September 1999

Environmental Technology Verification Test Method

General Ventilation Filters

Prepared by

RTI

Research Triangle Institute

Under a Cooperative Agreement with

EPA U.S. Environmental Protection Agency

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The EPA, through its Office of Research and Development (ORD), partially funded and managed the extramural research described here under Cooperative Agreement No. CR 822870.

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Foreword

The Environmental Technology Verification Test Method, General Ventilation Filters, provides guidance for verification tests. The test protocol is intended to be a standalone document.

Reference is made in the protocol to the ASHRAE 52.2P "Method of Testing General Ventilation Air-cleaning Devices for Removal Efficiency by Particle Size" Fourth Composite Working Draft issued in May 1998. The ASHRAE 52.2P document was issued solely for the purpose of soliciting review comments and is **not** a standard. As a result, ASHRAE 52.2P is not currently available from ASHRAE. However certain test specifications such as particle size distribution parameters and quality assurance requirements from ASHRAE 52.2P are used in this protocol with attribution and appropriate caveats. The reason for this approach is that it is believed that the ASHRAE 52.2P standard will likely not be substantially modified in these fundamental areas before being issued in 1999. It is important to support our industrial stakeholders by ensuring that the data developed under the ETV program will be consistent with eventual commercial practice. This approach has been implemented with approval by ASHRAE.

There are two technical points of exception between this ETV test protocol and the ASHRAE 52.2P method:

a) The first dust loading step in ASHRAE 52.2P or "conditioning step" has been the subject of review and research during the last 6 months. In particular, it was found that ASHRAE loading dust appeared to enhance the performance of certain kinds of media filters over that experienced when filtering ambient or indoor particulate matter. As a result the first loading step has been modified to use a submicrometer aerosol for conditioning.
b) The "Minimum Efficiency Reporting Value" (MERV) is unique to ASHRAE 52.2P and for that reason it is inappropriate to include this reporting method in the protocol. The protocol will not include the MERV but information will be available in the verification report to calculate this result if desired.

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1.0 PURPOSE

The test method establishes a procedure for evaluating the efficiency of general ventilation filters as a function of particle size and as a function of loading.

2.0 SCOPE

The method provides a procedure for counting airborne particles from 0.3 µm to 10 µm in diameter both upstream and downstream of an air cleaning device and calculating the removal efficiency by particle size.

The method provides a procedure for determining efficiency of new unused air cleaning devices and of the same devices after subsequent particle loading.

3.0 REFERENCED DOCUMENTS

ANSI/ASME N510, *Testing of Nuclear Air-Cleaning Systems.* American Society of Mechanical Engineers, New York, NY, 1980.

ASHRAE Standard 52.1, *Gravimetric and Dust-Spot Procedures for Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter*. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA, 1992.

ASHRAE Proposed Standard 52.2P, *Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size, Fourth Composite Working Draft.* American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA, 1998. (Draft released for a limited time for review and is currently not available from ASHRAE.)

IEST-RP-CC007.1. *Testing ULPA Filters*. Institute of Environmental Sciences and Technology, Mount Prospect, IL, 1992.

4.0 DEFINITIONS AND ACRONYMS

4.1 Definitions

Some terms are defined below for the purposes of this method. When definitions are not provided, common usage shall apply.

airflow rate: the actual volume of test air passing through the device per unit of time, expressed in m^3/s [ft^3/min (cfm)], to three significant figures.

charge neutralizer: a device that brings the charge distribution of the aerosol to a Boltzman charge distribution. This represents the charge distribution of the ambient aerosol.

coefficient of variation: standard deviation of a group of measurements divided by the mean, expressed as a percentage.

conditioning aerosol: the generated aerosol used during the conditioning step. The aerosol particles are composed of potassium chloride having a mean diameter of approximately 0.1 µm and generated for a duration of 8 hours at a rate that produces a concentration of about 200,000 particles/cm^3 in the challenge air stream.

conditioning step: loading procedure performed after the initial efficiency test to reveal changes in efficiency that a filter may undergo during the early stages of use.

correlation ratio: the ratio of downstream to upstream particle counts without the test device installed in the test duct and determined from the average of at least three samples. This ratio is used to correct for any bias between upstream and downstream sampling and counting systems.

correlation ratio data acceptance criteria: criteria used to determine the adequacy of the correlation data.

device: throughout this method the word "device" means air-cleaning equipment used in general ventilation for the removal of particles, specifically, the air cleaner being tested.

disposable air filters: filters that are designed to operate through a specified performance range and then be discarded and replaced.

dust increment: the amount of dust fed during the loading procedure.

face area: the gross area of the device exposed to airflow. This area is measured in a plane perpendicular to the axis of the test duct or the specified direction of airflow approaching the device. All internal flanges are a part of this area, but items such as mounting hardware and electrical raceways normally mounted out of the airstream are not included. Face area is measured in m^2 (ft^2), to three significant figures.

face velocity: the rate of air movement at the face of the device (airflow rate divided by face area) expressed in m/s (fpm), to three significant figures.

final filter: a filter used to collect the loading dust that has passed though a device during the test procedure.

final resistance: the predetermined resistance to airflow of the air cleaning device at which the test is terminated and results calculated, expressed in Pa (in. H_2O).

general ventilation: the process of moving air into or about a space or removing it from the space. The source of ventilation air is either air from outside the space, or recirculated air, or a combination of these.

initial resistance: the pressure loss of the device operating at a specified airflow rate with no dust load, expressed in Pa (in. of H_2O).

isokinetic sampling: sampling in which the flow in the sampler inlet is at the same velocity as the flow being sampled.

loading dust: a compounded synthetic dust used for air cleaner loading.

media: for a fibrous-type air cleaner, media is that part of the device that is the actual dust-removing agent. Webs of spun fiberglass and papers are examples of air filter media.

media velocity: the speed at which air moves through the filter media (airflow rate divided by net effective filtering area). The term is not applicable to plate-type electronic air cleaners. Media velocity is measured in m/s (fpm), to three significant figures.

