Standard Test Method for Grease Particle Capture Efficiency of Commercial Kitchen Filters and Extractors[1]

This standard is issued under the fixed designation F2519; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method can be used to determine the grease particle capture efficiency of components and systems used in commercial kitchens to capture grease effluent prior to entering the exhaust duct. The results can be used to select a filter system best suited to a particular application.

1.2 This test method is applicable to filter components and systems. The performance information is obtained for new or clean filters and does not include the performance of used or loaded filters.

1.3 The filter can be evaluated with respect to the following (where applicable):

1.3.1 Pressure drop as a function of airflow through the filter (10.3), and

1.3.2 Particulate capture efficiency by particle size (10.4).

1.4 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are for information only.

1.5 *This test method may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASHRAE Standard:*[2]

ANSI/ASHRAE Standard 52.2-1999, Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size

2.2 *ISO Standard:*[3]

ISO Standard 3966, Measurement of Fluid Flow in Closed Conduits—Velocity Area Method Using Pitot Static Tubes

3. Terminology

3.1 *Definitions:*

3.1.1 *airflow rate, n*—volumetric flow rate of air that passes through a filter or a bank of filters.

3.1.2 *capture efficiency, n*—proportion of aerosol particles removed by a filter as a function of particle size, usually expressed as a percentage.

3.1.3 *cartridge filter, n—removable extractor*, a removable, integral component of listed exhaust hoods, which is typically constructed of stainless steel and containing a series of horizontal baffles designed to remove grease and drain it into a container.

3.1.4 *fixed extractor, n—water-wash hood or linear slot hood*, a fixed, integral component of listed exhaust hoods, which is typically constructed of stainless steel and containing a series of horizontal baffles that run the full length of the hood.

3.1.5 *grease filter, n*—device installed into a hood to capture grease effluent before it enters the exhaust duct. Several identical devices may be installed in parallel in a hood. The device may consist of more than one component or section.

3.1.6 *pressure drop, n*—change in static pressure between the front surface of the grease filter and its rear surface under the rated airflow rate conditions.

3.1.7 *reference hood, n*—Type I exhaust hood used for the "no extractors" condition when measuring the efficiency and pressure drop of fixed extractor hoods. This is typically the same hood that is used for testing removable grease filters and removable cartridge filters.

3.2 *Symbols:*

E = capture efficiency
n = number of sample sets

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[2] Available from American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE), 1791 Tullie Circle, NE, Atlanta, GA 30329.

[3] Available from International Organization for Standardization (ISO), 1 rue de Varembé, Case postale 56, CH-1211, Geneva 20, Switzerland.

P = penetration
t = t distribution variable
T = sampling time
W = counts of each size range (or channel) with test device(s) installed
WO = counts of each size range (or channel) without test device(s)
δ = standard deviation of a sample

3.3 *Subscripts:*

b = background
c = correlation
e = estimated
i = sample number
lcl = lower confidence limit
n = number of sample sets
o = observed
t = testing a filter
ucl = upper confidence limit
w = with test device(s) installed
wo = without test device(s) installed

4. Summary of Test Method

4.1 There are three predominant classes of filters in kitchen ventilation grease extraction systems: removable baffle filters, removable cartridge filters, and fixed extractors.

4.2 Removable baffle and cartridge filters to be tested are installed into the test system.

4.2.1 Identical filters to be tested are installed into a standard 4-ft canopy hood connected to a nominal 12-in. round duct exhaust system. The filters should fit tightly together and into the opening and any bypasses larger than ⅛-in. wide on the ends are sealed.

4.2.2 For fixed-extractor systems, a reference hood shall be used for testing conditions that call for no filters to be installed in the hood. Testing requires switching between the reference hood and the fixed extractor hood.

4.2.3 A filter system to be used in a non-standard canopy hood is installed at the height of actual application above the floor and connected to a nominal 12-in. round duct exhaust system.

4.2.4 The static pressure drop across the filters is recorded at the test airflow.

4.2.4.1 For removable baffle or cartridge filters, the net filter pressure drop is determined by subtracting the pressure drop of the hood when the filters are removed from the pressure drop measured when the filters are installed. The total exhaust volumetric flow rate must be equal in both pressure drop measurements.

4.2.4.2 For fixed-extractor hood systems, the pressure drop is determined by subtracting the pressure drop of the reference hood when the filters are removed from the pressure drop measured on the fixed-extractor hood. The total exhaust volumetric flow rate must be equal in both pressure drop measurements.

4.3 The total airflow rate through the exhaust system is set so that the volumetric flow rate through the filter under test is equivalent 250 cfm per linear foot (width) of filter (based on external filter dimensions).

4.3.1 Performance may also be evaluated at other airflows in accordance with manufacturer recommendations (see Appendix X1).

4.4 Balanced makeup air shall be provided at 75 ± 5°F and 50 ± 20 % RH.

4.5 Particulate capture efficiency for removable grease filter or removable cartridges is determined by comparing particle concentration versus size in the exhaust duct with and without the filters installed.

4.5.1 Particulate capture efficiency for hoods with fixed extractors is determined by comparing particle concentration as a function of particle size in the exhaust duct with the fixed extractor hood and the reference hood without the filters installed.

4.5.2 The test aerosol is oleic acid that covers a size range from 0.3 to 10 µm in diameter or as specified by the manufacturer. Efficiency shall be reported as zero from 0.3 µm to the lower limit of the test conditions. Particulate concentration measurements (as a function of particle size) are taken in the exhaust duct using an isokinetic sampling probe and an optical particle counter. The particulate capture efficiency is determined by taking the difference between the particle concentration with and without the filters installed at each particle size range set on the particle counter.

5. Significance and Use

5.1 The pressure drop results can be added to the pressure drops of other components in an exhaust system to determine the total exhaust fan pressure requirement.

5.2 The particulate capture efficiency can be used with known particulate size emission data for a cooking appliance-food product combination to determine the total mass of grease particles captured by the filter, the total mass of grease particles that pass through the filter, and the particle size distribution of the grease particles that pass through the filter. Fig. 1 shows an example particle capture efficiency curve.

6. Apparatus

6.1 *Mandatory and Discretionary Requirements*—Critical dimensions and arrangements of the test apparatus are shown in Figs. 2-5. Vertical ductwork may also be used with the same critical dimensions (duct diameter, length, and so forth). All dimensions shown are mandatory unless otherwise indicated. Units shown are in inches unless otherwise indicated. The design of equipment not specified, including but not limited to exhaust fan, makeup air system, and external structural supports, is discretionary, but the equipment must have adequate capacity to meet the requirements of this test method.

6.2 *Test Facility:*

6.2.1 *Exhaust Hood:*

6.2.1.1 The test installation should have a canopy exhaust hood which meets these requirements: 4 ft (1.2 m) in width and depth, minimum 2 ft (0.61 m) in height, wall mounted with the lower edge of the hood 6½ ft (2.0 m) from the floor and with a 12 in. (0.305 m) diameter round duct collar mounted on top

