LENNOX COMMERCIAL / 2021

ULTIMATE IAQ

A STUDY ON REDUCING AIRBORNE CONTAMINANTS USING COMMERCIAL IAQ TECHNOLOGY: MERV 16 FILTRATION AND UVC

LENNOX IAQ

Building Better Air

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THE COVID-19 PANDEMIC HAS HIGHLIGHTED THE KEY ROLE THAT HVAC PLAYS IN HEALTHY BUILDING ENVIRONMENTS.

Lennox is making sure that commercial buildings have access to the right products and services to get back to business safely. In this effort, Lennox has created the Building Better Air initiative.

The building better air initiative creates a framework to help improve indoor air quality of any space.

- The first step, Evaluate, is simply to check the current condition and capabilities of your equipment. Here, it is important to measure the condition of the equipment, verify the ventilation capabilities, and check to see if you have any existing IAQ accessories serving the space.
- The next step is to Solve any issues that may be present. The information gathered during the IAQ evaluation can help to make an informed choice between retrofitting existing equipment, repairing damaged equipment, or replacing old systems in disrepair.
- The final step is Maintain. Better indoor air quality is not a one-and-done process. It is important to make sure the system is operating as intended throughout its lifespan. After improvements have been made, it is important to institute a proper preventative maintenance plan to ensure your system remains effective.

EVALUATE

Check Condition and Capabilities of Current HVAC Equipment

- ❍ Condition of Equipment
- ❍ Verify Ventilation
- ❍ Current IAQ Accessories

SOLVE

Implement Indoor Air Quality Improvements

- ❍ **Retrofit** Existing Equipment
- ❍ **Repair** Damaged Equipment
- ❍ **Replace** Old Equipment

MAINTAIN

Ensure the System Remains Effective

- ❍ Change Filters
- ❍ Keep Equipment Clean
- ❍ Conduct Preventive Maintenance

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This whitepaper study is intended to provide more detailed information on the SOLVE portion of the Building Better Air initiative.

INDOOR AIR QUALITY SOLUTIONS

Indoor Air Quality is not new to the HVAC industry, and the right contractor will be able to follow best practices to implement IAQ solutions.

- **Eliminate** – Remove the root cause of pollutants and contamination through source control.
- **Ventilate** – Diluting contaminants in the space by bringing on fresh air.
- **Humidity Control** – Maintain the correct level of RH% in the space to prevent contaminant growth and spread.
- **Air Treatment** – Reduce or remove contaminants that cannot be controlled at the source.
- **Monitor** – Verify improvements are operating as intended and implement a maintenance program to keep them operating.