net effective filtering area: the total area in the device on which the dust collects. For devices using fibrous media, it is the net upstream area of the media exposed to airflow measured in the plane or general surface of the media. Net effective area excludes the area blocked by sealants, flanges, or supports. In electronic air cleaners, it is the total exposed surface of those electrodes available for dust precipitation, including the ionizing section but excluding the supports, holes, and insulators. Net effective filtering area is measured in m^2 (ft^2), to three significant figures.

particle size: the polystyrene latex (PSL) light scattering equivalent diameter expressed as a diameter in micrometers, (µm, 10^{-6} meters).

penetration: the fraction (percentage) of particles that pass through the air cleaner.

penetration data acceptance criteria: criteria used to determine the adequacy of the penetration data.

polydisperse: an aerosol characterized by a wide distribution of particle sizes.

rated airflow: the airflow rate in m^3/s (cfm) at which the device is tested.

rated final resistance: the operating pressure loss at the specified airflow rate at which a device should be replaced or renewed, as recommended by the manufacturer, expressed in Pa (in. H_2O).

reference filters: dry media-type filters that are carefully measured for resistance and initial efficiency immediately after a test system is qualified. These filters serve as references to insure that the test system continues to operate as it did when it was qualified.

resistance: the loss of static pressure caused by the device operating at a stated airflow rate, expressed in Pascals (in. H_2O) to an accuracy of ±2.5%

test aerosol: polydisperse solid-phase (i.e., dry) potassium chloride (KCl) particles generated from an aqueous solution, used in this method to determine the particle size efficiency of the device under test.

test rig: the total assembly consisting of the test duct, the aerosol generator, the loading dust feeder, the particle counter(s) and associated accessories, instrumentation, and monitoring equipment.

4.2 Acronyms

ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
CV	coefficient of variance
HEPA	high efficiency particulate air
IEST	Institute of Environmental Sciences and Technology
OPC	optical particle counter
PSL	polystyrene latex (spheres)
RTI	Research Triangle Institute
ULPA	ultra low penetration air

5.0 TEST APPARATUS

5.1 Introduction

The test rig combines the aerosol generation, sampling, and overall duct configuration developed by RTI as part of the ASHRAE- and EPA-sponsored research with a high airflow capacity (3000 cfm) blower, mixing baffles, and airflow measurement device of the large-scale test duct used in ASHRAE Standard 52.1. Features of the test duct (Figure 1) include:

- Positive pressure to minimize room air infiltration.
- Inlet air drawn from indoors or recirculated air to maintain temperature and humidity within desired range.
- HEPA-filtered inlet to remove ambient aerosol.
- HEPA-filtered exhaust to allow indoor discharge.
- Artificially generated, solid-phase, polydisperse potassium chloride salt challenge aerosol.
- Low particle loss sampling system consisting of a single optical particle counter (OPC) or dual OPCs.
- Inclusion of a downstream mixing baffle to ensure well-mixed aerosol conditions at the downstream sample probes.
- 180º bend in downstream duct to bring upstream and downstream sample locations in close proximity to each other, greatly reducing sample line length and sample losses and facilitating use of a single OPC.

5.2 Test Duct

The following is an example of a test rig successfully used for filter testing. The test rig's ducting is a square cross-section 610 x 610 mm (24 x 24 in.), 14 gauge stainless steel. The upstream and downstream mixers are per ASHRAE 52.1. The blower has a flow capacity of 1420 L/s at 3.2 kPa (3000 cfm at 13 in. H_2O). The inlet and outlet filter banks consist of two 610 x 610 x 51 mm (24 x 24 x 2 in.) prefilters and two 610 x 610 x 305 mm (24 x 24 x 12 in.) high efficiency particulate air (HEPA) filters rated at 940 L/s (2000 cfm) each. Airflow is measured with an American Society of Mechanical Engineers (ASME) flow orifice as specified in ASHRAE 52.1. The system includes a means of controlling airflow. Room or recirculated air is used as the source, and the flow is exhausted back into the room after passing though the exhaust HEPA bank. Air may be recirculated directly without exhausting into the room if appropriate cooling or air conditioning is employed.

To mix the test aerosol with the air stream, an orifice plate and mixing baffle per ASHRAE 52.1 should be used immediately downstream of the aerosol injection point. An identical orifice plate/mixing baffle should be added after the 180º bend or at the same relative point in a straight-line system.

