Method for Measuring Performance of Portable Household Electric Room Air Cleaners

AHAM AC-1-2013

ASSOCIATION OF HOME APPLIANCE MANUFACTURERS

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PREFACE

The Association of Home Appliance Manufacturers (AHAM) develops standards in accordance with AHAM's "Policy and Procedures Governing Technical Standards" which states:

> "AHAM Standards shall be in the best interest, mutually, of consumers who use appliances, the industries which provide and service appliances, and other interested parties. They shall relate to actual use conditions, be technically and scientifically sound."

Use or observance of AHAM standards is voluntary.

This standard contains test procedures which may be applied to any brand or model of portable household electric room air cleaners within the stated confines of the standard's limits of measurability for measuring performance. Results of tests in accordance with this standard may be publicly stated.

With regard to safety, AHAM recommends that all appliance products - both major and portable appliances - manufactured or marketed in the United States be submitted to an appropriate independent Nationally Recognized Testing Laboratory for inspection and listing in conformance with the safety standards and procedures followed by such laboratories. The relevant standards for portable household electric room air cleaners are UL 867, "Standard for Electrostatic Air Cleaners" and UL 507, "Standard for Fans."

The annexes to this standard are included for informational purposes only unless the annexes are noted as normative.

AHAM welcomes comments and suggestions regarding this standard. Any standard may be reviewed and improved as needed. All standards must be updated or reconfirmed at least every five years. Any interested party, at any time, may request a change in an AHAM standard. Such request should be addressed to AHAM's President, and should be accompanied by a statement of reason for the request and a suggested alternate proposal.

This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of any regulatory limitations prior to use.

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1. PURPOSE

This standard method establishes uniform, repeatable procedures and standard methods for measuring specified product characteristics of portable household electric room air cleaners.

The standard methods provide a means to compare and evaluate different brands of portable household electric room air cleaners regarding characteristics significant to product use.

The standard methods of measurement are not intended to inhibit improvement and innovation in product testing, design or performance.

2. SCOPE

This standard method applies to portable household electric room air cleaners as defined in Section 3.

This standard method includes definitions and safety characteristics of portable household electric room air cleaners of the types indicated.

This standard method measures the relative reduction by the air cleaner of particulate matter suspended in the air in a specified test chamber. It also prescribes a method for measuring the operating power and standby power of the air cleaner.

This standard method has defined limits of measurability based on the statistical accuracy of the methods. Based on a 95% confidence limit (2 standard deviations), a CADR cannot be distinguished between zero (0) and a CADR rating less than those CADR limits shown below. Therefore, the standard only applies to air cleaners with minimum CADR ratings of:

Dust	CADR = 10 cfm
Cigarette smoke	CADR = 10 cfm
Pollen	CADR = 25 cfm

The maximum CADR values are determined based on theoretical maximum limits. The theoretical maximum limits are determined by the maximum number of initial available particles, the acceptable minimum number of available particles, an average background natural decay rate (from statistical study), the size of the test chamber, and the available minimum experiment time. CADR values for dust and cigarette smoke greater than those listed will not have the necessary statistical data required by this method. CADR values for pollen greater than those listed will not have the necessary statistical data required by this method. CADR values for pollen approaching that listed are normally determined by pooling of the test value data determined under this method. Therefore, the standard only applies to air cleaners with maximum CADR ratings of:

Dust	CADR = 400 cfm
Cigarette smoke	CADR = 450 cfm
Pollen	CADR = 450 cfm

The precision of the Standard as based on a 0 CADR air cleaner expressed as 2 standard deviation limits (95%) are:

Dust	CADR = ± 10 cfm
Cigarette Smoke	CADR = ± 10 cfm
Pollen	CADR = ± 25 cfm

3. DEFINITIONS

3.1 Portable Household Electric Room Air Cleaner ("Air Cleaner")

An electric appliance with the function of removing particulate matter from the air and which can be moved from room to room. Herein referred to as "air cleaner."

3.1.1 Air Cleaner - Floor Type

Floor type air cleaners are designed to stand alone on the floor of a room and are designated as stand-alone floor models by the manufacturer. Appliances of this type are tested on the floor facing the test window as close to the center of the test chamber as possible.

3.1.2 Air Cleaner - Table Type

Table type air cleaners are designed to set on a table or counter by the manufacturer. Appliances of this type are tested on the table stand facing the test window at the center of the test chamber.

3.1.3 Air Cleaner - Wall Type

Wall type air cleaners are designed either to attach to a wall and are designated as wall mountable by the manufacturer or as a plug-in air cleaner. A wall type air cleaner must include appropriate wall mounting brackets or specifically designated instructions to mount the air cleaner integrally to the wall (i.e. not a shelf). Appliances of this type are tested on the wall mount stand facing the test window placed at the center of the test chamber (refer to Annex G).

3.1.4 Air Cleaner - Combination Type

Combination type air cleaners are designed to operate in one or more orientations/positions (floor, table, wall) as designed by the manufacturer. A combination type air cleaner may be tested at the center of the test chamber facing the test window on the floor, table, or wall mount stand, according to how it has been designated by the manufacturer (See 3.1.1, 3.1.2 and 3.1.3).

3.1.5 Air Cleaner - Ceiling Type

Air cleaner appliances designed to be mounted on the ceiling are considered outside the scope of this method as defined in Section 3. Uniform testing practices and statistical examination of such appliances have not been conducted.

3.1.6 Air Cleaner - Plug-In Type

A fixed location air cleaner directly connected to an electric receptacle (outlet) by means of direct plug-in (no electric cord). Appliances of this type are tested at the lower level electrical receptacle of the plug-in type test stand facing the test window as shown in Annex G.

3.2 Design Characteristics of Portable Household Electric Room Air Cleaners

3.2.1 Fan with Filter

Air cleaners that operate with an electrical source of power and which contain a motor and fan for drawing air through a filter media.

3.2.2 Fan and Electrostatic Plates

Air cleaners that operate with a fan and incorporate electrically charged plates or wires to electrostatically collect particulate matter. Such devices may include a filter(s).

3.2.3 Fan Filter with Ion Generator

Air cleaners that incorporate an ion generator in addition to a fan and filter.

3.2.4 Ion Generator

Air cleaners that incorporate an ion generator only.

3.2.5 Hybrid

Any air cleaner employing a combination of the above definitions of fan with filter, electrostatic plate/wire, and ion generator.

3.2.6 Other Types

A device that has the stated capability to reduce the concentration of particulate matter in a room. Such devices do not have to contain a fan and can incorporate any of the particle removal methods noted above.

3.3 Test Particulate Matter

3.3.1 Cigarette Smoke

Smoke produced by burning cigarette tobacco with air forced through the cigarette's filter having particle sizes detected from 0.10 µm to 1.0 µm diameter.

3.3.2 Air Cleaner Fine Fraction Test Dust

Commercially available test dust with particle sizes detected from 0.5 µm to 3.0 µm.

3.3.3 Pollen

Particulate matter naturally occurring from plants. The pollen to be used is Paper Mulberry Pollen (non-defatted) with a particle size range of 5 µm to 11 µm, including fragments.

3.4 Test Chamber

The room size chamber for determining performance in removing particulate matter from the air. (The specifications for the AHAM chamber are in Annex A.)

3.5 Air Circulating Equipment

3.5.1 Ceiling mixing fan

A high volume ceiling fan used to mix the test chamber during contaminant aerosol generation.

3.5.2 Recirculation Fan

A fan capable of producing between 300 and 400 cfm and used for the purpose of maintaining a homogeneous environment within the test chamber (as specified in Annex A).

3.6 Particulate Matter Removal

The reduction of particle number concentration in air due to the operation of the air cleaner.

3.7 High Efficiency Particulate Air (HEPA) Filter

An air filter with greater than or equal to 99.97% removal of dioctyl phthalate at 0.3 μm diameter. NOTE: The fractional efficiency of such filters can be verified using Mil-Std-282 or IEST-RP-CC007.1

3.8 Aerosol Generator

A device that produces and disseminates liquid or solid particles that are suspended in air.

3.8.1 Cigarette Smoke Generator

An aerosol generator that disseminates test cigarette smoke with particle sizes specified in Section 3.3.1 into the air.

3.8.2 Dust Generator

An aerosol generator that disseminates test dust with particle sizes specified in Section 3.3.2 into the air.

3.8.3 Pollen Generator

An aerosol generator that disseminates test pollen with particle sizes specified in Section 3.3.3 into the air.

3.9 Cigarette Humidity Chamber

A chamber able to maintain a temperature of 39 ^{o}F ± 3.6 ^{o}F (4^{o}C ± 2^{o}C) and relative humidity of (50 ± 10) %, for the long-term storage of test cigarettes

3.10 Particle Number Concentration

Number of particles per cubic centimeter of room air.

3.10.1 Initial Concentration

The particulate concentration at the start of test time (t=2 for smoke test, t=0 for dust or pollen test).

3.10.2 Background Concentration

The particulate concentration in the test chamber before the particulate is introduced to the chamber.

3.11 Aerosol Spectrometer

Device for measuring particle size distribution in room air (See Annex A).

3.12 Cigarette Smoke Diluter

Device for reducing the concentration of cigarette smoke by a known factor to a concentration suitable for instrument measurement.

3.13 Natural Decay

The reduction of particulate matter due to natural phenomena in the test chamber: principally agglomeration, surface deposition (including sedimentation), and air exchange.

3.14 Clean Air Delivery Rate (CADR)

The measure of air cleaner performance by this test procedure Clean Air Delivery Rate (CADR) is defined as the measure of the delivery of contaminant free air, within the defined particle size range, by an air cleaner, expressed in cubic feet per minute (cfm). Clean Air Delivery Rates are the rates of contaminant reduction in the test chamber when the air cleaner is turned on, minus the rate of natural decay when the air cleaner is not running, multiplied by the volume of the test chamber as measured in cubic feet (See Section 8.5). CADRs values are always the measurement of an air cleaner performance as a complete system, and they have no linear relationship to air movement per se or to the characteristics of any particular particle removal methodology.

3.15 Room Size

Maximum suggested room size for an air cleaner. The room size is determined by mathematical modeling of steady state and is based on the CADR requirement to remove 80% of cigarette smoke particles between 0.1 and 1.0 microns on a steady-state (continuous) basis. See 8.6 and Annex E.

4. GENERAL CONDITIONS FOR MEASUREMENT

Conduct measurements under the following conditions:

4.1 Electrical Supply

Standard frequency and voltage for the CADR testing and operating power test are listed under 4.1.1 and 4.1.2. Other frequencies and voltages may be used to produce CADR values. The specific electrical supply conditions shall be concurrently reported with the applicable CADR values.

NOTE: Refer to Section 9 for the Measurement of Operating Power Test.

4.1.1 Frequency

(60±1) Hertz

4.1.2 Voltage

Operate air cleaner at (115 ± 1) Volts.

NOTE: Refer to Section 10 for the Voltage requirements for the Measurement of Standby Power Test.

4.2 Test Chamber Ambient Temperature

Test Chamber ambient temperature is to be (21 ± 3)^{O}C [(70 ± 5)^{O}F] with a relative humidity (RH) of (40 ± 5)% for CADR and the Measurement of Operating Power tests.

NOTE: Refer to Section 10 for the Temperature requirements for the Measurement of Standby Power Test.

4.3 Test Chamber Air Exchange Rate

The test chamber air exchange rate is to be less than 0.03 air changes per hour (ACH) as determined by ASTM E 741 (*Standard Test Method for Determining Air Change in a Single Zone by Means of a Tracer Gas Dilution*) or an equivalent method.

