

## **FILTERS AND MAINTENANCE**

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### **Summary**

Air filtration provides the most effective means to control contaminants by reducing their concentrations to acceptable levels and improve indoor air quality. There are several different types of filters that are used in all types of air handling and air conditioning units to remove particulates and gaseous contaminants. Proper filtration also protects the equipment and distribution networks, improves performance and reduces maintenance cost. Filters are selected according to their efficiency, initial cost, maintenance, and operating criteria. In order to deal with indoor contaminants we usually give priority to the most common and hazardous ones, selecting and using the proper filters to remove them from the ventilated air and then use fresh outdoor air to dilute them or the exhaust air to remove them from their source. All this requires careful design decisions, proper system installation, operation and maintenance, to keep a well performing system both in terms of IAQ and energy consumption.

### **1. Introduction**

Air filtration provides the most effective means to control contaminants by reducing their concentrations to acceptable levels or removing them from the ventilation air all together. Filters in one form or another are being used in practically all types of air handling and air conditioning units. It is common practice to use filters to remove particulate contaminants from indoor and outdoor air, and in more demanding applications even microorganisms and gaseous contaminants. Filtering of indoor air may also prove to be beneficial in terms of energy conservation since cleaned indoor air can be recirculated to reduce the amount of outdoor air, provided that indoor air quality (IAQ) is maintained at acceptable levels. Proper filtration also protects the equipment and distribution networks, improves performance and reduces maintenance cost.

There is a great diversity of different types of filters that can practically handle any kind of problem. Most common air filters and atmospheric dust collectors (mixture of smoke, mists, fumes, particulates, and fibers) are selected according to their efficiency to remove different particle sizes and expected loading. Initial cost, maintenance and operating criteria need to be carefully assessed along side with performance, in order to make the proper selection.

Particulate contaminants include numerous airborne physical matter like pollen, microorganisms, dust, fumes and smoke. Particles can range from 0.01  $\mu\text{m}$  to more than 100  $\mu\text{m}$ . Actually it is the smallest particles that are of most relevant importance to human health since they can easily penetrate into the human respiratory system and become a health hazard. At the same time this kind of particles is the most difficult to control and remove from the ventilation air.

Gaseous contaminants must also be considered. Indoor air may contain different gases and vapors from indoor source (i.e. carbon monoxide from occupants, radon, ozone, nitrogen oxides, volatile organic compounds like formaldehyde, from numerous other indoor sources). One way to handle this is by using outdoor air to dilute them.

This is common practice to control odors and other common contaminants, even in naturally ventilated buildings. This kind of an approach though may encounter two kinds of problems. First, the outdoor air may not be free from similar contaminants. Second, the use of more and more outdoor air in mechanically ventilated and air-conditioned buildings is a very energy consuming process, since the outdoor air needs to be conditioned before it can be supplied indoors.

Air filtration can again be used to handle both indoor and outdoor contaminants, thus making possible the use of return air (recirculation) and mixing with outdoor air that all together is properly treated before the ventilated air is supplied to the indoor spaces.

However, controlling all possible indoor and outdoor contaminants is not a simple task. Its overall effectiveness greatly depends on the overall system design and operation of the ventilation system, since there are practically countless sources and hundreds of different contaminants.

However, frequently design decisions and selections of system components including filters, are based acceptable indoor concentration levels for the most common contaminants for a given application. Although outdoor contaminants will probably be the same for a given location, different function buildings (i.e. residences, offices, theaters, and hospitals) will have many different indoor pollution sources and contaminants.

Accordingly, to deal with indoor contaminants we usually give priority to the most common and hazardous ones, selecting and using the proper filters to remove them from the ventilated air and then use fresh outdoor air to dilute them or the exhaust air to remove them from their source. All this requires careful design decisions, proper system installation, operation and maintenance, to keep a well performing system both in terms of IAQ and energy consumption.

## 2. Filter Characteristics

Filter selection is based upon the function and the role of the filter under different operating conditions. They are differentiated based on their effectiveness to remove certain categories of air particulate.

The most common parameters that are used to differentiate and rate different filters include:

- **Efficiency:** the ability of the filter to withhold particles from the air stream expressed as a percentage. A high efficiency means that the filter can remove from the air smaller size particles.
- **Air flow resistance:** the static pressure drop as the air stream flows through the filter, for a given volumetric flow rate. The value of the pressure drop depends on how clean the filter is. After a certain period of use, depending on the type of the filter, the various contaminants that have been removed from the filter reduce the filter porosity so the air flows with greater difficulty through the filter. The fans have to be properly sized to account for this pressure drop.
- **Dust holding capacity:** the amount of dust that can be withheld by the filter before there is a noticeable drop on its efficiency or exceeds a maximum value of pressure drop, for a specified air flow rate.

