EUROVENT/CECOMAF

EUROVENT 4/10 - 2005

IN SITU DETERMINATION
OF FRACTIONAL EFFICIENCY
OF
GENERAL VENTILATION FILTERS

EUROVENT 4/10 - 2005

IN SITU DETERMINATION
OF FRACTIONAL EFFICIENCY
OF
GENERAL VENTILATION FILTERS

EUROVENT 4/10

Sixth Edition, January 2005

Published by EUROVENT / CECOMAF
62 bl de Sébastopol
75003 Paris, France

Tel.: 33 1 49 96 69 80
Fax: 33 1 49 96 45 10
E-mail: s.becirspahic@eurovent-certification.com

C O N T E N T S

1 Introduction

The purpose of this paper is to establish guidelines for a test procedure for evaluating the performances of air cleaning devices as a function of particle size in an installation.

There may be possible to analyse filter performance further by using this method of efficiency determination and calculate the amount of dust held in the filter from the number of particles retained by the filter. Results as the efficiency vs. dust load and pressure drop vs. dust load can then be obtained.

2 Scope - Field of Application

This recommendation describes a method of measuring the performance of general ventilation air cleaning devices in an installation.

The method of testing measures the performance of air cleaning devices in removing particles of specific diameters. The recommendation describes a method of counting particles of 0.2 µm to 1.0 µm upstream and downstream the air cleaner in order to calculate the removal efficiency by particle size.

The recommendation also describes performance specifications for the equipment and defines methods of calculating and reporting the results.

Filter installations are often of various construction models, from a single filter to a bank consisting of many filters. This is a method how to perform a check on one or several filters in an installation. This method can give indication of the filter performance. The complete installation can also be tested using this method. This requires however more subjective judgements by the operator.

Supply air to a general ventilation system contains particles of a broad size range. Coarse as well as fine particles may cause problems for fans, heat exchangers etc., decreasing the function when covering vital parts of the system. In respect of health issues the most interesting particle range is the fine particles (<2.5 µm). In normal ventilation air most of the particles present are smaller than 1.0 µm and because of this and the fact that sampling losses are relatively low for fine particles has led to the measuring range of 0.2-1.0 µm in this recommendation. Additional values of particles >1.0 µm may be included. Large particles in outdoor air are normally few and have higher losses in sampling system. Results in the range >1.0 µm will therefore have lower accuracy and should be interpreted with respect to this.

An optical particle counter sizes the particles based on their optical properties. During in-situ measurement conditions, the optical properties of the particles may differ from the optical properties of the particles used when calibrating the particle counter (usually latex particles) and testing in laboratory. Thus the particle counter could size the particles different but count the number of particles correctly.

By adding an extra reference filter, the effect of varying measuring conditions can be reduced. Additionally, using this enhanced test method, the results can be used to correct the measured efficiencies in relation to the efficiency of the reference filter measured in laboratory using a standardized test aerosol:

The results from using the standard method or the enhanced method will give both users and manufacturers a better knowledge of actual filter and installation properties.

3 Definitions

Filter Installation :
A single filter or a group of filters mounted together with the same inlet and outlet of air.

Diluter/Dilution System:
A system for reducing the sampled concentration in order to avoid coincidence error in the particle counter.

Maximum Measured Concentration:
50% of the maximum particulate concentration at 5% coincidence loss stated by the manufacturer.

Particle Counter:
Optical particles counter using light scattering technique for determination of particle size.

4 Test Equipment

4.1 Particle Counter

Optical particle counter with a laser or a white light source having a capability of measuring particles in the size range of 0.2-1.0 µm, divided into minimum 3 ranges (f. ex. 0.2-0.3, 0.3-0.5 and 0.5-1.0). Additional values of particles >1.0 µm may be included.

The particle counter shall be periodically calibrated with mono-dispersed latex particles.

4.2 Diluter

Dilution system with the capability of diluting the aerosol concentration to an acceptable level.

Correction for any particle losses in the measuring range must be done when using the dilution system for determining fractional efficiency.

4.3 Pump

May be used to control the sample flow rate through the sampling probes - Primary flow (q1).

A pump is not necessary when the sample flow (q2) to the counter is sufficient for isokinetic sampling. In that case, the primary flow (q1) and the sample flow (q2) is the same.

4.4 Sampling System

Figure 1 shows a normal sampling system

4.4.1 Sampling Probes

The sampling probe shall consist of a sharp edge nozzle connected to the sample line leading to the auxiliary pump. The diameter of the nozzle is dependent on the sample flow (q1) in order to get isokinetic sampling. The diameter should not be less than 8 mm.

4.4.2 Sampling Lines

Sampling lines upstream and downstream should be of equal length and as short as possible to avoid losses. Material shall preferably be of a type with minimum particle losses, f. ex. tygon.

4.4.3 Sampling Points

Sampling points should be placed close to the filter, see Figure 2. If the complete installation is to be tested the sampling points should be further away to achieve good mixing of airflow through filters, frames, doors etc. A measurement of a complete installation is more difficult and it is a good practice to plan the measurement carefully and in detail describe how it was made.

4.4.4 Valve (Manual or Automatic)

A valve may be used to switch between up- and downstream sample points.
The valve shall be constructed so particle losses are identical regardless upstream or downstream measurement. No influence on efficiency due to the valve construction is permitted.

4.4.5 Pump

An auxiliary pump may be used if the particle counter sample flow (q2) is too low to get isokinetic sampling. The overdriving line shall then be fitted with an isokinetic sampling nozzle directly connected to the counter, see Figure 3.

