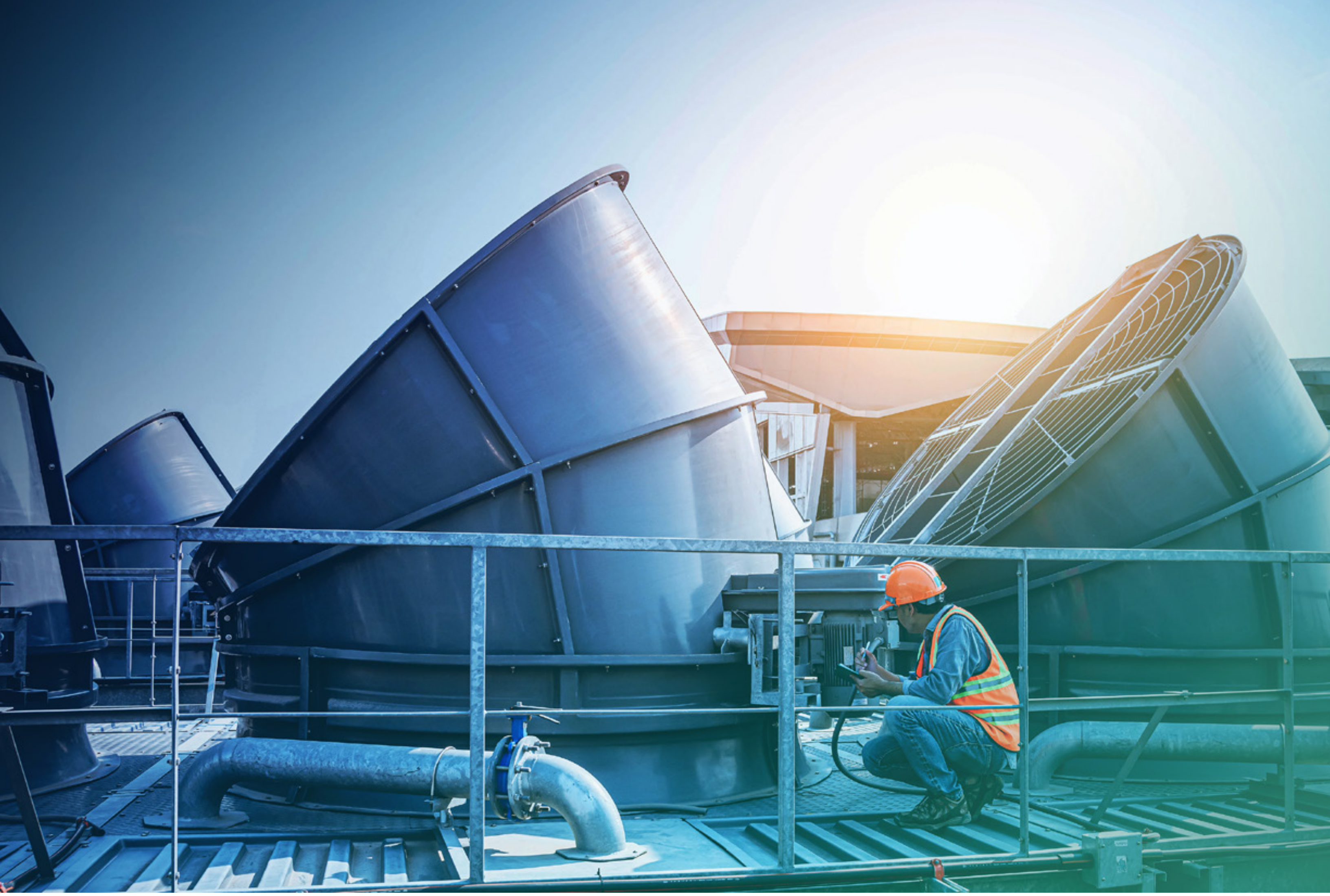
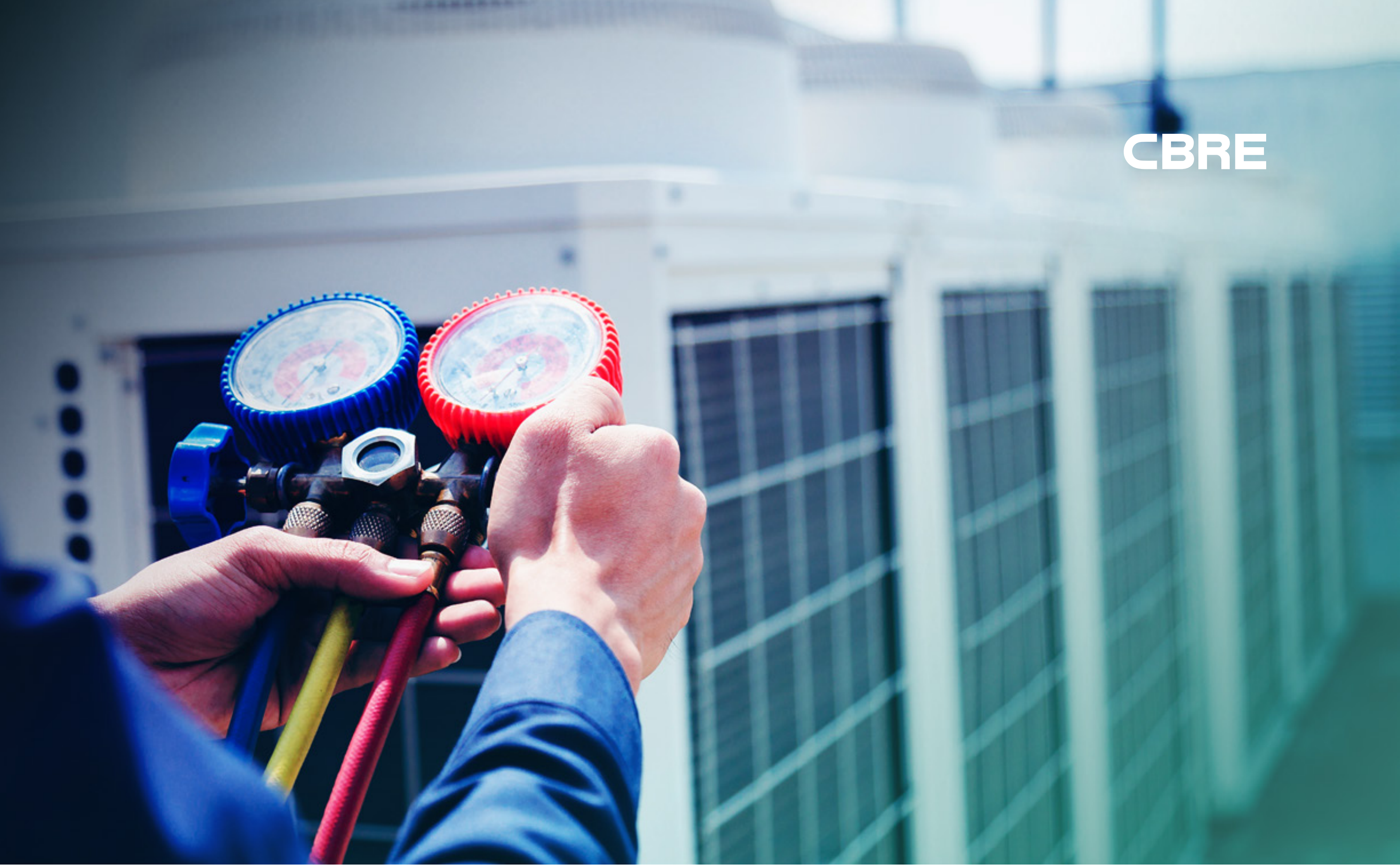


