

ASHRAE Standing Standard Project Committee 52.2
Cognizant TC: TC 2.4, Particulate Air Contaminants and Particulate Contaminant Removal Equipment
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NOTE

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FOREWORD

ANSI/ASHRAE Standard 52.2-2012 incorporates Addendum b into the standard's previous edition, Standard 52.2-2007. Addendum b was part of a larger plan to combine Standards 52.1 and 52.2 into a single standard on air filter testing. Part 1 of Addendum b incorporates the 52.1 sections on arrestance and dust-holding capacity into Standard 52.2 and deletes some references to Standard 52.1 that occur in Standard 52.2. Part 2 of Addendum b adds a new informative appendix to the standard, Appendix J. Informative Appendix J provides an optional method of conditioning a filter using fine potassium chloride (KCl) particles to demonstrate efficiency loss that might be realized in field applications.

Standard 52.2 was developed so that both users and specifiers can compare products, predict a uniform level of known performance under operating conditions with reasonable certainty, and determine appropriate air-cleaner efficiencies for specific situations.

Historically, standards for testing air cleaners have been developed in response to the needs of the times. Protection of machinery and coils came first, then reduction of soiling. Now concerns about indoor air quality and respirable particles, protection of products during manufacturing, and protection of HVAC equipment have prompted development of this test standard based on particle size.

Standards Project Committee (SPC) 52.2 was first organized in 1987 to develop a particle size test procedure but was disbanded in 1990 after it became evident that basic research was needed. In 1991, a research contract (ASHRAE Research Project RP-671, Reference A.2 in Informative Appendix A) was awarded to review test methodology and recommend approaches for obtaining particle size efficiency data. After the research project was completed and accepted in 1993, SPC 52.2 was reactivated with members representing a broad range of interests.

The standard was then formally published in 1999; immediately ASHRAE Technical Committee 2.4 started work on two new research efforts. The first, ASHRAE RP-1189, "Investigation of Mechanisms and Operating Environments that Impact the Filtration Efficiency of Charged Air Filtration Media," and the second, ASHRAE RP-1190, "Develop a New Loading Dust and Dust Loading Procedures for ASHRAE Filter Test Standard 52.1 and 52.2," were completed by 2003. The standard was republished in 2007 and Addendum b, resulting from the research projects, was published in 2008.

SPC 52.2 debated many questions in writing this standard. Comments on some of the more important of these questions, which are included in Informative Appendix A,

regard the bend in the test duct; the use of a particle's physical size, its aerodynamic size, or its light-scattering size; dust loading and minimum efficiency reporting; the particle size range covered by the standard; and the selection of the test aerosol.

Description of Standard

This standard addresses two air-cleaner performance characteristics of importance to users: the ability of the device to remove particles from the airstream and its resistance to airflow. Air-cleaner testing is conducted at airflow rates not less than 0.22 m³/s (472 cfm) nor greater than 1.4 m³/s (3000 cfm).

A sample of air from a general ventilation system contains particles with a broad range of sizes having varied effects, sometimes dependent on particle size. Coarse particles, for example, cause energy waste when they cover heat transfer surfaces. Fine particles cause soiling and discoloration of interior surfaces and furnishings as well as possible health effects when inhaled by occupants of the space. When air cleaners are tested and reported for efficiency in accordance with this standard, there is a basis for comparison and selection for specific tasks.

The test procedure uses laboratory-generated KCl particles dispersed into the airstream as the test aerosol. A particle counter measures and counts the particles in 12 size ranges, both upstream and downstream, for the efficiency determinations.

This standard also delineates a method of loading the air cleaner with synthetic dust to simulate field conditions. A set of particle size removal efficiency (PSE) performance curves at incremental dust loading is developed and, together with an initial clean performance curve, is the basis of a composite curve representing the minimum performance in each size range. Points on the composite curve are averaged and the averages are then used to determine the minimum efficiency reporting value (MERV) of the air cleaner.

Coarse air cleaners may be tested for particle size removal efficiency when they are clean with results reported in the prescribed format. (An example of a coarse air cleaner is the so-called "furnace" filter, a flat panel with a cardboard frame and spun glass fiber media.) However, this new edition of the standard also provides the basis for evaluation using the loading dust efficiency by weight, or "arrestance," as well as an estimate of predicted life called dust holding capacity.

Electronic Air Cleaners

Some air cleaners, such as externally powered electrostatic precipitators (also known as electronic air cleaners), may not be compatible with the loading dust used in this test method. The dust contains very conductive carbon that may cause electrical shorting, thus reducing or eliminating the effectiveness of these devices and negatively affecting their MERVs. In actual applications, the efficiency of these devices may decline over time, and their service life is dependent on the conductivity and the amount of dust collected.

Passive Electrostatic Fibrous Media Air Filters

Some fibrous media air filters have electrostatic charges that may be either natural or imposed upon the media during manufacturing. Such filters may demonstrate high efficiency when clean and a drop in efficiency during their actual use cycle. The initial conditioning step of the dust-loading procedure described in this standard may affect the efficiency of the filter but not as much as would be observed in actual service. Therefore, the minimum efficiency observed during testing may be higher than that achieved during actual use.

Not an Application Standard

Users should not misinterpret the intent of this standard. This is a test method standard, and its results are to be used to directly compare air cleaners on a standardized basis irrespective of their applications. Results are also used to give the design engineer an easy-to-use basis for specifying an air cleaner. It is entirely possible that an industry organization may use this test method as the basis for an application standard with, for example, different final resistances.

Footnotes are used throughout this standard to provide nonmandatory guidance for the user in addition to the nonmandatory guidance found in the informative appendices. Footnotes are for information only and are not part of the standard.

Acknowledgments

SSPC 52.2 wishes to acknowledge with thanks the contributions of many people outside the voting membership, including European filtration authorities who made suggestions through the committee's international member. We are also indebted to the many media/filter manufacturers and third-party companies that have supported the committee by providing access to skilled and informed volunteers.

