur in a medical setting if someone has to handle respiratory secretions such as saliva or mucus from an infected person.

Additionally, a WHO publication also states that the spread of this virus is through discharge of droplets while coughing and sneezing. Droplets are estimated to fall to the surface in a distance of about one meter. However, smaller droplets released while talking or brisk breathing may travel a longer distance (say, 1.5 meters). These droplets can directly transmit to people in the vicinity, or people can get infected from contact with these surfaces and then touching their face, i.e. eyes, nose, or mouth. The third possibility could be re-entrainment of these particles when the contaminated surface gets disturbed through some activity.

Also, till date there has not been any well documented outbreak that is traced to aerosol transmission, e.g. planes evacuating citizens from COVID-19 outbreak have not reported either their pilots or staff or co-passengers being infected with the disease, even while ferrying COVID-19 positive patients.

However, there is only a single evidence of a hospital study that reveals that some strains of COVID-19 virus remain suspended and infectious inside the ICU and in-patient toilets with high occupancy¹. This suggests the possibility of aerosol transmission in concentrated patient locations of hospitals.

Therefore, air conditioning systems in residential, work, entertainment and public places play only an exceedingly small role in infectious disease transmission, including COVID-19. Although knowledge is emerging as to how this virus spreads, it may take much longer before a consensus emerges.

In view of the above, until now it can be assumed that other mechanisms (contact-based) listed below are likely to be more prominent in virus transmission:

- Direct personal contact (handshake, hugs etc.).
- Droplet based contact due to proximity.
- Indirect contact like frequently touched surfaces such as railings and door handles.
- Through touching of hands to eyes, nose and mouth.

Reducing the Spread of the Virus

Considering the above, it is evident that good hygiene strategies of habit change, social distancing, frequent surface cleaning and frequent hand-wash are far more important than air conditioning. Also, as we all shall now start routine work within the COVID-19 situation, it is important that in addition to the above precautions we must behave as if we are infected, and take extra precautions. This is important as the symptoms of the disease appear after 7-8 days of getting infected, and proper precautions would reduce further spread of the virus.

Considering the present economic situation of the country, the Government will be forced to ease out the lockdown and lift restrictions to allow businesses to resume. Although the operation of businesses will never be the same as earlier, to keep things going every business will have to devise certain guidelines to resume operations. The weather condition of our country in the coming months will force businesses to resort to the use of air conditioning systems.

Air Conditioning and COVID-19

To address the air conditioning systems of buildings that are planning to resume functioning during COVID-19, the following actions are recommended:

- Introduce frequent cleaning and disinfection of frequently touched surfaces.
- Place hand sanitizers at various locations.
- Stop use of water coolers and dispensers temporarily.
- Stop use of tea and coffee dispensers.
- Arrange seating plan based on social distancing.
- Provide signage promoting hygiene and social distancing.

Once these measures are put in place, we need to understand the likely possibilities of spread of the virus through air conditioning, if at all it exists, so as to take precautions in the

operation of air conditioning and ventilation systems in these premises to minimize the chances of COVID-19 spread.

Let us analyze the effect of factors governing air conditioning: temperature, humidity, particulate matter and air speed/velocity.

Space Temperature

We can rule out the effect of space temperature, since there is no conclusive finding till date confirming that between 20-27°C inside space temperature, COVID-19 virus gets less effective.

Space Humidity

Again, there are no findings that can confirm reduction in the effectiveness of COVID-19 virus spread in air-conditioned space with humidity of 40-60% maintained in almost all comfort applications, although while recommending higher humidity we should not forget other bacteria generation possibilities attached to it.

Particulate Matter

There is more concern about outside air than the inside conditioned air. Moreover, the intensity and spread profile in countries with very low ambient PM levels does not support the claim that PM can be a carrier for spread of COVID-19.

Air Speed/Velocity

In case air speed/velocity is high and horizontal, it can increase the sphere of spread arising from the sneezing or coughing of a COVID-19 patient. Although WHO recently communicated that there is no strong evidence for adopting measures against the aero-transported contagion for COVID-19, it emphasized the need for taking one-meter distance from coughing or sneezing individuals as safe².

To study the possibility of transmission of this disease by air, a few researchers and scientists studied the effect by simulating the dispersion of multi-dimensional polydisperse droplets exhaled during a sneeze in a microclimatic urban setting. Although this does not exactly relate to the inside conditions of air-conditioned space, it has some relevance to the effect of air velocity on the spread of disease.

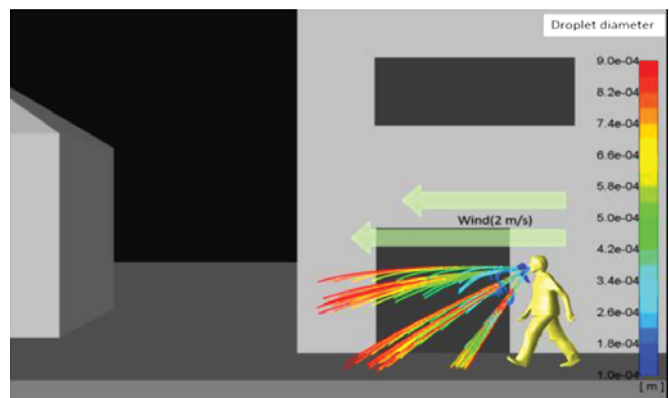


Figure 1: Dispersion of multi-dimensional polydisperse droplets

“Our results indicate that the effect of microclimate is very relevant over the propagation of droplets, where dispersion is enhanced by the turbulent wind,” explain the authors³.

Though the above report is not peer-reviewed and cannot be considered authentic, simple principles of nature also support the theory that wind velocity helps carry small particles to longer distances. In addition to the above, there is enough material floating around that has created sufficient confusion about the virus transmission route.

The above findings reveal that air conditioning, although highly dependent on air re-circulation, has an exceedingly small role to play in the spread of COVID-19 disease through the airborne transmission route except for one factor, i.e. the velocity of supply air striking the occupants. Also, in case a COVID-19 positive person is sitting in an office, the virus source lies in the occupied zone where mixing of air is happening due to the air conditioning system.

Thermal Comfort Applications

Leaving aside healthcare and special applications, people use fans, desert coolers, window air conditioners, split air conditioners, VRVs/VRFs and central plants for thermal comfort. As the studies until now reveal, COVID-19 is not an airborne infectious disease; so, it is evident that we should not hesitate to use air conditioning. However, considering that air velocity/speed can transmit this virus to a longer distance, it becomes imperative to safeguard ourselves from this mode of transmission. Let us consider the possibility in each application.

Ceiling Fans

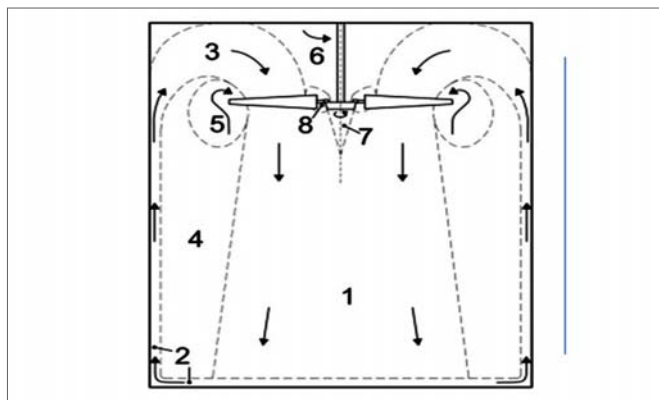


Figure 2: Air flow from a ceiling fan

As ceiling fans push the air downwards, there is very little chance of spreading the virus. Rather, they will force the virus to get stuck to surfaces below and so can be used without fear.

Wall Fans

Wall fans throw air horizontally and hence should be avoided as they can become the cause of spread by carrying the virus to a longer distance.

Desert Coolers/Room Coolers

Desert coolers are generally window-mounted and use outside air. Although outside air is preferred, considering the high horizontal velocity discharge from these units, there are chances of spread. It is recommended that both desert coolers and room coolers, if at all used, should be used with precautions



Figure 3: Desert cooler and room cooler

to avoid any chances of a blast of air directly over the occupants. Room coolers use re-circulatory air and hence should be used by placing them near open windows, allowing higher chances of fresh air intake.

Window ACs

Window air conditioners should be used with care by adjusting the supply air grille preferably upward or in a position to avoid any possibility of the virus getting into the supply air stream.

Hi-Wall Split ACs



Figure 4: Air flow from a high wall split AC

The supply louver should be adjusted in the top horizontal position to avoid any possibility of occupants facing direct supply air stream.

Cassette Units



Figure 5: Air flow from a cassette unit

In case of cassette units, all four supply air louvers should be adjusted in top horizontal position to avoid any possibility of occupants facing direct supply air stream.

continued on page 49

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A view of National Cancer Institute, Nagpur

HVAC for Healthcare Facilities in Times of COVID-19

By **K. Ramachandran** Director, Eskayem Consultants, Mumbai

“The very first requirement in a hospital is that it should do the sick no harm”

Florence Nightingale, 'Note on Hospitals', 1863

Introduction

What the 'Lady with the Lamp' wrote more than 150 years ago is unfortunately still very true about our hospitals, and the COVID-19 pandemic has exposed the inadequacies like nothing else in the past. We are seeing entire hospitals turning into infected zones because of one patient testing positive for COVID-19, throwing our healthcare delivery system out of gear and turning away seriously ill patients. The number

About the Author

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of lives lost due to this will not find a place in statistics for Coronavirus released by the authorities, but is likely to exceed even the Corona fatalities. We are also witnessing a large number of healthcare workers getting infected with the virus.

Even a city like Mumbai that should be having the best of healthcare systems in the country by far, had only one centre for treating infectious diseases, viz., Kasturba Hospital in Central Mumbai, which did not even have a functional ICU or an Intensivist on its rolls. An infection such as COVID-19, which along with co-morbidities can prove fatal, would need specialised facilities for cardiac care, diabetic patient care, dialysis, etc. and if they are absent, admitting co-morbid patients in such a facility is as good as signing their death warrant.

While infection control in healthcare facilities is a vast subject, this article looks at only one aspect of it: How to provide thermal comfort and indoor air quality to the patients and all others who need to be present in the facility without compromising their well-being.

Types of Healthcare Facilities in India

For understanding the HVAC system design in our healthcare facilities, we will categorise them as under:

Multi-speciality Hospitals in the Private Sector

They provide a variety of services and are equipped with the following sections or departments:

- Patient care spaces – rooms as well as wards
- Intensive care units
- Surgery and critical care – operating rooms, catheterization laboratories (cath labs), delivery rooms, etc.
- Diagnostics and treatment – OPD, examination and therapy rooms
- Ancillary – radiology, laboratories, blood bank, etc.
- Administration – offices
- Sterilization and supply – CSSD, linen storage, etc.
- Hospital services – food service, laundry
- Engineering services – AC plant, electrical rooms, water storage and treatment, fire protection

General Hospitals

They are run by the government or local bodies such as municipal corporations. These institutions also provide the complete gamut of services or even better, but except for some premier institutions such as the AIIMS, infrastructure facilities are basic. For example, except for a few paying beds, the general wards are mostly non-air conditioned.

Primary Health Centres

They are run by the government or local bodies. They are generally the first point of contact for the patient with the healthcare system, either for consultation with a doctor or for primary diagnostic investigations. They are well spread out all over the country and most of them are in rural or semi-urban areas. In most cases, they are also called upon to provide trauma care.

Diagnostic Clinics

This is where patients come with a referral for undergoing diagnostic tests such as MRI and CT scan, and no major treatment involving anaesthesia or surgical intervention is offered. These clinics are generally in urban and semi-urban centres and are privately owned.

Clinics

They are run by general practitioners or specialists (outside of hospitals) where consultation and, in rare cases, minor surgical procedures are carried out. They are privately owned and offer no in-patient facilities. For all practical purposes, dental clinics also fall in this category.

Nursing Facilities, Old Age Homes and Hospices

They are becoming popular especially in urban India with an increasing proportion of senior citizens and nuclear families.

HVAC Requirements for Healthcare Facilities

The functional requirements of each of these facilities guide their air conditioning and ventilation requirements. Generally, the requirements are:

- Temperature and humidity control
- Maintaining indoor air quality (IAQ)
- Distribution of air
- Control of air flows (pressure relationships between spaces)
- Contamination control
- System dependability and redundancy

Control of infection has always been a major factor in healthcare facility design. Besides controlling temperature and humidity in the conditioned spaces, the HVAC system is called upon to maintain specified rates of dilution through ventilation (as defined by the number of outdoor or fresh air changes in an hour) as well as cleanliness of the room air by filtration (as defined by the number of total air changes in an hour). Besides these, the pressure differential between spaces determine the direction and rate of air flows.

Infections can spread from an infected individual to a susceptible person either through direct or indirect contact. Direct contact is through touch, oral secretions or skin lesions as well as through transfusions or injections. Indirect contact occurs through touching an intermediate surface such as a door knob, food tray or some other similar surface that may be contaminated.

Most or all of the well-maintained healthcare facilities are equipped to handle and prevent such direct as well as indirect spread of infections. Following are some of the measures:

- 1 Hand rails and such other contact surfaces are made out of materials resistant to bacteria and are easily cleanable with disinfectant.
- 2 Provision of single patient rooms with attached bath rooms.
- 3 Reduced travel distances for patients and attending staff.
- 4 Hand washing facilities and protocols.
- 5 Strictly enforced SOPs for transfusions and such other procedures.

However, such protections that are fairly standard and easily enforced do not prevent cross contamination or person to person transmission through small airborne particles that may contain pathogens.

Airborne Infection – Pathogens

To understand air borne contamination, an understanding of disease-causing pathogens is necessary.

Pathogens fall into three major taxonomic groups: viruses, bacteria and fungi. Contagious bacteria and viruses come almost exclusively from humans.

Most of the micro-organisms are uni-cellular. While a bacterial cell is about 1 micrometre (1 μm), a virus is 10 times smaller at about 100 nano meters (100 nm).

Viruses do not have a cell structure and they need a host cell to survive and replicate. Once they enter a host cell, they acquire the characteristics of the host. A reservoir allows the pathogens to survive in a given environment for a specified period of time. The reservoir can be an infected human being or even a surface such as a table top or a food tray. An active carrier can be an infected human being or a domestic pet.

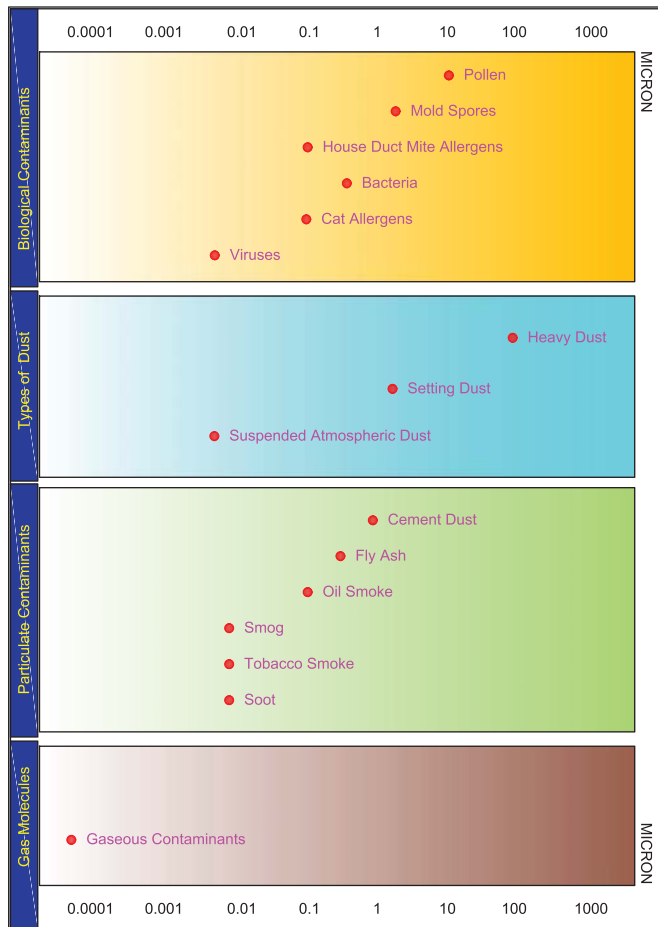


Figure 1: Relative sizes of micro-organisms

An active carrier can be symptomatic or asymptomatic, depending on whether it exhibits the symptoms of the disease or not. A passive carrier can transmit the disease from one person to another without getting infected oneself.

Airborne transmission occurs when the pathogen is carried in an air stream over large distances. In case of airborne transmission, pathogens generated by an infected individual – through coughing, sneezing or even exhalation – are picked up by an air stream and carried to another person who can get infected by breathing it in.

Both direct and indirect transmissions can be prevented by keeping a safe distance from the infected individual, wearing personal protective gear, frequent washing of hands and

other medical and non-medical protocols. However, preventing transmittal of airborne infections is a totally different proposition.

SARS-CoV2 Virus

Coming specifically to the SARS-CoV2 virus that causes the COVID-19 infection, it has an incubation period ranging from 7 to 14 days. It is also claimed that a major percentage of infected individuals (some studies estimate it as high as 80%) are asymptomatic or do not show any symptoms of the disease.