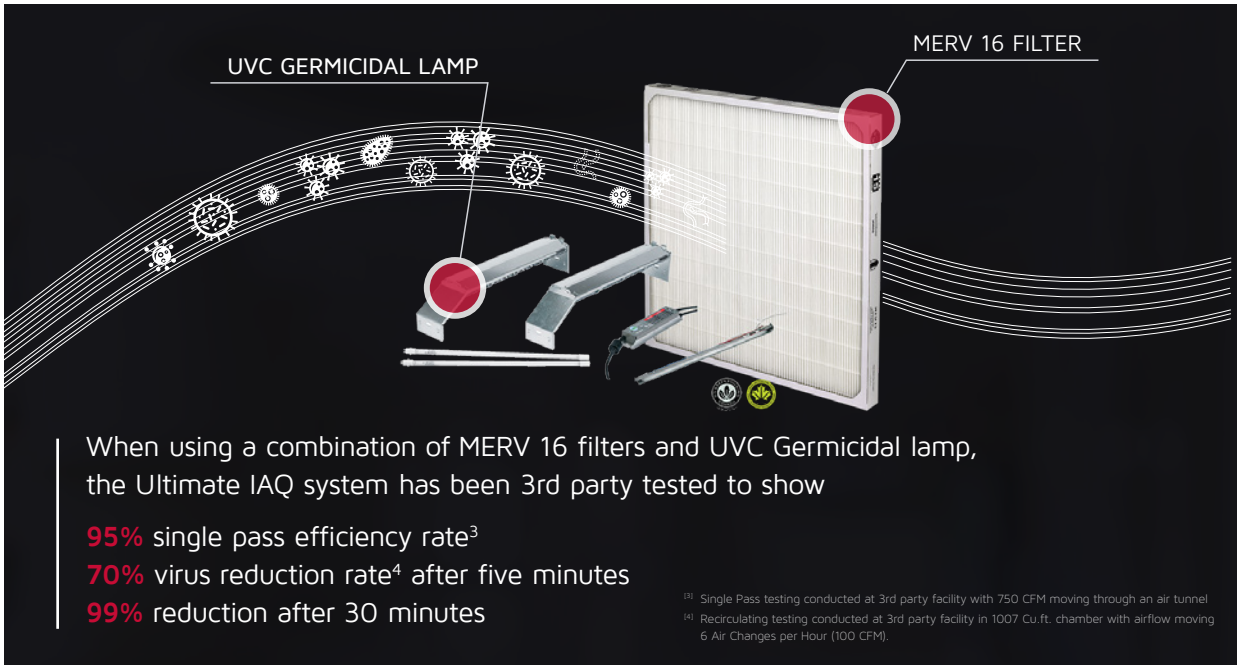
LENNOX APPROACH TO COMMERCIAL IAQ

With a focus on developing solutions for the Air Treatment category, Lennox has focused on utilizing and expanding on existing technologies in the commercial RTU space. Namely, UVC Germicidal Lamps and healthcare grade, MERV 16 filtration. UVC Lights have been used for surface disinfection and air treatment in the HVAC industry in the past, while MERV 16 filters have only been utilized in very specific applications with high end, customized AHUs. This study is intended to validate the importance of these technologies within a Commercial HVAC system.

Commercial RTU Ultimate IAQ system capable of removing over 99% of the virus that causes COVID-19 from the air

Ultimate Indoor Air Quality system consisting of a combination of MERV 16 Filter and UVC Germicidal Light provides:

- 95% Single Pass Capture Efficiency
- 70% Reduction of Coronavirus after 5 minutes
- 99% Reduction of Coronavirus after 30 minutes4



[1] When used properly with other best practices recommended by CDC and others; commercial filtration and UVC lights can be part of a plan to reduce the potential for airborne transmission of COVID-19 indoors.

[2] Removal efficiency based on third party testing results using MS-2 bacteriophage (ATCC 15597-B1). Bacteria representative of virus-sized particles like SARS-CoV-2, the virus that causes COVID-19. April 2021.

[3] Single Pass testing conducted at 3rd party facility with 750 CFM moving through an air tunnel.

[4] Recirculating testing conducted at 3rd party facility in 1007 Cu.ft. chamber with airflow moving 6 Air Changes per Hour (100 CFM).

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OBJECTIVE

In the last year ASHRAE Epidemic Task Force has produced quite a few documents regarding guidance for the public and professionals in dealing with SARS-Cov-2. While that guidance has evolved over time as our scientific understanding of how a virus is transmitted has increased, a core tenant of the guidance has remained constant. This core recommendation is to provide and maintain a minimum outdoor air rate for ventilation, using combinations of filters and air cleaners and to use devices for which effectiveness and safety are clear. Other recommendations include the use of 1) PPE and sanitation, 2) reduction of air currents that increase the direct transmission, 3) maintaining the temperature and humidity set points and 4) verify the systems are operating properly.

The Lennox approach to support the core ASHRAE recommendation of clean ventilation / recirculated air is to use a combination of MERV 16 (hospital grade) filtration along with germicidal ultraviolet lights. Both technologies show strong documentation for effectiveness and safety in applications.

Numerous other air cleaning technologies are currently being promoted however, due to a lack of standard test protocols to support the effectiveness and safety claims, as well as Lennox testing and independent peer reviews, Lennox can make no specific recommendations about these technologies at this time.

To verify performance of the Lennox filter technology and germicidal lights, Lennox conducted a series of tests at an independent Laboratory (LMS Technologies, Inc) in the spring of 2021. The testing included both single pass and multi-pass tests to document the effectiveness of each arrangement, and to provide the best understanding of the technology applied in building spaces as it relates to providing a clean controlled environment.

