HVAC Air Filtration Basics & Rating

February 2, 2021

White Paper - Volume 18

Headquarters Address:
300 E-Business Way, Suite 300
Cincinnati OH 45241
Phone: 513-201-3100
Fax: 513-201-3190

E-mail:
info@bsiengr.com

Website:
www.bsiengr.com

CONTENT

ABSTRACT

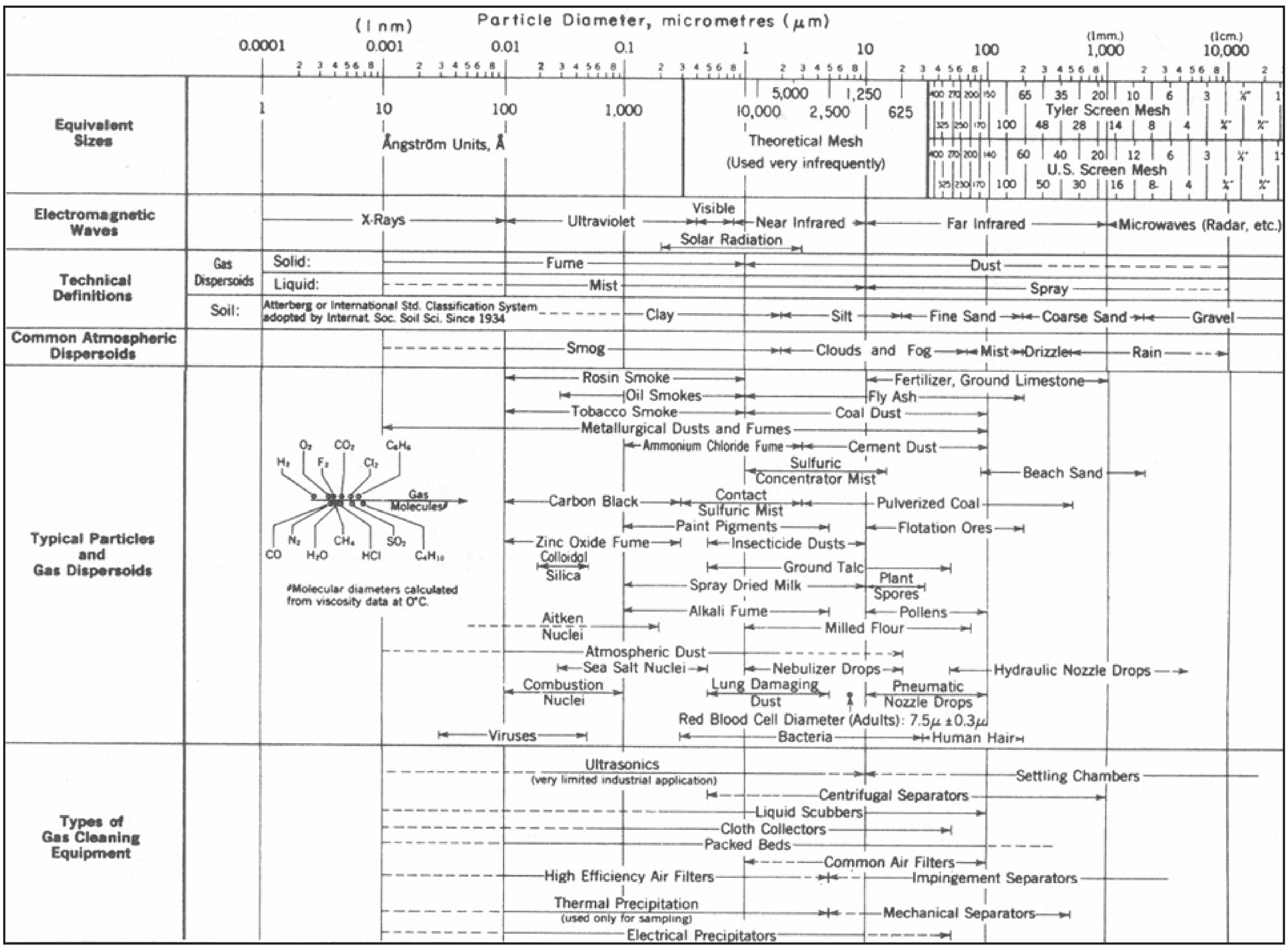
This white paper provides a tutorial on the various types of filtration and their application in heating, ventilation, and air conditioning systems or HVAC systems. In addition to everything from heat load calculations to acoustics and building codes, filtration is among the long list of items that engineers are required to understand. For most building applications, the American National Standards Institute and the American Society of Heating, Refrigerating and Air-Conditioning Engineers or ANSI/ASHRAE Standard 62.1, *Ventilation for Acceptable Indoor Air Quality*, defines minimum filtration levels. However, the amount and type of filtration should be given careful consideration for each building project because it can significantly impact both occupant comfort and equipment performance. The basics of filtration is covered including filter types, filter rating, the application of filtration types, and when to get help.