4.4 Test Chamber Particulate Concentrations

4.4.1 Measurability

The acceptable range of particle concentrations for the initial test condition (time (t) =2 minutes for cigarette smoke, t=0 minutes for dust or pollen) are:

(See Appendix H)

Cigarette Smoke: 24,000 to 35,000 particles/cc (diluter may be required)

Sampling period, (20 sec. @ 0.06 liter/min ± 5 %)

Dust: 200 to 400 particles/cc

Sampling period, (20 sec. @ 1 liter/min ± 5 %)

Pollen: 4 to 9 particles/cc

Sampling period, (20 sec. @ 1 liter/min ± 5 %)

NOTE: Use of a particle counter with different flow rates than the ones specified above is acceptable as long as the particle counter provides equivalent performance characteristics.

The lower limit of instrument measurability is based on a minimum of 10 particle counts and is defined by the practical counting limits of particle measuring instrumentation. These are:

Dust	0.03 particles/cc
Cigarette smoke	20 particles/cc
Pollen	0.03 particles/cc

4.4.2 Test Chamber Background Concentration

The allowable concentration of particulate matter in the test chamber prior to the introduction of the test particulate. This concentration is not to be greater than the lower limit of instrument measurability. (If the instrument's measurability lower limit cannot readily be achieved, further test chamber cleaning procedures shall be performed.)

4.5 Chamber Equipment

The recirculation fan is to be operated throughout all tests in Sections 5, 6, and 7. See Annex A for proper positioning of the recirculation fan.

4.6 Test Equipment Preparation

4.6.1 Check contaminant generating, measuring and recording instruments, and data processing equipment for readiness per manufacturer's instructions (See Annex C).

4.6.2 Air cleaner is installed per manufacturer's instructions, placing the air cleaner (or test fixture containing the air cleaner) in the center of the test chamber, facing the test window, positioned with its air discharge as close as possible to the test chamber center. For air cleaners that discharge air in a specific direction, the air discharge shall not be pointed toward the particle monitors. If manufacturer's instructions do not specify (and air cleaner is not a floor model), place the air cleaner on the table for test. [Refer to Section 3.1 for positioning of specify types of air cleaners in the test chamber.] Air cleaners with multi-level performance fan settings are typically adjusted to the highest air cleaning mode setting for test. Other performance settings shall be concurrently reported with the applicable CADR values (See Annex C).

5. TEST PROCEDURE FOR DETERMINING PERFORMANCE ON CIGARETTE SMOKE.

To determine the performance on cigarette smoke, perform the test procedures prescribed in Sections 5.1 and 5.2 sequentially during the same test period (Annex C, III.A). An appropriate cigarette smoke sample diluter (see Annex A) is to be used with the cigarette smoke monitor.

5.1 Natural Decay Measurement

5.1.1 Place the air cleaner to be tested in the test chamber in accordance with Section 4.6.2 and set the air cleaner controls to the conditions for test. Test for proper operation, then shut off with switch external to test chamber.

5.1.2 Operate the ceiling mixing fan and create a log file for the run.

5.1.3 Using the test chamber HEPA filter, allow the test chamber air to clean until the background concentration in the size range of 0.1 μm to 1.0 μm reaches a concentration of less than 20 particles/cc. Simultaneously operate the environmental control devices until the test chamber conditions (temperature and RH) are as specified in Section 4.2.

5.1.4 Procedure

5.1.4.1 When an acceptable test chamber background concentration (particle number concentration) is achieved (as indicated in Section 5.1.3) record the background concentration, turn off the test chamber environmental control system (humidifiers, HEPA filter, blowers, supply dampers, and return dampers.)

5.1.4.2 Immediately light, then place one standard cigarette obtained from the cigarette humidity chamber in the cigarette smoke generator, seal generator, open valve to test chamber, and turn on 4-6 scfh air supply to the cigarette generator to provide the required initial concentration (24,000 to 35,000 particles/cc as noted in Section 4.4.1).

NOTE: It should take approximately 45 seconds to reach the required initial concentration.

5.1.4.3 Turn off air supply and close test chamber valve.

5.1.4.4 Mix cigarette smoke for one minute after the initial concentration has been reached, then turn off ceiling mixing fan. The recirculation fan will continue to operate for the duration of the test.

5.1.5 Three minutes after turning off ceiling mixing fan, begin to acquire the cigarette smoke particulate concentration. This test point is the initial concentration (t=2 minutes). If the cigarette smoke concentration is not within the initial limits (refer to Section 4.4.1), terminate the run.

5.1.6 Acquire particle concentration data at one-minute intervals 20 minutes. A minimum of nine data points having particle concentrations greater than the lower limit of instrument measurability are required.

5.1.7 Record the average RH and temperature of the test chamber during the test period. Values outside the limits in Sections 4.2 and 4.3 invalidate the run.

5.1.8 Calculate the decay constant for cigarette smoke per Section 8.2.

5.1.9 Determine the acceptability of the run by calculating the standard deviation of the natural decay in accordance with Section 8.3. A standard deviation of less than the 95% confidence limit of 0.002 min^{-1} or 10%, whichever is greater, determines the acceptability of the run.

5.2 Cigarette Smoke Particulate Matter Removal Measurement with Air Cleaner Operating (includes natural decay)

5.2.1 Operate the ceiling mixing fan and create a log file for the run.

5.2.2 Using the test chamber HEPA filter, allow the test chamber air to clean until the background concentration in size range of 0.1 μm to 1.0 μm reaches a concentration of less than 20 particles/cc and simultaneously operate the environmental control devices until the test chamber conditions (temperature and RH) are as specified in Section 4.2.

5.2.3 Procedure

5.2.3.1 When an acceptable test chamber background concentration is achieved (as indicated in Section 5.2.2), record the background concentration, turn off the test chamber environmental control system (humidifiers, HEPA filter, blowers, supply dampers and return dampers.)

5.2.3.2 Immediately light, then place one standard cigarette obtained from the cigarette humidity chamber in the cigarette smoke generator, seal generator, open valve to test chamber, and turn on 4-6 scfh (about 45 sec.) air supply to the cigarette generator to provide the required concentration (as noted in Section 4.4.1).

5.2.3.3 Turn off air supply and close chamber valve. Mix cigarette smoke for one minute, then turn off ceiling mixing fan. The recirculation fan will continue to operate for the duration of the test. Wait one minute for fan to stop. Turn on air cleaner. The time at which the air cleaner is turned on is defined as time (t) = 2 minutes.

5.2.4 Two minutes after turning on the air cleaner, begin to acquire the cigarette smoke particulate concentration. This test point is the initial concentration. If the cigarette smoke concentration is not within the initial limits (refer to Section 4.4.1), terminate the run.

5.2.5 Acquire particle concentration data at one-minute intervals for 20 minutes, beginning at the two minute point (t=2 minutes). Use all acceptable data points. Refer to Section 8.1 for Elimination of Data Points to determine acceptability. A minimum of nine acceptable data points are required.

NOTE: The operating power test described in Section 9 can be conducted during this particle concentration data acquisition phase if desired.

5.2.6 Turn off the air cleaner. Record the average RH and temperature of the test chamber during the test period. Values outside the limits in Sections 4.2 and 4.3 invalidate the run.

5.2.7 Calculate the decay constant for cigarette smoke per Section 8.2.

5.2.8 Determine the acceptability of the run by calculating the standard deviation of the particulate matter removal in accordance with Section 8.3. A standard deviation of less than the 95% confidence limit of 0.008 min^{-1} or 10%, whichever is greater, determines the acceptability of the run.

5.2.9 Determine the CADR of the air cleaner in accordance with Section 8.4.

5.2.10 Determine the acceptability of the test by calculating an estimate of the standard deviation for a single test CADR according to Section 8.5. A two standard deviation estimate of less than CADR of 9 cfm or 10%, whichever is greater, determine an acceptable test.

6. TEST PROCEDURE FOR DETERMINING PERFORMANCE ON TEST DUST

To determine the performance on test dust, perform the test procedures prescribed in Sections 6.1 and 6.2 sequentially during the same day (Annex C, III.B.)

6.1. Natural Decay Measurement

6.1.1 Place the air cleaner to be tested in the test chamber in accordance with Section 4.6.2 and set the air cleaner controls to the conditions for test. Test for proper operation, then shut off with switch external to test chamber.

6.1.2 Operate the ceiling mixing fan and create a log file for the run.

6.1.3 Using the test chamber HEPA filter, allow the test chamber air to clean until the background concentration in the size range of 0.5 µm to 3.0 µm reaches a level of less than 0.03 particle/cc. Simultaneously operate environmental control devices until the test chamber conditions (temperature and RH) are as specified in Section 4.2.

6.1.4 Procedure

6.1.4.1 When an acceptable test chamber background concentration is achieved (as indicated in 6.1.3) record the background concentration. Turn off the test chamber environmental control system (humidifiers, HEPA filter, blowers, supply dampers and return dampers.)

6.1.4.2 Immediately turn on the air supply to the aerosol generator and then the aerosol generator. Continue to generate test dust until the particle concentration in the test chamber reaches the required initial concentration (200 to 400 particles/cc as noted in Section 4.4.1).

6.1.4.3 When the concentration is within initial test limits, turn off the aerosol generator air supply and aerosol generator. CAUTION: A radioactive source is utilized by the dust generator for charge neutralization.

6.1.4.4 Mix dust for one minute after the initial concentration has been reached, then turn off ceiling mixing fan. Wait one minute for the fan to stop. The recirculation fan will continue to operate for the duration of the test.

6.1.4.5 Begin to acquire the particle concentration with the dust monitor. This test point is the initial concentration (t=0 minutes). If the test dust concentration is not within initial limits, terminate the run.

6.1.5 Acquire particle concentration data at one-minute intervals for 20 minutes. A minimum of nine data points having particle concentrations greater than the lower limit of instrument measurability are required.

6.1.6 Record the average RH and temperature of the test chamber during the test period.

6.1.7 Calculate the decay constant for test dust per Section 8.2

6.1.8 Determine the acceptability of the run by calculating the standard deviation of the natural decay in accordance with Sections 8.3. A standard deviation of less than the 95% confidence limit of 0.001 min^{-1} or 10%, whichever is greater, determines the acceptability of the run.

6.2. Dust Particulate Matter Removal Measurement with Air Cleaner Operating (includes natural decay).

6.2.1 Operate the ceiling mixing fan and create a log file for the run.

6.2.2 Using the test chamber HEPA filter, allow the test chamber air to clean until the background concentration in the size range of 0.5 µm to 3.0 µm reaches a concentration of less than 0.03 particle/cc. Simultaneously operate the environmental control devices until the test chamber conditions (temperature and RH) are as specified in Section 4.2.

6.2.3 Procedure

6.2.3.1 When an acceptable test chamber background concentration is achieved (as indicated in 6.2.2), record the background concentration, turn off the test chamber environmental control system (humidifiers, HEPA filter, blowers, supply dampers and return dampers.)

6.2.3.2 Immediately turn on the air supply to the aerosol generator and then the aerosol generator. Continue to generate test dust until the particle concentration in the test chamber reaches the required initial concentration (200 to 400 particles/cc as noted in Section 4.4.1).

6.2.3.3 When the concentration is within initial test limits, turn off the aerosol generator air supply and aerosol generator. CAUTION: A radioactive source is utilized by the dust generator for neutralization.

6.2.3.4 Mix dust for one minute, then turn off ceiling mixing fan. Wait one minute for fan to stop. Turn on air cleaner. This is t=0 minutes.

6.2.4 Begin to acquire the particle concentration with the dust monitor at t=0 minutes. This test point is the initial concentration. If the test dust concentration is not within the initial limits, terminate the run.

6.2.5 Acquire particle concentration data at one-minute intervals for 20 minutes, beginning at t = 0 minutes. Use all acceptable data points. Refer to Section 8.1, Criteria for Elimination of Data Points to determine acceptability. A minimum of nine acceptable data points are required.