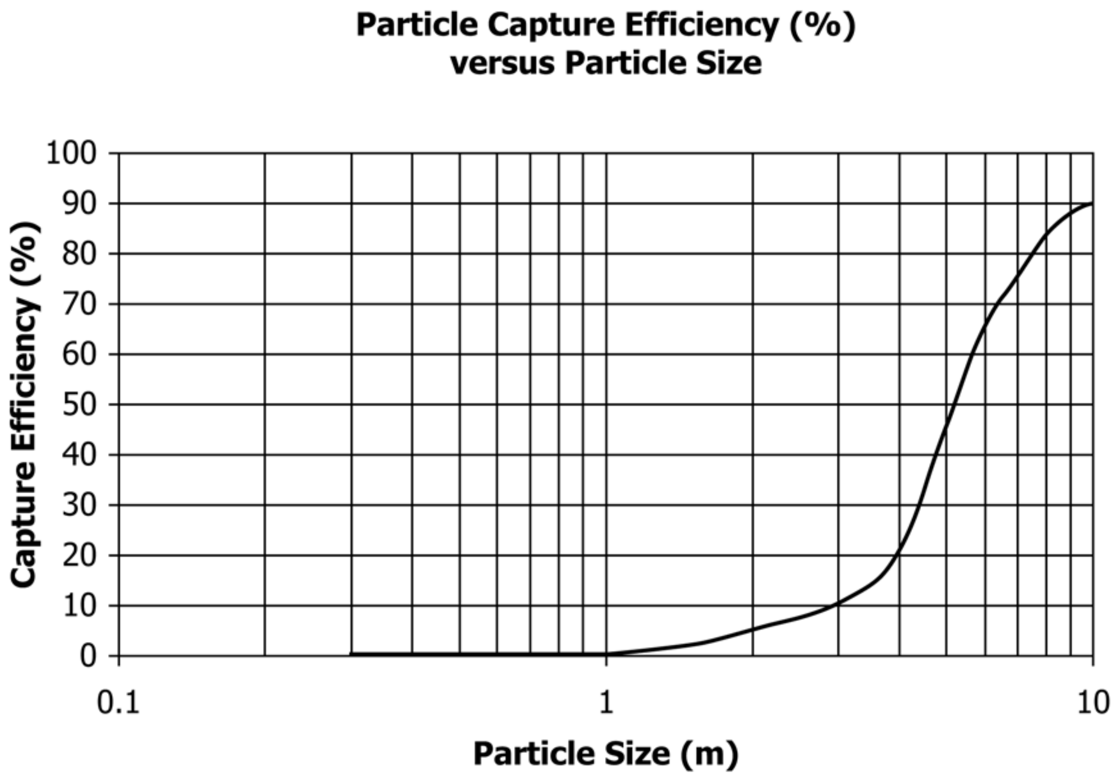

FIG. 1 Particle Capture Efficiency Example Curve

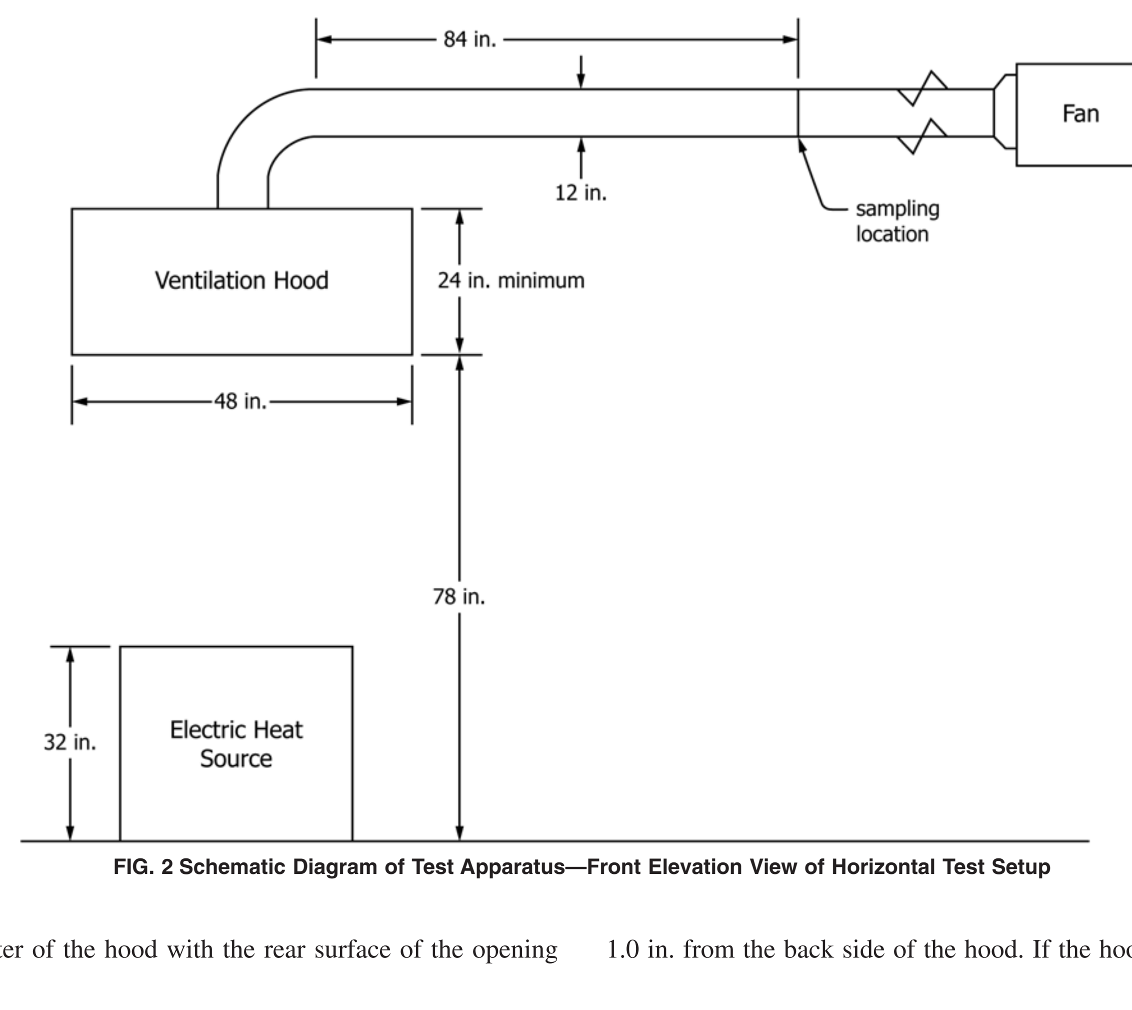

FIG. 2 Schematic Diagram of Test Apparatus—Front Elevation View of Horizontal Test Setup

in the center of the hood with the rear surface of the opening 1.0 in. from the back side of the hood. If the hood is installed

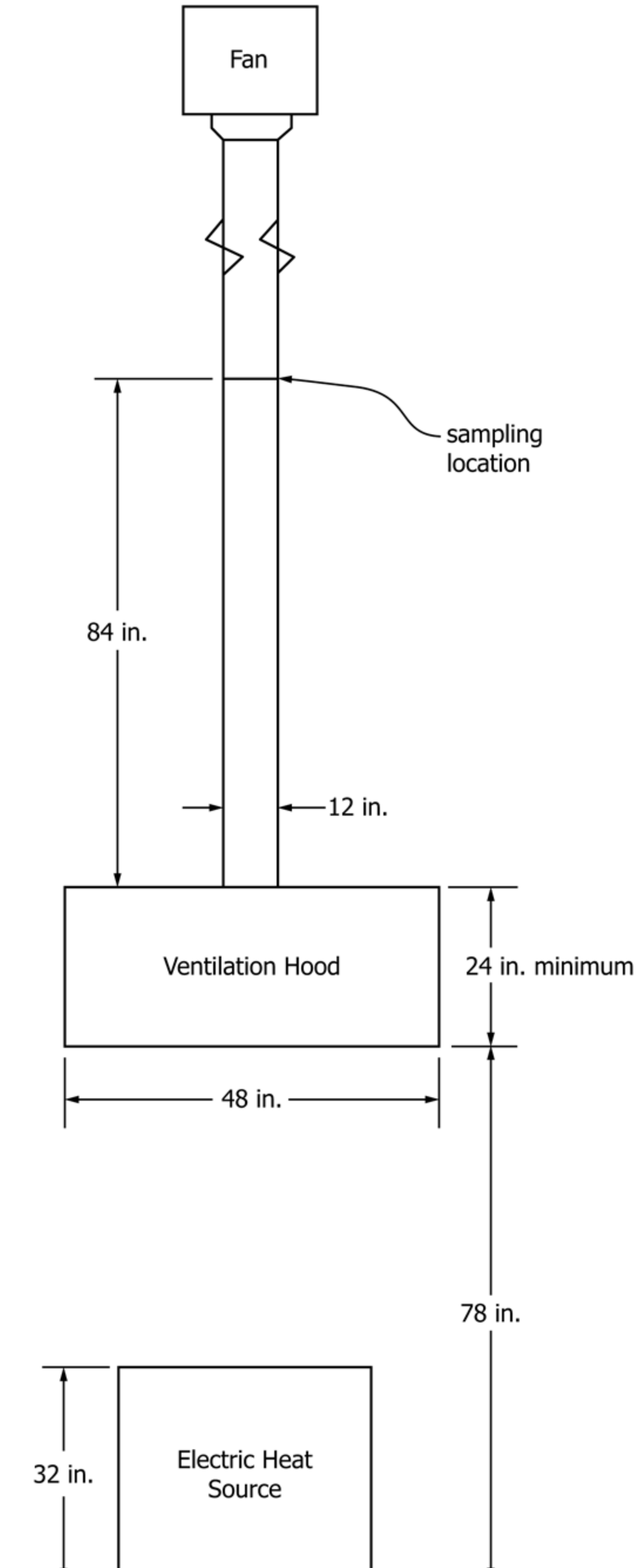

FIG. 3 Schematic Diagram of Test Apparatus—Front Elevation of Vertical Test Setup

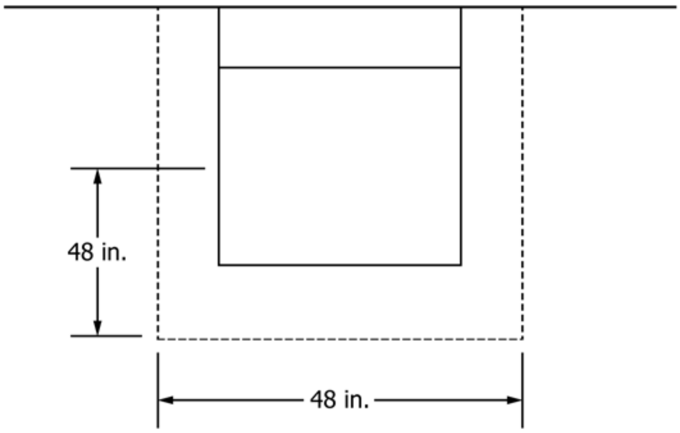

FIG. 4 Schematic Diagram of Test Apparatus—Plan View

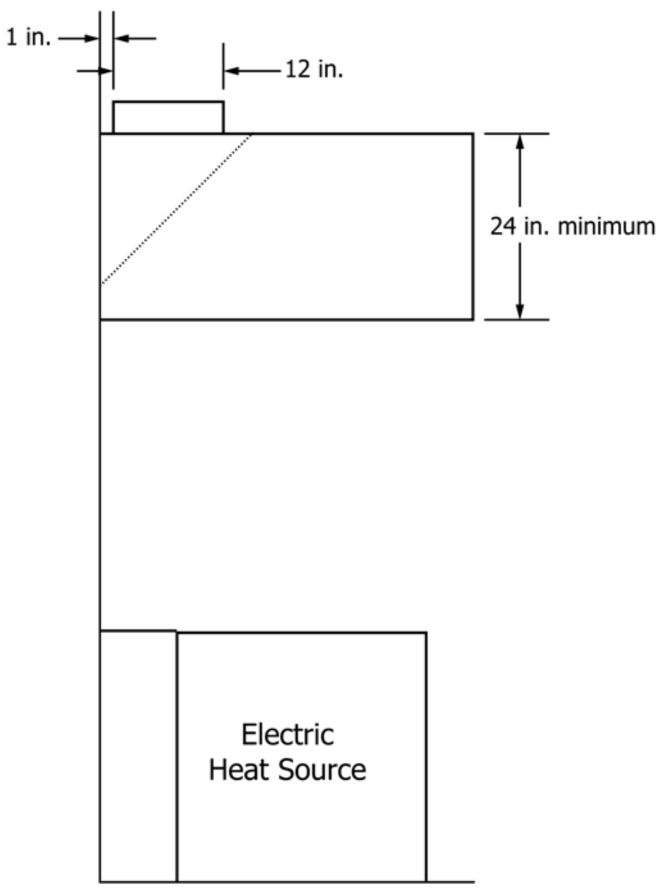

FIG. 5 Schematic Diagram of Test Apparatus—Side Elevation View

at a different height, a distance of 46 in. must be maintained between the appliance surface and bottom of the hood. The hood shall contain means for securing grease filters under test in a position typical in application.

6.2.1.2 Hoods with fixed extractors should be built to match the description given in 6.2.1.1 as closely as possible without affecting the hood's extraction efficiency.

6.2.1.3 The typical reference hood will be a canopy exhaust hood matching the one described in 6.2.1.1 and shown in Fig. 6. If the hood with fixed extractors cannot be built to match 6.2.1.1, then the reference hood shall be built to match the hood with fixed extractors.

6.2.1.4 To facilitate switching hoods, the lab may build rolling stands for each reference hood and the current hood being tested. These stands may be rolled in and out of the test rig. Care should be taken to insure that both hoods are installed in the same location at the same height (6½ ft) each time.

6.2.1.5 The test apparatus shown in Figs. 2-5 is designed for test filters with a nominal height of 20 in. It is permitted to test a bank of several filters in parallel if the width of an individual filtration device is less than 50 % of the width of the hood. Spacers may be added symmetrically on both ends of the filter under test if the filter does not span the entire width of the hood.

