TECHNICAL BULLETIN

Independent Evaluation of Viral Mitigation Utilizing UV and Photohydroionization (PHI) Technologies in HVAC Units

TB21-1023

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Background:

With the ongoing global pandemic, organizations like ASHRAE (The American Society of Heating, Refrigerating and Air-Conditioning Engineers) have invested significant time and effort into better understanding the technology that can capture, mitigate and/or eliminate the virus particles associated with Covid-19 (SARS-CoV-2).

Released in August 2020, *Study of Viral Filtration Performance of Residential HVAC Filters* was published in the ASHRAE journal and investigated the effectiveness of mechanical filtration in HVAC applications. The findings were that:

- High efficiency residential HVAC filters were effective at capturing airborne virus particles.
- Filter viral filtration efficiency (VFE) was generally correlated to its MERV (Minimum Efficiency Reporting Values) rating, i.e., the higher the MERV rating, the higher the viral filtration efficiency.

https://www.ashrae.org/file%20library/technical%20resources/covid-19/zhang_digital-first.pdf

Considering these results, CaptiveAire began to recommend a minimum of MERV 13 filtration for recirculated airstreams.

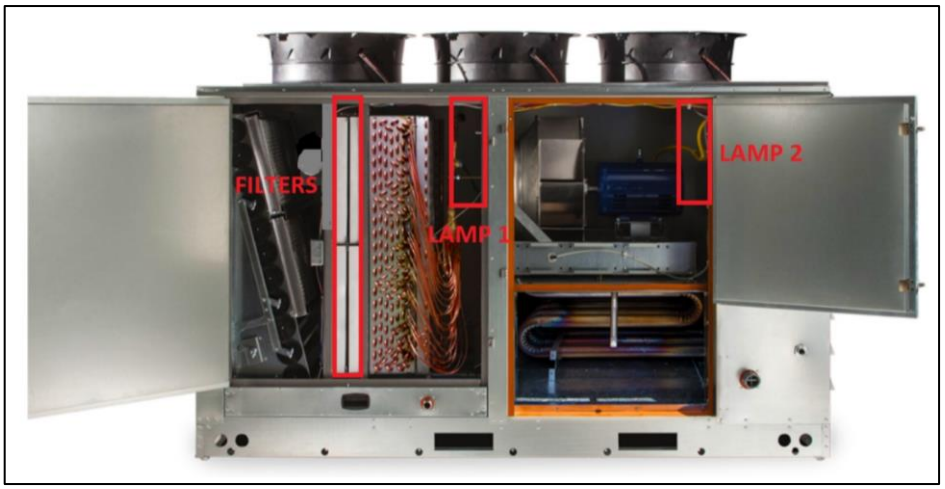
In conjunction with industry studies, CaptiveAire has also performed VFE tests with a third-party testing agency. This bulletin will discuss the findings, which mirror results published by ASHRAE.

Details:

LMS Technologies, an independent air and filter testing company, was contracted by CaptiveAire to determine the effectiveness of mechanical filtration, UV-C and photohydroionization (PHI) oxidizing technologies, as well as the combination of mechanical filtration with each of these technologies when employed within a packaged roof top HVAC unit.

Testing was performed using MS-2 Bacteriophage virus. The average viral particle size for MS-2 Bacteriophage virus is approximately 27 nm (0.027 microns), which is much smaller than the SARS-CoV-2 virus which averages around 120 nm (0.120 microns). The tests were performed in the same apparatus type utilized in the ASHRAE 52.2 test tunnel standard (52.2-2017: Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size), cited above.

Single pass viral capture efficiency of mechanical filters (MERV 8, 13, 15 and HEPA) were tested by themselves, then with the addition of UV-C and PHI, at three different air velocities. For UV-C and PHI, tests were performed with a fixture downstream of the in-unit cooling and reheat coils, and additionally with a fixture installed in the blower section. Additionally, the effect of the UV-C and PHI was tested without mechanical filtration.



4641 Paragon Park, Raleigh, NC 27616 | Phone: 800.334.9256 | Service: 866.784.9600 | www.captiveaire.com

Mechanical Only Filtration:
LMS Technologies testing confirmed the findings of ASHARE's August 2020 study; that VFE increased proportionally with the filter's MERV rating. In testing, the findings were:

- HEPA filters captured up to 93.6% of viral load in a single pass.
- Capture efficiencies of mechanical filters were comparable across the different airflow values that were tested.