THE PURPOSE OF HVAC AIR FILTRATION

Filtration is used to control particulate and biological contaminants and keep them out of the building. Air borne contaminants can enter from outside the building such as dust, dirt, powder, fumes, and microorganisms. Other contaminants are generated within the building, such as man-made fibers, dust, and microorganisms.

Figure 1 shows the range of particle sizes. A typical cubic foot of air has 2.5 billion particles in it. While 99% of the individual particles are smaller than 1 micron, 70% of total weight comes from particles larger than 1 micron. This creates a need for two-part filtration – one step to remove the bulk of the material and a second step to remove fine particulate.

Figure 1 - Relative Particle Size

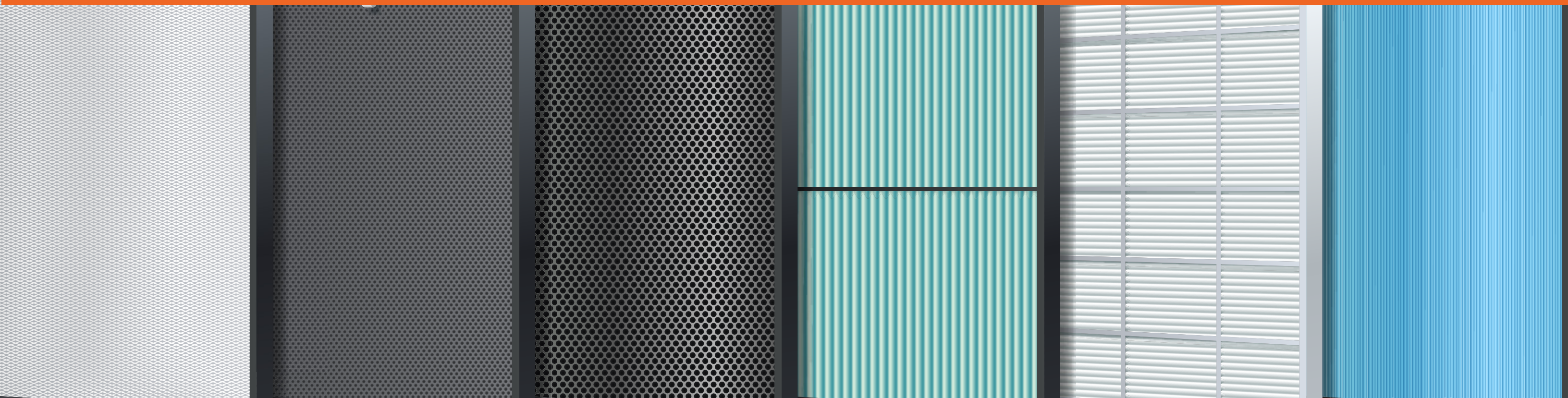


Gaseous contaminants normally pass through a particulate filter and require the use of different filtration technology, which is usually some form of chemical treatment. Sometimes, both types of filtration may be required depending on the application. Biological contaminants are essentially particulate, so they can be controlled by an appropriate particulate filter.

Ultraviolet lights provide another method for controlling biological contaminants. When applied properly, they can be effective at killing pathogens. However, in much the same way as chemical filters, ultraviolet lights do not remove particulates, so some form of particulate filtration is required.

The original focus of HVAC filtration was on protecting HVAC equipment and avoiding unsightly staining of diffusers and ceilings. More recently, occupant health has become the main focus. From a human comfort and health point of view, buildings have much higher population densities and pollutant sources, so maintaining acceptable indoor air quality is more of a challenge. HVAC equipment can become a source of biological pollutants. For example, mold can propagate inside the dark, dirty and moist environment of a HVAC system if not properly maintained.