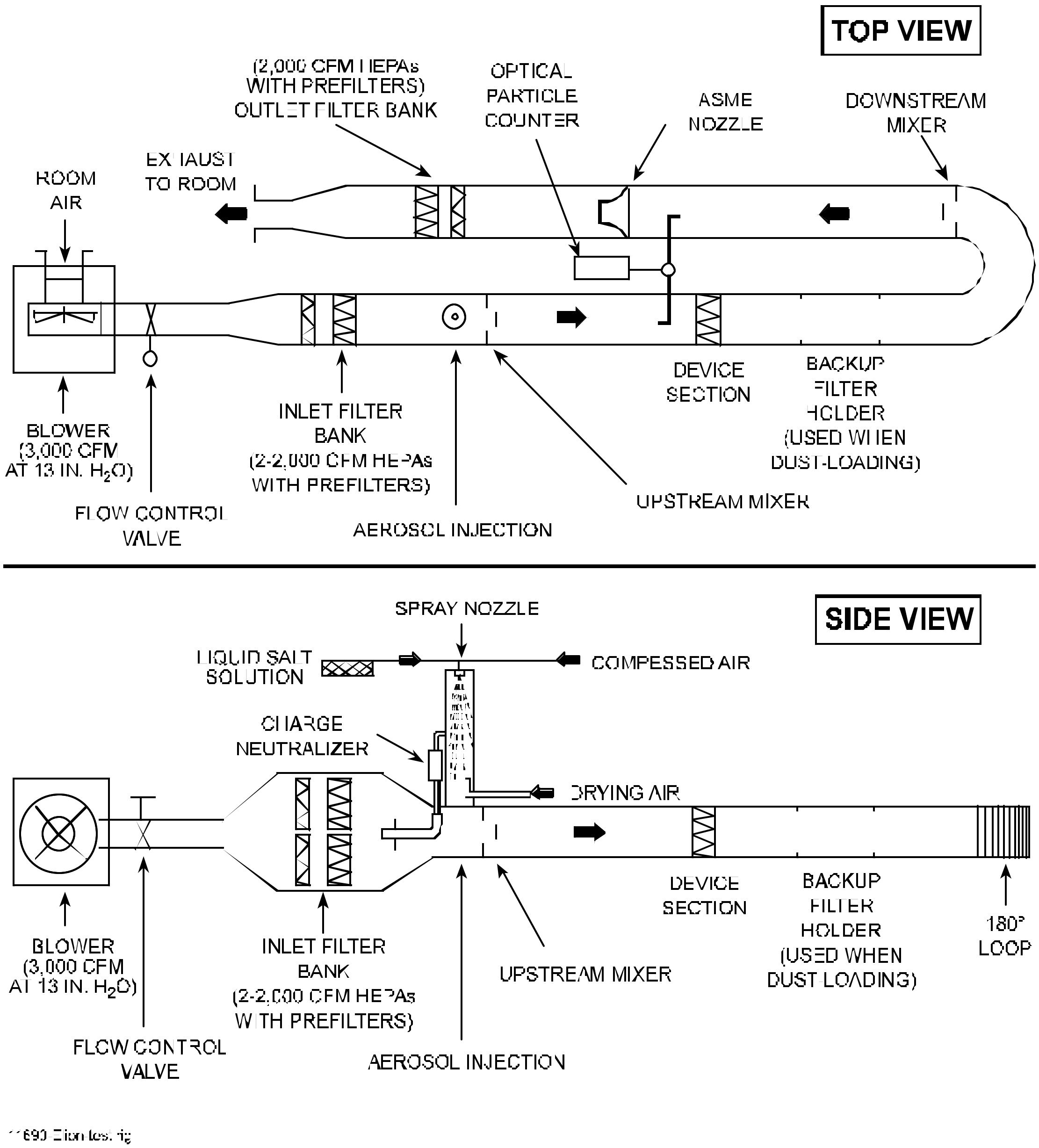

Figure 1. Schematic illustration of test apparatus

5.3 Optical Particle Counter

Aerosol concentration should be measured with a Climet Instruments Model 226 OPC or equivalent. This OPC uses a high intensity illumination source and has a wide collection angle for the scattered light. The OPC's sampling rate should be 0.12 L/s (0.25 cfm).

The output of the OPC should input to a Climet Instruments Model 8040 multichannel analyzer or equivalent capable of handling a minimum of 12 sizing channels. The particle diameter range boundaries required are listed in Table 1.

Table 1. Minimum Sizing Channels Required for OPC[a]

Range	Diameter Range (µm)		Geometric Mean Particle Diameter (µm)
	Lower Limit	Upper Limit	
1	0.30	0.40	0.35
2	0.40	0.55	0.47
3	0.55	0.70	0.62
4	0.70	1.00	0.84
5	1.00	1.30	1.14
6	1.30	1.60	1.44
7	1.60	2.20	1.88
8	2.20	3.00	2.57
9	3.00	4.00	3.46
10	4.00	5.50	4.69
11	5.50	7.00	6.20
12	7.00	10.00	8.37

[a]From ASHRAE 52.2P (1998)

5.4 Challenge Aerosol Generation

The challenge aerosol should be generated by a TSI generator or equivalent, as illustrated in Figure 2. The test aerosol is solid-phase dry potassium chloride (KCl) generated from an aqueous solution. The aerosol is generated by nebulizing an aqueous KCl solution with a two fluid (air and water) air atomizing nozzle (Spray Systems ¼ J siphon spray nozzle or equivalent). The hole in the air cap is increased to 3.2 mm (0.125 in.) inner diameter.

The nozzle is positioned at the top of a 0.30 m (12 in.) diameter, 1.3 m (51 in.) tall transparent acrylic spray tower through which drying air flows at 1.89 L/s (4 cfm). After generation, the aerosol passes through a TSI, Inc., Model 3054 aerosol neutralizer or equivalent to neutralize any electrostatic charge on the aerosol. To improve the mixing of the aerosol with the air stream, the aerosol should be injected counter to the airflow as illustrated in Figure 2.

The KCl solution is prepared by combining approximately 300 g KCl with 1 L deionized water. The solution is fed to the atomizing nozzle by means of a metering pump. Varying the operating air pressure of the generator allows control of the mean diameter of the challenge aerosol.