NOTE: The operating power test described in Section 9 can be conducted during this particle concentration data acquisition phase if desired.

6.2.6 Turn off the air cleaner. Record the average RH and temperature of the test chamber during the test period. Values outside the limits in Sections 4.2 and 4.3 invalidate the run

6.2.7 Calculate the decay constant for test dust per Section 8.2

6.2.8 Determine the acceptability of the run by calculating the standard deviation of the particulate matter removal in accordance with Sections 8.3. A standard deviation of less than the 95% confidence limit of 0.003 min^{-1} or 10%, whichever is greater, determines the acceptability of the run.

6.2.9 Determine the CADR of the air cleaner in accordance with Section 8.4.

6.2.10 Determine the acceptability of the test by calculating an estimate of the standard deviation for a single test CADR according to Section 8.5. A two standard deviation estimate of less than a CADR of 10 cfm or 10%, whichever is greater, determines an acceptable test.

7. TEST PROCEDURE FOR DETERMINING PERFORMANCE ON PAPER MULBERRY POLLEN

To determine the performance on paper mulberry pollen, perform the test procedures prescribed in Sections 7.1 and 7.2 sequentially during the same day (see Annex C, III.C).

7.1 Natural Decay Measurement

7.1.1 Place the air cleaner to be tested in the center of the test chamber in accordance with Section 4.6.2 and set the air cleaner controls to the conditions for test. Test for proper operation, then shut off and switch external to test chamber.

7.1.2 Operate the ceiling mixing fan and create a log file for the run.

7.1.3 Using the test chamber HEPA filter, allow the test chamber air to clean until the background concentration in the size range of 5 µm to 11 µm reaches a concentration of less than 0.03 particle/cc. Simultaneously operate the environmental control devices until the test chamber conditions (temperature and RH) are as specified in Section 4.2.

7.1.4 Procedure

7.1.4.1 When an acceptable test chamber background concentration is achieved (as indicated in Section 7.1.3), record the background concentration, turn off the test chamber environmental control system (humidifiers, HEPA filter, blowers, supply dampers and return dampers.)

7.1.4.2 Attach one of the pre-weighed paper mulberry pollen sample bottles to the pollen generator (see Annex C, III.C).

7.1.4.3 Open the test chamber valve to the pollen generator and turn on the pollen generator air supply at 20 psig [1.4 kg/cm2] for 10 seconds. Turn off the air supply and close the test chamber valve.

7.1.4.4 Mix pollen for one minute after the initial concentration has been reached, then turn off ceiling mixing fan. Wait one minute for the fan to stop. The recirculation fan will continued operation for the duration of the test.

7.1.5 Begin to acquire the particle concentration with the dust monitor. This test point is the initial concentration (t=0 minutes). If the pollen concentration is not within the initial limits (4 to 9 particles/cc as noted in Section 4.4.1), terminate the run.

7.1.6 Acquire particle concentration data at one-minute intervals for 10 minutes. A minimum of five points having particle concentrations greater than the lower limit of instrument measurability are required.

NOTE: The minimum of five points required for pollen is less than the minimum of nine points required for tobacco smoke and dust due to the faster pollen decay rate and due to the shorter data acquisition period specified for pollen.

7.1.7 Record the average RH and temperature of the test chamber during the test period.

7.1.8 Calculate the decay constant for pollen per Section 8.2.

7.1.9 Determine the acceptability of the run by calculating the standard deviation of the natural decay in accordance with Sections 8.3. A standard deviation of less than the 95% confidence limit of 0.009 min^{-1} or 10%, whichever is greater, determines the acceptability of the run.

7.2 Pollen Particulate Matter Removal Measurement with Air Cleaner Operating (includes natural decay).

7.2.1 Operate the ceiling mixing fan and create a log file for the run.

7.2.2 Using the test chamber HEPA filter allow the test chamber air to clean until the background concentration in the size range of 5 µm to 11µm reaches a concentration of less than 0.03 particle/cc. Simultaneously operate the environmental control devices until the test chamber conditions (temperature and RH) are as specified.

7.2.3 Procedure

7.2.3.1 When an acceptable test chamber background concentration is achieved (as indicated in Section 7.2.2) record the background concentration, turn off the test chamber environmental control system (humidifiers, HEPA filter, blowers, supply dampers and return dampers.)

7.2.3.2 Attach one of the pre-weighed paper mulberry pollen sample bottles to the pollen generator (see Annex C, III.C).

7.2.3.3 Open the test chamber valve to the pollen generator and turn on the pollen generator air supply at 20 psig [1.4 kg/cm2] for ten seconds. Turn off the air supply and close the test chamber valve.

7.2.3.4 Mix pollen for one minute, then turn off the ceiling mixing fan. Wait one minute for fan to stop. Turn on air cleaner. This is t=0 minutes.

7.2.3.5 Begin to acquire the particle concentration with the dust monitor at t=0 minutes. This test point is the initial concentration. If the test pollen concentration is not within the initial limits, terminate the run.

7.2.4 Acquire particle concentration data at one-minute intervals for 10 minutes, beginning at t = 0 minutes. Use all acceptable data points. Refer to Section 8.1, Elimination of Data Point, to determine acceptability. A minimum of five acceptable data points are required.

NOTE: The minimum of five points required for pollen is less than the minimum of nine points required for tobacco smoke and dust due to the faster pollen decay rate and due to the shorter data acquisition period specified for pollen.

7.2.5 Turn off the air cleaner. Record the average RH and temperature of the test chamber during the test period. Values outside the limits in Sections 4.2 and 4.3 invalidate the run.

7.2.6 Calculate the decay constant for pollen per Section 8.2.

7.2.7 Determine the acceptability of the run by calculating the standard deviation of the particulate matter removal in accordance with Sections 8.3. A standard deviation of less than the 95% confidence limit of 0.022 min^{-1}_or 10%, whichever is greater, determine an acceptable run.

7.2.8 Determine the CADR of the air cleaner in accordance with Section 8.4.

7.2.9 Determine the acceptability of the test by calculating an estimate of the standard deviation for a single test CADR according to Section 8.5. A two standard deviation estimate of less than CADR = 23 cfm or 20%, whichever is greater, determines an acceptable test.

8. CALCULATION PROCEDURES (Refer to Annex D)

8.1 Criteria for Elimination of Data Points from an AC-1 Run

There are four criteria for eliminating a data point from an AC-1 run. The first is operator error. The second is equipment error either in the sensing, recording, or reporting of information. The third is the data point is not within the 95% prediction limit of the regression line. The fourth is decay below the lower limit of instrument measurability.

Criterion 1.

Any noted operator error results in the elimination of the data point whether or not the data point (corresponding to the time the error is noted) is found within acceptable or anticipated concentration ranges.

Criterion 2.

Any noted equipment error will result in the elimination of the data point (corresponding to the time the error is noted) whether or not the data point is found within acceptable or anticipated concentration ranges. Typically, this type of error invalidates the entire run.

Criterion 3.

Any data points found to be outside the 95% prediction limits of the regression slope line will result in the elimination of the data point. The cause of the outlier data may or may not be due to test chamber instrumentation, air cleaner inconsistency, or other test chamber effects.

Criterion 4.

Any data point resulting in a reported concentration below the instrument measurability limit will be eliminated along with all subsequent data points in the run. Subsequent data points are eliminated based on the anticipated theoretical reduction of concentration with time. Any data point taken after one rejected for Criterion 4 would be theoretically expected to also be eliminated by Criterion 4.

8.2 Calculating the Decay Constant

Since the test chamber air exchange is negligible (maximum contribution to slope of 0.00051 min^{-1}) the air exchange rate is not included in the calculations.

8.2.1 The decay constant, k, for particulate matter is based on the formula:

$$C_{t_i} = C_i e^{-kt_i} \qquad \text{(equation 1)}$$

where:

C_{t_i} = concentration at time t_i (particles/cc)

C_i = concentration at t = 0 minutes

k = decay rate constant (minutes $^{-1}$)

t_i = time (minutes)

8.2.2 The decay constant, k, is obtained using the linear regression on the $\ln C_{t_i}$ and t_i using the formula:

$$k = \frac{S_{XY}}{S_{XX}}$$

(equation 2)

where:

$$S_{xy} = \sum_{i=1}^{n} t_i \ln C_{t_i} - (1/n)\left(\sum_{i=1}^{n} t_i\right)\left(\sum_{i=1}^{n} \ln C_{t_i}\right) \qquad \text{(equation 3)}$$

$$S_{xx} = \sum_{i=1}^{n} (t_i)^2 - (1/n)\left(\sum_{i=1}^{n} t_i\right)^2 \qquad \text{(equation 4)}$$

When the above calculations are used for natural decay measurements in Sections 5.1, 6.1 and 7.1, the results represent the natural decay rate in test chamber air.

When the above calculations are used for the total particulate matter removal measurements in Sections 5.2, 6.2, and 7.2, the results represent the air cleaner particulate matter removal rate, including the natural decay rate.

8.3 Computation of the Standard Deviation Estimate for the Slope of One Regression Line

Step 1: Calculation of Standard Deviation of a Regression Line. An estimate of the standard deviation about the regression line is calculated as follows:

$$S_{reg} = \sqrt{\left[(1/(n-2))\sum_{i=1}^{n}(\ln C_{t_i} - b - m t_i)^2\right]} \qquad \text{(equation 5)}$$

where:

S_{reg} = estimated value of the overall standard deviation

n = number of pairs of data points used in the regression

b = the intercept of the regression line (equivalent to an estimated initial concentration) expressed as ln(particles/cc)

m = the slope of the regression line expressed as min^{-1}

t_i = time (in minutes) at data point "i"

$\ln C_{t_i}$ = natural logarithm of the concentration at time t_i

Step 2: Calculation of Standard Deviation Estimate of the Regression Line Slope. The Standard Deviation Estimate of the slope of the regression line is calculated as follows:

$$S_{Slope} = \sqrt{\frac{S_{reg}^2}{S_{xx}}} \qquad \text{(equation 6)}$$

8.4 Performance Calculation.

The performance of an air cleaner is represented by a clean air delivery rate (CADR). The method for calculating the clean air delivery rate is:

$$\text{CADR} = V(k_e - k_n) \qquad \text{(equation 7)}$$

where:

CADR = clean air delivery rate (cu. ft/min)

V= volume of test chamber, cu. ft.

k_e= total decay rate, min^{-1}

k_n = natural decay rate, min^{-1}

8.5 Calculation of the Standard Deviation Estimate of the CADR for a Single Test

The Standard Deviation Estimate as described above for each of the natural and total decay lines can be combined using error propagation analysis on the equation used to compute the CADR in Section 8.4.

The test chamber volume is taken as a constant and the following equation is used to estimate the standard deviation for the CADR computed for the pair of regression lines.

$$S_{CADR} = 1008\sqrt{S_{(slope,k_e)}^2 + S_{(slope,k_n)}^2} \qquad \text{(equation 8)}$$

where:

S_{CADR} = the estimated standard deviation for CADR (cu ft./min)

$S_{(slope,k_e)}$ = the estimated standard deviation of the total decay rate (min^{-1})

$S_{(slope,k_n)}$ = the estimated standard deviation of the natural decay rate (min^{-1})

1008 = the volume of the test chamber in ft^3, treated as a constant, which is used to put the estimated standard deviation value in CADR units.