Healthcare applications require a higher standard of filtration. Cleanroom classification is often based on the filtration level. A FS 209 Class 10,000 (ISO 14644-1 Class 7 or ISO Class 7) clean room has 10,000 particles at 0.5 microns or less per cubic foot. A FS 209 Class 10 (ISO Class 4) clean room has only 10 particles per cubic foot. FS stands for the U.S. General Service Administration's (GSA's) federal standard, and ISO stands for the International Organization for Standardization. The more restrictive levels, e.g. ISO Class 4, require advanced filtration system design. Health care facilities need to control biological contaminants; in critical areas such as operating rooms and intensive care units (ICU's), the filtration system must be able to stop most if not all pathogens.



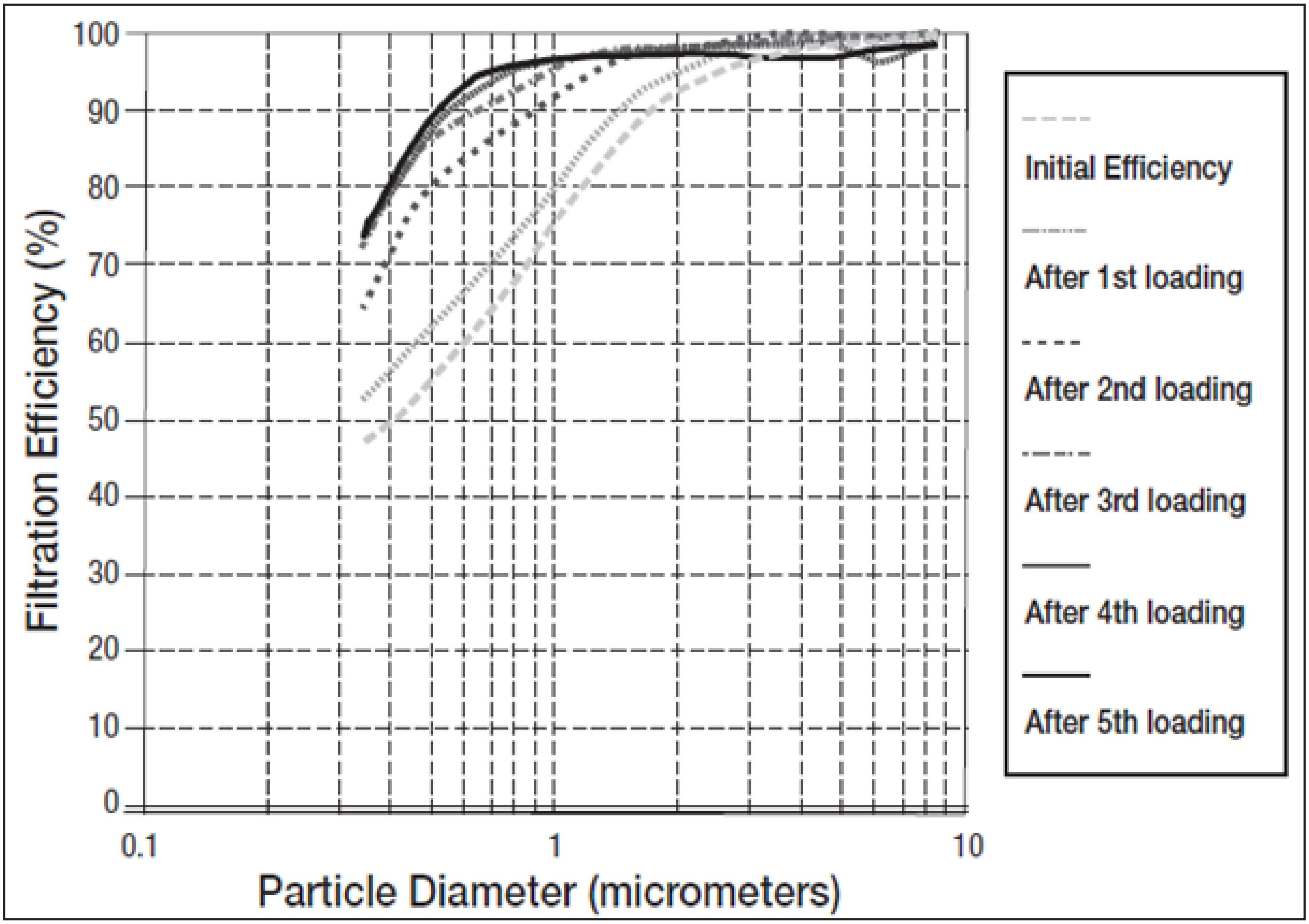
RATING FILTER ELEMENTS

ASHRAE has an old and a new standard for filter testing. The old Standard 52.1, Gravimetric and Dust-spot Procedures for Testing Air Cleaning Devices Used in General Ventilation for Removing Particulate Matter, provides familiar ratings for most HVAC engineers. When a filter is referred to as being a "35% efficient pleated 2-inch throwaway", the filter was rated using the 52.1 Standard. Standard 52.1 initially rated filters on their ability to "arrest" material that would have an adverse effect on HVAC equipment. The "arrestance" test uses a defined mixture of particles and is the average performance over the life of the filter. The filter is able to arrest smaller material as it gets dirtier.

Over time, the tests evolved to include a dust spot test to rate the filter's ability to stop fine particles that could soil and stain the building walls and its contents (e.g., the stains around diffusers). The dust spot test uses atmospheric air, which can vary from test location to test location. When a single efficiency number is given (say 95%), it is the average because there is a portion of time when the filter is not as efficient as its nominal filter efficiency suggests. In fact, the filter goes through a wide range of efficiencies as it goes from clean to dirty. This is why the filter manufacturers provide a range of efficiencies in their catalogs for each filter. A filter with a 25% dust spot efficiency will usually have an arrestance above 90%. The percent efficiency that is referenced is the dust spot efficiency.