The size of SARS-CoV2 virus is estimated between 80 and 160 nanometres. Particles expelled by an infected person while coughing, sneezing or talking typically range from 1 to 100 microns, which is 6 to 12 times the size of the virus (at the minimum droplet size). The droplets that may fall on nearby objects can remain active from a few hours to a few days. By taking precautions such as wearing a face mask, keeping social distancing, frequent hand washing, etc., direct transmission can be prevented to a great extent.

However, small particles (< 5 microns) of these droplets can stay airborne for hours and can also be transported over long distances in an air stream. Depending on the relative humidity (RH) of the space, the water particles in the droplets evaporate and desiccate in a very short time and the virus itself can remain active in the air stream for hours.

In case the space is conditioned by an air handling system with recirculation (like most of the installed systems at public spaces such as air terminals, cinema halls and even hospital wards), the air stream can carry the virus not only in its forward path but also in the return air stream and back into the conditioned area through the air handling unit (AHU).

The American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), through its position document

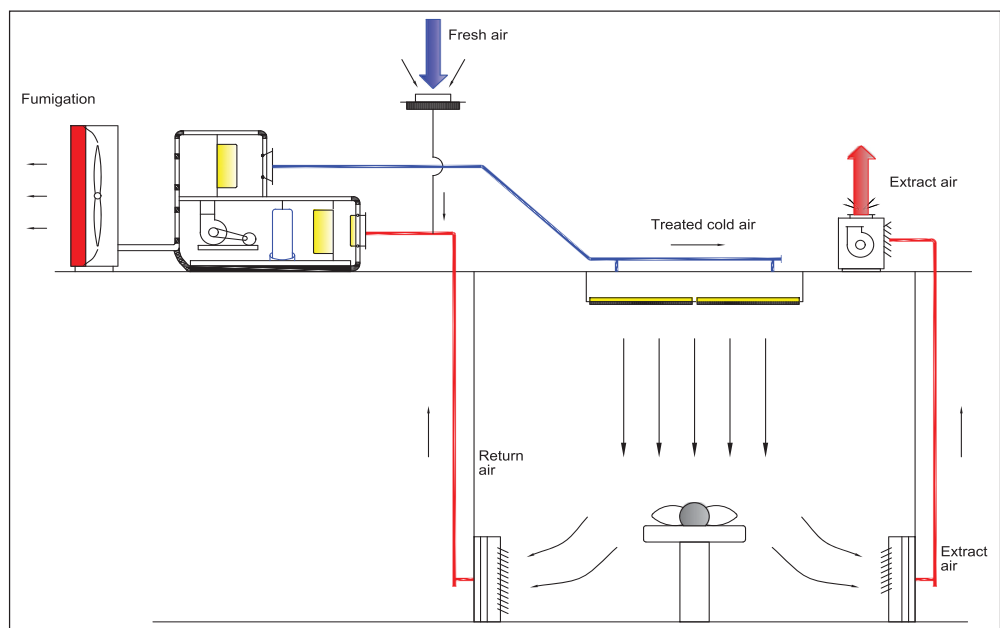


Figure 2: Spread of the virus in recirculation systems

on Airborne Infectious Diseases issued on April 14, 2020, has modified its earlier stand and states as under:

“Transmission of SARS-CoV2 through the air is sufficiently likely that airborne exposure to the virus should be controlled. Changes to building operations, including the operation of HVAC system, can reduce airborne exposures.

Ventilation and filtration provided by the HVAC system can reduce the airborne transmission of SARS-CoV2 and thus the risk of transmission through air.”

European Society of HVAC Professionals (REHVA), in its COVID-19 guidance document, advocates taking all measures that help to control the airborne infection route of the virus. REHVA goes on to recommend avoiding recirculation of air in affected spaces and states that it is more important to prevent contamination and protect public health than providing thermal comfort to occupants.

With the large influx of COVID-19 infected patients as well as patients with suspected infection, it has become necessary to relook at measures to prevent the spread of airborne infections. It is all the more important because most of the carriers (those who are in incubation period as well as the large majority who are asymptomatic) will not exhibit any symptoms but will be able to pass on the virus to susceptible persons who may spend time with them in a room served by a recirculating air system. We may recall the large number of positive cases among people who returned to India from countries abroad who, most likely, got the infection when they were waiting at air terminals. So also, the medical personnel who move around in hospital wards where COVID-positive patients are being treated and who get infected inspite of wearing PPEs, are victims of transmission through air.

Deviating from the main topic, we need to take note that the home-made cloth masks as well as the triple layer surgical masks that are being popularised do very little to protect the wearer from infection. These masks neither have the filtration efficiency required to filter out airborne particles as small as the virus, nor are they designed to have an air tight fit around the nose and mouth. While they do block the viral spread in about 60% of the cases, the protection is offered to others and not to those wearing the mask. Only a proper N 95 mask, that too worn properly with no air gap between the face and the mask, can protect the wearer from airborne infection.

Consider the scenario that you are in a doctor’s waiting room with some form of infection that has pulled down your immunity, and have got your nose and mouth covered with a home-made cloth mask, and a SARS-CoV2 infected person who is completely asymptomatic is in the same room and a good distance away from you. As is generally the case, a high wall mounted split unit with no fresh air provision is cooling the room. The chances of the airstream carrying the virus from the exhalation of the infected person in the return air path and sending it back to you through the unit is indeed very high.

Experts opine that the virus is going to stay with us for a long time and, inspite of vaccines and herd immunity, may never get completely eliminated for years. This puts a heavy responsibility on the HVAC community to find out a solution to the airborne spread of infection.

HVAC Solution to Airborne Spread of Infection

Let us examine how this can be done.

Besides the basic functions of controlling temperature and humidity, the HVAC system in a healthcare facility is called upon to do the following functions:

Maintain Quality of Indoor Air through Dilution

This is defined by the number of outdoor or fresh air changes in an hour.

Maintain Air Quality Through Filtration of Recirculated Air

This is defined by the number of total air changes in an hour as well as the type of filters inserted in the path of recirculated air.

Maintain Desired Pressure Differential Between Adjoining Spaces

This would direct and control air flows from one area to another.

ASHRAE Standard 170 specifies various parameters for each of the spaces in a healthcare facility. Almost the same parameters are adopted by India’s National Building Code (NBC) 2016, and a few examples are given in *Table 1*.

Table 1: Examples of healthcare facility parameters

| S. No. | Functional Space | Temperature °C | RH% | Minimum Total Air Changes | Minimum Outdoor Air Changes | Pressure Relation to Surrounding Area |
|--------|----------------------------|----------------|----------|---------------------------|-----------------------------|---------------------------------------|
| 1 | Operating Theatres | 18 to 24 | 45 to 55 | 25 | 5 | Positive |
| 2 | ICU | 20 to 24 | 30 to 60 | 6 | 2 | Equal |
| 3 | Patient Rooms | 24 +/-1 | 30 to 60 | 6 | 2 | Equal |
| 4 | Immuno-suppressed Patients | 24+/-1 | 30 to 60 | 12 | 2 | Positive |
| 5 | Isolation Room | 24+/-1 | 30 to 60 | 12 | 2 | Negative |
| 6 | Out-patient Department | 22 to 24 | 30 to 60 | 12 | 2 | Negative |

In recirculating air systems, the particulate matter in the airstream gets arrested by multiple banks of filters having increasingly tight filtration efficiencies for different sizes of particulate matter. Along with other particles in the air stream, bacteria and viruses also get trapped in these filter banks. Particle sizes and filter efficiencies required for various spaces in healthcare

facilities are specified in NBC 2016, and a sample extract may be seen in Table 2.

Table 2: Particle sizes and filter efficiencies for various healthcare spaces

| S. No. | Functional Space | First Filter Bank | Second Filter Bank |
|--------|-------------------|------------------------------------|------------------------------------|
| 1 | General OT | 3 to 10 microns 70 % efficiency | 0.3 to 1 Micron 85 % efficiency |
| 2 | ICU, Patient Care | 3 to 10 microns 70 % efficiency | 0.3 to 1 Micron 85 % efficiency |

Contagious pathogens – both bacteria and viruses – originate almost exclusively from humans and, where airborne transmission is involved, special care has to be taken to arrest their passage through recirculating type air systems.

Presently, most of the better designed hospitals are equipped with central AHUs where cooling is provided by circulating either chilled water or a refrigerant gas (DX system). However, many of the smaller facilities are equipped with split air conditioners, cassette units and even window air conditioners.

Table 3: Recommended filtration systems for different types of healthcare facilities

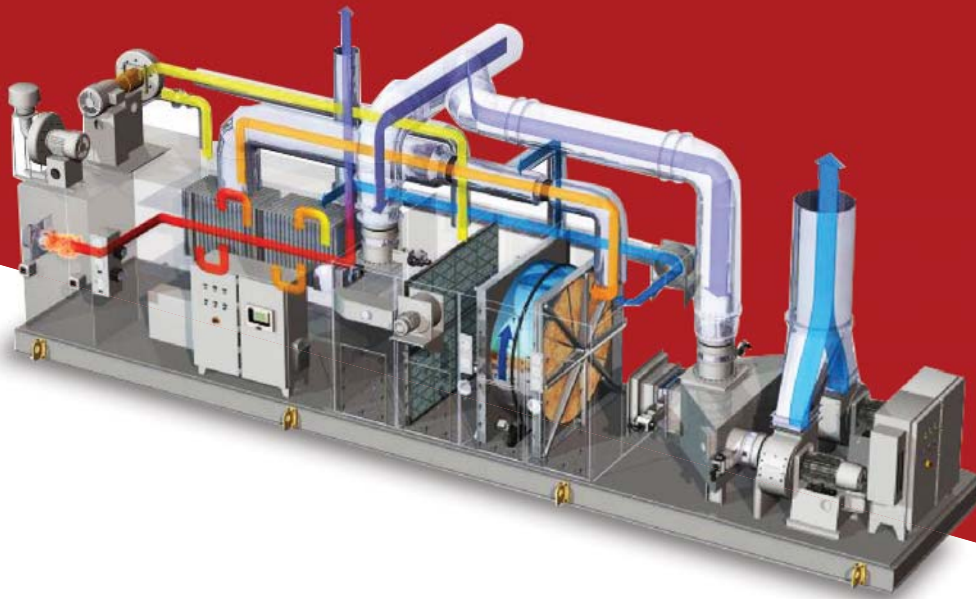
| S. No. | Type of Facility | Functional Space | Temp. °C | RH % | Minimum Total Air Changes | Minimum Outdoor Air Changes | Pressure Relation to Surrounding Area | Filtration System |
|--------|---|--------------------------------|------------------------|----------|---------------------------|-----------------------------|---------------------------------------|---|
| 1 | Multi-speciality hospitals in private sector and premium government/municipal hospitals | 1.1 Operation theatres | 18 to 24 | 45 to 55 | 25 | 5 | Positive | Prefilters MERV 8 and Post filters MERV 14 |
| | | 1.2 ICU | 20 to 24 | 40 to 70 | 6 | 2 | Equal | Prefilters MERV 8 and Post filters MERV 14 |
| | | 1.3 Patient rooms | 20 to 27 | 40 to 70 | 6 | 2 | Equal | Prefilters MERV 8 and Post filters MERV 14 |
| | | 1.4 Immuno-suppressed patients | 24 +/- 1 | 40 to 70 | 12 | 2 | Positive | Prefilters MERV 8 and Post filters MERV 14 Terminal filters H13 or better as per IS 1822 |
| | | 1.5 Isolation room | 24 +/- 1 | 40 to 70 | 12 | 2 | Negative | Prefilters MERV 8 and Post filters MERV 14 |
| | | 1.6 Out-patient department | 22 to 24 | 40 to 70 | 12 | 2 | Negative | Prefilters MERV 8 and Post filters MERV 14 |
| 2 | Government/municipal hospitals at district level | 2.1 Operation theatres | 18 to 24 | 45 to 55 | 25 | 5 | Positive | Prefilters MERV 8 and Post filters MERV 14 Terminal filters H13 or better as per IS 1822 Separate AH Unit for each operating room |
| | | 2.2 ICU | 20 to 24 | 40 to 70 | 6 | 2 | Equal | Prefilters MERV 8 and Post filters MERV 14 |
| | | 2.3 Patient rooms | Non-AC | Non-AC | 12 | 12 | Equal | Ventilation system with 2 Stage evaporative cooling where possible with MERV 8 filters |
| | | 2.4 Immuno-suppressed patients | 24 +/- 1 | 40 to 70 | 12 | 2 | Positive | Prefilters MERV 8 and Post filters MERV 14 Terminal filters H13 or better as per IS 1822 |
| | | 2.5 Isolation room | 24 +/- 1 | 40 to 70 | 12 | 2 | Negative | Prefilters MERV 8 and Post filters MERV 14 Exhaust filters H 13 or better as per IS 1822 |
| | | 2.6 Out-patient department | Non-AC | Non-AC | 12 | 2 | Equal | Ventilation system with 2 Stage evaporative cooling where possible with MERV 8 filters |
| | | 2.7 Doctor's consulting rooms | 26 +/- 1 | 40 to 70 | 12 | 2 | Equal | Prefilters MERV 8 and Post filters MERV 14 |
| 3 | Primary health centres in rural and semi-urban areas | 3.1 Out-patient department | Non-AC | Non-AC | 12 | 12 | Equal | Ventilation system with 2 Stage evaporative cooling where possible with MERV 8 filters |
| | | 3.2 Doctor's consulting rooms | 26 +/- 1 | 40 to 70 | 12 | 2 | Equal | Prefilters MERV 8 and Post filters MERV 14 |
| | | 3.3 Procedure rooms | 24 +/- 1 | 40 to 70 | 12 | 2 | Negative | Prefilters MERV 8 and Post filters MERV 14 |
| | | 3.4 Patient lying-in rooms | Non-AC | Non-AC | 12 | 12 | Equal | Ventilation system with 2 Stage evaporative cooling where possible with MERV 8 filters |
| 4 | Diagnostic centres | 4.1 Equipment rooms | As specified by vendor | | 15 | 3 | Positive | Prefilters MERV 8 and Post filters MERV 14 |
| | | 4.2 Doctor's consulting rooms | 26 +/- 1 | 40 to 70 | 12 | 2 | Equal | Prefilters MERV 8 and Post filters MERV 14 |
| | | 4.3 Patient waiting rooms | Non-AC | Non-AC | 12 | 12 | Equal | Ventilation system with 2 Stage evaporative cooling where possible with MERV 8 filters |
| 5 | Family physicians and specialists consulting rooms | 5.1 Doctor's consulting rooms | 26 +/- 1 | 40 to 70 | 12 | 2 | Equal | Prefilters MERV 8 and Post filters MERV 14 |
| | | 5.2 Procedure rooms | 24 +/- 1 | 40 to 70 | 12 | 2 | Negative | Prefilters MERV 8 and Post filters MERV 14 |
| | | 5.3 Patient waiting rooms | Non-AC | Non-AC | 12 | 12 | Equal | Ventilation system with 2 Stage evaporative cooling where possible with MERV 8 filters |
| 6 | Nursing homes, old age homes and palliative care | 6.1 Dormitories and rooms | 26 +/- 1 | 40 to 70 | 6 | 2 | Equal | Prefilters MERV 8 and Post filters MERV 14 |
| | | 6.2 Common recreation rooms | Non-AC | Non-AC | 12 | 12 | Equal | Ventilation system with 2 Stage evaporative cooling where possible with MERV 8 filters |

Note: All the above spaces are to be served by air handlers or fans that can deliver the required air quantity against the static pressure offered by the filter banks.

continued on page 47

VOC ABATEMENT & SOLVENT RECOVERY SYSTEM

FEATURES:



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WHAT IS A VOC ABATEMENT & SOLVENT RECOVERY SYSTEM?

It is a system to **combust, recover and refine Volatile Organic Compounds (VOCs)** which are exhausted from facilities. Due to the usage of VOC abatement systems, VOCs in the targeted exhaust gases can be combusted and purified air can be released to the atmosphere.

Casilica utilise an Adsorption technique to adsorb VOCs physically by using activated carbon and an incombustible adsorbent (hydrophobic zeolite etc.). Re-use is possible by recovery of VOCs and no intermediate compounds are generated during the process.

These systems have been used for VOC removal in chemical processes, cleaning and air conditioning for clean rooms.

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- ◆ Wood finishing
- ◆ Liquid Crystal Panels (LCDs, OLEDs etc)

continued from page 45

Therefore, one of the first steps such facilities should take is to disable recirculating type systems. These systems should be replaced by central AHUs that have the capability to dilute the contamination by drawing in fresh outside air as well as filter out bacteria and viruses by enhanced circulation through filter media. In case immediate replacement is not feasible, a safe option will be to shut down the AC System and use operable windows with exhaust fans fitted as a temporary measure.

Also, currently many of the healthcare facilities (even the better class ones) do not follow the ASHRAE Standard 170 for their patient wards. While good care is taken in case of operation theatres, patient wards and ICU facilities are served by air handlers with bare minimum filtration. This needs to change in the post COVID-19 scenario.

When an existing AHU is retrofitted with better class of filters (having higher filtering capability), the pressure drop of the system is bound to go up and this may need upgrading of the fan and its motor too.