8.6 Calculation of Suggested Room Size

The suggested Room Size for an air cleaner is based upon the CADR obtained for cigarette smoke as determined in Section 5. The Room Size is based upon the ability of the air cleaner in CADR to reduce the concentration of particles in a room at steady-state to a new steady-state concentration 80% less than the original when the air cleaner is operating. The theoretical assumptions of the room characteristics are based upon a mixing factor equal to 1.0, an air exchange rate of 1.0 hr^{-1}, a cigarette smoke particle natural decay equal to the average background natural decay rate (from statistical study), a ceiling height of 8 ft. (2.4 m), and a cigarette smoke particle generation or influx rate such that a cigarette smoke particle concentration of unity (1) is maintained at the initial steady-state. A standard first-order differential equation is utilized for the calculation that is derived in Annex E and summarized as:

Room Size (square feet) = cigarette smoke CADR x 1.55

Room Size (square meters) = Room Size (square feet) x 0.093

where CADR is the Clean Air Delivery Rate determined from Equation 7

9. MEASUREMENT OF OPERATING POWER[1]

9.1 Conditions of Measurement

The measurement described in this section shall be conducted in accordance with the conditions described in Section 4. For equipment (and its accuracy specification), refer to Annex A.

Note: This measurement can be conducted simultaneously with the tobacco smoke or dust particle matter removal tests noted in either Sections 5.2.5 and 6.2.5 as both of these tests are of sufficient length.

9.2 Conditioning of Air Cleaner Prior to Measurement

Prior to measuring operating power, the air cleaner motor must be properly broken in by running the air cleaner, without filters, for 48 hours.

9.3 Measurement Procedure

9.3.1 After the air cleaner motor has been properly conditioned, in accordance with the equipment manufacturer's instructions, connect the power measuring instrument between the power supply and the air cleaner under test.

Turn the air cleaner on with all settings/options set at maximum level and reset the power measuring instrument.

9.3.2 Adjust the power supply indicator to 115 V – 60 Hz.

9.3.3 Allow the air cleaner to run for 2 minutes without taking any Watt readings. After this 2 minute initial run time, begin recording Watt readings at one-minute intervals for 13 minutes. The entire test should take 15 minutes total.

9.4 Operating Power Results

9.4.1 To obtain the operating power of the air cleaner in Watts, average the data points. Up to three of the 13 readings may be thrown out as anomalous to address potential line surges and other variables.

[1] In accordance with the U.S. Environmental Protection Agency (EPA) Air Cleaner Energy Star Requirements Eligibility Criteria – Energy Consumption Test Protocol.

10. MEASUREMENT OF STANDBY POWER[2]

10.1 Conditions of Measurement

10.1.1 Air Speed - The tests shall be carried out in a room that has an air speed close to the air cleaner under test of ≤ 0.5 m/s.

10.1.2 Ambient Temperature - The ambient temperature shall be maintained at (21 ± 3) ˚C throughout the test.

10.1.3 Voltage - Voltage supply shall be at 115 volts ± 1 volt.

For equipment (and its accuracy specification), refer to Annex A.

NOTE: The measured power for some products and modes may be affected by the ambient conditions (e.g. luminance, temperature).

10.2 Preparation of Air Cleaner Model for Testing

Tests are to be performed on a single room air cleaner model. The air cleaner shall be prepared and set up in accordance with the manufacturer's instructions, except where these conflict with the requirements of this test procedure. If no instructions are given, then factory or "default" settings shall be used, or where there are no indications for such settings, the air cleaner is tested as supplied.

For air cleaners having a rechargeable battery, standby mode is measured on the charger or docking/base station with the air cleaner detached from its regular source of power in the 'on' position.

10.3 Test Procedure

10.3.1 This test procedure may only be used where the selected mode and measured power are stable. A variation of less than 5% in the measured power over 5 minutes is considered stable for the purposes of testing for standby power usage under this specification. Instrument power readings may be used in this case.

10.3.2 Connect the air cleaner to be tested to the metering equipment in the stable mode.

10.3.3 After the air cleaner has been allowed to stabilize for at least 5 minutes, monitor the standby power for not less than an additional 5 minutes.

10.3.4 If the power level does not drift by more than 5% (from the maximum value observed) during the latter 5 minutes, the load can be considered stable and the power can be recorded directly from the instrument at the end of the 5 minutes.

10.4 Test Results

Standby power shall be reported as the average power in Watts rounded to the second decimal place.

---

[2] In accordance with the U.S. Environmental Protection Agency (EPA) Air Cleaner Energy Star Requirements Eligibility Criteria – Test Procedure for Measuring Standby Power.

11. REPORTING

The template test data sheets shown in Annex F identify the parameters that must be recorded during CADR testing and reported for each test.

12. SAFETY

It is recommended that air cleaners meet the relevant safety requirements of Underwriters Laboratories Inc., such as UL 867, Standard for Electrostatic Air Cleaners, latest edition*, and UL 507, Standard for Fans, latest edition*.

* Copies of UL Standards are available through COMM 2000, 1414 Brook Drive, Downers Grove, IL 60515, 1-888-UL33503, www.comm-2000.com, E-mail: sales@comm-2000.com.

ANNEX A – NORMATIVE
DETAILS OF TEST CHAMBER CONSTRUCTION AND EQUIPMENT

Test Chamber Construction

(Equivalent Material and Equipment Substitutes Are Acceptable)

Note: No silicone caulk is to be used in the test chamber.

Chamber size:	Inside dimensions, 10 ½ ft. x 12 ft. x 8 ft., 1008 ft^3 (3.2 m x 3.7 m x 2.4 m, 28.5 m^3)
Framework:	Standard 2 in. x 4 in. (5.1 cm x 10.2 cm) construction, sealed at floor line, inside and outside with caulking compound
Walls:	½ in. (1.3 cm) wallboard over 3/8 in. (0.9 cm) plywood
Flooring:	Seamless, smooth surface, full width linoleum or vinyl
Filtration:	High efficiency particulate air (HEPA) filter 99.97% efficient for 0.3 µm DOP cigarette smoke (1000 cfm). Pre-filter 60% ASHRAE efficiency roughing filter 20-30% ASHRAE efficiency
Paint:	White, washable latex semi-gloss
Ceiling Fan:	3 blade, 36 in. (0.91 m), ceiling fan 395 RPM Stock No. 4C852 Amps 0.5, Volts 120, Weight 28 lbs (12.7 kg) or equivalent.

Available from W.W. Grainger

Motor and Blower for Reconditioning

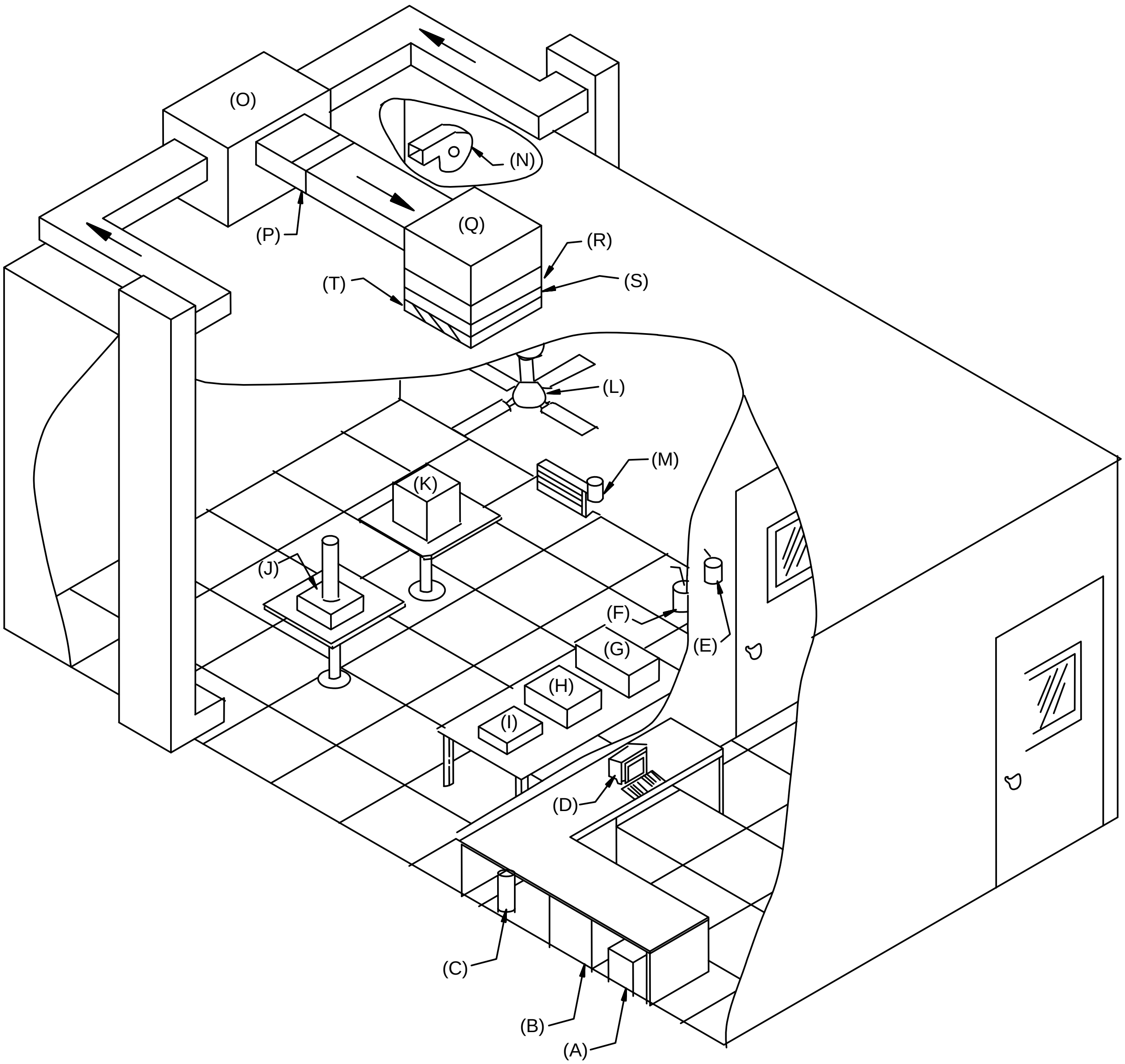
Loop:	750 cfm (21.5 m^3/m) fan, 4 in. (10.2 cm) WG, 3/4 HP motor, 208 Volts, 3 phase

Recirculation Fan

Position:	The recirculation fan is positioned 60 in. (1.5 m) from the floor to the center of the motor and 15 in. (0.4 m) from the back wall to the fan unit.
Table Stand:	Height: 29.25 in. (0.74 m) from the floor

Table top size: 14 x 22 x 1 in. (0.36 m x 0.56 m x 0.03 m)

AIR CLEANER CHAMBER SCHEMATIC



(A) VOLTAGE REGULATOR
(B) DATA ACQUISITION AND CONTROL INTERFACE
(C) AIR SUPPLY (FILTER/DRIER)
(D) COMPUTER TERMINAL
(E) CIGARETTE SMOKE POT
(F) POLLEN GENERATOR
(G) DUST AND POLLEN MONITOR
(H) SMOKE MONITOR
(I) CIGARETTE SMOKE DILUTER
(J) DUST GENERATOR
(K) TEST AIR CLEANER
(L) CEILING MIXING FAN
(M) RETURN AIR DAMPER (2)
(N) RECIRCULATION FAN
(O) HUMIDIFIER
(P) PREFILTER
(Q) BLOWER SECTION
(R) HEPA FILTER
(S) ELECTRIC HEATER
(T) SUPPLY AIR DAMPER

TEST CHAMBER EQUIPMENT

(Equivalent Substitutes are Acceptable)

<u>Recirculation Fan</u>

Available from:
W.W. Grainger, Inc.
6285 E. Molloy Rd.
Syracuse NY 13057
Phone: (800) 323 0620
Web site: www.grainger.com

Model No. 4C448
Shaded Pole Blower

<u>Relative Humidity - Temperature Sensor</u>
Available from:
Vaisala, Inc.
100 Commerce Way
Woburn, MA 01801
Phone: (781) 933 4500
Web site: www.vaisala.com