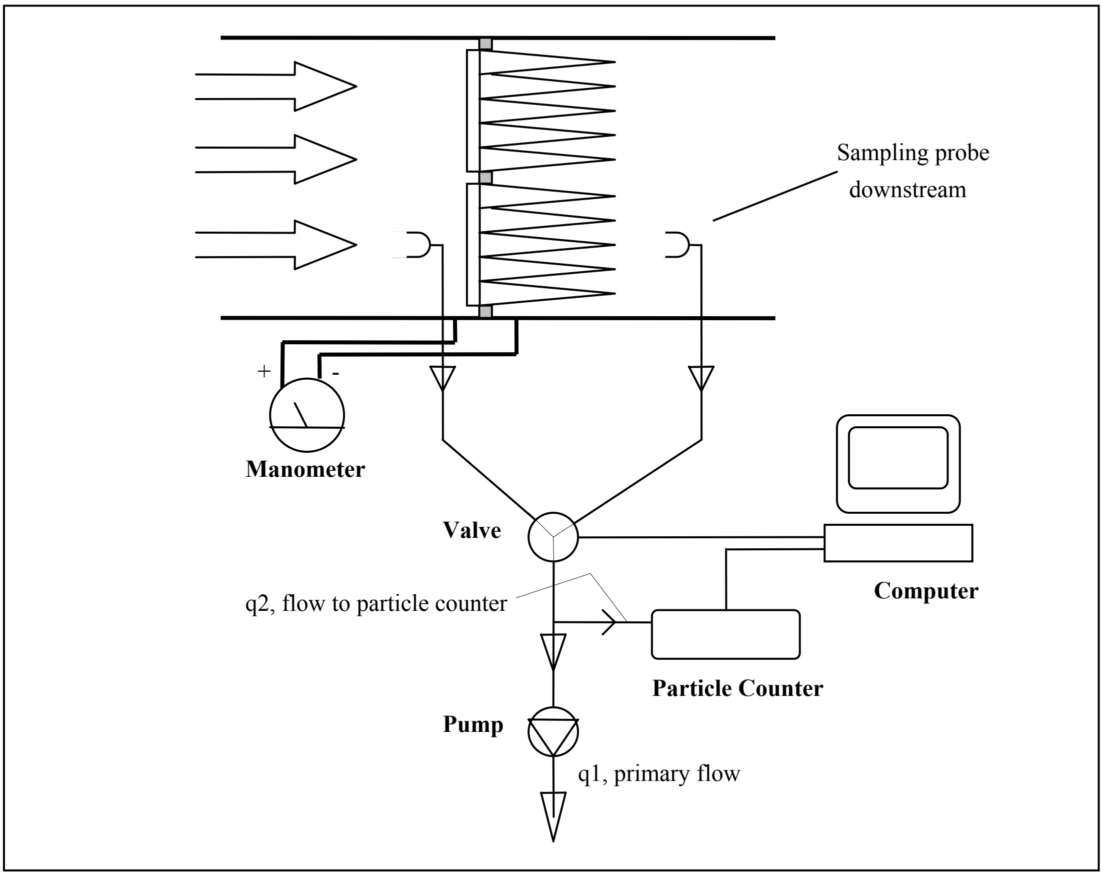


Figure 1: Sampling System

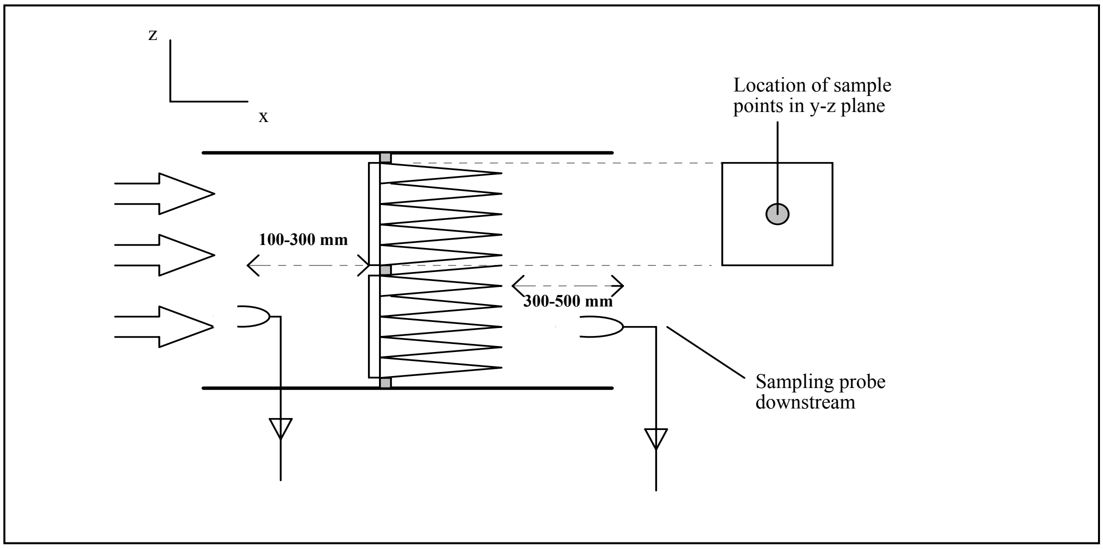


Figure 2: Sample Point Location

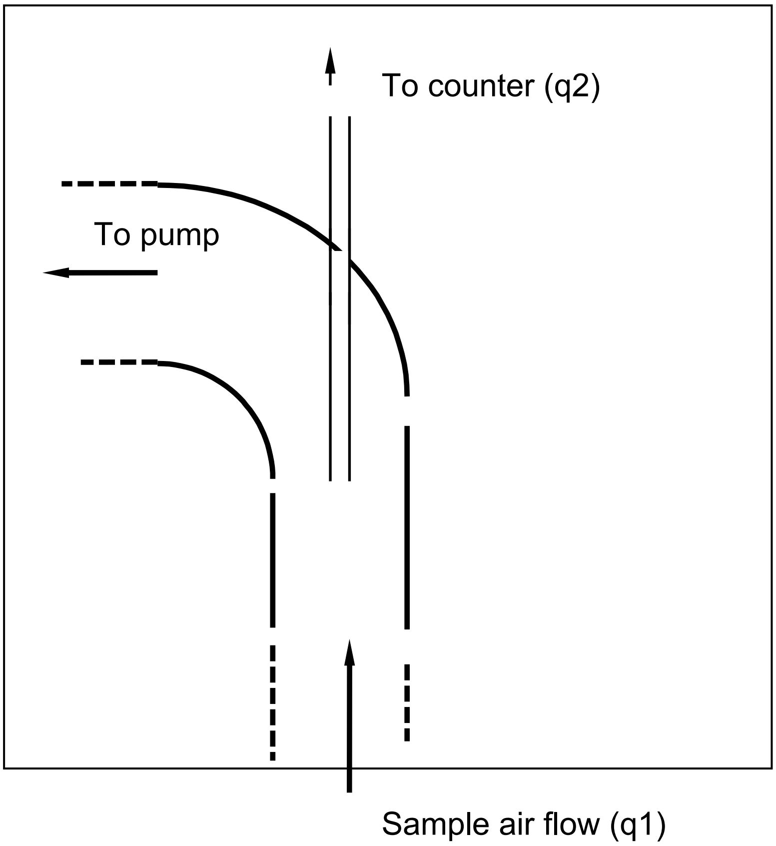


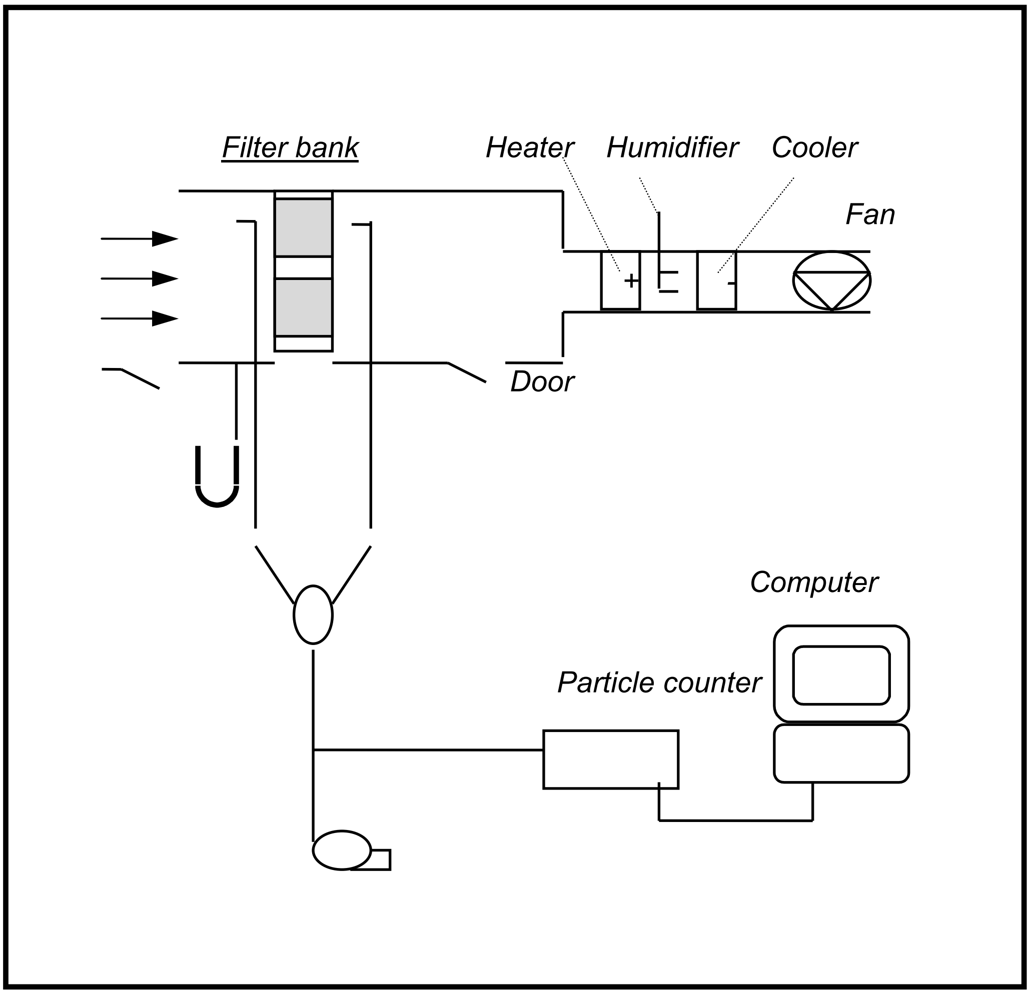
Figure 3: Sampling Line to Particle Counter

5 Installation

Minimum requirements for making a fractional particle efficiency test are:

- Possibility to place a probe upstream and downstream the filter.
- For filter efficiency measurement no obvious leaks in the frame system etc. should be permitted.
- The aerosol concentration must be within the range of the measuring equipment (particle counter, diluter) and high enough to produce reasonable statistical accuracy for the result.
- The ambient aerosol used for test should preferably be of a “normal” distribution and the composition should not be extreme. It should therefore be avoided to measure in extreme environments like high relative humidity or air containing process gases, see errors.

