

Filtration and Building Security

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Since 9/11, homeland security experts, including the U.S. military and the National Institute for Occupational Safety and Health have promoted high-efficiency filtration, including chemical air cleaning, as a “silver bullet.” The central idea is to use the building HVAC system as the ultimate defense barrier to protect building occupants from airborne environmental hazards.

This article briefly summarizes performance advantages and provides a reality check of the limitations of particulate filtration and chemical air cleaning (FAC). With this knowledge, users can make more informed decisions regarding selection, application, and operation of these systems to harden the protection of their buildings.

Building Protection

The following recommendations are based upon declassified military standards for use under the severe exposure risks of battlefield conditions and are applicable to buildings having similar

exposure risks. The heart of this guidance consists of the following:

HEPA filtration (high-efficiency particulate arrestor or arrestance air filter). HEPA is used for control of solid particulate matter, such as respirable spores, bacteria, or radioactive particles. These filters are widely used in cleanrooms, hospital operating rooms, and pharmaceutical and electronic manufacturing.

HEPA's removal efficiency is 99.97% of particles larger than 0.3 microns. At the time of their development in World War II, this was considered to be the most penetrating particle size. However, it is now known that this size constraint

is closer to 0.2 microns, meaning that filter efficiency increases on either side of the size band. This efficiency level is comparable to a MERV 17 designation (Minimum Efficiency Reporting Value as determined by ANSI/ASHRAE Standard 52.2-1999, *Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size*). Versions of the filter are available with even higher efficiencies, up to 99.999%—a MERV 20 designation.

HEGA air cleaning (high-efficiency gaseous adsorber). HEGA is for chemical molecular control, such as toxic industrial chemicals (TICs) or war gases. The HEGA uses a specially treated carbon called ASZM-TEDA that is designed to control designated war gases (the acronym indicates the reagents used to treat the carbon). Chemical filters using other containment configurations and other sorbents, such as untreated carbon, permanganate treated alumina, or blends of sorbents are used for

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odor control, pollution control, and industrial applications. Both technologies were derived from work in WWII for the containment of radioactive iodine around nuclear reactors.

Proper prefiltration enhances the life cycle of these high-performance components. Lower efficiency and lower cost filters in the MERV 6 to 13 range are used as sacrificial guard prefilters. Likewise, lower efficiency and lower cost chemical filters can broaden the control and enhance the life cycle of the HEGA cartridges.

Monitoring ensures sustained performance of the systems. Pressure gages and sampling cartridges monitor airflow performance and indicate optimal change times.

Air capture is equally important to ensure all air entering the building is treated with FAC. Thus, total air capture isolates the space from an external environmental contaminant source. Although this implies that the outdoor air is the primary source, maximum protection is achieved by also treating the return or mixed air since random infiltration or an internal release may be the source.

Positive pressurization of the building by sustaining at least 0.02 to 0.03 in. w.g. (5 to 7 Pa) pressurization minimizes the risk of infiltration. This is often sufficient to overcome normal wind pressures on the envelope.

Safe havens can be employed using these same guidelines of filtration and pressurization if a specific area within the building has been designated as a high-risk area.

Reality Check for Owners

The reality is that in many existing buildings, these optimal and ultimate controls may not be possible or practical. In other cases, risk assessment and determination may not indicate the need for as severe a level of protection, yet some incremental enhancement is desirable. The following discussion is intended to assist owners of existing buildings to help increase their building's resistance to airborne contaminants and to do the best they can within their own unique constraints.

Reality 1: Air Capture

This reality is that the delivered performance of filtration is dependent on total capture of air. This starts with ventilation air since all air that comes into the building must be treated. It also includes the return air system that may or may not be ducted providing varying degrees of capture and control. Unducted return systems provide the least control. Also, the exhaust system interface often can override or interfere with pressure barriers and relationships causing spaces or the building to go negative.

Even minor pressure differentials of a few pascals can negate zoning and intended air pathways. Thus, the role of

stack effect and the pumping action of elevator shafts must be considered.

Location of the filtration systems is important—whether in outdoor air, return air, or combined in mixed air—as this can be critical to sizing, efficiency, and life-cycle determination. Zoning and location are especially critical if specific space within the facility has been selected as a safe haven. This space must be totally isolated from the balance of the building and treated with independent filtration to protect building occupants temporarily during an emergency.

Air capture was the subject of a September ASHRAE Journal article (“Building Ventilation and Pressurization as a Security Tool”) by Andy Persily, Ph.D., Fellow ASHRAE, where readers can gain further understanding of the critical nature of air bypass and leakage around buildings.

