Guidance for

Protecting Building Environments from Airborne Chemical, Biological, or Radiological Attacks

ECONOMIC CONSIDERATIONS

Costs associated with air filtration and air-cleaning systems can be divided into three general categories: initial costs, operating costs, and replacement costs. Although some users might consider only the initial costs when selecting an appropriate filtration system, it is important to weigh carefully all of the life-cycle costs. The HVAC design engineer should assist you in understanding the costs and benefits of various air-filtration options.

Initial Costs

Initial costs include those for original equipment—the filter rack system, individual filters, and auxiliary equipment—and the usual direct and indirect costs associated with installing a new system related to the electrical, ducting, and plumbing work. The total purchase cost of the filtration system is the sum of the costs for the filter rack system, filters, and auxiliary equipment; instruments and controls; taxes; and freight. For particulate filters, expenses generally increase as filter efficiency and quality increase. For some applications, a lower-efficiency filter (e.g., MERV 12) may be adequate and can be used instead of a HEPA filter (MERV 17) to control costs while achieving adequate performance. For gas-phase filters, the cost differences among sorbents can be dramatic. For example, natural zeolite, alumina, and activated carbon are generally the least expensive sorbents. Specialty carbon (such as ASZM-TEDA), synthetic zeolite, and polymers are typically much more expensive (as much as 20 times more expensive). A trade-off to consider is that carbon needs to be replaced frequently (every 6 months to 5 years), while zeolite and polymer replacement can occur less frequently.

Other factors that influence the initial costs of a system include the volumetric flow rate, contaminant concentrations, and in the case of adsorption systems—bed size, sorbent capacity, and humidity. Volumetric flow and pressure drop may be the most important factors because they determine the size of the ductwork and filter rack, as well as the blower and motor. Effective sorbent filters typically have a resistance of at least 125 Pa (0.5 in. water gauge) for thin beds and 500 Pa (2.0 in. water gauge) or more for deep beds.

Operating Costs

Annual operating costs include operating labor and materials, replacement filters, maintenance (labor and materials), utilities, waste disposal, and equipment depreciation. These costs vary, based upon the specific filtration system. Many of these costs should be considered in terms of the present value of money. Operating and maintenance labor costs depend on the filter type, size, and operating difficulty of a particular unit. Electrical costs to operate the blowers are directly related to airflow through and pressure drop across the filters.

Replacement Costs

An important part of replacement costs relates to the estimated life of the filtration system. As filter life increases, the cost per operating hour falls. However, when mechanical filters are exposed to contaminated air, the pressure drop across them increases, and this can increase electrical costs. Costs can be minimized by your evaluation of the system and selection of the best final pressure drop to replace filters, based upon extended filter life and minimized power requirements.

Factors affecting particulate filter life include contaminant concentration, particle size distributions, airflow rates, and filter efficiency and quality. Particulate filters are frequently used in multiple stages to extend the life of more expensive final stage filters. Factors affecting gas-phase filter life include removal capacity and sorbent weight, sorbent collection efficiency, airflow rates, and molecular weight and concentration of the contaminant. Filter replacement labor costs depend on the number, size, and type of filters, their accessibility, how they are held in the filter rack, and other factors affecting labor.

Cost Data

The cost of air-filtration and pressurization systems in new construction is about $6/ft^2 of floor area for basic, continuous HEPA and gas-phase V-bed filtration, using activated carbon. Operating costs are on the order of $5.40/m^2/yr ($0.50/ft^2/yr). Adding sensors and on-demand military style radial HEPA or carbon filters can cost up to $430/m^2 ($40/ft^2), and operating costs can increase to over $16/m^2/yr ($1.50/ft^2/yr). The cost of renovating an existing system may be up to three times more than the cost of new construction, depending on the amount of demolition, new ductwork, and enlargement of mechanical spaces required.

In most filter applications, the size of the filter bank is determined by the size of the heat transfer coils. The filter is placed upstream of the coils to reduce soiling. The filter bank is sized to the coil because the coil area is the point in the ducted portion of the air distribution system having the lowest velocity. The lower velocity of air through an air filter will result in a lower pressure drop across the filter. A lower pressure drop across the filter leads to a lower system pressure drop, resulting in lower fan horsepower and operating energy. In most cases, sizing a moderately efficient air-filtration system to be larger than the coil area will result in high filter rack costs, which are not offset by a significantly reduced filter pressure drop. However, as the cost of energy increases, the benefit of lower pressure drop filters and larger filter racks becomes apparent.