For the different types of healthcare facilities in our country described above, temperature, RH and air circulation parameters as well as recommended system details are tabulated in Table 3. Except for critical spaces such as operating theatres and ICUs, the parameters given in the table are more relaxed than those specified in ASHRAE 170. They have been given with a view to implement better filtration levels and a larger number of total air changes consistent with removal of the virus from the recirculating air stream.

Because of the nature of the virus, all visitors to the facility need to be considered as potential carriers of the virus. Therefore, all those who visit the facility, including those who come to attend outpatient departments or for undergoing diagnostic procedures, should be protected from the virus. This would mean that in healthcare facilities all recirculation systems need to be fitted with pre- and post-filters as per Table 3.

However, it needs to be stressed that even at the relaxed temperature and humidity conditions specified in Table 3, the cost of implementing filtration to specified levels is going to push up the system installation costs, space requirements as well as operating costs including energy and filter replacement costs. This needs to be balanced with the huge burden of medical costs due to hospital acquired infection (HAI) as well as interruptions due to contamination and risk to healthcare workers including doctors and nurses.

In the age of COVID-19, any healthcare facility in the country should be able to accept and attend to COVID infected patients as well as COVID negative patients by observing social distancing and other hygiene measures without bothering about airborne transmission of the disease.

Patients who have been tested positive for the virus can be kept in common isolation wards or rooms. These wards or rooms need to be maintained at a negative pressure to prevent spread of infection outside the containment area. They should be attended by healthcare workers in full protective gear and N 95 face masks. Masks of lower grade are not useful for this application and must not be used.

Care of patients who have not tested positive for the virus is in fact more complicated. They should not be placed in a common ward or in an ICU with multiple beds, since any one patient who is infected can pass on the infection to others. In the short term, the only solution seems to be to test each of them for the virus and only those tested negative should be admitted in a common ward. This, however, is easier said than done.

A short-term measure to reduce the spread of infection will be to convert the recirculating system into a 'once through' system. This can be done by blocking the return air path to the AHU by closing the return air vents in the room, or by closing the damper in the return air path, or even by physically blocking the return air outlet in the AHU room. The AHU needs to run with 100% fresh (outdoor) air and if the provision is not adequate, a ducted fan assisted system needs to be provided. Care should be taken to see that outdoor air is picked up from an area free of contaminants and at least 10 metre away from exhaust outlets. Similarly, for extracting the exhaust air, a fan and duct system would be required with adequate care taken to see that contaminated air from the ward is treated before it is let out in a safe place.

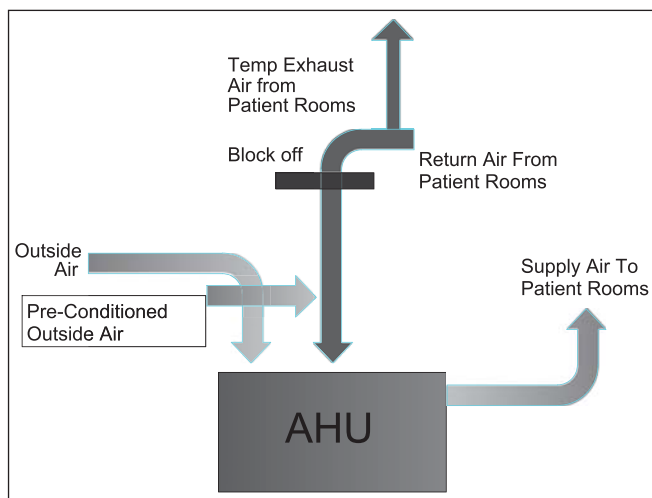


Figure 3: Preventing recirculation in existing AHU

A long-term solution would be to revamp the air distribution system in the wards ensuring adequate fresh air for dilution, and also provide the required number of total air changes for effective filtration. The AHU will need to be equipped with both pre- and post-filter banks in multiple stages. This will require replacement of the fan and the motor to take care of the increased static pressure. In many cases, the AHU itself may require to be replaced and for existing installations, space availability to house the filters will also pose problems. The return air from the wards will need to be ducted back into the AHU. In many current installations, return air is taken through the false ceiling; this needs to be avoided. This, again, is going to be a major challenge in running hospitals.

In locations where weather conditions permit, it may also be possible to design evaporative cooling systems for

patient wards, OPD and similar other spaces and provide a once through air circulation system for these spaces achieving the relaxed temperature and humidity conditions specified in Table 3.

Exhaust air from patient wards and ICUs would contain pathogens and should not be discharged outside without treatment. Exhaust air may be discharged through HEPA filters (minimum H 13 Class), or the air can be heated to 75°C for 15 minutes so that the viruses get killed. Chemical disinfection is also possible by letting out the exhaust air through a diffused aeration tank containing 1% sodium hypochlorite solution. It is advisable to exhaust the air at a height of 3m above the tallest point of the building and away from air intake points. The exhaust duct, for its entire length, has to be under negative pressure to ensure that there is no escape of contaminated air to the surroundings. This can be achieved by providing HEPA filters as close to the air intake as possible and the exhaust fan at the discharge end of the ducting system.

Other than dilution and filtration measures described above, there are several air purification measures that claim to be effective for removal or reduction of the virus from the air stream. A few of them are described below.

Ultraviolet Germicidal Irradiation (UVGI)

This is useful to provide surface disinfection and limit the growth of bacteria and viruses. UVGI lamps are typically located downstream of the cooling coil and drain pan in the AHU. The UVGI energy directed on surfaces helps dissolve the various organisms. However, UVGI – used primarily to prevent microbial growth at the cooling coil – will not be useful to irradiate viruses in the air stream. This is because the high air velocities obtaining at the cooling coil do not allow sufficient exposure time to irradiate the viruses in the air stream. Duct mounted UVGI of sufficient intensity can result in higher aerosol exposure and quicker deactivation.

Upper air UVGI devices are located within the occupied room and are designed and installed to irradiate the air in the upper regions of the space. Depending on fixture placement and adequacy of air currents bringing the contaminated air into the upper UV zone, these systems can help control transmission of airborne pathogens at source. In combination with appropriate room ventilation strategy, these devices can reduce the spread of airborne infections.

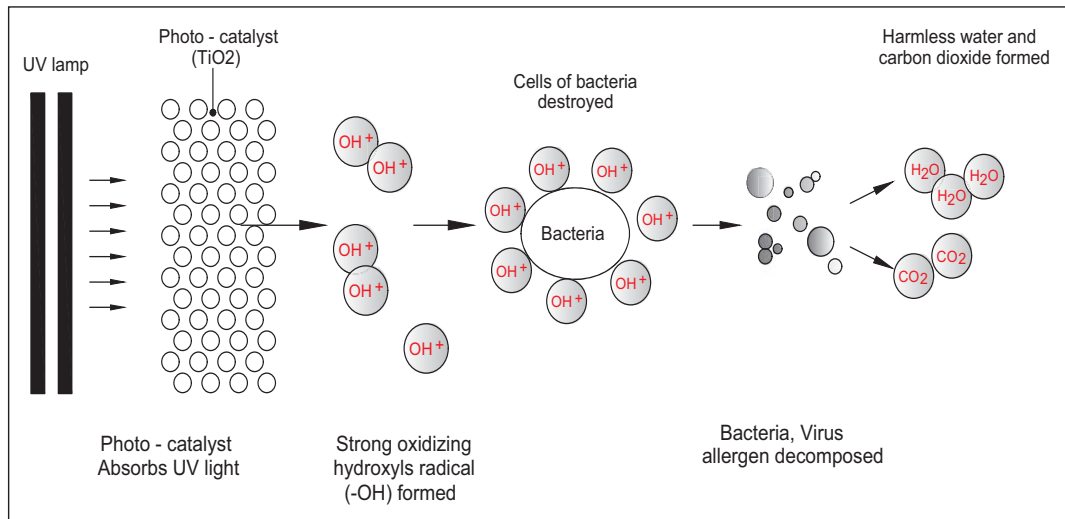


Figure 4: Working of photocatalytic oxidation unit

In-room UVGI can also be installed in patient rooms between successive occupants using elevated levels of irradiation during the unoccupied period. This, however, is only a surface disinfecting strategy and has no continuing effect on the room air.

Photo Catalytic Oxidation (PCO)

PCO uses a broad-spectrum UV light to impinge on a thin film of titanium dioxide (catalyst) creating free hydroxyl radicals that can neutralize both bacteria and viruses. They have been known to neutralize particles as small as .001 microns (See Figure 4).

Electronic Air Cleaners (EAC)

EAC employs an electric charge to form a strong electrostatic field and electrons present in air contaminants are energized and pushed at high velocity from negative to positive charged field. The particles are trapped in charged collector plates. There are electronic air cleaners available in the market which claim filtration efficiency equivalent to MERV 14 grade filters. Such air cleaners are available both for mounting within the AHU as well as for independent mounting (See Figure 5).

It needs to be emphasised that other than filtration, all the above air cleaning techniques are to be proved for their efficacy as well as safety for use in healthcare environment. A lot of research, development and validation on these systems are expected to take place in the immediate future.

Relative Humidity

Relative humidity levels of 40% to 70% have been found to limit the spread of airborne viruses. At lower RH levels, infectious droplets can quickly evaporate and shrink and can therefore remain in the airstream for longer periods. Higher levels of RH reduce the time period for which the droplets remain active.

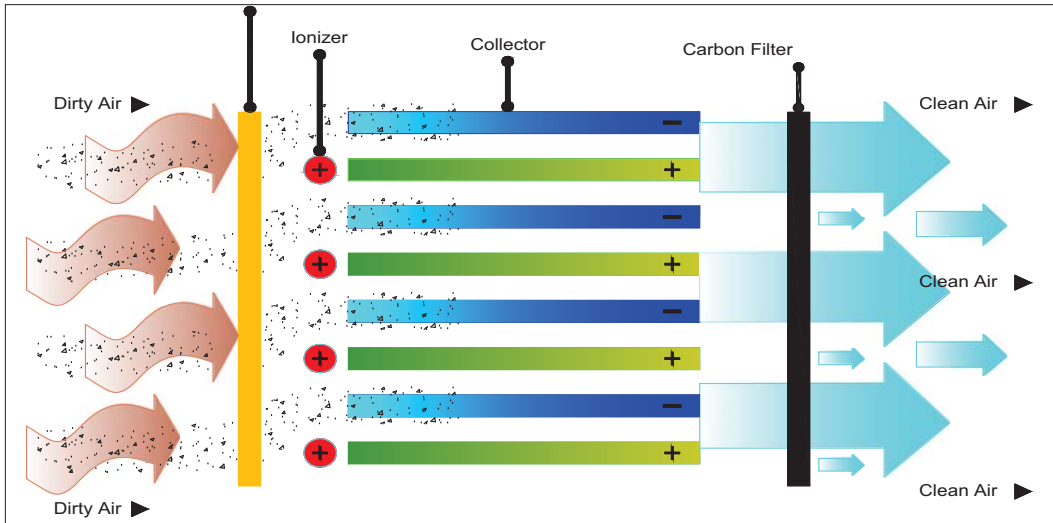


Figure 5: Working of electronic air cleaner

Temperature

It has also been found that virus survival decreases as temperature increases. Since comfort temperature is reckoned to be from 24°C to 30°C, it may be advisable to operate the air conditioning system close to the upper zone, say from 27°C to 29°C with reasonable air movement for occupant comfort. In fact, with the varying climatic condi-

tions in the country across geographies as well the seasonal and day and night variations, a broad operating range from 20°C to 28°C may be recommended.

in hospitals are unavoidable. While admitting that the measures suggested in this article, such as enhanced filtration in all areas, are difficult to implement and expensive to carry out, it is hoped that HVAC professionals working in the healthcare field will weigh these disadvantages against the need for a safer environment not only for patients but also for healthcare professionals and others who visit the facility. ❄

Conclusion

Hospital acquired infection was taken for granted in the past, but the COVID-19 pandemic has made its repercussions far too serious to accept. With the possibility of the virus being part of our lives in the foreseeable future, modifications to HVAC systems

Operation of Thermal Comfort Systems during COVID-19 *continued from page 39*

Central Air Conditioning with AHU Supply through Grilles

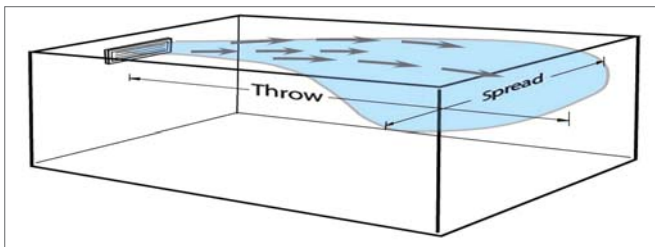


Figure 6: Air flow from a grille

The louvers of grilles of air-conditioned spaces receiving conditioned supply air through grilles should be kept in an upward angular position to avoid any possibility of occupants getting into the direct supply air stream.

Central Air Conditioning with AHU Supply through Diffusers

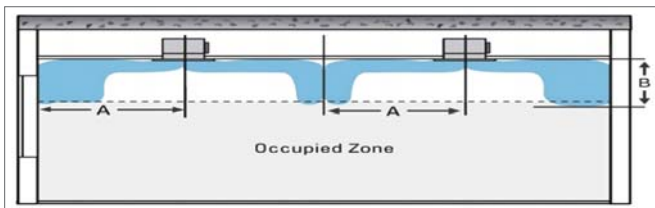


Figure 7: Air flow from diffusers

Air-conditioned spaces provided with ceiling diffusers may be utilized without hesitation as their air supply pattern avoids direct throw, as shown in Figure 7.

Conclusion

Finally, it can be concluded that if air conditioning systems are used with caution, there seems to be no cause for concern. In addition to the recommendations given above, some additional precautions are suggested to ward off the exceedingly small possibilities of virus spread, if they exist:

- Allow maximum fresh air by opening fresh air dampers to fully open position, as recommended by ASHRAE and REHVA.
- Clean filters and coils more frequently.
- CO₂ setting of demand control ventilation system should be set to 400 ppm to allow for more fresh air.
- Split ACs and VRV/VRF systems should be used with fresh air supply. In case this provision does not exist in the present system, exhaust fans or partially opened windows should be used to compensate for that.

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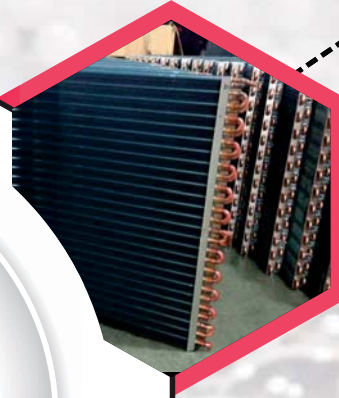
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Resilient and Future Proof HVAC Systems for Post COVID-19 Buildings

By **Guruprakash Sastry** Regional Head - Infrastructure, Infosys Limited, Bengaluru

Introduction

Humanity is today witnessing an unprecedented global situation, where domestic and international travel has been banned in most countries, and cities are forced into lockdown where people are allowed to step out of their homes only for essential supplies and services. All this is necessary to contain the spread of the pandemic COVID-19¹ that has wreaked havoc across the globe and claimed hundreds of thousands of lives.

The world has been through epidemics and pandemics in the past too, which have caused significant loss of human lives and sometimes changed the course of history. What makes COVID-19 different is that it spreads fast and is said to be ten times deadlier than the 2009 flu pandemic, according to the World Health Organization (WHO). The main mode of transmission is said to be through droplets of saliva or discharge from the nose when an infected person talks, coughs or sneezes. The infection is said to cause mild to moderate respiratory illness and may be more severe in people with underlying medical conditions. According to WHO, air borne transmission of COVID-19 may be possible in specific circumstances, and particles less than 5 micron in size are known to remain in air for long periods of time and travel for distances over a few metres.

The best way to prevent transmission of COVID-19 is to maintain good hygiene and respiratory etiquette while coughing and sneezing². A major step taken by many countries to avoid transmission is social distancing, and hence the lockdown that is in effect in large parts of the world.

About the Author

Guruprakash Sastry is a green building professional with over 16 years of experience. Currently working as Regional Head – Infrastructure at Infosys, he is a key member of the Projects team and is also responsible for driving environmental sustainability initiatives across Infosys campuses. In the last 11 years at Infosys, he has been instrumental in implementing several innovative technologies in buildings in areas of energy, water and waste, including the first radiant cooled commercial building in India.

The Post-lockdown Scenario

Businesses like malls, theatres, hotels and retail outlets have shut temporarily, while some businesses have shifted to the work-from-home mode wherever possible. It makes us wonder when normalcy will be restored; or will this be the new normal? Corporates with large inventories of office buildings (especially the IT and ITES sectors) have to enable work from home for their employees, while also maintaining their office buildings to ensure that all systems are in good working condition when offices resume operations. Critical infrastructure like data centers and server rooms need to be running as always and need resources for maintenance and operation. In many cases, buildings need to be operational to enable remote desktop connectivity to enable employees at home to connect to specific networks or applications. This means the Heating, Ventilation & Air Conditioning (HVAC) systems need to be operational in buildings as required. Other sectors like hospitality and retail need to operate mechanical systems like HVAC regularly to ensure that the equipment is in good running condition when regular operations resume in the coming weeks or months. This would be a major

challenge, given the situation of lockdown across the country. Movement of people and materials is heavily restricted, and getting manpower for operations and maintenance is both a risk and a challenge. In such a scenario, how does one ensure seamless and uninterrupted operations of HVAC systems while also ensuring *good health* and *energy efficiency*?