The new standard is ANSI/ASHRAE Standard 52.2, Method of Testing General Ventilation and Air Cleaning Devices for Removal Efficiency by Particle Size. Standard 52.2 is focused on minimizing health risks from particulate matter. This standard requires testing the filter with a controlled aerosol, e.g. potassium chloride, instead of "typical" air. A particle counter is used to measure the arresting ability of the filter over 12 size ranges from 0.30 micron up to 10 microns. The filter is loaded in increments from clean to dirty with a pre-defined dust mixture and then re-tested. Once this is done, a chart can be drawn that shows filter efficiencies for different particle sizes from clean to dirty as shown in Figure 2.

Figure 2 - Standard 52.2 Filter Efficiency Curve



The performance of the filter is then compared to a predefined set of parameters called a minimum efficiency reporting value or MERV. MERV values range from 1 to 20. Table 1 shows a comparison of the MERV rating versus the Standard 52.1 method.

Table 1 - Comparison of MERV Rating to the Dust Spot Efficiency by Standard 52.1 Method

Standard 52.2 (MERV)	Approximate Standard 52.1		Particle Size Range
	Dust Spot Efficiency	Arrestance	
15	>95%	N/A	1
14	90-95%	>98%	1
11	60-65%	>95%	2
8	30-35%	>90%	3
6	<20%	85-90%	3

ACCEPTABLE INDOOR AIR QUALITY

ANSI/ASHRAE Standard 62.1, Ventilation for Acceptable Indoor Air Quality, defines the minimum ventilation rates required to obtain acceptable indoor air quality. The premise is that the outdoor air is of acceptable quality, and that ventilating a building with it will control indoor contaminants through dilution. Table 2 was developed by the U.S. Environmental Protection Agency (EPA) and provides ambient air quality standards for outdoor air. About 60% of the U.S. population lives in "non-attainment" areas, where conditions exceed the EPA table. Standard 62 requires that the outdoor air be treated if it does not meet the levels required by the U.S. EPA table.