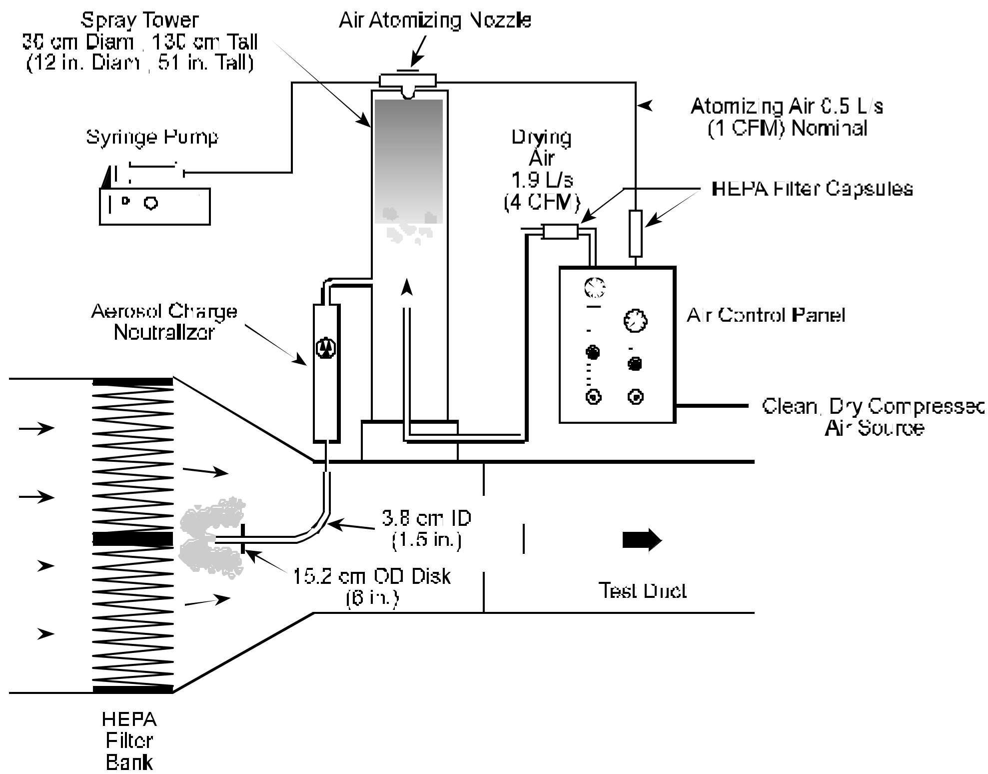

Figure 2. Details of the example aerosol generating system

5.5 Aerosol Sampling System

Losses in the aerosol sampling system shall not exceed 50%. The example shown is constructed of 14 mm (0.55 in.) inner diameter stainless steel lines or equivalent, using gradual bends [radius of curvature = 57 mm (2.25 in.)] when needed. The "Y" fitting connecting the upstream and downstream lines to the OPC merges gradually to minimize particle loss in the intersection of the "Y" due to centrifugal or impaction forces. The fitting may be custom-made per Figure 3.

Immediately above the "Y," an electrically actuated ball valve is installed in each branch (Parker Model EA Electro-Mechanical Valve Actuator or equivalent). The opening and closing of the valves are automatically controlled by the OPC's sequential sampling interface board. The valves take approximately 2 seconds to complete an opening or closing maneuver.

Isokinetic sampling nozzles of the appropriate entrance diameter are placed on the ends of the sample probes to maintain isokinetic sampling for all the test flow rates.

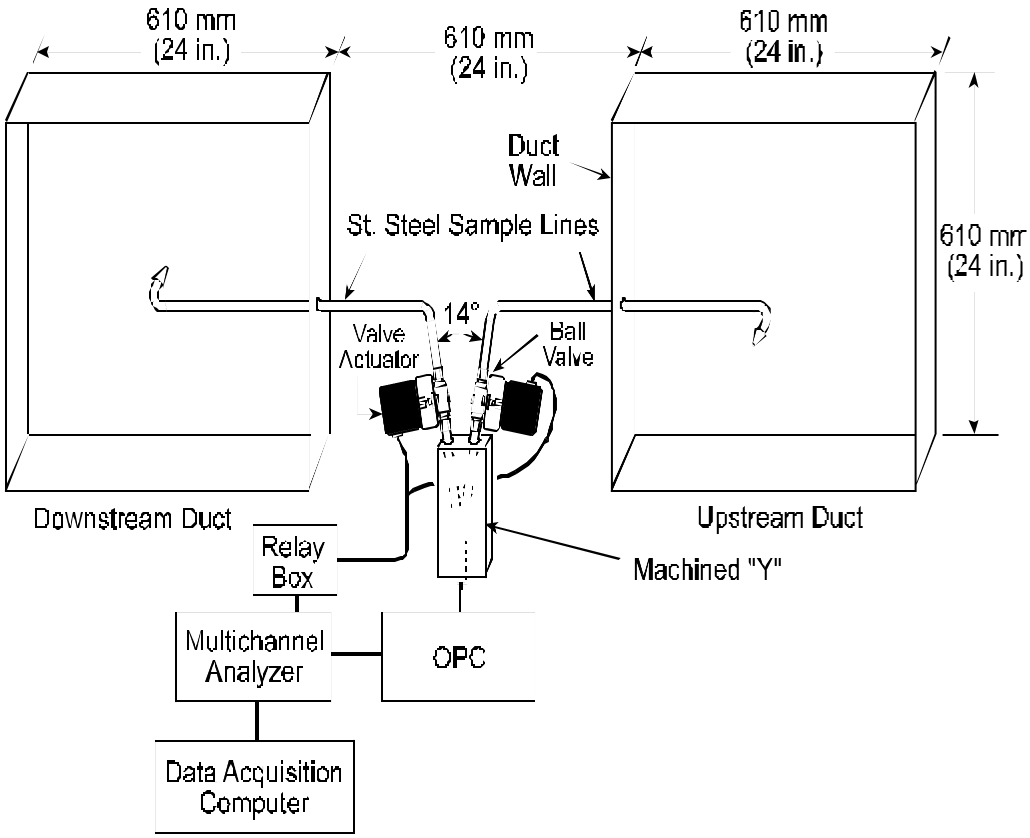

Figure 3. Schematic diagram of the example aerosol sampling system

5.6 Conditioning Aerosol Generation

The conditioning aerosol should be generated by a 3-nozzle (12-jet) Laskin nozzle or equivalent. The test aerosol is solid-phase dry potassium chloride (KCl) generated from a 1% aqueous solution. The KCl solution is prepared by combining KCl and deionized water at the ratio of 10 g KCl to 1 L deionized water.

The output of the Laskin nozzle should be injected into the spray tower (as shown earlier in Figure 2) into which drying air flows at 1.89 L/s (4 cfm). After generation, the aerosol passes through a TSI, Inc., Model 3054 aerosol neutralizer or equivalent to neutralize any electrostatic charge on the aerosol. To improve the mixing of the aerosol with the air stream, the aerosol should be injected counter to the airflow as was illustrated in Figure 2.