It should be noted that the surrogate virus MS2 was used in these experimental laboratory techniques. MS2 is often used a surrogate for SARS-CoV-2, it is more difficult to inactivate then SARS-CoV-2 and will provide a more conservative result.

The bacteriophage MS2 is also smaller than SARS-CoV-2 by particle size (23-28 nm4 compared to 100nm5) which makes it a reasonable candidate on which to conservatively test the effects of filtration.

[4] Bar-On, Yinon M, et al. "Sars-Cov-2 (Covid-19) by the Numbers." ELife, vol. 9, 2020, doi:10.7554/elife.57309.

[5] Kuzmanovic, Deborah A., et al. "Bacteriophage ms2." Structure, vol. 11, no. 11, 2003, pp. 1339–1348., doi:10.1016/j.str.2003.09.021.

METHOD

In a single pass arrangement, the air is contaminated prior to entering the device. The effectiveness of a single pass system is measure by comparing the incoming level of contamination to the exiting level of contamination. Such a measurement provides the most repeatable and consistent performance of the system's ability to clean or clear a contaminant from the airstream. However, it does not consider the aspect of recirculated air and the benefits of multiple passes through the system.

In a multi-pass arrangement, the chamber or room itself is contaminated and the response time to remove the contamination is measured. This is done by measuring the contamination level in the room over time to determine how long it takes for the system to clean or clear the contaminants from the chamber or room. This effectively considers the aspect of recirculation in a space.

Lennox used both methods to establish how airborne pathogens can be removed from the controlled space as well as the effectiveness and safety of the Lennox approach. As stated, this approach utilizes a combination of both highly effective MERV 16 filtration an UVC lights to eliminate airborne pathogens more quickly and effectively than other currently available technologies. Each of the experimental procedures evaluate the ability of the Lennox approach to provide the cleanest possible air to the controlled space.

SINGLE PASS ARRANGEMENT

Figure 1 illustrates the single pass arrangement, the pathogen MS2 was nebulized and injected into the airstream ahead of the proprietary MERV 16 filter / UVC arrangement. Air samplers were installed, (SCK Bio-Stage impactor), ahead of and after the MERV16 / UVC combination in order to determine the reduction of PFU's. (Plaque Forming Units)