Required fan horsepower is related to the total system pressure drop. For example, improving filtration to increase the filter pressure drop from 250 to 500 Pa (1.0 to 2.0 in. water gauge) will boost the total system pressure drop from 1000 to 1250 Pa (4.0 to 5.0 in. water gauge). However, in this example, the higher pressure drop will increase the required fan horsepower by roughly 40%.

The costs and benefits of the filters should be considered. A 25% ASHRAE filter (0.61 by 0.61 m [2 by 2 ft]) will cost approximately $10 to $20, while an 80% or 90% ASHRAE filter will cost in the range of $40 to $75, respectively. For example, if a system uses 60 filters at a cost of $70 each and they are replaced annually, the present value of the enhanced filters over 25 years will cost approximately $14,000. The benefits of higher-efficiency filters may include less need for coil cleaning and a reduced pressure drop due to cleaner coils. If these two factors save $1,000 annually, the present value of the savings is $17,500, which compensates for the increased filter cost.A standard HEPA filter (0.61 by 0.61 m [2 by 2 ft]) costs approximately $100 to $250. Initial HEPA filter pressure drops are around 250 to 325 Pa (1.0–1.5 in. water gauge), depending on the design flow rate, fan performance curve, and related issues. Peak pressure drops can be as high as 750 Pa (3.0 in. water gauge). Analysis has compared the cost efficiency (particle removal rate divided by life cycle costs) of HEPA filters to ASHRAE 25%, 80%, and 90% filters [Kowalski et al. 2002]. This analysis showed that ASHRAE 80% and 90% filters are substantially more cost efficient than HEPA filters.

Filter replacement time must be a trade-off with the energy cost, which is associated with driving the air through the high-pressure drop filter. The higher the cost of energy, the more frequently the building operator should change out the higher-pressure drop filters. The number of filters that should be used in the design is limited by the available space and energy savings from reducing the system pressure drop. If energy is inexpensive, then fewer filters may be used. However, this does not take into account the environmental impact of wasted energy. If energy costs are high or are expected to increase over the life of the system, then selecting the maximum number of filters for the available space should be considered, along with filter rack costs.

The cost of a standard size (0.61 by 0.61 m [2 by 2 ft]), individual, high-efficiency gas-phase filter is about $2,000 to $4,000. These high filter costs drive the design to use as few filters as possible. High energy costs (>$0.40 per kilowatt hour [kW?h]) are required before it is cost effective to increase the number of filters, thus, reducing the system pressure drop (energy) costs. Lower-efficiency and lower-cost gas-phase filters are available for indoor air quality applications. Less expensive gas-phase filters should be designed using the cost trade-off techniques described for particulate filters. However, you should recognize that these lower-cost options may not have the adequate adsorption capacity needed to provide protection during a CBR event.

CONCLUSIONS

Filtration and air-cleaning systems may protect a building and its occupants from the effects of a CBR attack. Although it is impossible to completely eliminate the risk from an attack, filtration and aircleaning systems are important components of a comprehensive plan to reduce the consequences. CBR agents can effectively be removed by properly designed, installed, and well-maintained filtration and air-cleaning systems. These systems have other benefits besides reducing clean-up costs and delays, should a CBR event occur. These benefits include improving building cleanliness, improving HVAC system efficiency, potentially preventing cases of respiratory infection, reducing exacerbations of asthma and allergies, and generally improving building indoor air quality. Poor indoor air quality has also been associated with eye, nose, and throat irritation, headaches, dizziness, difficulty concentrating, and fatigue [Spengler et al. 2000].

Initially, you must fully understand the design and operation of your existing building and HVAC system. Backed with that knowledge, along with an assessment of the current threat and the level of protection you want from your system, you can make an informed decision regarding your building's filtration and air-cleaning needs. In some situations, the existing system may be adequate, while in others major changes or improvements may be merited.

In most buildings, mechanical filtration systems for aerosol removal are more common than sorbents for gas and vapor removal. Decisions regarding collection efficiency levels of particulate filters should be made with respect to ASHRAE Standards 52.1 and 52.2. Selection of the best sorbent or sorbents for gaseous contaminants is more complex. ASZM-TEDA carbon is recommended for classical chemical warfare agents. Other sorbents have been developed to collect specific TICs. To optimize effectiveness, you should minimize air infiltration and eliminate filter bypass. Maintenance plans and operations should ensure that the system works as intended for long periods. Life-cycle analysis will ensure that filtration and air-cleaning options satisfy your building's needs while providing protection to the building occupants.