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Environmental Health & Engineering

Performance Testing of Trane CleanEffects Whole House Air Cleaning System

PERFORMANCE TESTING OF TRANE CLEANEFFECTS WHOLE HOUSE AIR CLEANING SYSTEM

Prepared for:

Trane Residential Systems
6200 Troup Highway
Tyler, TX 75707

Prepared by:

Environmental Health & Engineering, Inc.
60 Wells Avenue
Newton, MA 02459

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LIST OF ABBREVIATIONS AND ACRONYMS

ACH	air changes per hour
AHAM	Association of Home Appliance Manufacturers
AHU	air handling unit
APS	Aerodynamic Particle Sizer™
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc.
ASTM	American Society for Testing and Materials
C_o	initial concentration
C_r	concentration in return air
C_s	concentration in supply air
C_{ss}	concentration at steady-state
C_t	concentration at a specific time
cfm	cubic feet per minute
EAC	electronic air cleaner
EH&E	Environmental Health & Engineering, Inc.
EPA	U.S. Environmental Protection Agency
HEPA	high efficiency particle air
hr^{-1}	per hour
HSPH	Harvard School of Public Health
HVAC	heating, ventilating, and air-conditioning
k	first-order exponential decay rate or total aerosol removal rate (k_t)
k_a	aerosol removal by air exchange or exfiltration
k_{ac}	aerosol removal by an air cleaner
k_{AHU}	aerosol removal within the air handling unit (AHU)
k_p	aerosol removal by losses to surfaces within the home
k_t	total aerosol removal rate
MSDS	material safety data sheet
NIST	National Institute for Standards and Technology
$PM_{2.5}$	particulate matter less than 2.5 micrometers in aerodynamic diameter
ppb	parts per billion
R^2	square of the linear correlation
SF_6	sulfur hexafluoride
t	time
WHCADR	whole house clean air delivery rate
μg/g	micrograms per gram
$\mu g/m^3$	micrograms per cubic meter
μm	micrometer

1.0 EXECUTIVE SUMMARY

1.1 INTRODUCTION

Environmental Health & Engineering (EH&E) evaluated the performance of Trane CleanEffects™ whole house air cleaning system through comparison to industry standards, the performance of alternative systems, and health-based considerations. The testing was conducted as a joint research project between investigators from EH&E and from the Harvard School of Public Health (HSPH).

The evaluation was conducted between May and December 2005 in a test home located adjacent to EH&E's main office in Newton, Massachusetts. The performance of Trane CleanEffects™ and selected other systems was evaluated in the test home under controlled and well-documented conditions. The in-duct and portable air cleaning systems tested were:

- 1- inch standard filter
- 5- inch pleated filter
- Conventional electronic air cleaner (EAC)
- Trane CleanEffects™
- Hunter Quiet Flo™ HEPA Air Purifier Model 30216
- Ionic Breeze Quadra™ Silent Air Purifier

EH&E ascertained the whole house air effectiveness of each air cleaner based on continuous particle concentration measurements made in multiple locations of the test home following the introduction of a fine dust standard and fungal spores. From the data collected, the efficacy of each filtration method was characterized as whole house aerosol removal rate, whole house clean air delivery rate, and indoor-outdoor ratio. Information on the nominal removal efficiency of the selected in-duct air cleaners was obtained as well.

1.2 MATERIALS AND METHODS

The testing was conducted in a 1,350 square foot multi-room modular home located on the property of EH&E's headquarters in Newton, Massachusetts. The EH&E test home was configured and instrumented to be consistent with the test home used by the National Institute of Standards and Technology (NIST) on their Gaithersburg, Maryland, campus (Persily et al. 2003).

Ventilation in the test home was provided by a central forced air handler unit (AHU) that provided 1,273 cubic foot per minute (cfm) of air. The supply air system was balanced so each room received approximately 1 cfm of conditioned air per square foot of floor space. A single return air grille in the dining room returned air to the AHU from the test home. Consistent with typical residential installations, the AHU did not have an outdoor air intake.