1. PURPOSE

This standard establishes a test procedure for evaluating the performance of air-cleaning devices as a function of particle size.

2. SCOPE

2.1 This standard describes a method of laboratory testing to measure the performance of general ventilation air-cleaning devices.

2.2 The method of testing measures the performance of air-cleaning devices in removing particles of specific diameters as the devices become loaded by standardized loading dust fed at intervals to simulate accumulation of particles during service life. The standard defines procedures for generating the aerosols required for conducting the test. The standard also provides a method for counting airborne particles of 0.30 to 10 μm in diameter upstream and downstream of the air-cleaning device in order to calculate removal efficiency by particle size.

2.3 This standard also establishes performance specifications for the equipment required to conduct the tests, defines

methods of calculating and reporting the results obtained from the test data, and establishes a minimum efficiency reporting system that can be applied to air-cleaning devices covered by this standard.

3. DEFINITIONS AND ACRONYMS

3.1 Definitions. Some terms are defined below for the purposes of this standard. When definitions are not provided, common usage shall apply (see Reference 3, Informative Appendix G).

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.

arrestance (A): a measure of the ability of an air-cleaning device with efficiencies less than 20% in the size range of 3.0–10.0 μm to remove loading dust from test air. Measurements are made of the weight of loading dust fed and the weight of dust passing the device during each loading step. The difference between the weight of dust fed and the weight of dust passing the device is calculated as the dust captured by the device. Arrestance is then calculated as the percentage of the dust fed that was captured by the device.

average arrestance (A_{avg}): for an air-cleaning device with efficiencies less than 20% in the size range of 3.0–10.0 μm , the average value of the arrestances made on the device during the loading test, weighted by the amounts of dust fed to the device during each incremental dust loading step.

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 (CV): standard deviation of a group of measurements divided by the mean.

correlation ratio data acceptance criteria: criteria used to determine the adequacy of the correlation data, further defined in Section 10.6.2.

correlation ratio (R): the ratio of downstream to upstream particle counts without the test service installed in the test duct; is 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, and its calculation is described in Section 10.3.

device: throughout this standard the word *device* refers to 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 holding capacity (DHC): the total weight of the synthetic loading dust captured by the air-cleaning device over all of the incremental dust loading steps.

dust increment: the amount of dust fed during a definite part of 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 through a device during the test procedure.

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

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, 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 water).

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

loading dust: a compounded synthetic dust used for air-cleaner loading. Specifications for this dust are given in Section 6.2.

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 rate of air movement 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 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 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 size expressed as a diameter in micrometers (μm , 10^{-6} m).

penetration: the fraction (percentage) of particles that pass through the air cleaner as described in Section 10.4.

penetration data acceptance criteria: criteria used to determine the adequacy of the penetration data, further defined in Section 10.6.4.

polydisperse: a characteristic of an aerosol for which the width of its number distribution shows a geometric standard deviation of $\delta_g > 1.5$.

rated airflow: the airflow rate in m^3/s (cfm) at which the device is tested. In this standard it is specified by the manufacturer in accordance with Section 8.1.

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

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 ensure that the test system continues to operate as it did when it was qualified. See Section 5.16.1.

resistance: the loss of static pressure caused by the device operating at a stated airflow rate, expressed in Pa (in. of water) to an accuracy of $\pm 2.5\%$.

test aerosol: polydisperse solid-phase (i.e., dry) potassium chloride (KCl) particles generated from an aqueous solution, used in this standard to determine the particle size efficiency of the device under test. Generation of the test aerosol is described in Section 5.3.

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

3.2 Acronyms

APC	aerodynamic particle counter
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
CV	coefficient of variation
DHC	dust holding capacity
HEPA	high-efficiency particulate air
MERV	minimum efficiency reporting value
OPC	optical particle counter
PSE	particle size removal efficiency
PSL	polystyrene latex, referring to commercially available particles of various specific sizes
SAE	Society of Automotive Engineers
ULPA	ultra-low penetration air

4. TEST APPARATUS

4.1 Mandatory and Discretionary Requirements. Critical dimensions and arrangements of the test apparatus are shown in the figures of this section and Section 5. All dimensions shown are mandatory unless otherwise indicated. Tolerances are given on each drawing, and either SI or I-P dimensions are acceptable for any element of the system.

Units shown are in mm (in.) unless otherwise indicated. The design of equipment not specified, including but not limited to blowers, valves, and external piping, is discretionary, but the equipment must have adequate capacity to meet the requirements of this standard.

4.2 Test Duct

4.2.1 The test duct is defined in Figures 4-1, 4-2, and 4-3 and is primarily of square cross section, 610 × 610 mm (24 × 24 in.). The duct material must be electrically conductive and electrically grounded, have a smooth interior finish, and be sufficiently rigid to maintain its shape at the operating pressures. The inlet filter bank must contain high-efficiency particulate air (HEPA) filters. Increasing the cross section of the duct at the inlet filter bank to accommodate more than one 610 × 610 mm (24 × 24 in.) HEPA filter to minimize pressure drop is allowed. The inlet filter bank must discharge along the centerline of the upstream mixing orifice. System airflow is measured with an American Society of Mechanical Engineers (ASME) flow orifice (Reference 4). The duct must be operated at positive pressure, i.e., the blower discharges into the duct upstream of the test device.

4.2.2 The bend (item 19 of Figure 4-1) in the duct is optional, thereby allowing both a straight duct and a U-shaped duct configuration. Except for the bend itself, all dimensions and components (including the downstream mixing orifice and baffle) are the same for the straight and U-shaped configurations.