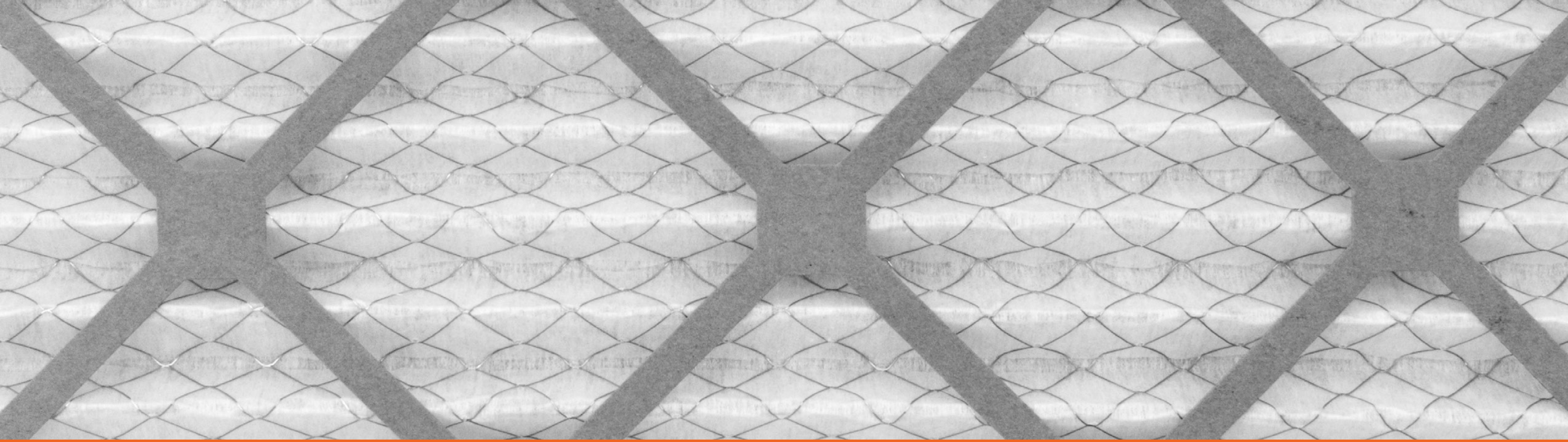
Table 2 - National Primary Ambient-Air Quality Standards for Outdoor Air as set By the U.S. Environmental Protection Agency

Contaminant	Long Term Concentration Averaging			Short Term Concentration Averaging		
	μg/m³	ppm		μg/m³	ppm	
Particles (PM 10)	80	0.03	1 year	365[a]	0.14	24 hours
Carbon Monoxide	50[b]	-	1 year	150		24 hours
Carbon Monoxide				40,000	35	1 hour
Oxidants (ozone)				10,000	9	8 hours
Nitrogen Dioxide	100	0.055	1 year	235[c]	0.12	1 hour
Lead	1.5	-	3 months[d]			

Standard 62 Addendum S requires that filters with no less than MERV 6 or 25% efficiency be used upstream of all cooling coils or other condensate-producing devices. Addendum R requires that each ventilation system with an outdoor air intake have the necessary devices to clean the air prior to its introduction into occupied spaces in locations where the outdoor air is not acceptable. For particulates, filters with a minimum MERV of 6 are required. Addendum Z addresses unacceptable outdoor air, requiring a minimum 40% efficient ozone removal system be included if the ozone is too high.

If the indoor air quality procedure of Standard 62 is used, then the indoor contaminants must be identified and maintained at the same level as acceptable outdoor air. This will require some level of filtration, depending on the contaminants.

If an "extraordinary event" needs to be considered, such as a biological or radiological release from a nearby facility, ASHRAE has published a 75-page report, available on their website, for conducting an evaluation of the filtration system under consideration. One of the recommendations is to consider filters with the highest MERV feasible because most biological and radiological particles are in the range of 0.1 to 10 microns. A filter with a MERV rating of 14 to 20 can be very effective in defending against these particles.



GENERAL GUIDELINES: FILTRATION EFFICIENCY

As a minimum, the designer should meet the requirements of Standard 62.1, considering the recent addendums that address cooling coil filtration and the quality of outdoor air. For healthcare applications, the designer should follow specifications outlined in the American Institute of Architects or AIA guide to hospital design or the new ASHRAE design manual of healthcare design as outlined in Table 3.

Table 3 - Filter Efficiencies for Central Ventilation and Air Conditioning Systems in General Hospitals

Area Designation	No. Filter Beds	Filter Bed #1 (%)	Filter Bed #2 (%)
All areas for inpatient care, treatment, diagnosis, and those areas providing direct service or clean supplies such as sterile and clean processing, etc.	2	30	90
Protective environment room	2	30	99.97
Laboratories	1	80	-
Administrative, bulk storage, soiled holding areas, food preparation areas, and laundries	1	30	-

1. Additional prefilters should be considered to reduce maintenance required for filters with efficiency higher than 75 percent.
2. Filtration efficiency ratings are based on average dust spot efficiency per ANSI/ASHRAE Standard 52.1.