Two very important aspects that will define HVAC systems of the future are discussed here:

1. Robust building automation
2. HVAC systems providing high indoor air quality and efficiency, like radiant cooling

Building Automation

Smart buildings that have building automation systems to control most of the operations (especially those related to HVAC systems) are able to seamlessly manage operations remotely and ensure the required conditions in the buildings as well as manage and monitor operations of critical infrastructure. With a well-designed building automation system, the following can be achieved:

- Sensors and controllers manage the operations based on predefined algorithms.
- Dynamic scheduling of operations remotely – start and stop of chillers, pumps, cooling towers, air handling units (AHUs).
- Energy saving algorithms to ensure high efficiency operations – ramping up and ramping down equipment like chillers, pumps, cooling towers and AHUs to meet the required demand based on weather conditions, occupant loads, etc.

- Ensure thermal comfort and good indoor air quality – to maintain comfortable temperature and the right amount of fresh air, good quality of air, highlighting the need for filter change, etc.
- Minimum requirement of manpower for operations – automation system can be accessed remotely to monitor or control parameters by service personnel, thus minimizing the requirement of physical visits to the building.
- Highlight abnormal operational parameters immediately for action – real-time comparison of operational data with the design data of equipment (e.g. chiller efficiency), and highlight any deviation for timely action.
- Automatic alerts to facilities personnel in case of deviation in operational parameters – SMS alerts to the relevant facilities personnel to highlight a deviation in operations for a prolonged period where the system could not auto-correct the issue; alerts for critical infrastructure parameters, like data centers for temperature, relative humidity, etc.
- Automatic generation of daily, weekly and monthly reports on operations – to review efficiency, comfort and any other critical parameters for operations. This helps in comparison and benchmarking, and to identify opportunities for improvement, replacement, etc.
- Corrective action can be taken remotely by studying deviations and adjusting parameters as may be necessary.

Building automation has enabled these possibilities and reduced the need to source skilled manpower in such challenging times. It is a clear indication that building automation is not only

a tool to improve operational efficiencies, but a very important aspect for *resilience and future proofing* of buildings. Automation is one of the best uses of technology to minimize physical presence of manpower and also to empower operations teams to ensure uninterrupted and smooth operations of facilities without stress.

At Infosys, over 30 million square feet of space across India is managed remotely through a Central Command Center. Nearly 20,000 sensors collect 800,000 data points across buildings to make sure they operate efficiently. Smart automation at Infosys has ensured all advantages as listed above, and also ensured that operations of the systems are not affected by unforeseen circumstances like the one we are facing at present.



Figure 1 : Different systems in a building managed through smart automation

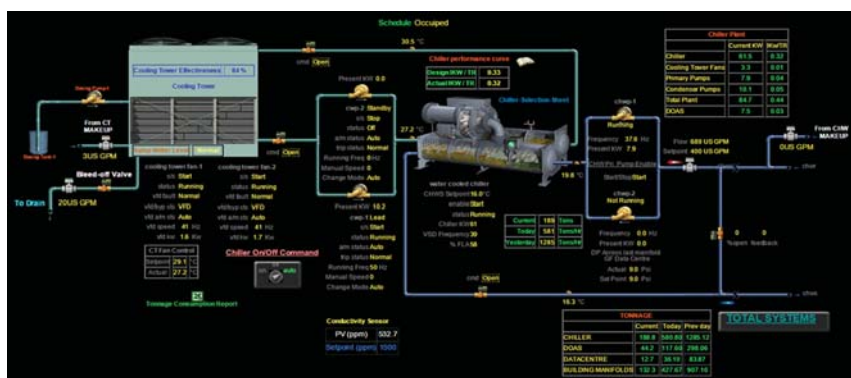


Figure 2: Chiller plant monitoring

space. In the present situation of COVID-19, there is no known air-borne transmission though smaller particle sizes can remain aerosolized in the space for many hours. As a precautionary measure, to minimize or avoid the possibility of transmission in residences, workplaces and other facilities, leading national and international HVAC organizations – namely ISHRAE, ASHRAE and REHVA – have issued guidelines for HVAC and ventilation in buildings^{3,4,5}. Each of these guidelines emphasizes the importance of fresh air ventilation in buildings so as to minimize transmission of infections and to maintain good health in general.

Conventional centralized HVAC systems have AHUs that circulate air into the building. For most spaces in offices buildings, ASHRAE Standard 62.1-2019 defines a minimum fresh air requirement of 5 cfm per person and 0.06 cfm per square foot of space. For an office with an occupant density of 100 ft² per person, the minimum fresh air requirement is calculated to be 11 cfm per person. An additional 30% fresh air is considered for green buildings providing better air quality, and therefore the fresh air requirement is calculated to be 14.3 cfm per person. The total air supply from the AHU is expected to be in the range of 90-100 cfm per person. Conventional HVAC systems are based on the convection mode of heat transfer and, therefore, require large volumes of air. Hence, increase in fresh air will result in higher energy consumption. So, there is always a compromise between indoor air quality and energy efficiency in conventional HVAC systems. Is there a way to achieve the best indoor air quality and high energy efficiency at the same time? The answer is yes.

Radiant Cooling

Radiant cooling is a system where the cooling load is split into sensible and latent loads, which are treated separately. Sensible load (comprising the envelope, lighting, computers, equipment and people) is addressed by a radiant surface, which can be a slab or ceiling cooled by circulating chilled water at a temperature of 16°C (with return at 20°C). Chillers operating at 16°C supply chilled water are about 40% more efficient than chillers operating at 8°C supply chilled water.

Latent load (moisture from outdoor air and people) is addressed by a Dedicated Outdoor Air System (DOAS), having

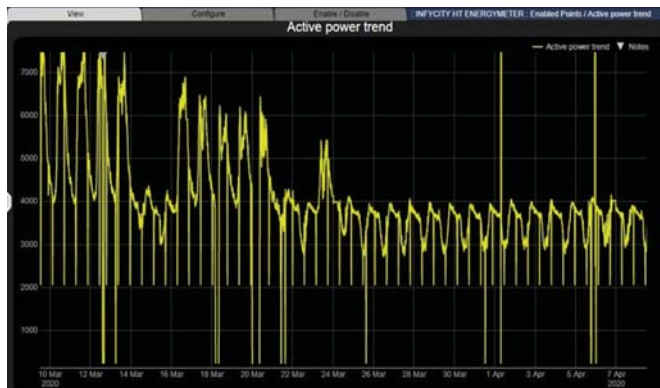


Figure 3: Power demand at Infosys Bangalore campus before and during the lockdown

dual chilled water coils – the first coil at 16-20°C, and the second coil at 8-15°C. The total air requirement in radiant cooling translates to about 17 cfm per person for an office building (Infosys as an example) to address latent loads. So, the air system in a radiant cooling is about 1/5th in volume compared to the conventional air conditioning system. Since the total air quantity is only marginally higher than the ASHRAE 62.1-2019 + 30% fresh air requirement, no recirculation of air is necessary in the DOAS, thereby ensuring high air quality in buildings. The overall HVAC energy consumption of radiant cooling is expected to be 30% lower than an efficiently designed conventional air conditioning system⁶.

Conclusion

To sum up, a radiant cooling system is a 100% fresh air system offering high indoor air quality and thermal comfort while at the same time ensuring high energy efficiency. The other advantages of a radiant cooling system include reduced space requirement for DOAS (compared to AHUs), reduced equipment, higher thermal comfort and no incremental capital cost.

When businesses start functioning slowly in the weeks and months to come, they will have to exercise utmost caution against transmission of any infection in workplaces and will leave no stone unturned to ensure employee health and safety. Providing good indoor air quality in buildings will be among the top priorities for corporates. Those with conventional air conditioning systems will have to provide maximum fresh air and compromise on energy consumption, and those with radiant cooling systems will have normal operations as usual, providing a high level of indoor air quality and low energy consumption.

Therefore, *radiant cooling* and *robust automation system* can be considered as resilient and future proof systems for buildings and are expected to see high adoption in the days to come.

Infosys has been a pioneer in radiant cooling systems in India. The first radiant cooled building at Infosys was commissioned in 2009. Today, Infosys has nearly 5 million ft² of space with radiant cooling across India, and all new buildings of Infosys have radiant cooling as a standard specification.

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Managing Healthcare by HVAC Post COVID-19

By Shankar Chatterjee Kolkata

Introduction

What is happening worldwide is difficult to express. It is causing acute desperation to do something at once that will bring some relief. The HVAC industry possesses the potential for handling the crisis quite effectively. Apart from researchers, HVAC is the only industry involved in such situations at a large scale. For example, critical patients in operation theatres and post-surgery would not survive but for an effective air conditioning system in place. Therefore, the HVAC industry needs to come to the forefront to introduce measures to curb the spread of viruses. In the post COVID-19 scenario, the industry could become one of our life supports. It must gear up, with its wealth of knowledge of the environment, to cope with the challenges in the war against the invisible enemy.

Till the time researchers are able to make a breakthrough in developing a vaccine, breaking of the chain of transmission and creating an appropriate indoor environment is the most effective strategy. In order to confront such a formidable and unforeseen situation, the very approach to the subject of HVAC engineering would undergo several major changes and the industry would come up with innovative ideas.

About the Author

Shankar Chatterjee started his career in a contracting company involved in marine air conditioning and low temperature cargo refrigeration. He joined Voltas, Kolkata in 1977 and handled challenging HVAC assignments on board naval survey vessels, Large Ship Tank Landing (LSTL) ships and frigates built by Garden Reach Shipbuilders & Engineers. Subsequently he served Voltas in Delhi and Mumbai, handling complex projects like Semiconductor Complex Limited, Mohali and Maruti Udyog, Gurugram. In 2003, he joined ETA Engineering LLC, Dubai and handled prestigious district cooling projects like The Burj Khalifa and Dubai Mall. In 2010 he joined Sterling & Wilson, Kolkata as General Manager (HVAC Projects), from where he retired at the age of 65 in 2013. Post superannuation, he handled a special assignment for one year at Al Futtaim Engineering LLC, UAE for a district cooling project in Doha.

Knowing the Enemy

A battle cannot be won without knowing who the enemy is. Therefore, in today's context, it is worth knowing a few facts concerning viruses, especially about their ease of survival and rate of growth.

While the ease of survival depends on the body temperature of the host in which they grow, the rate of growth depends on how closely the hosts coexist. Bats, for example, that have been transmitting time and again various types of viruses, could coexist in tens of thousands in a single small cave. This permits viruses to grow at an unimaginable pace. Thus, at the time of an outbreak, breaking the chain of transmission becomes a matter of paramount importance. In order to take corrective measures, let us have a clear understanding of the difference between bacteria and viruses.



Figure 1: High resolution photograph of bacteria

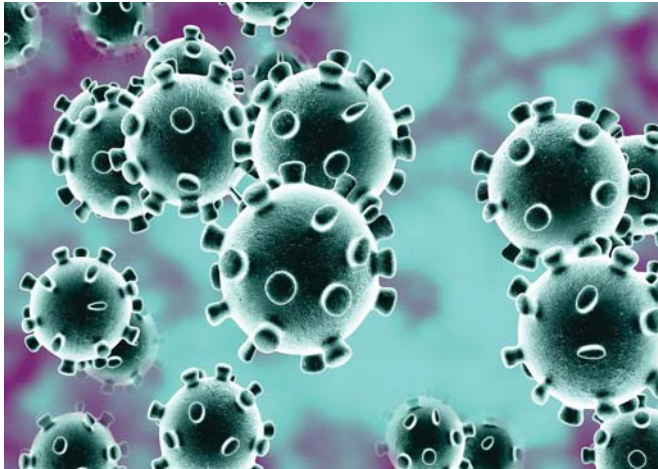


Figure 2: The novel coronavirus

What are Bacteria

- They are a category of living mono-cell organisms that can survive independently.
- They have no gender; in order to grow, they split and multiply.
- They cause localized infection in the body, but can be killed by antibiotics.
- Compared to viruses, they are many times larger, as large as five microns.
- Bacteria can be bad or good. For example, the bacteria that converts milk into yoghurt is good.
- Upon gaining access to a body through contaminated food, drink, objects, cuts, contacts with an infected body or inhaling droplets released when one is coughing or sneezing, bacteria cause diseases.

What are Viruses

- They are not living substances, thus have no cells.
- In order to exist and grow, they must be hosted by living bodies like animals or plants.
- Having been hosted, they make the host cells replicate their DNA and create new viruses at a highly accelerated pace, destroying the host cells.
- Viruses are capable of infecting the entire body and cannot be destroyed by antibiotics.
- Vaccines prevent their spread, and antiviral medicines retard their replication by interfering with viral enzymes only, but cannot destroy them
- They spread from host to host through air-borne droplets discharged while coughing, sneezing, etc. by an infected entity, or direct contact with the person, animal and insect bites, not caring to wash hands before eating and after handling pets, etc.
- They are much tinier in size than bacteria, less than one micron, thus difficult to identify.

We now have a basic awareness of the characteristics of bacteria and viruses. This awareness will help us in deciding the course of action for HVAC systems post COVID-19.

It is often said that the mightiest weapon one can possess is the precise awareness of the enemy.

Devising the Strategy

What matters the most to occupants among all the parameters of air conditioning is the temperature. There is a need for experimenting to ascertain its ideal value in the post COVID-19 scenario. State of the art new generation HVAC systems, methodically installed, are capable of contributing a lot in the current scenario. It is true that virology is a complex, vast and different subject altogether, yet the challenge remains that the improved post COVID-19 HVAC systems must possess the capacity to substantially control the existence of the virus in the conditioned environment. HVAC systems for several special applications had been controlling bacteria levels by employing filters with the appropriate efficiency. Now is the time to innovate means of stricter control over transmission of viruses, which cannot be destroyed.

So, let us revisit the concept of conventional air conditioning and the improvements that must be devised to make it compatible to the current requirements. For decades, we have been practicing HVAC engineering. During this period we also have brought about enormous improvements that include energy efficiency, integrating the system with BMS, etc. However, now onwards it is going to be a different challenge. The rate of success may be anybody's guess, but our sincere and all out efforts would fetch us a few long awaited goals, namely:

- Fine tuning of the air side design and equipment, emphasising healthcare.
- Perfecting our existing practices to ensure superior overall performance.
- Zero tolerance towards irregularities and negligence pertaining to healthcare and safety aspects.

Preparing the Action Plan

Even the longest journey in life commences with a single step. Let us start our journey to innovate ideas that will protect users from viruses like COVID-19. First of all, prioritization of activities has to be done. Before plunging into the core areas of concern, taking a look at the *established comfort zone* is necessary.

Conventional Comfort Zone

Defining the term 'comfort' is not easy. The range of related parameters is very wide. Human beings have survived in temperatures ranging from less than minus 50°F to over 200°F. Yet, a vast majority of people feel comfortable within a very narrow range of temperatures, viz. 12°F; to be precise, 68°F to 80°F. The range of temperatures and percent relative humidity of the 'comfort zone' were established based on the results of extensive surveys conducted across the world among various age groups of people.

The impact on human body of each combination of dry bulb temperature, relative humidity and air velocity within the limits of the comfort zone, is capable of providing the same feeling of warmth. Accordingly, comfort air conditioning systems are designed to satisfy the core conditions of the zone. For example, summer dry bulb temperature ranging from 72°F to 76°F and

relative humidity around 60%; and winter dry bulb temperature ranging from 68°F to 72°F with relative humidity around 55%. The internationally recognized air conditioning comfort zone was established giving the utmost priority to the occupant comfort level alone; in other words, to the combined effect of DB, RH and air velocity.

The priorities now have to be amended in line with the requirements of the post COVID-19 scenario. In the changed scenario, the priorities will be the aspects related to occupant health, primarily the purification of air. The control over dust and bacteria level in the environment, and the efficiency to curb transmission of viruses would be some top priority concerns. The majority of diseases being air-borne, surveillance would be the highest on air side parameters, air handling equipment, and function of air side controls.

We shall now proceed with identifying areas that are in our control as well as the improvements and innovations required to cope with the challenges ahead.