Reality 2: Understanding Cost Hurdles

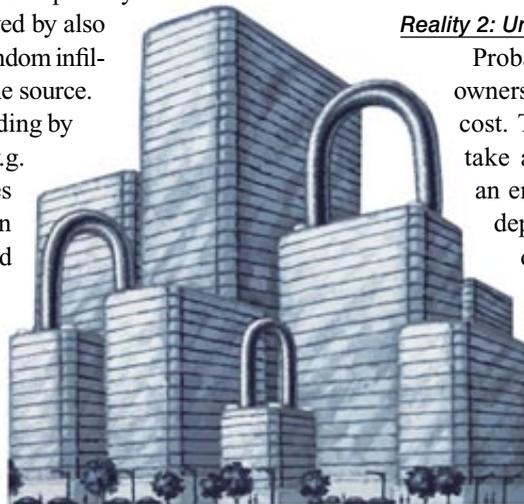
Probably the most difficult reality for building owners and designers are the hurdles of size and cost. These filtration systems are huge. They take as much or more footprint space than an entire air handler—up to 15 ft (4.6 m) in depth—because of airflow ratings, cartridge depths, and service access space requirements. This is mandated by the high pressure drop requirements of HEPA and HEGA cartridges. This also requires low airflow velocity rates in the 250 fpm (1.3 m/s) range that doubles the filter bank cross sectional size. Yet, total system pressure drops are still in the range of 6 to 9 in. w.g. (1500 to 2240 Pa) This can potentially triple HVAC energy costs.

First cost leaps from merely incidental to \$2 to \$3 per ft² (\$22 to \$30 per m²) This includes filter cost, housing cost, mechanical room cost, performance certification costs, and related air handler modifications to accommodate the higher pressure drops. It follows then that the owning and operating cost also can escalate from pennies per cfm to dollars per cfm. The good news is that these costs are mitigated by offsetting savings from system cleanliness and related efficiency gains; improved IAQ; and increased productivity of occupants.

A further bonus is that these costs can be incremental dependent upon efficiency and complexity of the system, meaning that lesser but acceptable improvements may be attainable at more modest costs.

Reality 3: FAC Is an Art Form and an Underused Asset

Filtration is not widely applied in commercial buildings other than some specialty buildings such as museums, large assembly, health care, and cleanroom applications. Thus, many users are not aware of filtration technologies, especially gas phase. Al-



Building Security

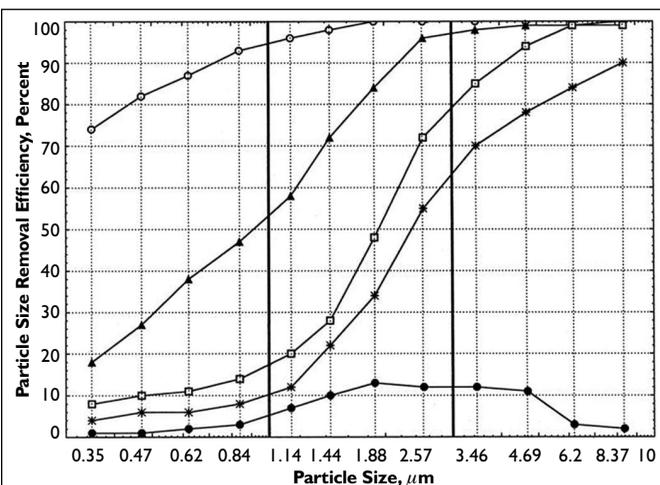


Figure 1: This graph illustrates typical fractional efficiency performance filters ranging from <MERV 4, 8, 9, 11, and 14, which are the data product of Standard 52.2-1999. Using the old 52.1 test, that correlates to <20, 25–30, 40–45, 60–65 and 90–95%. The advantages of the 52.2 Method of Test are that it provides a controlled test aerosol; tests for minimum efficiency, when clean, as well as more than five loading stages; and evaluates minimum efficiency over a range of 12 particle sizes from 0.3 to 10 microns. These resulting composite curves reveal the minimum efficiency of the filter over all particle sizes and over all loading stages. The three denoted bands from 0.3 to 1, 1–3, and 3–10 are then averaged to provide the easier designation handle—the MERV number. This precise efficiency information provides an understanding of minimum performance against known particles of known size, such as bacteria. It also illustrates that high removal efficiencies are possible with lower cost and lower pressure drop filters. Note that the MERV 14 filter will provide very good efficiency against one micron and larger sized particles, which may be acceptable based upon risk assessment. Experience in New York indicates that this increment of protection enhancement can be attained for pennies per square foot.