Model HMW 3OYB

<u>Temperature - Relative Humidity Reconditioning Loop Equipment</u>

<u>Humidifier</u>

Available from:
D.F. Brandt, Inc.
8152 Kirkville Road
Kirkville, N.Y. 13082
Web site: www.dfbrandt.com

Model RESDELUX
Steam Humidifier

<u>Cooling/Dehumidifying Equipment</u>
Available from:
Trane Co.
LaCrosse, WI 54601
Web site: www.trane.com

Model No. XE900 1 ton condensing unit
Model EAS Evaporator Coil

Reheater
Available from:
INDEECO
425 Hanley Industrial Court
St. Louis MO 63144
Web site: www.indeeco.com

10kw duct heater

Voltage Regulator

Available from:
Newark Electronics
4801 N. Ravenswood Ave.
Chicago, IL 60640
Phone: (312) 784 5100
Web site: www.newark.com

Sola Type 63-23-220-8 2 kVA 60 Hz
Single phase minicomputer regulator

Watt Transducer
Available from:
Ohio Semitronics Inc.
4242 Reynolds Drive
Hilliard, OH 43026
Phone: (800) 537 6732
Web site: www.ohiosemi.com

Model AGH-002B 300V, 5A watt transducer

Particulate Matter Generation and Measurement

Dust Generator
Available from:
TSI Inc
500 Cardigan Rd.
Shoreview, MN 55126
Phone: (800) 874 2811
Web site: www.tsi.com

Model 3400 Fluidized Bed Aerosol Generator

Dust Neutralizer
Available from:
TSI Inc.
500 Cardigan Rd.
Shoreview, MN 55126
Phone: (800) 874 2811
Web site: www.tsi.com

Model 3012 Aerosol Neutralizer

Dust/Pollen Particle Counter
Available from:
TSI Inc.
500 Cardigan Rd.
Shoreview, MN 55126
Phone: (800) 874 2811
Web site: www.tsi.com
Aerodynamic Particle Sizer® (APS) Spectrometer - Model 3321

Cigarette Smoke Monitor
Available from:
Particle Measuring Systems, Inc.
5475 Airport Blvd.
Boulder CO 80301
Phone: (800) 238 1801
Web site: www.particlemeasuringsystems.com

High Sensitivity Laser Aerosol Spectrometer Probe
PMS Model HS-LAS 32 Ch 0.0654-1.00

Pollen Generator

2 oz. screw-top glass laboratory sample jars sealed air tight with nominal 1/4 inch brass fittings for air entry, and pollen discharge.

Air Supply
Available from:
TSI Inc.
500 Cardigan Rd.
Shoreview, MN 55126
Phone: (800) 874 2811
Web site: www.tsi.com

Model 3074 - Air Supply System

Isokinetic Diluter
Available from:
Stainless Design Concepts
1117 Kings Hwy
Saugerties, NY 12477
Phone: (845) 246 3631
Web site: www.stainlessdesign.com

Custom Aerosol diluter - six to one dilution ratio at 1 cc/sec total flow rate.

Operating Power and Standby Power Measurement Watt Meter (or Equivalent Instrument)

Watt Meter or equivalent instrument capable of measuring true RMS watts
Accuracy: ± 1 % at 115 volts, 60 Hertz
Resolution: 0.01 Watt (or better)

ANNEX B - NORMATIVE

SOURCES OF PARTICULATES
(Equivalent Substitutes are Acceptable)

Air Cleaner Test Dust:

Powder Technology Inc. (PTI Inc.)
14331 Ewing Avenue South
Burnsville, MN 55306
Phone: (952) 894 8737
Web site: www.powdertechnologyinc.com
Fine Air Cleaner Test Dust

Cigarettes:

Kentucky Tobacco Research and Development Center (KTRDC)
University of Kentucky
Lexington KY 40506
Phone: (859) 257 1657
Web site: www.uky.edu/KTRDC

2R4F Research Cigarettes

Paper Mulberry Pollen: (Non-defatted)

Greer Laboratories Inc.
Box 800
Lenoir, NC 28645
Phone: (800) 378 3906
Web site: www.greerlabs.com

ANNEX C - INFORMATIVE

STANDARD LABORATORY OPERATION PROCEDURES WHEN TESTING PORTABLE ROOM AIR CLEANERS

I. Receipt of Test Air Cleaners

a. Air cleaners received for testing should be inspected upon receipt for shipping damage or other obvious visual defects. The supplier of the air cleaner should be notified immediately of defects or damage and provide a disposition.

b. Air cleaners should be logged in and forwarded to the test facility run-in room.

II. Test Chamber Preparation

Perform Startup and Cleaning Procedures in accordance with Sections VI and VII of this Annex.

III. Contaminant Preparation

a. Cigarette Smoke

1. Store an adequate number of cigarettes from a single pack at room temperature and a relative humidity of (70 ± 15) % for 24 to 72 hours prior to a test series.
2. Cigarette Smoke Generator, including injection tube, should be cleaned weekly.
3. For long term storage (i.e. more than 30 days) of Test Standard Cigarettes (Annex B), keep at a temperature of 39 ^{o}F ± 3.6 ^{o}F (4^{o}C ± 2^{o}C) and relative humidity of (50 ± 10) %.

b. Air Cleaner Test Dust

1. Special preparations of contaminant are not necessary.
2. Set pressure for dispersing dust at 40 to 60 psig [2.8 to 4.2 kg/cm^2] and check dryer desiccant.
3. For storage of the test dust specified in Section 3.3.2, store in a desiccating chamber with a maximum RH of 20%.

c. Paper Mulberry Pollen

1. 1.2g of uniformly mixed pollen is divided into 4 approximately equal sections using a razor blade or small fine edged micro-spatula. Pollen is to be divided in an area having no more than 40% RH.
2. Load each 1/4 of the pollen into separate generator jars.
3. Store loaded generator jars in desiccator with drying agent for a minimum of 24 hours prior to testing.
4. When ready to test, adjust air pressure of the pollen generator to 20 psig [1.4 kg/cm^2].
5. For long term storage of the pollen specified in Section 3.3.3, store in a desiccating chamber with a maximum RH of 20%.

IV. Startup Procedures

Note: These procedures are specific to the equipment listed in Annex A.

a. Turn on main power to computer and reconditioning system.

b. Start Reconditioning Loop and turn on Recirculation Fan to obtain test chamber ambient conditions.

c. Prior to Dust or Pollen tests, turn on APS 3321 as follows:

- Power switch on, wait ten seconds.
- Pump switch on, wait ten seconds.
- Laser switch on.
- Let the instrument warm up sufficiently.

d. Prior to Cigarette Smoke tests, turn on HS-LAS as follows:

- Power switch on, wait ten seconds
- Adjust sample flow (1 cc/sec); sheath flow (20 cc/sec)
- Wait a minimum of 30 seconds
- Check laser reference voltage (must be above 4.5v). If low, adjust per manufacturer's instructions
- Let the instrument warm up sufficiently.

e. Clean Test Chamber, according to procedures in Section VI.

f. When test conditions are safely within requirements, start test runs.

V. Shutdown Procedures

a. Turn on Reconditioning loop to remove residual particulates.

b. Power down APS 3321 in this order:

- Laser switch
- Pump switch
- Power switch

c. Power down HS-LAS by turning off power switch.

d. Turn off Recirculation Fan.

e. Perform full daily cleaning procedures (Section VI and VII).

f. Turn off Main power switch.

VI. Daily startup Cleaning Procedures

Note: These procedures were written for a specific facility and should be regarded as typical. They have been found to be sufficient to achieve required test chamber background concentrations.

a. Wash cigarette smoke generator and used pollen jars.

b. Use damp lint-free wipe to clean inside lids of cigarette smoke generator and pollen generator.

c. Damp sponge countertops and computer external surfaces.

d. Damp mop floor and anti-static mat.

e. Lift instruments and dust generator (carefully) and wipe bottom surface and table tops.

VII. Test Chamber Cleaning Procedures (shutdown and as required)

Note: These procedures were written for a specific facility and should be regarded as typical. They have been found to be sufficient to achieve required test chamber background concentrations.

a. Prepare anti-static cleaning solution (commercially available formula acceptable) in accordance with manufacturer's instructions. Use only damp sponge.

b. Mop Ceiling - Damp mop ceiling, including light fixture lenses. Rinse, wring out mop and change water frequently during mopping.

c. Mop Walls - Starting at wall next to door, damp mop walls in sections, working around the test chamber. Rinse, wring out mop and change water frequently during mopping.

d. Wash window - Wash with anti-static solution. Wipe with lint-free wipes.

e. Sponge - Start at door, working around the test chamber, using the sponge on all small surfaces. Rinse and wring out sponge frequently. Clean surfaces.

- Ceiling fan, including braces (perform first)
- Door, knob, closer and molding
- Temperature and RH sensor covers
- Small sections of wall
- Return air damper, linkage, and motor
- Recirculation fan and bracket, including fan blades
- Dust generator and pedestal
- Second Return air damper, linkage, and motor
- Instrument and table tops and legs

f. Mop Floor - Damp mop test chamber floor, starting at corner farthest from the door and working in sections toward the door. Rinse, wring out mop, and change water frequently during mopping.

VIII. Short Term Maintenance and Calibration Procedures

a. Perform tracer gas analysis on test chamber to determine air leakage rate at least at 6-month intervals. Note: The frequency of the tracer gas analysis checks should be increased if results during six month checks are not stable.

b. Check test chamber interior walls, ceiling and joints for damage and repair as necessary.

c. Blow out APS 3321 chassis every two weeks using 20-40 psig [1.4 to 2.8 kg/cm^2] filtered compressed air.

IX. Long Term Maintenance and Calibration Procedures

a. Return APS 3321 and HS-LAS particle counters to the manufacturer for cleaning and calibration annually.

b. Paint interior walls and ceiling of test chamber annually using white, washable latex semi-gloss paint (Annex A).

c. Calibrate the watt meter used for the operating power test to a standard traceable to the National Institute of Standards and Technology (NIST) on an annual basis.

ANNEX D - NORMATIVE

STANDARDIZATION OF AC-1 CALCULATIONS

Rounding Procedures for Data and Calculations

1. Raw data - round to four (4) significant figures
   - Dust: 111.12 = 111.1
   - Cigarette: 22,222 = 22,220
   - Pollen: 9.6666 = 9.667
2. Slope of decay line - round to five (5) decimal places
   - 0.15674323 = 0.15674
   - 0.01326781 = 0.01327
3. CADR and estimated value of two sigma

   Round to one (1) decimal place for tabulation and calculation

   150.3245 = 150.3

   Round to nearest whole number for Certification, Verification or other formal reporting.

   150.3 = 150

   The standard deviation of the slope of the regression line will be rounded to four (4) significant figures prior to computing the two sigma estimate.

ANNEX E - INFORMATIVE

DERIVATION OF EFFECTIVE ROOM SIZE

The AHAM Effective Room Size is based on several standard construction criteria for rooms, and a history of the natural decay rate of small particles as determined through ANSI/AHAM AC-1 for cigarette smoke.

