Schnackel engineers

ENHANCED HVAC INFECTION CONTROL: FILTRATION

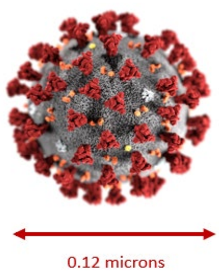
WHITE PAPER MAY 2020

This is the second in a series of white papers covering the topic of infection control in buildings through enhanced HVAC strategies.

Introduction

In this white paper, we will discuss the various performance characteristics of HVAC filters with the goal making an informed decision as to the right type of filter to use in a particular HVAC system application.

The removal of infectious particles from an airstream using filtration media is a difficult but not necessarily impossible task. Many infectious particles are extremely small in size, with the SARS-CoV-2 particle itself measuring only 0.12 microns (μm) in size.



SARS-CoV-2

However, individual infectious particles are not typically found floating in the air solo. They are usually attached to respiratory droplets, dust, water and other particles of varying size. The size of the particle carrying the virus greatly impacts the ability of the filtration media to remove the virus carrying particle and the virus with it. The larger the particle size, the easier it is to remove by filter media.

Very small particles can remain suspended in the air for long periods of time (up to 8 hours for a 1 μm particle) and travel for great distances in the space. They are also extremely difficult to remove with media filters. A 2015 study published by the National Institutes of Health examined the typical particle size associated with various types of respiratory viruses and found that these viruses were often found on particles as small as 0.3 to 0.7 μm.

HVAC Filter Media

Filter media comes in a wide variety of types, efficiency ratings, materials, and sizes. Since many infectious diseases are carried on particles as small as 0.3 μm, it requires a very high performance filter to be effective in removing the pathogens from an airstream once they reach the HVAC equipment. The typical disposable filters found in most HVAC equipment today do little to nothing to remove particles in the under 1 micron size range.

MERV Rating

Minimum Efficiency Reporting Value or MERV is a filter rating derived from ANSI/ASHRAE Standard 52.2 -- *Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size.* The MERV rating is on a scale of 1 to 16, MERV 1 being the lowest and MERV 16 the highest filter efficiency rating. The test measures the efficiency of the filter to capture particles of various sizes at established air flow rates. The particles sizes are grouped into three categories as seen in Table 1 below.

Standard 52.2 MERV	Composite Avg. Particle Size Efficiency % In Size Range, μm			Average Arrestance, %
	0.3 - 1.0	1.0 - 3.0	3.0 - 10.0	
1	n/a	n/a	<20	<65
2	n/a	n/a	<20	65 - 69
3	n/a	n/a	<20	70 - 74
4	n/a	n/a	<20	>74
5	n/a	n/a	≥20	n/a
6	n/a	n/a	≥35	n/a
7	n/a	n/a	≥50	n/a
8	n/a	≥20	≥70	n/a
9	n/a	≥35	≥75	n/a
10	n/a	≥50	≥80	n/a
11	≥20	≥65	≥85	n/a
12	≥35	≥80	≥90	n/a
13	≥50	≥85	≥90	n/a
14	≥75	≥90	≥95	n/a
15	≥85	≥90	≥95	n/a
16	≥95	≥95	≥95	n/a
17 (HEPA)	≥99.97	≥99	≥99	n/a
18 (HEPA)	≥99.997	≥99	≥99	n/a
19 (ULPA)	≥99.9997	≥99	≥99	n/a
20 (ULPA)	≥99.99997	≥99	≥99	n/a

Table 1
MERV ASHRAE Standard 52.2

A commercial air filter is tested under the ASHRAE Standard 52.2 at a face velocity of 492 fpm, unless noted otherwise on the manufacturer's test report. A filter will generally have a higher overall filtration performance level at a velocity lower than at 492 fpm. For example, a 24"x24"x1" filter would achieve very near a MERV 8 rating when installed in a 2,000 CFM system operating at 500 fpm, however it might perform at a higher than MERV 8 level when installed on a 1,200 cfm system operating at 300 fpm. Unfortunately, there is rarely any test data available to document the improved performance of a filter at lower velocities, however it is critical to maintain filter velocities below the ASHRAE test standard of 492 fpm to achieve the manufacturer's MERV rating and filter performance once installed in the system.

Historically Recommended Filter Standards

ASHRAE Standard 62.1-2019 _Ventilation for Acceptable Indoor Air Quality_ requires MERV 8 as a minimum standard for all commercial buildings. The following table (Table 2) provides general guidance from ASHRAE for filter applications by MERV rating in a pre-COVID-19 world:

Standard 52.2 MERV	Particle Size Range (µm)	Typical Applications	Typical Filter Type
1 - 4	> 10.0	▪Pre-Filters to protect higher cost downstream air filters ▪Lint or other rough particle air filters ▪Typical Residential ▪Typical Non-Ducted Fan Coil Units	▪Throwaway: Disposable fiberglass or synthetic panel ▪Washable: Aluminum mesh ▪Electrostatic: Self-charging panel
5 - 8	3.0 - 10.0	▪Pre-Filters to protect higher cost downstream air filters ▪ Typical Commercial Buildings ▪Better Residential ▪Industrial Workplaces ▪Paint Booth Inlets and Outlets	▪Pleated Filters: Disposable extended surface area ▪Cartridge Filters: Synthetic media ▪Throwaway: Disposable synthetic panel
9 - 12	1.0 - 3.0	▪Pre-Filters to protect expensive downstream air filters ▪Hospital General Care and Public Areas ▪Better Commercial Buildings ▪Best Residential	▪Pleated Filters: Disposable extended surface area 4"-6" deep ▪Pocket or Bag Filter: 12"-36" deep ▪Rigid Cell Box Filter: 6"-12" deep ▪V-Cell Filter 12" d
13 - 16	0.30 - 1.0	▪Final Filters ▪General Surgery ▪Best Commercial ▪Hospital Inpatient Care, Laboratories, etc. ▪Smoking Lounges	▪Pocket or Bag Filter: 12"-36" deep ▪Rigid Cell Box Filter: 6"-12" deep ▪V-Cell Filter 12" deep

Table 2
Filter Applications and MERV Ratings

Current LEED guidelines (Version 4.0 and 4.1) require a minimum of a MERV 8 rating for all recirculating space conditioning systems, with one LEED IEQ Credit available for utilizing a minimum of a MERV 13 rating on all units supplying outdoor air to the building, along with the other necessary improvements to achieve this Credit.

However, based on the desire to capture COVID-19 carrier particles, a minimum of a MERV 13 rating would be required to achieve even a 50% capture of particles under 1 microns, and a MERV 16 filter rating is required to achieve a 95% capture rate.

Filter Efficiency vs. Average Arrestance Ratings

The ASHRAE 52.2 test standard measures filter performance in terms of the efficiency and the average arrestance capabilities of the filter. These two metrics are very distinct from each other, however, they can create considerable confusion regarding filter efficiencies and manufacturer's claims. Do not let the average arrestance rating of a filter fool you into believing that an inexpensive filter is capable of achieving high levels of efficiency in air cleaning, particularly of small particles. It is not. The average arrestance rating of a filter is used only to rate the performance of filters that are not able to meet the minimum threshold of 20% on the particle size based efficiency tests.

The definition of these two ratings is as follows:

Arrestance: A measure of the ability of an air-cleaning device with efficiencies less than 20% in the size range of 3.0–10.0 µm to remove loading dust from test air. Measurements are made of the weight of loading dust fed and the weight of dust passing the device during each loading step. The difference between the weight of dust fed and the weight of dust passing the device is calculated as the dust captured by the device. Arrestance is then calculated as the percentage of the dust fed that was captured by the device.

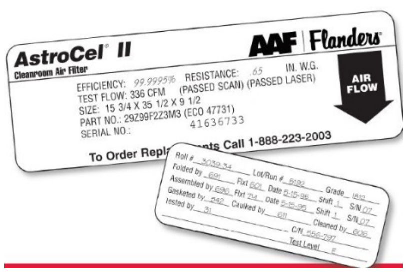
A filter with an average arrestance rating of 74%, is simply removing 74% of the weight of the particles in the test air stream. It is not removing any measurable amount of particles smaller than 3.0 microns, let alone any particles in the COVID-19 carrier particle size range of 0.3 to 0.7 µm.

Efficiency: The ratio of the downstream-to-upstream particle count over a series of 6 test cycles utilizing 12 different particle sizes ranging from 0.3 µm to 10.0 µm (72 total tests). The lowest values over the 6 test cycles are then used to determine the Composite Minimum Efficiency Curve.

HEPA and ULPA Filters:

As we have seen from Table 2, the ASHRAE MERV rating system application tables stop at a rating of MERV 16, with a minimum filter efficiency of 95% rating over a particle size range of 0.3 to 10 µm. That is a very efficient filter, however what if you want to go higher? HEPA or ULPA Filters can be the answer.

In general, filters with a rating of MERV 16 or below are considered to be HVAC-system-grade filters for residential, commercial and general hospital use. MERV 17 through MERV 20 filters are typically used only in sensitive surgical operating rooms, clean rooms, pharmaceutical manufacturing, radioactive particle filtration and other contexts that require absolute cleanliness.



ULPA Filter Label

A High Efficiency Particulate Air (HEPA) filter is a filter that can remove at least 99.97% of dust, pollen, mold, bacteria, and any airborne particles with a size of 0.3 µm and smaller. An Ultra Low Particulate Air (ULPA) filter is a filter that can remove at least 99.999% of those same particulates. Some ULPA filters can reach test efficiencies of 99.9997%. The diameter specification of 0.3 µm for HEPA and ULPA filter testing corresponds to the worst case - the most penetrating particle size (MPPS). Particles that are larger or smaller than 0.3 µm are trapped with the same or higher efficiency. Using the worst case particle size results in the worst case efficiency rating, i.e. 99.97% or better for all particle sizes for a HEPA MERV 17 rated filter. ULPA filters have been proven nearly 100% effective on particles as small as 0.12 µm, which is the size of an individual COVID-19 virus capsid.