4.2.3 Room air or recirculated air shall be used as the test air source. The temperature of the air at the test device shall be between 10°C and 38°C (50°F and 100°F) with a relative humidity of between 20% and 65%.¹ Exhaust flow shall be discharged outdoors or indoors or recirculated.²

4.2.4 An orifice plate and a mixing baffle shall be located downstream of the aerosol injection point. An identical orifice plate/mixing baffle shall be located downstream of the test device.³ The perforated diffusion plate should be located 152 mm ± 3 mm (6 in. ± 1/8 in.) downstream of the mixing orifice and mounted so that the centerline is in line with the hole in the mixing orifice.

4.2.5 The test aerosol shall be injected into the duct between the inlet filter bank and the upstream mixing orifice. The aerosol injection system shall produce an upstream challenge that meets the qualification criteria of Section 5.3. The injection system design is discretionary so long as it fulfills this requirement.

4.2.6 The test duct shall be isolated from vibration caused by the blower or other sources of vibration.

¹ A slight temperature increase with a corresponding decrease in relative humidity will occur as the room air passes through the blower.

² HEPA filtration of the exhaust flow is recommended when discharging indoors because test aerosol and loading dust may be present.

³ The downstream orifice serves two purposes. It straightens out the flow after going around the bend and it mixes any aerosol that penetrated the test device. Mixing the penetrating aerosol with the airstream is necessary in order to obtain a representative downstream aerosol measurement.

4.2.7 The test apparatus shown in Figure 4-1 is designed for test devices with nominal face dimensions of 610 × 610 mm (24 × 24 in.). Transitions in accordance with Figures 4-3a and 4-3b shall be used for test devices with face areas from 60% to 150% of the normal test duct cross section area of 0.37 m² (4 ft²). It is permitted to test a bank of several devices if the face area of an individual device is less than 60% of the duct area. It is also permitted to test specially sized air cleaners duplicating the structure of standard units if the size requirement cannot otherwise be met.

4.3 Aerosol Generator. Other than the requirements of the following subsections, design features of the aerosol generator are discretionary. Refer to Informative Appendix B of this standard for guidance.

4.3.1 The test aerosol shall be polydisperse solid-phase (dry) potassium chloride (KCl) particles generated from an aqueous solution. The aerosol generator shall provide a stable test aerosol of sufficient concentration over the 0.30 to 10 µm diameter size range to meet the requirements of Section 10 without overloading the aerosol particle counter.⁴ Refer to Section 5.6.

4.3.2 The aerosol generator shall be designed to ensure that the KCl particles are dry prior to being introduced into the test duct.

4.3.3 After drying, the aerosol shall be brought to a Boltzman electrostatic charge distribution by a beta or gamma radiation generator with an activity of at least 185 MBq (5 mCi) or a corona discharge ionizer.⁵ The corona discharge ionizer shall have a minimum corona current of 3 µA and shall be balanced to provide equal amounts of positive and negative ions.

4.4 Aerosol Sampling System. Other than the requirements of the following subsections, the design features of the sampling system are discretionary. Refer to Informative Appendix B of this standard for guidance.

4.4.1 The design criterion for the sampling system shall be to provide a particle transport of >50% for 10 µm diameter KCl particles from the sample probe inlet within the test duct to the inlet of the particle counter. This shall be verified by experimental measurement or by numerical calculation of particle transport based upon the geometry of the sampling system,⁶ the sampling flow rate, and particle deposition associated with diffusion, sedimentation, turbulent flow, and inertial forces.⁷

4.4.2 The use of a primary and secondary sampling system is allowed to optimize particle transport from the inlet probe to the particle counter.⁸ The primary/secondary sampling system shall meet the following criteria:

a. The portion of the primary sampling line in the duct shall block less than 10% of the duct cross-sectional area.

⁴ Air atomizing spray nozzles in which an aqueous KCl solution is nebulized with compressed air and then dried are a suitable means of aerosol generation.

⁵ Electrostatic charging is an unavoidable consequence of most aerosol generation methods.

⁶ For example: tube diameter, the number of bends, lengths of horizontal and vertical sections.

⁷ A numerical model of aerosol transport has been developed. See Informative Appendix G, Reference 14.

