

## AMBIENT AIR FILTRATION OPTIONS

### Summary

New ASHRAE standards require the use of particulate filters where air quality standards for particulate matter are exceeded and documentation of design decisions where other air quality standards are exceeded. This report reviews two filter arrangements currently used in healthcare, biotechnology and better commercial buildings and estimates annual costs for each. It reviews additional systems with higher control efficiency that might be applicable for new health care and biotechnology buildings and estimates annual costs.

### Introduction

The new amendments to ASHRAE Standard 62-2001, *Ventilation for Acceptable Indoor Air Quality*, require the use of particulate matter filters with a Minimum Efficiency Reporting Value (MERV) of 6 or higher whenever a building is located in an area that is not in compliance with the National Ambient Air Quality Standard (NAAQS) for particulate matter (Section 6.1.1 as amended May 27, 2003). Where other pollutants (besides ozone; it is dealt with separately) exceed their NAAQS, the design decisions regarding the control of these pollutants to protect indoor air quality must be documented.

The use of MERV to classify filters arises from ASHRAE Standard 52.2-1999, which is only now being fully implemented by the filter industry. It replaces the earlier test methods of dust spot efficiency and arrestance with a numeric scale based on the efficiency of removal of particles of specific sizes. The table below gives the definitions of the MERV in terms of particle size efficiency and the contaminants that each will typically control.

MERV	Efficiency	Contaminants
6	35% < Particles 3 to 10 micrometers <50%	Mold, cement dust
8	70% < Particles 3 to 10 micrometers <85%	Pesticide sprays, fogs
12	80% < Particles 1 to 3 micrometers <90%	Bacteria, acid mists
16	95% < Particles 0.3 to 1 micrometers	Tobacco and diesel smoke

### Pollutants

Urban air-sheds receive exhaust and waste streams from a myriad of combustion and industrial processes. A recent study by the Puget Sound Clean Air Agency<sup>1</sup> evaluated the

<sup>1</sup> L. Keill and N Maykutt, *Puget Sound Air Toxics Evaluation*, Puget Sound Clean Air Agency, October 2003

pollutants found in monitors near downtown Seattle and found higher concentrations of toxic air pollutants along the Interstate-5 corridor than had previously been understood. The more important pollutants are carbon monoxide, diesel particulate matter (DPM), benzene, carbon tetrachloride, and formaldehyde. The report identified DPM as of greatest concern.

DPM is the product of combustion from automobiles and trucks. The Environmental Protection Agency designates DPM as “reasonably anticipated to be a human carcinogen,” based on cancer rates in occupational groups with high exposure to diesel exhaust. DPM is created from the burning of diesel fuel. It consists of many different types and sizes of material, but generally ranges from 0.01 to 10 microns in size. The majority of the DPM (by mass) occurs at 0.1 to 0.5 microns with a mean of 0.3 microns. Like tobacco smoke, this is the size range that penetrates deepest into the lungs. Because DPM is a particulate, it can be filtered from the incoming air. However this size of particle is the most difficult to filter out.

Although the PSCAA report describes only pollutants that are not subject to national ambient air quality standards, the concerns raised by this report suggests the type of consideration and documentation required by ASHRAE 62-2001 would be appropriate for any new facility within approximately one-half mile of I-5 within Seattle, especially between approximately the Boeing Access Rd & I-5 interchange and the WA 520-I-5 interchange.

### **Existing building air intake systems**

Currently, many health care, biotechnology and better commercial buildings provide an effective air intake filtering system. Two model intake systems can be identified that are generally used at such facilities to reduce the particulate matter in the incoming air.

The most common air-intake particle control sy

filter from Tri-Dim. It is also a “depth” filter. The 4-ply filter is rated at about 60-65% initial efficiency for particulate matter of 1-1.5 microns. It is about 5% efficient for particles of 0.3 microns in size.

The second stage of the filtering process involves a high-efficiency rigid-V filter, similar to the extended surface MV series filter from Viledon, or Defiant Serva-Cell VA series from Purolator. The filter media consists of a custom organic synthetic material and its shape dramatically decreases the pressure drop that would be experienced with a flatter filter. The synthetic fibers of the filter create an electrostatic charge on the filter intended to increase particle collection. The efficiency of the filter used for a particular facility or area in the facility varies depending on the activities at that part of the facility. Biotechnology laboratories and patient areas in hospitals might be served with a Viledon MV95 filter that is 95% efficient at 1 micron. At 0.3 microns, this filter is about 80% efficient. The aggregate efficiency of this filter and the prefilter would be 99% for 1-micron particles and 87% for 0.3-micron particles.