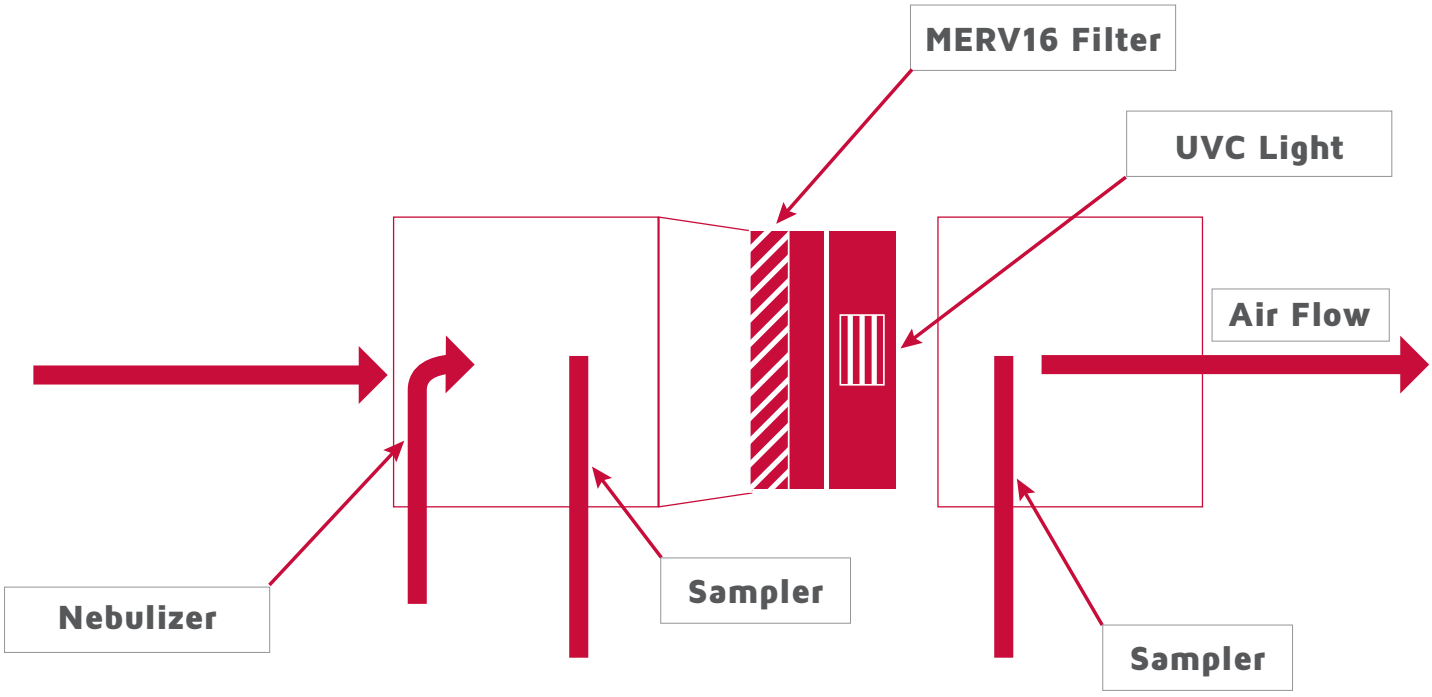

FIG. 1 Rendering of the single pass system showing the duct arrangement, nebulizer, air samplers

EXPERIMENTAL SINGLE PASS RESULTS

The following graph **Figure 2** illustrates the results of the testing conducted with MS2 bacteriophage virus in the air. Before and after treatment. The testing consisted of two different face velocities to evaluate the effectiveness over a typical operating range.

The results of the testing clearly demonstrate the effectiveness of a combination of the Lennox proprietary MERV 16 technology with the UVC lights in the airstream. Over 95% of the virus is removed from the airstream in a single pass thru MERV16 filter and UVC light. It should be noted that the two air velocities are consistent with the expected normal operating environment. The very large surface area of the Lennox MERV 16 filter allows for consistent operation and low pressure drop.

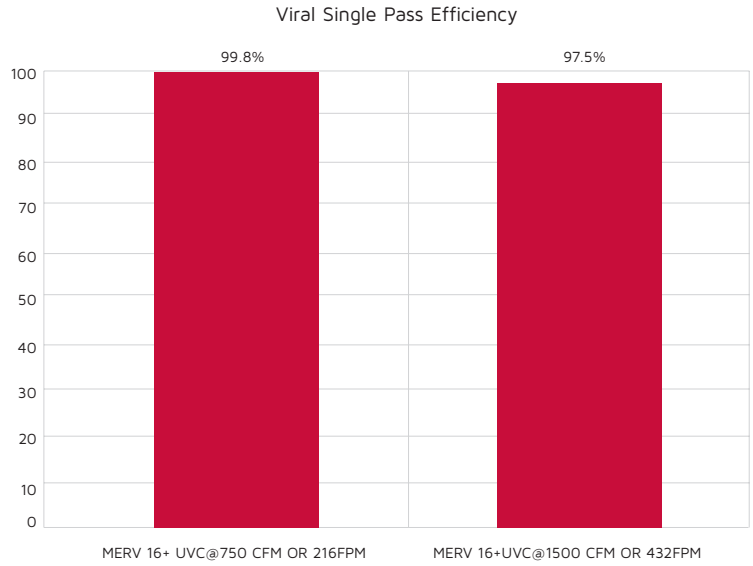

FIG. 2 Bar chart of results as presented to Management, showing the measured effectiveness at a single pass

MULTI-PASS ARRANGEMENT

Figure 3 illustrates the multi-pass arrangement, the pathogen (MS2) is nebulized and released into the chamber. When the pathogen is stable, the blower is turned on and the time to removal is measure. Air samples were collected on a timed basis, as well as surface samples to demonstrate the ability to clean the chamber. It should be noted, in this multi-pass testing the air in the space is not diluted with fresh outside air as expected in a commercial application, therefore giving a conservative result.