I. Basic indoor air model for particle concentrations

Concentrations of particles in indoor air are dynamic and result from the competition between various source and removal processes. Steady state can be defined as when neither the source nor the removal processes are rapidly changing and thus the indoor concentration is relatively constant. In this situation,

$$. C = \frac{\text{source terms}}{\text{removal terms}} = \frac{\text{indoor sources + outdoor sources}}{\text{ventilation + air cleaning + deposition}} \qquad (1)$$

Without air cleaning, particle removal is through ventilation and deposition. Rearranging these terms and substituting decay parameters for words in equation (1):

$$\text{Source terms} = C \times \left(k_V + k_{dep}\right), \qquad (2)$$

where k_V is removal rate due to ventilation (minutes^{-1}), k_{dep} is the removal rate due to deposition (minutes^{-1}) and when used in equation (3) below, k_{AC} is the removal rate due to air cleaning (minutes^{-1}). Steady-state for cleaning is defined by AHAM Air Cleaner Council as being 20% or less of the initial particle load in a room, or in other words: at least an 80% continuous removal of smoke particles. This defines a new steady state particle concentration, now with the air cleaner operating, C_{AC}, which equals 0.2C. Using the same formula as in equation (2) above,

$$\text{Source terms} = 0.2C \times \left(k_V + k_{dep} + k_{AC}\right). \qquad (3)$$

Since the source terms do not change – only the use of an air cleaner – the two equations can be combined through the equivalent source terms to give

$$C \times \left(k_V + k_{dep}\right) = 0.2C \times \left(k_V + k_{dep} + k_{AC}\right). \qquad (4)$$

Canceling the C's from both sides, rearranging and solving for the air cleaner removal rate:

$$k_{AC} = 4\left(k_V + k_{dep}\right). \qquad (5)$$

Recall that CADR is defined as $V \times \left(k_e - k_n\right)$, where V is the room volume (ft^3) and k_e and k_n are the decay rates with and without air cleaner operation, respectively (as defined in section 8.4).

Effectively then,

$$\text{air cleaner operating decay} = k_e = (k_v + k_{dep} + k_{AC}) \qquad (6)$$

and

$$\text{natural decay} = k_n = (k_v + k_{dep}) \qquad (7)$$

This difference in decay rates is k_{AC}, thus

$$\text{CADR} = V \times k_{AC} = 4V\left(k_V + k_{dep}\right). \qquad (8)$$

The objective is to show what size room results from the minimum air cleaner performance needed to provide an 80% reduction in steady-state particle concentrations. For simplicity, it is assumed that the ceiling height is 8 feet; this permits recasting of the equation in terms of floor area, A, a more commonly known description of room size than is room volume,

$$A = \frac{CADR}{32\left(k_V + k_{dep}\right)}. \tag{9}$$

Commonly accepted values for the two decay parameters are used. Typical air exchange (ventilation) rates for houses in the U.S. is 1 per hour, or $k_V = 0.01667$ minute^{-1}. For smoke, average deposition rates are 0.0034 minute^{-1}, as provide by AHAM through actual measurements by a third party independent laboratory. Substituting these values in equation (9):

$$A\ (ft^2) = CADR / [32(0.01667 + 0.0034)] = 1.557\ CADR\ (cfm) \tag{10}$$

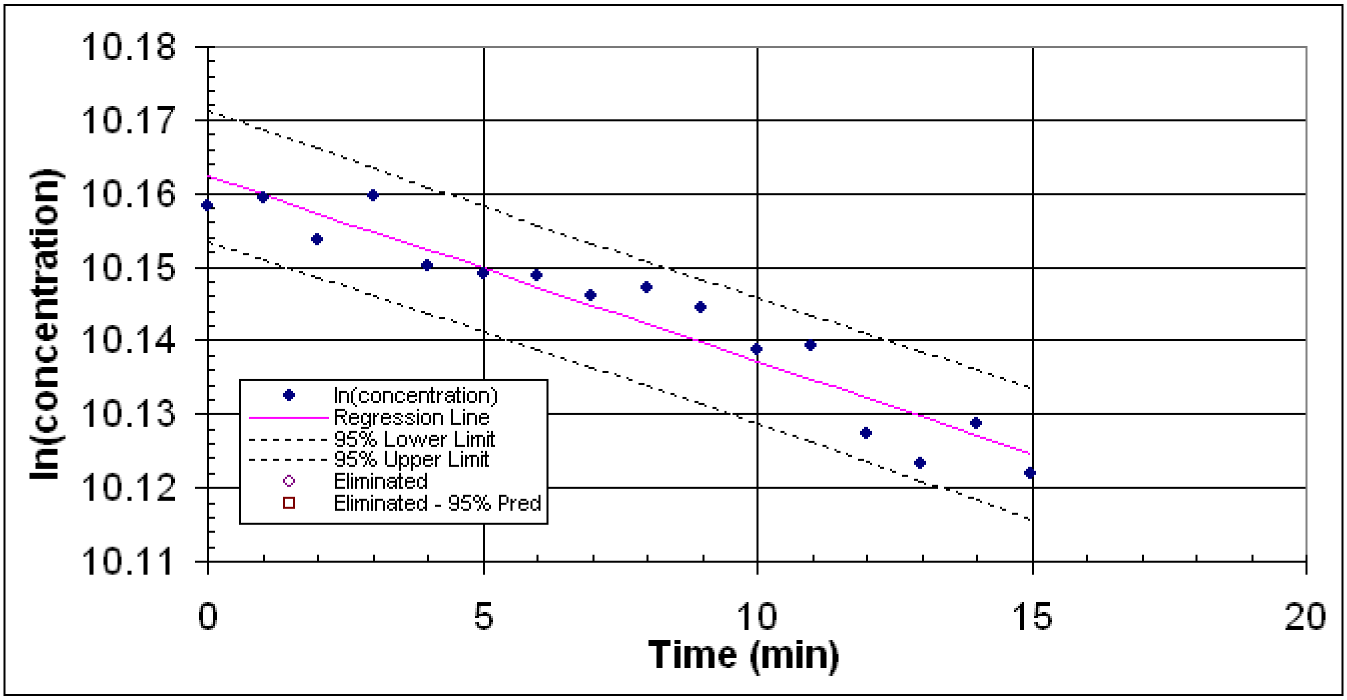
In a meeting of the AHAM Air Cleaner Council, the value of 1.557 was rounded to 1.55 for simplicity, thereby providing the standard equation:

$$\text{Square feet} = 1.55\ \text{cfm} \tag{11}$$

CADR. Based on this equation, an air cleaner with a CADR rating of 50 cfm can be used to clean a small room (78 ft^2). Likewise a CADR rating of 100 cfm would permit an air cleaner to be used in a 156 ft^2 room (~10 x 15 ft), and so forth. Conversely, this equation can also be used to determine what the CADR requirement is for a room or indoor space of a given size. For example, for a room size of 100 ft^2 a CADR rating of at least 64 cfm is needed.

ANNEX F – INFORMATIVE

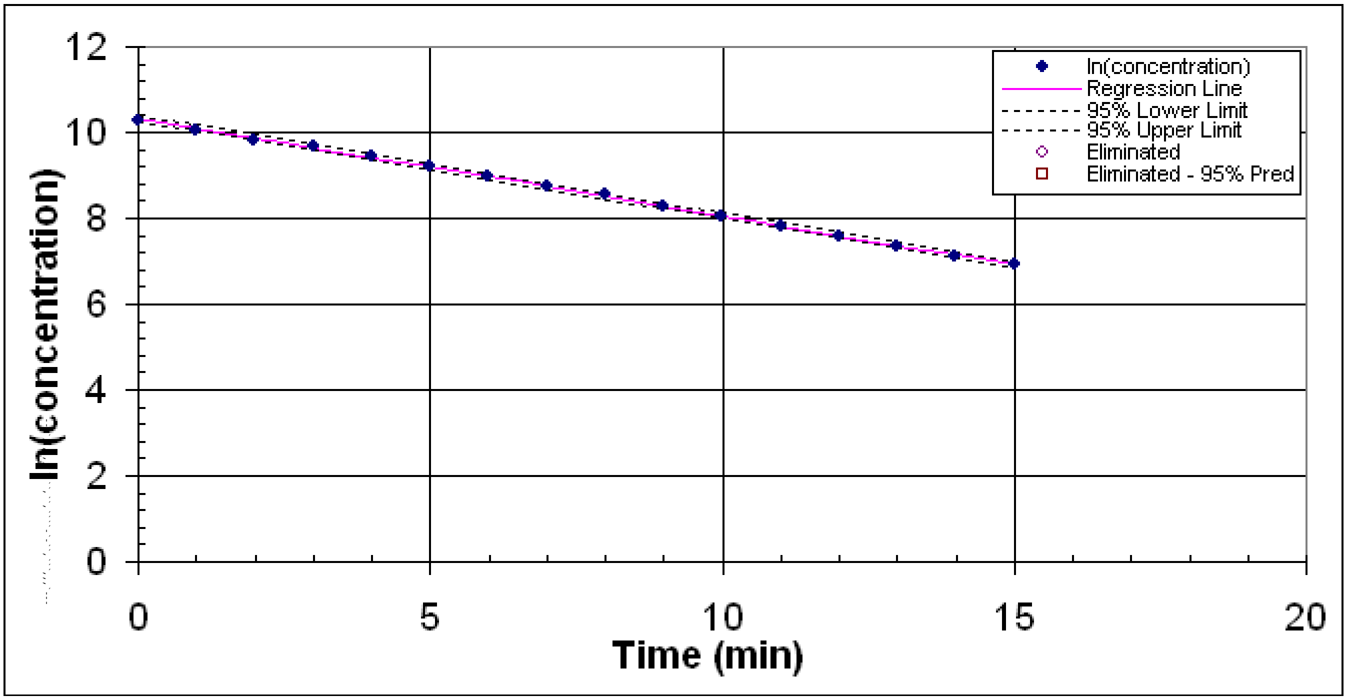
I. Example Data Sheet – Cigarette smoke Natural



TIME(MIN)	Cti	ln(Cti)	TIME(MIN)	Cti	LN(Cti)
0.00	25,802.39	10.16	11.00	25,320.37	10.14
1.00	25,831.96	10.16	12.00	25,019.76	10.13
2.00	25,682.27	10.15	13.00	24,918.43	10.12
3.00	25,840.89	10.16	14.00	25,051.80	10.13
4.00	25,598.50	10.15	15.00	24,880.55	10.12
5.00	25,568.31	10.15			
6.00	25,559.07	10.15			
7.00	25,492.24	10.15			
8.00	25,515.95	10.15			
9.00	25,448.19	10.14			
10.00	25,305.28	10.14			

Quantity	*Measured*	*Lower Limit*	*Upper Limit*	*Acceptable*
Decay Constant	0.00251	-	-	
Slope Standard Deviation (min $^{-1}$)	0.21	-	2.00	YES
Background at Injection (part/cc)	5.236	-	20.00	YES
Initial Concentration (part/cc)	25800	24000	35000	YES
Data points used	16	9	-	YES
Average Temperature (°F)	71	65	75	YES
Average Humidity (%RH)	40	35	45	YES
Average Input Voltage (volts)	120.9			
Average Test Unit Power (watts)	0.3			
CADR (cfm)	**226.5**			
CADR Standard Deviation (cfm)	1.6		22.7	YES