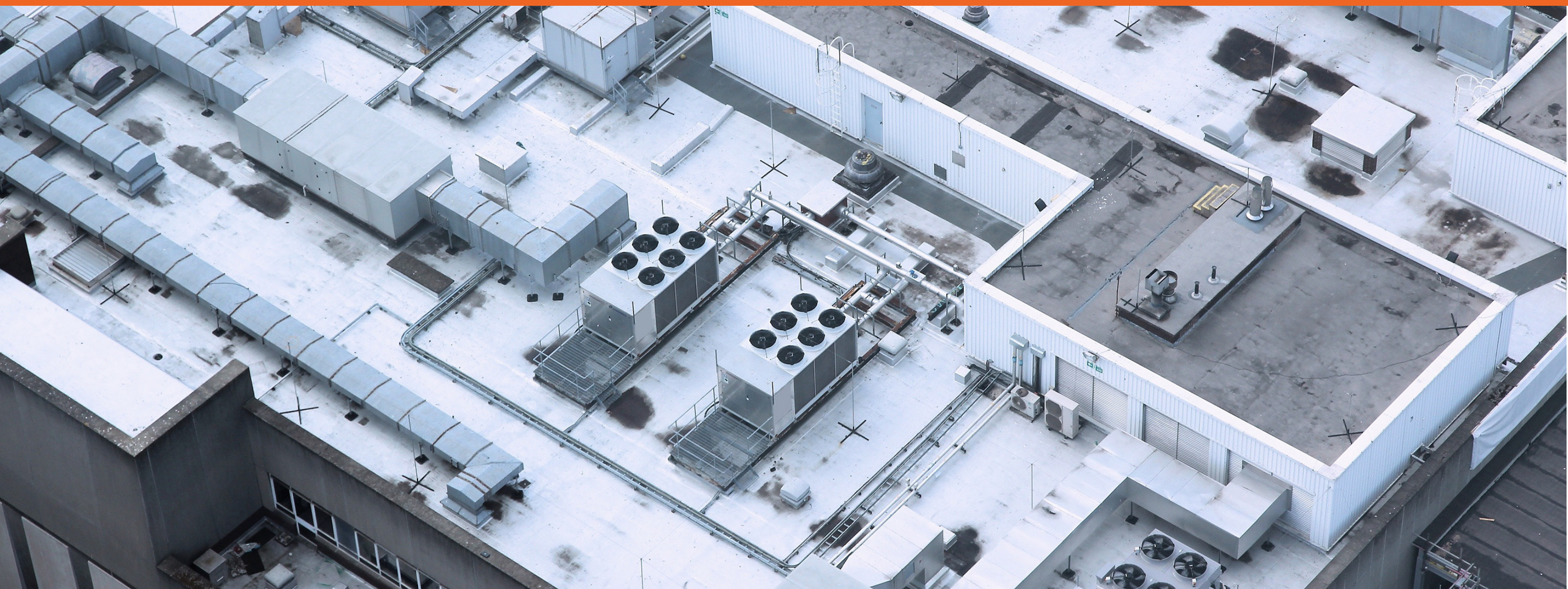
Filters should not be specified by just MERV or dust spot efficiency, but on their ability to arrest the particle size in question. For example, the particle size for a paint line is around 4 microns, so the filter should be effective specifically around 4 microns. Different filters with the same MERV number may be more or less efficient at arresting 4 micron particles, so it is important to review the filter effectiveness curves that are available from filter manufacturers.

The bulk of the weight of particulate matter comes from particles larger than 1 micron. The purpose of a pre-filter is to remove as much of this mass as possible. The final filter is then used to remove the high count but small weight of fine particulate. A typical maintenance arrangement will require the pre-filters to be changed quarterly and the final filters to be changed annually although this ultimately is controlled by usage.

Both filter banks can be held by the same filter rack at the front of an air handling unit, which can help to minimize the unit length. The filters are usually the first component after the mixing box, which is a common arrangement for high-end office and institutional applications.
Some applications, such as health care buildings, require that the final filters be the last component in the air stream so that they can capture any dust that is introduced into the air handling unit through servicing or infiltration. In this arrangement, the pre-filters remain at the front of the unit to protect the equipment.

Do not to use a blow through fan arrangement with final filters in the final position. The issue is that the cooled air will most likely be saturated, and the pressure drop through the filters will lower the partial pressure. This can result in moisture condensing on the filters. Draw through fan arrangements add the fan motor heat to the supply air and raise it above the dew point, making condensation less of an issue. A plenum fan should be considered for filters in the final position. The plenum fan will evenly distribute air across the entire filter bank and allow the air handling unit to be shorter in length.