Following methods described in the scientific literature (Howard-Reed et al. 2003), EH&E characterized the performance of each air cleaning system when challenged with a fine dust standard aerosolized inside the test home and with fungal spores present in outdoor air brought into the home. The primary metrics of analysis were the whole house aerosol removal rate, whole house clean air delivery rate (WHCADR), indoor-outdoor ratio of particle concentrations, and nominal particle removal efficiency.

WHCADR is analogous but not equivalent to the clean air delivery rate (CADR) metric associated with the Association of Home Appliance Manufacturers (AHAM) protocol for evaluation of portable electric air cleaners (AHAM 2002). WHCADR is determined under more real-world conditions than CADR. These conditions include a test space equivalent to the size of a typical residence, dynamic exfiltration rates, the presence of background particle concentrations, and particle loss on components of air handling equipment that comprise the ventilation system. Notably, the test space required by the AHAM protocol is too small to accommodate testing of a whole house air cleaning system. In short, WHCADR is the superior measure of how well an air cleaning device can control exposure to aerosols, within an actual home.

1.3 RESULTS AND CONCLUSIONS

Among the air cleaners tested, Trane CleanEffects™ demonstrated the:

- Greatest whole house aerosol removal rate for particles and fungal spores
- Greatest WHCADR for particles and fungal spores
- Lowest ratio of indoor-outdoor particle concentrations for all particle sizes
- Greatest nominal removal efficiency for all particle sizes.

Trane CleanEffects™ removed particles from indoor air of the test home faster than any of the other devices evaluated. The average whole house aerosol removal rate for Trane CleanEffects™ was approximately 7.2 per hour (hr^{-1}) for 0.3 – 0.5 micrometer (μm) particles. In other words, Trane CleanEffects™ removed 12% of the 0.3 – 0.5 μm particles in the indoor air of the test home each minute (7.2 per hour x 1 hour/60 minutes x 100 = 12% per minute). In comparison, a typical 1-inch disposable filter removed 0.3 – 0.5 μm particles at a rate of 0.02 hr^{-1} and therefore removed 0.03% of the particles each minute. The removal of 0.3 – 0.5 μm particles by Trane CleanEffects™ was approximately 360 times faster than removal by a typical 1-inch disposable filter.

Trane CleanEffects™ delivered more clean air per period of time than any of the other devices evaluated. For example, the WHCADR for a wide range of particle sizes (0.3 – 20 μm) achieved by Trane CleanEffects™ was 1,158 cfm. The corresponding WHCADR for a typical 1-inch disposable filter and 0.3 – 20 μm particles was 15 cfm. Thus, Trane CleanEffects™ delivered approximately 80 times more air free of 0.3 – 20 μm particles each minute than a typical 1-inch disposable filter.

Trane CleanEffects™ performed better than the portable electric air cleaners included in the testing. For 0.3 – 0.5 μm particles, the WHCADR for Trane CleanEffects™ was more than five times greater than the WHCADR achieved by a single portable air cleaner with an AHAM-rated CADR of approximately 220 cfm. Moreover, Trane CleanEffects™ WHCADR was nearly two times larger than the WHCADR achieved by five portable air cleaners operated simultaneously even though the total AHAM-rated CADR of the air cleaners was approximately equal to Trane CleanEffects™ WHCADR. These results suggest that 10 of the portable air cleaners may achieve the same air cleaning performance as Trane CleanEffects™.

The indoor-outdoor ratio is an important measure of performance because it indicates the ability of an air cleaner to remove particles of outdoor origin from indoor air. With respect to this metric, Trane CleanEffects™ performed among the best of the air cleaners tested. Operation of Trane CleanEffects™ yielded an indoor-outdoor ratio of 2%. In other words, steady-state concentrations of particles in indoor air were 98% lower than particle concentrations in outdoor air when Trane CleanEffects™ was operating.

Trane CleanEffects™ is differentiated from the other devices tested by the combination of high air flow rate and high removal efficiency for all sizes of particles. Trane CleanEffects™ is unique among the air cleaners tested for rapid and efficient removal of accumulation mode particles—particles with aerodynamic diameter between 0.1 and 2.5 μm. These characteristics correspond to rapid removal of particulate air pollutants that are generated indoors and that penetrate building envelopes from outdoors. Overall, the testing results indicate that operation of a whole house Trane CleanEffects™ system will reduce the burden of indoor air pollution relative to the use of portable air cleaners and other in-duct air cleaners.