UV-C Only Filtration:
Germicidal ultraviolet light rays have been used for inactivating microorganism such as germs, viruses, and bacteria commercially for decades. One requirement with UV-C is that the microorganism remain exposed to the light ray for a period (residence time) sufficient to inactivate or render it harmless. As it relates to HVAC units, like with all UV-C technology, the limited residence time the air results in limited efficiency improvements.
Each UV lamp used for testing was rated to 95 Watts.

The findings of these tests were:

- UV-C viral deactivation is comparable to a MERV-8 filter, approximately 20% reduction.
- Additional UV wattage did not increase effectiveness at medium and high airflow velocities.
- Viral UV-C deactivation increased to 35% with artificially low airflows of 160 FPM coil velocity (extended residence time) that would rarely be utilized in practice. This matches previous findings regarding the importance of residence time for UV-C effectiveness.

Photohydroionization (PHI) Only Filtration:
PHI technology and similar ionization products such as bi-polar ionization claim to resolve the residence time issue by introducing ions into the airstream, which can then later react with viral particulates. PHI specifically utilizes a catalyst exposed to the UV light, producing airborne oxides which react with particles in the airstream. PHI technology claims to create hydro-peroxides, superoxide ion and hydroxides – essentially ionized groups of molecules (O-OH, O_2^{-1}, OH^{-1}), which can attach to contaminants and revert back to oxygen and hydrogen once they've come in contact with pollutants. Though there is much discussion about how these ionized molecules kill microbes, limited data exists to support the effectiveness of PHI when utilized in an HVAC unit or duct system. Each PHI UV light fixture used for testing was rated to 11 Watts.

The findings of these tests were:

- PHI viral deactivation falls between a MERV 8 and MERV 13 mechanical filter, approximately 30% reduction
- Additional PHI wattage has minimal impact on effectiveness, less than 5% improvement.
- PHI does not improve with lower velocities, which is opposite of UV-C. This would imply that it potentially does improve upon the residence time problem.

Mechanical + UV-C Filtration:
The findings of these tests were:

- UV-C does not help when used in conjunction with HEPA filters as the HEPA filters have already removed the virus from the airstream prior to UV. This is true at all airflow ranges.
- MERV 13 filters + both UV-C bulbs have comparable viral removal efficiency as MERV 15 filters.
- MERV 15 filters + both UV-C bulbs have similar viral removal efficiency as HEPA filters

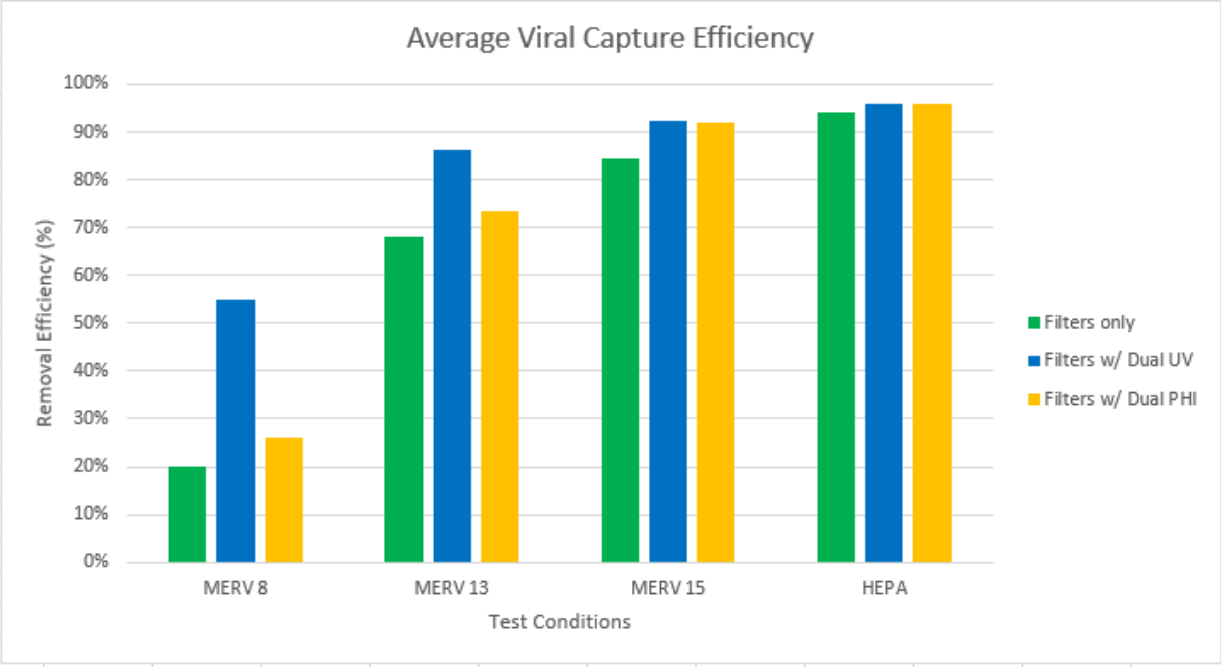
Mechanical + PHI Filtration:
The findings of these tests were:

