Best Practices in HVAC and Indoor Air Quality Technologies

A summary and guidelines from professionals at Ducts and Cleats

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Paper Overview:

With COVID-19, many businesses and homeowners are seeking to improve their HVAC (Heating, Ventilation, and Air Conditioning) systems. Currently, most buildings' HVAC systems could actually be helping to spread the virus due to the recirculation of air for maximizing efficiency and energy savings. This paper will be exploring related topics including:

1. What is HVAC, and why is it important when thinking about reopening during the COVID-19 pandemic?
2. Do all buildings need a completely new system, or can modifications be made to the pre-existing one?
3. How do different options compare with one another in terms of pathogen (e.g. viruses, bacteria, mold spores) removal?
4. How do different options compare with one another in terms of odor and toxic gas removal?
5. How do different options compare with allergen reduction?
6. How do the different options compare with ease of installation?

What is HVAC and why is it important when thinking about reopening during the COVID-19 pandemic?

A building's HVAC system is responsible for heating or cooling it, keeping those inside comfortable in spite of the outside air temperature. However, there are many airborne contaminants that linger in the air, such as VOCs (volatile organic compounds), pathogens like viruses, bacteria, and mold spores, as well as allergens. With these airborne pollutants, indoor air quality (IAQ) can decline quickly and pose a significant threat to the health of those inside. A wide range of health conditions are related to airborne pollutants including asthma and other respiratory issues, neurological problems, cancers, and birth defects.

Up until COVID-19, not much attention was paid to how to use a building's HVAC in a manner that supported good indoor air quality (IAQ). However, the harmful airborne contaminants mentioned above, including pathogens that are spread through airborne transmission can be spread by the building's HVAC system due to it recirculating air to minimize energy costs and maximize efficiency. Air is typically recirculated multiple times per hour depending on the design. Unfortunately, by recirculating air, contaminated air can be moved from an infected person or from the source of pollution to other parts of the building, thereby exposing other individuals. In fact, building HVAC systems have been found by many studies to play a role in spreading SARS-CoV-2, the virus that causes COVID-19. ASHRAE (The American Society of Heating, Refrigerating and Air-Conditioning Engineers) and the CDC (Centers for Disease Control and Prevention) have released recommendation guidelines that include updating and improving a building's HVAC system to specific standards prior to re-opening. With these guidelines, business owners are starting to examine the different options, but as they do so, they must consider the following:

1) The available IAQ technology types for HVAC systems do not completely remove all airborne particles on their own. However, combined, they should pack a powerful punch to ensure safety.

2) Available IAQ technologies usually have studies completed by their manufacturers. This is something to be aware of as these studies are, on average, not peer-reviewed or completed by unbiased third parties. To make sure that you are getting effective technology, make sure that the manufacturer provides other data from third parties or information from peer-reviewed literature.

So what are some of the types of available IAQ technologies that can be implemented as a stand-alone or added to the pre-existing HVAC system?

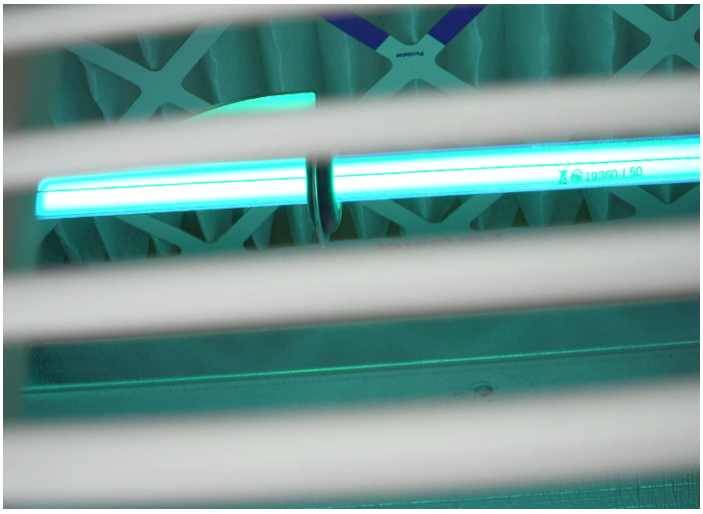
Proven technologies that can be added into a pre-existing HVAC system or on their own include ultraviolet-C (UVC) germicidal irradiation, ozone-free bipolar ionization, the installation of HEPA filters, humidity control, and increased ventilation with outside air. The benefits of each vary, and the remainder of this paper will look at each and their various benefits and considerations.