The operating air pressure of the Laskin nozzle is adjusted to provide a particle concentration in the challenge air stream of 125,000 particles/cm^3 ± 20%. This challenge condition is maintained for 8 hours. Means of replenishing the aqueous solution within the Laskin nozzle should be used to allow for continuous operation over the entire 8-hour period.

5.7 Dust Loading System

5.7.1 Loading Dust

Loading dust can be obtained commercially under the trade name ASHRAE® dust.

5.7.2 Dust Loading Apparatus

The dust loading apparatus is described in ASHRAE Standard 52.1.

6.0 SYSTEM QUALIFICATION TESTING

Qualification testing shall be completed before filter testing is attempted. The purpose of the system qualification tests is to quantify that the test rig and sampling procedures are capable of providing reliable fractional penetration measurements. The qualification tests are based on those in IEST-RP-CC7.1.

Qualification tests are performed for the following:

- Air flow uniformity in the test duct,
- Aerosol concentration uniformity in the test duct,
- Downstream detection of the aerosol,
- Aerosol generator response time,
- Upper concentration limit of the OPC,
- 100% efficiency test,
- Correlation ratio test, and
- Duct leak test.

The requirements for system qualification, summarized in Table 2, are as specified in ASHRAE 52.2P, a draft review standard that may be changed before approval.

These tests must be repeated after any change that may alter system performance.

Table 2. System Qualification Test Requirements

Parameter	Level Required[a]
Air Flow Uniformity: Based on traverse measurements made over a 9-pt. equal-area grid at each test flow rate.	CV<10%
Aerosol Concentration Uniformity: Based on traverse measurements made over a 9-pt. equal-area grid at each test flow rate.	CV<15%
Downstream Mixing: Based on a 9-pt. perimeter injection grid and cumulative downstream particle count.	CV<10%
Aerosol Generator Response Time	No pre-determined level.
Upper Concentration Limit: Based on limiting the concentration to below the concentration corresponding to the onset of coincidence error in the OPC.	No pre-determined level.
100% Efficiency: Based on HEPA filter test.	>99% for all particle sizes
Correlation Ratio: Based on five replicate tests at each flow rate.	0.3 to 1.0 µm; 0.90-1.10 1.0 to 3.0 µm; 0.80-1.20 3.0 to 10 µm; 0.70-1.30
Duct Leakage: Ratio of leak rate to test airflow rate.	<1.0%

[a] These levels conform to the levels required in ASHRAE 52.2P.

6.1 Airflow Uniformity in the Test Duct

The uniformity of the challenge airflow is determined by a nine-point traverse (Figure 4) immediately upstream of the device section. Airflow is measured with an Alnor Model 8500D-II Thermo-anemometer or equivalent. At each grid point, the average of 10 air flow readings taken over a 1-minute period is recorded. After measuring the 1-min average at each gridpoint, the traverse is repeated two more times, providing triplicate 1-min averages at each point. The triplicate values are then averaged for each point. This is done for airflows of 470, 940, and 1420 L/s (1000, 2000, and 3000 cfm).

For all three flow rates, the velocity at each gridpoint shall have a coefficient of variance (CV) value less than 10 %.

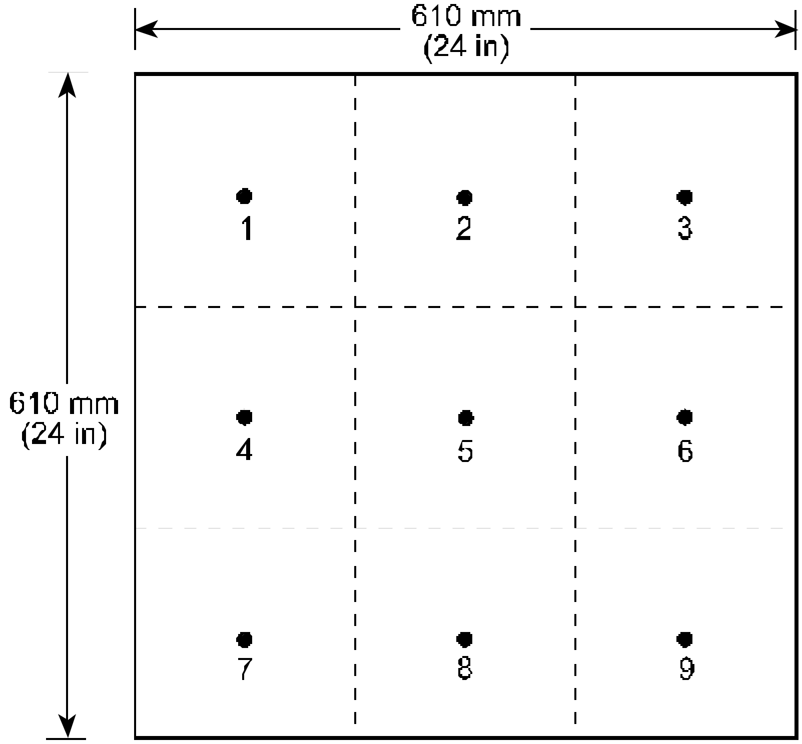

Figure 4. Nine-point equal area sampling grid for airflow and aerosol uniformity assessment

6.2 Aerosol Concentration Uniformity in the Test Duct

The uniformity of the challenge aerosol concentration across the duct cross section is determined by a nine-point traverse (same grid points as shown in Figure 4). The aerosol concentration is measured with the OPC. At each gridpoint, a 1-min sample is taken. After sampling from all nine points, the traverse is repeated four more times providing a total of five samples from each point. The five values for each point are then averaged. This is done for airflows of 470, 940, and 1420 L/s (1000, 2000, and 3000 cfm).

For each flow rate, the CVs for aerosol concentration uniformity for all particle sizes shall be less than 15 %.