UNDERSTANDING
HVAC & Indoor Air Quality Technologies & Practices

Insights and Guidance from Experts in CBRE Project Management

JUNE 2020

CBRE



Summary

Many building owners and occupiers are exploring HVAC modification strategies as part of their workplace reopening strategies.

+ Why are people looking at HVAC when thinking about strategies around reopening the workplace?
+ Do I need a new HVAC system, or what modification options exist?
+ How do they compare in terms of air quality improvement?
+ How do the options compare as far as cost?

This white paper provides a comparison of the most commonly deployed strategies, along with a detailed overview of each.

Strategy Overview

A building's heating, ventilation, and air conditioning (HVAC) system has always been known as the mechanical system in the building that appropriately heats and/or cools the building and its occupants. However, the perceived role of the HVAC system is changing. The recent COVID-19 pandemic has placed a lens on potential building impacts to occupant health and safety, and therefore, on the increased focus on the role of the HVAC system and how it can assist in the indoor air quality (IAQ). Organizations such as ASHRAE and the CDC have come out with many new or updated guidelines or standards specific to HVAC systems and IAQ, and many studies exist from other impartial organizations such as the National Institute of Health (NIH) or the Environmental Protection Agency (EPA).

Many different types of IAQ technologies and practices are available for many different types of HVAC systems. Which technology or design should be used? Which is the most effective? Which will keep my occupants safe? These are great and viable questions and attempting to dig through the research and appropriately answer for your unique situation can be a daunting task for companies. This white paper will assist with this research, analysis, and recommendations.

There are key considerations we should all review when deciding which technology or strategy would be best for our buildings:

1. Of the available IAQ technology types for commercial HVAC systems, and specifically those types discussed in this white paper (ultraviolet light, air ionization, high filtration, high ventilation and humidity control), none will completely remove all airborne particulates or prevent all microbial build-up. However, each of these technologies or strategies can make an impact on IAQ, as well as on the operation of the HVAC system.

2. Most manufacturers of IAQ systems have conducted studies as to the effectiveness of the systems they manufacture. However, most of these studies are not peer-reviewed, or conducted by impartial third parties. In fact, many of these studies have been funded and/or conducted by the manufacturer themselves. In reviewing a technology's effectiveness, it is imperative to ensure the data is from impartial, third-party research institutions as well as ASHRAE and/or CDC standards and guidelines.

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Why Indoor Air Quality?

The air in an occupied building will normally pass through an HVAC system multiple times per hour depending upon the building type and design. This means that the air we breathe as building occupants will be re-conditioned and re-circulated frequently by the HVAC system, and this includes all air particulates, both desirable and un-desirable. This recirculated air has been exposed to all conditions in the building, whether it be volatile organic compounds (VOCs) directly from a manufacturing process or direct output from building occupants in the form of carbon dioxide. Additionally, any airborne particulates carried by a person can be safely assumed to be part of the recirculated air. When evaluating indoor air quality and determining a plan of action with respect to HVAC systems, these compounds and particulates should be considered. While specific airborne pathogens or other microorganisms may often be the most news-worthy concern, the negative impacts of other airborne contaminants in the airstream is significant and detrimental to both a building occupant's health as well as their cognitive function[1]. Therefore, having an air quality strategy directly related to a building's HVAC system or design is extremely important so that the ability for a technology or strategy to control or remove these other airborne contaminants is not overlooked.

How can air quality be improved by the HVAC system?

Many different types of technology and design or control strategies are available to be implemented within an HVAC system. There are those that require additional hardware installation into or near the HVAC system such as ultraviolet germicidal irradiation (UVGI), air ionization or higher filtration (increasing the MERV rating of a filter, for example). These technologies are designed to either kill, inactivate, or sterilize pathogens (UVGI and air ionization), or trap pathogens or airborne contaminants (high filtration). Design or controls strategies such as higher ventilation, demand-controlled ventilation and humidity control also exist. These strategies focus on replacing recirculated air with outdoor air at a higher than normal rate or creating and maintaining optimal temperature and humidity conditions in the space to minimize the growth and/or spread of airborne contaminants or pathogens.