In Situ Fractional Efficiency Determination of General Ventilation Filters



6 Test Procedure

6.1 Airflow

The airflow over the filter unit shall if possible be estimated. The airflow over the whole installation shall if possible be measured or estimated. A velocity profile can be measured using an anemometer to check the air flow and the air distribution through the filters.

6.2 Relative Humidity

The relative humidity of the air in the installation shall be measured and recorded. Depending on equipment and outdoor particle composition high relative humidity (> 75 %) could influence the efficiency results. The enhanced test method described in chapter 11 can be used if measurements have to be made under high relative humidity conditions. The method enables a comparison of in-situ results with laboratory results and describes a method to correct the in-situ results with respect to the laboratory results.

6.3 Temperature

The air temperature shall be measured and recorded.

6.4 Pressure Drop

Shall be measured with a manometer of a good measuring ability in the range of 30-300 Pa. Pressure drop should be measured so only the static pressure over the installation will be recorded.

6.5 Fractional Particle Efficiency

- ◊ A visual inspection shall be made to ensure that the installation has no obvious leaks in the frame system. The particle concentration downstream of the filter should be checked in different places to insure that there are no leaks or weak points in the filter installation.

- ◊ The probes should be mounted so that a representative value of the concentration upstream and downstream is obtained, see Figure 1. The inlet of the probe upstream the filter should be located 100-300 mm upstream the filter surface. The inlet of probe downstream the filter should be located 300-500 mm downstream the end of the filter, see Figure 2. If the complete installation is to be measured the probes may have to be located in a different way, see Appendix A2.

- ◊ The flow at each sample point should be as isokinetic as possible. All sample points should be connected to one sampling tube leading to the particle counter. If a single particle counter is used, a valve can be mounted so it is easy to switch between upstream and downstream sample lines. All sampling tubes, valves, bends etc. shall be chosen so a minimum of particle losses in the measuring range occurs.

◊ To prevent that the concentration upstream not exceeds the particle counter maximum concentration, a diluter may be connected to the upstream sample point. After measuring five times of a minimum of 20 seconds and calculating the real concentration none of the measurements shall be above the maximum concentration.

If too high concentrations occur upstream a diluter must be used to lower the concentrations below the maximum concentration for the particle counter when measuring the efficiency. Corrections shall be made for any losses in the range 0.2-1.0 µm for the dilution system.

◊ The efficiency measurement is done by a series of minimum 12 counts of minimum 20 seconds conducted successively upstream and downstream of the filter. A purge of at least 20 seconds shall be made (dependent of the length of sampling lines and sample flow) upstream each count, or with a sample upstream or downstream without counting just to equalise the concentration in the transfer lines.

◊ For added accuracy the measurement could be repeated at additional downstream sampling points.

7 Checklist

◊ **Temperature and Relative Humidity**
Low air temperature or high relative humidity can influence the results and should be considered. The enhanced test method described in chapter 11 can be used to correct for variations in conditions compared with laboratory results.

◊ **Concentration Limit**
To avoid coincidence errors due to high concentration check the upstream concentration using a diluter. Start measure at a dilution ratio of 100. If the calculated concentration (= measured concentration x 100) is below 50 % of the instruments maximum concentration limit then the efficiency measurements can be done without a diluter. If the calculated concentration exceeds the limit a diluter must be used. In this case choose a suitable dilution ratio so the measured concentration of particles is high enough to achieve good statistical data but below the maximum concentration limit.
The actual concentration can then be calculated from the dilution ratio.

◊ **Zero Test**
Check the zero count both upstream and downstream by connecting an HEPA filter in the beginning of the sampling lines. Sampling probes may be disconnected, see Figure 4.

The sum of particles in all size range during a one-minute count shall be < 10.

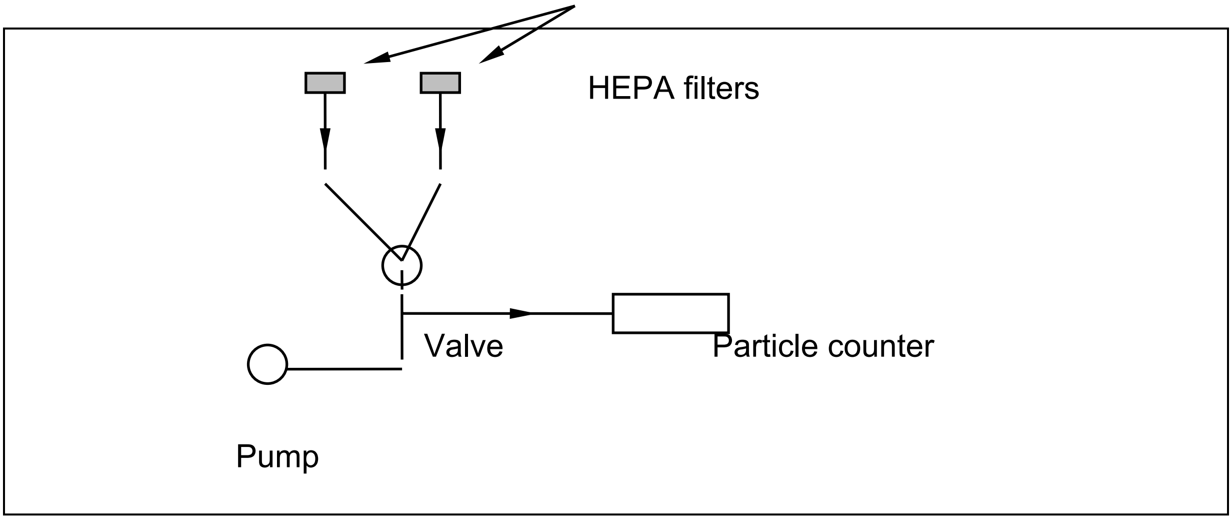


Figure 4: Principle of Checking Zero Count Rate of Sampling Lines.

◊ **Aerosol Composition**
To check that the ambient aerosol will have no significant differences in properties compared to the calibration aerosol (normally Latex) and because of that give large errors in size determination etc. the enhanced test method described in chapter 11 can be used.

8 Expression of Results

8.1 General information

A description of the installation shall be made including:

- number of filters in the installation
- type of filters
- dimensions of ducting
- schematic drawing over the installation
- location of all sample points (∆p, particle efficiency)
- if diluter is used
- which filters tested
- running conditions, type of outdoor environment, continuous or intermittent use of installation etc.
- when last replacement of filters were made
- other remarks

8.2 Airflow

The airflow over the filter bank and over the tested filter shall be reported.

8.3 Relative Humidity

The relative humidity of the air in the installation shall be reported.

8.4 Temperature

The air temperature shall be reported.

8.5 Pressure Drop

The measured pressure drop shall be reported.

8.6 Fractional Efficiency

The fractional efficiency and the uncertainty of the measurement shall be reported for the range 0.2-1.0 µm of minimum *3* size ranges. The efficiency shall be calculated as in Section 10.1.

9 Errors

Humidity
High relative humidity can cause variations in efficiency and pressure drop. High relative humidity increases the size of hygroscopic particles. Particles may dry before reaching the detection chamber in the particle counter and have a different size than at the air filter. The humidity can also change the refractive index of the particles and influence the measured size. The enhanced test method described in chapter 11 is used to correct the result.

Air Temperature
Cold conditions may lead to freezing of permanent installed sampling probes, particle counter problems etc.

Aerosol Composition
The refractive index, density, shape of the particles in the air can in extreme cases vary between different installations, which may give problems in size determination. By using the enhanced method described in chapter 11 this could be checked.

Uneven Aerosol Concentration
The concentration in an installation is normally not stationary and will show variations in time. This may be a problem when measuring with a single particle counter due to the time laps between upstream and downstream measurements. Therefore it is important that the measurement is consisting of many measurements upstream and downstream to get good statistical accuracy and that the uncertainty is determined.

Turbulent Airflow
The airflow dependent on the installation can be more or less turbulent and in extreme cases it is possible to have velocity components opposite the major airflow. It is therefore necessary to check that most of the airflow at the measuring point actually is going through the filter. By using a smoke generator to visualise the flow pattern checking can be made.