Test Site:	Measured Removal Efficiency Percentage				
Washington, D.C.	0.3	0.5	1.0	3.0	5.0
MERV 8	9.2	26.3	50.0	63.6	71.0
MERV 11	20.6	31.4	58.6	80.0	83.3
MERV 14	35.7	45.4	60.1	100.0	100.0
MERV 16	99.3	99.6	100.0	100.0	100.0

Figure 2: These field data were acquired during a study funded by the Alfred P. Sloan Foundation and Kimberly-Clarke, which analyzed the impact of various filtration efficiencies upon the occupied space of 50 building sites in five cities, including this critical government building in the Washington, D.C., area. The data compares MERV 16 minipleat performance to lesser MERV efficiencies. It uses particle count data to document the high level of filtration feasible in the supply air using fractional efficiency MERV 16 filters. In this case, the MERV 16 minipleats replaced MERV 13 and MERV 8 filter cartridges in the same holding frames without system modification. The air handlers were new and the filter systems treated blended outdoor and return air.

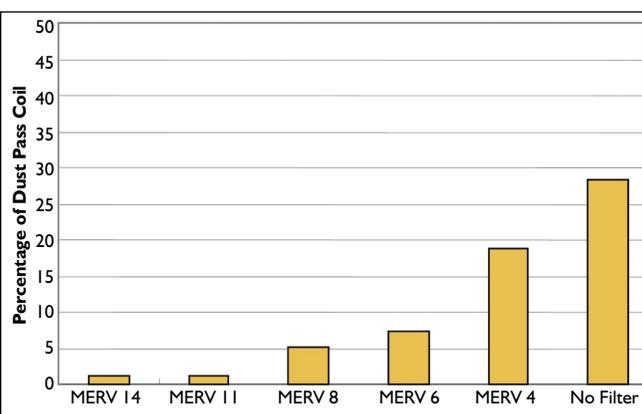


Figure 3: This chart is based on recent research sponsored by ARTI (the Research Institute of ARI). It illustrates the amount by mass of particulate that can penetrate the filter during a loading cycle based upon the MERV level. It vividly demonstrates the advantage of using higher MERV filters, whether the objective is a clean system or occupant protection. Thus, the higher the MERV efficiency, the cleaner the supply air—intuitive but now confirmed. This research also documented that energy savings from clean coils in both blower and refrigeration can help mitigate the increased first cost and operating cost of the higher MERV filters.

though Standard 52.2 has been published since 1999, its data product—the MERV—is not widely used by specifiers.

Gaseous filtration is even worse since an industry consensus test method does not exist for chemical filters (ASHRAE is in the process of developing Standard 145P). Since these products are not widely used in the building stock, their benefits and total value are not well understood by building owners, designers, or specifiers.

This reality is that filtration has been a housekeeping matter, and facility management is not aware of the critical nature of air cleaning in regard to life safety and security.

Reality 4: Filtration is Fractional in Efficiency

As an example of the art of filtration, it is important to understand the reality that, just like dilution, all filtration is fractional. Even the HEPA has a penetration of 0.03%. This means that of a million 0.3 micron sized particles/ft³ (35.3 million particles per m³) in outdoor air, 300 particles/ft³ (10 600 particles per m³) will break through. In a 100,000 cfm (47 190 L/s) system, that is a total of 30 million particles/min. breaking through.

The total retention HEGA may hold all of a specific chemical at a specific concentration for a period of time. However, other chemical species or a high concentration for an extended period can potentially overwhelm the active bed. Thus, neither the HEPA nor the HEGA are “total” or “absolute” protection.

The higher the challenge concentration load, the more contaminant breakthrough. If that contaminant is a highly contagious disease spore, it could be a severe problem.

However, this breakthrough is controllable by constant recleansing of the return air, as in the case of safe haven locations. However, if the air must be treated in a single pass, like outdoor air, the retention efficiency, breakthrough point, and life cycle become extremely critical.

Fractional efficiency comes into play with MERV 16 and less efficient filters. Their performance is also a function of particle size fraction. The saving reality of fractional efficiency is that incremental increases in efficiency yields incremental increases in occupant safety at incremental increases in cost.

Reality 5: Most Seals Are Flawed

Most installed filtration systems in commercial buildings have flawed seals that can steal efficiency and performance. In the same field study referenced in *Figure 2*, I found all 50 monitored systems had some form of seal failure or impairment. Thus, the role of filter seal and integrity is critical to the filtration system performance.

