December 2009

RECOMMENDATION

concerning

AIR FILTERS FOR BETTER INDOOR AIR QUALITY

The need to separate impurities from air or other gases has increased as regards both the degree of separation and the necessity to separate both gases and finer particles. Correct specification of filters is a prerequisite for the correct functioning of ventilation systems, for sensitive production or to protect humans and the environment and to improve indoor air quality.

Global climate change is an important issue and it is important for EUROVENT to support the efforts in the Energy Performance of Building Directive (EPBD) and at the same time consider the effect of indoor air quality.

Eurovent has always led the field in measuring and characterising air filters and provided the basis for common European Standards.

E U R O V E N T

EUROPEAN COMMITTEE OF AIR HANDLING, AIR CONDITIONING AND REFRIGERATION EQUIPMENT INDUSTRIES

WHY AIR FILTERS

A filter is a component of a system which, in conjunction with other components, can contribute towards a better indoor environment.

Ventilation System Protection

A precondition for maintaining function for a good number of years is that the system should be effectively protected, both on inlet and exhaust systems

Impurities must be stopped at the inlet and not be allowed to get into the system.

HYGIENE REQUIREMENT

Every day we breathe ca. 20-30 kg of air and take in 1 kg of solid and 3 kg liquid food. We should therefore make the same requirement of the air as we do of food and drink.

Atmospheric Air and Dust

Size of particles: Studies of atmospheric particles show that their distribution is often bimodal, i.e. particles are made up of two separate fractions, one with fine and one with coarse particles. The coarse particles, from ca 2.5µm upwards, are made up of natural dust from the effect of wind, erosion, plants, volcanoes, etc. The finer fraction is made up of particles smaller than 2.5µm and consists primarily of particles from human activity, combustion, traffic and processes.

Hygiene requirements for **particle concentrations** in the air have been based on concentrations of particles smaller than 10µm (particulate mass, PM_{10}). Studies [Ellringer 1997 and later studies] have shown a direct connection between lung diseases, lung capacity, death rate and finer particles and official requirements are under review, in both Europe and the USA, and are to be based on particles smaller than 2,5µm ($PM_{2.5}$).

To effectively eliminate these small particles and meet hygienic requirements finer filters are needed and the requirement for filtering of outdoor air, recycled air or exhaust air is increasing.

The **Number of particles** varies considerably with time and place. An urban environment or polluted environment thus requires an increasingly better filter quality.

Place	Particles/m^3
Clean Room	10^3
Arctic	10^7
Countryside	10^9
City	10^{11}
Tobacco smoke	10^{14}

Allergy: The problem of allergies has increased during the last few years and this can largely be attributed to airborne allergens such as pollen, spores, living or dead bacteria, dust, diesel fume, cigarette smoke etc. Tests have shown that an F7 filter can effectively reduce allergens in the air (Gustavsson 1996).

Carcinogenic potential of pollutants: It is known that the urban traffic environment is carcinogenic due to automotive gases and poly-aromatic hydrocarbons. An F8 filter reduces their effect by 80% (Gustavsson 1996).

Odours/gases: A large number of odours are borne by particles but for effective separation, chemical filters are very often required, something which can be justified in an urban environment.

FILTER RECOMMENDATIONS

EN 13779 defines three outdoor and four indoor air quality levels. For good practice the following guidelines are recommended for air filters.