A good practice is to measure a representative filter of the installation and exclude filters that seem to be in the risk of having this problem.

Coincidence Errors - Particle Counter
50% of the maximum concentration at 5% coincidence error must not be exceeded.

Particle Loss

- Sampling system
  Particulate losses in the range of 0.2 -1.0 µm shall give no significant influence on the efficiency measurement.
- Dilution system
  Particulate losses in the range of 0.2 -1.0 µm shall give no significant influence on the efficiency measurement.
- Isokinetic sampling
  Since the measuring range is below 1.0 µm, isokinetic sampling is not so important and it is therefore sufficient to measure with an approximate isokinetic probe and sampling flow. For particles > 1.0 µm the losses will be much higher and can therefore affect the result

10 Calculation of Results

10.1 Calculation of Fractional Efficiency

The calculation is based on EN 779:2002.

The basic expression of the fractional efficiency for a given particle size range (particles between two diameter values) is the ratio of the number of particles retained by the filter to the number of particles fed upstream of the filter.

The counts shall be conducted upstream and then downstream successively, the counting cycle being as follows for a given particle size range:

Table 1: Sampling Cycles

Counting Number	1	2	3	4	5	6	7	8	9	10	11	12	13
UPSTREAM	N_1		N_2		N_3		N_4		N_5		N_6		N_7
DOWNSTREAM		n_1		n_2		n_3		n_4		n_5		n_6	

Six "point" fractional efficiencies shall be calculated as follows:

$$E_1 = \left[1 - \frac{n_1}{\left(\frac{N_1 + N_2}{2}\right)}\right] \bullet 100 \qquad E_2 = \left[1 - \frac{n_2}{\left(\frac{N_2 + N_3}{2}\right)}\right] \bullet 100$$

$$E_3 = \left[1 - \frac{n_3}{\left(\frac{N_3 + N_4}{2}\right)}\right] \bullet 100 \qquad E_4 = \left[1 - \frac{n_4}{\left(\frac{N_4 + N_5}{2}\right)}\right] \bullet 100$$

$$E_5 = \left[1 - \frac{n_5}{\left(\frac{N_5 + N_6}{2}\right)}\right] \bullet 100 \qquad E_6 = \left[1 - \frac{n_6}{\left(\frac{N_6 + N_7}{2}\right)}\right] \bullet 100$$

The fractional efficiency shall be equal to the average of those efficiencies, i.e.:

$$\overline{E} = \frac{\sum_{i=1}^{6} E_i}{6}$$

10.2 Calculation of Uncertainty

The uncertainty on the average fractional efficiency as defined under paragraph 10.1 corresponds to a two-sided confidence interval of the average value based on a 95 % confidence level.

According to ISO 2854:1976:

$$\overline{E} - t_{1-\alpha/2} \frac{\delta}{\sqrt{n}} \leq \overline{E} \leq \overline{E} + t_{1-\alpha/2} \frac{\delta}{\sqrt{n}}$$

where

$\overline{E}$: Average efficiency

$$\overline{E} = \frac{\sum_{i=1}^{n} E_i}{n}$$

E_i : point value of the efficiency

$t_{1-\alpha/2}$: value depending on the degree of freedom "ν"

$\nu = n - 1$ (see ISO 2854:1976)

n : number of calculated point efficiency values E_i

δ : standard deviation

$$\delta = \sqrt{\frac{\sum \left(E_i - \overline{E} \right)^2}{n-1}}$$

11 Enhanced Test System

11.1 Principle of the Enhanced Test System

Using the enhanced test system illustrated in Figure 5 it is possible to measure almost simultaneously the efficiency of the filter system and a reference filter. The effects of varying measurement conditions can thus be reduced. Additionally the results can be used to correct the measured efficiencies in relation to the efficiency of the reference filter measured in laboratory using a standardized test aerosol. In order to avoid additional errors, the same optical particle counter should be used both in the laboratory and is-situ measurements. The reference filter should preferably be of the same type and efficiency level as the filter to be in-situ tested.

The enhanced test system includes three sampling lines, i.e. an additional sampling line and valve for the reference filter. The aerosol sampling system is used to measure particle concentrations alternatively from upstream and downstream of the test filter and reference filter. The timing of the measurement is shown in Table 2. If the aerosol concentration is steady within ± 10 %, the upstream measurements numbered 3, 7, 11, 15, 19 and 23 in Table 2 can be omitted to reduce the sampling time. The results are calculated both for the reference filter and the test filter using the procedures presented in chapter 10.

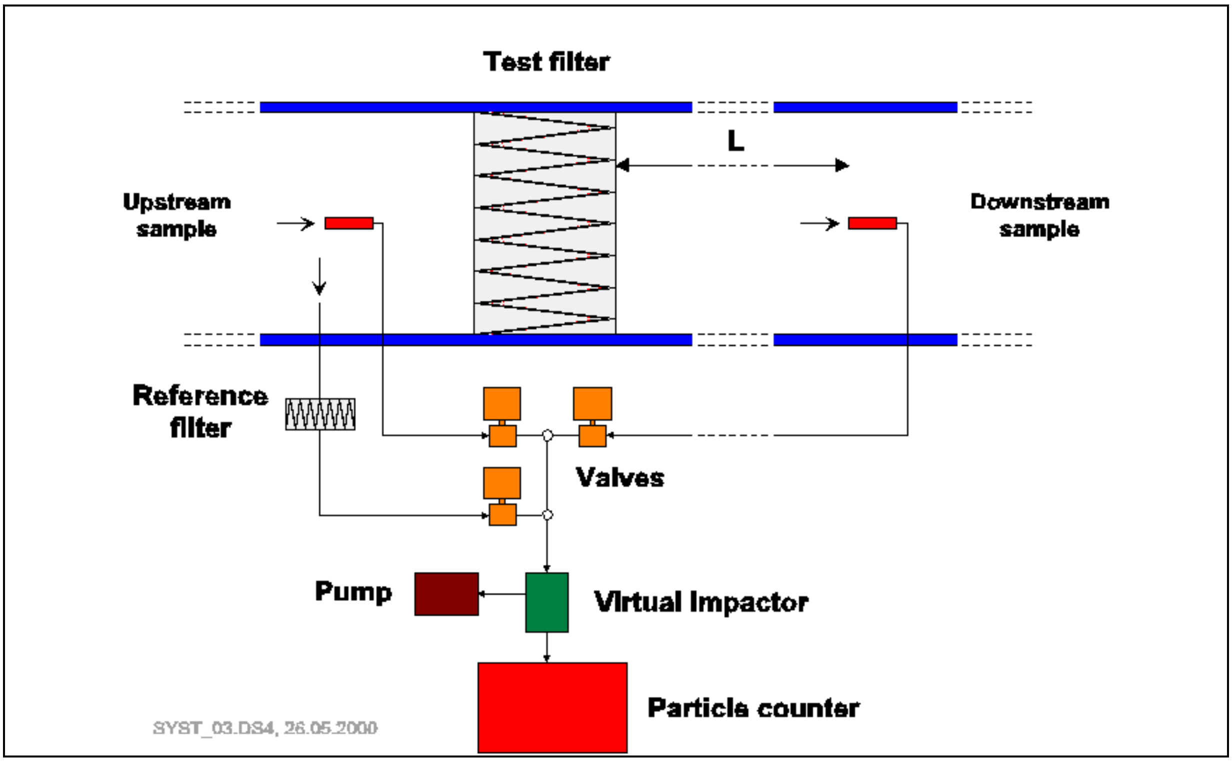


Figure 5: Schematic of the Enhanced Test System

Figure 5 shows an optional virtual impactor in the aerosol sampling line immediately upstream of the particle counter. With a properly designed virtual impactor it is possible to increase the number of larger particles seen by the particle counter and increase the otherwise poor counting statistics.