Setting the Best Achievable Goal

In order of priority, the key actions are:

- Extensive filtration of air in order to arrest contaminants like micro-organisms, viruses, etc. This is the bull's eye that we need to hit, in order to be successful in our mission.
 - Bringing about necessary changes in room environment parameters that would serve the present purpose better, and not copy-paste standard values of conventional air conditioning.
 - Introduction of adequate ventilation air, not as per the rule of thumb but the volume that would be sufficient for respiration and instant removal of heat and CO₂ released around the occupants.
 - Use of precision and heavy duty controls for accurate functioning to create an ideal room environment in terms of temperature, RH, air motion, dust and bacteria level, and control of viruses.
 - Treating the air for applications calling for 100% fresh air with an independent air handler, provided with filters of appropriate efficiency for pre-cooling and reducing the dust level.
 - Ensuring that all conditioned rooms are under positive air pressure to prevent infiltration of contaminated outdoor air and condensation of moisture on metal objects and glass surfaces.
 - Ensuring that plant operation is not left to the mercy of the operating staff, but integrated with BMS for accurate and intelligent operation, yielding better end results at reduced cost.
 - Replacing of all controls specially on the air side with solid state microprocessor based controls, in order to ensure accurate functioning of dampers, reheat, preheat systems and air handlers.
- Ensuring perfect throw of supply air from the outlets, which would entrain sufficient room air and mix well before getting diffused, resulting in uniform temperature across the room.
 - Modifying grilles and diffusers as required to ensure proper air distribution in the rooms to meet the actual load concentration, and not fixed CFM per person or square foot.
 - Ensuring large enough path to limit the velocity of return air travelling back to the air handlers from the rooms within the designed value but not exceeding 150 feet per second.
 - Ensuring strict adherence to methodically scheduled preventive maintenance of air handling equipment and filtration system for accurate control of air volume, airway resistance, etc.
 - A thorough balancing of air from the air handlers to the furthest grilles and diffusers of all the branches must be carried out and checked periodically to ensure that adjustments are intact.
 - Ensuring that the inner surface of the entire ducting, especially supply air duct, is cleaned thoroughly at regular intervals by professionals with the requisite expertise and arrangements.

Note : All the good work done by the filtration system to clean and purify the supply air would go in vain if the ducts carrying it all the way from air handlers to the rooms possess contaminants.

The cumulative cost involved in adhering to the above would be insignificant:

1. The high side of the system and the water circuits would call for hardly any changes.
2. The corrective measures stated above would also complement energy saving efforts.

In the Battlefield

Filtration

The conventional comfort air conditioning systems possess limited capacity for filtration, i.e. to arrest large particles like dust and lint and not sub-micron particles. In order to prevent transmission of viruses, the most effective strategy is to employ an appropriate filtration process in place. However, what prevents us from incorporating this facility is the cost. Let us analyse the filtration system needed *vis-a-vis* the cost involved.

- Viruses are less than one micron in size. A vast majority of them can be arrested by a filtration system with filters having a cleaning efficiency down to 0.3 micron. These higher efficiency filters are usually installed inside a plenum in the discharge side of the air handlers or at the supply air terminals that introduce air in the conditioned rooms.
- In order to ensure the durability of these fine filters, disposable and inexpensive pre-filters need to be installed in the return air path with the required cleaning and holding efficiency to arrest larger particles like dust and lint.
- When fine filters of the HEPA category are installed in the supply air plenum chamber, the ductwork between the plenum and the air terminals should be of stainless steel or equivalent, in order to prevent penetration or generation of

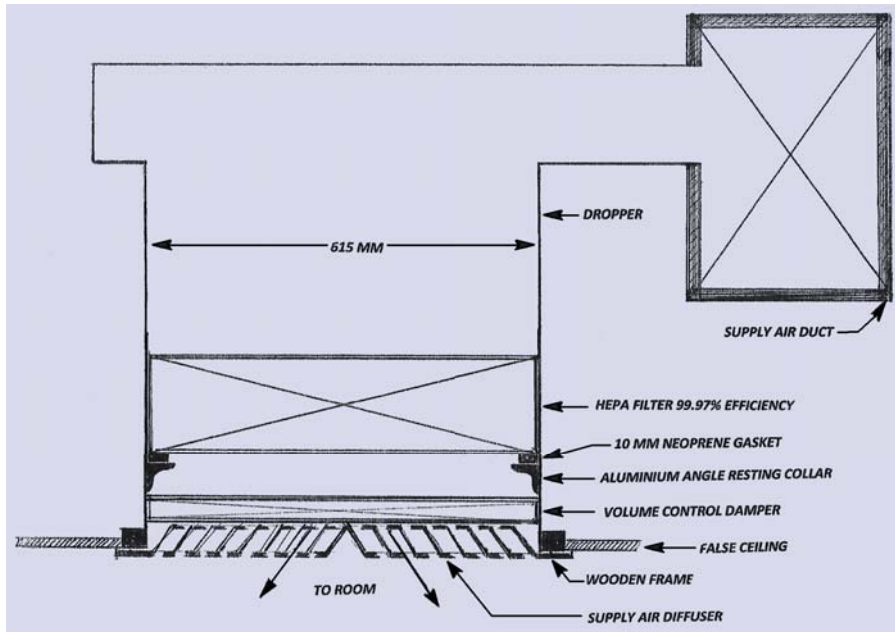


Figure 3: Details for installing HEPA filter at air terminal

contaminants within the duct. This cost can be avoided if the duct design permits HEPA filters to be installed directly at the individual air terminals.

- Installation of the required number of pre-filters would also be an additional cost.
- Apart from the initial cost of all the items as mentioned above, the filtration system would incur an operating cost too, namely the cost of enhanced fan power to overcome the airway resistance due to higher pressure drop across the series of filters.

The cumulative additional cost for an appropriate filtration system in place, inclusive of operating cost, would only be a small fraction of the overall installation cost of the AC system. Therefore the system provider can make a decision based on cost versus benefits.

Criteria for Selecting Filters

Fine filtering of room air being the area of utmost concern, it is worth knowing certain important aspects of the subject. There are two different criteria for ascertaining the effectiveness of a filter employed in air conditioning system.

- The capacity to hold dust particles in terms of weight.
- The extent to which the air passing through it can be cleaned, i.e. the tiniest particle that can be arrested by the filter.
- The cleaning ability of the filter is obviously important for the room environment, as the bacteria use dust particles as the mode of transportation. Therefore, curbing the spread of diseases by bacteria must be achieved by fine-filtering the air fed to air conditioned spaces.

Needless to mention that being much smaller in size, controlling viruses is more difficult and calls for much finer filtering.

Holding Capacity of Filter vis-à-vis Efficiency

Let us examine this aspect in the light of the current scenario.

The task we need to perform is to make the environment free of dust, micro-organisms, viruses, etc. But the million dollar question is, what is the level that will suffice? The answer is yet not very clear. All we know as of now is that the tiniest particle we need to arrest is the virus, which has a size less than one micron. But the fact of the matter is we are yet not aware of enormous varieties of unknown viruses, leave aside the awareness about their abnormally low sizes.

Under the circumstances, designers of HVAC systems select filters of various efficiencies and follow strictly the guidelines laid down concerning treatment of air, which stipulate that particle sizes less than 10 microns cause respiratory problems, since the human

body can filter out particles not less than 30 microns. The process of air treatment in HVAC is by means of purification of air and adding fresh air in the correct proportion for healthy breathing.

Mechanical filtration is the process of arresting dirt and particles mechanically by employing filters of the required capacity and efficiency. The selection of filters depends upon the class of cleanliness the spaces call for to suit the applications, namely from class 10,000 to Class 1:

- Filters used for initial cleaning of supply and return air for comfort air conditioning, i.e. arresting particle size >10 microns.
- Filters used in air conditioning of hospitals, operation theatres, control rooms of power stations, etc. for arresting particle sizes one to ten microns.
- Efficient Particulate Air (EPA) filters used in test laboratories, pharmaceutical factories, electronics product facilities, etc. for arresting particles <1micron, i.e. bacteria, smoke, fumes, etc.
- High Efficiency Particulate Air (HEPA) filters with arresting efficiency 99.97% at 0.3 micron, used for arresting microbes for final cleaning down to Class 5.
- Ultra Low Particulate Air (ULPA) filters with arresting efficiency 99.999% at 0.12 micron for arresting aerosols for final cleaning down to Class 1.

Electronic air filtration uses an electronic device meant for filtering coarse particles and other impurities floating in the air. The finer particles in the air such as bacteria and viruses are electrically charged, arrested on a plate and prevented from returning to the air stream. Unlike other air filters, electronic air filters are not required to be cleaned more often than once in three months. These filters are suitable for any type of HVAC systems. Electrostatic charge can enhance the trapping efficiency for micro-fine particles by 2,000%.

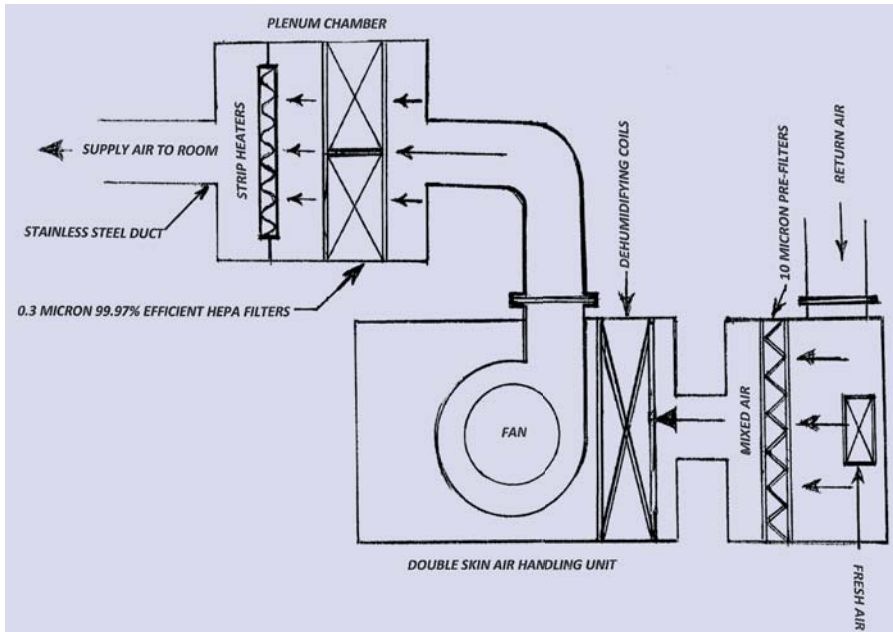


Figure 4: Schematic diagram of fine filtration system

Air purifiers gained a tremendous boost worldwide in the recent past. The air we breathe needs purification for protection against diseases like asthma, allergies and several air-borne unhealthy contaminants such as odours, cigar and cigarette smoke, etc. HVAC systems may be provided with several methods of air purification:

- HEPA filters have excellent filtration capacity but cannot arrest odours, gases and chemicals.
- Negative ionization device removes particles from air by magnetically attracting them.
- Activated carbon filtration absorbs volatile organic compounds (VOCs) such as perfumes, chemicals and formaldehyde that help people with 'multiple chemical sensitivity'.
- Ultraviolet (UV) lamp fitted in the purifier breaks the DNA of micro-organisms and arrests viruses and bacteria.
- Ozone generation involves cleaning contamination by generating ozone. This method is not as effective and reliable as the other methods. It often poses several problems.

Ventilation and Fresh Air Control

In order of priority, it is the next priority after filtration so far as purification of room environment is concerned. One must not confuse its actual requirement with the standard recommendations of conventional air conditioning, like 10-15% of circulation. It is important to be aware of all the adverse effects of poor ventilation:

- All occupants release heat and moisture depending on their activity level.
- They constantly emit CO₂ as per their metabolic rate.
- All occupants add more or less to the room odour level.
- While sneezing or coughing, occupants discharge air borne droplets.

In order to replace this contaminated air around the occupants and to dilute its concentration in room air, *fresh air*

as per the actual need, and not as per the rule of thumb, must be introduced instantly. As a matter of fact, adequate ventilation is an essential part of effective air treatment that calls for continuous introduction of fresh air into the controlled spaces. The exact ratio of conditioned to fresh air depends largely on the application. As mentioned above, comfort air conditioning usually requires 10% to 15% fresh air, but spaces like auditoriums, restaurants, etc. call for more fresh air based on the number of people. Operation theatres and FCUs in hotel rooms need 100% fresh air.

Air Side Parameters and Equipment

Air conditioning systems had been effectively contributing to the curbing of various air-borne diseases. However, the present circumstances would demand exercising even stricter control on such diseases. In order to make it happen, some measures need to be implemented.

Design and Selection Criteria

- Replace legacy single skin air handling units with bypass dampers, with new generation units.
- Select filters of appropriate cleaning efficiency that meets the application requirements.
- Design and implement logic control for accurate and auto operation of air handlers through BMS.
- Replace three-way motorized valves with two-way valves
- Employ only digital controls for fail-safe accurate operation of dampers, especially fresh air.

Workmanship Criteria

- Check the set of filters for appropriate efficiency before installing in air handlers.
- Ensure that the filters are installed correctly in position and the gaskets are intact.
- Ensure perfect sealing around the filters that would not allow any air to bypass them.
- Ensure scheduled maintenance of the filters to prevent them from clogging.

Faulty workmanship during installation can rob the filtration system of its entire capability.

Making the Design Health-centric

Famous Grandmasters often sacrifice a pawn on the chess board to pave the way to checkmate the opponent. So it is logical that users of air conditioning would be willing to compromise their comfort level a little, say by 1-2°F, if it is beneficial from healthcare and safety point of view and in conserving some

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continued from page 59

energy. The term 'feeling of warmth' is relative. It varies with the occupant's state of mind, activity level, physical condition, age and other factors. So a minor variation would not be unbearable.

Having a definite clue that both bacteria and viruses have close relationship with the ambient temperature that helps them to survive, making a minor amendment in the standard HVAC design would be worth it. We have discussed in the foregoing that comfort ACs in tropical countries are usually designed for 74°F +/- 2°F DB and 65 +/- 5% RH for summer. Shifting the range by a couple of degrees to 77°F +/- 1°F would hardly affect the comfort level, but can be a major advantage for occupant health.

Enhancing room air velocity marginally offsets the effect of elevated dry bulb temperature substantially.

Similarly, the upper limit of the RH range can be elevated from 65% to 70%. After all, the very purpose of controlling relative humidity is to permit evaporation of sweat as soon as it is released by the glands in our body, to keep the core body temperature steady around 98°F. This cools the surface temperature of our body and prevents it from becoming sticky. As long as the RH does not exceed 70%, the weather remains comfortable. In comfort air conditioning, RH higher than design can be tolerated for a longer time than higher temperature. Besides, the changes yield substantial conservation of energy in the bargain.

Case Study

- In a comfort AC application, in order to maintain a room dry bulb temperature at 74°F +/- 2°F and the relative humidity at 60 +/- 5%, the chillers are required to supply chilled water at 44°F.
- For the requirement of elevated parameters, i.e. dry bulb temperature at 76°F +/- 2°F and the RH at 65 +/- 5%, the chillers are required to supply chilled water at 46°F.
- The elevation of water temperature by 2°F results in various cost and energy savings.
- The elevated water temperature permit chillers to operate at higher suction pressure, reducing the kW.
- At low load conditions, an even higher chilled water supply temperature will satisfy the cooling load.
- The higher room RH would permit the dehumidifying devices to operate with higher apparatus dew point (ADP).
- The saving of energy is approximately 1% per °F increase in supply chilled water temperature.

Increasing chilled water temperature at low load conditions is now a proven method of conserving energy.

Let us now analyse the savings in the initial cost of new installations.

- The modified operating parameters would permit downsizing of the chillers.
- The design, having permitted downsizing of chillers, would call for downsizing of all other ancillary equipment and accessories accordingly.

Considering the above scenario, the industry and end users will have to take the final call.

Let us now analyse the benefits of elevating the upper limits of comfort zone parameters, besides making it more healthy and safe for the occupants. Let us make a case study in order to ascertain the benefits that could be derived by bringing about the proposed changes.

Emphasis on Indoor Air Quality

Of late the industry has become serious about indoor air quality, but the focus has been on other priorities like energy efficiency, automation etc., possibly due to lack of awareness and intention. The outbreak of COVID-19 would bring into focus the real worth of maintaining good indoor air quality. Since IAQ impacts occupational health and safety, certain health hazards like high blood pressure and pulse rate, sweating, head-ache, dizziness, breathing problems, etc. can be avoided by adhering to the recommended IAQ. There could be several standards to be adhered to in order to control the IAQ. The criteria that govern the performance of HVAC system by controlling parameters listed below automatically cover some of the ideal IAQ parameters.

- Temperature as per the comfort zone of the season.
- Relative humidity commensurate to the application.
- Dust, bacteria and other impurity levels.
- Adequate fresh air intake and air motion in conditioned spaces.
- Proper air distribution that ensures temperature variation within 2°F across the conditioned space.

However, overall control of indoor air quality covers several other aspects apart from the above. Other significant aspects, which include sources of contaminants that must be controlled are:

- *Human Respiration:* In overcrowded confined spaces, because of human respiration, carbon dioxide (CO₂) is produced at an accelerated rate that can cause its level to exceed the safe limit. Human metabolism is the greatest source of CO₂ that causes breathing problem, high blood pressure and several other health hazards to the occupants within a short span of time.
- *Building Materials and Furnishings:* Materials from newly built buildings and furnishings emit VOCs that make the occupants uncomfortable.
- *Office Appliances:* During usage, some appliances produce contaminants like carbon, and emit ozone, etc. that is harmful for the occupants to inhale.
- *Excessively High Humidity:* Erratic functioning of humidifiers, sources of water leakage into the room, infiltration of water vapour, indoor plants, etc. promote micro-biological growth,
- *Ducting Network:* Improper or no maintenance of ducting results in accumulation of a thick layer of dust over a period of time, which produces various harmful contaminants, odour, bacteria, etc.
- *Recycling of Air:* Re-entry of exhausted or polluted outdoor air in the conditioned space due to any reason whatsoever



Figure 5: Duct condition before and after cleaning

contaminates the room air, causing breathing problems for occupants.