The effective control of accumulation mode particles by Trane CleanEffects™ is of special interest because particulate air pollutants of anthropogenic origin are ubiquitous in this size range. Particles of anthropogenic origin are emitted directly from sources or formed from interactions among gases emitted from various sources. Examples of anthropogenic sources of accumulation mode particles emitted to outdoor air include cars and trucks, electric power plants, and manufacturing operations. Because of their small size, accumulation mode particles in outdoor air easily enter homes by moving through and around doors, windows, and other penetrations in the building envelope. Common indoor sources of accumulation mode particles include cooking and cigarette smoking. Accumulation mode particles also include constituents of biological origin such as mold spores, cat and dog allergen, bacteria, virus, and some pollen.

The control of particulate air pollution in the accumulation mode is important for public health because non-biological and biological particles in this size class have been associated with increased risks of a variety of adverse health outcomes. Particle concentrations are associated with increased risk of premature mortality and a variety of cardiopulmonary effects, including myocardial infarction (heart attack) and respiratory effects such as bronchitis and asthma attacks. Exposure to mold and certain animal allergens has been associated with asthma exacerbations and lower respiratory symptoms. Notably, a threshold for response of sensitized individuals to particle and allergen exposure has not been demonstrated. For these reasons, the demonstrated ability of Trane CleanEffects™ to remove particles rapidly from indoor and to achieve low steady-state levels of particles indoors is anticipated to have a health benefit.

2.0 INTRODUCTION

The following report describes a detailed evaluation of the air cleaning effectiveness of the Trane CleanEffects™ whole house air cleaning system by Environmental Health & Engineering, Inc. (EH&E). Testing was conducted between May and December 2005 in the test home located adjacent to EH&E's main office in Newton, Massachusetts. The testing was conducted as a joint research project between EH&E and investigators from the Harvard School of Public Health (HSPH).

Objective

The objective of the testing was to quantify the effectiveness of Trane CleanEffects™ for removing contaminants from indoor air through comparison to industry standards, the performance of alternative systems, and health-based considerations.

Approach

The performance of Trane CleanEffects™ and alternative systems was evaluated in the test home under controlled and well-documented conditions. Measurements were obtained to determine the whole-home particle removal and clean air delivery rate achieved by Trane CleanEffects™ and alternative systems. The in-duct air cleaning systems tested were:

- 1-inch standard filter
- 5-inch pleated filter
- Conventional electronic air cleaner (EAC)
- Trane CleanEffects™

EH&E also conducted tests with portable household electric air cleaners in the test home. The units and configurations tested were:

- 1 Hunter Quiet Flo™ HEPA Air Purifier Model 30216
- 5 Hunter Quiet Flo™ HEPA Air Purifier Model 30216
- 3 Ionic Breeze Quadra™ Silent Air Purifier

EH&E ascertained the whole house air effectiveness of each air cleaner based on continuous particle concentration measurements made in multiple locations of the test home following the introduction of a fine dust standard and fungal spores. The study was designed to allow determination of aerosol removal rate for the entire test home as well as single zones within the facility. From the data collected, the efficacy of each filtration method was characterized as whole house aerosol removal rate, whole house clean air delivery rate (WHCADR), and indoor-outdoor ratio. Information on the nominal removal efficiency of the selected in-duct air cleaners were obtained as well.

3.0 MATERIALS AND METHODS

3.1 OVERVIEW

Implementation of the testing program began with the configuration and characterization of the EH&E test home from April 14 through May 6, 2005. During this period, the air handling unit (AHU) and ductwork were installed, a tracer gas system was installed, and the ventilation characteristics of the test home were determined empirically. Over the ensuing three weeks, test protocols for fungal spores and particulate matter were refined and the test home was equipped with air quality monitoring instruments including particle counters, fungal spore traps, an ozone monitor, indoor and outdoor climate sensors, and particle generating equipment.