IAQ Technology: Ultraviolet-C Germicidal Irradiation (UVGI)

Technology Background

UVGI has been utilized in buildings since the 1930s as an air-cleaning technology with great success. The ultraviolet spectrum falls within the electromagnetic spectrum produced by the sun. Ultraviolet light is a shorter wavelength than visible light, and is typically divided into three sub-categories: UVA (315-400 nanometers(nm)), UVB (280-315 nm) and UVC (180-280 nm). UVA makes up 95% of the UV that reaches the earth's surface and causes our skin to tan. UVB, a shorter wavelength, makes up the other 5% and is what causes sunburn. UVC does not reach the earth's surface, which is fortunate because it is the most damaging to our cells' DNA, or deoxyribonucleic acid, which is essential to our body's proper functioning.

UVC damages DNA and its close relative, RNA, by causing mutations (changes) in their structure, known as pyrimidine dimers. This prevents our cells' enzymes from being able to make copies of the DNA, which makes them unable to reproduce. Remember, this type of UV light does not reach the surface of the earth, but we use this wavelength to destroy germs in the



same manner by causing irreparable mutations that lead to the death of the germ.

There is a diversity of UVGI equipment, but the following two types are the most common. In-duct UVGI is where UVC bulbs are mounted in HVAC ductwork or in the HVAC unit itself. The idea behind in-duct UVGI is to have contaminated air flow past the UVC bulb, getting cleaned as it is irradiated. Upper-room UVGI is another option, where UVC lights are installed in the upper part of a room. The bulbs only irradiate, or clean, the upper part of the room where the air breathed out by people in the room would most likely be found. This option is typically found in medical settings such as operating rooms.

Effectiveness and Advantages

UVGI has a long proven history in schools, hospitals, and other buildings. A peer-reviewed science article by Reed (2010) examined numerous 3rd party studies conducted on the efficacy and safety of the use of UVGI in eliminating germs in the air. Reed concluded that if used correctly, UVGI can be safe while at the same time being incredibly effective. ASHRAE also provides a good overview of UVCGI and its advantages, specifically its reduction in germs on HVAC surfaces and in the air, an increase in savings due to cleaning of coils and a possible investment return.

Considerations

There are a few considerations when determining if UVC is the best addition to your building. The first is that although UVC technology kills germs, it does not actually remove them from the air. Thus, an air filter is still required. A second consideration is that the timing and intensity of the exposure is critical for ensuring maximum effectiveness. As mentioned earlier in this paper, HVAC systems, on average, push air through at about 400-500 ft per minute. This is too fast for UVC to be effective and instead needs a slower airflow rate to provide the needed exposure rate when used in the air stream. Another consideration is that safety is required when handling the UV bulb. When the bulb is on, there should be avoidance of direct exposure.

Conclusion

In conclusion, UVGI is an effective and safe technology to help clean the air of germs. Furthermore, it does not require a costly redesign of the building's pre-existing HVAC system, and can either be retrofitted within the current system or nearby. Pairing UVGI with a filtration system is important since the technology does not remove air contaminants, instead killing the germs. When positioning the bulb inside the HVAC system or duct, the bulb should be at an acceptable intensity and should be immediately downstream of the drain pan and cooling coil. As a final note, ASHRAE does provide testing standards for UVGI in HVAC systems so that manufacturers can have their UV bulbs assessed using an industry-approved method.

