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Field testing of general ventilation filtration devices and systems for in situ removal efficiency by particle size and resistance to airflow

Essais in situ de filtres et systèmes de ventilation générale pour la mesure de l'efficacité en fonction de la taille des particules et de la perte de charge

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 29462 was prepared by Technical Committee ISO/TC 142, *Cleaning equipment for air and other gases*.

Introduction

The purpose of this International Standard is to provide a test procedure for evaluating the in-situ performances of general ventilation filtration devices and systems. Although any filter with a filtration efficiency at or above 99% or at or below 30% when measured at 0,4 µm could theoretically be tested using this International Standard, it may be difficult to achieve statically acceptable results for these type of filtration devices.

Supply air to the Heating, Ventilation and Air-Conditioning (HVAC) system contains viable and non-viable particles of a broad size range. Over time these particles will cause problems for fans, heat exchangers and other system parts, decreasing their function and increasing energy consumption and maintenance. For health issues, the fine particles (<2,5 µm) are the most detrimental.

Particles in the 0,3 µm to 5,0 µm size range are typically measured by particle counters that can determine the concentration of particles in specific size ranges. These instruments are commercially available and will determine particle size along with the concentration level by several techniques (e.g., light scattering, electrical mobility separation, or aerodynamic drag). Devices based on light scattering are currently the most convenient and commonly used instruments for this type of measurement and are therefore the type of device used within this International Standard.

Particles in the size range 1,0 µm to 5,0 µm are present in low numbers (less than 1%, by count) in outdoor and supply air and have higher sampling-system losses. Results in the range >1,0 µm will therefore have lower accuracy and so the results should be interpreted with respect to this.

During in-situ measurement conditions, the optical properties of the particles may differ from the optical properties of the particles used for calibrating the particle counter and testing it in the laboratory. Thus the particle counter could size the particles differently but count the overall 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.

It is important to note that field measurements generally result in larger uncertainties in the results compared to laboratory measurements. Field measurements may produce uncertainty from temporal and spatial variability in particle concentrations, from limitations on sampling locations due to air handling unit configurations, and from the use of field instrumentation. These factors may result in lower accuracy and precision in the calculated fractional efficiencies compared to laboratory measurements. This International Standard is intended to provide a practical method in which the accuracy and precision of the result are maximized (and the precision of the result quantified) by recommending appropriate sampling locations, sample quantities, and instrumentation. This International Standard is not intended to serve as a filter performance rating method. The results obtained from the test method described in this International Standard do not replace those obtained through tests conducted in the laboratory.

Field testing of general ventilation filtration devices and systems for in situ removal efficiency by particle size and resistance to airflow

1 Scope

This International Standard describes a procedure for measuring the performance of general ventilation air cleaning devices in their end use installed configuration. The performance measurements include removal efficiency by particle size and the resistance to airflow. The procedures for test include the definition and reporting of the system airflow.

The procedure describes a method of counting ambient air particles of 0,3 µm to 5,0 µm upstream and downstream of the in-place air cleaner(s) in a functioning air handling system. The procedure describes the reduction of particle counter data to calculate removal efficiency by particle size.

Since filter installations vary dramatically in design and shape, a protocol for evaluating the suitability of a site for filter evaluation and for system evaluation is included. When the evaluated site conditions meet the minimum criteria established for system evaluation, the performance evaluation of the system can also be performed according to this procedure.

This International Standard also describes performance specifications for the testing equipment and defines procedures for calculating and reporting the results. This International Standard is not intended for measuring performance of portable or movable room air cleaners or for evaluation of filter installations with and expected filtration efficiency at or above 99 % or at or below 30 % when measured at 0,4 µm.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 7726, *Ergonomics of the thermal environment — Instruments for measuring physical quantities*

ISO 14644-3, *Cleanrooms and associated controlled environments — Part 3: Test methods*

ISO 21501-4, *Determination of particle size distribution — Single particle light interaction methods — Part 4: Light scattering airborne particle counter for clean spaces*

3 Terms, definitions, and abbreviations

3.1 Terms and definitions

For the purpose of this document, the following terms and definitions apply.

3.1.1
air filter bypass
unfiltered air that has passed through the AHU filter installation but remained unfiltered because it bypassed the installed air filters

3.1.2
air velocity
rate of air movement at the filter

Note 1 to entry: It is expressed in m/s (fpm) to three significant figures.