Recommended minimum filter quality as requirement of indoor air quality [EN 13779:2007]

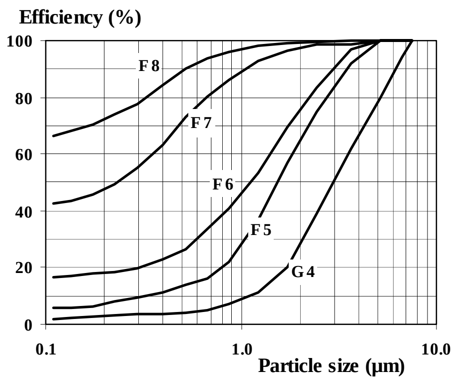
	Indoor Air Quality			
Outdoor Air Quality	**IDA 1** (High)	**IDA 2** (Medium)	**IDA 3** (Moderate)	**IDA 4** (Low)
ODA 1 (pure air)	F9	F8	F7	F5
ODA 2 (dust)	F7+F9	F6+F8	F5+F7	F5+F6
ODA 3 (very high dust or gases)	F7+GF+F9	F7+GF+F9	F5+F7	F5+F6

F5-F9=Filter class according to EN 779:2002. GF=Gas Filter (carbon and/or chemical filter)

AIR FILTERS in OPERATION

Separation: It is important to be aware of the filter's properties in real application. The following diagram shows how, in the case of new filters, separation varies with particle size and filter class. As the filter accumulates dust, the pressure loss increases and the deposit dust improves the mechanical separation. The filter class is based on the average efficiency in laboratory and a new filter normally has much lower initial efficiency.

In the case of electrostatically charged filters another effect can be seen. Separation may be significantly higher for new filters while during operation, the impurities neutralise the material and the filter's capacity to separate is reduced. Example shows where the efficiency of such F7 filters drop dramatically from more than 80 % to less than 20 % after a few weeks' operation [Lehtimäki 1997, Sintef 1995]. The behaviour of these filters has been confirmed later by round robin test in Eurovent and ISO and by ASHRAE research projects [See references]. The following figure should then be seen as an *indication of minimum separation during actual operation.*



Many filters in operation, especially those with electrostatically charged filter material, never reach the average efficiencies used for classification and the Swedish National Testing and Research Institute require the following minimum efficiencies in a real life time test.

Minimum requirements for fractional efficiency for different filter qualities during a six-month lifetime test, according to the Swedish SP method 1937.

Filter class	F6	F7	F8	F9
0,4 µm particle Efficiency	12%	50%	70%	80%

Average Pressure Loss

The average pressure loss during operation is dependent on the characteristics of the plant and is often taken to be the average value of initial pressure loss and final pressure loss of the filter. With the lower energy requirement, more and more systems are being designed for constant flow, and average pressure loss is the integrated value of the pressure loss during operation. Significant savings can thus be made using filters with a low pressure loss and small increase in pressure during the period of operation. The pressure drop normally increases with filter quality and it is important to use a low energy rated air filter. (See Eurovent Energy rating REC – in preparation).

Energy consumption

A filter's energy consumption, E, based on average pressure loss and constant air flow, can be calculated

$$E = \frac{Q \bar{P} T}{\eta \; 1000} \qquad \text{(kWh)}$$

where Q *is* Air flow (m^3/s)
$\bar{P}$ Average pressure loss (Pa)
T Operation time (hours)
η Efficiency of fan

Over one year (8760 hours), a 1 m^3/s filter with an average pressure loss of 100 Pa requires 1250 kWh if the fan's efficiency is set at 70 %. The energy cost is generally greater than the filter cost and pressure loss reduction becomes increasingly significant for energy reductions. 10 Pa lower pressure loss means 125 kWh less energy in this case.

Filter Replacement

Airflow changes in the plant have been the main criterion for changing filters, i.e. when pressure loss increases to the extent that the fan cannot maintain a specific minimum airflow. Reduction of **effect levels, energy consumption** or **economic** evaluation, i.e. when the energy cost and filter cost reach a minimum, are becoming increasingly significant.

Considerations of **hygiene** are being applied more and more to filter replacement. Studies [Möritz 1996, VDI 6022] have shown that with RH higher than 75% there is a risk of microbial growth in the filter and in the ventilation system. Filtering should take place in two steps. The first filter can often be exposed to high humidity or to rain and snow. Organic impurities also become caught in the filters and could be released later. Particles and endotoxins from micro-organisms can become loose in low quality filters.