IAQ Technology: Ozone-free bipolar ionization

Technology Background

Air ionization has been around for quite some time. It involves the production of ions, which are positively and negatively charged atoms or molecules in the case of bipolar (opposite charges-positive and negative) ionization. The ions are produced by an electronic device as air passes by and molecules found in the air are split (e.g. water vapor). The ions stick to air particles like magnets, making the air particles larger and more likely to be caught by the air filter. The ions are effective at eliminating odors by volatile organic compounds (VOCs) by converting them into harmless molecules. The positive and negative charges of the ions also allow them to stick to germs. When they attach to germs, they remove essential hydrogen away from them, causing death or the germ's neutralization so that it cannot infect us.

Effectiveness and Advantages

Although this technology is newer than UVGI, bipolar ionization still has quite a few studies supporting its positive impact on not only germ elimination, but also VOC and odor removal, as well as the assistance of reducing air particles by making them larger and easier to be caught by the building's air filter. In terms of ease of installation, it could not be easier. Being able to be added into the pre-existing system with ease, an ionizer can also be added in a stand-alone unit

with a fan and filter. When ASHRAE standard 62.1 is followed, another advantage of ionization is the reduction of outdoor air required in an indoor space.

Considerations

Since some air ionizers produce ozone in the process, it is important to choose a brand that is ozone free. Ozone is harmful when inhaled, and can be very damaging to the delicate structures of the lungs. Other considerations include the proper placement of the ionizer. A bipolar ionizer needs to be located within the air stream to distribute ions to the desired areas. Due to the limited life of the ions (60 seconds) the location within the ductwork is also crucial as too long of distance for the ions to travel to the desired location will result in low concentrations and less effectiveness in treating a space. Using a portable system that contains bipolar ionization combined with a HEPA filter placed within the room or space itself is one strategy to ensure effective amounts of ions in the space.

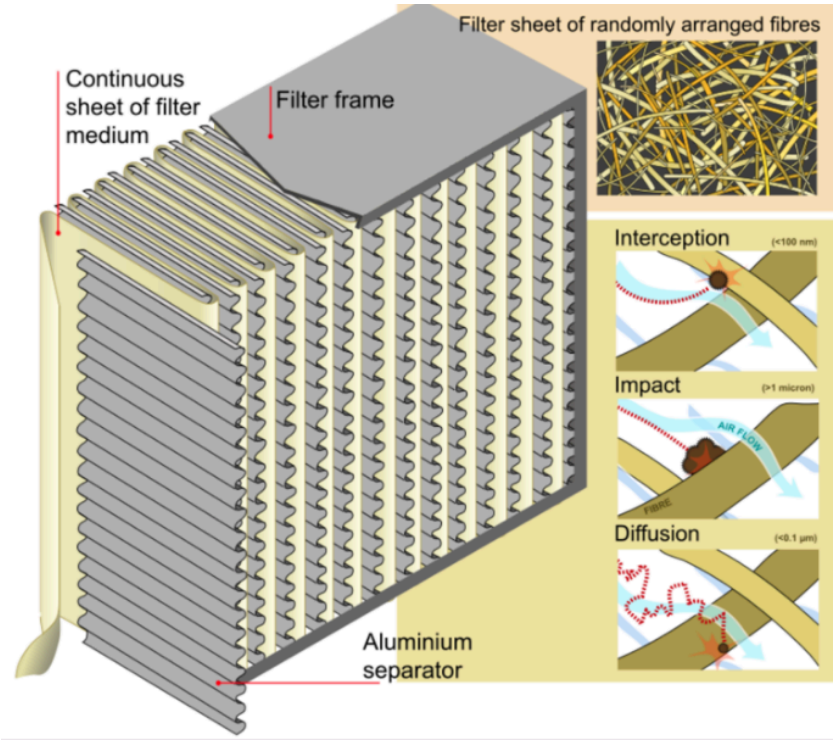
Conclusion

Bipolar ionization and NPBI offer an effective option when used in the pre-existing HVAC system or even on its own. The benefits are wide-ranging, with the ease of installation making it simple to add to any building. In order to remove air particles, the ionizing device must be paired with a filter. When picking out a device, there should be no ozone produced.