Static Pressure Concerns

As we have seen, a high filter efficiency (high MERV rating) is crucial to any attempt to reduce the spread of infection through the HVAC systems in buildings. However, it is not as simple as picking a filter with a high MERV rating.

Due to their dense media and small passageways, high efficiency filters present a considerable amount of resistance to airflow that can quickly overwhelm the fans and motors in typical residential and commercial HVAC systems. This increased resistance, if not properly accounted for, can cause serious damage to the HVAC equipment including frozen cooling coils and potentially dangerous over-temperature conditions on heaters. In addition, the increased air resistance will increase energy cost of operating the system.

The following table (Table 3) provides the typical recommended initial and final resistance values for various type of filters along with the associated HVAC equipment that can typically accommodate the specified static pressures levels without damage. Actual filter pressure drops vary widely from these values, so the manufacturer of the specific filter used must be verified to ensure that the HVAC system can support the pressure loss.

Standard 52.2 MERV	Initial Resistance (inH$_2$O)	Final Resistance (inH$_2$O)	Remarks
4	0.10 @ 500 fpm	0.30	▪24x24x1Typical ▪Fan coils and other non-recirculating systems
8	0.33 @ 500 fpm	0.6	▪24x24x1Typical ▪Furnaces, rooftop AC
13	0.38 @ 500 fpm	1.0	▪24x24x2 Typical ▪Rooftop AC, modular air handlers
14	0.65 @ 500 fpm	1.4	▪24x24x6 Typical ▪Rooftop AC, modular air handling units, custom air handling units
16	0.80 @ 500 fpm	1.5	▪24x24x12 Typical ▪Custom air handling units
17 (HEPA)	1.4 @ 500 fpm	2.0	▪24x24x12 Typical ▪Highly customized air handling units
20 (ULPA)	1.4 @ 250 fpm	Up to 4.0	▪24x24x12 Typical ▪Highly customized air handling units

Table 3
Sample Filter Pressure Drop

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Summary:

Filter efficiency standards are a complex subject that has been evolving for many years. ASHRAE Standard 52.2 provides a way, via the MERV ratings, to simplify the selection of the appropriate filter for any HVAC system. The particle size of the contaminant to be filtered, in conjunction with the static pressure capacity of the system, narrows the field to a manageable set of options.

Cost is a major consideration in the decision as to which filter to install. Filter costs vary from under $9 for a simple MERV 4 filter to upwards of $800 for a single HEPA or ULPA filter module, with a much lower CFM capacity, requiring multiple modules to achieve the same airflow capacity.

Filters in the most common MERV 8 and MERV 13 rating categories are typically priced at approximately $11.00 and $22.00 respectively for a 24"x24" face filter size. Moving up to a MERV 14 filter of the same size, which achieves a greater than 75% efficiency on 0.3 to 1.0 µm particles, will cost anywhere from $180 to $200. MERV 16 filters, which are the highest of the HVAC-system-grade filters, are approximately $300 each and achieve greater than 95% efficiency on 0.3 to 1.0 µm particles. (All prices are in 2020 dollars.)

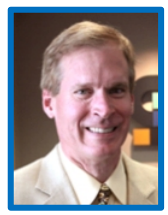
Provided that the additional filtration efficiency is determined to be warranted, the only other constraining factor is the ability of the HVAC system to accommodate the additional static pressure presented by the higher efficiency filters. This should be carefully analyzed before the decision is made to go to a premium efficiency filter. A relatively simple engineering analysis is necessary to confirm the static pressure capability of the HVAC system and to determine what upgrades may be necessary to accommodate the increased static pressure and increased physical size of the higher efficiency models.

Schnackel Engineers is available to assist architects and owners with the selection of the appropriate filter media for their individual situation and with any necessary upgrades required by the chosen filter selection.

About Pedro:

Pedro Ferrer, P.E., has been involved in the design of mechanical systems for malls, mixed-use developments, corporate offices, national retail roll-outs, commercial and institutional buildings for over 26 years with Schnackel Engineers. Pedro has a Bachelor of Science in Engineering Technology from the University of Nebraska in Omaha, and is a registered Professional Engineer.

About Gregory:



Gregory Schnackel, P.E., LEED AP has been involved in the design of mechanical, electrical, plumbing, fire protections and information technology systems for malls, mixed-use developments, corporate offices, national retail roll-outs, schools, hospitals, medical facilities, commercial and institutional buildings for over 40 years with Schnackel Engineers.

RESOURCES	
ASHRAE	https://www.ashrae.org/
U.S. Dept. of Energy.	https://www.energy.gov/
National Air Filtration Association	https://www.nafahq.org/
U.S. Environmental Protection Agency	https://www.epa.gov/
National Institutes of Health	www.nih.gov/