Through June 2005, the EH&E research team completed tests of fungal spore removal during operation of the AHU with selected in-duct filters. Tests were also conducted without a filter in the AHU to characterize fungal spore removal as a result of deposition within the ventilation system. In both cases, the observed particle removal rate includes deposition onto interior surfaces. This time was also used to evaluate the suitability of candidate aerosol generators for use during trials with a fine dust standard.

Tests with the fine dust standard began on June 29, 2005, and were completed on September 23, 2005. During this time the 1-inch filter, 5-inch filter, EAC, Trane CleanEffects™, and portable electric air cleaners were tested. In addition, substantial effort was devoted to evaluation of bypass associated with the in-duct filter carriage and AHU cabinet.

Additional fungal tests as well as tests using ambient aerosols were performed between September 23 and September 30, 2005. The fungal tests completed during this period involved the EAC and Trane CleanEffects™. Additional tests of aerosol removal efficiency and bypass were conducted in late September 2005.

Reduction and analysis of test data was initiated as results of individual tests became available. The bulk of the data analysis was completed in August, November, and December 2005.

3.2 TEST HOME

The testing was conducted in a multi-room modular home located on the property of EH&E's headquarters in Newton, Massachusetts. Figure 3.1 depicts the location and orientation of the test home. The test home is a manufactured building with the same general characteristics as the National Institute for Standards and Technology (NIST) test home (Persily et al. 2003).

Figure 3.1 EH&E Test Home in Newton, Massachusetts

The test home has a floor area of approximately 1,350 square feet and a ceiling height of approximately 8 feet. The interior of the test home is partitioned into three bedrooms, a kitchen, dining room, living room, den, bathroom, hallway, and mechanical space. Figure 3.2 is a schematic of the test home layout. The total volume of the test home after adjusting for object occupying space such as cabinetry, appliances, etc. is approximately 9,761 cubic feet.

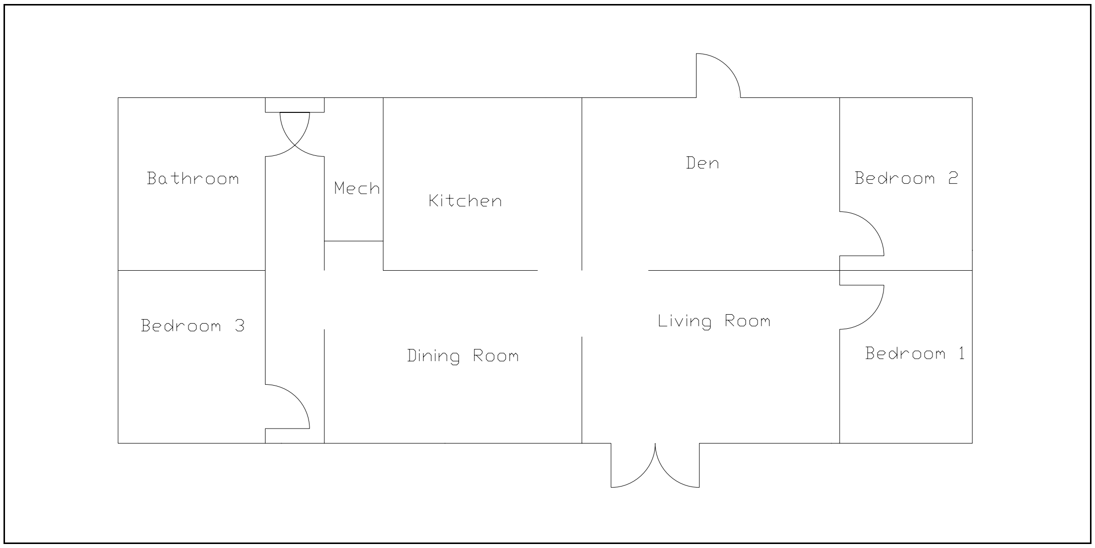


Figure 3.2 Test Home Schematic Floor Plan

The construction details of the test home include exterior walls insulated with R-22 Kraft faced-insulation. The sheathing on the exterior walls consists of a Tyvek® air infiltration barrier and 5/8-inch wood paneling. The interiors of the walls are constructed of 1/2-inch drywall and a vinyl covering. Modular wall systems were used as interior partitions. The roof is insulated and consists of 1/2-inch plywood covered with a 45 millimeter ethylene propylene diene monomer roof membrane. The ceiling is made of suspended gypsum ceiling tiles. The floor of the facility consists of 5/8-inch plywood decking covered with either commercial carpet or vinyl composition tile. Below the floor joists, the floor is insulated with R-22 un-faced insulation. The test home has six single hung windows measuring 23 inches wide by 60 inches and two exterior doors. One door is a 36-inch by 80-inch commercial steel, while the second door is a side by side double glass door that measures 72 inches by 80 inches.