Side load units, whether factory-built or contractor field-built, are the worst. Even small openings, cracks, or voids bypass large percentages of the airstream. Anecdotal data indicates that nominal gaps of 0.25 to 0.5 in. (6 to 13 mm) are common. These leaks can bypass up to 18% airflow. If the bypass is sufficient, increased filter efficiency will not be discernible downstream. In fact, it may drop because of even higher bypass rates induced by subtle increases in pressure drop.

Gaskets age, compress and lose resiliency, erode, soften to dust, drop off, or just disappear. Cartridges are not gasketed between filter frames, which seldom mate perfectly or distort when installed in a moist environment. Retainer systems are seldom caulked and retention clips fall off, don't work, corrode, or become inoperative. These seal flaws can substantially erode the expected performance of the filtration system and must be addressed before increases in efficiency can be attained. The correction of seal problems should be the first money spent on filtration enhancements.

Reality 6: Understanding Value

To fully appreciate the value of filtration, users should understand total cost as it applies to filtration products. Energy cost dominates and far outweighs all other related factors. Labor cost is further impacted by filter

life cycle and change-out pattern and disposal complexity. Thus, the longer the life, the lower the labor hours and the lower the time unit cost. The disposal cost of filters potentially contaminated with hazardous waste can far exceed the initial cost of the system.

With HEPA and HEGA containment, the change-out often involves testing and recertification for seal integrity. The least significant factor is the first cost or price of the filters.

Advertisement formerly in this space.



(Left) This system serves a surgery facility in Florida. Note the filter cartridge does not even fit in the track. (Center) This photo shows disappearing filter door gasket in a college science building in San Francisco. The door is downstream of the filters and upstream of the fan. (Right) This photo shows corrosion that has caused daylight holes to outdoors as shown in this campus library unit. This hole allows bypass around the filter bank.

Realities Summary

The purchasing decision should consider the filter system that lasts the longest, requires the least energy, and minimizes change-out labor and cost. Thus, the filter cartridge that has higher surface area, lasts longer and has lower pressure drop, but costs twice as much, is still the better purchase decision for life-cycle value.

Getting the Most of Existing Systems

Many owners of existing buildings have limited mechanical space, airflow capacity, or budgets. Thus, their reality is that they cannot apply the ultimate filtration system. Or perhaps, their risk does not warrant that high a degree of protection.

Fortunately, the fractional efficiency aspect of filtration offers incremental options that ratchet up the performance scale in cost, pressure drop, efficiency, and space requirements. Efficiencies of particulate filtration are available up to MERV16 in versions that can be successfully applied in conventional air handlers—often without major or expensive modifications.

Even gas phase sorbers are available in intermediate efficiencies and can use a selection or even a combination of sorbent types, such as potassium permanganate treated alumina, carbon and reagent-treated carbon.

Thus, building owners can opt for the incremental degree of filtration that they can apply and afford. Let's consider how building owners can get the most value out of their existing systems.

Seal everything. The first and most effective expenditure of time and money is filter seal. Seal, caulk, and gasket everything: the filter cartridge, the retainer bank, the tracking, the access door, and the air handler. The downstream effective increase in cleanliness can exceed a 20% improvement. Without proper sealing, enhanced filtration efficiency will be wasted.

Monitor. Once sealed, the system should be monitored and changed on the basis of airflow—not visual inspection or timed change-out. The 2 in. (50 mm) pleated filter is routinely changed quarterly based on manufacturer's recommendation. However, airflow monitoring might extend the actual change-out to six months or longer, which is a 100% increase in life and value.

Upgrade whenever possible. If 2 in. (50 mm) pleats are installed in front loading retainer frames, replacing them with

comparable 4 in. (100 mm) cartridges will more than double their lifetime and save more than half of their energy cost. The common MERV 5–6 pleat replaced with a MERV 8–11 pleat will also gain over 40 percentage points in efficiency at 3.0 microns. These newer enhanced pleats are widely available at nominal cost and pressure drop premiums.

If the retainers can accept 4 in. (100 mm) cartridges, upgrade to MERV 12 or 13 using high surface area minipleat panel filters to gain enhanced efficiency with nominal space requirements.

When medium efficiency MERV 8 to 12 bag filters are installed, upgrade to MERV 13 or 14 minipleat cartridges to gain efficiency with little pressure drop or space premium.

If your risk assessment indicates protection beyond MERV 14, the MERV 16 minipleat provides “near HEPA” efficiency of greater than 98% at 1 micron. The remarkable feature of this cartridge is that it operates at 500 fpm (2.5 m/s) at an initial pressure drop of 0.6 in. w.g. (150 Pa). Thus, it can be installed in the same retainer systems as the MERV 14 with little compromise in life cycle, room, and pressure drop.