Table 2 Sampling Cycles in the Enhanced Test System

Measurement Number	1	2	3	4	5	6	7	8	9	10	11	12	13
Upstream	$N_{u,1}$		$N_{u,2}$		$N_{u,3}$		$N_{u,4}$		$N_{u,5}$		$N_{u,6}$		$N_{u,7}$
Downstream		$N_{d,1}$				$N_{d,2}$				$N_{d,3}$			
Reference				$N_{r,1}$				$N_{r,2}$				$N_{r,3}$	

Measurement Number	13	14	15	16	17	18	19	20	21	22	23	24	25
Upstream	$N_{u,7}$		$N_{u,8}$		$N_{u,9}$		$N_{u,10}$		$N_{u,11}$		$N_{u,12}$		$N_{u,13}$
Downstream		$N_{d,4}$				$N_{d,5}$				$N_{d,6}$			
Reference				$N_{r,4}$				$N_{r,5}$				$N_{r,6}$	

procedure_01.xls, 16.06.2000

11.2 Determination of the Corrected Particle Size

An optical particle counter sizes the particles based on their optical properties. During in-situ measurement conditions, the optical properties of the particles may differ from the optical properties of the particles used when calibrating the particle counter (usually latex particles) and in laboratory tests. Thus the particle counter will size the particles different but count the number of the particles correctly. The resulting efficiency/penetration curve will have comparable efficiency values at different particle sizes compared with laboratory results. The particle sizes can be corrected by comparison to the laboratory penetration (or efficiency) curve of the reference filter as illustrated in Figure 6.

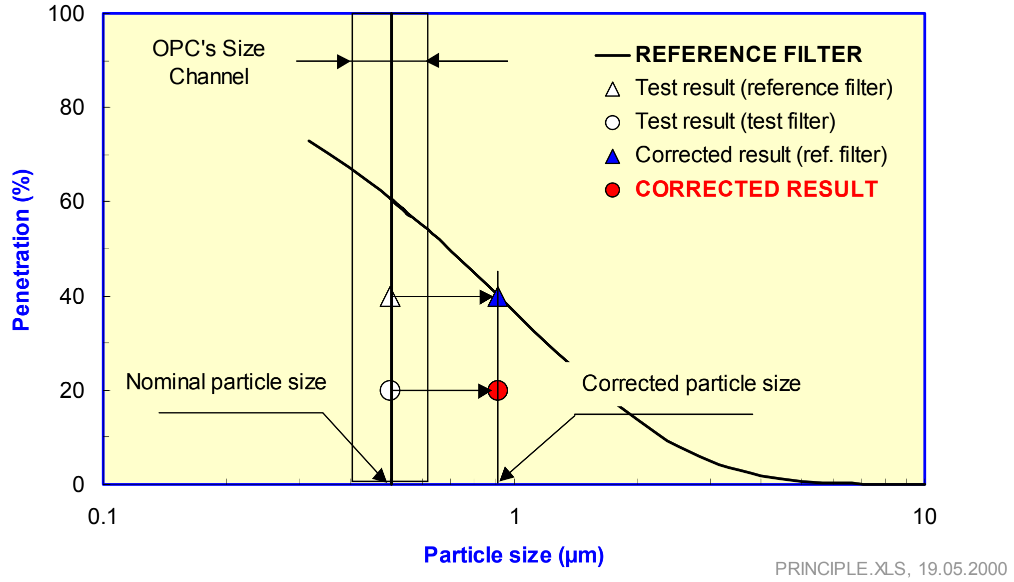


Figure 6: Determination of the Corrected Particle Size

The penetration of the reference filter measured with in-situ particles (test result of reference filter) is compared with the laboratory calibration curve of the reference filter in order to find the corrected particle size. The corrected particle size for a measured penetration for the reference filter is the particle size, which on the reference filter calibration curve has an equal penetration. This particle size correction is also made for the test filter data. The procedure is then repeated for all measured particle sizes.

11.3 Presentation of Results

When using the enhanced test system the test report should in addition to what is stated in paragraph 8 also present:

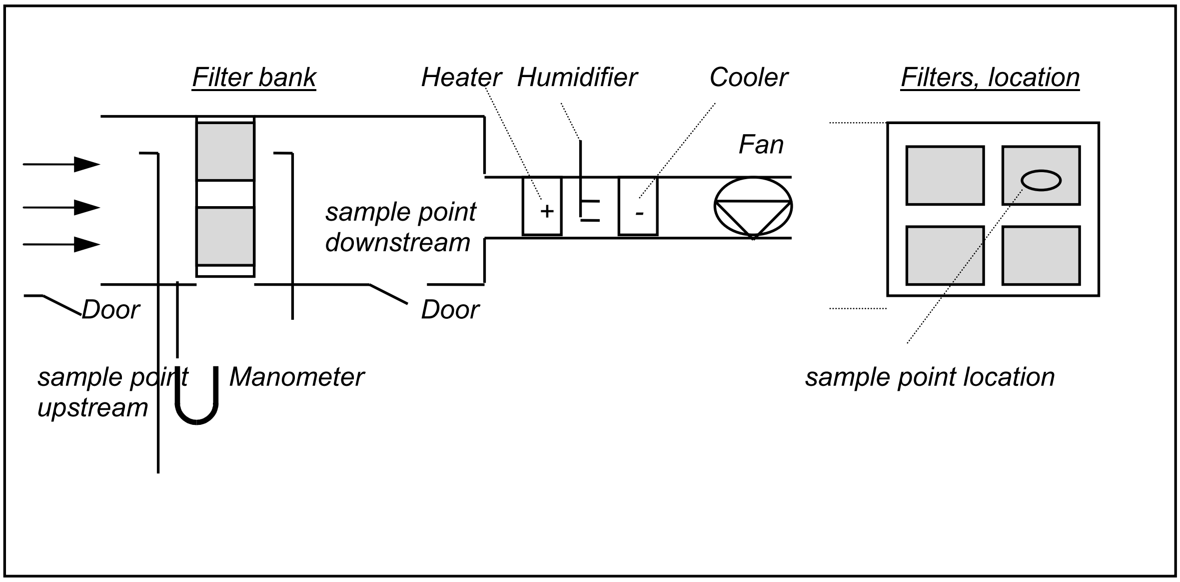
- efficiency of the reference filter measured in laboratory
- efficiency of the reference filter measured using ambient particles
- efficiency of the test filter measured using ambient particles
- efficiency of the test filter measured using ambient particles and the corrected particle sizes.

A. EXAMPLES

A1 Filter test - Example

A filter installation consisting of four filters in a bank are to be tested. The test procedure is according to chapter 6 (Test method) and chapter 7 (Checklist).

Schematic drawing of the installation:



A1.1 General

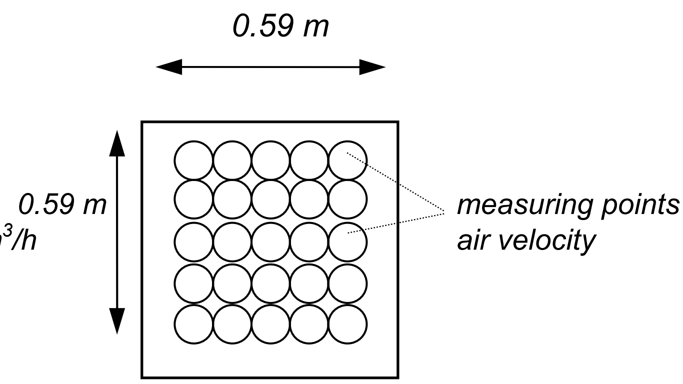
The sampling points were located so a minimum of influence from turbulence (from door, walls) was achieved. The pressure drop tap was located in the duct wall as close to the filters as possible. Relative humidity and temperature was measured on the upstream side close to filter bank. The air flow was 12800 m^3/h for the installation. A velocity profile was measured over the filter to be tested. Air flow calculated from this (25 points measured) gave approximate 3500 m^3/h over the filter.