The whole house ventilation system serving the test home is a Trane Modular Variable Speed AHU, model number TWE040E13FB, and a Trane split system heat pump, model number XL14i. Air was ducted throughout the facility with a sheet metal duct system installed just below the finished ceiling. Figure 3.3 depicts an example of the exposed ductwork in a bedroom.

Figure 3.3 Exposed Sheet Metal Ductwork in Bedroom One

The AHU provided 1,273 cubic foot per minute (cfm) of air. The supply air system was balanced so each room received approximately 1 cfm of air per square foot of floor space. A single return air grille in the dining room conveyed air to the AHU from the test home. Consistent with a typical residential installation, the AHU did not have an outdoor air intake.

3.2.1 Envelope Leakage

The envelope leakage rate of the test home was measured in accordance with American Society for Testing and Materials (ASTM) E779-99 by conducting a Minneapolis Blower Door Test (ASTM 1999). The test consists of a powerful variable speed fan that is sealed into an exterior doorway and used to blow air either into or out of the test home. Gauges are used during the testing to measure the pressure difference between inside and outside of the house. Figure 3.4 depicts the blower door test equipment on the exterior double door of the test home.

Figure 3.4 Blower Door Set Up on the Exterior Door of the Test Home

From the data collected during the testing EH&E determined that the approximate leakage area of the test home was 624 square centimeters.

3.2.2 Infiltration

The air exchange rate of the test home was measured in accordance with ASTM E741-00 with sulfur hexafluoride (SF_6) as the tracer gas (ASTM 2000). The testing was conducted by releasing SF_6 into the test home and recording the SF_6 levels in multiple areas of the test home over an extended time period. The decay rate of the SF_6 levels is used to calculate the air exchange rate. Three air exchange rate measurements were made prior to initiation of testing and the values ranged between 0.05 and 0.15 air changes per hour (ACH). As detailed later, air exchange rates of this magnitude were observed consistently throughout the testing program.

3.3 AEROSOL GENERATION

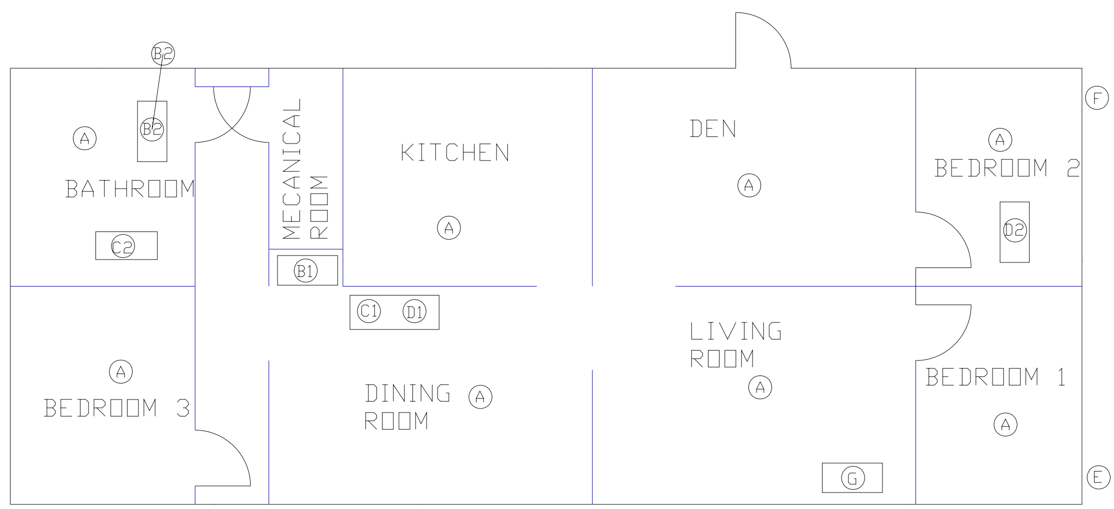
EH&E characterized the performance of each air cleaning system when challenged with a fine dust standard aerosolized inside the test home and with fungal spores present in outdoor air brought into the home. The fine dust standard used in this testing is identical to the dust material required by the AHAM protocol for evaluation of household portable electric air cleaners (AHAM 2002). The fine dust standard includes a wide range of particle sizes extending from less than 0.1 µm to 20 µm.