Which technology or strategy should be used? It depends, as there are many factors to consider. The remainder of this White Paper will look at each technology or strategy independently, with the goal of leveraging third party, unbiased research. Additionally, general framework will be provided as to the recommended use of each technology or strategy, as well as recommendations based upon building types and needs.

ULTRAVIOLET GERMICIDAL LIGHTS OVERVIEW

Technology Overview

Ultraviolet Germicidal Irradiation (UVGI) in HVAC involves installing ultraviolet lights (often referred to as "bulbs") in the HVAC system. The bulbs emit an intense, short wavelength light intended to kill or damage the cells inside microorganisms[14].

The light utilized in UVGI is UV-C light which has wavelengths between 100 to 290 nm[18]. Inside the spectrum of UV-C light, two subtypes are included, Far Ultraviolet Light, which is that between 100 to 200 nm, and Middle Ultraviolet Light, which is that above 200 nanometers[18]. The majority of UVGI equipment emits UV-C at a wavelength of around 254 nm in the Middle Ultraviolet spectrum.

Different types of UVGI products exist, with common applications being:

+ Upper room UVGI, where UV-C lights are positioned at the upper portion of an occupied room with the lights irradiating only the upper portion of the room[21]. The intent of upper room UVGI is to allow the UV-C light to irradiate only the upper portion of the room which is where the breathing exhaust of the building occupants will most often reside. This application is very common in medical settings, most commonly in operating rooms.

+ In-duct UVGI, where UV-C lights are mounted in enclosed HVAC ductwork or in the HVAC units themselves[21]. The intent of in-duct UVGI is to irradiate the HVAC air stream, or, if installed inside the HVAC unit, to also irradiate the cooling coils and drain pan.

+ Other applications exist but are less common than those mentioned above. These other application examples include, but are not limited to, mobile UV-C carts, UV-C wands, UV-C light fixtures and UV-C passageways.

Effectiveness and benefits

Studies have shown improvements in overall health of building occupants specific to respiratory symptoms and infection rates as well as a near 99% reduction of mold and bacteria growth on irradiated surfaces when UVGI is used[2]. UVGI has shown to inactivate viruses, bacteria, and fungi[5] and, if duration of exposure is long enough and intensity of the light is correct, UVGI has shown to be effective at inactivating respiratory viruses[3]. ASHRAE provides a good overview as well as the proven benefits of UVGI (14). Notably that UVGI:

+ Reduces microbial levels on HVAC surfaces and often in the air
+ Increases the expectation of energy savings due to a resulting drop in coil airside pressure drop and an increase in coil heat transfer
+ Leads to possible return on investment

As of the date of this white paper, one notable study has been conducted that is showing IAQ benefits of Far UV-C light, but the study has not yet been peer reviewed[19].

One of the typically known benefits of having UV bulbs irradiating HVAC cooling coils is the impact it has on maximizing coil efficiency and minimizing manual coil cleanings since the UV bulbs prevent mold and fungal growth and build-up on the coils themselves[14].

While UVGI has been shown to be effective at sterilizing or inactivating airborne particulates, UVGI does not remove them. Thus, like other IAQ technologies, mechanical filtration to trap and remove the now sterilized and/or inactivated particles is required.

It is of note that ASHRAE does provide testing standards for UV-C light in HVAC systems[5]. With these testing standards in place, UVGI manufacturers can test the effectiveness of their lights based on an industry approved testing method.

Concerns and drawbacks

Maximizing the effectiveness of UVGI requires two major components – light intensity and duration. If the intensity is too low, or the duration of exposure is too short, UVGI effectiveness will be reduced. The duration of exposure can often be the limiting factor in UVGI's effectiveness with a moving air stream. As was discussed earlier in this document, air streams in a typical HVAC system move very fast, on average between 400 to 500 feet per minute, and UVGI will typically need at least 15 minutes of continual exposure to inactivate airborne particulates[3]. However, taking advantage of UVGI's ability to sterilize and clean HVAC coils and drain pans should not be overlooked[5].

The UV-C light generated from UVGI bulbs is dangerous if people are exposed to it without any protection[14]. As such, when installing and using UV bulbs in an HVAC system, it is a good practice to also have a safety interlock measure installed in the HVAC system to avoid direct exposure of the UV-C light to people. A common example is a door interlock switch that would shut-off the UV bulb automatically if an HVAC access door is opened.

The study of the effectiveness of utilizing Far UV light may be of importance, as FAR UV light is less dangerous to humans when compared to Middle UV light[19]. However, as previously stated, this study has not yet been peer reviewed, and the optimum wavelength for UV-C light for addressing airborne particulates is around 265 nm[14], much higher than that of Far UV light. Additionally, the potential for ozone generation from UV light is high at smaller wavelengths[5].

Anticipated costs of implementation and ongoing maintenance

UVGI can be implemented in multiple ways inside an HVAC system. The most common would be to install UVGI bulbs on the leaving air side of the cooling coil to irradiate the coil and drain pan. In smaller systems, like small packaged rooftop units (RTUs), this can be accomplished by retrofitting the RTUs with one or more smaller UVGI bulbs. The cost to do so is generally low, with an expected cost of retrofitting a 7.5-ton RTU with UVGI bulbs being between $2,000 to $3,000. For larger systems such as built up air handlers (AHUs), the UVGI system used is larger and the installation of the system is more complex. The estimated cost to retrofit a 40-ton AHU, for example, would be between $5,000 to $8,000. Most HVAC manufacturers have options to install UVGI in their equipment at their factories at a lower cost at the time of HVAC equipment order.