6.3 Downstream Mixing of Aerosol

The test is conducted by first installing a HEPA filter in the device section. Aerosol is then injected immediately downstream of the HEPA filter at preselected injection points located around the perimeter of the test duct and at the center of the duct (Figure 5). Unlike the aerosol traverse, in this test the point of aerosol injection is traversed and the downstream sampling probe remains stationary in its normal center-of-duct sampling location. Unlike the grid points for the flow and aerosol traverses, this grid pattern includes points very close to the test duct walls. A Collison nebulizer generates the aerosol and the OPC measures total aerosol concentration (>0.3 µm) rather than examining the concentration in each of the OPC’s required 12 channels.

Regardless of where the aerosol was injected, the CVs for all downstream readings shall be less than 10 %.

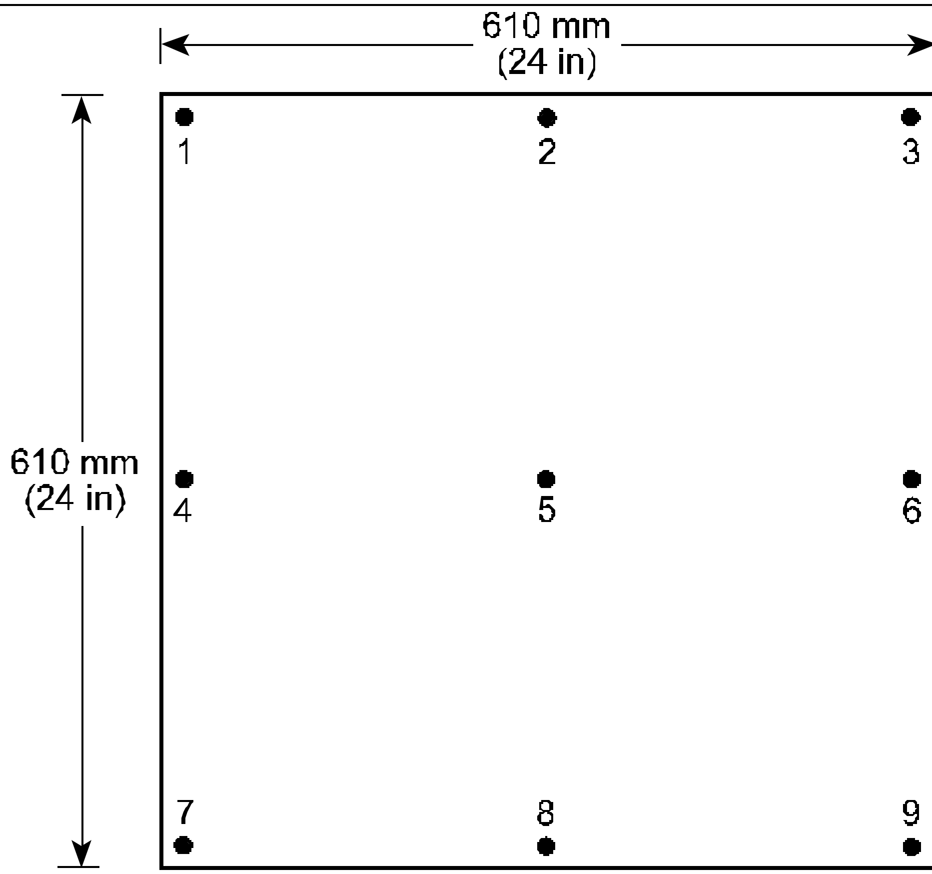

Figure 5. Nine-point perimeter injection grid to assess downstream mixing.
Perimeter points are 25 mm (1 in.) from duct wall.

6.4 Aerosol Generator Response Time

To ensure that sufficient time is allowed for the aerosol concentration to stabilize during the fractional penetration tests, the stabilization time for the aerosol to go from the background level to the test level is measured. This is done with the OPC sampling from the upstream probe.

Similarly, the time to return to the background levels after turning off the generator is measured. When turning on the generator, the air and liquid to the spray nozzle are shut off. The system may be purged with drying air and then allowed to run after the drying air has been turned off.

6.5 Upper Concentration Limit of the OPC

A series of initial efficiency tests shall be performed over a range of challenge aerosol concentrations to determine a total level for the efficiency tests that does not overload the OPC. The lowest total concentration shall be less than 1% of the instrument's stated total concentration limit. The filters selected for this test shall have an initial efficiency in the range of 30-70% as measured by the 0.3-0.4 µm diameter size range and greater than 90% efficiency for the 7.0-10.0 µm diameter size range. The aerosol for these tests shall be generated using the same system and procedures as described in Section

5.4. The tests shall be performed over a sufficient range of total challenge concentrations to demonstrate that the OPC is not overloaded at the intended test concentration.

6.6 100 % Efficiency Test

A 100 % efficiency test is performed as a normal initial efficiency test except that a HEPA filter is used. The efficiency test consists of the five alternating upstream and downstream background counts (KCl generator off), ten alternating upstream and downstream sample counts (KCl generator ON), and five alternating upstream and downstream background counts (KCl generator off). Penetration shall not exceed 1% for any particle size range.

6.7 Correlation Ratio Test

A zero percent efficiency (or blank) test is performed as a normal penetration test except that no air filter is used. Fifteen 100 % penetration tests are conducted, five at each of three flow rates: 470, 940, and 1420 L/s (1000, 2000, and 3000 cfm). The ratio of downstream to upstream particle counts for each size range shall fall within the limits specified in Table 2.

6.8 Test Duct Air Leakage Test

The leak rate of the test duct is evaluated by a method similar to American National Standards Institute (ANSI)/ASME N510. The test duct is sealed immediately upstream of the aerosol injection location and immediately upstream of the exhaust filter bank by bolting a gasketed solid plate to the duct opening. Air is then metered into the test duct until the lower test pressure is achieved. The airflow rate required to maintain constant pressure is measured and taken as the leak rate. This is repeated for the upper pressure level.

[CAUTION: Excessively high pressures may explode the test rig.]