The fine dust standard was aerosolized with a Pitt 3 Acoustical Generator designed and constructed by the University of Pittsburgh. The Pitt 3 Generator utilizes acoustical energy generated from a loudspeaker to aerosolize powdery materials. Energy from the loudspeaker, in the form of sound waves, vibrates a latex membrane that in turn vibrates the air column and fine dust standard in the plastic tube. The sound waves dispense the particles, which are then carried out with the airflow escaping the top of the plastic tube. Clean, filtered compressed air is supplied at the bottom of the tube and is delivered to the room from a hose attached to the top of the tube along with entrained particles.

3.4 INSTRUMENTATION

3.4.1 Sample Locations

The location of the sampling instruments throughout the test home is indicated on Figure 3.5.



LEGEND

	Instrument Name	Sampling Parameter
A	Sampling Port	Sulfur hexafluoride (SF_6)
B	Climet	Size-selective particle counter
C	TSI Dustrak	$PM_{2.5}$ mass concentration
D	Aerodynamic Particle Sizer	Size-selective particle counter
E	Weather station	Wind speed, direction
F	Weather station	Air temperature, relative humidity
G	Acoustical aerosol generator	Standard fine test dust

Figure 3.5 Test Home Sampling Locations and Equipment

3.4.2 Particle Measurement

Airborne particle concentrations were measured using three types of instruments: two models of the Climet™ laser particle counter (Climet Instruments Co., Redlands, California), the Aerodynamic Particle Sizer™, Model 3321 (TSI Inc., St. Paul, Minnesota), and the DustTrak (TSI Inc., St. Paul, Minnesota).

The Climet models CI-550 and Spectro.3 count particles from 0.3 μm to greater than 10 μm in aerodynamic diameter. The CI-550 particle counter measures six particle size ranges (six channels) including 0.3 – 0.5 μm, 0.5 – 1.0 μm, 1.0 – 3.0 μm, 3.0 – 5.0 μm, 5.0 – 10.0 μm, and greater than 10 μm. The Spectro.3 particle counter measures sixteen particle size ranges (16 channels) including 0.3 – 0.4 μm, 0.4 – 0.5 μm, 0.5 – 0.55 μm, 0.55 – 0.7 μm, 0.7 – 1.0 μm, 1.0 – 1.3 μm, 1.3 – 1.6 μm, 1.6 – 2.0 μm, 2.0 – 2.2 μm, 2.2 – 3.0 μm, 3.0 – 4.0 μm, 4.0 – 5.0 μm, 5 – 5.5 μm, 5.5 – 7.0 μm, 7.0 – 10.0 μm, and greater than 10.0 μm.

Each Climet instrument was connected to a valve that enabled sequential automated sampling from two separate locations. The Climet Spectro was set up to sample air from outdoors and in the bathroom, while the Climet CI-550 sampled air from the supply duct immediately downstream of the AHU and in the dining room near the AHU return grille. For the in-duct measurement, an isokinetic sample probe was used to ensure a representative air sample from the moving aerosol stream.

The Aerodynamic Particle Sizer™ (APS) measures a range of particle sizes from 0.5 μm to 20 μm with a maximum particle concentration of 1,000 particles per cubic centimeter at 0.5 μm. The APS instruments were used to measure particle levels at the return air grille intake for the AHU and in bedroom 2.

