Clean Indoor Air Sustainability and Energy Savings: Yes You Can Have It All.

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Most People think of filters as they think of a screen door or colander – particles are removed because they are too large to fit through the openings. Actually, this is the least common mechanism of filtration. Most air filtration is done through the principles of impingement, interception and diffusion and to a lesser extent, straining and electrostatic attraction.

A basic concept is that the functional part of a filter is the media and that media is made up of fibers, be they glass, synthetic, metallic, ceramic, etc. **Straining** is indeed a mechanism of filtration, but only acts on the largest particles in the air – for instance, leaves, lint, insects and large moisture droplets.

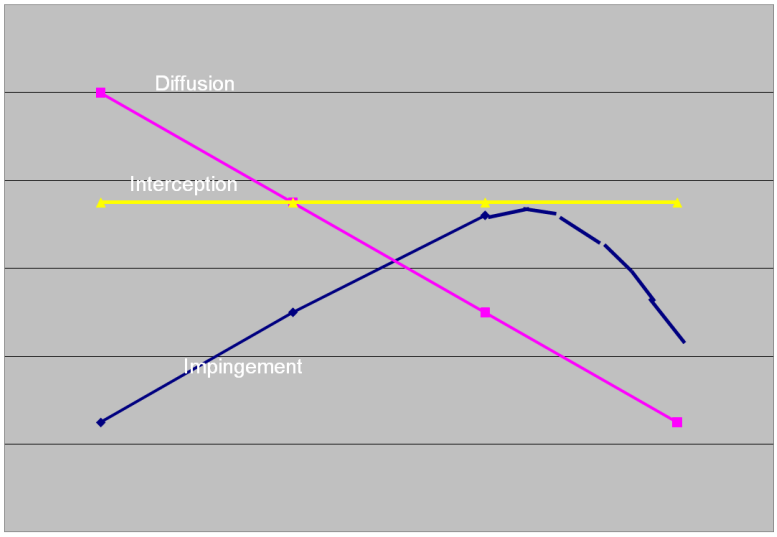
Like a large vehicle has momentum and cannot turn quickly, big particles traveling fast in the airstream are filtered because they cannot change direction and are captured by **Impingement**. Big particles traveling at high rates of speed. The airstream will flow around the fiber, but the particle, with more mass, will exit the airstream and impact itself on a fiber.

Particles in the airstream that are the same size or smaller than the filter fibers are captured by **Inteception.** This principle is particle-size dependent and the velocity it travels in the airstream are not usually as important as impingement or diffusion.

Smaller particles moving at slower speeds are captured because they are literally pushed against the fiber by gas molecules in the air. This principle is **Diffusion** as the particles literally diffuse across he face of the filter clinging to filter fibers.

Particles cling to filter fibers through weak molecular forces called van der Waal's forces – the electrical force attraction between opposite charges of molecules. When a filter is removed, a gentle tap onto a hard surface will dislodge many of the particles.

Electrostatic attraction naturally occurs in particles, fibers and a moving airstream. Polypropolene filters (also known as washable filters) use the force described above. Stronger electrical charges can be induced in filter fibers during manufacture. These fibers, called electret fibers, tend to collect dirt around the entire surface of the filter fiber and even cause particles to cling to particles.



This graph shows the relationship between Diffusion, Interception and Impingement. Diffusion is higher at lower velocities with smaller particles, impingement is higher at higher velocities with larger particles (to a point) and Interception is fairly constant with velocities and is particle and fiber size dependant.

Outdoor air is 98.5% composed of particles under 1 micrometer. Most all large particles – those above 10 micrometers – settle out in air. You probably have noticed these on the furniture and fixtures in your home or office. These large particles are usually distributed by vacuum cleaners and people bringing them into an environment. The smaller particles those under 10 micrometers, are those that get entrained in the moving air and can be filtered out by air filters. Some really small particles stay suspended in air forever, and never make it through a filter.

Your lungs are the place where the outside comes closest to the inside of your body – red blood cells are about 7 micrometers in diameter. When you don't use proper filtration in your building, your lungs become a filter. Our nose is a pretty good filter in that it stops the larger particles. All the way down through the airway passage, your bodily forces are working to remove particles of different sizes. Even particles that make it down to the smallest part of your lung – the alveoli are removed by other processes, however they can also be lung damaging.

This is why, early on, the air filter industry in conjunction with the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) developed test methods to determine the removal efficiency of a filter. These are industry standard test methods . In the case of HEPA filters, the military utilized specific methods for nuclear particle removal. And UL determined a test for fire rating. The ASHRAE tests are used to compare the performance of one filter to another, not to show performance in an application. The newer ASHRAE test in practice – 52.2 – is now the standard used…ASHRAE Standard 52.1 has been incorporated into 52.2 and is retired.