Ongoing required maintenance for the UVGI system is minimal, with the only significant requirement being an annual replacement of the bulbs (bulbs are typically rated for 9,000 hours of effective life, which is about 1 year of use). The bulbs themselves range in price from $50 to $100, and each HVAC system can have 1 or multiple bulbs. A 7.5-ton RTU may have 1 or 2 bulbs, whereas a 40-ton AHU can have 8 or more. Most manufacturers list no additional ongoing maintenance requirements.

Conclusion

Recent developments in UVGI technology along with the long history of use makes UVGI a good solution to be used in HVAC. UVGI is an economical approach to improved IAQ and can often be retrofitted inside or near installed HVAC equipment requiring little to no HVAC system re-design. UVGI does have its limitation in that it is not very effective at sterilizing a moving air stream. However, pairing a UVGI retrofit with the right filtration strategy can be a very economical clean air solution.

With multiple types and solutions of UVGI available, the following is good guidance for selecting and using UVGI:

+ UVGI effectiveness is directly related to the UV-C intensity and duration of exposure. As such, when selecting UVGI, pay close attention to the intensity of the bulbs as well as if and how the intensity may degrade over the life of the bulb. Positioning of the bulbs is also key as to maximize the UV-C light duration, and, if being used in an in-duct scenario, install the UV-C bulbs immediately downstream of the cooling coil and drain pan.

+ As discussed by ASHRAE[20], applying UVGI outside of a medical setting may best be done in high population density settings.

+ Far UV light studies are still early and not yet peer reviewed[19]. Thus, caution should taken if selecting a product that utilizes Far UV light, which is common with UVGI products that are being exposed directly to humans. The effectiveness and drawbacks of this type of light is still being evaluated.

AIR IONIZATION

Technology Overview

Air ionization in HVAC is the addition of ionized molecules into the airstream by an electronic device. The ionized molecules then attach themselves to air particulates, making the particulates physically larger. By the particulates becoming physically larger, they are more likely to become trapped in a downstream filter media. These ionizing systems may or may not generate ozone in this process[5]. Bi-polar ionization and needlepoint bi-polar ionization (NPBI) are very common types of air ionization technology.

In general, bi-polar ionization is the use of bi-polar ionizing tubes that generate an energy field converting air particles into positively and negatively charged ions, with the intent being that these charged ions attract themselves to air particulates. Needlepoint bi-polar ionization is different in that the power output of NPBI is typically lower than that of bi-polar ionization.

Effectiveness and benefits

Of the many studies conducted to determine the effectiveness of bi-polar ionization improving overall building occupant health, equal parts of those studies show positive impacts as those studies that show negative or no impact on the health of building occupants[5]. With this technology being relatively new for applications in HVAC, rigorous, peer-reviewed studies do not currently exist[21].

A potential benefit of air ionization technologies is the possible reduction of outdoor air required in a conditioned space. However, these claims should be taken cautiously, as specific procedures and or calculations must be followed per ASHRAE standard 62.1 to be able to reduce the minimum required outdoor air ventilation rates.

Concerns and drawbacks

Ozone generation in some bi-polar ionization air cleaners is possible. Not all produce ozone, but ozone has proven significant negative impacts on overall health[5,7]. Thus, determining if the ionization air cleaner generates ozone, and how much, is vital. Many NPBI manufacturers reference their technology as controlling the electric output below the level required to produce ozone.

Placement of a bi-polar ionizer in the airstream is critical, as the location of the filter and the filter's ability to trap the downstream particles of the electronic air cleaner needs to be considered.

No ASHRAE testing standard currently exists for neither bi-polar ionization nor NPBI or its effectiveness in HVAC equipment. This should be of concern, as there is no regulation by ASHRAE in the testing and regulation of these products.

Anticipated costs of implementation and ongoing maintenance

Bi-polar ionization or NPBI can be installed in the HVAC system as well as in the downstream (supply) ductwork. The location of installation, type, and size of equipment will all impact the cost of installation. A common retrofit application for Bi-polar ionization for a 7.5-ton RTU, for example, could be installing the device in the supply ductwork. An anticipated cost of doing so would be expected to range between $2,000 to $3,000. In larger equipment, the device could be installed inside the equipment, and anticipated cost of doing so could range between $7,000 to $10,000. Many manufacturers of HVAC equipment will allow installation of a bi-polar ionization or NPBI device at the HVAC manufacturer's factory at a lower cost.

Ongoing required maintenance for a typical bi-polar ionization or NPBI is very minimal, with the only significant requirement being a replacement of the ionizing tube periodically, typically every 2 years. The cost per tube is typically around $100, and each HVAC system can have 1 or more tubes. A 7.5-ton RTU will typically require only 1 tube, while a 40-ton AHU can require 4 or more.

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Conclusion

Bi-polar ionization and NPBI offer technology that can be useful in the correct setting. However, the health benefits in using this technology are still indeterminate. It can be reasonably assumed that this technology performs well in removing many VOCs, and more specifically, can perform well in removing specific VOCs that a building may be producing from a manufacturing process, for example. As a result, bi-polar ionization and NPBI may be a good choice if a building is looking to remove specific contaminants but may not be able to provide health benefits to the building occupants[5,7]. Bi-polar ionization and NPBI must also be paired with the correct filter to ensure proper removal of the intended particulates from the air stream.

The following guidance should be used in selecting and using bi-polar ionization and NPBI:

+ The potential for a reduction in the required outdoor air ventilation rate by using bi-polar ionization or NPBI is based upon specific calculations and/or due diligence per ASHRAE standard 62.1. Often, this reduction may need to be based upon studies and calculations for the specific building and surrounding outdoor air conditions where the technology is planned to be used. The procedures of ASHRAE standard 62.1 should be utilized and specifically referenced.

+ Ozone generation should be documented and provided by the manufacturer. Bi-polar ionization and NPBI may or may not generate ozone, however the specific amounts they generate should be provided, or if they do not generate, specific studies showing no ozone generation should be provided.

