Development of Field Test Method for Ventilation Filters

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Introduction

Ventilation filters are classified according to the results from standard laboratory tests. These tests, however, produce information which may be insufficient for estimating the true filter performance. The properties of a ventilation filter in the ambient air conditions may be quite different compared to filter behavior in the standard test. The disagreement may be especially strong in the case of electrostatically charged filters. The loss of electrostatic removal mechanism can lead to a significant decrease in the efficiency. The efficiency of the filter affects strongly on the quality of the supply air. Therefore, the measurement of the filter removal efficiency is of great importance.

The guidelines for the in situ determination of the fractional efficiency of ventilation filters have been defined in Eurovent method 4/10 (1). This method includes detailed instructions for the efficiency measurement procedure. It also includes instructions about the proper use of an optical particle counter (i.e. zero check, avoiding of excessive particle concentrations and extremely unfavorable test conditions).

The test conditions in the field tests can vary strongly depending on time and the location of the test site. Weather conditions together with the nearby particle sources may affect the concentration, size distribution and the optical properties of the ambient air particles. Thus, it is possible that the properties of ambient air particles vary strongly and rapidly which complicates the efficiency measurement. It is also possible that the concentration of ambient air particles is either too high or too low for a certain measurement instrument.

What Should Be Measured ?

The performance of ventilation filters is normally characterized with removal efficiency. It must, however, be noticed that removal efficiency is a relevant filter parameter only if the amount of collected material is of major interest. In ventilation applications the major interest should, however, be the amount of airborne material which penetrates the filter, i.e. the amount of particles in the filtered air. Thus, the right parameter for characterizing filter performance is penetration. It must also be emphasized that penetration depends on the particle size. Therefore, a penetration value without valid particle size information cannot be used to illustrate the efficiency of the filter.

The most advanced alternative to determine filter performance is to measure the penetration curve, i.e. penetration as a function of particle size. This, however, requires sophisticated particle measurement techniques which may limit the feasibility of the method.

Another approach is to utilize particle size selective measurement technique for determining penetration of particles within a limited particle size range. The selection of the particle size range (or ranges) is of great importance. It is reasonable to assume that the basic reasons for filter testing in field conditions are:

- to check if the efficiency for fine particles has changed significantly from the expected value (e.g. electrostatically charged filters)
- to check if is there is a significant leakage in the filtration system

Taking into account the general behavior of the filter penetration curve (see example in Figure 1), the most suitable size range for the efficiency loss test is around the particle size corresponding to the maximum penetration. On the other hand, filter leakage can be most effectively determined by measuring penetration of large particles, i.e. size range where penetration should be practically zero.

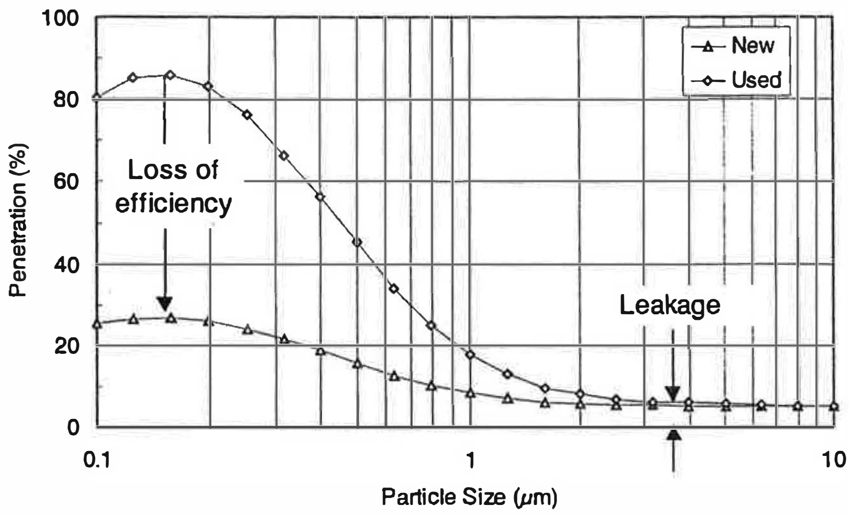

Figure 1. Schematic illustration of the filter properties which should be measured.