A1.2 Results

Air conditions

RH :	*65 %*
Temperature:	*16℃*
Mean air velocity:	*2.8 m/s*
Estimated air flow:	*≈ 3500 m^3/h*

(=2.8x0.59x0.59x3600)



Filter Installation

Number of filters in installation:	*4*
Filter dimensions:	*0.592x0.592x0.550 m*
Duct dimensions	
Upstream:	*3x2.5 m*
Downstream:	*3.5x2.5 m*

Filter type:	*F7*
Manufacturer:	*XXXXX*
Model no:	*XXXXX*
Last filter Replacement:	*1995- xx-xx*

***Remarks**: Air handling unit for inlet air to office building. Inspection/service doors on upstream and downstream side of filter bank see schematic drawing. Installation is running 24 H/day, 5 days/week. Moderate cleanliness on downstream side, dirty on upstream side.*

Efficiency Measurement

Filter type:	*F7*
Manufacturer:	*XXXXX*
Model no:	*XXXXX*
Air flow filter:	*3500 m^3/h*
Pressure drop Installation (Pa):	*85 Pa*
Aerosol:	*Outdoor air*
Sample points:	*300 mm upstream, 500 mm downstream*
Reference filter:	*F7, compact filter, 0.3x0.3x0.2 m.*

Instruments

Particle counter:	*LAS X, size range 0.10-7.5 µm* *max. concentration/channel: 1000 000/l*
Manometer:	*Magnehelic, 0-500 Pa*
Diluter:	*xxxx*
RH:	*xxxx*
Thermometer:	*xxxx*

a) Concentration Measurement:

5 measurements at upstream side with diluter xxxx. Dilution ratio: R = 100 and R=1

	Concentration - Calculated (particles/l)	
Size range (µm)	Dilution ratio R= 100	No dilution R=1
0.10-0.12	112000	144520
0.12-0.15	152000	162010
0.15-0.20	162000	172100
0.20-0.25	45100	50980
0.25-0.35	30200	34020
0.35-0.45	10500	15250
0.45-0.60	9800	10950
0.60-0.75	7100	9980
0.75-1.00	9800	8720
1.00-1.50	2100	4560
1.50-2.00	100	230
2.00-3.00	0	40
3.00-4.50	0	20
4.50-6.00	0	0
6.00-7.50	0	0
>7.50	0	0

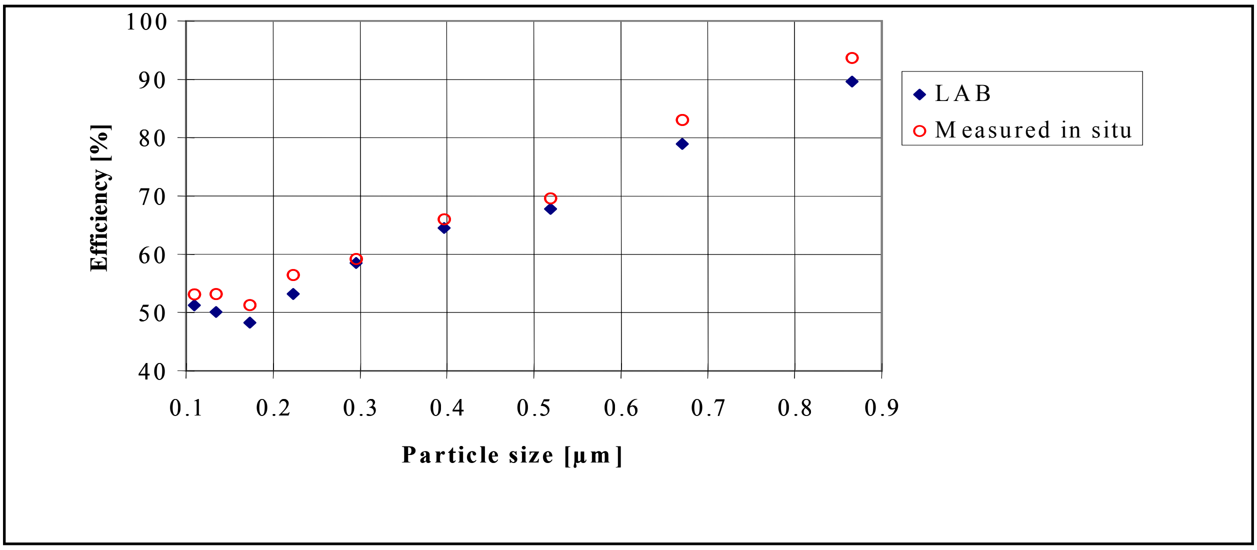
Conclusion:
No diluter required since the concentrations measured with and without diluter shows concentrations of the same magnitude and the measured concentration is below 50 % of the maximum concentration of LAS X (1,000,000 x 0.5 = 500,000 /l)

b) Zero Check

Absolute filter connected on upstream and downstream side, sum of particles counted during one minute < 10.

c) Aerosol Composition

Reference filter connected as in Figure 5. The maximum difference from laboratory test on the size range 0.2-1.0 µm was 3 %.



RESULT form particle count on XXXX filter

Size range (µm)	**Upstream (particles/l)** Measurement no: 1	2	3	4	5	6	7	Upstream particles/l mean
0.10-0.12	119530	102340	98700	119850	132410	145620	160050	125500
0.12-0-15	134560	135535	154061	140696	149824	140194	155961	144405
0.15-0.20	166410	196701	172109	189463	191340	197884	167012	182988
0.20-0.25	87540	92661	105018	104057	95526	102632	87604	96434
0.25-0.35	76410	77497	90241	79942	92167	95203	87965	85632
0.35-0.45	24590	25735	26240	27166	27658	27801	24987	26311
0.45-0.60	19230	21611	21898	21578	19781	19929	20938	20709
0.60-0.75	14510	17316	17023	15663	17771	18165	18259	16958
0.75-1.00	5420	6199	5604	5578	7021	6120	6039	5997
1.00-1.50	980	994	1108	1272	1152	1218	1235	1137
1.50-2.00	720	907	995	919	814	938	729	860
2.00-3.00	310	200	192	300	120	95	115	190
3.00-4.50	10	5	0	5	5	2	0	4
4.50-6.00	0	0	2	0	2	0	2	1
6.00-7.50	0	0	0	0	0	0	2	0
> 7.50	0	0	2	0	1	0	0	0

Size range (µm)	**Down-stream (particles/l)** Measurement no: 1	2	3	4	5	6	Down-stream particles/l mean
0.10-0.12	58942	49605	49393	60531	63667	72249	59064
0.12-0-15	67277	63731	76192	68535	73353	66956	69341
0.15-0.20	85614	101698	90653	99261	100222	103188	96773
0.20-0.25	40025	44021	48770	47700	43306	46185	45001
0.25-0.35	33137	33566	41295	34538	42379	41744	37776
0.35-0.45	9514	9742	9992	10510	10261	10169	10031
0.45-0.60	6094	7070	6903	6604	6173	6337	6530
0.60-0.75	3924	4470	4598	4287	4637	4999	4486
0.75-1.00	973	1090	915	842	1154	962	989
1.00-1.50	95	115	183	75	210	186	144
1.50-2.00	100	90	290	116	115	55	128
2.00-3.00	5	10	10	45	20	15	18
3.00-4.50	1	1	0	1	1	1	1
4.50-6.00	0	0	0	0	0	0	0
6.00-7.50	0	0	0	0	0	0	0
> 7.50	0	0	0	0	0	0	0

Results

	Efficiency (%)						Efficiency	
Size range	Measurement no:						average	stdev
(µm)	1	2	3	4	5	6	(%)	(%)
0.10-0.12	46.87	50.65	54.80	52.01	54.20	52.73	51.9	2.9
0.12-0-15	50.18	55.99	48.30	52.82	49.41	54.78	51.9	3.1
0.15-0.20	52.84	44.85	49.86	47.87	48.50	43.44	47.9	3.4
0.20-0.25	55.58	55.46	53.35	52.20	56.29	51.45	54.1	2.0
0.25-0.35	56.94	59.98	51.47	59.87	54.76	54.42	56.2	3.3
0.35-0.45	62.19	62.51	62.58	61.66	63.00	61.47	62.2	0.6
0.45-0.60	70.16	67.50	68.25	68.06	68.91	68.99	68.6	0.9
0.60-0.75	75.34	73.96	71.87	74.35	74.19	72.55	73.7	1.3
0.75-1.00	83.26	81.52	83.64	86.63	82.44	84.18	83.6	1.8
> 1.00	90.24	90.19	79.83	89.68	84.05	88.16	87.0	4.2

Calculated Efficiency and Uncertainty, according to Eurovent 4/10 *(for calculations, see Section 10.2)*