- PHI offers very little improvement over mechanical filtration, less than 10% at all filtration ranges.
- The viral effectiveness improvement is diminished as the filtration efficiency is increased.

Analyzing the Impact of Mechanical Ventilation on the Results:
The test results from LMS Technologies are for sealed systems, as outlined in the ASHRAE 52.2 Test Tunnel Standard. In practice, nearly all buildings and applications have outdoor air ventilation included as required by ASHRAE 62.1, the standard of Ventilation for Acceptable Indoor Air Quality.

When ventilation is included in the analysis, it can be quickly determined from basic arithmetic that the impacts of UV-C and PHI technologies are negligible. Although they may offer approximately 10 to 20% reduction in viral deactivation when coupled with lower MERV rated filtration, such impacts would be reduced when taking into account dilution of the airstream via outdoor air, and the fact that in practice the air containing the viral particle would pass through the mechanical filtration multiple times per hour, each time becoming slightly less contaminated.

Return on Investment (ROI):
Assuming an HVAC unit runs 16 hours a day, 365 days a year and with 2 filter changes a year and 1 UV-C bulb change a year, over the course of 10 years, standalone MERV 15 filter are very comparable in cost to a MERV 13 + UV or MERV 8 + UV combinations. Both UV-C and PHI lights have similar initial capital expense. A mechanical filtration only approach offers the lowest initial capital expense.



Conclusions:
MERV 13 filters strike an excellent balance between cost and effectiveness in viral capture efficiency. MERV 15 or HEPA filters can increase viral capture efficiency to levels that exceed those provided by ancillary UV based technologies. Mechanical filtration is a less complex technology than UV-C or PHI lights, and as such, has predictable maintenance expenditures.

When outdoor air ventilation is included in the calculation, the purpose of UV-based HVAC technologies is further diminished. Better indoor air quality can be achieved simply with increased outdoor air and good mechanical filtration. In addition to robust filtration of any recirculated air, a simple increase in the number of air changes per hour (ACH) is an effective way to rapidly decrease indoor viral contamination levels.

Design Recommendations:

- UV-C / PHI or other ionization technology is not a substitute to mechanical filtration or better ventilation rates.
- MERV 13 filters should be used as a minimum filter requirement in DOAS and Roof Top HVAC Units. If elevated filtration is required, MERV15 or HEPA should be supplied.
- UV-C / PHI or other ionization technology should not be installed in DOAS or Roof Top Equipment due to high initial cost and lack of substantial deactivation of virus.

Additional Thoughts:

With the understanding that real-world viruses are transmitted through a medium, making the particle size larger for easier capture by mechanical filtration, SARS-CoV-2 virus particles are over 4 times larger than the tested virus particles and thus, mechanical filtration will intuitively provide even more effective performance than the LMS Technologies results imply.

Furthermore, real-world virus carriers such as water droplets from a sneeze form a shield around the virus, requiring substantially more UV-C or oxidizing energy to break down virus particles.

The long-term impacts of ozone are understood. Although UV-C, PHI and similar ionization technologies have improved to reduce the risk of ozone in recent years, introduction of hydro-peroxides, superoxide ion and hydroxides by such technologies are not yet studied in sufficient detail to know their long term impacts. Further evaluation is required.

The intent of PHI and oxidizing technologies is to create ions, which are naturally occurring in outdoor air. Instead of using technologies to increase ionization, simply using clean outdoor air, which contains ions naturally, is the preferred approach.