- **Humidification and Pre-heating:** Applications such as air conditioning of operation theatres, treated air for FCUs in hotel rooms, and processing halls in pharmaceutical works that require fresh air during low ambient humidity and temperature, call for humidification and/or pre-heating of intake air.

IAQ Parameters

There is a need for strict adherence to the ranges of key IAQ parameters, regardless of the air quality index (AQI) of the particular location.

- Carbon dioxide (CO₂): not exceeding 1,000 PPM
- Carbon monoxide (CO): not exceeding 100 PPM
- Ozone (O₃): not exceeding 0.1 PPM
- VOCs: not exceeding 0.1 mm Hg
- Dust, smoke and ash level: not exceeding 10 mg/m³

AQI describes the prevailing quality of air of a particular location.

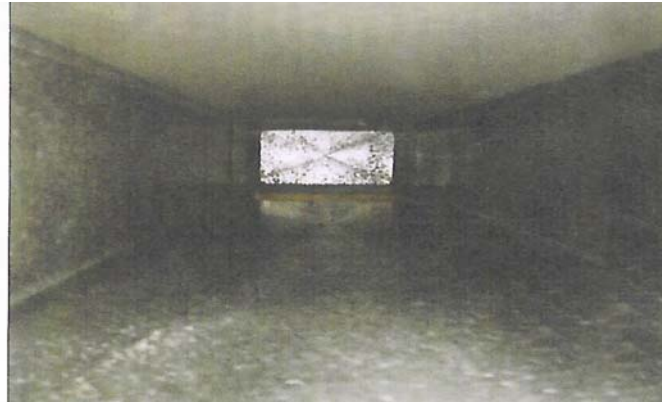
Cleanroom Application

Air acts as a transporter of floating particles in the environment. Hence its cleanliness is crucial to restrict the contaminants within a specified limit. Various standards of cleanliness are maintained for meeting the requirements of the specific application.

Cleanrooms call for special type of construction to facilitate controlling the environment of confined spaces meant primarily for manufacturing products of the following categories:

- Electronic hardware including precision produces like Integrated Circuits (microchips).
- In pharmaceutical factories, a cleanroom serves the purpose of controlling bacteria, viruses, several types of pathogens, etc. for manufacturing various drugs.

The most widely used filter in cleanrooms is the High Efficiency Particulate Air (HEPA) grade filter with the capacity to arrest 0.3 micron diameter particles at 99.97% efficiency, used in most of the cleanroom applications. The equation used in calculating filtering efficiency is:



$$E = (1 - D/U) \times 100$$

Where E = Efficiency (percent)

D = Downstream contaminant level

U = Upstream contaminant level

It is desirable that the filters employed cause minimum pressure drop and permit maximum air flow.

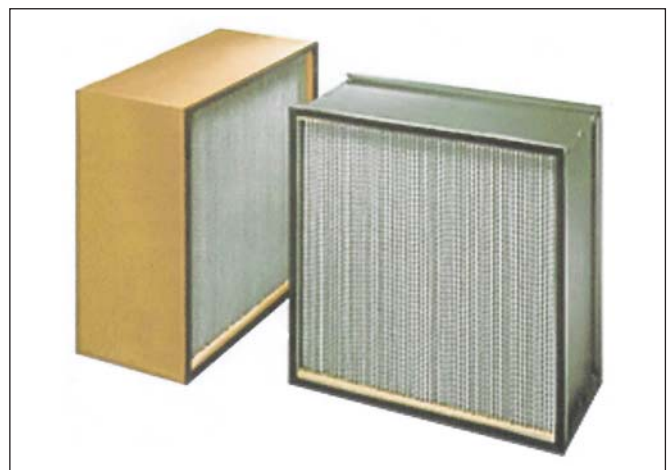


Figure 6: HEPA filters

A HEPA filter is 99.97% efficient down to 0.3 micron particle size at a face velocity of 4-5 feet per second. (Incidentally, a human hair is around 100 microns thick). It is made of 100% micro-fibreglass with a diameter of around 3 microns, forming a highly dense mat. While passing through the mat, particles in the air stream are arrested by one of the following three processes:

- The process of diffusion
- The process of interception
- The impact on inertia

The air stream, upon entering the filter, gets thoroughly diffused and intercepted. The impact of these factors, combined with the retarded velocity that impacts the *inertia* of the airstream also, permits arrest of particles down to 0.3 microns. Filtering at this microscopic scale eliminates some viruses too.

High efficiency filters of HEPA and ULPA categories are factory tested, packed and transported in protective sheet

metal casings. However, during unloading and shifting to the place of temporary storage at site, it could sustain damages like distortion, pin holes, cracked gasket, etc. So it is very important to check the filters thoroughly for any damage prior to installing them.

Even the slightest damage to a HEPA filter could cause serious impairment of the clean room environment.

Air Movement

In addition to temperature and relative humidity, the other factor that matters the most in creating a comfortable environment is air motion. However, its importance has never been adequately emphasised in the past, unlike the other two factors. At higher than the design temperature and RH conditions, air movement is the most effective and inexpensive way to achieve a comfort level. This is because higher air velocity removes dissipated heat, exhaled CO₂ and odour faster. Therefore air movement deserves its due priority in designing an HVAC system.

Need for Awareness

A large number of users do not fully understand the concept of air conditioning. For them it is simply cooling of air. The definition of air conditioning nowhere mentions the word 'cooling', but refers to simultaneous control of temperature, relative humidity, air movement and air cleanliness. The controlled temperature in air conditioned environment has a relationship with the metabolism and core temperature of the human body, and we know that, in isolation, it has no bearing on comfort. It is wrong to consider cooling as the yardstick for measuring the efficiency of air conditioning.

Let us take the case of an air conditioned railway coach. A vast majority of the passengers would demand maximum cooling regardless of the prevailing temperature. Their growing demand would compel the AC attendant to operate all the units on full load, including the standby capacity. Moreover, they would also ensure that all the overhead fans are ON, thereby virtually converting the coach into a cold storage. Often the temperature would go down to 70°F or even lower. On the other hand, while going to bed at night they would make sure to wrap the blankets that are provided by the Railways. As a result, elderly travellers and children would be most uncomfortable.

So the questions that arise are:

- Why at all should an air conditioned environment call for the use of a blanket for a healthy person?
- Why would the AC operator need to switch ON the standby units even when the ambient temperature is favourable?
- Why should the sick and elderly passengers be forced to suffer discomfort?

In fact, if an infected person is travelling during the incubation period, the infection would spread faster at the lower temperature.

It is worth taking a look at the ambient temperatures of the European countries that reeled under the onslaught of the deadly virus. During the peak period of confirmed infected cases, the ambient temperatures of all those countries and the USA were below 60°F. It does not appear to be a mere coincidence. It is reasonable to assume that the spreading of viruses has a relationship with the average ambient temperature.

Another area that calls for better awareness is infiltration of outdoor air. The most common complaint of occupants regarding air conditioning is less cooling. In an endeavour to instantly resolve the complaint, the operating staff would close fresh air dampers in order to reduce the outdoor air load and increase the cooling effect, but in vain.

Without fresh air intake, the conditioned space no longer remains under positive pressure to prevent infiltration. The inrush of humid and contaminated ambient air into the conditioned spaces due to the difference in densities between indoor and outdoor air, results in several adverse effects such as:

- Allowing dust, bacteria and other contaminants directly into the rooms.
- The humid air, upon reaching its dew point, starts to condense on cold surfaces in the space.
- The air gives up heat of condensation and adds sensible heat to the room air due to the temperature difference.

In view of the above, it is by far better to ex-filtrate a little conditioned air than to permit infiltration. Unfortunately, a vast majority of HVAC systems in the country are not BMS controlled but dependant on the operating staff who have limited awareness of the critical aspects of air conditioning.

To offset the effect of infiltrated outdoor air, additional CFM as well as lower ADP is required.

Conclusion

While the magnitude and devastating impact of the novel coronavirus worldwide is difficult to fathom, what remains in the control of HVAC professional is to convert it into an opportunity. Since the subject is related to environment, safety and healthcare, the HVAC industry is the one most suited to play a role. HVAC professionals must accept the challenge and make the most of it.

Air conditioning had always been expensive and shall remain so, so long as its utility is restricted to mere comfort. However, the time has come when it can become indispensable to healthcare and safety, giving true value for money.

Like all the previous pandemics such as the Spanish Flu, Plague, SARS (COV2) etc., COVID-19 too would be controlled one day. Researchers are leaving no stones unturned to find a remedy, including plasma therapy and anti-body tests. A breakthrough is just a matter of time. In the meanwhile the HVAC industry, instead of looking at the issue from the disaster management point of view, must grab the opportunity by helping to arrest its spread. The industry must graduate to becoming a life support system against air-borne diseases, apart from providing comfort. ❁



Practical Approach to Design Challenges for COVID-19 Facilities

By Sameer Mehta Hosmac India, Mumbai

Introduction

COVID-19 or the strain of coronavirus disease that was first identified in 2019 is now known to be a virulent strain. Much has been written on the subject and much more has been discussed in the industry as it has become the most significant disruption in our lifetimes.

There have been instructions about preventive care, lockdowns, social distancing, self-quarantine and vigorous hand-washing. Significantly, it has now come to the fore that COVID-19 is not merely a contact infection contracted by exposure to large droplets thrown up in the course of coughing and/or sneezing, but is virtually an airborne infection – as the organism can remain suspended in air long after it is expelled.

A colleague had drawn up a projection of the incidence soon after the lockdown was announced, and while the numbers were scary, scarier is the fact that as of date, she is startlingly close to the actual numbers. How does the healthcare industry cope with this? And what role would the HVAC industry play?

About the Author

Sameer Mehta has been in the healthcare infrastructure industry for over 18 years, and is currently responsible for projects at Hosmac India, encompassing design, project management and equipment planning. His exposure spans from administration and finance to medical planning, architecture and engineering. He began his career at Hosmac with a cardiac super-specialty in Mumbai and has been instrumental in projects aggregating over 16 million square feet. New products and services such as Lender's Independent Engineers and Build Services have been introduced, making Hosmac Projects the first hospital consultancy firm to venture into these spaces. A stickler for conformance to healthcare standards, he strongly believes in the need to comply with international design standards and accreditation norms that are based on evidence. He has also reached out to various budding professionals by sharing his learnings in academia at various business schools and institutions.

Quarantine and Isolation

The scope of this write-up focuses on suspected and confirmed positive patients and not on suspects.

Suspects, by dint of having been exposed but yet not presenting with symptoms, are a subject of quarantine. Quarantine is for people who may have been exposed, but not developed symptoms and therefore need to be isolated from those who have not been exposed. Self-quarantine can be in a room within home. A person may be quarantined in a dedicated facility or, in cases of exigency, hotel rooms too.

More often than not, the ordinary individual presenting with symptoms will go to the neighbourhood clinic or healthcare facility. It takes time and space to assess and to evaluate. During the primary examination, a sample

(typically a swab from the nose or the throat) is drawn from the patient and tested. As at the time of writing, there are over 140 government testing centres and 65 private laboratories. A cursory check with the healthcare industry has indicated test turnaround times ranging from eight to 24 hours. How does one manage the patient until then?

One comes across instances of large quarantine facilities being set up in stadia and barracks, most certainly for want of better alternatives. But in doing so and creating a cohort of suspects, there is a very high probability of the symptomatic and/or the asymptomatic carrier exposing all others in the cohort to the very real risk of contracting the infection. Therefore, a patient presenting *with* symptoms and awaiting results must be accommodated in an infectious isolation room.

As the test result arrives, depending on whether or not the patient tests positive, he/she may begin to display further symptoms of the disease. It is estimated that about 10% (some say up to 20%) of the patients, especially with co-morbidities, may require critical care.

WHO has notified that COVID-19 patients undergoing aerosol generating procedures, such as positive pressure ventilation – bilevel positive airway pressure (BiPAP) and continuous positive airway pressure (CPAP), endotracheal intubation, airway suction, high frequency oscillatory ventilation, tracheostomy, chest physiotherapy, nebulizer treatment, sputum induction, bronchoscopy, etc. could potentially be sources of airborne transmission. Even turning the patient to the prone position or disconnecting the patient from the ventilator – seemingly simple procedures – expose the health care worker to risk. It is known that respiratory distress is one of the symptoms of COVID-19 and one or more of such procedures are only to be expected.

The International Health Facility Guidelines specify infectious isolation rooms with additional barriers beyond the conventional anteroom, for quarantine isolation. It is advisable to accommodate such patients in a quarantine isolation room that is also designed and equipped as a critical care bed. This allows the health care worker to don protective gear while entering the room, but also

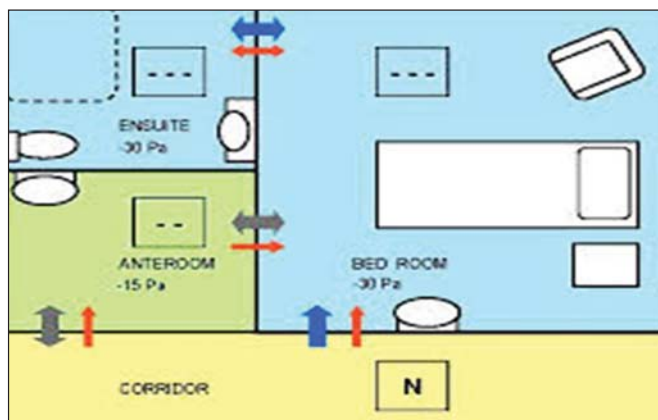


Figure 1: International Health Facility Guidelines for isolation rooms. Blue arrows: beds, patients; Grey arrows: staff, visitors; Orange arrows: airflow

allows exit through another room essentially for de-gowning, disinfecting and disposals.

HVAC Design Considerations

Isolation Room

The key to a negative pressure isolation room is relatively simple: equip the room with an exhaust that extracts more air than the supply. A key consideration is that the exhaust must not be clubbed with other exhaust systems in the building, not even that of toilets, so as not to encounter the possibility of a back draught and inadvertent contamination. There have been contemplations around natural ventilation, cross-ventilation, etc. as an alternative to HVAC. However, such an arrangement is fraught with the challenges of dust, vermin, discomfort in the event of extreme temperature and humidity, inadequate air changes and importantly, unintended airflows of the air from the room. Therefore, a properly designed HVAC system is a safer bet to contain the infection while maintaining the patient in a comfortable environment.

The design considerations for the HVAC system for an isolation room are:

Temperature

Maintaining temperature is desirable but not critical, except in case of critical care bed-spaces.

Relative Humidity

RH is to be maintained at 55+/-5%, as is ordinarily comfortable for the occupant.

Air Changes

A minimum of 12 total Air Changes Per Hour (ACPH) and two fresh ACPH must be maintained for the patient room. The ante-room may be maintained with 10 total ACPH. Air re-circulation by means of a room unit to meet the ACPH requirement is not permitted.

Filtration

Supply air does *not* require HEPA filters. The air must be exhausted and not recirculated. There are two schools of thought regarding the location of exhaust grille/diffuser. One recommends placing the exhaust ducts 150-300 mm above floor level to discharge vertically externally. The Facility Guidelines Institute recommends discharge above the patient, head-side.

Pressure Gradient

The room should be maintained at negative pressure of (-)15 pascals in case an ante-room is not provided; else the ante-room should be at (-)15 pascals and the patient room and the *ensuite* toilet at (-)30 pascals. In any case, the pressure gradient between two adjacent, pressurized zones should not be less than 15 pascals. Clearly, airflow must be from the corridor through the ante-room (where provided) to the patient room.

Monitoring

There *must* be adequate means of monitoring the differential pressure on a continuing basis.

Power Back-up

It is mandated that the system should have a power back-up so there is no chance of the pressure gradient being neutralized or reversed.