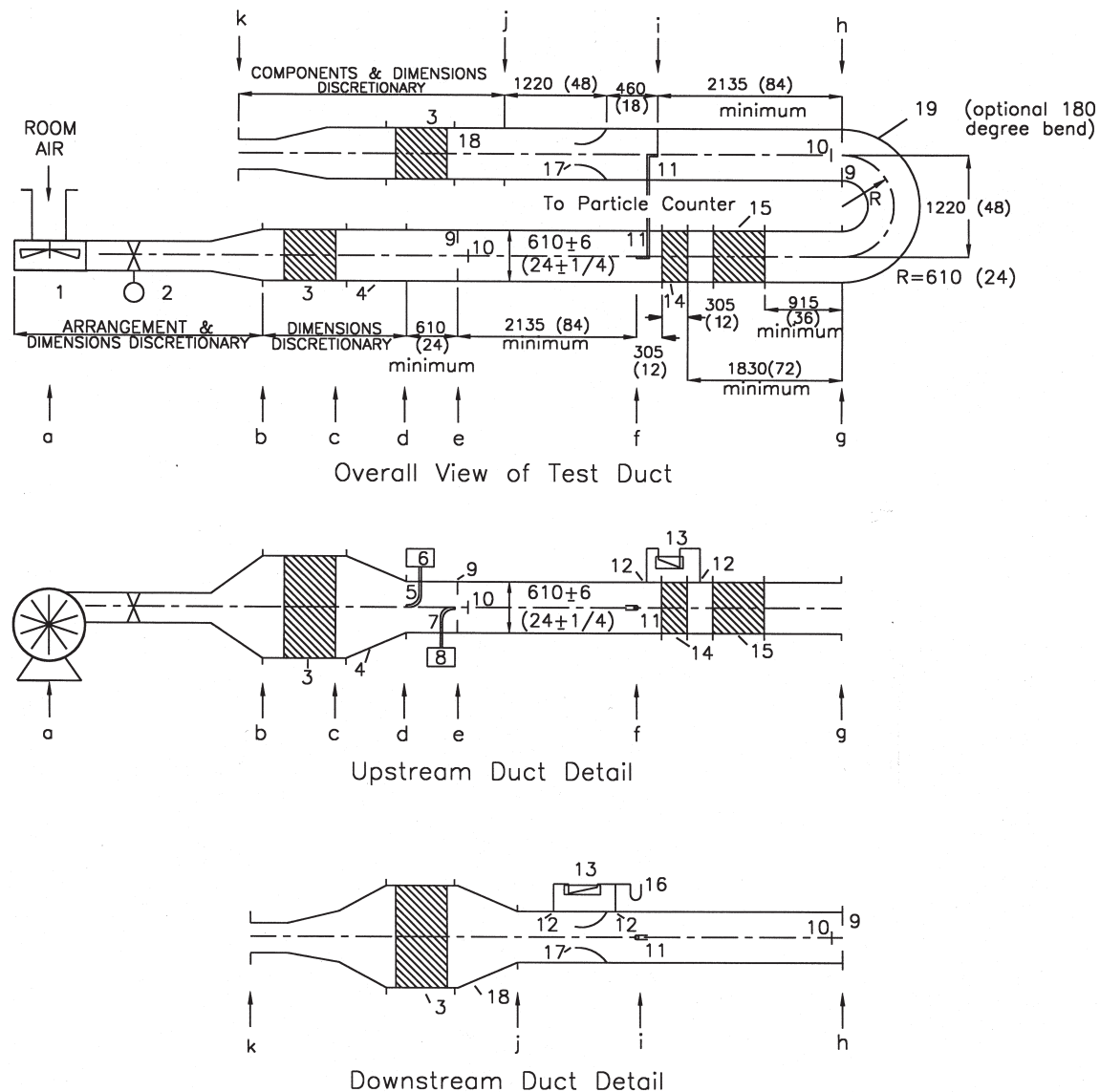


Figure 4-1 Schematic of the test duct (notes and legend are below). Dimensions are in mm (in.).

Notes for Figure 4-1:

1. Duct segments "d" through "j" shall have a cross section of 610 × 610 mm (24 × 24 in.), excluding the device section that has transitions as shown in Figures 4-3a, 4-3b, and 4-3c.
2. Segments "b" through "g" shall be in centerline alignment.
3. Segments "h" through "j" shall be in centerline alignment.
4. Upstream airflow and aerosol traverse measurements in accordance with Section 5 shall be performed at "f."
5. Aerosol injection shall occur between "c" and "e"; design discretionary in accordance with Section 4.2.4.
6. Side-by-side or over-and-under arrangements of the upstream and downstream sections of the test duct are allowed.

LEGEND FOR FIGURES 4-1 and 4-2d

- | | |
|---|---|
| 1. Blower | 10. Perforated diffusion plate |
| 2. Flow control valve | 11. Location of sample probe |
| 3. HEPA filter bank | 12. Static tap |
| 4. Transition, if any, from filter bank to 610 × 610 mm (24 × 24 in.) ducting. Maximum transition half angle = 45°. | 13. Manometer |
| 5. Aerosol injection tube | 14. Air cleaner device and transitions (if any) |
| 6. Aerosol generator | 15. Final filter (installed only during dust loading) |
| 7. Dust feed pipe | 16. Vertical manometer |
| 8. Dust feeder | 17. Main flow measurement nozzle |
| 9. Mixing orifice | 18. Transition, if needed |
| | 19. Bend, optional |