6.2.2 *Round Exhaust Duct,* 12 in. (0.305 m) in diameter, connected to the duct collar on the top of the exhaust hood and leading to an exhaust fan. All duct connections shall be sealed. The duct may be horizontal or vertical. If horizontal, it must have a 90-degree elbow configured as shown in Fig. 7. The elbow must have a centerline duct radius of 14-in.

NOTE 1—The r/D ratio is 1.167 for this configuration.

6.2.2.1 The distance from the duct collar for a vertical exhaust duct or from the end of the 90 degree elbow for a horizontal exhaust duct to the sampling location shall be 84 in. If a different sampling location is used, or a different exhaust configuration is used, an aerosol uniformity test shall be conducted.

6.2.2.2 The minimum distance from the sampling location to the nearest duct fitting or fan inlet shall be 24 in.

6.2.3 *Exhaust Fan,* capable of moving 1000 ft^3/min (472 L/s) through the filters under test and the additional exhaust system components at the test static pressure condition. The fan shall have a variable frequency drive or other means to control the airflow rate. The exhaust shall be discharged outdoors.

6.2.4 *Makeup Air System,* a means for providing makeup air at 75 ± 5°F and 50 ± 20 % relative humidity to match exhaust rate without disturbing the airflow pattern near the exhaust hood.

6.2.5 *Heat Source,* a uniform electric heat source with a solid metal surface, a minimum 2 ft. deep by 3 ft. wide, maintained at an average surface temperature of 375 ± 5°F.

NOTE 2—A commercial electric griddle with a rated input between 7 and 10 kW and been shown to work well as a heat source.

6.2.5.1 The cooking surface of the heat source shall be 32 in. (0.81 m) above the floor. The heat source shall be centered under the hood from side to side and from front to back. Any air gap between the rear of the heat source and the back wall shall be sealed with a horizontal sheet of stainless steel positioned at the same height as the rear of the heat source.

6.3 *Instrumentation:*

6.3.1 *Flow Metering Station,* installed in the exhaust duct for measuring the airflow rate through the filters under test. Options include a grid of local velocity measurements using the log-Tchebycheff method, a flow nozzle, or an orifice plate.

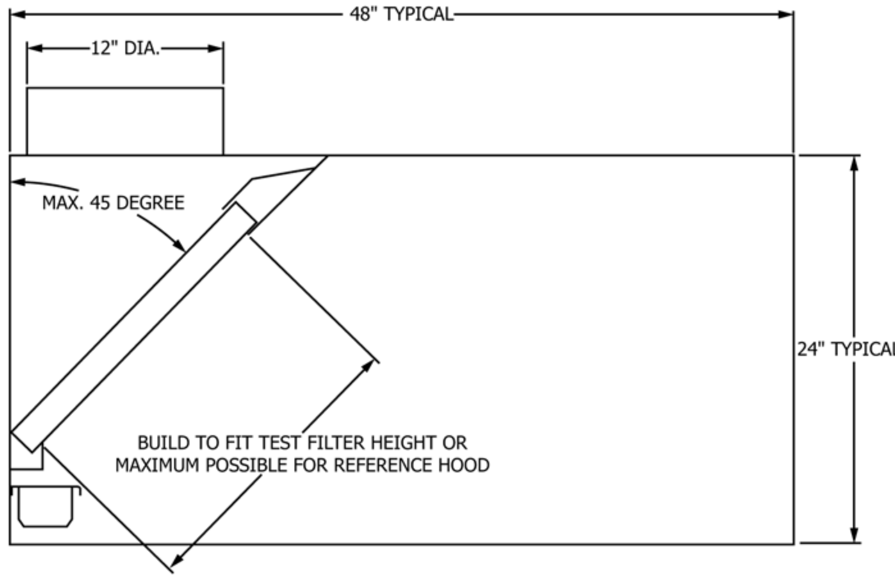

FIG. 6 Schematic Diagram of Reference Hood

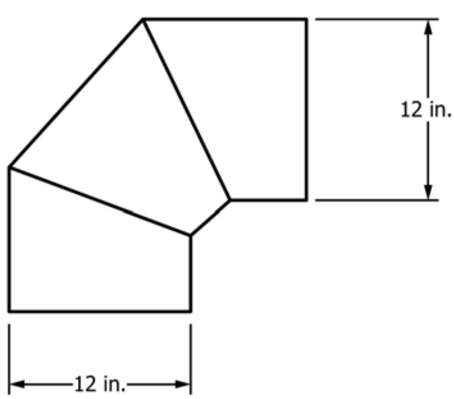

FIG. 7 Schematic Diagram of 90-Degree Elbow to Connect the Duct Collar on the Canopy Hood to a Horizontal 12 in. Diameter Round Exhaust Duct

If a nozzle or orifice plate is used, it must be mounted downstream from the particle sampling location.

6.3.1.1 Airflow rate may be determined using velocity traverse measurements according to the log-Tchebycheff method (ISO Standard 3966). Local velocities shall be measured at the particle sampling location using a pitot tube, hot film anemometer, or hot wire anemometer. Velocity profiles shall be measured without filters installed in the hood and with test filters installed. Results shall be used to determine airflow rate versus fan speed with and without filters installed to set the fan speed for proper airflow rate. The airflow and filter static pressure shall be continuously monitored.

6.3.1.2 Airflow rate may be determined by means of ASME long-radius flow nozzles with static taps. The dry bulb temperature, absolute pressure, and relative humidity of the exhaust airflow shall be measured in the duct immediately upstream of the flow-measuring device. These values shall be used for calculation of airflow rate. Measurements shall be made with and without the test filters installed to set the fan speed for proper airflow rate at each test condition.

6.3.2 *Barometer,* for measuring absolute pressure of the air entering the exhaust hood. The barometer shall have a resolution of 0.2 in. Hg (670 Pa).

6.3.3 *Differential Pressure Gage,* for measuring the pressure drop across the filters under test. The pressure gage shall have a range from 0 to 5 in. water (0 to 2.5 kPa), and have an accuracy of 1 % at full scale.

6.3.4 *Temperature Sensors,* industry standard Type T or K thermocouples, one mounted at the inlet to the particle sampling probe in the exhaust duct to measure the temperature of the exhaust, the other located 6½ ft from the floor and 6 ft in front of the center of the exhaust hood with radiation shielding to measure the dry bulb temperature of the makeup air.

6.3.5 *Humidity Sensor,* relative humidity sensor or dew point hygrometer to determine the relative humidity of the makeup air at a height of 6 ½ ft above the floor and 6 ft in front of the center of the exhaust hood.

6.4 *Aerosol Generation System:*

6.4.1 Other than the requirements of the following subsections, design features of the aerosol generator are discretionary. Refer to Appendix X2 for guidance.

6.4.2 The test aerosol shall be polydisperse liquid-phase oleic acid particles generated from a solution. The solution may be pure reagent grade oleic acid or a mixture of reagent grade oleic acid and isopropyl alcohol. The aerosol generator shall provide a stable test aerosol of sufficient concentration over the diameter size range to meet the requirements of Section 12 without overloading the aerosol particle counter. See 8.4. The aerosol generator shall be designed to ensure that all alcohol is evaporated from the particles prior to being introduced into the test section.

6.4.3 After any alcohol evaporation necessary, 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. 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.

6.4.4 The test aerosol shall be injected vertically upward at a point centered on the heated surface (front to back and side to side) and from 11 to 13 in. in height above the surface of the heat source. The injection system design is discretionary provided it fulfills the requirement.

6.5 *Aerosol Sampling and Measurement System:*

6.5.1 *Aerosol Sampling Probe,* for sampling particles in the exhaust duct. The probe shall be sharp edged and designed for isokinetic sampling at the given average duct velocity.

6.5.2 The design criterion for the sampling system shall be to provide a particle transport of >50 % for 10 μm diameter oleic acid particles from the sampling probe inlet within the exhaust duct to the inlet of the particle counter.

6.5.3 *Diluters,* if used, shall provide equal dilution of both samples taken with and without the test filter installed in the hood. Dilution of just the sample without the filter installed is disallowed.

6.5.4 *Particle Counters,* permitted are optical counters (OPC) with wide-angle collection optics or other counters demonstrating good correlation in measuring particle size efficiencies, such as an aerodynamic particle counter (APC). An APC shall first be tested with oleic acid aerosol to establish the relationship between the aerodynamic particle size and the light-scattering particle size determined by an OPC. Calibrate the APC with polystyrene latex (PSL) spheres and use the relationship to express results as equivalent light-scattering size of oleic acid.

NOTE 3—Different instruments categorize particle size using different means. With an OPC, a beam of light is used to measure the geometric size of the particle, which is called the geometric mean diameter, d_e. An APC instrument measures the aerodynamic size of the particle, d_a. The relationship between these two is shown in Eq 1. Therefore, to convert the reported data from an APC to an OPC, Eq 2 shall be used. For oleic acid, the density is 1.117 gm/cm^3.

$$d_a = d_e \cdot \sqrt{\rho} \tag{1}$$

where:

d_a = aerodynamic particle size,
d_e = geometric particle size, and
ρ = density of the particle.

$$d_e = \frac{d_a}{\sqrt{\rho}} \tag{2}$$

6.5.4.1 The particle counter shall be capable of counting and sizing individual oleic acid particles in the particle diameter size range.

6.5.4.2 The particle counter shall measure the aerosol particles in its native particle size ranges and then the test aerosol particles shall be reported in 12 size ranges as shown in Table 1. The particle counter's correlation of measured response to physical particle size shall be monotonic for PSL particles from 0.30 to 10 mm, such that only one size range shall be indicated for any measured response.

6.5.4.3 The particle counter shall be calibrated annually using known size PSL spheres.

6.5.4.4 The particle counter shall have less than 10 % coincidence loss at a particle counting rate of 300 000 particles/min and shall have a minimum inlet volume flow rate of 0.100 cfm. This flow rate shall not change more than 2 % with a 4.0 in. of water change in the pressure of the sampled air.

TABLE 1 Particle Counter Size Range Boundaries

Range	Lower Limit (μm)	Upper Limit (μm)	Geometric Mean Particle Size (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

6.6 *Data Acquisition System(s),* for monitoring and recording the surface temperature distribution on the griddle, the temperature and relative humidity of the makeup air, the temperature in the exhaust duct, and the particle concentration versus size in the exhaust duct, is discretionary.