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The Royal League

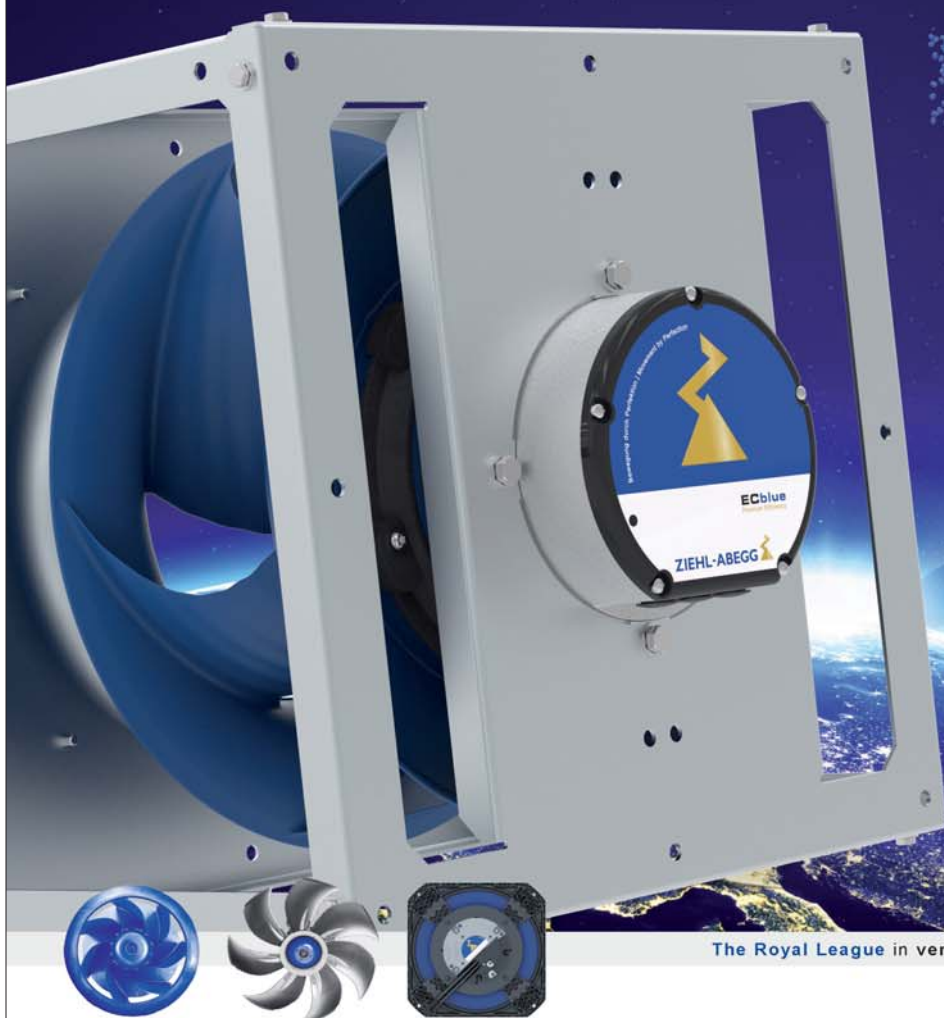
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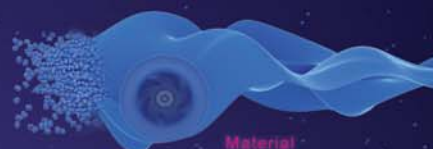
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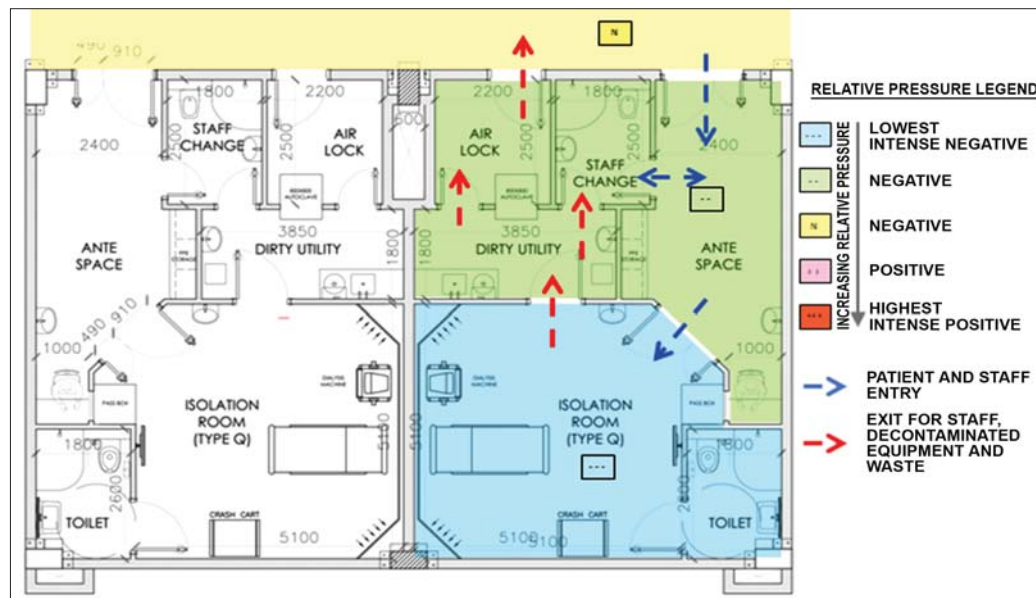


Figure 2: Class Q quarantine room

Treatment Facilities

The governments, and quite a few hospitals in the private sector too, have and are setting up COVID-19 treatment facilities, some of them temporary. Space and resources usually being constraints, one may consider the following scheme:

- Chiller or VRV – either source – may be considered. The lead time for sourcing, availability of space, budget and phased development are various considerations that help determine the choice.
- Air handling unit (AHU) with two-stage filtration (coarse + micro-vee) is mandated for all patient spaces. Where height is a constraint, one may have to resort to a treated fresh air (TFA) unit coupled with fan coil units in the rooms. While recirculating units are not encouraged, the once-through system design ensures there is no cross-infection, the rooms are afforded individual temperature control and maintained at negative pressure with ease.
- Provide for dehumidification (strip heaters or desiccant dryers) to avoid high humidity levels as we contend with pre-monsoon and monsoon climatic conditions.
- Consider ducted exhaust that is *not* combined with other exhaust ducting within the facility. The exhaust must be discharged such that it is not directed towards any fresh air intake. A distance of minimum 8m is mandated. Where this poses a challenge, one may provide for a receiver where the air is treated at 75°C for 15 minutes to disinfect the exhaust. Alternatively, provision of HEPA filter in exhaust has been considered acceptable.
- Wall-mounted pressure differential manometers (magnehelic gauges) with alarm, for continuous pressure monitoring, are easy to install. It will be important to allow a time-delay for the alarm trigger to allow for the times when the doors are opened; this will reduce the incidence of false alarms.

Conversion of Existing Facilities

However, where existing facilities are sought to be converted into isolation rooms, the following may ease the proposition:

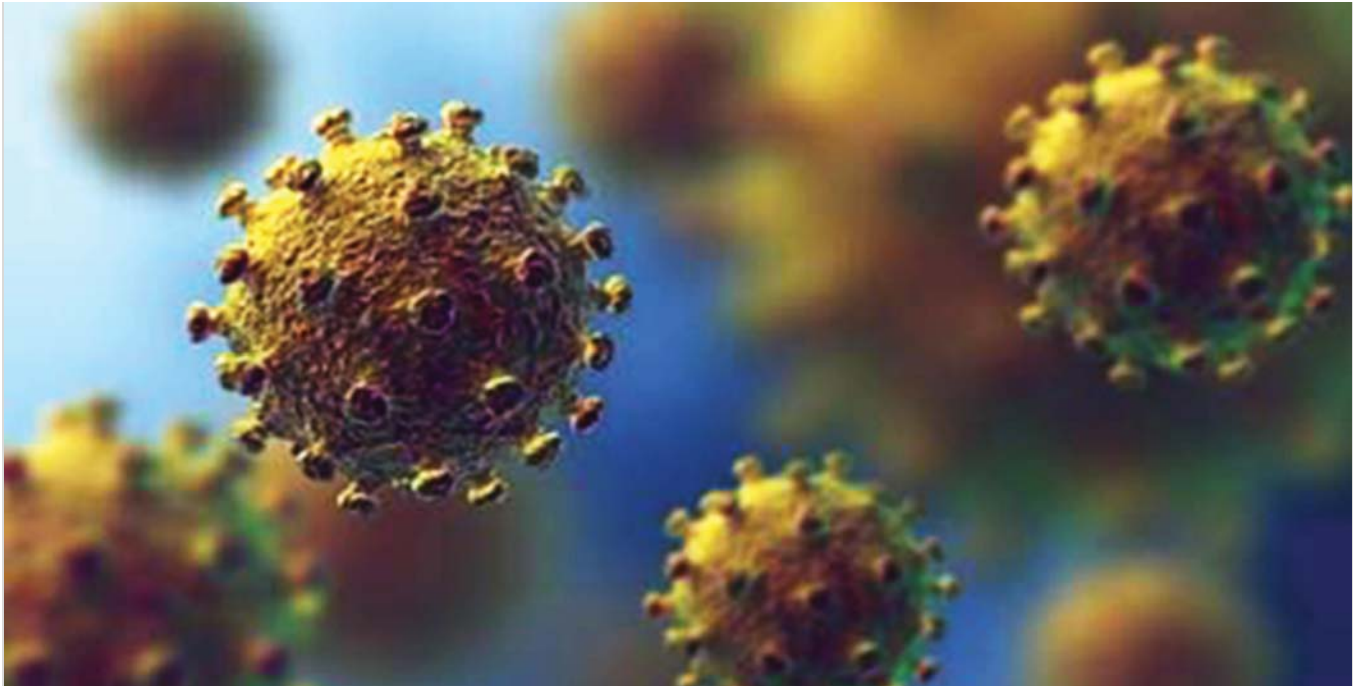
- Single occupancy rooms are easier to convert into isolation rooms. Please note that this will not hold good for critical care.
- Doors to the room and any other unintended opening must be checked and sealed.
- Door seals may be considered along with shutters to avoid leakages.
- Typically, single occupancy rooms are designed for four ACPH, fed through a TFA unit and the corresponding exhaust provided through the toilet. While it may not be feasible to augment the overall ACPH to 12, as mandated by augmenting the air supply, the toilet exhaust would need to be replaced with a higher capacity depending on the supply and the room volume calculations. This is owing to the fact that the typical in-patient accommodation is designed for neutral pressure. Also, it would be important to ascertain and ensure that there is no fresh air intake in the vicinity of the exhaust, and that the exhaust is not close to other habitable spaces.
- Till the time a magnehelic gauge is installed, a flutter strip should serve the purpose as a short-term, interim arrangement.

Please note that this is not ideal and not as per recommendations, but is better than placing patients in a multiple occupancy ward.

The healthcare facility should be equipped to provide dialysis, extra corporeal membrane oxygenation, diagnostics such as X-ray, CT scan, ultrasound, doppler and procedural spaces such as an operating room, bronchoscopy, etc. These require their own set of ventilation and air-conditioning requirements.

Queries, if any, may be sent to the Editor and we shall try and answer these to the best of our abilities.

- Pre-fabricated and pre-insulated ducting and piping can reduce the installation turnaround time.
- There are instances where VAV boxes have been deployed for supply to isolation rooms. One may question whether this is admissible, especially considering the mandated constant volume systems, given the mandate for the defined minimum ACPH. This works well when an electronically commutated exhaust fan is correlated with the air supply, controlled through building automation systems.



Restarting HVAC Operations After a Prolonged Lockdown

By **E. R. Muralikanth** Proprietor, M. K. Services, Chennai

Introduction

A lockdown is a long shutdown of business and establishments within the boundaries of a territory, to safeguard the population from potential forces that can jeopardize lives due to natural or manmade errors.

Some examples of such natural potential forces are heavy earthquakes, heavy landslides, forest fires, and spread of disease (such as the present COVID-19).

Examples of manmade errors necessitating a lockdown are the Bhopal gas tragedy, accidental explosion in a petrochemical plant, nuclear power plant faults and the nuclear bomb.

During a lockdown offices, factories, malls, shops, cinema halls, schools and colleges, religious places and many more establishments that can pose a hazard if open, are shut down. Some establishments may be exempted on a need basis.

Some health problems associated with a lockdown occur from indoor air within confined space, cold, cough, skin rashes, and eye irritation.

All parts of the country are currently under lockdown with different degrees of severity. Calibrated relaxation is taking place, depending upon the situation in each area.

About the Author

E. R. Muralikanth is a mechanical engineer with more than 30 years of experience, presently working as a freelance consultant providing consultancy services in HVAC, fire protection systems, storage tanks, utility and chemical process piping systems. He is associated with some of the leading architects and MEP consultants in Chennai, mainly for cleanrooms and hospitals. His core areas in HVAC are cleanroom design, low RH systems requiring lower than 15% RH, process flue gas treatment for chemical factories, dust control systems for powder handling processes, and HVAC integration with fire protection systems. He has been working with different industries in the past 30 years, mainly associated with chemical factories and pharma industries, where indoor as well as exhaust air quality is important.

Sources of Infection

The main sources of infection are bacteria, virus, fungus and amoeba. They enter the body through air (nasal and optical), water and food (digestive system), air and water (skin), direct into the blood through injections (infected syringes, expired drugs), and in some cases through open cuts and wounds.

Nasal infection can present as cold, cough, pneumonia, bronchitis, asthma, etc. Optical infection can take the form of conjunctivitis and similar eye allergies. Infection of the digestive system can take the form of typhoid, jaundice, diarrhoea, etc. The skin can

exhibit skin burns, rashes, fungal growth in feet and armpits, secondary infection on exposed wounds, etc.

HVAC Systems During Lockdown

All HVAC systems would have been switched off during the total lockdown phase. They are the main consumers of energy, and the main source of pure or impure air within conditioned spaces. What are the possible problems one can come across while the systems are restarted after a prolonged shut down?

Table 1 gives the possible effects of a long shutdown, and the corresponding concerns. The corrective action is given in subsequent paras.

Table 1: Effects of prolonged shut down of an HVAC system

| S. No. | Description | Concern |
|--------|---|---|
| 1 | Excessive dust accumulation in AHU, ducts, coils, etc. (similar to the dust when a house is locked for 10-15 days) | When AHU is started, all dust will immediately start flowing across, and cause breathing difficulty |
| 2 | Humidity and dust form a scale in AHU, inside the duct, and in the conditioned space | Humidity is trapped in conditioned space for long duration, hence high concentration of fungus, mould, etc. |
| 3 | Bird droppings, dead rats, lizards, insects, etc. inside AHU room (if not properly closed) | Bad smell, and high source of infection |
| 4 | Wherever return duct is left open in AHU room (AHU without return air plenum), dead rats, lizards and birds above false ceiling, may be in the duct also; live rats and birds may also be present | Bad smell, and high source of infection |
| 5 | Filters in AHU damaged due to rat bites | Such filters are useless, and arranging new filters at short notice may be difficult |
| 6 | V-belt becomes hard after long stoppage and causes high friction; its elasticity is lost | V-belt may break shortly after starting the unit |
| 7 | AHU drain tray contains stagnant water for long time, including water in U-trap | Bad smell, promotes bacteria and fungus growth |
| 8 | Drain line choked with dead insects, rats, etc. | Bad smell, and high source of infection |
| 9 | Heavy fungus growth above false ceiling due to cold air trapped for long time | Causes dust allergy |
| 10 | Control cables and signal cables damaged by rat bites | Unit may not start, or not work properly |

Stagnant Spaces

Stagnant air spaces during normal operation are shown in Figure 1. The main reason for stagnation is very low air changes per hour (less than 6 ACH). Microbe colonies form easily in stagnant spaces.

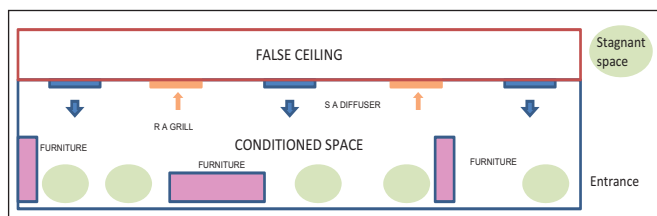


Figure 1: Air stagnant points during normal operation

Microbe Colonies

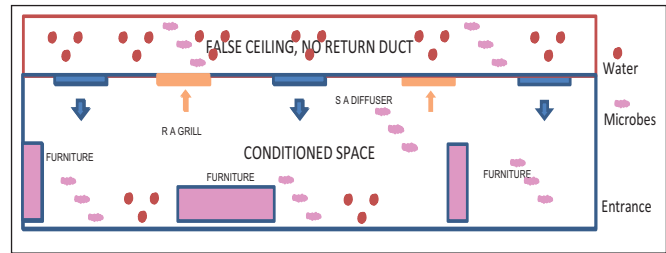


Figure 2: Formation of microbe colonies

Air Handling Units

Air handling units constantly deliver filtered air and maintain the specified room conditions such as temperature, relative humidity, limits of contamination (particles), etc. They are used in applications like restaurants, airports, offices, factories, hospitals, cinema halls and auditoriums. After a prolonged shut down, the left over moisture in the unit and dust cause growth of microbes.

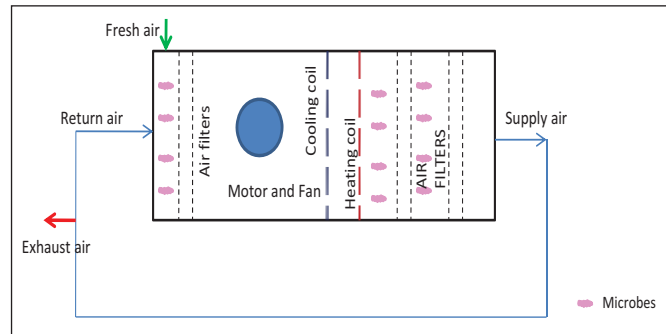


Figure 3: Air handling unit with microbe colonies

When the unit is started after a long shut down, all microbes settled in different parts start moving due to blower pressure. They come to 'life' due to various nutrients, and start multiplying. Microbes need a carrier to move from place to place (air, water, objects, humans, animals, etc.)

