#1146

DESIGN CRITERIA FOR AIR FILTRATION IN GENERAL INDUSTRIAL VENTILATION

Kim Hagström, Helsinki University of Technology, Espoo, Finland
Rolf Holmberg, VTT Building Technology, Espoo, Finland
Matti Lehtimäki, VTT Manufacturing Technology, Tampere, Finland
Raimo Niemelä, Finnish Institute of Occupational Health, Helsinki, Finland
Jorma Railio, Association of Finnish Manufacturers of Air Handling Equipment, Eteläranta 10, PL 10 FIN-00130 Helsinki, Finland
Eero Siitonen, Ekono Energy Ltd., Espoo, Finland

ABSTRACT

There has been a lack of fact-based knowledge for design and operation of supply-air filters for general industrial ventilation. A multi-company project within the Industrial Ventilation (INVENT) technology programme was started in 1994 to tackle this issue which is assumed to be the most problematic one, according to the feedback from end-users in several industries.

The main objectives of the project were to build up a methodology for the control of particulate contaminants in industrial premises and to define the basic criteria for design and optimal selection of supply and recirculation air filters. This methodology will take into account outdoor air quality, desired indoor air quality, emissions from the processes and cleaning of ductwork and equipment.

The first stage of the project, finalized at the end of 1995, included state-of-art surveys, preliminary case studies and a preliminary proposal for a filter performance classification. The second stage, currently ongoing, will include validation of the existing knowledge by laboratory and field tests, development of an expert system for filter selection, and draft contributions to the Design Guide Book for Industrial Ventilation (DGB).

DESIGN CRITERIA AND FILTER SELECTION

The detailed design of air cleaning systems should be based on well defined target levels of airborne contaminants and it should result in a guaranteed performance. To achieve this goal and to define the requirements for the filter performance, it is also essential to know the particle concentration and the size distribution in the air to be filtered.

However, it is reasonable to assume that in most cases the design of the air filtration system does not require detailed information about the particle concentrations and particle size distributions. The design in these cases can be based on the assumption that the air to be filtered does not contain any especially hazardous contaminants and the total concentrations are well below occupational exposure limits. Also it can be assumed that a minor inaccuracy, when selecting the minimum efficiency of the filter, does not lead to serious contaminant problems.

The suggested design approach is based on the definition of target levels for filter performance in such a way that they are easy to understand by all parties including end-users. It is also required that there is a simple physical explanation which clarifies the result. This can be achieved when a certain target level is applied, i.e. the end-user must be able to easily understand the advantages and disadvantages of different target levels. Furthermore, the target levels are defined in such a way that the achievement of the designed values as guarantee values can be checked out by using relatively simple measurement techniques.

Target levels for filter performance

The present work introduces a new style of filter performance classification which aims to avoid the vagueness of the present classification styles. It suggests a three-level classification which can be used when making rough estimates about the proper level of air filtration in different types of buildings and environments.

The conventional classifications (e.g. Eurovent 4/5, or the G-and F-classes according to EN 779) provide only part of all essential information about the filter performance. In fact, these classifications have been developed for rating in test conditions only, and with only a vague connection to filter performance in the real world.

The basic idea of the new approach is to define target levels with the aid of an expression which includes exact information on the required filter performance and the particle size at which the required performance must be achieved in all conditions of operation throughout the lifetime of the filter. This approach is assumed to encourage all parties to use well-defined data when describing the performance of filters.

The suggested basic target levels for filter performance have been expressed in the form of cleanliness classes as follows:

T5/10 The maximum allowable penetration for $5\mu m$ particles is 10 %. This filter is assumed to effectively capture large particles, which may cause dust accumulation e.g. in ventilation ducts (settling dust)

T1/10 The maximum allowable penetration for $1\mu m$ particles is 10 % (minimum efficiency 90 %). This filter is assumed to cause significant decrease in the concentration of those particles which effectively deposit in the human respiratory system.

T0,5/10 The maximum allowable penetration of $0{,}5\mu m$ particles is 10 %. This filter is assumed to be effective even for fine particles, i.e. the particles which orginate from combustion processes (traffic and energy production) and atmospheric gas to particle conversion. (Also a considerable part of staining particles.)

The advantage of this type of classification is that filter performance is unambiguously specified in terms of maximum penetration at a certain particle size value.

Industrial environment categories

The premises in industrial environment can be characterized in categories. For each category, it is possible to recommend one target level for filter performance, see Table 1.