The first filtration step should thus be carried out using a filter of at least F7 quality and be changed after a maximum period of one year's continuous operation or earlier if final pressure drop is reached. The second filter step of at least F7-quality is normally placed downstream heaters and not exposed to high RH. They will effectively stop micro-organisms and particles and can remain in place for ca. two years, provided the final pressure loss is not reached within this period.

LIFE CYCLES

Environment - Life cycle analysis (LCA)

Global environmental questions have increased in significance during the last few years. A life cycle analysis (LCA) analyses the environmental effect with reference to ecological effects, health effects and consumption of resources.

LCA analysis of a filter shows that operation often corresponds to 70-80% of the filter's total environmental load and is absolutely decisive as regards environmental effect. Raw material, refining, manufacturing and transports correspond to ca. 20-30%, whilst the used filter contributes at most 1%. Filters made of plastic or other inflammable material can render 10-30 kWh energy when burned, which correspondingly reduces the total environmental load with 0.5 to 1%. On the other hand, if the pressure loss in the filter is reduced by 10 Pa, the environmental load is reduced by 125 kWh per year or approximately 5% decrease in the filter's total environmental load.

Life cycle cost (LCC)

Life cycle analysis (LCA) does not take account of economic aspects while a life cycle cost analysis (LCC) (Eurovent REC 10) takes account of the costs of investment, energy, maintenance and dumping the final waste product throughout the lifetime of a plant.

Future costs of replacement filters and energy are calculated according to the present value method. The final result for a 1 m^3/s filter with average pressure loss of 200 Pa may be as shown by the following table, if the calculation is based on a ten-year period.

Type of cost	*Relative cost (%)*
Investment	4.5
$\mathbf{LCC}_{Energy}$	80.8
$\mathbf{LCC}_{maintenance}$	14.2
$\mathbf{LCC}_{Disposal}$	0.5
$\mathbf{LCC}_{\mathbf{Total}}$	100 %

The table shows that energy costs account for 80% of the total cost during the plant's period of operation. The actual costs of the filter, investment and maintenance correspond to ca. 20%, while the costs of dumping amount to only 0.5 %.

LCC analyses provide an excellent tool for minimising the filter costs of a plant. As in the case of LCA, the operation and low pressure loss are absolutely decisive as regards the costs of the filter function.

SUMMARY AIR FILTERS

The following should be borne in mind when planning filter installations.

- Great care is required regarding the positioning and design of the **air intake** to avoid drawing in local impurities and rain or snow. For design see EN 13779.
- The risk of microbial growth is low but to minimize the risk, the ventilation system should be designed so that **RH** is below 75 % in all parts of the system.
- For reasons of hygiene, the **inlet air** should be filtered in two steps /6/. The first filter in the air intake must be of at least F5 quality but preferably F7. The second filter step should be of at least F7 but preferably F9 quality. If there is only one filter step, the minimum requirement is for F7 quality.
- As regards **recirculation air,** at least F5 quality must be used to cope with contamination of components in the system, but the minimum requirement is for F7, if the environment in the room is to be improved.
- **The exhaust air system** must be protected from contamination by at least F5 quality.
- Extract air from **kitchen** shall always be cleaned in a first step with a special filter for grease, which can be cleaned easily.
- Filters must not be **installed** directly after the fan outlet, or across places where there is a big change in area or velocity.
- **The final pressure drop** is calculated and selected with regard to permitted variations in flow, the filter's life cycle costs and life cycle analysis. Eurovent REC 10)
- **Dust holding capacity** and **test** results from laboratory trials differ from performances in actual use due to the coarse artificial dust used in laboratory and shall not be used to predict life performances.
- **The efficiency** must not deteriorate below the defined minimum values specified in SP method 1937.