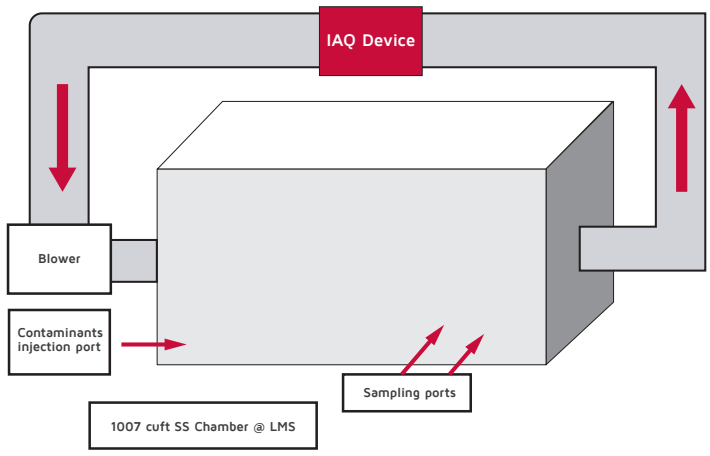

FIG. 3 Rendering of the Multi-pass system showing the duct arrangement, injection port, air samplers

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EXPERIMENTAL MULTI-PASS RESULTS

Figure 4 represents the effectiveness of removing pathogens relative to the natural decay can be clearly seen. The x axis is time from the stable pathogen injection to measurement and the y axis is the logarithmic decline of pathogens. Thus, in the biomedical field this represents a 99.999 reduction in pathogens, that is a 5 log reduction.

While it is important to recognize the reduction in biomedical terms, most users can more clearly understand the actual reduction in virus counts as a percent reduction. Figure 5 represents the actual reduction in count of relative to time and natural decay. The y axis represents the percent of MS2 removed or eliminated from the airstream x axis represents the time from start of the testing. The Lennox approach rapidly and effectively removes the pathogens from the chamber.

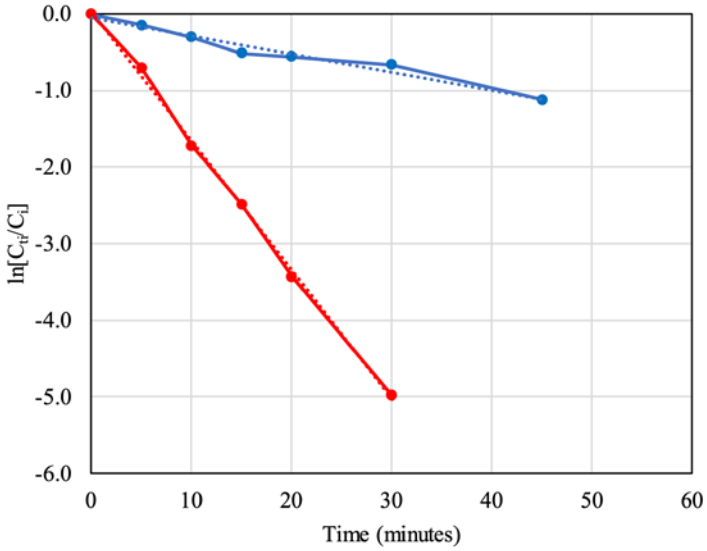

FIG. 4 Logarithmic plot of pfu's MERV16 + UVC and natural decay vs.Time @100 CFM

With the multi-pass test the room air is contaminated first and must be recirculate thru the MERV16 and UVC to remove the pathogens. Thus, with 95% first pass effectiveness, the initial reduction in pathogens is very rapid and quickly approaches 100% removal.