TABLE 1. Recommended target levels for dust filters in different environmental categories.[1)]

Environment category:	SUPPLY AIR	RECIRC. AIR [2)]	EXHAUST AIR
1. Covered processes No stationary working places, occupation is only temporary. Main part of the particulates is process emissions and the process does not set any requirements for cleanliness.	T5/10 [3,4,5)]	T1/10	-
2. Working environments in industry Spaces with stationary working places and continuous occupancy. Particulate levels may vary considerably between different spaces. Supply air is normally better ducted and distributed than in category 1.	T1/10 [5)]	T1/10	-
3. Spaces with special cleanliness requirement (incl. clean rooms) Spaces that set special requirements on air cleanliness. Typical in electrotechnical, pharmaceutical and foodprocessing industry. Also special rooms such as electrical equipment, tele, automation, and computer rooms and rooms for personal protection. Special guidelines are to be followed when they exist.	T0.5/10 [6)]	T0.5/10 [6)]	- [6)]
4. Laboratories, kitchens, smoking rooms Rooms where possible exhaust air filtration and increased need for cleaning of exhaust ductwork has to also be taken into account.	T1/10 [5,7)]	-	[6)]
5. Offices, other official spaces and residential areas Ductworks and used components, such as VAV-regulators, humidity and air quality sensors, are usually more complicated in offices than in industrial premises. Among other things it makes ductwork cleaning more difficult and expensive.	T1/10 [5,7)]	T1/10	-

1) Cleanliness class T5/10: The maximum penetration of particulates >5μm (removal of settling dust) is 10 %.
Cleanliness class T1/10: The maximum penetration of particulates >1μm (coarse particles are removed) is 10 %.
Cleanliness class T0.5/10: The maximum penetration of particulates >0.5μm is 10 %.
2) Particle size distribution of emission from indoor sources has to be taken into account when selecting a recirculation air filter. Usually a recirculation air filter should be at least the same class as in supply air.
3) If supply air is ducted it is recommended to use T1/10.
4) In some cases supply air can exhausted without filtration. In such case ventilation system components (coils, fans, etc.) have to be chosen and located so that they do not collect dust and are easy to clean.
5) It is recommended to use at least cleanliness class T1/10 next to a heat-recovery unit. If the unit is difficult, it is recommended to use class T0.5/10.
6) Special guidelines are to be followed if they exist.
7) T0.5/10 is recommended in areas where there are high emissions from traffic and energy sources.

The proposed target levels in relation to present filter classes
The correlation between present filter classification tests and filter performance in the field is weak. This situation together with the lack of design criteria and too many filter classes has led to non-fact based selections of filters in most cases.

New test methods based on a filter's fractional efficiency make it possible to compare the performance of filters and filter media in practice. According to the latest measurements and discussions in Finland it is also evident that the presently used filter classification has too many classes in order to make a distinction between different classes (filters tested according to EUROVENT 4/5 /2/, 8 classes EU1-EU8 for normal ventilation purposes). Even more confusing is that the test results of several manufacturers' EU6-class filters show a wide variation in filter performance, when new methods are used. The initial efficiency of some EU6-class filters was even poorer than that of EU5-class filters, which were measured in the same tests. /1/

Based on the tests of several glass fibre bag filters of different filter classes /1/ it is possible to define which of the present filters achieve the recommended cleanliness classes. (The penetration (efficiency) of different classes represents the average values of all tested filters.) Uncharged fibre filters, such as glass fibre filters, normally have the highest penetration as clean, so the requirement has to be compared to the penetration curves of clean and recharged filters.

The relation between the filter classes and the cleanliness classes, based on the measurements /1/, is shown in table 2.

TABLE 2. Approximate relation between the target levels (cleanliness classes) of dust filters and lowest acceptable filter classes, when maximum allowed penetration of nominal particle size is 10% in each cleanliness class.

TARGET LEVEL	FILTER CLASS[1]
T5/10	EU4 (EU5)
T5/10	EU7
T0,5/10	EU8

1) Filter classes according to EUROVENT 4/9 /4/. Corresponding classes according to EN779:1993 /4/ are G4, F7 and F8.

TECHNICAL - ECONOMICAL OPTIMIZATION

The basis and problems of optimization are discussed and written down in this project. The knowledge is still at too general a level to be used in optimization. The aim is to develop an expert system for filter selection and optimization.

The most important technical figure in system optimization is the maximum allowed final pressure drop of filter, which depends on the allowed air flow change during operation and fan performance. This figure should be calculated in the course of the design phase, corrected after installation, if e.g. fan parameters are changed, and must not be exceeded in operation.

The properties of filter material and construction have to be taken into account as well. Breakage of the material is not a problem in normal cases, but too high a pressure drop can cause increased penetration of fine dust (coarse filters).