95 % CI, gives for

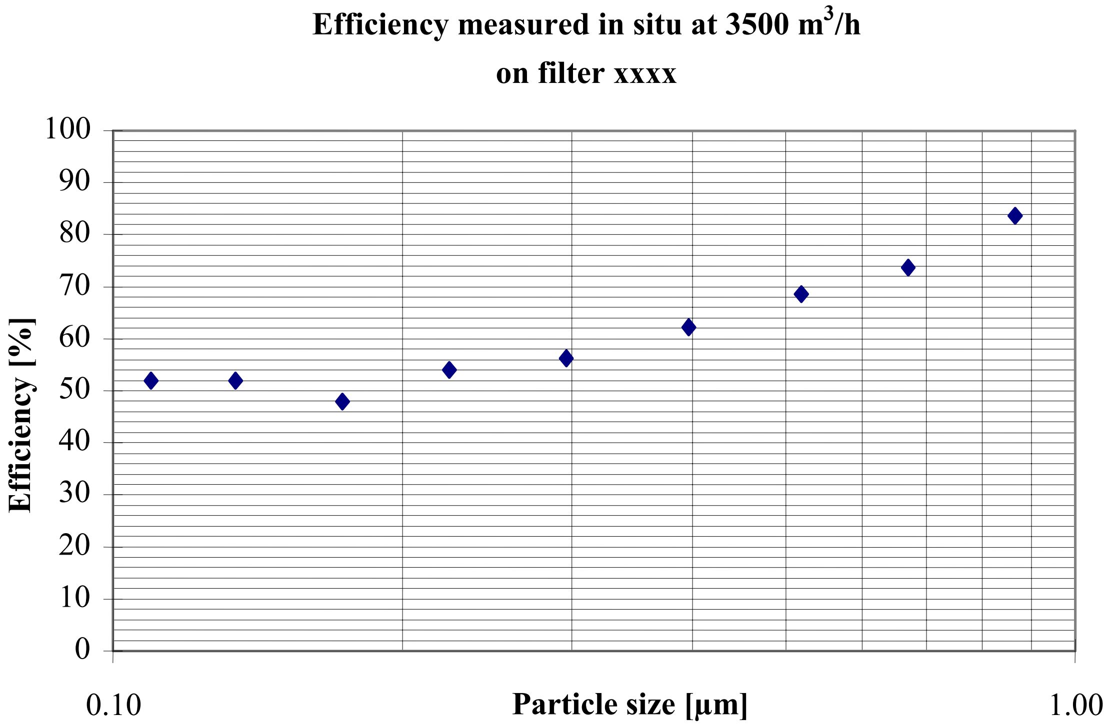
$n = 6$

$\nu = n - 1 = 6 - 1 = 5$

$\mathbf{t_{1-\alpha/2}} = \mathbf{2.57}$ (section 10.2)

Mean values

Size range (µm)	Upstream (particles/l)	Downstream (particles/l)	Efficiency average (%)	stdev (%)	Uncertainty +/- (%)
0.10-0.12	125500	59064	51.9	2.9	3.0
0.12-0-15	144405	69341	51.9	3.1	3.2
0.15-0.20	182988	96773	47.9	3.4	3.6
0.20-0.25	96434	45001	54.1	2.0	2.1
0.25-0.35	85632	37776	56.2	3.3	3.5
0.35-0.45	26311	10031	62.2	0.6	0.6
0.45-0.60	20709	6530	68.6	0.9	1.0
0.60-0.75	16958	4486	73.7	1.3	1.3
0.75-1.00	5997	989	83.6	1.8	1.8
> 1.00	2193	290	87.0	4.2	4.4

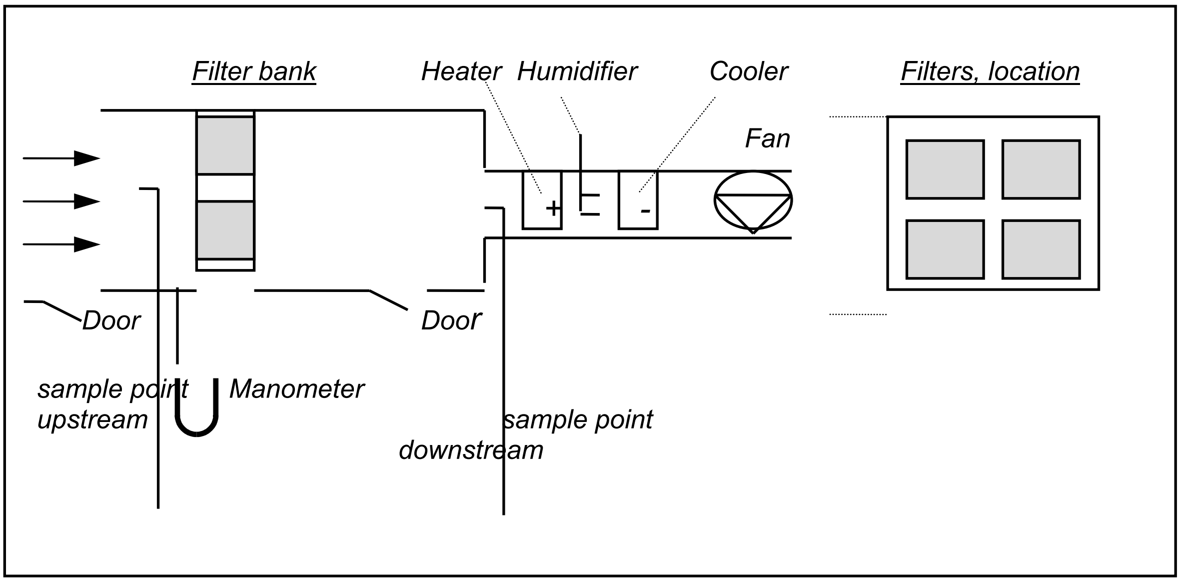


Efficiency measured in situ at 3500 m3/h
on filter xxxx
100
90
80
70
60
50
40
30
20
10
0
Efficiency [%]
0.10
Particle size [µm]
1.00

A2. Installation Efficiency

A filter installation consisting of four filters in a bank are to be tested. The test procedure is according to chapter 6 (Test method) and chapter 7 (Checklist). The installation efficiency was to be tested.

Schematic drawing of the installation:



A2.1 General

The sampling points were located so the installation efficiency was measured, see drawing above.

The pressure drop tap was located in the duct wall as close to the filters as possible. Relative humidity and temperature was measured on the upstream side close to filter bank.

The air flow was 12800 m^3/h for the installation. Note: leakage may occur through frames, door on downstream side. The area on the downstream side was moderate dirty.

A2.2 Result

Filter installation data, airflow, and concentration equal to example A1.
Zero check and Aerosol composition equal to example in A1.

RESULT form particle count - installation

Size range (µm)	Upstream (particles/l) Measurement no: 1	2	3	4	5	6	7	Upstream particles/l mean
0.10-0.12	115420	102340	98700	119850	132410	145620	160050	124913
0.12-0-15	127800	129451	145941	147839	139615	136735	147791	139310
0.15-0.20	170590	185449	184171	183934	187398	173676	187295	181788
0.20-0.25	79580	92131	80997	88080	88927	80680	92216	86087
0.25-0.35	69250	70170	84369	77113	81507	74674	77684	76395
0.35-0.45	21050	25666	21269	23737	26141	23160	25989	23859
0.45-0.60	17840	20898	22046	19201	22005	20086	18598	20096
0.60-0.75	14580	15632	18506	15747	14841	17616	16946	16267
0.75-1.00	4980	5166	6319	5462	6121	5306	5394	5535
1.00-1.50	780	786	910	1017	816	901	964	882
1.50-2.00	690	874	740	952	721	757	707	777
2.00-3.00	290	200	192	300	120	95	115	187
3.00-4.50	0	5	0	5	5	2	0	2
4.50-6.00	0	0	2	0	2	0	2	1
6.00-7.50	0	0	0	0	0	0	2	0
> 7.50	0	0	2	0	1	0	0	0