For the airflow measurement to be representative of the airflow through the air cleaner, air leakage from the test duct should not exceed 1 % of the total flow.

7.0 TEST METHOD

7.1 Qualification Testing

Additional qualification testing shall be performed on a continuing basis. The purpose of these ongoing tests is to quantify that the test rig and sampling procedures are providing reliable fractional penetration measurements. The qualification tests are based on those in IEST-RP-CC7.1.

Qualification tests are performed for the following:

- 100 % efficiency,
- OPC sizing accuracy,
- OPC zero count,
- Background particle count,
- Correlation ratio test, and
- Pressure drop across empty test section.

The frequency and requirements for the ongoing qualification tests are summarized in Table 3.

Table 3. Ongoing Qualification Test Requirements

Parameter	Frequency[a]	Control Limits[a]
100% Efficiency: Based on HEPA filter test	Monthly	>99% for all particle sizes
OPC sizing accuracy check: Sample aerosolized PSL spheres.	Daily	Relative maximum must appear in appropriate sizing channel
OPC zero count: OPC samples HEPA-filtered air.	Each test	<10 counts/minute over 0.30 to 10 µm range
Correlation ratio:	Each test	0.3 to 1.0 µm; 0.90-1.10 1.0 to 3.0 µm; 0.80-1.20 3.0 to 10 µm; 0.70-1.30
Pressure drop: Across empty test section	Each test	<8 Pa (0.03 in. H_2O)
Upstream background particle counts: KCl aerosol generator turned off.	Each test	<5% of upstream challenge counts in each channel[b]
Downstream background particle counts: KCl aerosol generator turned off.	Each test	<5% of upstream challenge counts in each channel[b]

[a] These levels conform to the levels required in ASHRAE 52.2P.
[b] For the initial efficiency tests only, both the upstream and downstream background particle counts must be less than 5% of the upstream challenge particle counts in each channel when the aerosol generator is on. This requirement does not apply after conditioning or incremental dust loading.

7.1.1 100 % Efficiency Test

A 100 % efficiency test is performed as a normal penetration test except that a HEPA filter is used. Cross contamination between the upstream and downstream samples and insufficient purging between samples are potential conditions that could limit the ability to meet this requirement.

On at least a monthly basis, a HEPA filter will be tested following the same procedures as used for testing ventilation filters. Penetration shall not exceed 1% for any particle size range.

7.1.2 OPC Sizing Accuracy Check

The sizing accuracy of the OPC is checked by sampling an aerosol containing monodispersed polystyrene latex (PSL) spheres of known size.

This is not a calibration but simply a calibration check of the OPC that is performed daily. A relative maximum particle count shall appear in the particle counter sizing channel that encompasses the PSL diameter.

7.1.3 OPC Zero Count

The OPC's zero count level will be measured by sampling HEPA-filtered air. This will be done by attaching a HEPA capsule directly to the OPC sample inlet and/or by sampling the HEPA-filtered air of the test duct when the aerosol generator is turned off.

This check is performed at the start of each efficiency test. The counts will be summed to confirm that they are below 10 per minute. On the test run sheet, the operator denotes if an acceptable zero count was achieved.

7.1.4 Background Particle Count

Background counts will be made before and after generating test aerosols during every efficiency test. Upstream and downstream sampling is done sequentially, starting with an upstream sample U_b followed by a downstream sample D_b, alternating back and forth five times.

7.1.5 Correlation Ratio Test

A zero percent efficiency (or blank) test is performed as a normal penetration test except that no air filter is used. It is performed immediately prior to each filter test. The purpose is to ensure that the bias between the upstream and downstream samples is within acceptable limits. The ratio of downstream to upstream particle counts for each size range shall fall within the limits specified in Table 3. If they are found to be out of range, the data will be inspected for possible clues, and corrective action (such as cleaning the sample lines) may be required to obtain acceptable results. The filter test cannot be conducted until an acceptable 100% test is achieved.

7.1.6 Pressure Drop

The pressure drop across the empty test section shall be measured as part of each correlation ratio test. The measured pressure drop across the empty test section shall be less than 8 Pa (0.03 in. H_2O).

7.2 Test Procedure

1. Warm up OPC and install proper sample tips for isokinetic sampling.
2. Perform monthly 100% efficiency test (if necessary) to confirm that it is within the range established in the qualification tests. If not, take corrective action and repeat this step.
3. Perform daily calibration check of OPC sizing accuracy to confirm that it is within the range established in the qualification tests. If not, take corrective action and repeat this step.
4. Perform OPC zero check to confirm that it is within the range established in the qualification tests. If not, take corrective action and repeat this step.
5. Perform correlation ratio test and record pressure drop to confirm that they are within the range established in the qualification tests. If not, take corrective action and repeat this step.
6. Install an air-cleaner test device, and bring the test duct to the desired flow rate.
7. Verify that the test duct's relative humidity and temperature are within their respective operating ranges. Run the test duct for 15 minutes for the air cleaner to equilibrate.
8. With the aerosol generator off, obtain five measurements of the upstream and downstream background particle counts. For some dust-loaded air cleaners, shedding of the loading dust may

lead to background counts in some sizing channels that are known (from experience) to be too high (e.g, exceed 10% of the expected downstream concentration when the aerosol generator is turned on). In this case, repeating step 6 may bring the background counts down to acceptable levels.

9. Turn on the aerosol generator and allow it to run for 10 minutes to stabilize.

10. After the stabilization period, obtain 10 upstream and 10 downstream particle counts. These are obtained in an up-down-up-down fashion until 10 of each are obtained. Each sample shall last 1 minute.

11. Turn off the aerosol generator. Wait 10 minutes, then obtain five additional upstream and downstream background measurements.

12. Verify that data meet acceptance criteria for minimum upstream particle counts and for penetration. The acceptance criteria are outlined in Section 10.3.