The filter selection always has to be started from the target level. After the qualification of acceptable filtering methods is done, acceptable methods can be quantified economically in order to:

- compare the total economy of a filter meeting minimum requirements to more effective solutions

- compare filters with equal class with respect to lifetime and initial and final pressure drop

- define economical final pressure drop

- compare economy of different filter constructions (compact vs. bag filters etc.) or properties (e.g. bag length) with respect to dust holding capacity and lifetime.

Because of the lack of knowledge of filter performance in real conditions and of the influences of filtering e.g. to dust growth of ductwork and ventilated spaces, many assumptions and simplifications have to be made during calculations. This results in the fact that the reliability of general calculations is questionable. Thus, economical optimization can be used in single cases effectively, especially during operation time, when more accurate information of local conditions is available than during design phase.

SECOND STAGE (1996-97), THE MAIN OBJECTIVES

The main objectives and tasks for the second stage of the INVENT project are:

- write international guidelines for filtering fundamentals, filter selection, optimization and maintenance (contributions to the Design Guide Book),
- develop an expert system for filter selection
- found an impurity database consisting of data on concentrations and particle size distribution of emissions from different sources
- produce new data on filter performance in real conditions and on particulate measurement techniques by laboratory and field tests.

As part of this second stage, pilot field tests and one series of laboratory tests have been made to give a solid background to long-term field tests, which will continue till the end of 1997. The pilot field tests were made to test the measurement techniques and to produce some information on the filter behaviour in suburban environment. The laboratory tests were made for pre-selection of filters to the long-term field tests and to study the filter behaviour in different controlled loading conditions. The tests have already revealed strong variations in filter performance, taking into account that all filters should be of the same filter class (F7) according to standard tests, and these variations will be studied further in the full-scale field tests. /5/

EXPERT SYSTEM - SOME PRELIMINARY FEATURES

In the enclosure, the framework, methodology and blocks of the planned expert system are described.

The expert system will be developed in at least two steps, starting with the contents of the basic framework. At the moment, the following tasks are being planned:

1. To collect the existing material on outdoor air conditions, emission sources, target levels and filter performance, and equations to be used for filter selection.
2. To restructure the existing data (units, form, curves...)
3. To develop and validate the factors and equations
4. To complete a manual version of the expert system; this shall serve as a guideline for filter selection, and be included in the Design Guide Book (DGB).
5. To convert the expert system block by block into electronic form, including

- simplified filter selection process
- detailed selection of filter
- feasibility comparison of filters
- total control of particulate contaminants

ome additional remarks to the blocks (for DGB purposes):

. Properties of the outdoor air: the expert system shall contain a database of existing "typical" figures that an be selected for dimensioning (default values). If more precise values are known in the specific case (e.g. wn measurements), these can be used instead.

Process description: principles of general process description will be presented in Volumes A 'undamentals) and B (Systems and Equipment), specific items as appropriate branchwise in Volume C \pplications)

Target levels: to be based on the Cleanliness Classification. In the DGB, principles to be presented in olume A, and in addition process related in Volumes B and C.
Source description: a database to be developed.
ocks from the lower part (6...12) are planned to be included in the filtration blocks in Volume B.