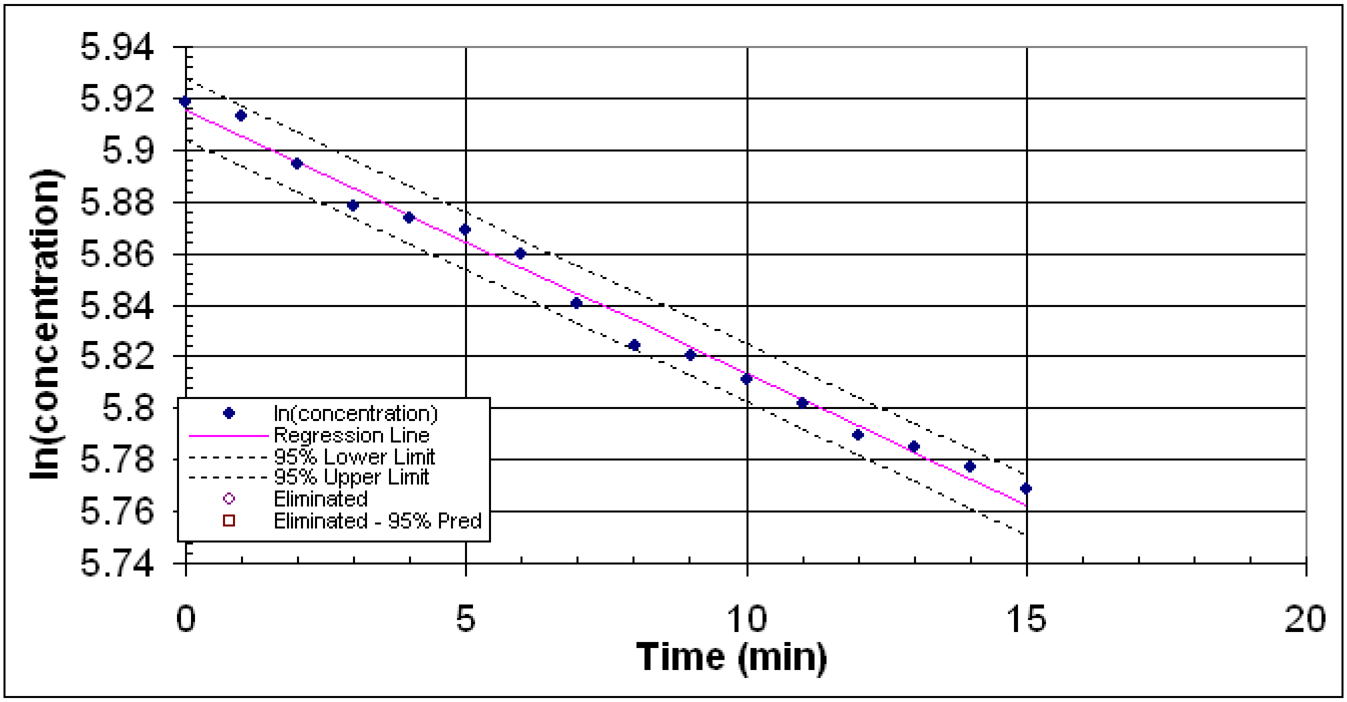
II. Example Data Sheet – Cigarette smoke Measured



TIME(MIN)	Cti	ln(Cti)	TIME(MIN)	Cti	LN(Cti)
0.00	29,549.52	10.29	11.00	2,458.76	7.81
1.00	23,348.25	10.06	12.00	1,992.14	7.60
2.00	18,686.36	9.84	13.00	1,564.02	7.36
3.00	15,875.55	9.67	14.00	1,245.86	7.13
4.00	12,811.57	9.46	15.00	1,012.09	6.92
5.00	9,949.32	9.21			
6.00	8,030.79	8.99			
7.00	6,396.24	8.76			
8.00	5,189.18	8.55			
9.00	3,886.34	8.27			
10.00	3,052.90	8.02			

Quantity	*Measured*	*Lower Limit*	*Upper Limit*	*Acceptable*
Decay Constant	0.22726	-	-	
Slope Standard Deviation (min^{-1})	1.63	-	22.91	YES
Background at Injection (part/cc)	8.624	-	20.00	YES
Initial Concentration (part/cc)	29550	24000	35000	YES
Data points used	16	9	-	YES
Average Temperature (°F)	71	65	75	YES
Average Humidity (%RH)	41	35	45	YES
Average Input Voltage (volts)	120.5			
Average Test Unit Power (watts)	100.8			
CADR (cfm)	**226.55**			
CADR Standard Deviation (cfm)	1.6		22.7	YES

III. Example Data Sheet – Dust Natural



TIME(MIN)	Cti	ln(Cti)	TIME(MIN)	Cti	LN(Cti)
0.00	371.89	5.92	11.00	330.94	5.80
1.00	369.70	5.91	12.00	326.79	5.79
2.00	363.04	5.89	13.00	325.31	5.78
3.00	357.23	5.88	14.00	322.93	5.78
4.00	355.40	5.87	15.00	320.02	5.77
5.00	353.80	5.87			
6.00	350.54	5.86			
7.00	343.87	5.84			
8.00	338.37	5.82			
9.00	337.08	5.82			
10.00	334.01	5.81			

Quantity	*Measured*	*Lower Limit*	*Upper Limit*	*Acceptable*
Decay Constant	0.01021	-	-	
Slope Standard Deviation (min^{-1})	0.28	-	1.03	YES
Background at Injection (part/cc)	0.021	-	0.03	YES
Initial Concentration (part/cc)	371.9	200	400	YES
Data points used	16	9	-	YES
Average Temperature (°F)	70	65	75	YES
Average Humidity (%RH)	40	35	45	YES
Average Input Voltage (volts)	120.8			
Average Test Unit Power (watts)	0.3			
Coefficient of Determination	0.990	0.980	-	YES
CADR (cfm)	**233.51**			
CADR Standard Deviation (cfm)	1.3	-	23.4	YES

IV. Example Data Sheet - Dust Measured

TIME(MIN)	Cti	ln(Cti)	TIME(MIN)	Cti	LN(Cti)
0.00	310.19	5.74	11.00	20.41	3.02
1.00	225.87	5.42	12.00	16.10	2.78
2.00	181.95	5.20	13.00	13.21	2.58
3.00	139.72	4.94	14.00	10.07	2.31
4.00	110.55	4.71	15.00	7.62	2.03
5.00	85.76	4.45			
6.00	69.81	4.25			
7.00	53.35	3.98			
8.00	42.85	3.76			
9.00	32.70	3.49			
10.00	26.68	3.28			

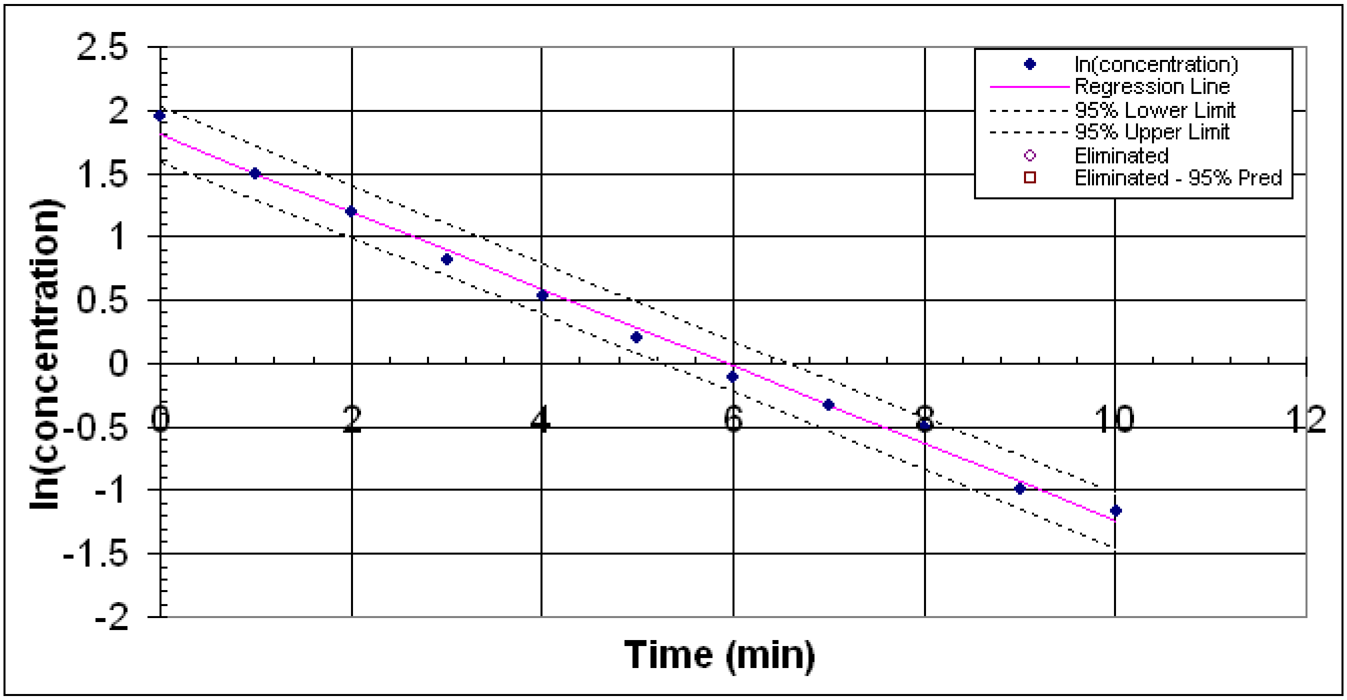
Quantity	*Measured*	*Lower Limit*	*Upper Limit*	*Acceptable*
Decay Constant	0.24186	-	-	
Slope Standard Deviation (min^{-1})	1.3	-	24.38	YES
Background at Injection (part/cc)	0.021	-	0.03	YES
Initial Concentration (part/cc)	310.2	200	400	YES
Data points used	16	9	-	YES
Average Temperature (°F)	71	65	75	YES
Average Humidity (%RH)	38	35	45	YES
Average Input Voltage (volts)	120.7			
Average Test Unit Power (watts)	97.3			
Coefficient of Determination	1.000	0.980	-	YES
CADR (cfm)	**233.51**			
CADR Standard Deviation (cfm)	1.3	-	23.4	YES

V. Example Data Sheet - Pollen Natural

TIME(MIN)	Cti	ln(Cti)	TIME(MIN)	Cti	LN(Cti)
0.00	7.66	2.04			
1.00	6.75	1.91			
2.00	5.84	1.76			
3.00	5.70	1.74			
4.00	5.11	1.63			
5.00	4.54	1.51			
6.00	3.75	1.32			
7.00	3.50	1.25			
8.00	2.90	1.07			
9.00	2.83	1.04			
10.00	2.77	1.02			

Quantity	*Measured*	*Lower Limit*	*Upper Limit*	*Acceptable*
Decay Constant	0.10849	0.095	0.143	YES
Slope Standard Deviation (min $^{-1}$)	4.98	-	10.94	YES
Background at Injection (part/cc)	0.021	-	0.03	YES
Initial Concentration (part/cc)	7.665	4	9	YES
Data points used	11	5	-	YES
Average Temperature (°F)	70	65	75	YES
Average Humidity (%RH)	39	35	45	YES
Average Input Voltage (volts)	121.0			
Average Test Unit Power (watts)	0.3			
Coefficient of Determination	0.982	0.980	-	YES
CADR (cfm)	**197.90**			
CADR Standard Deviation (cfm)	9.7	-	39.6	YES