Because the 52.1 test did not measure the **size** of the particle – just the amount – an ASHRAE Committee was formed and a research project was done to develop a method to show removal by a filter based on particle size. A new challenge aerosol had to be found because outdoor air does not have consistent particle size distribution nor quantity. Potassium chloride was found to be the best and easiest aerosol for this purpose. Also, the Committee wanted to know the **minimum efficiency** of the

filter, rather than average efficiency as reported by ASHRAE 52.1. The minimum efficiency of the filter is typically in its clean configuration, since it would only become more efficient from this number. And this number, called a Minimum Efficiency Reporting Value (MERV) would be more like the European one-number system.

Even a new style of test device was developed to help shorten the distance for the particle counter lines. The 52.2 test duct begins by taking laboratory room air that is conditioned to ASHRAE Standard 55 (temp & relative humidity parameters) and using a HEPA filter, removes all particles. Potassium chloride is then injected upstream of the first optical particle counter (OPC) sample point and upstream of the filter under test. The particle counter determines the number and size of particles in the challenge stream. This aerosol then passes through the filter under test and, if not captured, pass around to the second particle counter sample point downstream. The air is then HEPA filtered to remove all remaining particles and recirculated to the laboratory. By this method, we know exactly how many of what size particles are captured by the filter under test. The dust loading is done exactly as in 52.1 and an efficiency test is run between each loading. The final efficiency numbers are used to determine the MERV value.

Utilizing the data points, an average is obtained in one of 3 efficiency ranges – E1 is 0.3 to 1.0 micrometers, E2 is 1.0 to 3.0 micrometers and E3 is 3-10 micrometers. By working backward from the 3.0 to 10 micrometer removal efficiency, one completes the numbers until there is no removal above the stated number in the MERV determination chart.

Two new items added to 52.2 within the last two meetings of the Standing Standards Project Committee. First, Addendum B was added to bring the testing of lower MERV number filters using the Arrestance test and dust holding capacity from ANSI/ASHRAE 52.1 method of test. This allowed the Committee to retire the 52.1 Standard. With lower efficiency filters, you will find the arrestance information and the average arrestance numbers.

In addition, total dust in grams captured by the filter under test will be shown. This information can possibly be useful in determining the time in service of a filter.

The second item added to ANSI/ASHRAE 52.2 is the Informative Appendix J also known as the Conditioning Step. Some electrically enhanced media have the fiber charge blinded by dust then loaded with smaller particles such as those found in the outdoor environment. The conditioning step is designed to provide critical filter applications with a method of determining how much the efficiency will drop in efficiency when loaded with these smaller particles.

End users of filters applied in critical applications may want to have their filters tested with the Conditioning Step. When Appendix J testing is done, it is noted by an “A” after the word MERV…for example a MERV 14 filter tested with the conditioning step would have a test report shown MERV A14

HEPA filters may be tested to ANSI/ASHRAE 52.2 Standard (MERV 17-20) however the DOP test has become the standard used for them. This test challenges with DOP or PAO which is aerosolized to a single size 0.3 micrometer particle. Downstream penetration readings determine efficiency of a HEPA.

Minimum efficiency of a filter that can be called at HEPA is 99.97% retention of 0.3 micrometer particles. HEPA filters can have efficiencies of 99.999% and are called ULPA or 99.9999% called SULPA – Ultra Low Penetration Air and Super Ultra Low Penetration Air Filters.

Because gas molecules are extremely small – much smaller than particles – ranging from 0.01 micrometer and below, they must be captured by a different method than particulate filters. Removal of gas-phase odor molecules is done by the mechanisms of Adsorption and Chemisorption. Adsorption is usually done by activated carbon – a universal substance for odors – and chemisorption is usually done with either potassium permanganate or activated carbon that has been treated with a chemical that chemically alters the odor molecule.

In summary, particles are captured by several different mechanisms and tested using ANSI/ASHRAE Standard 52. Gaseous contaminants are much smaller and are captured with activated carbon or chemically treated carbon or potassium permanganate.

Here is how we are defining "sustainability" in this presentation. We want facility managers to look beyond the initial cost of an item or piece of equipment to the life cycle cost of that item. This would include factors like energy use, how much additional pollution of the environment the item might have – in the case of air filters we are talking disposal in landfills and related costs, this also includes the use of facility personnel time to change filters, and providing a better environment to a facility. As is being demonstrated in research in the US and other countries, the indoor environment has a major impact on occupant's health and productivity.