High efficiency particulate air filters or HEPA filters are tested in a different manner than other commercial particulate filters. A HEPA filter is 99.97% efficient at arresting a 0.3 micron particle. They are tested by exposing the filter to Dioctyl-Phthalate particles, which are 0.3 microns in size. For every 10,000 particles, only 3 can get through the filter. An ultra-low particulate air filter or ULPA filter is 99.999% efficient at stopping 0.3 micron particles.



GENERAL GUIDELINES

PRESSURE DROP

As filters accumulate particles, their pressure drop increases. Filter manufacturers provide both clean and dirty filter pressure drops. The change can be significant. Consider clean 30% pre-filters and 95% bag filters. The pressure drop is only 0.6 in. w.c. when they are clean, but it climbs to 2.0 in. w.c. when they are dirty. If the HVAC system is designed based on clean filters, the air flow will not meet design conditions as soon as the filters begin to load up.

In critical airflow applications, such as space pressurization and high air change rates, designing a system based on dirty filters will provide the required air flow rate at all times. Choose a fan with a very steep fan curve so changes in static pressure result in only small changes in air volume. It may also be necessary to provide a method for modulating the fans to maintain the design airflow rate. Using the fan curve, check the airflow rate with clean and dirty filter differential pressures to determine if the space pressurization remains acceptable.

VELOCITIES

Filters have a maximum allowable velocity. Most are rated at 500 fpm, which is the typical face velocity for a cooling coil in an air handling unit. Some packaged rooftop units operate at much higher face velocities. The maximum filter face velocity should be ascertained and confirmed to be acceptable.

It may be economically justifiable to use a face velocity below 500 fpm, particularly for constant volume units with high operating hours such as health care, pharmaceutical, etc. Reducing the internal static pressure drop can often provide enough fan power savings to offset any increase in capital cost. The increased filter area reduces the frequency of filter changes as well.

GENERAL GUIDELINES: CONFIGURATIONS

Bag and cartridge filters have the same efficiency, but bag filters take up more space because they are longer than cartridge filters, and they can sag at low air flow rates. However, bag filters are about half the price of the equivalent cartridge filter, and they have an abundance of surface area, which can result in less frequent changes being required. Consider bag filters in applications where filters will be changed frequently.

The use of carbon and similar filters is generally limited to industrial applications. On occasion, poor outdoor air quality requires gas filtration for conventional HVAC applications. These are specialized filters that require expert assistance. The designer should first look for all possible methods to relocate the intake before considering carbon filters.

Ultraviolet or UV lights kill bacteria, viruses and spores when applied properly. They enhance medium range particulate filters that are not efficient enough to arrest pathogens. In addition, they can minimize bacteriological growth inside the air handling unit.

Electrostatic filters operate by charging a grid that causes particulates to adhere to the grid. Once the grid is dirty, it requires cleaning. The advantage of this system is the low static pressure drop. They are particularly attractive for small units and residential applications. The disadvantage of electrostatic filters is that efficiency decreases as they become dirty. Disciplined maintenance is required to maintain good performance. Larger scale systems charge particulates causing them to adhere together so that conventional filters can arrest particulates that would otherwise pass-through the filter elements. Electrostatic filters are very popular in casino and similar applications where there is tobacco smoke.

CONCLUSION

Filtration is a key component in achieving acceptable indoor air quality and can play a critical role when extraordinary event scenarios need to be considered. Cost analysis can be performed when needed to evaluate the capital and operating costs especially when higher pressure drops are encountered. This can lead to a clear understanding about the minimum and maximum required filtration and the advantages and disadvantages of enhanced filtration.

THANK YOU

FOR CHOOSING US!

BSI Engineering is a full-service provider of engineering and design services for a very broad range of industry sectors.

The majority of our 200+ employees have over twenty years of technical experience and are ready to add their expertise to your project from any of our midwestern office locations. We deliver exceptional value for our clients wanting a fully integrated, engineering-led EPCM model.

BSI ENGINEERING
designing for the *future*
building on the *past*

300 E-Business Way, Suite 300
Cincinnati OH 45241

Phone: 513-201-3100
Fax: 513-201-3190

E-mail: info@bsiengr.com
Website: www.bsiengr.com