Test Methods

Filter performance can be measured with a several direct reading instruments including:

- optical particle counters
- electrical aerosol analyzers
- aerosol mass monitors
- aerosol photometers

Besides these, filter properties can be studied by means of integrating measurement methods:

- aerosol sampling on membrane filters & gravimetric analysis
- filter sampling with size selective pre-separator
- cascade impactor

In this study most of the measurements have been made with optical particle counter, Besides this, gravimetric method and cascade impactors have been used. Some experiments with aerosol photometers and Piezobalance mass monitors have also been made. Measurements have been made both in the field conditions and laboratory.

Results

The basic gravimetric method was used in a field test in which properties of ventilation filters in urban air were measured (2). The penetration values calculated from the weekly averages of particle mass concentrations from both sides of the filter are shown in Figure 2. These results show that total mass penetration values vary in a very wide range. The strong variations are caused by the changes in the particle size distribution. The results in Figure 2 clearly indicates that this method cannot be used for characterizing filter properties in field conditions.

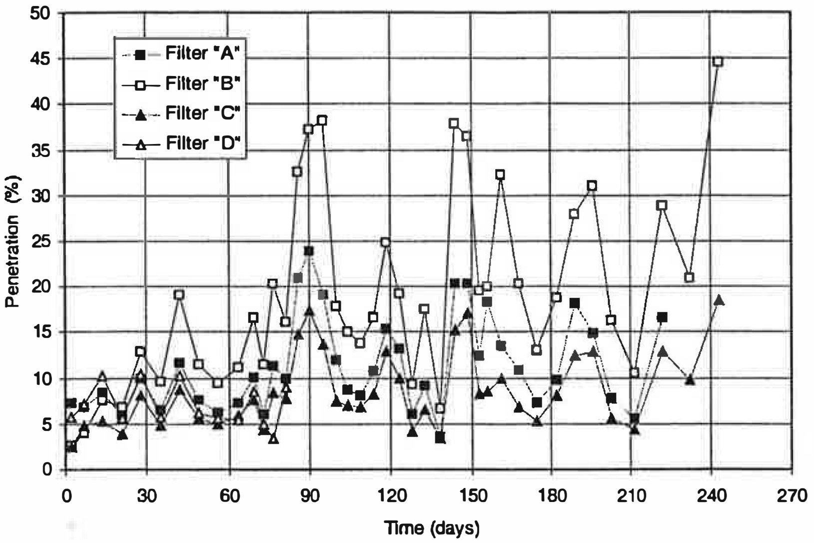

Figure 2. Total mass penetration measured with gravimetric method.

Figure 3 illustrates the penetration values corresponding to the particle size range below 2.5 μm. These values were calculated from the ambient air size distributions measured with cascade impactors. Filtered air was assumed to contain only fine particles, i.e. the downstream mass concentration can be assumed to directly correspond to the fine particle fraction. The results in Figure 3 show that fine particle penetration values still vary significantly.

Figure 4 shows an example from a study in which optical particle counter (MetOne 237) was used to measure the penetration of a F7 synthetic filter at ambient air conditions. The optical particle counter was equipped with valve system which was used to measure particle concentrations from both sides of the filter. The results in Figure 4 correspond to the particle size range 0.3 – 0.5 μm (channel boundaries of the OPC). These results indicate that the measured penetration values vary relatively strongly even though a narrow size range is used. This may be due to the inaccuracy of particle sizing caused by the variations in the optical properties of the particles.