Areas that demand very clean incoming air, such as operating rooms in a hospital, might utilize a high-efficiency HEPA filter system. These HEPA filters are similar to the Purolator Ultra-Cell 95, which is 95% efficient at 0.3 microns and near 100% at 1 microns. Carbon-impregnated filters are being utilized in buildings that are susceptible to the intake of exhaust from vents containing organic chemicals. However, the long-term effectiveness of carbon-impregnated filters at removing air contaminants is even more dependent on maintenance cycle length than is the case with other filters.

## Upgrade options for existing systems

The first model system described above is already quite efficient at eliminating small particulates from the incoming air stream. It is estimated that 75% of 1-micron particles, and 40% of 0.3 micron particles are removed from air. If it is desired to improve this performance, several options are available to increase the efficiency of the existing system.

One approach would be to convert to the MERV 8 pre filter and MERV 14-16 main filter system. This would increase the filter efficiency of the system to about 99% of 1-micron particles and about 87% of 0.3-micron particles. An alternative would be to add pre-filtering to the MERV 11 system. A two-stage system consisting of a 4-ply Tri-Dek-type pre-filtering and a MV65 main filtering would achieve an aggregate efficiency of 95% for 1-micron particles and 61% for 0.3-micron particles.

When retrofitting new filters into an existing system it is important to remember that higher efficiency filters will significantly increase the load on the fans. In general, the fans for an existing system will be already operating at maximum capacity, thus, hindering the system’s ability to handle more filters or higher efficiency filters, either of which would increase pressure drop, increase power costs and, potentially, decrease total flow.

## Upgrade Cost Analysis

The costs of upgrading the filter system per unit are estimated in this section. This model system is based on a 2,000-cfm unit with the filter dimensions of 24x24 inches. Other

factors, such as electricity cost, and the amount of dust entering the system is based on a general case because the actual values will vary depending on many factors. Costs of maintenance and other labor are not included in this analysis.

Based on the number of times filters are usually changed in a year in a relatively clean air area, it is estimated that 3,500 grams (approximately 8 lbs) of dust enters a 24x24 inch filter unit a year, on average. Accounting for filter efficiency and dust holding capacity, the number of times a year a filter unit must be changed can be calculated. The increasing pressure drop across the filter unit between new and change out can be used to calculate the amount of electricity consumed due to the filter, each year. The annual operating cost for each type of filter is reported in Table I.

**Table I. Annual Operating Cost of Filter system unit.**

<u>Filter</u>	<u>Cost/unit</u>	<u>Life w/o Pre-filter (months)</u>	<u>Life w/ Pre-filter (months)</u>	<u>Average Pressure drop (inches)</u>	<u>Electricity used (kWhr)*</u>	<u>Electricity cost**</u>	<u>Total w/o pre-filter</u>	<u>Total w/ pre-filter</u>
4-ply pre-filter	\$7.00	3	NA	0.65	1445	\$79.46	NA	\$107.46
Viledon MV65	\$75.00	6	36	0.86	1912	\$105.14	\$255.14	\$130.14
Viledon MV95	\$105.00	3	18	0.90	2000	\$110.03	\$530.03	\$180.03

NA: does not apply

\*Assumed average fan power efficiency of 93%

\*\*Electricity cost based on \$0.055/kWhr

Average pressure drop is based on an assumed 1.5 inches pressure drop at change out for each type of main filter and 1.0 inches for the pre-filter.

A single stage MV65 filter has a total estimated annual cost of about \$255.14, as shown in Table I. If pre-filtering were added to each unit, then the operating cost for the MV65 filter alone would fall to \$130.14, with extension of the change out time to once every three years from twice a year. However, the additional 4-ply filter also has an operating cost associated with it of \$107.46 a year. Therefore, the total operating cost of the upgraded system will be \$237.60 a year, which is a savings of \$17.54 per unit per year. Note that maintenance and labor cost is not included in this estimate, which would be less with fewer changeouts. Upgrading the system to allow use of the prefilters will require planning, engineering and construction. Whether or not these costs would be recovered by the savings is very facility-specific.

If the air-intake systems are upgraded facility wide to the high-efficiency (MERV 14-16) system suggested earlier, then all filter units would need to add pre-filtering and change the MV65 to a MV95. The total operating cost of a unit utilizing a 4-ply filter and a MV95 is \$287.49. This upgrade results in an extra \$32.35 per year per unit in operating cost. Maintenance and labor cost is not included. Again upgrading the system to allow use of prefilters will require planning, engineering and construction.

## New Buildings

New buildings serving the health care, biotechnology and better commercial markets should consider a filtration system using MERV 8 prefilters and MERV 11 final filters, but possibly MERV 14-16 where superior performance is needed.