HIGH FILTRATION

Technology Overview

High filtration is the usage of a high MERV rated air filter in the airstream of an HVAC system. Filter ratings are based on an efficiency standard, or MERV rating, which measures the effectiveness of the filter to remove particles of a particular size. A MERV 1 filter will have the lowest removal efficiency while a MERV 16 filter will have the highest removal efficiency. The low-end standard in commercial HVAC equipment is typically a MERV 7 or MERV 8, with upgradable options to a MERV 11 or MERV 13 being very common. HEPA filters are those with a MERV rating above 16, and they will be rated to remove at least 99.97% of airborne particulates down to the size of 0.3 microns[15].

Effectiveness and benefits

High filtration has been proven to be effective at removing particles from an air stream[6], and an upgrade from a MERV 7 to a MERV 11 filter has good, predictable health benefits[8] while resulting in a more manageable air side pressure drop. ASHRAE has recently stated that using filters with a MERV rating as low as 13 can be efficient at capturing some airborne viruses[21].

The removal effectiveness of a filter will depend not only on the MERV rating but also on the airflow volume as well as filter loading, or how much dirt, dust, and debris the filter is currently holding. Thus, it is vital to monitor and change filters frequently to ensure their maximum effectiveness.

ASHRAE has testing procedures in place for air filtration in HVAC, and thus, all filter manufacturers have a common testing method.

Concerns and drawbacks

The higher the MERV rating and effectiveness of air filters, the higher the airside pressure drop. This will pose a problem to an HVAC system as a larger fan motor or fan assembly may be required to overcome this pressure drop. Thus, in deciding the filter MERV rating to use, a higher rating is not always the best solution, or even a viable solution. Typically, a MERV 13 to MERV 15 is accepted as high filtration in an office setting[20,21], while HEPA level filtration is required in healthcare settings. Using a HEPA filter, however, often requires new HVAC equipment, or a significant re-design of the system.

Anticipated costs of implementation and ongoing maintenance

The cost of the filters themselves are typically low. MERV 11 filters are typically $10 to $20 per filter, with a 7.5-ton RTU requiring 2 to 4 filters, and a 40-ton AHU typically requiring 6 or more. MERV 13, 15 and HEPA are more expensive but typically have a modest price increase compared to a MERV 11. The true cost to consider, however, is the cost associated with the impact on the HVAC system, or even if the current HVAC system can support a higher rated filter. These costs could vary wildly and may even result in the purchase and installation of new HVAC equipment if high filtration is desired.

Conclusion

High filtration can be a simple, effective solution if used correctly. Since the majority of HVAC equipment installed currently uses a MERV 8 or less filter, upgrading to a MERV 11 is in-expensive and provides a large increase in filter efficiency. Before upgrading to a higher rated filter, the system must be checked to ensure that the additional pressure drop of the filter will not pose a problem with the HVAC equipment. However, the pressure drop from a MERV 8 to a MERV 11 is minimal. If a MERV 13 or higher filter is to be used, it can be expected that the HVAC equipment will need modifications to accommodate. Any improvement in the MERV rating of an air filter is an improvement in the air filtration. Even if a specific MERV rating cannot be achieved, do not let this stop efforts to increase the air filtration.

HIGH VENTILATION (OUTDOOR AIR)

Technology Overview

High ventilation is the act of introducing conditioned outdoor air into the building at a higher than normal rate. ASHRAE standard 62.1, along with many building codes, will dictate minimum rates of outdoor air introduction into a building depending upon building type, building use and occupancy level. High ventilation is the act of exceeding these dictated minimum rates.

The most common way to introduce outdoor air into a building is via an air economizer. Per ASHRAE standards and/or multiple building codes, air economizers are used on nearly all RTUs and AHUs and can manipulate the amount of outdoor air introduced into the building based upon the temperature and humidity of the outdoor air compared to those same conditions inside the building.

Dedicated outdoor air units, or make-up air units, are commonly used to provide a higher level of outdoor air into the building. These types of HVAC units are designed specifically to handle the higher heating and/or cooling load of outdoor air and as a result, will typically provide a lower airflow rate when compared to conventional RTUs or AHUs. As an example, a conventional RTU may circulate air at a rate between 300 to 400 CFM (with only 10 to 20 % of this being outdoor air) whereas a dedicated outdoor air unit will provide a lower airflow rate, typically 200 to 250 CFM, with all of this being outdoor air. When a dedicated outdoor air system is used, best practice is to use ancillary HVAC equipment in the space to appropriately control space temperature and humidity, since a dedicated outdoor air unit or make-up air unit cannot directly control the temperature or humidity inside the building[16, 17].

Demand Controlled Ventilation (DCV) is a common control strategy applied with outdoor air. The most common approach with DCV involves the monitoring of carbon dioxide in the space as a direct correlation to the occupancy level. As more people enter the building or a specific building space, the carbon dioxide level increases which will then send a signal to the outdoor air system allowing the outdoor air system to raise the rate of outdoor air introduction into the space. As people then leave the building or space, the carbon dioxide level decreases, and the outdoor system reduces the rate of outdoor air introduction.

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Effectiveness and benefits

Studies have shown improved indoor air quality with increased ventilation rates[11]. More and more studies are also being conducted to evaluate the impact that increased ventilation rates have on the cognitive function of building occupants. Results of one study show improvements in the cognitive function with increased ventilation rates[12].

ASHRAE Standard 62.1 provides guidelines around ventilation rate requirements and acceptable procedures. Additionally, numerous other building codes have adopted more stringent ventilation requirements.

Concerns and drawbacks

Air quality standards in the region need to be considered. If the building is in an area with significant outdoor air pollutants, then the introduction of higher amounts of outdoor air may be detrimental to the health of the building occupants.