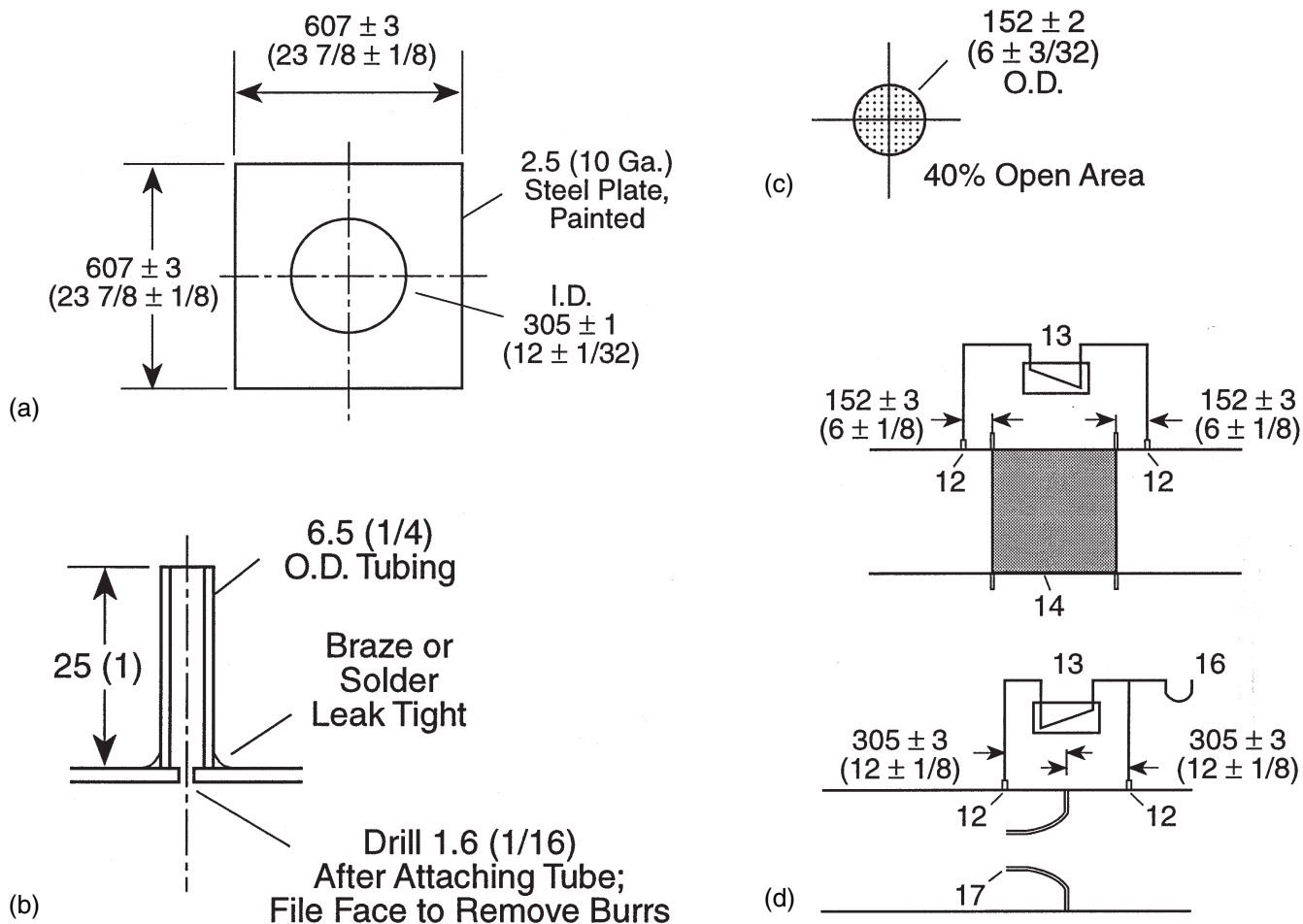


Figure 4-2 Details of test duct components. Dimensions are in mm (in.).

- (a) Mixing orifice.
- (b) Static tap.
- (c) Perforated plate with a sufficient number of equally spaced holes to provide 40% open area.
- (d) Static tap locations.

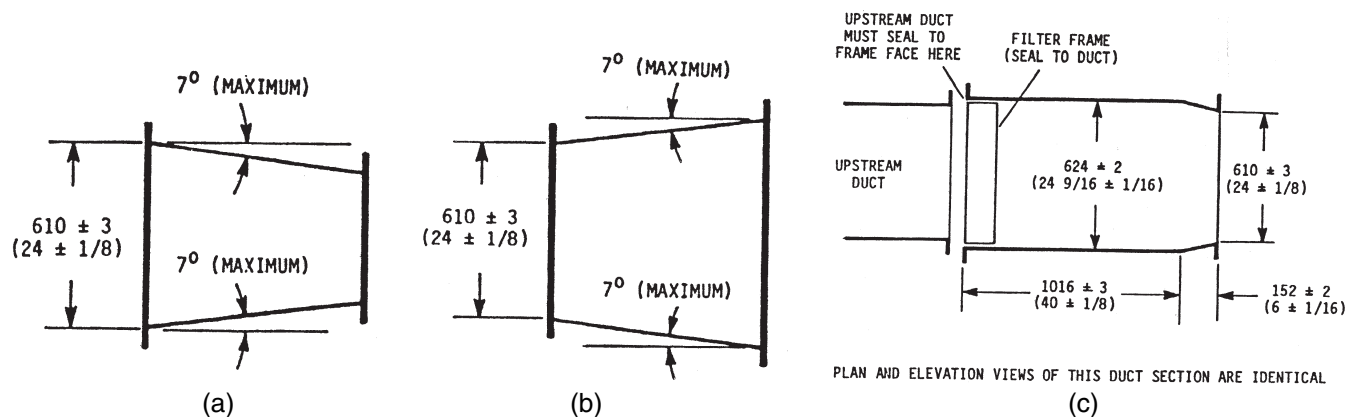


Figure 4-3 Dimensions are in mm (in.).

- (a) Transition: test air cleaner dimensions smaller than test duct (asymmetrical dimensions are allowed).
- (b) Transition: test air cleaner dimensions larger than test duct (asymmetrical dimensions are allowed).
- (c) Allowable special duct section for nonrigid air cleaners (must be symmetrical).

- b. Isokinetic sampling (to within 10%) shall be maintained on both primary and secondary probes.
- c. Flow through the primary sampling system shall be measured to within 5% with volumetric devices (e.g., orifice plates and rotometers).
- d. Combined particle losses in the primary and secondary system shall be <50% for 10 µm diameter KCl particles, based on particle transport modeling.
- e. The upstream and downstream primary sampling systems shall be of equal length and equivalent geometry.
- f. The upstream and downstream secondary sampling systems shall be of equal length and equivalent geometry.
- g. The airflow rate of the upstream primary system shall be <2% of the system airflow rate.
- h. The airflow rate of the downstream primary system shall be <2% of the system airflow rate. The extracted airflow rate shall be added to the measured duct airflow rate to obtain the test airflow rate.
- i. The auxiliary pump and associated flow control and flow measurement devices of the primary sampling lines must be downstream of secondary probes.

4.4.3 Diluters, if used, shall provide equal dilution of both the upstream and downstream samples. Dilution of just the upstream samples is disallowed.

4.4.4 The upstream and downstream sample lines (both primary and secondary, if used) shall be made of rigid electrically grounded metallic tubing having a smooth inside surface, and they must be rigidly secured to prevent movement during testing. The upstream and downstream sample lines are to be nominally identical in geometry. The use of a short length (50 mm [2 in.] maximum) of straight, flexible, electrically dissipative tubing to make the final connection to the aerosol particle counter is acceptable.⁹

4.4.5 The inlet nozzles of upstream and downstream sample probes shall be sharp edged and of appropriate entrance diameter to maintain isokinetic sampling within 10% at the test airflow rate.