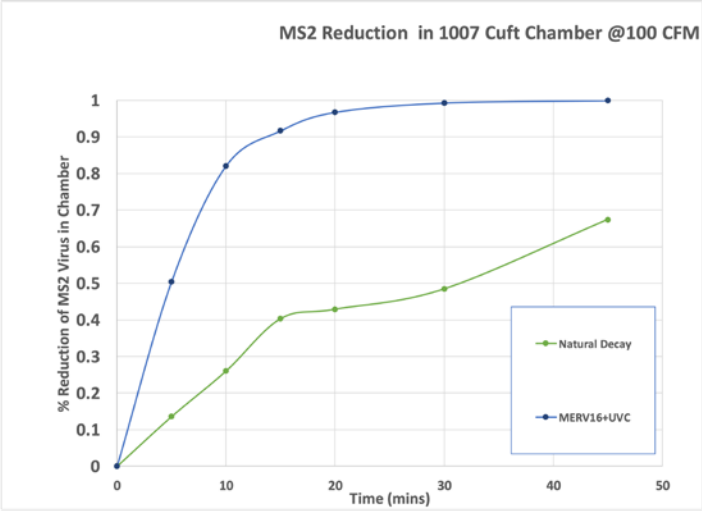

FIG. 5 Percent reduction vs time MERV 16 + UVC @ 100 CFM

Figure 5 represents a rate of 6ACH, with a single air change occurring at 10 minutes. Over 80% of the pathogen is removed in a single air change and by three air changes, 30 minutes, virtually all pathogens are removed.

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ASHRAE's latest guidance recommends maintaining the temperature and humidity set points while retaining the minimum outdoor air flows for ventilation with an additional requirement to flush the space between occupancies. Studies have shown in a well mixed space concentrations fall by more than 95% after just 3 air changes with uncontaminated air. ASHRAE has adopted this strategy but also recognizes the energy penalty associated with this level of outside air. In its latest guidance ASHRAE confirms the 3 air changes in 30 minutes can be with equivalent clean air and more specifically that the flushing of a space can take credit for air circulated thru filters.

Removal efficiency	ACH						
	2	3	4	5	6	8	10
99.5	95.4	47.7	31.8	23.8	19.1	15.9	13.6
99	82.9	41.4	27.6	20.7	16.6	13.8	11.8
97	63.1	31.6	21.0	15.8	12.6	10.5	9.0
95	53.9	27.0	18.0	13.5	10.8	9.0	7.7
93	47.9	23.9	16.0	12.0	9.6	8.0	6.8
91	43.3	21.7	14.4	10.8	8.7	7.2	6.2

TABLE 1 Minutes to achieve Removal efficiency vs Equivalent Air Changes

Table 1 represents the number of minutes it will take to achieve a specific virus removal efficiency based on equivalent clean air supplied by the Lennox IAQ system. Thus, with only 3ACH the Lennox IAQ system can match the ASHRAE recommendation of 95% reduction in 27 minutes with equivalent clean air without the need to bring in addition outdoor air to flush the occupied space. In addition at 6 ACH (equivalent to the recommended 3 air changes in 30 minutes) the Lennox IAQ system will achieve 99.5% removal efficiency in just 19 minutes. Thus, the Lennox IAQ system will save energy and simultaneously reduce the purge time recommended between occupied times. In addition, if the air is continually recirculated, the reduction in pathogens is continuous and will lessen the exposure time during occupied periods.