7. Reagents and Materials

7.1 *Test Aerosol*—The test aerosol shall be liquid oleic acid particles generated from a solution. The oleic acid shall be reagent grade. The solution may consist of 100 % oleic acid. If necessary, reagent grade isopropyl alcohol may be used in the solution to assist the performance of the aerosol generator. The volume of isopropyl alcohol shall be based on the manufacturer's specification for the generator.

8. Preparation of Apparatus

8.1 Apparatus qualification tests shall verify quantitatively that the test rig and sampling procedures are capable of providing reliable pressure drop and particle size efficiency measurements. The tests shall be performed in accordance with Table 2.

8.1.1 Qualification tests shall be performed for:

8.1.1.1 Air velocity uniformity in the exhaust duct,

8.1.1.2 Aerosol concentration uniformity in the exhaust duct,

8.1.1.3 Aerosol concentration limit in the exhaust duct,

8.1.1.4 Aerosol generator response time,

8.1.1.5 Particle counter zero,

8.1.1.6 Particle counter sizing accuracy,

8.1.1.7 Radioactivity of the aerosol neutralizer, and

8.1.1.8 Electric heat source surface temperature.

8.2 *Velocity Uniformity in the Exhaust Duct:*

8.2.1 The uniformity of the air velocity in the exhaust duct at the sampling location shall be determined by three six-point traverses using the grid points shown in Fig. 8 and specified in Table 3, in the 12-in. diameter exhaust duct at vertical, and at 60 degrees clockwise and counter-clockwise from the vertical. The velocity measurements shall be made with an instrument

TABLE 2 Summary of System Qualification Measurement Requirements

Parameter	Requirement
Aerosol Uniformity: Based on traverse measurements over the 25-point grid at each test airflow rate	Coefficient of variation must be <15%
Upper Concentration Limit: Based on limiting the concentration to below the level corresponding to the onset of coincidence error	No predetermined level
Aerosol Generator Response Time	No predetermined level
Particle Counter Zero Count Check: Based on HEPA filer attached to the instrument's inlet	<10 counts per minute over the 0.3 to 10 µm range
Particle Counter Sizing Accuracy Check: Based on sampling of aerosolized monodispersed PSL spheres of known size	Relative maximum must appear in the appropriate sizing channel.
Aerosol Neutralizer Activity: Based on detection of radioactive source within neutralizer	Radioactivity must be detected.
Heat Source Surface Temperature: Based on thermocouples connected to the cooking surface	Average surface temperature must be 375 ± 5ºF.

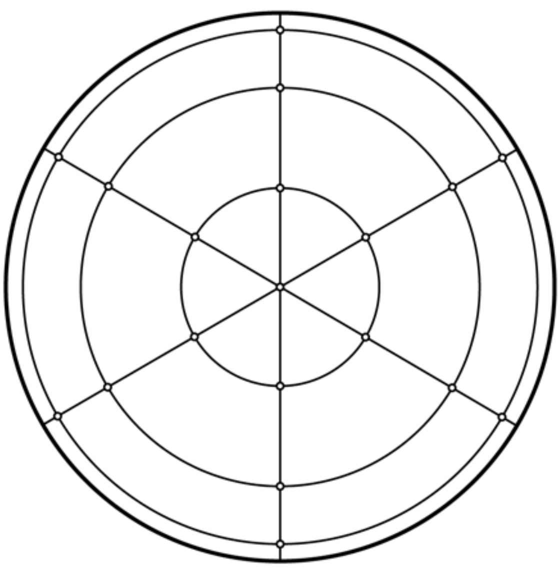

FIG. 8 Schematic of Velocity Measurement Locations Within the Exhaust Duct

TABLE 3 Position of Measurements According to log-Tchebycheff Rule for a 12-in. Duct

Sample Point	Distance from Side Wall Inlet Opening, in.
1	0.384
2	1.620
3	3.852
4	8.148
5	10.380
6	11.616

having an accuracy of 10 % with approximately 10 fpm resolution. The uniformity test shall be performed at an airflow rate of 1000 cfm.

8.2.2 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 1-min period. The traverse shall then be repeated two more times to provide triplicate 1-min averages at each point for the given airflow rate. The average of the triplicate readings at each point shall be computed.

8.2.3 The CV (where CV is the coefficient of variation computed as the standard deviation/mean) of the nineteen corresponding grid point air velocity values shall be less than 10 %.

8.3 *Aerosol Concentration Uniformity in the Exhaust Duct:*

8.3.1 The uniformity of the aerosol concentration in the exhaust duct at the sampling location shall be determined by a twenty six-point traverse using the grid points shown in Fig. 9 and specified in Table 4 in the 12-in. diameter exhaust duct. The inlet nozzle of the sample probe shall be sharp edged and of appropriate entrance diameter to maintain isokinetic sampling within 10 % at the test airflow. The uniformity test shall be performed at an airflow rate of 1000 cfm.

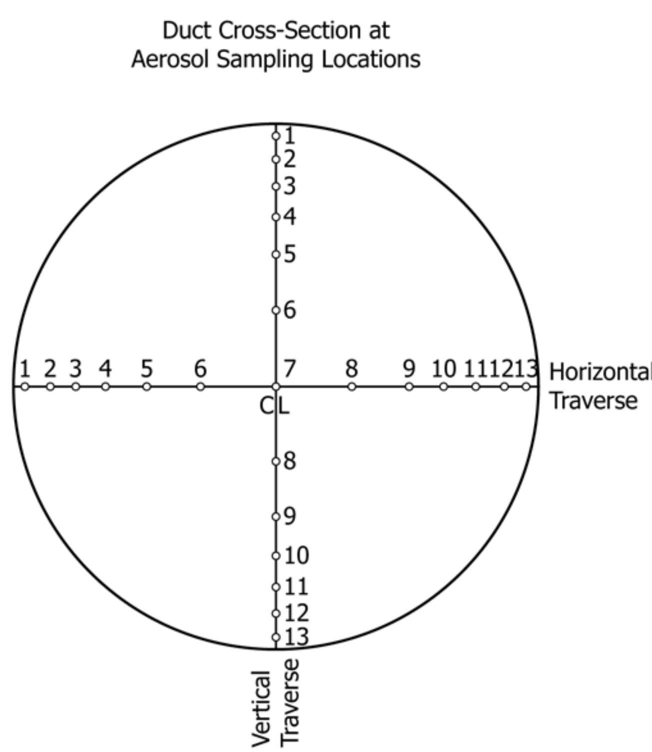

FIG. 9 Schematic of Particle Concentration Measurement Locations Within the Exhaust Duct

TABLE 4 Sample Point Locations for Duct Aerosol Spatial Uniformity Tests for a 12-in. Duct

Sample Points	Distance from Side Wall Inlet Opening, in.
1	0.252
2	0.804
3	1.416
4	2.124
5	3.000
6	4.272
7	6.000
8	7.728
9	9.000
10	9.876
11	10.584
12	11.196
13	11.748

8.3.2 The oleic acid aerosol shall be provided by the aerosol generator specified in 6.4 and the aerosol shall be injected vertically upward from a point 12 in. (±1 in.) above the center of the griddle. The aerosol sampling probe shall remain stationary in its normal center-of-duct sampling location.

8.3.3 The aerosol concentration measurements shall be made with a particle counter meeting the specifications of 6.5.4. A one-minute sample shall be taken at each grid point with the aerosol generator operating. After sampling all 26 points, the traverse shall be repeated four more times to provide a total of five samples at each point. The five values at each point shall be averaged for each of the particle counter size ranges.

8.3.4 The CV of the corresponding 26 grid point particle concentrations shall be less than 15 % in each of the particle counter size ranges.

8.4 *Concentration Limit in the Exhaust Duct:*

8.4.1 A series of initial tests shall be performed over a range of challenge aerosol concentrations, with no filters installed, to determine a total concentration level for the particle size efficiency tests that does not overload the particle counter. The lowest total concentration level shall be less than 1 % of the instrument's stated total concentration limit. The tests shall be performed with no filters installed in the hood and at an exhaust airflow rate of 1000 cfm.

8.4.2 The aerosol for these tests shall be generated using the same system and procedures as specified in 10.5.3 for the particle size efficiency tests.

8.5 *Aerosol Generator and Sampling System Response Time:*

8.5.1 Measure the time interval for the aerosol concentration to go from background level to steady test level after turning the aerosol generator on. The test shall be performed at an airflow rate of 1000 cfm with the aerosol sampling probe inlet located at the center of the exhaust duct.

8.5.2 Measure the time interval for the aerosol concentration to return to the background level after turning off the generator. The exhaust flow rate shall be maintained at 1000 cfm.

8.5.3 These time intervals shall be used as the minimum waiting time between (*1*) activating the aerosol generator and beginning the particle counter sampling sequence, and (*2*) deactivating the aerosol generator and beginning the particle counter sampling sequence for determination of background aerosol concentrations.

8.6 *Particle Counter Zero:*

8.6.1 The zero count of the particle counter shall be verified to be <10 total counts per sample time, as determined in 12.5.2.2, used during testing in the 0.30 to 10 µm size range when operating with a HEPA filter attached directly to the instrument's inlet.

8.7 *Particle Counter Sizing Accuracy:*

8.7.1 The sizing accuracy of the particle counter shall be checked by sampling aerosols containing monodispersed spheres of known size. Two sizes shall be used; one between 0.3 and 1 µm and the other between 1 and 10 µm. The particles may be solid polystyrene spheres or liquid drops of known composition. A relative maximum particle count shall appear in the particle counter sizing channel that encompasses the known diameter of the monodisperse aerosol.

8.8 *Confirmation of the Activity of the Aerosol Neutralizer:*

8.8.1 The activity of the radiation source within the aerosol neutralizer shall be confirmed by use of an appropriate radiation detection device. The measurement may be relative (as opposed to absolute) but shall be adequate to indicate the presence of an active source and shall be capable of being performed in a repeatable manner.

8.8.2 The measurement shall be repeated annually and compared to prior measurements to determine if a substantial decrease in activity has occurred. Replace neutralizers showing a lack of activity in accordance with the manufacturer's recommendations.

8.9 *Electric Heat Source Temperature:*

8.9.1 The average surface temperature of the plate of the heat source shall be 375 ± 5°F.

8.10 *Summary of Qualification Test Requirements*—Qualification test criteria shall conform to Table 2.

8.11 *Apparatus Maintenance*—Maintenance items and schedules shall conform to Table 5.

9. Preparation of the Test Sample(s)

9.1 The filter device(s) to be tested shall be new (unused) and prepared in accordance with the manufacturer's recommendations.