4.5 Device Flow Measurement. Flow measurement shall be made by means of ASME long-radius flow nozzles (see Figure 9-1) with static taps as in Figure 4-2b located as shown in Figure 4-2d. The temperature, absolute pressure, and relative humidity of the test airflow shall be measured in the duct immediately upstream of the flow-measuring orifice. These values shall be used for calculation of airflow rate.

⁸ The primary lines (one from the upstream duct, one from the downstream duct) draw the samples from the duct and transport them to the vicinity of the particle counter(s). The primary system uses an auxiliary pump and flow metering system to operate at a higher airflow rate than would be provided by the particle counter(s) alone. The higher airflow rate combined with larger diameter sampling lines improves particle transport. The particle counter(s) then draws a lower flow rate sample from the primary line. The sample lines from the particle counter(s) to the primary sample lines are termed the *secondary sample lines*.

⁹ This often relieves stress that would be placed on the instrument's inlet.

**TABLE 4-1 Particle Counter(s)
Size Range Boundaries**

Size Range	Size Range Boundaries		Geometric Mean Particle Size, µm
	Lower Limit, µm	Upper Limit, µm	
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

4.6 Particle Counter(s)

4.6.1 Permissible particle counters are optical particle counters (OPCs) with wide angle collection optics or other counters demonstrating good correlation in measuring particle size efficiencies, such as aerodynamic particle counters (APCs).¹⁰ An APC shall first be tested with KCl to establish the relationship between the aerodynamic particle size and the light-scattering particle size determined by an OPC. Calibrate the APC with PSL and use the relationship to express results as equivalent light-scattering size of KCl.

4.6.2 The particle counter(s) shall be capable of counting and sizing individual KCl particles in the 0.30 to 10 µm diameter size range. The counting efficiency shall be at least 50% for 0.3 µm PSL particles.

4.6.3 The particle counter(s) shall measure the test aerosol particles and then group them into 12 size ranges. The range boundaries based on the physical size of the KCl aerosol shall conform to Table 4-1. The particle counter's correlation of measured response¹¹ to physical particle size shall be monotonic for PSL particles from 0.30 to 10 µm, such that only one size range shall be indicated for any measured response.

4.6.4 The size calibration of the particle counter shall be to report the actual physical size of the PSL particles, and it shall be performed at least annually.

4.6.5 At least 90% of all observed counts shall register in size ranges 4 and 5 of Table 4-1 when the particle counter is challenged with monodisperse 1.0 µm diameter PSL particles.

¹⁰ An OPC determines particle size based on the intensity of the particle's scattered light. An APC determines particle size by measuring the time of flight of the particle.

¹¹ Voltage, for example.

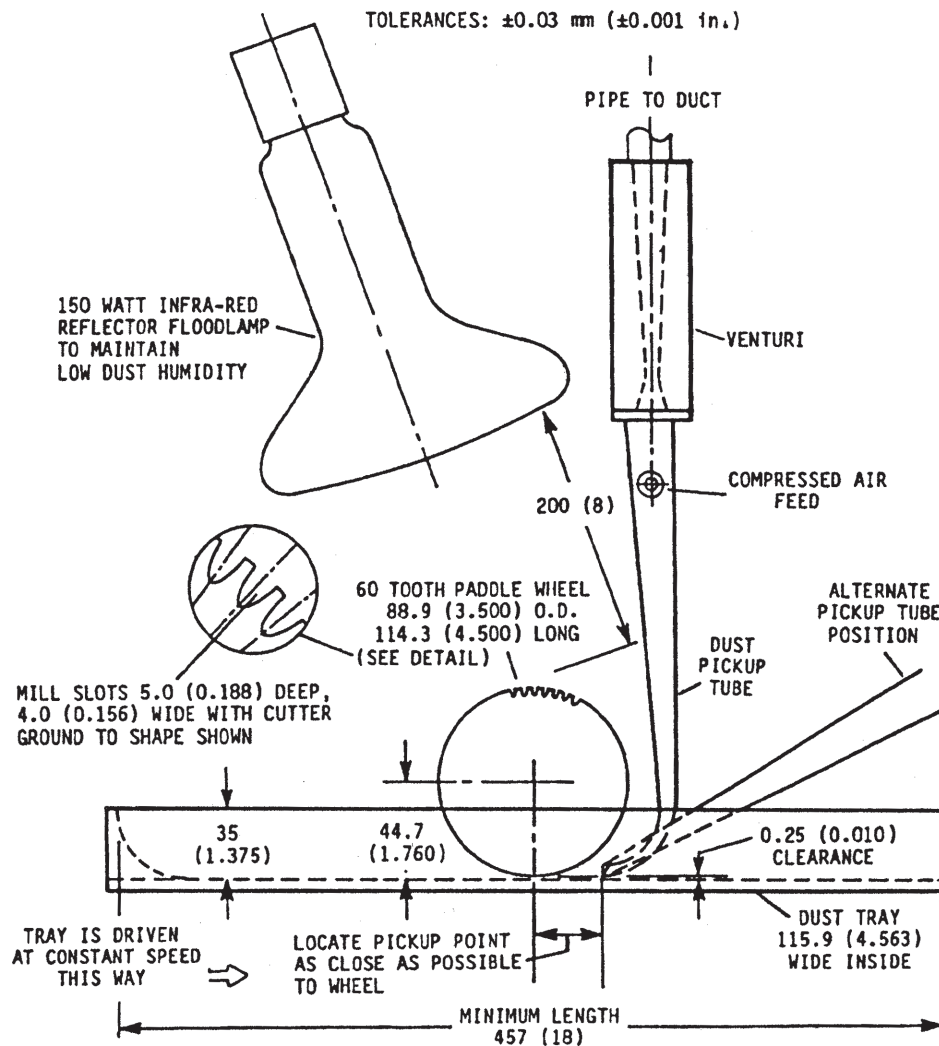


Figure 4-4 Critical dimensions of dust feeder assembly. Dimensions are in mm (in.).