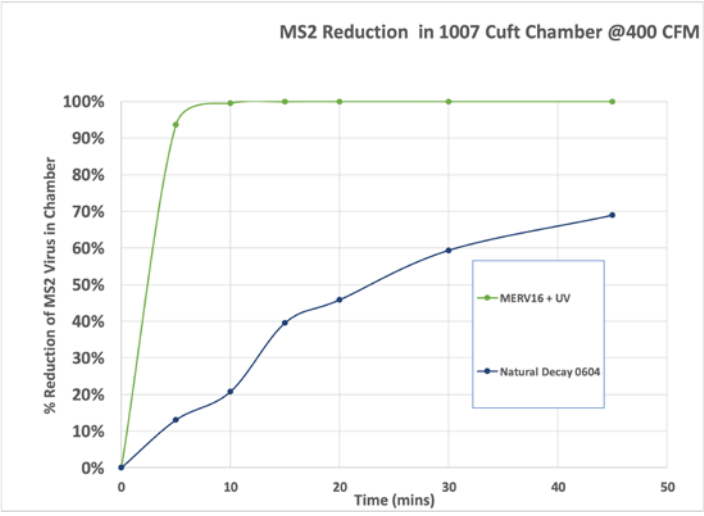

FIG 6. Percent reduction vs time MERV 16 + UVC @ 400 CFM

Figure 6 represents a much higher airflow rate and clearly demonstrate an even shorter time to achieve the room air changes while not degrading the ability remove the pathogens. Thus, in systems where high airflow or frequent air changes are a requirement the Lennox IAQ system will perform at the same high level of virus removal. The system is able to handle much higher air flows without the fear of insufficient residence time thru the filter and UVC.

In conjunction with the air contamination testing, surface testing was included in this study. The Merv16 and UVC technology cleaned the air very quickly and did not allow these very small particles to settle before being removed. Thus, the testing again verified the ability of the Lennox technology to keep the building air clean by removing airborne particles before they have time to settle on surfaces.

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CONCLUSION

When used properly with other best practices recommended by CDC and others; commercial filtration and UVC lights can be part of a plan to reduce the potential for airborne transmission of COVID-19 indoors. The testing conducted in this study illustrates effectiveness for these indoor air quality technologies at removing contamination from an airstream. While the testing was conducted in a laboratory setting, the effectiveness in a commercial HVAC application can be understood. The use of the Lennox IAQ strategy meets the ASHRAE Epidemic Task Force Recommendations in several ways:

1. Maintains the minimum ODA flows for ventilation
2. Uses MERV 16 (hospital grade filtration) without detrimental additional pressure drop
3. Uses effective and proven technologies
4. Uses existing control options to reduce exposure while minimizing any energy penalty
5. Maintains a continuous clean air supply during occupied periods
6. Allows a building space to be flushed with equivalent clean air in minutes without expensive outdoor air introduction.

The single-pass testing was conducted at airflows of 750 and 1500 CFM, which seem may be low for a commercial system; however, a commercial application will scale to would likely use multiple filters and or larger UVC light to increase effective surface area. In this case, the air velocities of 216 and 432 fpm become very applicable in a corresponding commercial setting.

Similarly, for the multi-pass testing, the airflows of 100 and 400 CFM are very low for recirculation of air through a traditional commercial rooftop unit. However, when accounting for the size of the chamber (1007 cu. ft.), the corresponding air changes per hour of 6 and 24 ACH are directly applicable to commercial spaces.

The testing of these commercial indoor air quality technologies was conducted with consideration for how they would be used. Additionally, each technology has an important role to play in a commercial HVAC system:

- The commercial filters are designed to do the upfront work at catching contaminants that are circulated in the system. MERV 16 filters are rated to remove up to 95% of particulates d own to 0.3 microns, allowing them to catch some of the smallest pollutants.
- UVC Germicidal lights are designed to target contaminants past the filter. When used in commercial rooftop units, UVC lights are most effective at preventing contaminant buildup on interior surfaces such are the evaporator coil and drain pan; however, the UVC lights also target any airborne particulates that pass the filter.

Although each technology serves its own purpose in the commercial system, these devices are best used in combination. When used together in a commercial system, the MERV 16 filter and UVC light have proven effective at removing 99% of the virus that causes COVID-19 from the airstream. When applied together in a commercial application, these IAQ technologies become useful tools to prevent the spread of infectious disease indoors.

References
ASHRAE Journal Guidance for Building Operatons During the COVID 19 Pandemic May 2020
ASHRAE Epidemic Recommendations. Jan 6 2021
ASHRAE Journal Reducing Airborne Infectious Aerosol Exposure May 2021
ASHARAE Journal Study of Viral Filtration performance of Residential HVAC Filters August 2020

Since 1895, Lennox Commercial has been creating reliable, innovative heating and cooling systems that help businesses reduce operating costs while maintaining comfort.

Over a century later, we continue to build on this foundation, finding new ways to help meet today's business challenges. With a wide range of ENERGY STAR® certified products that lower costs through reduced energy demand, Lennox is a single source for efficient, reliable HVAC solutions that professionals continue to depend on—year in and year out.

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