- The **tightness** and c**ondition** of the filter are checked regularly by visual inspection of the plant. No visible or traces of leakages should be accepted. Maximum bypass leakage is specified in EN 1886.
- **Filters** and filter **housings** must be clearly **marked** with the type and designation of the filter, date, etc.
- In the case of more stringent requirements, **in situ** checks of the filter are carried out (Eurovent 4/10)
- **Filters must be replaced** when the pressure loss reaches the specified final pressure loss or when the following hygiene interval is reached, if this is earlier:

  -The first filter step should be replaced after a maximum operating period of 8760 hours and

  -The second filter step and filters in exhaust or recycled air systems should be changed after a max of two years' continuous operation.
- **Filter time replacement**: For hygienic reasons, the filter should be replaced after the pollen and spore season in the autumn. In case of high demand, filters can also be changed in spring after the heating season to eliminate odours combustion products.
- **Chemical filters** should be considered in urban environment (ODA 3) or to eliminate odours.
- **Filters should be replaced** carefully and using protective equipment so that the impurities trapped do not escape.
- **Dumping/Disposal:** The disposal varies in different countries and places. In general it is a good idea to incinerate filters in well-filtered furnaces in order to burn trapped impurities, reduce quantities of waste, and recover some energy. Filters from normal ventilation systems could also be dumped at a landfill.

References

1. *ASHRAE research report 1189 Phase I Report. 2002.* Investigation of Mechanisms and Operating Environments that impact the Filtration Efficiency of Charged Air Filtration Media.
2. *ASHRAE research report 1189 Phase II Report. 2005.* Investigation of Mechanisms and Operating Environments that impact the Filtration Efficiency of Charged Air Filtration Media.
3. *Ellringer P.J, Whitcomb L*. 263 Indoor Air Quality Studies in the State of Minnesota. Advancing Filtration Solutions 1997.
4. *EN 779:2002*. Specifications for Particulate Air Filters for General Ventilation.
5. *EN 1822:1998 Part 1 to 5 .* Determination of Efficiency of High efficiency air filters
6. *EN 1886.* Ventilation for buildings – Air handling units – Mechanical performances.
7. EN 13779:2007. Ventilation for non-residential buildings – Performance requirements for ventilation and room-conditioning systems
8. *EUROVENT/CECOMAF 4/10:2004.* In Situ Fractional Efficiency Determination of General Ventilation Filters.
9. *EUROVENT/CECOMAF Recommendation REC. 10:2005.* Life Cycle Cost of Air Filters.
10. *EUROVENT/CECOMAF 4/yy:2007.* Energy rating of air filters. (under preparation)
11. *Eurovent RRT.* Eurovent 2004 round robin test on the basis of EN 779 Annex A and long time tests in real life. Final report NTV 2005/007
12. *Gustavsson J*. Cabin Air Filters. Performances and Requirements. SAE Conference, Detroit. Feb 1996.
13. *ISO/TC 142 WG3Document N012. ROUND ROBIN TEST* – Preconditioning. 2006-06-15
14. *Lehtimäki M*. Performance of Ventilation Filters. Pilot Field Tests, Material Test and Full Scale Field Test. Tampere, December 18, 1997
15. *Möritz M*. Verhalten von Mikroorganismen auf Luftfiltern. Universität Berlin 1996
16. *Nordtest Method NT VVS 117*. Electret Filters: Determination of the Electrostatic enhancement factor of Filter Media. December 1997.
17. *SINTEF*. Lifetime tests of Air Filters in Real Applications. Sintef, STF A95027, Mars 1995.
18. *SP-Swedish National Testing and Research Institute, SP-method 1937*. Certification rules for air filters. SPCR022-1998.
19. *VDI 6022:2006.* Hygienic aspects for the planning, design, operation and maintenance of HVAC systems.

REC 06

For more information contact:
Sylvain COURTEY
Eurovent WG Secretariat
62 bld de Sébastopol, 75003 PARIS
Tel 33 1 49 96 69 80; Fax 33 1 49 96 45 10