Increase surface area. Whenever feasible, use the highest surface area filter possible as this disproportionately yields greater life cycle and value, increased efficiency, and lower energy usage.

Prefilter only where necessary. To enhance and protect the higher cost HEPA and HEGA final filters, use “guard” filters to catch large mass particulate load and high concentration gaseous spikes. This protects both the performance and the expected life cycle of these systems. Based upon personal field research experience and a large body of anecdotal evidence, the most cost-effective particulate guard prefilter is the MERV 13 minipleat.

The most practical, cost effective, and useful guard filter for high-efficiency HEGA cartridges is the extended media carbon or carbon/permanganate alumina blend in an immobilized fabric matrix. Both guard filters are extended media cartridges that operate at acceptable pressure drops. Further, they do not require further prefiltration, which leads to the next point.

Eliminate prefilters whenever possible. In spite of the previous comments, further prefiltration of intermediate ef-

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iciency filters can be wasted cost, labor, space, and energy. Obviously, heat exchange surfaces require protection, but unless an unusually heavy load of contamination exists in the outdoor air, the life-cycle extension of the final medium efficiency filter will not justify the additional life-cycle cost burden of the prefilter.

Apply SIP. To gain high levels of protection in smaller, isolated spaces, consider shelter in place (SIP). This can take the form of adapted air-handling units to serve an isolated zone or self-contained factory manufactured SIP units that incorporate all the essential filter components within a self contained blower housing capable of limited air distribution within a safe haven zone.

Although higher in cost per cfm than central systems, the SIP provides a simple and cost-effective option when dealing with smaller safe haven retrofit applications rather than treating an entire building. Likewise, standby units can be rigged with all the appropriate filtration to treat air that is diverted during a known emergency. Their weakness is knowing when to turn them on, which could be a case of too much, too late.

New Capital Installations

When dealing with new construction, renovations, or when risk assessments substantiate mechanical alterations, the following recommendations will gain the most value from new capital installations.

Start with risk assessment. Base your efficiency and equipment selections on your assessment of risk and vulnerability. With known targets of concern, the appropriate type and efficiency filtration can be applied.

Build-in seal. Regardless of the selection, focus on proper filter system seal. This is always more thoroughly and more cost effectively done during the installation process.

Employ the increments. Understand that particulate and gas phase filters offer increments of performance that can be matched with risk and exposure models.

Deal with cost. Deal upfront with the hurdle or “gate” represented between MERV16 and MERV 17. This incremental increase in performance represents a quantum leap in filter bank size, cost, pressure drop, energy, and operating cost.

Apply life-cycle cost. Understand and apply life-cycle analysis and make selections based on total system value—not first cost.

Use ASHRAE Standard 62. ANSI/ASHRAE Standard 62.1-2004, *Ventilation for Acceptable Indoor Air Quality*, approaches air quality primarily from a dilution standpoint, but it also recognizes that similar contaminant control can be attained with filtration (extraction) as prescribed in the Indoor Air Quality Method. This allows for ventilation reduction when filtration is used.

Since enhanced filtration and air cleaning is involved for purposes of building security, both capital and operational costs can be reduced through the IAQ method when renovations or new construction are involved in the hardening process. Reduction of outdoor air is limited by needs for makeup and pressurization, but reduction of excess ventilation made possible by the IAQ method also reduces exposure to external chemical/biological challenges.

Oversize, oversize, oversize. Whenever possible, oversize the filter system to proportionately lower the airflow rating of the filter cartridges and attain even greater proportionate gains in lower pressure drop, decreased energy, lengthened life and increased dirt holding capacity, with positive impact on lifetime cost and value.

Carefully consider and evaluate new technologies. Emerging contaminant control technologies should be considered during the renovation or new construction stage, but with caution. For example, using UVGI (ultra-violet germicidal irradiation) has demonstrated enhanced control features when used in conjunction with HEPA filtration. The design team should be extremely cautious about unproven products of systems, regardless of the claims, since their application is a life/safety issue. Further, if the claims sound to good to be true, they probably are.

Conclusions

I believe filtration can be a silver bullet to improve the airborne environmental protection of your facility *if* you understand the realities of your building and *if* you understand the applicable filtration technologies and *if* you appreciate how to gain full value of your filtration upgrades.

Filtration can be the silver bullet to attain your cleanliness and safety goals, whether they are the ultimate and ideal safe haven building or merely incremental protection for improved occupant comfort, productivity, indoor air quality, and system operating efficiency. ●