EFERENCES

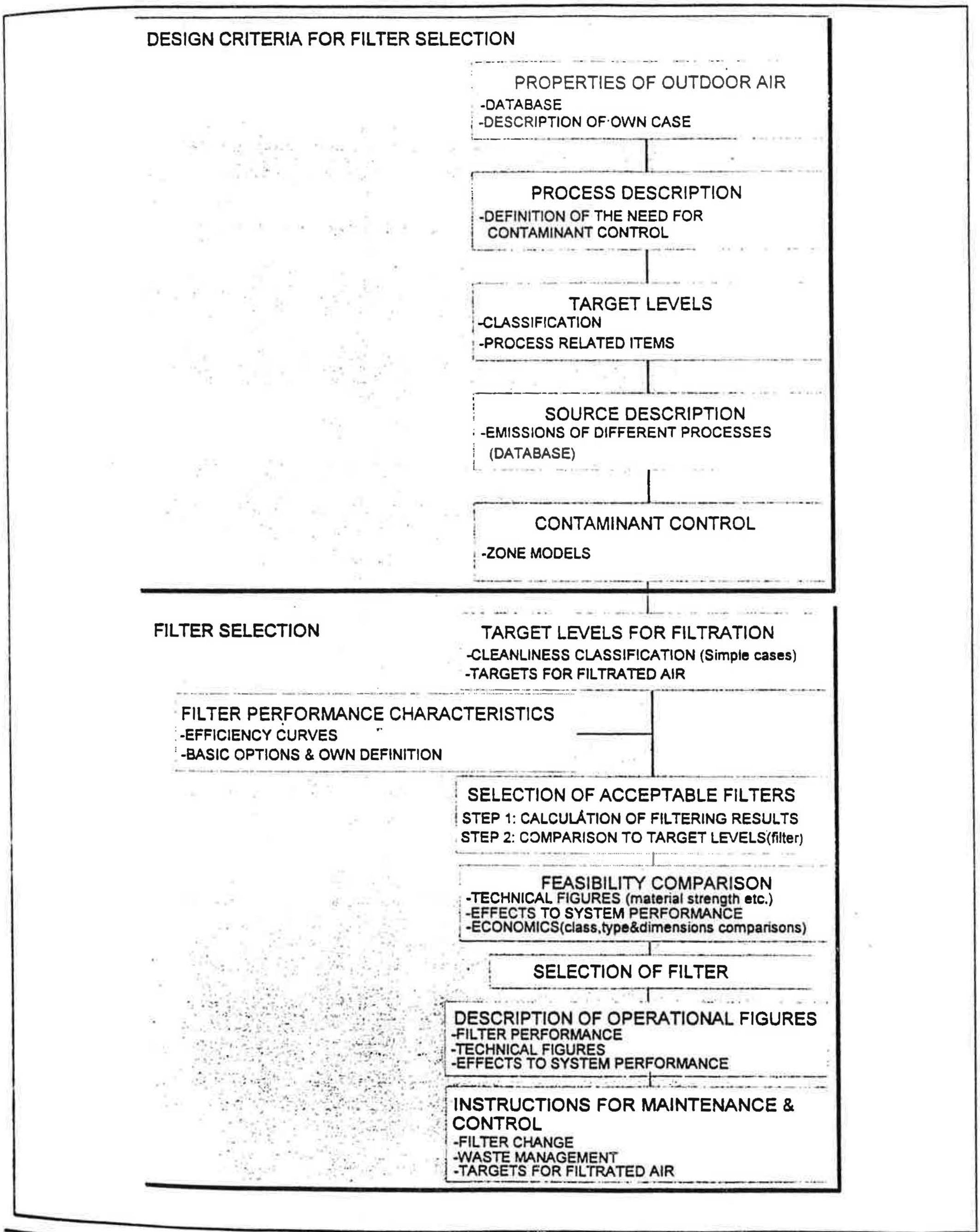
ılmberg R., Modern characteristics of filter performance for general air filters, INVENT-Report 31, 1993. (In Finnish)

ırovent 4/5, Method of testing air filters used in general ventilation

ırovent 4/9, Method of testing air filters used in general ventilation for determination of fractional efficiency.

I 779:1993, Particulate filters for general ventilation - requirements, testing, marking.

htimäki, M., Performance of the ventilation filters, pilot field study and filter material loading test. VTT Manufacturing Technology, 1996 (unpublished draft report)


DESIGN CRITERIA FOR FILTER SELECTION
PROPERTIES OF OUTDOOR AIR
-DATABASE
-DESCRIPTION OF OWN CASE
PROCESS DESCRIPTION
-DEFINITION OF THE NEED FOR CONTAMINANT CONTROL
TARGET LEVELS
-CLASSIFICATION
-PROCESS RELATED ITEMS
SOURCE DESCRIPTION
-EMISSIONS OF DIFFERENT PROCESSES (DATABASE)
CONTAMINANT CONTROL
-ZONE MODELS
FILTER SELECTION
TARGET LEVELS FOR FILTRATION
-CLEANLINESS CLASSIFICATION (Simple cases)
-TARGETS FOR FILTRATED AIR
FILTER PERFORMANCE CHARACTERISTICS
-EFFICIENCY CURVES
-BASIC OPTIONS & OWN DEFINITION
SELECTION OF ACCEPTABLE FILTERS
STEP 1: CALCULATION OF FILTERING RESULTS
STEP 2: COMPARISON TO TARGET LEVELS(filter)
FEASIBILITY COMPARISON
-TECHNICAL FIGURES (material strength etc.)
-EFFECTS TO SYSTEM PERFORMANCE
-ECONOMICS(class,type&dimensions comparisons)
SELECTION OF FILTER
DESCRIPTION OF OPERATIONAL FIGURES
-FILTER PERFORMANCE
-TECHNICAL FIGURES
-EFFECTS TO SYSTEM PERFORMANCE
INSTRUCTIONS FOR MAINTENANCE & CONTROL
-FILTER CHANGE
-WASTE MANAGEMENT
-TARGETS FOR FILTRATED AIR