4.6.6 The particle counter shall have less than 10% coincidence loss at a particle counting rate of 300,000 particles per minute¹² and shall have a minimum inlet volume flow rate of 47.2 cm³/s (0.100 cfm). This flow rate shall not change more than 2% with a 1000 Pa (4.0 in. of water) change in the pressure of the sampled air.

4.6.7 The measured particle concentration shall be no more than 200 particles/m³ (5.66 particles/ft³) when the particle counter is sampling air with a HEPA or ULPA filter on its intake.

4.6.8 Dual particle counters, if used, shall be closely matched in design and sampling flow rate.

4.7 Test Apparatus for Dust Loading

4.7.1 The test apparatus and materials required by the dust loading procedure shall include:

- Dust feeder
- Dust injection tube

- Backup filter
- Backup filter duct section
- Loading dust
- Seals for the particle counter sampling probes
- Dust feeder venturi calibrator

4.7.2 The dust-feed tube leading from the dust feeder to the center of the dust mixing orifice shall discharge along the centerline of the mixing orifice that is located on the centerline of the test duct.

4.7.3 The general design of the dust feeder and its critical dimensions shall conform to Figures 4-4 and 4-5. Backflow through the pickup tube from the positive-pressure duct shall be prevented when the feeder is not in use.¹³

4.7.4 The aspirator venturi dimensions shall be monitored periodically in accordance with Table 5-2 to ensure that the tolerances shown in Figure 4-5 are met.¹⁴

4.7.5 The gage pressure on the air line to the venturi corresponding to an airflow rate out of the dust-feeder pipe of

¹² The particle counting rate is the product of the particle concentration and the viewed volume flow. Example: 100 particles/mL · 3000 mL/min = 300,000 particles/min.

¹³ This can be achieved by installing a full-port ball valve in the duct feed pipe between the venturi and the test duct.

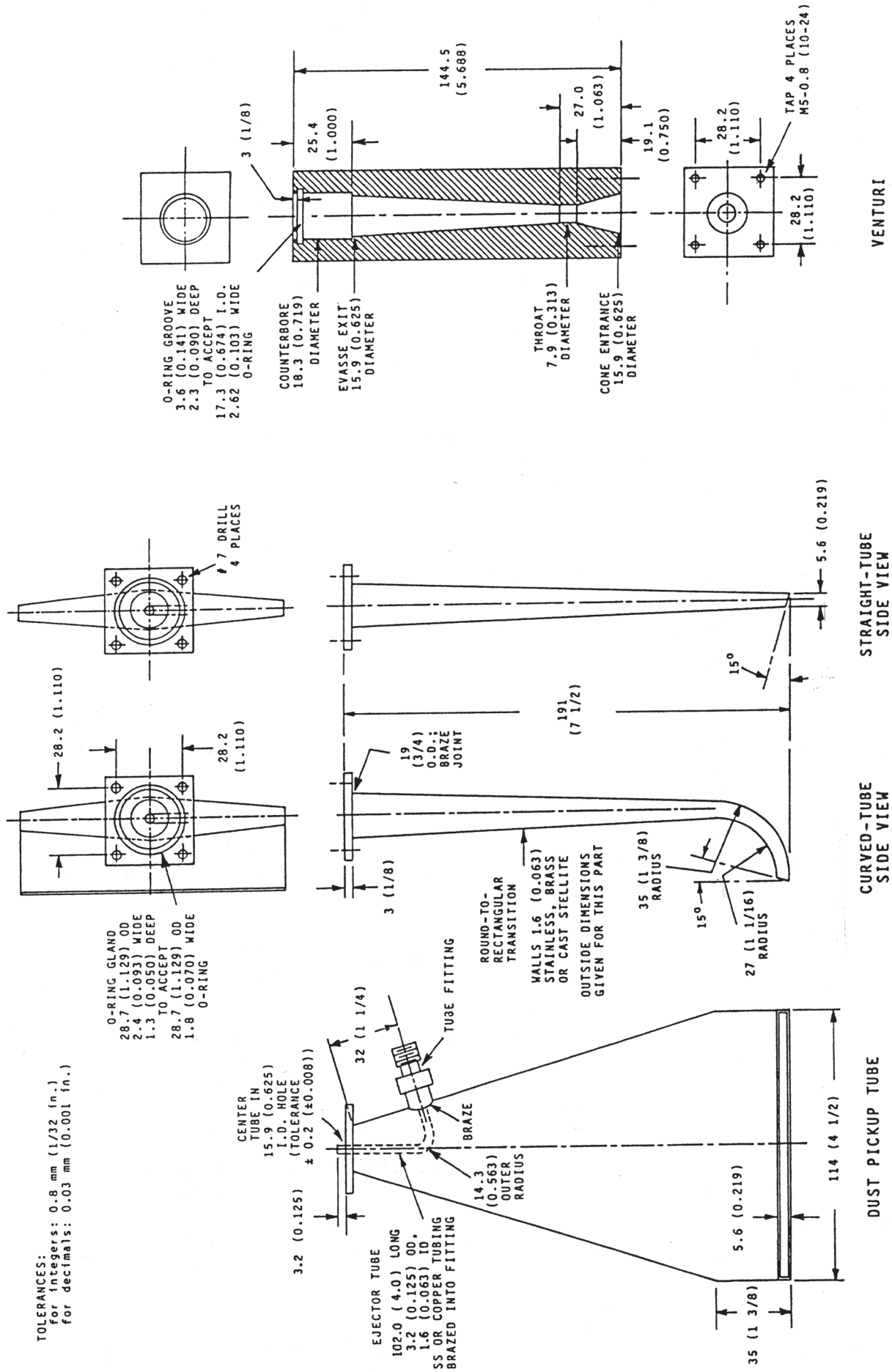
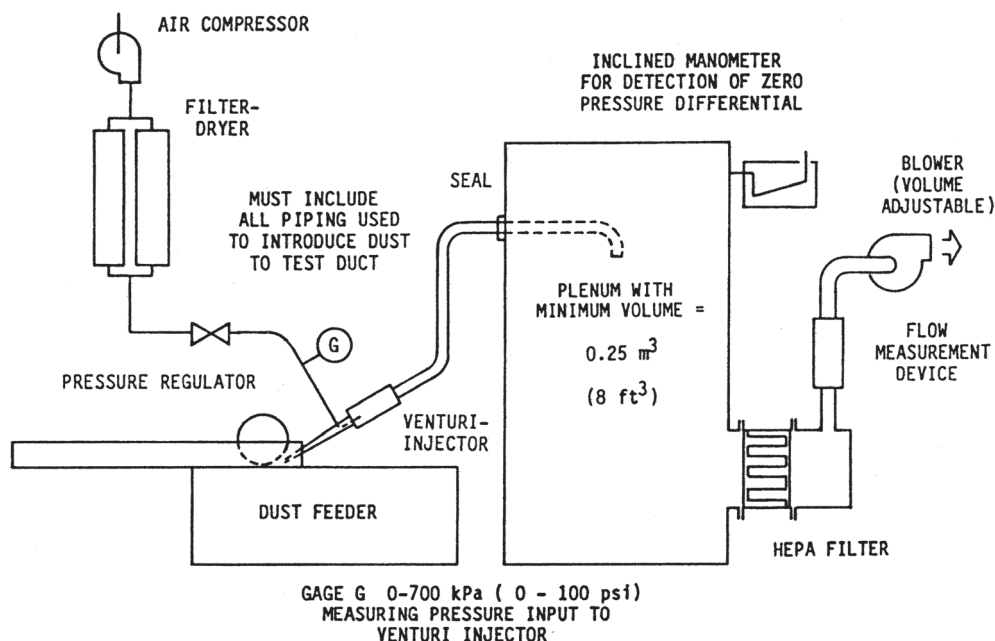