3.4.3 Other Parameters

Ambient indoor temperature and relative humidity were measured in each room of the test home with a HOBO™ model H8 portable temperature/relative humidity data logger manufactured by Onset Computer Corp. (Bourne, Massachusetts). Test house air handler fan amperage draw was measured with a HOBO™ equipped with an external

AC current sensor input. Temperature and relative humidity sensors were compared to primary standards. As discussed above, air exchange rate was measured during each test according to ASTM E779-98. Outdoor temperature, relative humidity, wind speed, and direction were measured with a Davis weather station during each test as well.

3.4.4 Portable Air Cleaners

In addition to Trane CleanEffects™ and other in-duct air cleaners, EH&E included two types of portable air cleaners in the testing program: the Hunter Quiet Flo™ HEPA Air Purifier Model 30216 and the Ionic Breeze Quadra™ Silent Air Purifier. The Hunter model is manufactured by Hunter Fan Company (Memphis, Tennessee) and equipped with 3 user selectable fan speeds. The Hunter units were run at the highest fan speed, approximately 220 cfm of air, during the testing. The Ionic Breeze model tested is manufactured by Sharper Image (San Francisco, California) and has electronically charged rods that capture particles. The Ionic Breeze does not have any fans or filters.

3.5 CLEANING PROTOCOL

To ensure that the test home environment was consistent among trials, EH&E carried out a cleaning protocol between tests. Prior to cleaning, EH&E set the AHU fan to run continuously and verified that the heat pump was not being used to condition the space. The AHU cooling coil was disengaged to prevent condensation from forming on the coil and possibly enhancing particle removal.

To remove particles from the air between tests, EH&E installed a five-inch pleated in-duct filter in the AHU and allowed the system to run for 30 minutes. While the AHU was operating, the carpet in the test home was vacuumed with a Dirt Devil Vision™ vacuum equipped with high efficiency particle air (HEPA) filtration. After vacuuming, the AHU was run an additional 10 minutes to filter out any particles suspended by the vacuuming operation. The air cleaner being tested was then placed in the AHU.

3.6 TEST PROTOCOL

Monitoring data were collected for at least 10 minutes of data prior to the beginning of each test. After the proper air cleaner was installed in the AHU and the fan was operating again, the aerosol generator was run for one minute. During the introduction of fine test dust, a vacuum cleaner with the filter and bag removed was operated in the area of the AHU return grille to suspend carpet dust and thereby increase the number of coarse (>2.5 μm particles) particles in the air. After the aerosolization period, the AHU (and portable air cleaners when tested) was run for approximately 80 minutes. At the end of each test, data collected by the monitoring equipment was downloaded to a network drive and underwent preliminary data reduction. The test protocol was repeated generally 6 times for each combination of air cleaner and challenge aerosol (fine test dust or ambient fungal spores). Protocols for the fine dust standard and fungal spore tests are presented in Appendix A and B, respectively.

3.7 DATA ANALYSIS

Raw data generated from the multi-channel sampling equipment was sorted and organized into the following discrete size bins:

- 0.3 – 0.5 microns (Climet only)
- 0.5 – 1.0 microns
- 1.0 – 3.0 microns
- 3.0 – 5.0 microns
- 5.0 – 10.0 microns
- 10.0 – 20.0 microns

Fungal spore samples were identified to the level of genus or spore type.

The size-specific particle data and total fungal spore concentrations collected during the respective tests were analyzed to ascertain nominal removal efficiency, whole aerosol removal rate, and whole house clean air delivery rate,

Details of the data analysis methods are described below.

Removal Efficiency

Particle concentration measurements were made upstream and downstream of the in-duct air cleaners to ascertain nominal size-specific removal efficiencies and thereby support interpretation of the whole house air cleaning data. The protocols employed in the test home were designed to allow determination of whole house particle removal rates rather than removal efficiency for in-duct air cleaners. For example, determination of removal rate requires that concentrations change over the course of a test. In contrast, protocols for determination of removal efficiency require that concentrations remain constant over a test (ASHRAE 1999). In addition, the determination of removal efficiency for an air cleaner requires zero by-pass. However, the whole house testing regimen employed by EH&E used a standard air handler cabinet with no special modifications to eliminate by-pass. For these reasons, the removal efficiencies observed during the test home work are considered nominal and qualitative rather than a quantitative measure of air cleaner efficiency.