Increasing ventilation rates often requires a full HVAC system re-design. Not all systems can be retrofitted to significantly raise ventilation rates as this often requires larger equipment and/or significant changes to current ductwork.

Anticipated costs of implementation and ongoing maintenance

An HVAC system that conditions high levels of outdoor air has a high cost in both procurement as well as operation. For example, in the case of an RTU, a standard RTU will bring in ~10-20% of its air directly from the outdoors. A dedicated outdoor air unit (100% outdoor air) will cost 2-3 times the amount of the purchase price of standard RTU equipment. Additionally, in many situations, outdoor air has a higher cooling or heating load than recirculated air. As a result, the ongoing costs of operating outdoor air equipment is higher than standard RTUs.

Using a dedicated outdoor unit also requires the installation and use of smaller HVAC equipment to appropriately control space temperature and humidity[16, 17].

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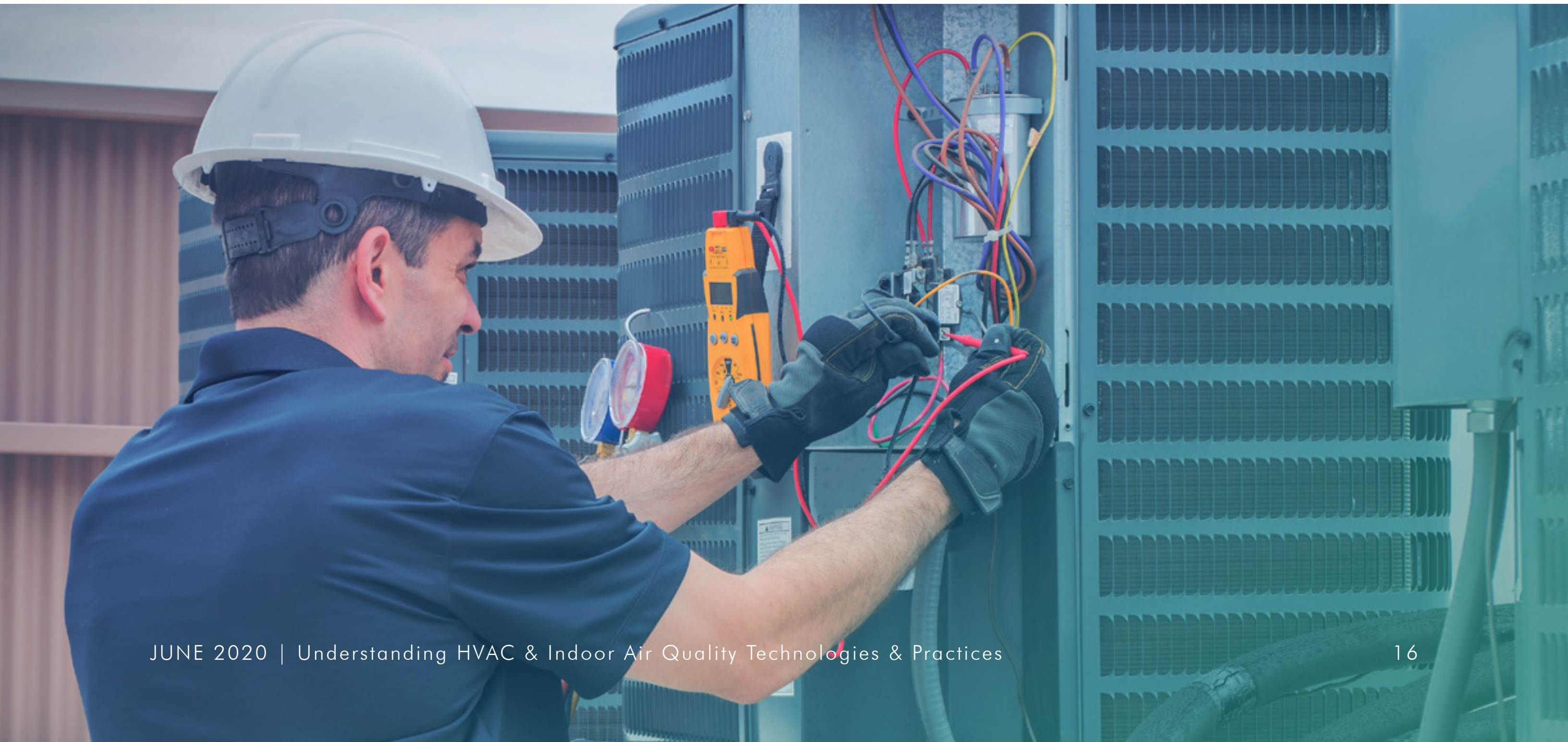
Conclusion

Higher ventilation rates should always be a focal point of a building's IAQ solution. However, the amount that ventilation rates can be increased in a building varies based upon many factors. Rarely is it economical or even practical to significantly raise ventilation rates in a current building, and often requires a costly system re-design. However, smaller steps can and should be taken. Good practices are to ensure that a building's ventilation system is using outdoor air economizers, and that these economizers are fully operational. If a building's RTUs or AHUs do not have outdoor air economizers, many systems can be retrofitted, or, if the RTU or AHU is planned for replacement, the new units should include economizers. Using an enthalpy economizer in-lieu of a dry bulb economizer in the majority of ASHRAE climate zones can show benefit.

Most buildings either have or are planned to have an integrated building management system (BMS), and these systems should always be commissioned to both monitor outdoor air conditions and control outdoor air economizers or the means to which outdoor air is introduced into the building. It is imperative that this outdoor air control strategy continue to be monitored, maintained and rarely overridden. Too often, the outdoor air control scheme can quickly be overridden and forgotten, and thus the ventilation rates will be significantly reduced.

If a building's HVAC system is planned for re-design, or if a new building is being developed, now is a good time to review the building's outdoor air strategy and look to design around high ventilation.