There are various test methods for different applications. The American Society of Heating, Refrigerating and Air Conditioning Engineers Inc. (ASHRAE), the Air-Conditioning and Refrigeration Institute (ARI), the Air Filter Institute (AFI), the U.S. National Bureau of Standards (NBS), and the British Standards Institution (BSI) have developed several standards for different ventilation experiments (Table 1).

Organization	Standard
ARI	<ul style="list-style-type: none"><li>• Commercial and Industrial Air Filter Equipment. ARI Standard 850-84. Air Conditioning and Refrigeration Institute, Arlington, VA.</li><li>• Residential Air Filter Equipment. ARI Standard 680-86. Air Conditioning and Refrigeration Institute, Arlington, VA.</li></ul>
ASHRAE	<ul style="list-style-type: none"><li>• Methods of Testing Air Cleaning Devices Used in General Ventilation for Removing Particulate Matter, ASHRAE Standard 52-76, American Society of Heating, Refrigerating and Air Conditioning Engineers Inc, Atlanta, GA.</li></ul>
BSI	<ul style="list-style-type: none"><li>• Methods of Test for Air Filters Used in Air Conditioning and General Ventilation. BS 2831, London, UK</li><li>• Methods of Test for Low-Penetration Air Filters, BS 3928, London, UK.</li></ul>

Table 1. Representative filter test methodologies.

The filters used in central ventilation systems should be rated at 30-35% efficiency. Where smoking is permitted, filters with a minimum rating of 80% are required before any effective amount of tobacco smoke is removed.

Filter performance is significantly reduced with their use and depending on the filter type and operating conditions (i.e. air quality and amount of contaminants that are encountered) they have to be periodically replaced or cleaned. Manufacturer specifications are indicative and the filter condition needs to be constantly monitored since distinct operating conditions determine the actual filter condition. Otherwise the filters can not operate properly and can even become a source of pollution and cause an increase of indoor air contaminants. Specific guidelines are usually available from manufacturers, while specific test methodologies are also available in literature and technical standards from organizations like ASHRAE.

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### **Biographical Sketch**

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Mechanical engineer, research director at the Institute for Environmental Research & Sustainable Development, National Observatory of Athens. Leader of Group Energy Conservation, staffed by an associate research scientist and three research assistants. Ph.D. & M.S.M.E. from Georgia Tech., B.S.M.E. from Michigan Tech. Active in the areas of energy conservation, building energy performance assessment, thermal and solar building applications, renewable energy sources, analysis and numerical modeling of thermal energy systems, HVAC systems. Previous affiliations with the University of Athens, Central Institute for Energy Efficiency Education, Protechna Ltd, Technological Educational Institute of Pireaus, British-Hellenic College, American Standards Testing Bureau Inc., American Combustion Inc., Georgia Institute of Technology, Hellenic Shipyards Co., Georgia Power Co. Participated in various European and national research projects, as a project manager and scientist in charge, including projects on energy renovation of office and apartment buildings, HVAC systems in hospital operating rooms, solar absorption heat pump, solar control, passive cooling, regional development of renewable energy sources. Private practice included electromechanical design and installation projects for new constructions and renovations of residential and office buildings, and a small size industrial building. Member of the Hellenic Technical Chamber (Chartered Mechanical Engineer), EUR ING, Hellenic Society of Mechanical - Electrical Engineers, Hellenic Society of Heat and Power Cogeneration, Hellenic Forum for the Dissemination of Renewable Energy Sources (ELFORES), ASHRAE (Founder representative and president of Hellenic Chapter 1999-2000, Regional Chair in Europe 2002-2006), ASME Fellow. Author and co-author of over 54 papers in international Journals and 80 papers in Conferences, chapter contributions in 12 scientific books and numerous technical project reports. Member of the editorial board Int. J. "Energy & Buildings"; Invited Reviewer of papers for the Journals of Solar Energy and Applied Meteorology, ASHRAE Transactions, IBPSA; Invited Technical Assessor for the European Architectural Competition Living in the City and Working in the City (under the auspices of the European Commission); Member of The Scientific Research Society; Pi-Tau-Sigma, Honorary Mechanical Engineering Fraternity.