9.2 The number of identical devices to be tested simultaneously shall equal the number of devices that will span the width of the exhaust hood in the test facility.

9.3 Install the new, clean filter/device(s) for every series of tests. Installation shall be equivalent to a typical kitchen application with no additional sealing except openings larger than ⅛-in. wide at the ends.

9.3.1 If the devices do not span the entire hood opening provided in the test facility, spacers must be installed on each end to center the test devices in the hood and to prevent air from passing around the ends.

9.3.2 If the devices cannot be installed in the existing hood at the test facility, a new 4-ft wide exhaust hood with the appropriate mounting hardware shall be installed in the facility and characterized as in Section 8, or the mounting hardware in

TABLE 5 Summary of Apparatus Maintenance Schedule

Maintenance Item (Subsection Reference)	Incorporated Into Each Test	Bi-Annually	After a Change That May Alter Performance	Comment
Pressure drop across empty test section (11.2)	X			
Background particle count (12.2)	X			
Particle counter zero check (7.6)	X			
Particle counter primary calibration using PSL				Note 1
Air velocity uniformly (7.2)			X	
Aerosol uniformity (7.3)			X	
Generator response time (7.5)			X	
Overloading test of particle counter (7.4)			X	
Confirmation of neutralizer radioactivity (7.8)		X		Note 2
Flow rates, pressure drops, temperature, relative humidity, and so forth				Note 3
Cleaning of test duct and components				Note 4

NOTE 1—Calibration performed annually

NOTE 2—Wash the inside of radioactive neutralizer every 1-h of use. Check balance of the corona discharge ionizer monthly, per manufacturer's instructions.

NOTE 3—In accordance with manufacturer's recommendations but at least annually.

NOTE 4—Cleaning intervals of the test duct, aerosol generator system, aerosol sampling lines, and other test components is discretionary.

the existing hood shall be changed to accommodate the devices as they would be installed in the field.

9.4 At the beginning of every test, the airflow must be verified to be within 5 % of that obtained from a new filter at the same pressure drop.

10. Procedure

10.1 *Airflow Rates for Tests:*

10.1.1 Particle size efficiency tests shall be run and reports generated for an airflow rate as specified in either 10.1.2 or 10.1.3.

10.1.2 The total airflow rate through the exhaust system is set so that the volumetric flow rate through the filter under test is equivalent 250 cfm per linear foot (width) of filter device (based on external filter dimensions).

10.1.3 Performance may also be evaluated at other airflows in accordance with manufacturer recommendations (see Appendix X1).

10.2 *Test Sequence:*

10.2.1 The sequence of tests on the device(s) shall be as follows:

10.2.1.1 Resistance versus airflow rate as described in Section 10.3.

10.2.1.2 Particle size collection efficiency as described in Section 10.4.

10.3 *Measurement of Resistance to Airflow:*

10.3.1 The airflow rate shall be determined using one of the methods described in Section 6.3.1.

10.3.2 Remove any test device(s) from the exhaust hood.

10.3.3 Measure and record the differential pressure between the static pressure tap installed in the hood downstream of the test device(s) and the room air in the test facility at a minimum of four airflow rates: 50 %, 75 %, 100 %, and 125 % of test airflow rate.

10.3.4 Install the device(s) in the exhaust hood as described in Section 9.

10.3.4.1 If testing removable baffle filter or cartridge filter, install the device(s) in the exhaust hood as described in Section 9.

10.3.4.2 If testing a hood with a fixed extractor, remove reference hood and install test hood. To save on the number of set-ups, this may be delayed and done in conjunction with 10.4.2.

10.3.5 Repeat measurements described in 10.3.3. If testing a hood with a fixed extractor, this may be delayed and done in conjunction with 10.4.2.

10.4 *Particle Size Collection Efficiency:*

10.4.1 The aerosol sampling sequence for removable grease filters and cartridge filters shall consist of the following steps:

10.4.1.1 *No Device in Hood*—Sample background aerosol twice without generator operating.

10.4.1.2 *Device(s) in Hood*—Sample background aerosol twice without generator operating.

10.4.1.3 *No Device in Hood*—Sample with aerosol generator turned on after sufficient time to reach steady emission following the results of tests described in 8.5.1.

10.4.1.4 Turn aerosol generator off and install device(s) to be tested in hood.

10.4.1.5 *Device(s) in Hood*—Sample with aerosol generator turned on after sufficient time to reach steady emission following the results of tests described in 8.5.1.

10.4.1.6 Turn the aerosol generator off and remove test device(s) from the hood.

10.4.1.7 *No Device in Hood*—Sample with aerosol generator turned on after sufficient time to reach steady emission following the results of tests described in 8.5.1.

10.4.1.8 Repeat 10.4.1.3 – 10.4.1.7 for as many sample sets as necessary to meet data requirements for the reported data.

10.4.1.9 *No Device in Hood*—Sample background aerosol twice without generator operating.

10.4.1.10 *Device(s) in Hood*—Sample background aerosol twice without generator operating

10.4.2 The aerosol sampling sequence for fixed extractors shall consist of the following steps:

10.4.2.1 *Reference Hood, No Device in Hood*—Sample background aerosol without generator operating, 10.4.2.2 *Reference Hood, No Device in Hood*—Sample with aerosol generator turned on after sufficient time to reach steady emission following the results of tests described in 8.5.1.

10.4.2.3 Turn aerosol generator off.

10.4.2.4 Remove reference hood and replace with fixed extractor hood. Care must be taken to insure setup of aerosol generator, ductwork, and aerosol sampling equipment is not disturbed or is setup identical to prior to switching hood.

10.4.2.5 If not done previously, complete differential pressure measurements for 10.3.4 and 10.3.5.

10.4.2.6 *Fixed Extractor Hood Installed*—Sample background aerosol without generator operating.

10.4.2.7 *Fixed Extractor Hood Installed*—Sample with aerosol generator turned on after sufficient time to reach steady emission following the results of tests described in 8.5.1.

10.4.2.8 Turn aerosol generator off.

10.4.2.9 Remove fixed extractor and replace with reference hood. Care must be taken to insure setup of aerosol generator, ductwork, and aerosol sampling equipment is not disturbed or is setup identical to prior to switching hood.

10.4.2.10 *Reference Hood, No Device in Hood*—Sample with aerosol generator turned on after sufficient time to reach steady emission following the results of tests described in 8.5.1.

10.4.2.11 Repeat 10.4.2.1 – 10.4.2.10 (except 10.4.2.5) as many times as necessary to meet data requirements for the reported data.

10.4.2.12 *Reference Hood, No Device in Hood*—Sample background aerosol without generator operating.

10.5 *Penetration:*

10.5.1 The device(s) shall be installed in the test facility for determination of particle penetration as a function of particle size. For the purposes of this test method, penetration P shall be the fraction of particles approaching the device(s) that pass through. The general equation to determine penetration at any particle size shall be:

$$P = \left(\frac{particle\ concentration\ with\ test\ device(s)\ installed}{particle\ concentration\ without\ test\ device(s)\ installed} \right) \quad (3)$$

with the particle concentration measured in the exhaust duct downstream of the device(s) and the particle generator on.

10.5.2 Background counts shall be made before generating test aerosols. The background counts shall be made with no test device(s) installed in the hood.

10.5.3 Start generating the oleic acid aerosol when background counts are complete. Start sampling with no test device(s) installed. Follow the test sequence outlined in 10.4.1. A difference between sampling time with no device(s) installed, T_{wo}, and sampling time with a test device(s) installed, T_w, is allowable.

10.5.4 Aerosol generation shall be turned off and background sampling shall be repeated with no test device(s) installed in the hood after completion of the required penetration sampling sets.

10.5.5 Particle penetration through the test device(s) shall then be calculated in accordance with 11.6.

11. Calculation and Reporting

11.1 Test results shall be reported using the test report format shown in this test method. Figs. 10-13 comprise the complete test report and are examples of acceptable forms. Exact formats are not required, but the report shall include the items shown.

11.2 The summary section of the performance report shall include the following information:

11.2.1 Name and location of the test laboratory.

11.2.2 Date of the test.

11.2.3 Test operator's name(s).

11.2.4 Brand and model number of the particle counting and sizing device.

11.2.5 Grease filter manufacturer's name (or name of the marketing organization, if different from the manufacturer).

11.2.6 How the sample was obtained.

11.2.7 Description of the grease filter, including:

11.2.7.1 Brand and model number,

11.2.7.2 Physical description of construction (for example, single stage, two-stage with prefilter, passive or electrically powered),

11.2.7.3 Face dimensions and depth of each module,

11.2.7.4 Number of modules installed in the hood during each test,

11.2.7.5 Total width of installed modules, and

11.2.7.6 Any other pertinent descriptive attributes.

11.2.8 Operating data as stated by the manufacturer:

11.2.8.1 Test conditions for reporting purposes, airflow rate,

11.2.8.2 Pressure drop at rated airflow rate, and

11.2.8.3 Any other operating data furnished.

11.2.9 Test data:

11.2.9.1 Makeup air temperature and relative humidity,

11.2.9.2 Makeup air barometric pressure,

11.2.9.3 Temperature at sampling point in exhaust duct,

11.2.9.4 Airflow rate through the hood and test filters, and

11.2.9.5 Average griddle surface temperature.

11.2.10 Results of pressure drop testing.

11.2.11 Results of filter efficiency testing:

11.2.11.1 A curve in Fig. 12 format for filter efficiency versus particle size, and

11.2.11.2 A table in Fig. 13 format.

11.3 The calculations and data quality requirements of 11.4 – 11.8 are to be performed separately for each of the particle size bins of the particle counter.