CONTROLLING HUMIDITY

Technology Overview

Controlling humidity is the act of either adding or removing moisture from the air. In a typical HVAC system, moisture can be added to the air by using a humidifier, which can be located either inside the HVAC equipment or in the supply duct work. Both methods are common and are often used in dry climates or in northern climates during the heating season.

Removing moisture in an HVAC system is done via normal cooling means. However, controlling the moisture in the space within an acceptable range will usually require the use of an active dehumidification system, with the most common being a measure of re-heat. Re-heat is the act of adding heat to the air cooled by the HVAC system to introduce dry, room temperature air to the space. By doing so, the HVAC system can still remove the moisture from the air (via normal cooling means), but not over-cool the space. A very common technology to re-heat the air is called hot gas re-heat. To a lesser effective extent, variable frequency drives (VFDs) on supply fans can be utilized to maintain a lower relative humidity, as the VFD can slow the fan speed allowing for more moisture removal during the cooling process.

Effectiveness and benefits

It is generally accepted that the proper range to maintain relative humidity in the space is between 40-60%. Above 60% poses a strong risk for mold growth, which results in negative impacts to both building occupants as well as the building structure[9]. Below 40% shows higher risk of transmission of airborne contaminants. In a study published by the National Institute for Occupational Safety and Health (NIOSH), the infectivity of influenza viruses was 3 to 5 times higher at relative humidity at less than 23% than the it was at relative humidity greater than 43%[10].

Concerns and drawbacks

Controlling the humidity in the space will require additional items in the HVAC system which will add system cost and most likely require additional space. Adding a humidifier in an AHU or in the supply ductwork will also require a water or steam connection to the equipment and may require ongoing water treatment, depending upon the water quality and/or manufacturer's requirements. Most HVAC manufacturers will provide factory options for humidifiers to be installed in their AHUs and retrofitting supply ductwork with a humidifier is typically non-invasive.

Installing a hot gas re-heat coil in an AHU or RTU typically needs to be done during the manufacture of the AHU or RTU and can rarely be retrofitted. Thus, utilizing hot gas re-heat to keep the relative humidity below 60% is normally a design consideration. With a hot gas re-heat coil installed, there is additional static pressure inside the AHU or RTU which must be overcome by the supply fan. In a retrofit scenario, a VFD on the supply fan can be installed or modified to slow fan speed and allow for further moisture removal during the cooling process.

In all humidity control scenarios, the humidity must be monitored in the space. As a result, a humidistat or other means to directly monitor relative humidity must be utilized in the space.

Anticipated costs of implementation and ongoing maintenance

The cost of installing a humidifier varies widely since there are multiple humidifier types and installations. In general, retrofitting a supply duct work with a humidifier for a 7.5-ton RTU can range from $2,000 to $5,000. Installing a humidifier in a 40-ton AHU could range from $6,000 to $12,000.

Hot gas re-heat, when installed by an HVAC equipment manufacturer at their factory, is relatively inexpensive. Installing a hot gas re-heat coil in a 7.5-ton RTU can range between $1,200 and $1,800. Installing a hot gas re-heat coil in a 40-ton AHU at the HVAC equipment manufacturer's factory can range between $3,000 to $5,000.

Ongoing maintenance of a humidifier typically involves annual inspection and cleaning of the humidifier as well as periodic water treatment. Ongoing maintenance of a hot gas re-heat coil is minimal, typically only requiring coil inspection and periodic coil cleaning.

Conclusion

Controlling relative humidity in the space is not just a good IAQ strategy, but a good HVAC strategy. Foremost, if the building is in an area of high outdoor humidity (for example, ASHRAE climate zones 1,2 and 3 or coastal environments) then designing the HVAC system to incorporate re-heat is a good practice. If located in a dry climate, or in a heating dominate climate such as ASHRAE climate zones 5, 6 and 7, using a humidifier to maintain relative humidity above 40% can help avoid the spread of airborne contaminants[10].

Controlling humidity should be one of the first items reviewed in a building's IAQ strategy. Simple controls strategies can be put in place such as adjusting supply fan speed or installing a humidifier into the supply air duct work.

Clean Air Technology Summary

	UVGI	Bi-Polar Ionization	High Filtration	High Ventilation	Controlling Humidity
What is it?	+ Ultraviolet (UV-C) bulbs emit intense light to kill or damage cells inside microorganisms	+ Creation of ionized molecules that attach to air particles, making them larger and more likely to be filtered	+ Using a higher MERV rating of the air filter in the HVAC system	+ Increasing a building's ventilation above minimum required rates	+ Maintaining relative humidity (RH) in the space between 40 – 60%
Effectiveness on IAQ	+ UVGI has proven to significantly reduce mold and bacterial growth on cooling coils + Has shown reduction in the transmission of airborne contaminants	+ Studies researched are neutral in the potential improvements in overall IAQ	+ Higher MERV rated filters have shown to have predictable health benefits	+ Higher ventilation has proven improvements in IAQ and in cognitive function of building occupants	+ Relative humidity above 60% will promote mold growth + Relative humidity below 43% can result in an increase in the spread of airborne contaminants
Impact on HVAC system efficiency	+ Will typically improve efficiency	+ Minimal	+ Will typically lower efficiency as MERV rating increased	+ Will typically lower efficiency as ventilation rates increase	+ Will typically lower efficiency
Concerns & Drawbacks	+ May require additional space in HVAC system + Harmful to people if in direct exposure	+ May require additional space in HVAC system + Potential ozone generation	+ High MERV filters will typically result in higher airside pressure drop	+ Air quality in the local area must be considered + May require a system re-design	+ Requires additional space and can require additional fan power
Cost to implement / retrofit (7.5-ton RTU example)	+ $2,000 to $3,000 to retrofit a 7.5-ton RTU	+ $2,000 to $3,000 to retrofit a 7.5-ton RTU	+ Not all systems can support a higher MERV filter. Increasing to a MERV 11, for example, should be less than $100 in filter costs.	+ A new dedicated outdoor air system can cost between $12,000 to $15,000, and additional system re-design needs to be considered	+ Maintaining below 60% RH can cost $1,200 - $1,800 (installed at factory) + Maintaining humidity above 40% RH can cost $2,000 - $5,000 (retrofit)
Ongoing Maintenance costs	+ Annual bulb replacement of $50 to $100 per bulb, systems may have 1 or more bulbs	+ Bi-annual replacement of tubes which can cost ~$100 per tube, systems can have 1 or more tubes	+ Routine filter changes, with filter prices varying depending on filter size and MERV rating	+ Minimal. Typically, no additional compared to conventional system	+ Minimal for maintain below 60% RH + Water treatment possible for maintaining above 40% RH
ASHRAE Testing / Design Procedure in place?	+ Yes	+ No	+ Yes	+ Yes	+ Yes