IAQ Technology: HEPA Filter

Technology Background

A HEPA (high efficiency particulate air) filter provides high filtration at the highest MERV (minimum efficiency reporting value). The MERV scale ranges from 1-20 and is determined by ASHRAE. A MERV 1 filter will have the lowest removal efficiency while a MERV 20 filter would have the greatest filtration efficiency. Typically, an average low-end commercial HVAC filter is a MERV 7 or 8. HEPA filters are rated at a MERV 17 or higher, being able to filter 99.97% of all air particles that are 0.3 microns or bigger. It is important to keep in mind that these values are based on minimum efficiency, so the filter should do



even better. A HEPA filter is not like a typical air filter, having considerable thickness of multiple mats of fibers randomly arranged to help catch a variety of particle sizes.

Effectiveness and Advantages

HEPA filters are quite efficient at removing air particles. With infectious air droplets (containing viruses and other germs) being around 5 microns in size, a HEPA filter is a highly beneficial addition to a building to help capture these.

Considerations

It is typically a challenge to add a HEPA filter into the pre-existing HVAC system, due to its higher MERV rating. As the MERV rating goes up, so does the airside pressure drop, which will likely require the installation of a larger fan to accommodate the pressure drop. Because of this, adding a HEPA filter into the pre-existing HVAC system can be very challenging, if not impossible. A stand-alone unit with a fan that can accommodate the HEPA filter, however, is a viable non-costly option that still makes adding a HEPA filter into the building viable. Another consideration is that it is beneficial to add a pre-filter in the set-up to help remove the larger particles, leaving the smaller particles to be caught by the HEPA. This extends the usage life of the HEPA. Lastly, HEPA filters are proficient at capturing air particles, but they are unable to trap odors and VOCs, making it important to combine with ionization if the goal is to eliminate them.

Conclusion

A HEPA filter can be a highly effective and simple addition if the pre-existing HVAC allows for the upgrade or a stand-alone feature can be added. Although still more expensive than a lower MERV filter, a HEPA is still an affordable solution. Before adding a HEPA filter, an assessment should be completed to make sure that it can be added into the pre-existing HVAC system or where a stand-alone unit could be placed to make sure it works at its greatest potential. In order to reap all of the benefits, a HEPA filter should be combined with ionization to eliminate odors and VOCs from the air.

IAQ Technology: Humidity Control

Technology Background

Building humidity is conducted by removing or adding moisture to achieve a certain moisture percentage. It can be added by a humidifier inside the HVAC system or in the supply duct work. Moisture can be removed by the normal cooling process. Maintaining the level of moisture in the building typically requires the incorporation of a dehumidification system which will almost always work through the process of re-heat, which works by adding heat to the air that is being cooled in an effort to add dry air to the space. In this way, the HVAC system lowers the moisture level in the air through the normal cooling means, but does drop the temperature too low in the space by doing so.

Effectiveness and Advantages

The ideal humidity range for a space is between 40-60%. Anything above 60% supports mold growth, which can lead to deleterious health effects. On the other hand, relative humidity below 40% facilitates airborne transmission of germs like viruses. Therefore, maintaining the humidity in a space within that range reduces mold growth and airborne transmission of germs.

Considerations

Maintaining a specific humidity level will require added devices to the pre-existing HVAC system would require more space and would also likely add to the system cost. Furthermore, the addition of a humidifier would also require a water connection, which might require recurring water treatment. Most HVAC suppliers provide options for humidifiers to be added into the HVAC system or retrofit the supply ductwork. All devices installed would require the additional installation of a humidistat to accurately monitor the humidity levels in the space.

Conclusion

Maintaining humidity levels in a space is good for both IAQ and the HVAC system in general. Controlling humidity helps to prevent mold growth and airborne transmission of diseases. It can often be the first step that is looked at when trying to improve a building's IAQ.