11.4 *Aerosol Generator Output and Background Data Reduction:*

11.4.1 The counts from two samples taken without the test device(s) installed that were taken immediately before and after a test with the test device(s) installed shall be arithmetically averaged to obtain an estimate of what the counts would have been in the exhaust duct without a test device, at the same time when the counts were taken with the test device(s) installed using the following equation:

$$WO_{i,e,t} = \frac{WO_{i,o,t} + WO_{(i+1),o,t}}{2} \quad (4)$$

Page 1 of___

Grease Filter Performance Report Summary

(This report applies to the tested device only)

Laboratory Data

Report No.________________ Test No.________________ Test date________________
Test laboratory____
Address____
Test operator(s)______________________________ Supervisor____________________
Particle counter: Brand____
Model____

Grease Filter Manufacturer's Data

Manufacturer____
Brand______________________________ Model______________________________
Sample obtained from____
Catalog rating: Airflow rate (CFM)____
Pressure Drop (in. H_2O)____
Other operating specifications____

Device Description

Dimensions: height (in.)__________ width (in.)__________ depth (in.)__________
Number of modules installed during test________________________________
Total installed width (in.)____
Physical Description____
Other Attributes____

Test Conditions

Makeup air: temperature (°F)____________________ RH (%)__________________
barometric pressure (in. Hg)________________________________
Exhaust hood airflow rate____
Test aerosol chemical composition________________________________

Pressure Drop Test Results

Pressure drop (in. H_2O)__________________ at (CFM)__________________________

Comments:

FIG. 10 Sample Grease Filter Performance Summary Report

where:

$WO_{i,e,t}$ = the estimated count with no test device(s) installed,
$WO_{i,o,t}$ = the first count measured without a test device, and
$WO_{(i+1),o,t}$ = the second count measured without a test device.

11.4.2 The background counts taken before and after the aerosol generation test shall be arithmetically averaged using the following equations:

$$\overline{WO}_b = \frac{\sum_{i=1 \to n} WO_{i,o,b}}{n} \tag{5}$$

$$\bar{W}_b = \frac{\sum_{i=1 \to n} W_{i.o.b}}{n}$$

where:

$\overline{WO}_b$ = the average of the background counts without a test device, and
$\bar{W}_b$ = the average of the background counts with a test device(s) installed.

11.4.3 The standard deviation of the background counts shall be determined by:

$$\delta_{wo,b} = \sqrt{\frac{\sum_{i=1 \to n} \left(WO_{i,o,b} - \overline{WO}_b\right)^2}{n-1}} \tag{6}$$

$$\delta_{w,b} = \sqrt{\frac{\sum_{i=1 \to n} \left(W_{i,o,b}\ \bar{W}_b\right)^2}{n-1}}$$

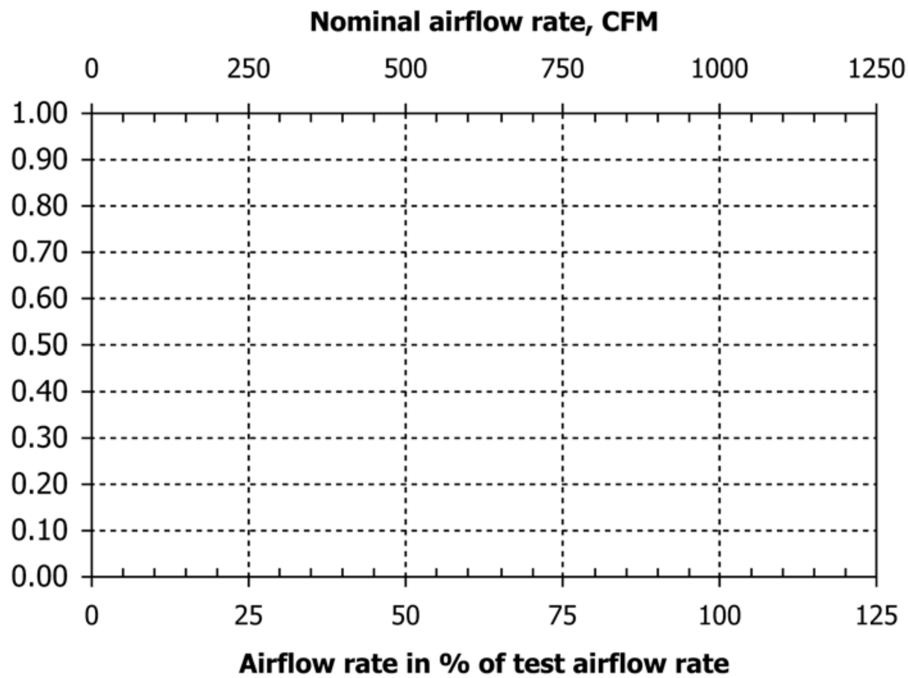

FIG. 11 Airflow Resistance Versus Airflow Rate Through a Grease Filter

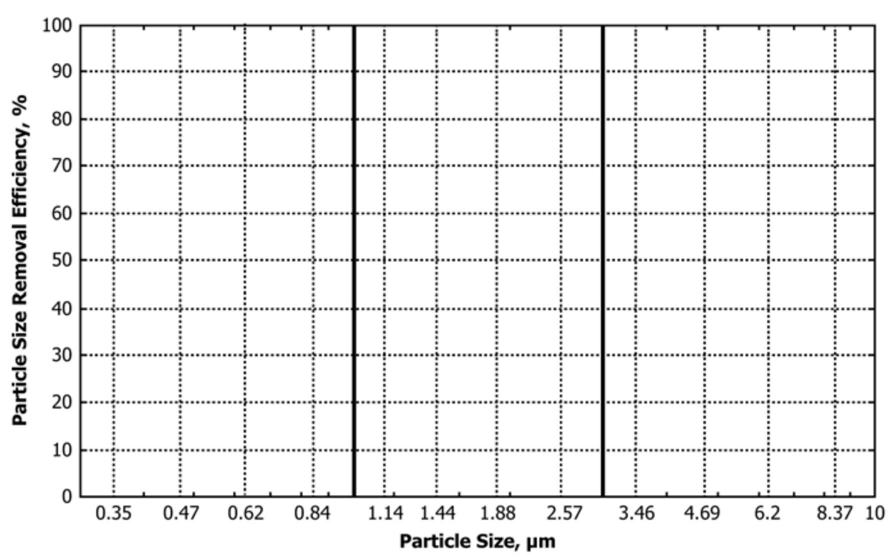

FIG. 12 Particle Removal Efficiency Versus Particle Size for a Grease Filter

where:

$\delta_{wo,b}$ = the standard deviation of the background counts without a test device, and
$\delta_{w,b}$ = standard deviation of the background counts with a test device installed.

11.4.4 The 95 % upper confidence limits of the background counts are determined by

$$\overline{WO}_{b,ucl} = \overline{WO}_b + \delta_{wo,b} \cdot \frac{t}{\sqrt{n}} \tag{7}$$

$$\overline{W}_{b,ucl} = \overline{W}_b + \delta_{w,b} \cdot \frac{t}{\sqrt{n}} \tag{8}$$

$\overline{WO}_{b,ucl}$ *and* $\overline{W}_{b,ucl}$ = the 95 % upper confidence limits of the background counts without and with a test device installed, respectively, and
t = is found by using the *t* distribution chart, Table 6, for a given *n*.

11.5 *Aerosol Count Acceptance Criteria:*

11.5.1 *Maximum Background Counts:*

11.5.1.1 The 95 % upper confidence limit of the background counts with and without the test device installed shall be less than 5 % of the average estimated count without a test device when the aerosol generator is on:

Test Data for Grease Filters					
Size Range No.	Geometric Mean of Particle Size Range, µm	Number of Samples	Average Counts Without Filters	Average Counts With Filters	Calculated Particle Size Efficiency, %
1	0.35				
2	0.47				
3	0.62				
4	0.84				
5	1.14				
6	1.44				
7	1.88				
8	2.57				
9	3.46				
10	4.69				
11	6.20				
12	8.37				

FIG. 13 Test Data Report Form

TABLE 6 *t* Distribution Variable

Number of Samples, *n*	Degrees of Freedom, *v* = *n* – 1	*t*
3	2	4.303
4	3	3.182
5	4	2.776
6	5	2.571
7	6	2.447
8	7	2.365
9	8	2.306
10	9	2.262
11	10	2.228
12	11	2.201
13	12	2.179
14	13	2.160
15	14	2.145
16	15	2.131
17	16	2.120
18	17	2.110
19	18	2.101
20	19	2.093
21	20	2.086
22	21	2.080
23	22	2.074
24	23	2.069
25	24	2.064
26	25	2.060
27	26	2.056
28	27	2.052
29	28	2.048
30	29	2.045
inf.	inf.	1.960

$$\overline{W}_{b.ucl}, \overline{WO}_{b,ucl} < \frac{\sum_{i=1 \rightarrow n} WO_{i,e,c}}{n \cdot 20} \quad (9)$$

11.5.2 *Minimum Average Upstream Counts:*

11.5.2.1 The sum of the estimated counts without a test device shall be 500 in each of the particle size channels. If sufficient numbers of counts are not obtained, the sampling time or aerosol generation rate shall be increased. The aerosol concentration shall not exceed the upper concentration limit of the particle counter as determined by 6.5.4.

11.6 *Penetration Data Reduction:*

11.6.1 The counts from two samples taken without the test device(s) installed that were taken immediately before and after a test with the test device(s) installed shall be arithmetically averaged to obtain an estimate of what the counts would have been in the exhaust duct, without a test device, at the same time when the counts were taken with the test device(s) installed, using the following equation:

$$WO_{i,e,t} = \frac{WO_{i,o,t} + WO_{(i+1),o,t}}{2} \quad (10)$$

where:

$WO_{i,e,t}$ = the estimated count with no test device(s) installed,
$WO_{i,o,t}$ = the first count measured without a test device, and
$WO_{(i+1),o,t}$ = the second count measured without a test device.

11.6.2 The background counts taken before and after the penetration test shall be arithmetically averaged using the following equations:

$$\overline{WO}_b = \frac{\sum_{i=1 \rightarrow n} WO_{i,o,b}}{n} \quad (11)$$

$$\overline{W}_b = \frac{\sum_{i=1 \rightarrow n} W_{i,o,b}}{n}$$

where:

$\overline{WO}_b$ = the average of the background counts without a test device, and
$\overline{W}_b$ = the average of the background counts with a test device(s) installed.

11.6.3 The observed penetration for each particle size shall be calculated for each sample set with and without a test device using the observed count with a test device installed, the count without a test device, the average background count with a test device, the average background count without a test device, the sampling time without a test device, and the sampling time with a test device using the following equations:

$$P_{i,o} = \frac{W_{i,o,t} - \overline{W}_b}{WO_{i,e,t} - \overline{WO}_b} \cdot \frac{T_{wo}}{T_w}, \text{ if } \overline{W}_{b,ucl} \leq 0.05 \frac{\sum_{i=1 \to n} WO_{i,o,wo}}{n} \left(\frac{T_w}{T_{wo}} \right) \quad (12)$$

$$P_{i,o} = \frac{W_{i,o,t}}{WO_{i,e,t}} \cdot \frac{T_{wo}}{T_w}, \text{ if } \overline{W}_{b,ucl} > 0.05 \frac{\sum_{i=1 \to n} WO_{i,o,wo}}{n} \left(\frac{T_w}{T_{wo}} \right) \quad (13)$$

where:

$P_{i,o}$ = the observed penetration,
T_{wo} = the sampling time without a test device, and
T_w = the sampling time with a test device installed.