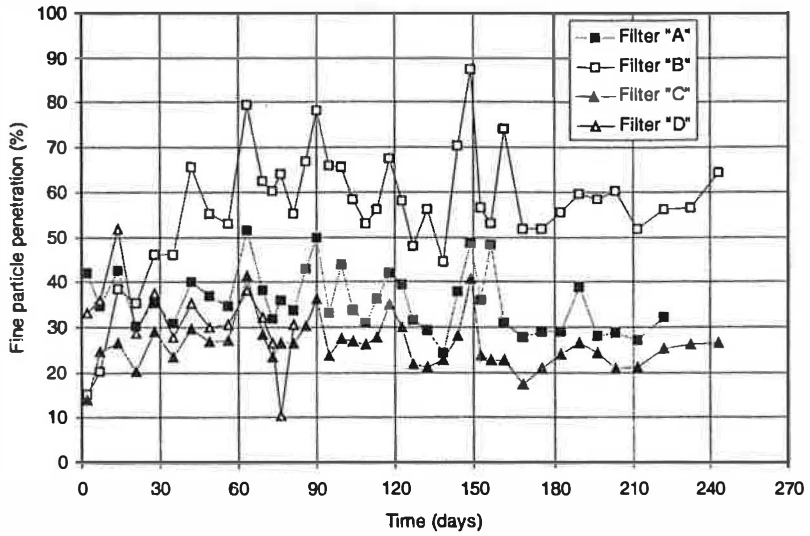

Figure 3. Fine particle penetration values measured with gravimetric method.

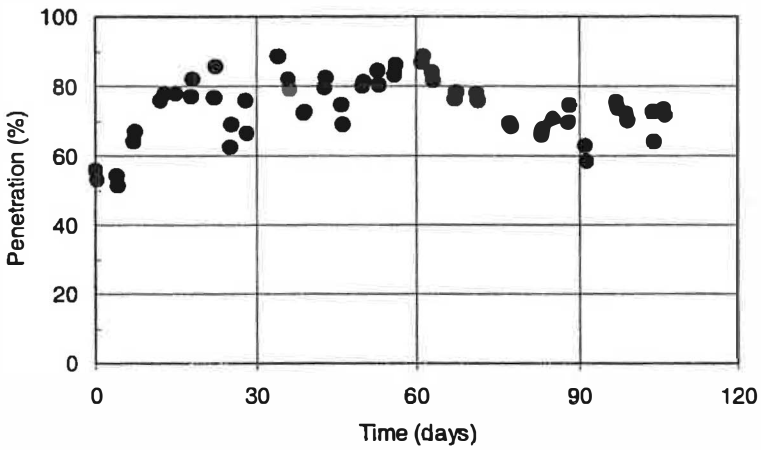

Figure 4. Filter efficiency measured with portable particle counter. Particle size range 0.3–0.5 µm, ambient air particles.

Conclusions

The experimental results obtained with different measurement instruments indicate that accurate determination of filter efficiency in field conditions is very difficult. In ambient air test conditions there are several factors which influence the accuracy of the measurement. The most promising methods are optical particle counter and the gravimetric method which is based on the particle size selective sampling.

Filter penetration measurement with optical particle counter requires that the particle concentration is within the operation range of the instrument. The reliability of the measurement can be improved with the aid of reference filter method, i.e. efficiency of a reference filter with known penetration characteristics is measured at the test site and the results are used to estimate if the test conditions are favorable for reliable filter test. The poor statistical accuracy for large particles can be improved with the aid of a virtual impactor. Reliable measurement also require that sampling from both sides of the filter can be made without significant particle losses. Downstream sampling must be realized in such a way that measured concentration represents the whole air flow (i.e. adequate mixing of the air).

Filter performance can also be measured with gravimetric methods provided that particle size selective sampling is used. In principle, cascade impactors can be used to measure the penetration as a function of particle size. The upstream and downstream impactors must, however, be identical. One of the advantage of the cascade impactor method is the additional information about the ambient air mass size distribution. Aerosol sampling with inertial impactor makes it possible to determine penetration values at a narrow particle size range. Thus, the fine particle penetration can be measured by using a filter sampler equipped with impaction pre-separator. Impactor sampling can also be used to measure large particle penetration which is a good measure for filter leakage.

References

1. Eurovent 4/10-1996. In Situ Determination of Fractional Efficiency of General Ventilation Filters. Eurovent/Cecomaf, Paris 1996.
2. Lehtimäki M and Taipale A. Performance of Ventilation Filters (Pilot field study, material test and full scale field test). TAKE IAQ E, Report 26, Finnish Development Center for Building Services, Helsinki 1999.