3.1.3
allowable measurable concentration of the particle counter
fifty percent of the maximum measurable concentration as stated by the manufacturer of the particle counter

3.1.4
coefficient of variation
CV
standard deviation of a group of measurements divided by the mean

3.1.5
diluter
dilution system
system for reducing the sampled concentration to avoid coincidence error in the particle counter

3.1.6
filter efficiency
removal efficiency of a filter as determined by this International Standard, where upstream and downstream particle count measurements are taken close to the filter being tested

3.1.7
filter installation

filtration devices and systems such as a single filter or a group of filters mounted together with the same inlet and outlet of air

3.1.8

general ventilation
process of moving air from outside the space, recirculated air, or a combination of these into or about a space or removing it from the space

3.1.9
isoaxial sampling
sampling in which the flow in the sampler inlet is moving in the same direction as the flow being sampled

3.1.10
isokinetic sampling
technique for air sampling such that the probe inlet air velocity is the same as the velocity of the air surrounding the sampling point

[Source: ISO 29464:2011; 3.1.144]

3.1.11
particle counter
device for detecting and counting numbers of discrete airborne particles present in a sample of air

[Source: ISO 29464:2011; 3.1.27]

3.1.12
particle size range
defined particle counter channel

3.1.13
reference filter
small dry media-type filter that has been laboratory tested for removal efficiency by particle size

3.1.14
removal efficiency by particle size
ratio of the number of particles retained by the filter to the number of particles measured upstream of the filter for a given particle-size range

3.1.15
resistance to airflow
loss of static pressure caused by the filter and filter loading which is measured with the filter operating at the measured air velocity

Note 1 to entry: It is expressed in Pa (in WG) to two significant figures.

3.1.16
system efficiency
removal efficiency of a filter system where upstream and downstream particle count measurements may be across several filter banks or other system components

3.2 Abbreviations

AHU	Air Handling Unit
CV	Coefficient of Variation
HEPA	High Efficiency Particle Air (as per ISO 29463-1)
HVAC	Heating, Ventilating and Air-Conditioning
MERV	Minimum Efficiency Reporting Value
OPC	Optical Particle Counter
RH	Relative Humidity
ULPA	Ultra Low Penetration Air
VAV	Variable Air Volume
VFD	Variable Frequency Drive

4 Test equipment and setup

4.1 Particle counter

The particle counter should be capable of measuring particles in the size range 0,3 µm — 5,0 µm, in a minimum of four ranges with a minimum of two ranges below 1,0 µm (for example: 0,3 µm — 0,5 µm, 0,5 µm — 1,0 µm, 1,0 µm — 2,0 µm and 2,0 µm — 5,0 µm). For maintenance and calibration of the particle counter, see 4.9

4.2 Diluter

A dilution system capable of diluting the aerosol concentration so the particle concentration level is within the acceptable concentration limit may be used. Choose a suitable dilution ratio so that the measured concentration of particles is well within the allowable measurable concentration limits of the particle counter so as to achieve good statistical data (see 9.1.2). If a dilution system is used, it is to be used for both upstream and downstream sampling. The dilution system shall not change air flow to the particle counter.