Figure 4-5 Dust feeder/ejector/venturi and pickup tube details. Dimensions are in mm (in.).



Note:

Gage G shall measure the pressure of the air supplied to the ejector tube supply line. This venturi calibrator shall be used to determine the pressure reading required to achieve air output from the dust feeder pipe of $6.8 \pm 0.2 \text{ dm}^3/\text{s}$ ($14.5 \pm 0.5 \text{ cfm}$) when there is zero pressure differential between the plenum and ambient. See Section 4.7.5.

Figure 4-6 Dust feeder venturi calibrator.

$6.8 \pm 0.2 \text{ dm}^3/\text{s}$ ($14.5 \pm 0.5 \text{ cfm}$) shall be measured periodically in accordance with Table 5-1. The required gage pressure on the ejector tube supply line necessary to provide this airflow at discharge duct pressures of 0, 500, 1000, 1500, 2000, and 2500 Pa (0, 2, 4, 6, 8, and 10 in. of water) above ambient pressure shall be determined using the test device shown in Figure 4-6. The compressed air supply shall be fitted with a filter-dryer system to provide clean, oil-free air with a dew point no higher than 1.7°C (35°F).

5. APPARATUS QUALIFICATION TESTING

5.1 Apparatus qualification tests shall verify quantitatively that the test rig and sampling procedures are capable of providing reliable particle size efficiency measurements. The tests shall be performed in accordance with Table 5-1.

Qualification tests shall be performed for:

- Air velocity uniformity in the test duct
- Aerosol uniformity in the test duct
- Downstream mixing of aerosol
- Overload tests of the particle counter
- 100% efficiency test
- Correlation ratio test
- Aerosol generator response time
- Duct leakage test
- Particle counter zero
- Particle counter sizing accuracy
- Radioactivity of the aerosol neutralizer
- Dust feeder airflow rate
- Final filter efficiency

¹⁴ The thoroughness of dust dispersion by the feeder is dependent on the characteristics of the compressed air, the geometry of the aspirator assembly, and the rate of airflow through the aspirator. The aspirator venturi is subject to wear from the aspirated dust and will become enlarged with use.

5.2 Velocity Uniformity in the Test Duct

5.2.1 The uniformity of the challenge air velocity across the duct cross section shall be determined by a nine-point traverse (Figure 5-1) in the $610 \times 610 \text{ mm}$ ($24 \times 24 \text{ in.}$) duct immediately upstream of the device section. The velocity measurements shall be made with an instrument having an accuracy of 10% with 0.05 m/s (approximately 10 fpm) resolution. The uniformity test shall be performed at airflow rates of 0.22, 0.93, and $1.4 \text{ m}^3/\text{s}$ (472, 1970, and 2990 cfm).

5.2.2 A one-minute average velocity shall be recorded at each grid point. The average must be based on at least ten readings taken at equal intervals during the one-minute period. The traverse shall then be repeated two more times to provide triplicate one-minute averages at each point for the given airflow rate. The average of the triplicate readings at each point shall be computed.

5.2.3 The CV (where CV is the coefficient of variation, computed as the standard deviation/mean) of the nine corresponding grid point air velocity values shall be less than 10% at each airflow rate.¹⁵

5.3 Aerosol Concentration Uniformity in the Test Duct

5.3.1 The uniformity of the challenge aerosol concentration across the duct cross section shall be determined by a nine-point traverse in the $610 \times 610 \text{ mm}$ ($24 \times 24 \text{ in.}$) duct immediately upstream of the device section (i.e., at the location of the upstream sample probe), using the grid points as shown in Figure 5-1. The traverse shall be made by either (a) installing nine sample probes of identical curvature,

¹⁵ If the required degree of velocity uniformity is not achieved, confirm that the blower is providing a constant airflow rate by repeating sampling at the center-of-duct location and confirm that the upstream mixing orifice and baffle are properly centered. Changes may be required to the discretionary ductwork upstream of the upstream mixing orifice.