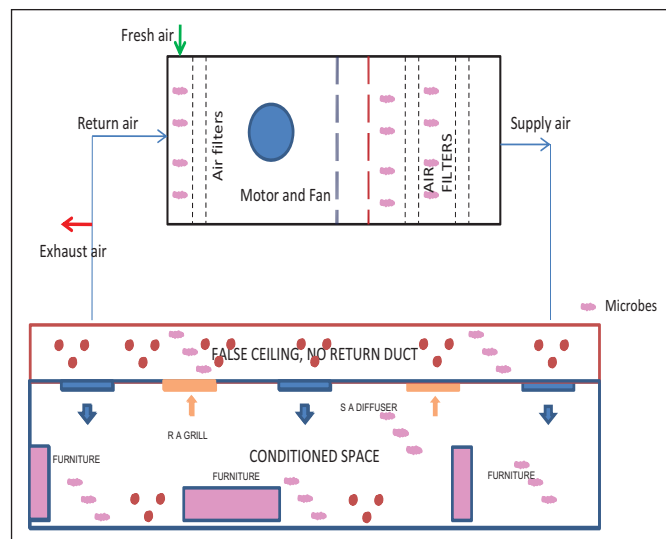


Figure 4: Conditioned space without return duct

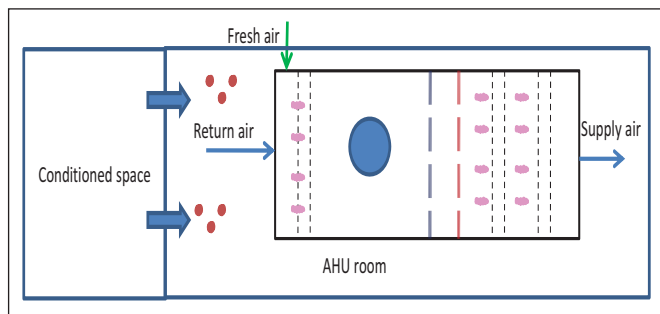


Figure 5: Return air from conditioned space without RA plenum in AHU room

In the example shown in Figure 5, there is no return air plenum in the AHU, and air returns directly to the AHU room. A lot of condensation takes place in this room, which promotes microbial growth. The AHU room door is difficult to open and close due to the high vacuum pull of the fan. This pulls all the microbes from the conditioned area, especially close to the AHU room door.

Start-up Procedure

Filter Cleaning

In the AHU, there are typically 20, 10 and 5 micron filters. Generally, synthetic filters are woven type and washable. They can be washed with detergent solution. Filters with media are not washable, and are meant for dry cleaning only.

Remove all the filters from the AHU and from the duct path wherever installed. Remove terminal HEPA filters also if applicable.

For washable synthetic filters, the procedure is:

- Soak the filters in normal soap solution (any detergent) for 30-45 minutes.
- Gently hand-clean them with soft plastic brush (an old tooth brush will do fine).
- Do not apply hard pressure or steel wire brush to clean the filters. The wire may damage the filter media.
- Remove the filters and dip them in clean water for a few minutes.
- Keep the filters in a clean natural ventilated place for natural drying of water droplets.
- Clean the filters with a hand blower (single phase blower generally used by AC technicians).
- Filters will be clean and ready for use.

Caution

Do not use diesel, kerosene, petrol, thinner or similar flammable solvents to clean the filters. These solvents leave behind a thin oily layer and dust sticks to the filters easily and is difficult to remove.

Do not clean the filters with compressed air. Compressed air will hit the media like a bullet and damage it. Compressed air velocity is 3,000 fpm, and filters are designed for 500 fpm only. Compressed air will also damage the adhesive glue used to fix the filter with the frame.

Cleaning of AHUs

- Drain the old condensate water if trapped in the coil section. Use compressed air to clean the drain pipe till the farthest end to remove stagnant old water in the drain line.
- Pour a little sodium hypochlorite solution (1:100) in the U-trap and the drain pipe to kill the bacteria or fungus, if any. Clean the inside surfaces of the AHU with wet cloth using sodium hypochlorite solution (1:100). This is a disinfectant and will kill bacteria, fungus, etc. present in the AHU chamber.

Caution

Please use rubber safety gloves and face mask while handling sodium hypochlorite solution. If it splashes on the eye, flush with plenty of water and seek medical attention. Follow the safety precautions laid down by the manufacturer.

- Use water spray gun to clean the cooling and heating coil fins with soap solution and sodium hypochlorite solution (1:100).

Caution

Protect all inside electrical parts like motor, door limit switch, lamp, electrical heater, etc. from water contact. Water entry into these parts can be potentially dangerous.

- Replace the V-belts since they can break any time after the AHU is put into operation. It is not advisable to run with the same belts since they would have already served for 18 months or more.
- After cleaning the coil fins, remove all the water collected in the AHU chamber.
- Clean the inside with dry cloth.
- Open chilled water across the coil, drain the old water, and close the drain valve. Check for any chilled water leakages in the coil, gasket, etc. and attend the leakage.

For DX systems, check the gas pressure. If need be, add more gas.

- Start the AHU without cooling coils and filters. The air flow will push all the settled dust into the duct, and it will fall into the conditioned space.
- Run the AHU for 15-20 minutes, then stop it for 15 minutes. This will allow the disturbed particles in the conditioned area to settle down.
- Open the AHU chamber, and clean the surfaces internally with wet cloth.

Repeat this exercise 10-12 times.

- Simultaneously, send a few people into the conditioned space to check for any bad smell due to bird feathers, lizards, rats, dead insects, etc. and clean the premises. During this period, keep all the doors and windows of the conditioned space open. This will help in displacing the old stale air from the conditioned space, and the bad smell can be removed faster. If the toilet and pantry are a part of the conditioned space, switch on the exhaust fans also to expel stale air from the space.

All the above cleaning activity may take a full day or even more depending on the number of air conditioned systems in the building, number of floors, etc. Adequate material and manpower must be deployed to work on this effectively.

After completing all the above, the system will be ready for use. Put back all the filters in place, and start the AHU.

Caution

During these operations, please disengage the BMS. All commands should be in manual mode only. It is dangerous to work in auto mode.

Follow proper LTCT procedure (Lock, Tag, Check, Try) when handling electrical and rotating parts.

When cleaning the AHU with sodium hypochlorite, ensure use of proper PPE. Adequate ventilation is a must since this chemical will release chlorine gas. Heavy exposure to chlorine gas may cause giddiness.

Read the procedure for using sodium hypochlorite given in the safety manual published by the supplier.

Cleaning of Water Systems

There may be air-cooled or water-cooled chillers, or both, in the same premises.

Chilled Water Circuit

Since water circulation has been stopped for a long period, a lot of suspended particles would be stagnant at some places, especially at the elbows, tees, etc.

- Clean the strainer of the pump, and the AHUs.
- Drain all the old water, and provide new water.
- If chilled water chemical dosing is in practice, follow the action

plan of the chemical dosing agency for proper redosing of the chemicals.

Hot Water Circuit

Same as above.

Condenser Water Circuit

- Drain the sump water completely.
- Check for insects, frogs, birds, leaves, algae, etc., and clean or dispose them.
- Follow the same procedure as for chilled water.

After completing the cleaning of AHU, chilled water, hot water, condenser, etc., the systems can be put into operation.

Cleaning and Restart of Split AC and VRV Systems

In some premises there may be multiple ceiling or wall mounted split ACs, or ductable systems. In some premises there may be VRVs with multiple ceiling or wall mounted indoor units or ductable systems. For these systems, open all the indoor units, clean the filters, check for any damage to wires, etc. and switch ON.

Keep the doors and windows open for 2-3 hours with the systems ON.

Some part of the stale air will be replaced by the marginal draft given by the indoor unit fans.

If possible, run the exhaust fans of the toilet and pantry (if they are part of the same conditioned space). This will help in removing the old air faster. ❄

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Eurovent and REHVA Want HVACR Businesses as Essential Services

Eurovent and REHVA have called upon all relevant authorities in the European Union (EU) and globally to recognise the manufacturing, distribution, installation, maintenance, and repair of HVACR equipment as essential business activities and, therefore, exempt them from COVID-19 shutdown orders and travel restrictions. They have asked that HVACR manufacturers must be allowed to ensure a minimum of production and guarantee the availability of spares and replacements.

Meanwhile, several countries around the world have shut down non-essential businesses until further notice. These shutdowns include the manufacturing of HVACR equipment and components, and might lead to shortages

of supplies and services that ensure the integrity of HVACR installations in critical infrastructure during and in the wake of the COVID-19 pandemic, both in Europe and regions dependent on supplies from European manufacturers.

Eurovent and REHVA have also called upon the EU and all its member states to coordinate better to ensure the continuity of supply chains in critical infrastructure. HVACR equipment supports critical infrastructure in the healthcare, food cold chain, data centre and building sectors. Prolonged shutdown of HVACR manufacturing activities might have severe consequences during and after the COVID-19 pandemic.

ASHRAE Organizes Virtual Conference for US\$ 99

ASHRAE is organizing a four-day live 2020 ASHRAE Virtual Conference at a reduced registration fee of US\$ 99 for ASHRAE members in this period of COVID-19. The cost to attend the virtual conference is US\$ 329 for non-members that includes an annual ASHRAE membership.

The virtual conference will cover more than 90 technical sessions, updates from Society leaders, and virtual networking events. Technical sessions will be available starting June 22, with conference activities and additional live sessions addressing the latest information relating to the COVID-19 pandemic taking

place daily starting June 29 and continuing through July 2. Conference registration is now open at [ashrae.org/2020virtual](https://www.ashrae.org/2020virtual). For more details, please visit:

<https://www.ashrae.org/conferences/ashrae-2020-virtual-conference>

“While we realize that there is no substitute for the special level of interaction that face-to-face conferences provide, we are excited to present this unique format for our members to interact, collaborate and learn,” said 2019-20 ASHRAE President Darryl K. Boyce, P.Eng.

ASHRAE Offers COVID-19 Building Readiness/ Reopening Guidance

The ASHRAE Epidemic Task Force has developed guidance on mitigating potential health risks during the reopening of buildings that were closed during the COVID-19 pandemic. ASHRAE's recommendations for reopening buildings are outlined in the frequently asked questions (FAQs) section of its COVID-19 Resources webpage available at:

<https://www.ashrae.org/technical-resources/resources>

ASHRAE Publishes Updated Legionella Guideline

ASHRAE has published an updated guideline to assist in control of legionellosis associated with building water systems. ASHRAE Guideline 12-2020, *Managing the Risk of Legionellosis Associated with Building Water Systems*, provides guidance useful in the implementation of ANSI/ASHRAE Standard 188, *Legionellosis: Risk Management for Building Water Systems*. The guideline is intended for use by owners of human-occupied buildings and those involved in the design, construction, installation, commissioning, management, operation, maintenance, and service of centralized building water systems and components.

ASHRAE Releases Updated Position Document on Infectious Aerosols

ASHRAE's Environmental Health Position Document Committee has revised the position document, 'ASHRAE Position Document on Infectious Aerosols'. The document states that HVAC systems can have a major effect on the transmission of the disease.

This position document provides recommendations on the following:

- The design, installation, and operation of heating, ventilating, and air-conditioning (HVAC) systems, including air-cleaning, and local exhaust ventilation (LEV) systems, to decrease the risk of infection transmission.
- Non-HVAC control strategies to decrease disease risk.
- Strategies to support facilities management for both everyday operation and emergencies.

ASHRAE's Taylor asks WHO to Review 40%-60% RH Policy

Dr. Stephanie Taylor, an infection control consultant at Harvard Medical School, ASHRAE Distinguished Lecturer (DL), and member of the ASHRAE Epidemic Task Group is seeking signatories for a petition asking the World Health Organization (WHO) to review the scientific evidence related to indoor humidity and respiratory immune system response, viral transmission, and virus inactivation.

According to a report, "There is now overwhelming scientific evidence that a mid-range air humidity has significant benefits for human health," Taylor said. "It is very possible for us to be managing the indoor air quality of our public buildings in line with this evidence. The time has come for regulations on indoor air quality to include a humidity level of 40%-60% RH. This is the optimal level for our respiratory immune system and will reduce the spread of seasonal respiratory illnesses and their burden on society."

WHO sets guidance for indoor air quality on issues such as pollution and mold. It currently offers no recommendations for a minimum humidity level in public buildings.

Sandeep Nair has been elevated as the President of Emerson Commercial & Residential Solutions for Asia Pacific, the Middle East and Africa. He has served in various units in Emerson. He holds a bachelor's degree in mechanical engineering and a master's in management. He began his journey with the US-based company in India as a senior manager at Tata Liebert, a



Sandeep Nair

joint venture of Emerson. As he scaled up the career ladder, he got the opportunity to manage people and get a firm footing in lean manufacturing principles. He describes himself as a people person, and believes in the power of teams to win together. In his current position, he plans to look for future growth avenues for the company.

Based in Missouri, the USA, Emerson – a Fortune 500 technology and engineering company – serves industrial, commercial and consumer markets. The company registered US\$18.4 billion in revenue for the financial year ended September 30, 2019. The company's business is grouped into two platforms: automation solutions, and commercial & residential solutions. ❖

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Lars Erik Knaack is the CEO of Denmark-based NOVENCO Building & Industry.

He was recently in India on a business promotion visit, during which the *Journal* interviewed him. Here are some excerpts:

Journal (J): What is NOVENCO's engagement with the Indian market?

Lars Erik Knaack (LEK): For almost a year, NOVENCO Building & Industry has been having a representation in Mumbai, headed by Devendra Mishra. NOVENCO is entering the Indian market with a wide range of high energy efficient fans for wide use in different applications and industries. The product range covers high energy efficient axial flow fans, car park and tunnel jet fans.

J: Please tell us in brief about the history of your company.

LEK: NOVENCO Building & Industry dates to 1947, when we began design, development and production of the first fans. Much has followed and vast experience has been gained with implementation and adaptation of products and systems. Today, this knowledge and achievements go into our research and development of new products and improvements that are on the technological forefront, and in sync with the UN Sustainable Development Goals.

J: What is NOVENCO's flagship product?

LEK: At NOVENCO we are proud to make fans for a greener world. Our ZerAx axial flow fans are at work around the clock all over the world to reduce carbon emissions and make this planet a better world and place for everyone. The predominant features of the ZerAx fans are the market's highest fan efficiencies of up to 92%, and a 98% recyclability rating, bringing down energy expenditures and lowering the strain on the earth's resources. The ZerAx is a fan for the environment and the world. This fan is also a world leader when it comes to durability and sound levels. A product lifetime of over 20 years and low sound levels add up to make ZerAx fans probably the most profitable and environmentally friendly fans in the world.

J: What does NOVENCO focus on while designing its fans?

LEK: The importance of energy efficiency to the world as well as to India grows each year. NOVENCO's ambition is to be on the technological forefront when it comes to energy and cost-efficient ventilation. We focus on sustainability in the construction and production of our products and are proud to have launched products that meet market demands as well as the environmental standards of tomorrow.

J: Please give some examples of NOVENCO's innovations in the field of air movement.

LEK: Thirty years ago, when no one thought of jet fans in car park ventilation systems, NOVENCO invented the ductless car park ventilation system. The use of jet fans was a pioneering application and set a new industry standard. Today, NOVENCO still pioneers the use of fans in uncommon fields of application with the installation of axial flow fans in air handling units (AHUs). Manufacturers of plug and centrifugal fans are sceptical for various reasons, but several retrofit projects around the world continue to deliver Proof of Concept (PoC) after installation of NOVENCO's ZerAx axial fans, which result in energy saving of up to 50%.

J: What is the technological edge that NOVENCO's fans have over competitive offerings?

LEK: The big difference between axial, centrifugal and plug fans lies in the operating principle. While centrifugal and plug fans build total pressure from static pressure alone, axial fans build this from both static and dynamic pressures. High-efficiency axial fans are in this way much more energy efficient, with reduced operating costs and lower carbon emissions. The NOVENCO ZerAx fans for AHUs are complete plug-and-play solutions for easy installation in new projects or for retrofit of existing installations.

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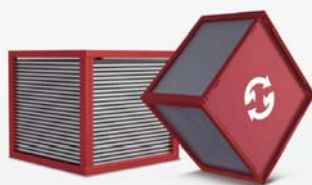


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Daikin adheres to E-waste Rules notified by MoEF. For more information on E-waste disposal and exchange policy please contact our Customer Service Centre. We have not authorised any E-commerce website to sell our products.



COOLEST TIME TO RENEW YOUR ISHRAE MEMBERSHIP

To grow in a robust system
refer a friend or colleague

New Membership

| Membership Tenure | For 3 Years | For 10 Years |
|-------------------|--|---|
| Registration Fee | Rs. 1,500 | Rs. 1,500 |
| Annual Fee | Rs. 3,000 (for 3 Years @ Rs. 1,000 per annum) | Rs. 7,500 (for 10 Years @ Rs. 750 per annum) |
| GST | 18% | 18% |
| Total (Incl. GST) | Rs. 5,310 | Rs. 10,620 |

Visit
www.ishraehq.in
for more information.

Membership Key Benefits

- An excellent platform to envision your professional advancement
- Networking opportunities, meet the like-minded people
- Let ISHRAE promote you!
- Opportunities for local involvement at the regional and chapter level
- Exclusive discounts on Publications and workshops
- Frequent invitations to various Conferences, Seminars, Workshops and Exhibitions
- Get periodic updates on ISHRAE accomplishments through newsletters

About the Society

- Established in 1981
- Over 12000 HVAC&R Industry members
- Over 7500 student members
- 41+ chapters spread in various cities all over the country
- Conducts technical training courses through educational arm "ISHRAE Institute of Excellence"

For further queries, please contact
ISHRAE Headquarters

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