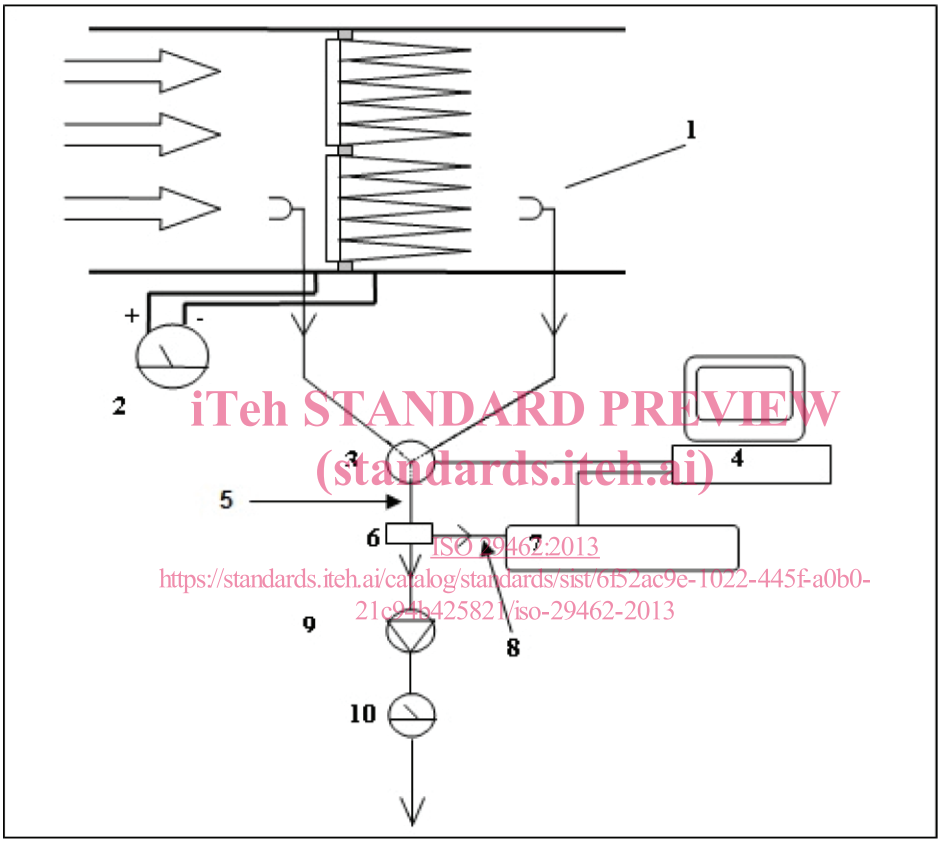
4.3 Pump

A pump may be used to control the rate of the sample flow (q_s) through the sampling probes. A pump is not necessary when the counter flow (q_{pc}) to the counter or diluter is sufficient for isokinetic sampling. In this case the sample flow (q_s) and the counter flow (q_{pc}) are the same.

4.4 Sampling system

4.4.1 General

Figure 1 shows the elements of a typical sampling system.



Key

1	sampling downstream	6	diluter
2	manometer	7	particle counter
3	valve	8	q_{pc} – flow to particle counter
4	Computer	9	pump
5	q_s – primary flow	10	flow meter

Figure 1 — Sampling system

4.4.2 Sampling probes

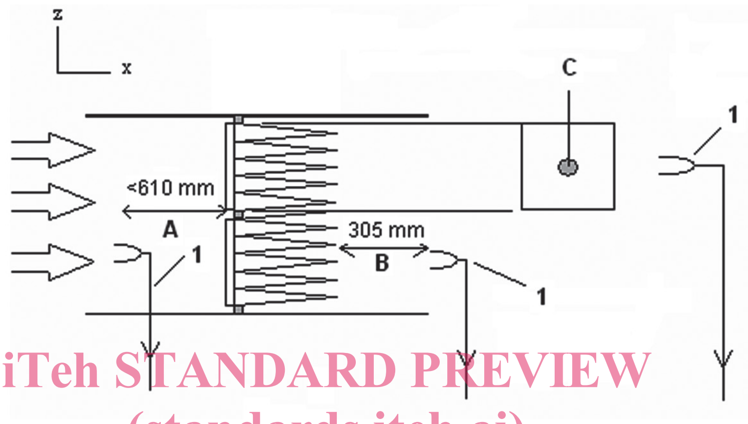
The sampling probe should consist of a sharp edged nozzle connected to the sample line leading to the auxiliary pump or particle counter. The diameter of the nozzle is dependent on the sample flow (q_s) in order to get isokinetic sampling. The diameter should not be less than 8 mm.

4.4.3 Sampling lines

Sampling lines upstream and downstream should be of equal length and as short as possible to avoid losses. Material should preferably be of a type with minimum particle losses for filter installations. Software is available to calculate line losses.[2]

4.4.4 Sampling locations

Sampling locations should be placed close to the filter as shown in Figure 2. If the system efficiency is to be tested, the sampling locations should be further away to achieve good mixing of airflow through filters, frames, doors, etc. Measurement the system efficiency is more difficult and therefore it is good practice to plan the measurement carefully and describe in detail how it was made.



Key

A minimum distance between the sampling probe and the filter

B distance between the end of the filter and the sampling probe

C location of sample points in y-z plane for filter efficiency tests

1 downstream sampling probe location for filtration system efficiency test

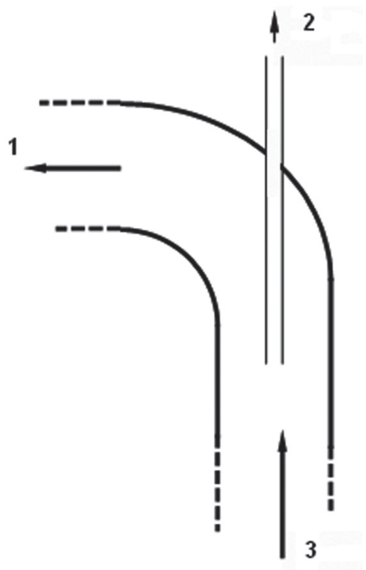
Figure 2 — Sample locations

4.4.5 Valve (manual or automatic)

A valve may be used to switch between upstream and downstream sample locations. The valve should be constructed so that particle losses are identical in upstream and downstream measurements. No influence on efficiency due to the valve construction is permitted (for example, four-point ball valves of sufficient diameter may be used).