After the initial efficiency is tested, the filter is conditioned and its efficiency is tested again. The filter is then subjected to four incremental dust loadings; the filtration efficiency is measured after each loading. The final dust loading step is completed when the filter's resistance to airflow reaches a predetermined value specified by the manufacturer. The complete test sequence is illustrated in Table 4.

Table 4. Testing Sequence

Step: Description	**Air Cleaner**	**Conditioning Generator**	**KCl Generator**	**Dust Feeder**
1: Correlation ratio	None	Off	**ON**	Off
2: Resistance vs. airflow	Installed	Off	Off	Off
3: Initial Efficiency[a]	Installed	Off	**ON**	Off
4: Conditioning	Installed	**ON**	Off	Off
5: Efficiency after Conditioning[a]	Installed	Off	**ON**	Off
6: First dust loading[b]	Installed	Off	Off	**ON**
7: Efficiency after first dust loading[a]	Installed	Off	**ON**	Off
8: Second dust loading[b]	Installed	Off	Off	**ON**
9: Efficiency after second dust loading[a]	Installed	Off	**ON**	Off
10: Third dust loading[b]	Installed	Off	Off	**ON**
11: Efficiency after third dust loading[a]	Installed	Off	**ON**	Off
12: Fourth dust loading[b]	Installed	Off	Off	**ON**
13: Efficiency after fourth dust loading[a]	Installed	Off	**ON**	Off

[a] Each efficiency test consists of the background counts (KCl generator off), sample counts (KCl generator ON), and background counts (KCl generator off).

[b] Prior to each dust loading, the duct airflow is turned off, the final filter is installed, and the particle counter inlet probes are capped. The duct airflow is then resumed. After each dust loading, the duct airflow is turned off, the particle counter inlet probes are uncapped, and the final filter is removed. The duct airflow is then resumed.

8.0 AEROSOL CONDITIONING

After being tested for initial efficiency, the filter shall be exposed to the conditioning aerosol as described in Section 5.6. This corresponds with Step 4 in Table 4.

After aerosol conditioning, the fractional efficiency is measured as described in Section 7.2.

9.0 DUST LOADING

The procedure for dust loading is described in ASHRAE Standard 52.1. Table 4 indicates that dust loading occurs as Steps 6, 8, 10, and 12.

After each dust increment, the fractional efficiency is measured as described in Section 7.2.

10.0 CALCULATIONS

10.1 Nomenclature

P_o = Observed penetration

D = Downstream particle count

D_b = Downstream background count

U = Upstream particle count

U_b = Upstream background count

P = Penetration corrected for P_{100} value

P_{100} = 100% penetration value determined in system qualification tests

s = Sample standard deviation

CV = Coefficient of variance

CV_u = Upstream coefficient of variance

CV_d = Downstream coefficient of variance

Overbar "—" denotes arithmetic mean of quantity

10.2 Equations

Analysis of each test involves the following quantities:

- P_{100} value for each sizing channel from the system qualification tests,
- 10 upstream background values,
- 10 downstream background values,
- 10 upstream values with the aerosol generator on, and
- 10 downstream values with the aerosol generator on.

Using the values associated with each sizing channel, the observed penetration associated with each particle sizing channel is calculated as shown in Eq. (1). The corrected penetration for each particle sizing channel is calculated as shown in Eq. (2).

$$(1) \qquad P_o = \frac{\left(\overline{D} - \overline{D_b}\right)}{\left(\overline{U} - \overline{U_b}\right)}$$

$$(2) \qquad P = \frac{P_o}{P_{100}}$$

Most often, the background levels will be small compared to the values when the aerosol generator is on. However, for some types of air cleaners, shedding of the loading dust may result in high background levels over portions of the size range. The filtration efficiency is calculated as shown in Eq. (3).

$$(3) \qquad Filtration\ \ Efficiency\ \ (\%) = (1 - P) \times 100$$

Negative filtration efficiencies are reported as zero.

10.3 Acceptance Criteria for Data

After each filtration efficiency test, data must be checked against the following criteria before proceeding. If the acceptance criteria are not satisfied, the test must be repeated. Repeating the test before proceeding will not compromise the integrity of the method.

For each channel, a minimum total of 500 particle counts for the challenge aerosol is required. The total is summed over the 10 upstream readings taken during testing, as shown in Eq. (4).

$$(4)\ For\ \ each\ \ channel, \quad \sum_{i=1}^{10} U_i > 500 \quad where\ i = sample\ \ reading$$

For each channel of each test, the standard deviation of observed penetration is calculated based on the CV of the upstream and downstream particle counts and must satisfy the limits shown in Eqs. (5) and (6).

$$(5) \quad s_{P_o} = P_o \times \sqrt{CV_d^{\ 2} + CV_u^{\ 2}} < 0.1 \quad for\ \ 0.3 - 3.0\ mm\ diameter$$

$$(6) \quad s_{P_o} = P_o \times \sqrt{CV_d^{\ 2} + CV_u^{\ 2}} < 0.3 \quad for\ > 3.0\ mm\ diameter$$

11.0 DOCUMENTATION AND REPORTING

The test report will consist of calculated and reported data. Raw data shall be included as an appendix.

11.1 Raw Data

Test data and notes are recorded in laboratory notebooks. Test personnel shall record:

- Testing date and location
- Manufacturer and model number
- Physical description of filter
- Pressure drop across the filter
- Qualification tests
- Ancillary environmental data

Raw data recorded on instrument printouts are taped into the laboratory notebook. These include:

- Upstream particle count
- Downstream particle count
- Upstream particle count, background
- Downstream particle count, background

11.2 Calculated Data

Calculated data shall include:

- observed penetration,
- corrected penetration,
- sample standard deviation, and
- coefficient of variation for all particle diameters.

11.3 Reported Data

Reported data shall include:

- the testing date and location,
- a physical description of the device,
- filtration efficiency curves from each test and their averages,
- tabulated efficiency data,
- efficiencies at particle diameters,
- results of control tests, and
- the pressure drop across the filter.

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