HVAC IAQ TECHNOLOGY SUMMARY AND RECOMMENDATIONS

The best option for HVAC technology will not be the same for every building. There are many, many factors to consider, and the below guidance can be used to assist. The following considers the information discussed in this white paper in an easy to use format based upon generalized HVAC strategy (retrofitting or replacing) and budgets. It is of utmost importance to understand that there is no technology or strategy available that will fully eliminate the transmission of airborne contaminants. But even small actions taken can show improvements in building IAQ.

I will retrofit my HVAC equipment or modify my HVAC strategy

- **LOWEST COST SOLUTIONS, EASIEST TO IMPLEMENT**
    + What MERV ratings are the air filters? If they are lower than MERV 11, look to replace to a minimum of MERV 11. The HVAC system needs to be considered for being able to accept and handle a higher MERV rating. MERV 13 filters are a good MERV target to achieve if the HVAC equipment can sustain.
    + Do you have outdoor air economizers installed? If yes, are they operating properly? Reviewing your economizer operation may show that your system is not optimized for outside air. If no outdoor air economizers are installed, it is recommended to review if the equipment can be retrofitted, and if not, and if the equipment is close to the end of ASHRAE recommended useful life, look at the benefits of replacing the equipment and including economizers.

- **MEDIUM COST SOLUTIONS, MID-LEVEL COMPLEXITY TO IMPLEMENT**

  + Review how you are controlling humidity. Relative humidity levels in the space should be kept between 40% to 60%. If you're in a heating dominant climate or very hot and dry climate, humidifiers should be used to keep relative humidity in the space above 40%. humidifiers can either be installed inside the AHU or RTU (space permitting), or in the supply ductwork. If you're in a humid climate, look at how the relative humidity is being maintained below 60%. If there is no dehumidification strategy, consider installing re-heat into the HVAC system. If installing re-heat cannot be done, consider installing supply fan speed control (e.g. VFD) and/or adjusting the fan speed to allow for further moisture removal from the air.

  + Adjust your control strategy to operate HVAC equipment 24/7. Use the filters of your HVAC system as much as possible and look to bring in more outdoor air in the evenings or mornings when outdoor air conditions permit.

  + Installation of a technology such as UVGI, Bi-Polar Ionization or Needlepoint bi-polar ionization. Review the benefits and drawbacks of each to determine which is best for your scenario. Remember that even with these technologies installed, it is important to review your filter strategy and ensure you have the right level of filtration.

- **HIGHEST COST SOLUTIONS, HIGHEST COMPLEXITY**

  + Significantly raise your ventilation rates. Outdoor air conditions and quality must be considered. Beyond installing or adjusting outdoor air economizers, this solution will require some measure of system re-design to ensure that when raising ventilation rates, space temperature and humidity are not negatively impacted as well as the air distribution system can support the airflow.

I will replace my HVAC

- **LOWEST COST SOLUTIONS**

  + Adjust your HVAC equipment design standards to use a minimum MERV filter rating, typically MERV 13 or higher, unless the HVAC equipment cannot support. Recommend not using less than a MERV 11. This will likely impact the fan and/or fan motor sizing. Most HVAC equipment manufacturers can model the operation of HVAC equipment with different MERV ratings selected.

  + Adjust your HVAC design standards to require outdoor air economizers as standard. The majority of RTUs in the HVAC market, 3 tons and larger, have an economizer option, both enthalpy as well as dry bulb economizers. Utilizing an enthalpy economizer is recommended most often, depending on your climate zone.

- **MEDIUM COST SOLUTIONS**

  + Adjust your design standards to ensure humidity is controlled actively. This means the inclusion of humidifiers and/or re-heat options.

- **HIGHEST COST SOLUTIONS**

  + Adjust your design standards to have HVAC equipment that can support the inclusion of a technology such as UVGI, bi-polar ionization or Needlepoint bi-polar ionization. Most often, this may mean having HVAC equipment with a larger physical footprint.

  + Adjust your design standards for a baseline ventilation rate, above what is recommended by ASHRAE 62.1 and/or local building codes. Outdoor air conditions and quality must be considered. This will likely be the most expensive solution, as it will call for near full system re-design.

I am designing a new building or new system

Consider the same solutions as discussed when replacing HVAC above. If you are already in the design phase or plan to be, this is a great opportunity to consider significantly higher ventilation rates, since higher ventilation rates will most likely require a full system re-design.

In General

The right solution to improve a building's IAQ will be unique to that building, its use, its owner and its occupants. Quite often, the best solution may be a hybrid approach of 2 or more strategies discussed here, or even the inclusion of a strategy not discussed. For that, it's best to lean on the industry experts, most notably, ASHRAE. ASHRAE has decades of analysis, design standards and best practices to utilize. This breadth of data can be cumbersome, but it must be considered.

For more information, our teams can provide consultative support and turnkey project delivery as you review options and determine the program that fits your portfolio needs.

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