4.4.6 Isoaxial sampling nozzle

If a pump (see 4.3) is used to obtain isokinetic sampling, the sample line should then be fitted with an isoaxial sampling nozzle directly connected to the particle counter or diluter as shown in Figure 3.



Key

1 pump flow

2 q_{pc} – flow to particle counter

3 q_s – sample flow

Figure 3 — Isoaxial sampling line to particle counter

4.4.7 Flow meter

A flow meter is necessary if a pump is part of the sampling system. The flow meter should be located in-line with the pump inlet or outlet.

4.5 Air velocity measurement instrument

The instrument used to measure the air velocity should have sufficient operational limits such that the system airflow is within the limits of the instrument. The instrument should be chosen in accordance with ISO 7726 . An instrument that records data values and will average those values is recommended. Ideally, the instrument should have the ability to correct measurements to standard sea level conditions.

4.6 Relative humidity measurement instrument

The instrument used to measure the relative humidity of the system airflow should have sufficient operational limits such that the system relative humidity is within the limits of the instrument and should be chosen in accordance with ISO 7726. An instrument that records data values and will average those values over time is recommended.

4.7 Temperature measurement instrument

The instrument used to measure the temperature of the system airflow should have sufficient operational limits such that the system temperature is within the limits of the instrument and should be chosen in accordance with ISO 7726. An instrument that records data values and will average those values over time is recommended.

4.8 Resistance to airflow measurement instrument

The instrument used to measure the resistance of the filter bank should have sufficient operational limits such that the filter bank resistance is within the limits of the instrument, and should be chosen in accordance with ISO 14644-3. An instrument that records data values and will average those values over time is recommended.

4.9 Test equipment maintenance and calibration

Maintenance items and schedules should conform to Table 1.

Table 1 — Apparatus maintenance schedules

Maintenance item	Incorporated into each test	Annually	After a change that may alter performance	Comment
Particle counter zero check	X			
Sampling system zero check	X			
Resistance to airflow	X			
Air velocity	X			
Temp, RH in sample air stream and at particle counter	X			
Upstream concentration test	X			
Reference filter test (field)	optional			
Reference filter test (lab)		X	X	
Particle counter primary calibration		X	X	
Temp, RH, air velocity, resistance to airflow equipment calibration		X*	X	* or as required by equipment manufacturer
Dilution system ratio check		X	X	
Check sample probes for damage	X			

5 Site evaluation

5.1 General

This section identifies the recommended minimum site requirements for performing a removal efficiency test.

5.2 Filter installation pre-testing inspection

Pre-inspection of filters and air handling units is necessary to determine whether a filter installation is suitable for evaluation using this International Standard. It is also used to gauge whether any potentially hazardous conditions exist that would exclude or restrict access to the air handling unit.

Items to inspect include (but are not limited to) those provided in Annex A.

5.3 Approval for testing

Once the pre-testing inspection has been completed and the filter installation determined to be suitable for testing, then the "approval for testing form" should be completed and signed by representatives of the building owner or manager and the company performing the testing. A suitable form is shown in Annex B.

6 Test procedure

6.1 Air velocity

Air velocity through the filter installation should be maintained constant for the duration of the test. This is possible if the fan speed is controllable through Variable Frequency Drive (VFD) or Variable Air Volume (VAV) boxes and other modulating dampers are not allowed to adjust. In addition, the percentage of outside air in the supply air should also be kept constant to reduce fluctuations in particle count that would influence the test results.

The air velocity at the face of the filters should be measured using the instrument identified in 4.5. Air velocity measurements may be taken either upstream or downstream of the filters, but downstream is recommended. Since air velocity can vary significantly over the area of a filter installation, sampling points should be chosen such that measurements are taken at a minimum of 25 % of the filters and are distributed uniformly over the area of the filter installation. The measurement device should be extended away from turbulence caused by personnel or other obstructions. The velocity coefficient of variation (CV) (see 9.3) should be less than 25 %.