11.6.4 The observed penetrations shall be arithmetically averaged to determine an average observed penetration value using the following equation:

$$\bar{P}_o = \frac{\sum_{i=1 \to n} P_{i,o}}{n} \quad (14)$$

where:

$\bar{P}_o$ = the average observed penetration value, and
n = the number of samples.

11.6.5 The standard deviation of the observed penetration shall be calculated as follows:

$$\delta_t = \sqrt{\frac{\sum_{i=1 \to n} \left(P_{i,o} - \bar{P}_o \right)^2}{n-1}} \quad (15)$$

where:

δ_t = the standard deviation of the observed penetration.

11.6.6 The 95 % confidence limits of the penetration shall be determined by:

$$\bar{P}_{lcl} = \bar{P}_o - \delta_t \cdot \frac{t}{\sqrt{n}} \quad (16)$$

$$\bar{P}_{ucl} = \bar{P}_o + \delta_t \cdot \frac{t}{\sqrt{n}} \quad (17)$$

where:

$\bar{P}_{lcl}$ *and* $\bar{P}_{ucl}$ = the lower and upper confidence limits, respectively, of the final penetration, and
t = is found by using the t distribution chart, Table 6, for a given n.

11.7 *Penetration Data Acceptance Criteria:*

11.7.1 The number of sample runs shall be at least three and sufficient to satisfy the following conditions:

$$\delta_t \cdot \frac{t}{\sqrt{n}} \leq 0.07 \cdot \bar{P}_o \text{ or} \leq 0.05, \quad (18)$$

whichever is greater, for channel numbers 1 − 8

$$\delta_t \cdot \frac{t}{\sqrt{n}} \leq 0.15 \cdot \bar{P}_o \text{ or} \leq 0.05, \quad (19)$$

whichever is greater, for channel numbers 9 and 10

$$\delta_t \cdot \frac{t}{\sqrt{n}} \leq 0.20 \cdot \bar{P}_o \text{ or} \leq 0.05, \quad (20)$$

whichever is greater, for channel numbers 11 and 12

where the channel number and OPC size ranges are given in Table 1. This requirement shall be satisfied before moving on to subsequent sample sets. If the above condition cannot be met, the upper confidence limit for penetration, $\bar{P}_{ucl}$, shall be used to calculate efficiency for that particle size range.

11.7.2 *Maximum Background Counts:*

11.7.2.1 The 95 % upper confidence limit of the background counts determined for the penetration tests, with and without the test device installed, shall be less than 5 % of the average estimated count without a test device when the aerosol generator is on:

$$\overline{W}_{b,ucl}, \overline{WO}_{b,ucl} < \frac{\sum_{i=1 \to n} WO_{i,e,c}}{n \cdot 20} \quad (21)$$

11.7.3 *Minimum Average Upstream Counts*—The sum of the estimated counts without a test device shall be 500 in each of the particle size channels. If sufficient numbers of counts are not obtained, the sampling time or aerosol generation rate shall be increased. The aerosol concentration shall not exceed the upper concentration limit of the particle counter as determined by 6.5.4.

11.8 *Capture Efficiency:*

11.8.1 The particle capture efficiency for each particle size range is the fraction of particles that are captured by the filter. The general equation is:

$$\text{capture efficiency} = \quad (22)$$

$$\left(1 - \frac{\text{particle concentration with test device(s) installed}}{\text{particle concentration without test device(s) installed}} \right) \times 100$$

$$= \left(1 - \bar{P}_o \right) \times 100$$

where:

$\bar{P}_o$ = the average observed penetration for a given particle size range.

12. Precision and Bias

12.1 *Precision:*

12.1.1 *Repeatability (within laboratory, same operator and equipment)*—The repeatability for each reported parameter is being determined.

12.1.2 *Reproducibility (multiple laboratories)*—The interlaboratory precision of the procedure in this test method for measuring each reported parameter is being determined.

12.2 *Bias*—No statement can be made concerning the bias of the procedures in this test method because there are no accepted reference values for the parameters reported.

13. Keywords

13.1 cooking; efficiency; effluent; filter; grease; kitchen; particle; pressure drop; test method

APPENDIXES

(Nonmandatory Information)

X1. COMMENTARY

INTRODUCTION

The steering committee that consisted of representatives from commercial kitchen equipment manufacturers and users met several times during the development of this test method and reached consensus on several issues including: testing new/clean filters, grease particle capture vs. particle size, location of sampling, particle size range, effluent challenge, use of a griddle, and round robin testing. Each of these is discussed in more detail below and in the University of Minnesota report.

X1.1 *Testing New Filters:*

X1.1.1 Although the pressure drop and grease capture efficiency will change as filters become loaded with grease, this test method only addresses the performance of new, clean filters. The effect of filter loading with grease and subsequent cleaning may be the subject of a subsequent test method.

X1.2 *Grease Particle Collection:*

X1.2.1 Cooking effluent that enters an exhaust hood usually contains grease in both particulate and vapor phases. There may also be particles of other composition and additional components such as water. Filters are expected to perform differently on these different components of cooking effluent. The intent of this test method is to determine the grease particle capture efficiency of grease particles only. The capture and removal of other constituents of cooking effluent such as grease vapor is not included here and may be the subject of a subsequent test protocol.

X1.3 *Filter Test Facility:*

X1.3.1 The choice of filter test facility was based on making the filter(s) resemble the installation and operation as similar to actual use in a commercial kitchen as possible.

X1.3.1.1 Installation of grease filters under test in a canopy hood would provide an installation nearly identical to what would be found in the field

X1.3.1.2 The air leakage around the filters would be similar to that found in an actual commercial kitchen application.

X1.3.1.3 The slope of the filters would be the same as in the actual application.

X1.3.1.4 The airflow pattern through the filters would be as close as possible to what the filters would experience in an actual kitchen.

X1.3.2 The use of a canopy hood arrangement would allow the testing of individual filter modules or a complete hood-grease removal system.

X1.3.3 The pressure drop through the filter(s) under test will be more realistic than mounting individual filter modules in a test duct.

X1.4 *Test Protocol:*

X1.4.1 The particle collection efficiency is determined by sampling the aerosol in the exhaust duct with and without the filter(s) installed. The main reason for this choice of sampling protocol is that it is nearly impossible to accurately measure the aerosol concentration before the filter with the choice of test facility (filter(s) mounted in a canopy hood). The samples taken in the exhaust duct reported in the University of Minnesota report were found to be well-mixed so that a single point sample accurately represents the total aerosol concentration in the exhaust duct.

X1.4.2 Taking both samples at the same location in the exhaust duct requires a single isokinetic sampling probe, a single section of transport tubing and a single particle counter. Bias of the measurement system will cancel out when comparing measurements made with and without the filter(s) installed.

X1.5 *Selection of the Particle Size Range:*

X1.5.1 The particle size range (0.3 to 10.0 µm) and the particle size bins (see Table 1) were selected to coincide with ASHRAE Standard 52.2. The ASHRAE standard method of test is widely used for ventilation filters. Organizations that currently have the particle instrumentation capable of meeting the requirements of this test method will also be able to meet the present standard.

X1.5.2 The upper size limit of 10 µm was chosen primarily because well-designed grease filters should be able to remove nearly all particles larger than 10 µm. Therefore it should not be necessary to quantify filter efficiency for particles larger than this. It is also difficult to generate sufficient numbers of large particles with a typical aerosol generator to meet the statistical data requirements of this test method. Transport of particles larger than 10 µm through sampling lines is also difficult with significant losses.

X1.5.3 The primary reason for selecting 0.30 µm as the lower limit was to permit the test facility to choose from a wide variety of commercially available off-the-shelf particle counters. Expensive or custom-built particle counters are not needed for the tests.

X1.6 *Selection of Oleic Acid as the Test Aerosol:*

X1.6.1 Particulate oleic acid was chosen as the test aerosol as a surrogate for real cooking aerosol. It is a readily available substance, low cost, non-hazardous, and is a significant component of beef fat and comprises nearly 100 % of olive oil.

X1.6.2 Oleic acid aerosol is liquid in form and more closely represents the behavior of liquid grease particles in cooking effluent than solid particles that may bounce from collecting surfaces.

X1.6.3 Oleic acid can be diluted with isopropyl alcohol to assist the aerosol generation process by reducing the liquid feed viscosity. Sufficient dilution will also reduce the resulting aerosol mass median diameter so different aerosol size distributions can be generated using the same generator.

X1.7 *Round Robin Testing:*

X1.7.1 The initial plan was to conduct round robin testing before adoption of a standard method of test. However, the steering committee decided against it for the following reasons:

X1.7.1.1 The method is based on a thorough research project conducted at the University of Minnesota and follows the recommendations made in their final report.

X1.7.1.2 Extensive data quality criteria are included in the standard.

X1.7.1.3 Even if a number of laboratories could be convinced to build the test facility before the standard is accepted and published, and if they were ready to start testing immediately, a round robin would delay the adoption of a standard by at least two years.

X2. TEST PROCEDURE SUGGESTIONS

X2.1 *Introduction:*

The ability to generate, sample, and measure particles over the 0.30 to 10 μm diameter size range is critical to the successful performance of a grease filter particle removal efficiency test. The design of an aerosol generation system and an aerosol sampling system believed to meet the required performance criteria of this test method is described in this Appendix. These designs are based on those developed in the Particle Technology Laboratory at the University of Minnesota during the development of this test method. This test method has intentionally made the design of the system elements discretionary so as not to hinder the development and implementation of improved methods.

X2.2 *Particle Counter:*

X2.2.1 The aerosol concentrations in the University of Minnesota study were measured with an OPC using a white-light illumination source and a wide collection angle for the scattered light. The OPC's sampling rate was 0.10 cfm.

X2.2.2 One minute samples were obtained by the OPC. Subsequently, the data were downloaded to a computer were they were stored in data files for analysis.

X2.3 *Aerosol Generation:*

X2.3.1 The test aerosol used in the University of Minnesota study consisted of liquid oleic acid particles that were generated from a 2 + 1 solution of oleic acid and isopropyl alcohol.