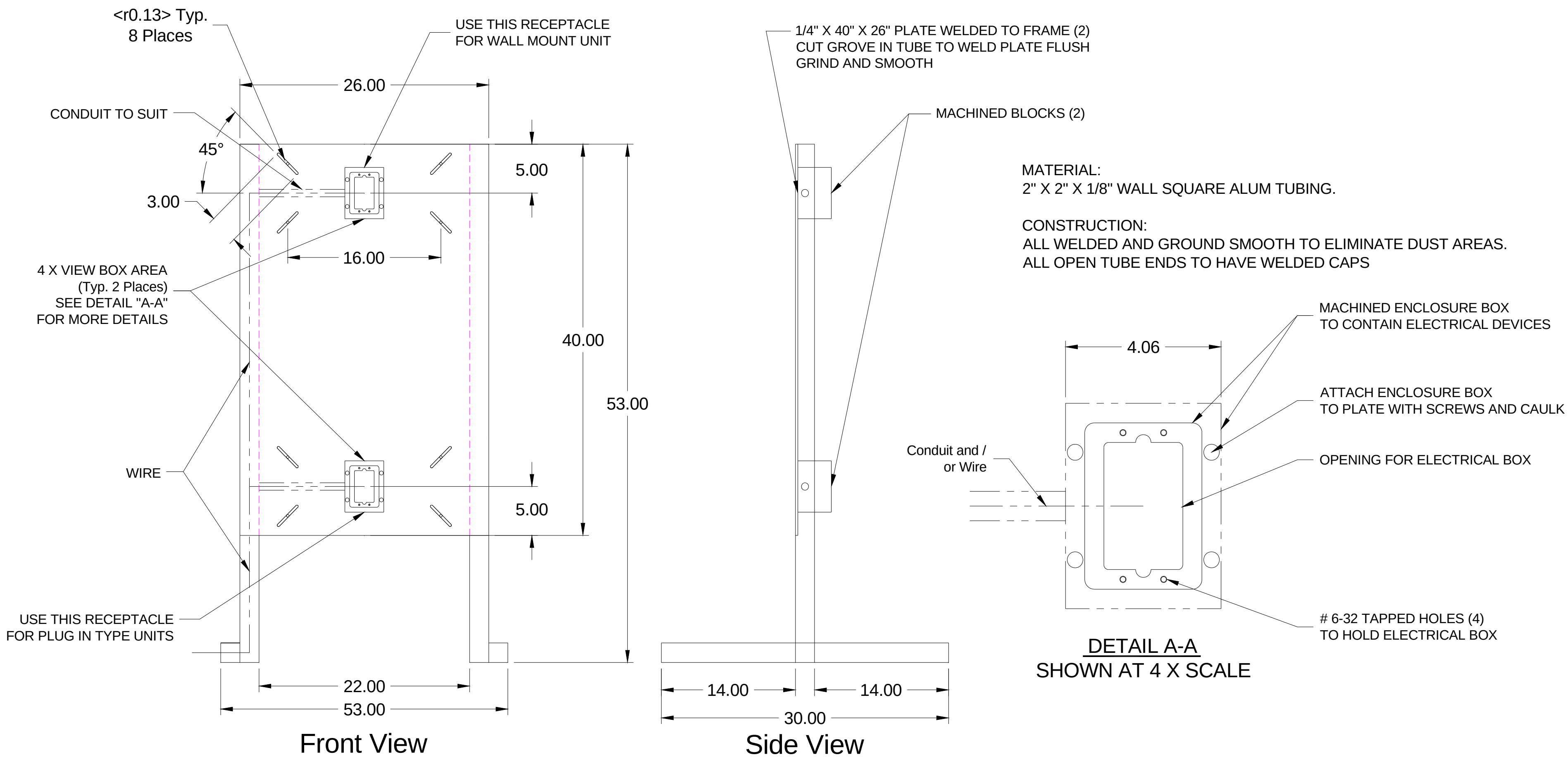
VI. Example Data Sheet – Pollen Measured



TIME(MIN)	Cti	ln(Cti)	TIME(MIN)	Cti	LN(Cti)
0.00	6.97	1.94			
1.00	4.48	1.50			
2.00	3.32	1.20			
3.00	2.27	0.82			
4.00	1.70	0.53			
5.00	1.22	0.20			
6.00	0.90	-0.11			
7.00	0.72	-0.33			
8.00	0.61	-0.50			
9.00	0.37	-0.99			
10.00	0.31	-1.16			

Quantity	***Measured***	***Lower Limit***	***Upper Limit***	***Acceptable***
Decay Constant	0.30482	-	-	
Slope Standard Deviation (min^{-1})	8.27	-	30.73	YES
Background at Injection (part/cc)	0.03	-	0.03	YES
Initial Concentration (part/cc)	6.975	4	9	YES
Data points used	11	5	-	YES
Average Temperature (°F)	70	65	75	YES
Average Humidity (%RH)	39	35	45	YES
Average Input Voltage (volts)	120.7			
Average Test Unit Power (watts)	92.9			
Coefficient of Determination	0.994	0.98	-	YES
CADR (cfm)	**197.90**			
CADR Standard Deviation (cfm)	9.7	-	39.6	YES

ANNEX G – TEST STAND FOR WALL MOUNT AND PLUG-IN TYPE AIR CLEANERS



07/01/05

ANNEX H – INFORMATIVE

DATA ACQUISITION - SEQUENCE OF STEPS AND TIMELINES

A. Sequence of Steps

1. Clean test chamber thoroughly
2. Set up the Air Cleaner test sample in the test chamber
3. Turn on the test facility lab computer
4. Turn on the Test Chamber Environmental Control System (humidifiers, HEPA filter, blower, supply dampers and return dampers)
5. Turn on the Recirculation Fan. This fan remains on for the duration of the test.
6. Turn on Ceiling Mixing Fan.
7. Monitor background concentration
8. When acceptable background concentration is obtained, turn off the Test Chamber Environmental Control System
9. Inject pollutant to specified concentration
10. Turn off air supply used to inject the pollutant and close pollutant injection valve
11. Allow the pollutant to mix for 1 minute (via the Mixing Fan and Recirculation Fan)
12. Turnoff the Mixing Fan.
13. Wait one minute for the Mixing Fan to stop
14. Begin Particle Counter Sampling and Data Acquisition:
    a. Cigarette Smoke
        i. If this is a measured unit run, turn on test sample now.
        This is time (t) = 0 minutes.
        ii. Wait 2 additional minutes (due to diluter sampling delay) before acquiring data.
        iii. Begin data acquisition by taking a 20 second* sample at one minute intervals beginning at t= 2 minutes.
        iv. Obtain at least 9 data points.
    b. Dust
        i. If this is a measured unit run, turn on the test sample now.
        This is t= 0 minutes
        ii. Begin data acquisition by taking 20 second* sample at one minute intervals beginning at t= 0 minutes.
        iii. Obtain at least 9 data points.

c. Pollen

   i. If this is a measured unit run, turn on the test sample now.
      This is t = 0.

   ii. Begin data acquisition by taking a 20 second* sample at one minute intervals beginning at t = 0 minutes.

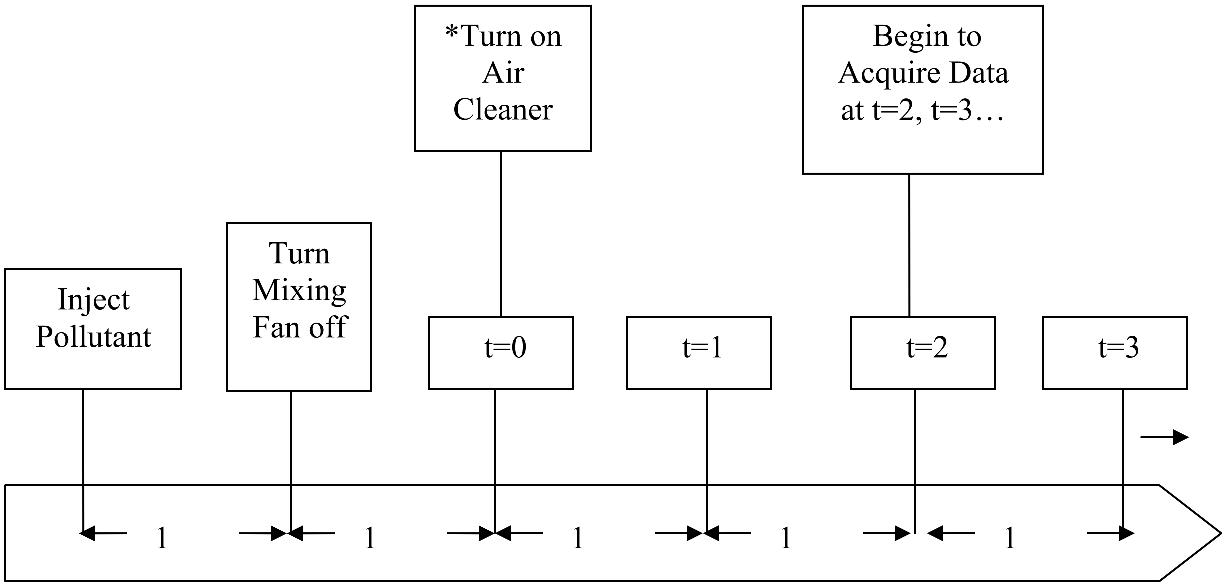
   iii. Obtain at least 5 data points.

15. Test Sequence Complete

16. Perform Data Analysis

- The particle counter sample period is normally 20 seconds, but will be dependent on the specific instrument used.

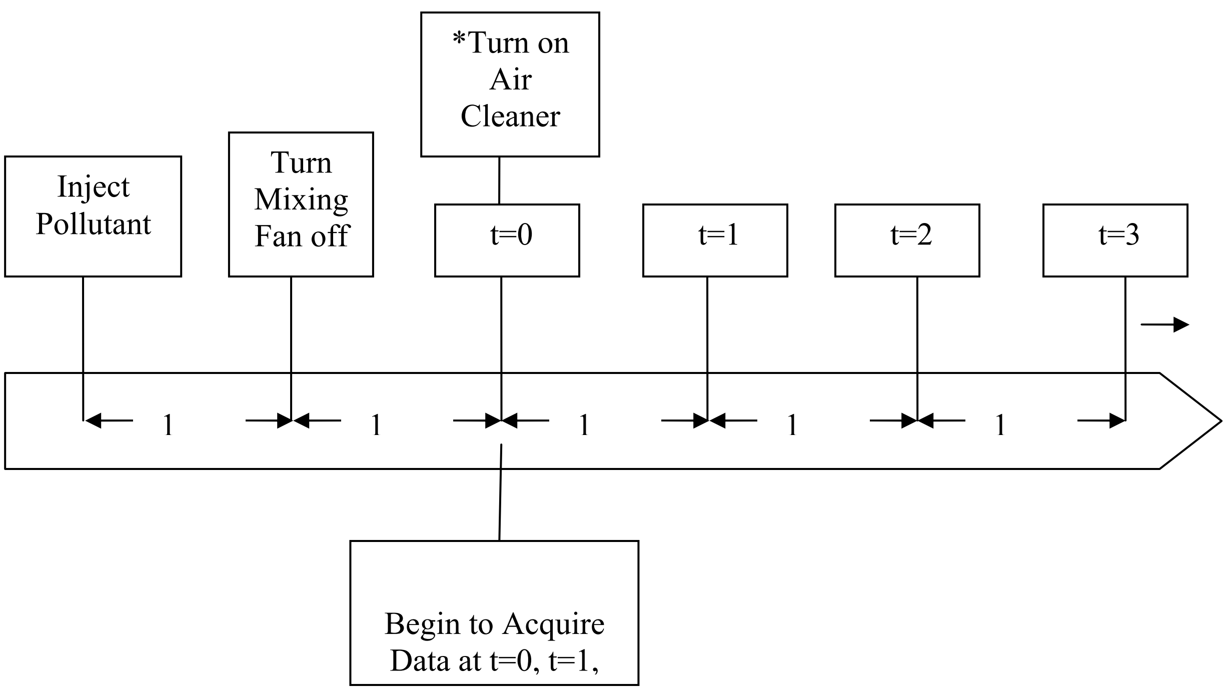
B. Timeline for Cigarette Smoke Data Acquisition



For Cigarette Smoke, obtain at least 9 data points (over 20 minutes).

For natural decay measurements, do not turn on air cleaner*, and begin data acquisition at t=2.

C. Timeline for Dust and Pollen Data Acquisition



For Dust, obtain at least 9 data points (over 20 minutes).

For Pollen, obtain at least 5 data points (over 10 minutes).

Method for Measuring Performance of Portable Household Electric Room Air Cleaners

AHAM AC-1-2013

Correction Sheet
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ASSOCIATION OF HOME APPLIANCE MANUFACTURERS

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Correction Sheet to AHAM AC-1-2013

Page 28, Annex B – Normative, Cigarettes, should read as follows:

Cigarettes:
Kentucky Tobacco Research and Development Center (KTRDC)
University of Kentucky
Lexington KY 40506
Phone: (859) 257 1657
Web site: www.uky.edu/KTRDC

3R4F Research Cigarettes