Size range (µm)	Downstream (particles/l) Measurement no: 1	2	3	4	5	6	Down-stream particles/l mean
0.10-0.12	63712	47411	63983	64423	69664	77806	64500
0.12-0-15	58959	73209	79052	88415	60999	65697	71055
0.15-0.20	84044	98098	102651	96076	98071	100012	96492
0.20-0.25	40494	52729	43700	39389	47345	48970	45438
0.25-0.35	41120	41464	46694	46450	39012	34507	41541
0.35-0.45	9756	11307	8211	11383	14402	9229	10715
0.45-0.60	6118	9023	7558	8228	7193	6542	7444
0.60-0.75	4952	6767	9241	5168	4884	8709	6620
0.75-1.00	1925	1589	1710	1642	1377	1082	1554
1.00-1.50	110	150	95	80	220	90	124
1.50-2.00	108	143	124	187	125	140	138
2.00-3.00	115	12	12	12	12	12	29
3.00-4.50	50	1	15	5	5	1	13
4.50-6.00	1	2	10	0	12	0	4
6.00-7.50	0	0	0	0	0	0	0
> 7.50	0	0	0	0	0	0	0

Results

	Efficiency (%)							
Size range (µm)	Measurement no: 1	2	3	4	5	6	**Efficiency average (%)**	**stdev (%)**
0.10-0.12	41.48	52.83	41.45	48.92	49.89	49.09	47.3	4.7
0.12-0-15	54.16	46.83	46.18	38.48	55.85	53.82	49.2	6.6
0.15-0.20	52.79	46.92	44.23	48.25	45.68	44.59	47.1	3.2
0.20-0.25	52.83	39.09	48.31	55.49	44.17	43.35	47.2	6.2
0.25-0.35	41.01	46.34	42.17	41.43	50.04	54.70	45.9	5.5
0.35-0.45	58.23	51.82	63.51	54.36	41.58	62.44	55.3	8.1
0.45-0.60	68.41	57.98	63.35	60.06	65.82	66.18	63.6	4.0
0.60-0.75	67.22	60.36	46.04	66.21	69.90	49.60	59.9	9.9
0.75-1.00	62.05	72.33	70.97	71.64	75.89	79.77	72.1	5.9
> 1.00	78.84	83.42	87.59	85.59	78.11	86.30	83.3	4.0

Calculated Efficiency and Uncertainty, according to Eurovent 4/10 *(calculations, see Section 10.2)*

95 % CI, gives for

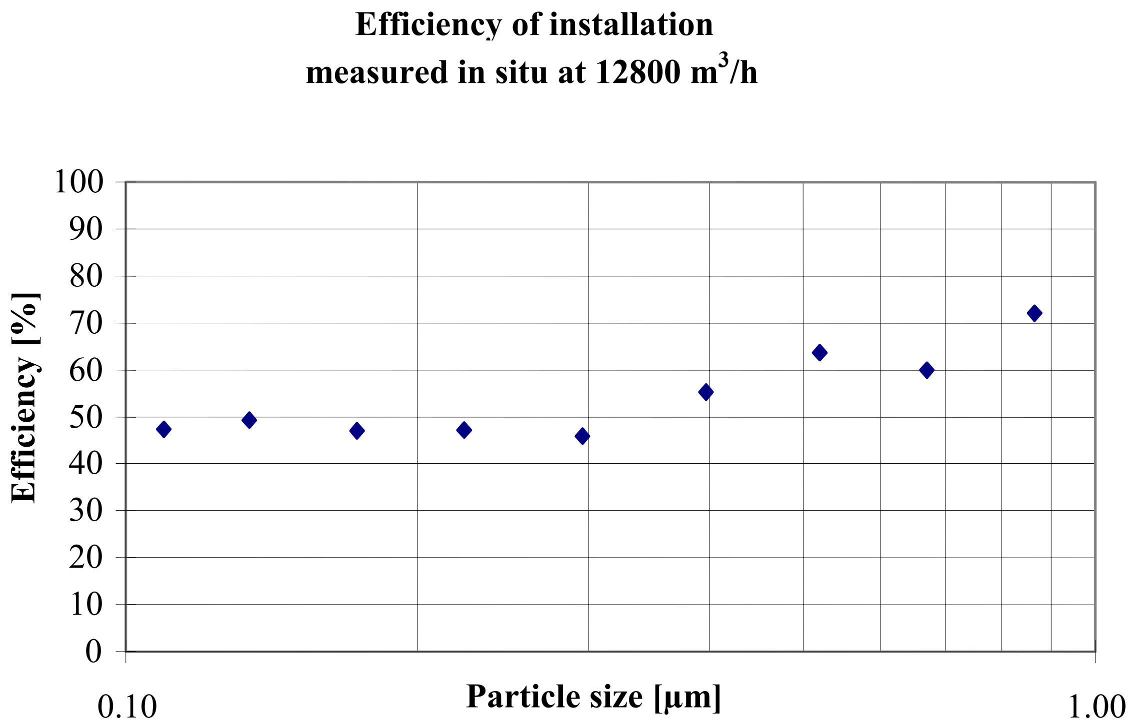
n = 6

ν = n -1 = 6-1 = 5

$\mathbf{t_{1-\alpha/2}}$ **= 2.57** (Section 10.2)

Mean values

Size range (µm)	Upstream (particles/l)	Downstream (particles/l)	Efficiency average (%)	stdev (%)	Uncertainty +/- (%)
0.10-0.12	124913	64500	47.3	4.7	4.9
0.12-0-15	139310	71055	49.2	6.6	7.0
0.15-0.20	181788	96492	47.1	3.2	3.3
0.20-0.25	86087	45438	47.2	6.2	6.5
0.25-0.35	76395	41541	45.9	5.5	5.8
0.35-0.45	23859	10715	55.3	8.1	8.5
0.45-0.60	20096	7444	63.6	4.0	4.2
0.60-0.75	16267	6620	59.9	9.9	10.4
0.75-1.00	5535	1554	72.1	5.9	6.2
> 1.00	1851	308	83.3	4.0	4.2


Efficiency of installation
measured in situ at 12800 m3/h
Efficiency [%]
100
90
80
70
60
50
40
30
20
10
0
0.10
Particle size [µm]
1.00

B. References

1. EN 779:2002. Particulate air filters for general ventilation - Determination of the filtration performance.
2. ISO 2854:1976. Statistical interpretation of data - Techniques of estimation and tests relating to means and variances.
3. NT VVS 128. Field test method for the measurement of filter efficiency. Nordtest.
4. Lehtimäki M. & Taipale A., Field test method for the measurement of filter efficiency. NT Techn Report 531. Nordtest.

NATIONAL ASSOCIATIONS

BELGIUM
AGORIA
80 bd Reyerslaan
1030 Brussels
Tel.: 32 2 7067985
Fax: 32 2 7067966

FINLAND
FAMBSI
Eteläranta 10, P.O.Box 10
00131 Helsinki
Tel.: 358 919231
Fax: 358 9624452

FRANCE
UNICLIMA
92038 Paris La Défense Cedex
Tel.: 33 1 47176292
Fax : 33 1 47176427

GERMANY
FV ALT im VDMA
Postfach 710864
60498 Frankfurt/Main
Tel.: 49 69 66031227
Fax: 49 69 66031218

ITALY
ANIMA
Via Angelo Scarsellini, 13
20161 Milan
Tel.: 39 02 45418500
Fax: 39 02 45418545

ITALY
CO.AER
Via Angelo Scarsellini, 13
20161 Milan
Tel.: 39 02 45418556
Fax: 39 02 45418545

NETHERLANDS
FKL
Postbus 190
2700 Ad Zoetermeer
Tel.: 31 79 3531350
Fax: 31 79 3531365

NORWAY
NVEF
Postboks 7174 Majorstua
0307 OSLO
Tel.: 47 2 3087751
Fax: 47 2 3087752

SLOVENIA
HVAC Cluster / Grozd KGH
Vojkova 4
5280 Idrija
Tel.: 386 5 3734120
Fax: 386 5 3734142

SPAIN
AFEC
Francisco Silvela, 69-1°C
28028 Madrid
Tel.: 34 91 4027383
Fax: 34 91 4017927

SPAIN
ANEFRYC
Principe de Vergara, 72
28006 Madrid
Tel. : 34 91 4113271
Fax : 34 91 5637105

SWEDEN
KTG
P.O.Box 55 10
11485 Stockholm
Tel.: 46 8 7820800
Fax: 46 8 6603378

SWEDEN
SWEDVENT
P.O.Box 175 37
11891 Stockholm
Tel.: 46 8 7627500
Fax: 46 8 6681180

TURKEY
ISKID
Ruhi Bagdadi Sok No:1 Balmumcu
80700 Istanbul
Tel.: 90 212 2881570
Fax: 90 212 2725652