Air velocity measurements should be conducted as close in time to resistance to airflow and removal efficiency testing as possible. This is to ensure that the system air velocity does not change significantly between the time of the velocity measurements and the time of the resistance to airflow and removal efficiency tests. Preferably, air velocity measurements should be conducted before and after the resistance to airflow and removal efficiency testing, with the velocity measurements averaged.

EXAMPLE

1st test: velocity measurement [average velocity = 2,0 m/sec (394 ft/min)]

2nd test: resistance to airflow measurements

3rd test: removal efficiency testing

4th test: velocity measurements [average velocity = 2,2 m/sec (433 ft/min)]

In this example, the reported average velocity would be 2,1 m/sec (414 ft/min).

More frequent velocity measurements may be taken in systems exhibiting a high degree of variability in velocity over time.

6.2 Relative humidity

The instrument(s) identified in 4.6 should be used for these measurements. The relative humidity (RH) of the air passing through the filter installation is recommended to be within the range of the particle counter and/or the RH measurement device used for the duration of the test. If system efficiency is being determined, the RH should be measured and recorded at the locations of the upstream and downstream probes. If measuring filter efficiency, the RH should be measured and recorded at one of the locations of the upstream or downstream probes. In addition, the RH should be recorded at the particle counter location. Wet-bulb temperature measurements may be used in lieu of RH measurements.

6.3 Temperature

The instrument(s) identified in 4.7 should be used for this measurement. The temperature of the air passing through the filter installation should be within the operating range of the particle counting equipment. If system efficiency is being determined, the temperature (i.e., dry-bulb temperature) should be measured and recorded at the locations of the upstream and downstream probes. If measuring filter efficiency, the temperature should be measured and recorded at one of the locations of the upstream or downstream probes. In addition the temperature should be recorded at the particle counter location. Care should be exercised if temperatures are extreme and/or outside of a normal equipment operating range. Particle counts should not be measured if temperatures are below freezing (see Clause 8).

6.4 Resistance to airflow

Resistance to airflow across the filter installation should be measured using the resistance to airflow instrument(s) identified in 4.8. If existing pressure reading equipment is installed, the resistance to airflow equipment may be connected to use the existing installed pressure probes. If existing probes are to be utilized, care shall be taken to ensure the existing probes are properly installed to read the static pressure and no component of velocity pressure. To read static pressure, the hole in the probe should be perpendicular to the flow with no obstructions prior to the probe so as to create a vortex. If air is being forced into the pressure probe, it will read velocity pressure instead of static pressure. Do not use existing probes if they appear to be bent, broken, clogged, non-functioning or not installed properly so they will give an accurate reading of the resistance to airflow from the filters only. If the existing probes cannot be restored to an acceptable level of functioning prior to the testing, they should not be used.

Ideally, resistance to airflow measurements will be recorded for each filter bank separately. However, in some cases the resistance value recorded will be a combination of multiple filters in series as it will be physically impossible to measure separate resistance to airflow values.

It is good practice to measure at least 25 values for resistance to airflow over at least two total minutes and then average the measured values to determine the resistance to airflow. The CV should be calculated and recorded for this data.

6.5 Removal efficiency

6.5.1 Removal efficiency tests

There are three types of tests described herein.

Filter efficiency

The purpose of this test is to determine the efficiency of the filter(s) for removing airborne particles. Downstream sampling locations should be chosen such that representative samples of air passing through the filters are obtained.

System efficiency

The purpose of this test is to determine the efficiency of the filtration system for removing airborne particles. The filtration system includes the filters and filter-holding frames. Downstream sampling locations and/or methods should be chosen such that representative samples of the total airflow passing through the filtration system are obtained. This includes air passing through the filters and around the filters (i.e. air filter bypass).

Other "system" tests

In addition to measuring filtration performance at the air filtration installation, this International Standard may also be used to compare the concentration of airborne particles in different sections of an air handling unit and therefore test the air handling system as a whole.

NOTE In this International Standard the results of other "system" tests are not referred to as "efficiencies" since the term "efficiency" implies that only particle-removal processes (and not particle addition) are involved. As the definition of the "system" gets larger due to the addition of other HVAC system components between the upstream and downstream locations, significant sources of particles (e.g. from leaks in the air handling unit housing) may affect the downstream particle concentrations.

For example, consider the following air handling unit:

1st component: prefilter installation

2nd component: cooling coil

3rd component: supply fan