X2.3.2 The test aerosol was formed by passing liquid solution through a modified TSI Model 3450 Vibrating Orifice Aerosol Generator (VOAG). The vibrating orifice was replaced by an Alltech nebulizer. The syringe pump used for the liquid feed was found to be unstable at the high flowrates used so it was replaced with liquid feed from a small tank supplied with regulated compressed air. Clean, dry compressed air was supplied around the nozzle as in the VOAG design to dilute the aerosol and minimize agglomeration of the particles. The aerosol was then passed through a charge neutralizing column that contained six NRD Model 2U500 Staticmaster Po210 (500 μCi) radioactive sources. Previous tests performed in ASHRAE 1033-RP indicated that six strips were sufficient to bring the aerosol very close to a Boltzmann charge distribution. The resulting aerosol covered the particle size range of interest (0.3 to 10 μm) with sufficient concentration to produce concentrations similar to those produced when cooking hamburger but not large enough to overload the particle counter when a diluter with a 50 + 1 dilution ration was used upstream of the OPC.

X2.4 *Aerosol Sampling System:*

X2.4.1 The sampling lines must be carefully designed and constructed to minimize the loss of particles. In the University of Minnesota study, the aerosol isokinetic sampling inlet was formed from a stainless steel tube of 0.554 in. I.D. and 0.630 in. O.D. with the inlet located at the centerline of the exhaust duct. The tube had a sharp-edged inlet followed by a 90-degree bend with an inner radius of curvature of 4.0 in. just downstream from the inlet. A second, smaller isokinetic probe was inserted into the portion of this tube that protruded from the exhaust duct. The second probe was formed from a stainless steel tube of 0.170 in. I.D. and 0.245 in. O.D. This also had a sharp-edged inlet and passes the aerosol to be measured directly into the aerosol diluter.

X3. SAMPLE CALCULATIONS

X3.1 *Introduction*—This section provides a sample of data collected during an efficiency test and shows how these data have been analyzed to provide filtration penetration and efficiency results versus particle size. The data were obtained using a typical grease baffle filter as the test filter.

X3.2 *Raw Particle Count Data*—Table X3.1 shows the particle number count data obtained during a test using an optical particle counter. Note that oleic acid particle generator produces a wide range of particle sizes covering the entire range desired and that the number of particles increases rapidly as their size diminishes.

X3.3 *Computed Results*:

X3.3.1 Table X3.2 shows the estimated counts expected without the filter during the time when the data with the filter in place were obtained. These are arithmetic averages of the counts taken before and after each test with the filter in place.

X3.3.2 Table X3.3 shows the particle penetration through the filter versus test number and particle size.

X3.3.3 Table X3.4 shows the average particle penetration through the filter as a function of particle size. The results have been computed by averaging the results shown in Table X3.3. The collection efficiency is also shown that corresponds to the average penetration. The collection efficiency is plotted in Fig. X3.1. The standard deviation of the penetration is given as are the lower and upper confidence limits of the penetration results.

X3.3.4 Acceptance criteria are given in Table X3.5. The penetration error ratio for each particle size in this example is well below the maximum allowed.

TABLE X3.1 Raw Particle Count Data From Tests on a Grease Baffle Filter

Size Range, µm	Bg Count	Without Baffles	With Baffles	Without Baffles	With Baffles	Without Baffles	With Baffles	Without Baffles	With Baffles	Without Baffles	With Baffles	Without Baffles	Bg Count	Mean Particle Size, µm
0.30–0.40	1180	1 750 000	1 710 000	1 750 000	1 730 000	1 740 000	1 750 000	1 725 000	1 725 000	1 775 000	1 730 000	1 760 000	11 920	0.35
0.40–0.55	185	1 133 000	1 101 500	1 140 900	1 123 500	1 133 500	1 120 500	1 123 500	1 111 005	1 117 250	1 099 500	1 132 150	6560	0.47
0.55–0.70	35	603 500	580 400	599 200	591 500	599 000	588 100	589 900	580 300	584 550	573 900	586 800	3040	0.62
0.70–1.00	30	512 500	492 650	508 250	511 900	513 250	506 150	505 950	495 490	500 200	486 710	499 400	2645	0.84
1.00–1.30	5	220 800	210 400	210 350	211 400	211 700	204 550	204 550	201 020	200 400	192 400	199 600	1225	1.14
1.30–1.60	10	177 090	169 720	166 720	159 500	159 200	155 250	153 800	149 505	148 400	145 250	148 200	680	1.44
1.60–2.20	5	166 895	152 800	153 300	149 500	148 100	142 050	142 650	136 110	134 010	133 750	136 650	500	1.88
2.20–3.00	0	63 000	60 400	59 900	59 100	59 800	56 825	56 510	54 800	55 500	53 350	54 015	110	2.57
3.00–4.00	0	15 265	14 930	14 600	15 360	15 595	14 920	14 775	14 370	14 110	13 580	13 680	25	3.46
4.00–5.50	0	9960	9290	9495	9100	9210	8675	8525	8230	8255	8020	8240	5	4.69
5.50–7.00	0	5180	4725	5025	4566	4740	4190	4745	4125	4440	4035	4320	0	6.20
7.00–10.0	0	1590	1360	1630	1300	1400	1240	1485	1140	1325	1120	1200	0	8.37

TABLE X3.2 Estimated Particle Counts Without the Filter During the Time the Filter Tests Were Conducted

Mean Particle Size, µm	$WO_{1,e,t}$	$WO_{2,e,t}$	$WO_{3,e,t}$	$WO_{4,e,t}$	$WO_{5,e,t}$
0.35	1 750 000	1 745 000	1 732 500	1 750 000	1 767 500
0.47	1 136 950	1 137 200	1 128 500	1 120 375	1 124 700
0.62	601 350	599 100	594 450	587 225	585 675
0.84	510 375	510 750	509 600	503 075	499 800
1.14	215 575	211 025	208 125	202 475	200 000
1.44	171 905	162 960	156 500	151 100	148 300
1.88	160 098	150 700	145 375	138 330	135 330
2.57	61 450	59 850	58 155	56 005	54 758
3.46	14 933	15 098	15 185	14 443	13 895
4.69	9728	9353	8868	8390	8248
6.20	5103	4883	4743	4593	4380
8.37	1610	1515	1443	1405	1263

TABLE X3.3 Particle Penetration Through the Filter Versus Test and Particle Size

Mean Particle size, µm	$P_{1,o}$	$P_{2,o}$	$P_{3,o}$	$P_{4,o}$	$P_{5,o}$
0.35	0.977	0.991	1.010	0.986	0.979
0.47	0.969	0.988	0.993	0.992	0.978
0.62	0.965	0.987	0.989	0.988	0.980
0.84	0.965	1.002	0.993	0.985	0.974
1.14	0.976	1.002	0.983	0.993	0.962
1.44	0.987	0.979	0.992	0.989	0.979
1.88	0.954	0.992	0.977	0.984	0.988
2.57	0.983	0.987	0.977	0.978	0.974
3.46	1.000	1.017	0.983	0.995	0.977
4.69	0.955	0.973	0.978	0.981	0.972
6.20	0.926	0.935	0.884	0.898	0.921
8.37	0.845	0.858	0.860	0.811	0.887

TABLE X3.4 Computed Penetration Results, Capture Efficiency, Standard Deviation and Confidence Limits

Mean Particle Size, µm	Average Obs. Penetration $\bar{P}_o$	Ccapture Efficiency, E, %	Standard Dev. Penetration, $\bar{o}_t$	Confidence Limits Penetration	
				P_{lcl}	P_{ucl}
0.35	0.989	1.14	0.013	0.972	1.005
0.47	0.984	1.62	0.010	0.971	0.997
0.62	0.982	1.80	0.010	0.969	0.995
0.84	0.984	1.61	0.015	0.966	1.002
1.14	0.983	1.69	0.015	0.964	1.002
1.44	0.985	1.46	0.006	0.978	0.993
1.88	0.979	2.08	0.015	0.961	0.998
2.57	0.980	1.99	0.005	0.974	0.986
3.46	0.994	0.56	0.016	0.975	1.014
4.69	0.972	2.81	0.010	0.959	0.984
6.20	0.913	8.72	0.021	0.886	0.939
8.37	0.852	14.78	0.028	0.818	0.886

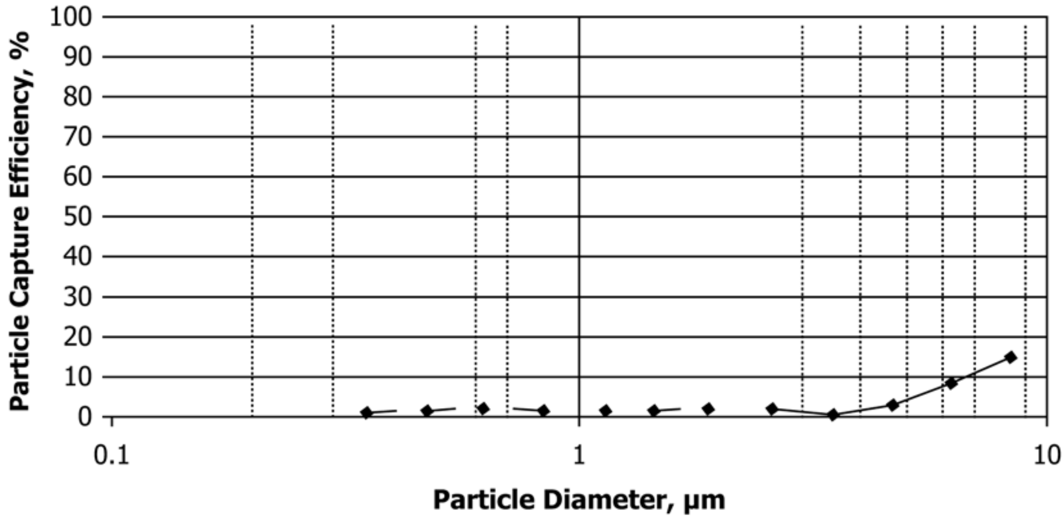

FIG. X3.1 Particle Capture Efficiency Versus Particle Size

TABLE X3.5 Penetration Error Ratio Computed and Maximum Allowed for Each Particle Size

Mean Particle Size, µm	Acceptance Criteria	
	$\sigma_c \cdot t/\sqrt{n}$	Maximum Allowed
0.35	0.02	0.07
0.47	0.01	0.07
0.62	0.01	0.07
0.84	0.02	0.07
1.14	0.02	0.07
1.44	0.01	0.07
1.88	0.02	0.07
2.57	0.01	0.07
3.46	0.02	0.15
4.69	0.01	0.15
6.20	0.03	0.18
8.37	0.03	0.17

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