IAQ Technology: Ventilation with Outside Air (High Ventilation)

Technology Overview

The ventilation of a space using conditioned outdoor air at a higher than normal rate is known as high ventilation. Minimum rates of outside air introduction into the building is determined by ASHRAE standard 62.1, as well as many building codes. When the set minimum rate is exceeded, this is considered high ventilation. Typically, adding more outside air is done using an air economizer. An air economizer can adjust the amount of outside air being brought into a building based on the temperature and relative humidity of the air both indoors and out. Outdoor air units are also used to bring in more outside air. They have been developed to produce a lower airflow rate than average. Considering it is solely outdoors, an ancillary HVAC system should also be present to still control the indoor space's temperature and humidity. The most common ancillary system is Demand Controlled Ventilation (DCV),

which measures carbon dioxide levels (correlated with occupancy inside). With a rise in carbon dioxide levels, the introduction of outdoor air also increases.

Effectiveness and Advantages

One of the simplest ways to improve IAQ is by increasing high ventilation. ASHRAE standard 62.1 provides guidelines for the ventilation rate requirements and procedures. Furthermore, many building ordinances have gone beyond this standard, adding even more stringent ventilation standards.

Considerations

Incorporating high ventilation in a space is advantageous unless it is in an area where outside air pollution is of concern. Furthermore, enabling a greater increase in outside air often will depend upon the redesign of the pre-existing HVAC system, which can be costly. Another downside is that the increased amount of outdoor air that needs to be cooled or heated to meet the needs of the inside space also adds much more cost and is not often economical.

Conclusion

Improving a building's ventilation with outside air is often the first measure that can be implemented. However, the process of installing the proper equipment must be dealt with carefully and the right device for the building chosen wisely, making an assessment of the current system a good decision.

Summary of IAQ Technologies

Technology	UVGI	Bipolar Ionization	HEPA Filter	Humidity Control	High Ventilation
What is it?	Ultraviolet light produced by a UV bulb kills germs by causing DNA mutations	Device that produces positive and negative-charged ions that stick to germs and other air particles, making them more likely to be caught by the air filter	Filter with at least a MERV 17 rating. Captures at least 99.97% of all air particulates 0.3 microns or bigger	Maintaining an indoor space's relative humidity levels between 40-60%. Reduces mold growth and airborne transmission of diseases	Increasing more outside air in an indoor space beyond the minimum required rate set by ASHRAE

How well does it improve IAQ?	Reduces airborne transmission of diseases by killing germs	Reduces germs, VOCs, odors, and makes air particles larger to help filters catch them	At minimum efficiency, catches 99.97% of all air particulates that are 0.3 microns or bigger	Reduces mold growth and airborne transmission of disease when between 40-60%	Improves IAQ by adding cleaner outside air into an indoor space
Effects on HVAC efficiency	Typically cleans coils so improves efficiency	Minimal	Efficiency decreases as MERV rating increases	Usually lowers efficiency	Efficiency decreases as ventilation increases
Considerations	-Does not eliminate germs from the air- only kills them -Does not eliminate VOCs or odors -Does not remove air particulates -Direct exposure is harmful	-Works best with a filter to help remove air particulates -Some devices produce dangerous ozone	-Difficult to add in pre-existing HVAC systems, often requiring a stand-alone unit or a redesign in order to have one in the building -Does not eliminate VOCs or odors	-Requires additional space and more power required from the fan	-Should not be used in areas with outside air pollution -Could require a redesign

Best Practices in HVAC and Indoor Air Quality Technologies Conclusion

Every building is unique, and thus the best options for improving the IAQ of each building will be different. Some options might not work with a building's pre-existing HVAC system, and thus, a stand-alone unit that includes those options may be one way to incorporate these otherwise unfeasible options. This paper summarized the most common IAQ technologies, their effectiveness and benefits, as well as considerations for each. Every step taken to improving a building's IAQ is one more step towards protecting its occupants from indoor air pollution. Overall, the use of multiple technologies is often the best way to go to provide the maximum protection.

Hagborn, M., Nordgren, J., Nybom, R., *et al.* 2015. Ionizing air affects influenza virus infectivity and prevents airborne-transmission. *Scientific Reports* 5: 11431.
Reed, N. 2010. The History of Ultraviolet Germicidal Irradiation for Air Disinfection. *Public Health Reports* 125(1): 15-27.