In addition, filters tend to be easily damaged when shipped or kept in inventory so there's an 18.5% cost with this, and because they are bulky, they take up space in a dumpster and the facility pays for sending them to a landfill.

Energy Consumption (kWh) = $Q \times \Delta P \times t / \eta \times 1000$

Q = Air Flow (m^3/sec) t = Time in Operation (hrs)

ΔP = Avg. Pressure Loss (Pa) η = Fan/Motor/ Drive Efficiency

This really is not usually the case with filter pressure drop. A filter will not display an increase in resistance .01" each day for days, then require changing. They will load up very slowly at first, then as the dust particles begin to occupy a lot of space between the fibers where air used to pass, the resistance will begin rising. At the end of the filter's life is when the loading is the fastest.

Here is the summary of all of the costs just discussed. Even with the higher initial first cost, the high capacity pleat offers a savings of $238.77 in this example - **$185.27 just in electricity cost savings which is 77% of the total!**. Now, while this does not sound like much, this actual example is one of 8 buildings in an office park – all having similar HVAC systems for savings. The point is, this is the low hanging fruit…the easy painless way to utilize a formula to realize savings in energy and other total costs and increase the sustainability of the HVAC equipment and building furniture and fixtures. Just coincidently,

it helps improve the overall indoor air quality since the high capacity pleat is a couple of MERV points higher in efficiency.

- EA Credit 6 - 1 point - Document sustainable building cost impacts.
- NAFA Life Cycle Costing Formula can document sustainable impact on existing building

Under the Energy & Atmosphere, you have a prerequisite on building commissioning and the new ASHRAE Guideline (GPC 26) can help you with this procedure. Measuring air filter efficiency in-situ will provide even more useful information on system performance and airflow to help you document the commissioning process.

There is also an easy credit under E & A for training operation and maintenance staff on system operation and the NAFA Certified Technician (NCT) program is in place and ready for your use. Go to www.nafahq.org and click on accreditations to get more information on this.

The Indoor Environmental Quality (IEQ) category has some interesting items…while we agree that outdoor air ventilation is necessary for the dilution of certain contaminants in an occupied building, we are just as sure that there are contaminants in the outdoor air that come into a building and contaminant the space such as Ozone. This contaminant would be better removed before it entered the building through molecular filtration media such as activated carbon. Therefore, we know that you would agree that <u>just ventilation</u> does not by itself mean health and well-being.

We are pleased to see that recognition is given to the large amounts of contaminants that can be generated during construction and renovation activities, hence the point given for having MERV 8 filters at all return grills during this activity.

Because there are still many contaminants – both particulate and gas-phase – in building materials, using molecular filters to remove these contaminants instead of raising the temperatures in the building using the "bake-out" idea may provide another opportunity for an extra point, since the building must meet LEED levels of 5 contaminants of concern. There is also a point available for documentation of decreased absenteeism or other positive health improvements. Also, under 4.2 there is a point for other improvements in work or productivity gains that can be documented such as decreased error rates or increase work output.

There is a point given for using at least a MERV 13 filter as the ongoing filter for the system. Because of the use of newer configurations of air filters, and working with air filter professionals, you should be able to get MERV 14 – 15 air filtration with a lower pressure drop and longer filter life in service.

Using HEPA filtered cleaning equipment (vacuums cleaners by janitorial staff) will gain another point and will help eliminate one of the main causes of particulate contamination in buildings – that of vacuuming dirt and not having a quality filter on the vacuum cleaner. Again, this is easy. Finally, LEED does provide you, the building owner or manager with an open category where you can apply innovative applications beyond those listed in the LEED categories. For example, bathroom air in most commercial buildings does not have increased levels of humidity like residential bathrooms and the air is not dirty with

particulates. By simply running all building bathroom exhaust through activated carbon and removing odor contaminants, you can dump this air back into the recirculation stream and save on conditioning makeup air for exhaust and remove one negative air source in your building. For many commercial buildings, this is very large amount of air and dollars of savings.

In summary – looking at all of the costs for air filtration, you can impact sustainability of your system and facility. And you are doing something great for the environment through better utilization of resources. LEED provides the application of air filtration in several categories for a total of at least 6 points and then, as many as your creativity can devise.

NAFA now has a certification program for member products that assures the user that advertised information about product effectiveness and efficiency are backed with scientific testing. NAFA continues to educate its own member by providing certification programs, technical seminars and national conferences to educate and inform their members. As with any profession, there are many people claiming to understand filtration. Being a NAFA Certified Air Filter Specialist (CAFS) or NCT assures you the user that this individual has studied and passed a national examination relative to the field of air filtration and knows and understands how to effectively provide your clean air needs.