Most air intake systems have their filters positioned upstream of the fan. Filters are generally designed to operate under suction rather than pressure. However, if one wishes to obtain the filter efficiency indicated by choosing a MERV 14 to 16 final filter, it is important that the secondary filter be placed downstream of the fans. This will ensure that no contamination of the air-stream occurs after filtration. Fans can pull dust and other pollutants into the duct from openings in the fan housing or ducting. Placing the filters downstream of the fans ensures that this extra contamination is filtered out.

If MERV 14 filters are used for the new systems, then the 87% 0.3-micron efficiency can be expected. However, a more efficient system can be achieved by applying compact box filters as the main filter in each system. For example, Viledon makes filters that have the same dimensions as the Viledon MV95 filters and consist of a high-strength glassfiber paper mesh with conical pleat geometry to limit the pressure drop. They have high efficiencies and are 100% humidity resistant. The MX100 is the highest efficiency filter and is rated at 99.9% efficiency for 1-micron particles, and 95.5 % efficiency for 0.3-micron particles. The MX98 filter is rated at 99% efficiency for 1-micron and 90% efficiency for 0.3-micron particles. The lower grade MX filters would not be as efficient as the MV95 filters. Using the same standard 4-ply pre-filter, applying the MX100 and MX98 filters would result in aggregate efficiencies of near 100% and 99.8% for 1-micron particles, and 97.1% and 93.5% for 0.3-micron particles respectively. These filters create a higher pressure drop than their MV cousins, requiring a heavier fan system.

To ensure greater efficiencies for the elimination of 0.3-micron particles than the 97.1% that the best of these systems can achieve, an additional option that can be considered is the addition of a tertiary stage. A 95-99.99% HEPA filter can be added to this stage to ensure that nearly 99.99% of 0.3-micron particles are eliminated from the incoming air-stream. However, this will be a costly step for a small gain in efficiency from that which is already being achieved. A 95% HEPA filter added to the system would increase efficiency for the 87% system to 99.65%. A new fan system could be designed to provide this extra pressure drop where this higher control efficiency is justified. This would double the pressure drop from around 2 inches of water to about 4 inches of water. This alternative is not being recommended except for special situations.

## New Facility Air-intake Systems Cost Analysis

The operating costs for the proposed systems are discussed in this section. As before, these model systems are based on 2,000-cfm units with the filter dimensions of 24x24 inches. Other factors, such as electricity cost, and the amount of dust entering the system is based on a general case because the actual values will vary depending on many factors. The cost of maintenance and labor is not included in this analysis.

As before, an estimated 3,500 grams of dust enters a unit a year on average. Accounting for filter efficiency and dust holding capacity, the number of times a year a unit must be changed can be calculated. Also, the amount of electricity consumed due to the average pressure drop across a filter can be calculated.

The annual operating cost for each filter system is included in Table II. Each system in the analysis includes a 4-ply pre-filter. The same cost per unit per year included in Table I for the pre-filters is used for the new systems and is added onto the total. This average cost was estimated to be \$107.46 per unit.

**Table II. Annual Operating Cost of Filter system units.**

<u>Filter</u>	<u>Cost/unit</u>	<u>Life (months)</u>	<u>Average Pressure drop (inches)</u>	<u>Electricity used* (KWhr)</u>	<u>Electricity cost**</u>	<u>Total w/ pre-filter</u>
Viledon MV65	\$75.00	36	0.86	1912	\$105.14	\$237.60
Viledon MV95	\$105.00	18	0.90	2000	\$110.03	\$287.49
Viledon MX95	\$157.18	36	0.96	2123	\$116.75	\$276.60
Viledon MX98	\$163.80	24	0.98	2178	\$119.81	\$309.19
Viledon MX100	\$236.90	24	1.65	3668	\$201.71	\$427.62

\* Assumed average fan efficiency of 93%

\*\*Electricity cost based on \$0.055 KW-hour

The average cost per year for each type of filter is included in Table II. Other manufacturer's filters are not included in this table but they do produce filters that are competitive with both types of filters. As mentioned above, the Purolator Serva-Cell rigid VA filters are similar to the MV series. The Tri-Dim Syn-Pac XL-II bag filters and the Tri-Cell Thin Line filters provide similar performance. The Purolator Serva-Cell extended surface ASHRAE rated filters are similar to and competitive to the Viledon MX line.

The MV95 and MX95 filters result in about the same operating costs. MX filters will hold more dust, so can be changed less often, but cost more per unit and place more stress on the fan with their higher pressure drop. MX95 filters also are less efficient at 0.3-microns. Because of the different maintenance cycles, a decision analysis should include maintenance costs.

Applying the MX98 line instead of the MV95 line would result in a 6.5% increase in efficiency at 0.3-microns. However, this would cost an extra 12% per unit.

Applying the MX100 line instead of the MV95 line would result in a 10% increase in efficiency at 0.3-microns. However, this would result in a substantial extra cost increase of 49%.