Nominal removal efficiency for each filter was determined from particle counts collected by a Climet instrument that sampled from return air (C_R) and supply air (C_S) for alternating one-minute periods during each test. The following equation was used to compute efficiency for each minute of a test:

$$Efficiency = \frac{(C_{R,t-2} + C_{R,t})/2 - C_{S,t-1}}{(C_{R,t-2} + C_{R,t})/2} x100 \qquad \text{Equation 3.1}$$

where t represents time in minutes.

Removal efficiency for each test was calculated as the average of the one-minute efficiencies.

Aerosol Removal Rate

Total aerosol removal rates were estimated from measurement data in two ways: (1) a non-linear model (PROC NLIN, SAS Institute, Cary, North Carolina) that estimates the parameters of a first-order exponential decay model and (2) parameters estimated from the ordinary least squares regression of natural log-transformed aerosol concentrations versus time.

Both estimation methods were conducted after a series of quality assurance and data reduction steps were applied to the particle count and mold spore data. Quality assurance fields in the raw data generated by the measurement instruments were examined for error codes. No error codes or messages were identified in data collected during the tests. Next, the data fields produced by each instrument were reduced to date, time, and aerosol concentrations. Plots of aerosol concentration versus time were generated and inspected by the data analyst and project manager for consistency with the conceptual model of first-order decay:

$$C_t = C_{ss} + (C_o – C_{ss})\ x\ e^{-kt} \qquad \text{Equation 3.2}$$

where,

C_t = concentration at a specific time (particles per ft^3)

C_{ss} = concentration at steady-state (particles per ft^3)

C_o = initial concentration (particles per ft^3)

k = first-order exponential decay rate or total aerosol removal rate (k_t)

t = time

The period of exponential decay in each test was defined by the time corresponding to the initial concentration (C_o) and the time segment that corresponded to steady-state aerosol concentrations (C_{ss}). The resulting data stream was analyzed according to the non-linear and regression models. The square of the linear correlation (R^2) between measured concentrations and concentrations predicted by the respective models was used to quantify the model fit. Estimates of the aerosol removal rate were restricted to tests with R^2 of at least 0.8. This decision rule did not have an important influence on the results because only approximately 4% of the tests resulted in an R^2 less than 0.8

The non-linear model requires fewer subjective assumptions than the regression model and therefore was considered to be the superior of the two methods. Accordingly, the aerosol removal rate estimated by the non-linear model is reported for tests where both the non-linear and regression models yielded an acceptable fit to the measured concentrations.

For tests in which a period of exponential decay could not be identified, the aerosol removal rate was not estimated quantitatively. In some tests, the concentrations of a certain particle size exhibited no apparent decay over time. In these cases, the aerosol removal rate was set to zero. In other tests, the airborne levels of a certain particle size (typically the 5 – 10 μm and 10 – 20 μm bins) were low (for example fewer than 5 particles counted per integration period) and exhibited a discontinuous rather than consistent decrease over time. In these cases, a period of exponential decay could not be identified and the aerosol removal rate was not estimated.

Decreases in aerosol concentrations following a short-term emission result from several removal processes including exfiltration, impaction on interior surfaces, impaction within the air handling unit, and removal by an air cleaning device. In general, the change in aerosol concentration over time is expressed as:

$$V\frac{dC_R}{dt} = Q(C_S - C_R) - L_d - L_a \qquad \text{Equation 3.3}$$

where,
V = volume of the building (cubic feet, ft^3)
t = time (hours, hr)
Q = volumetric flow rate of air through the AHU (cubic feet per hour, ft^3/hr)
L_d = rate of aerosol deposition to interior surfaces (particles per hour)
L_a = rate of aerosol exfiltration by air exchange (particles per hour)

Because the air cleaner and AHU are in series:

$$C_S = (1 - E_{ac})(1 - E_{ahu})C_R \qquad \text{Equation 3.4}$$

where,
E_{ac} = aerosol removal efficiency of the air cleaner
E_{ahu} = aerosol removal efficiency of the AHU

L_d and L_a are proportional to C_R:

$$L_d = \gamma_d \cdot C_R \qquad \text{Equation 3.5}$$

$$L_a = \gamma_a \cdot C_R \qquad \text{Equation 3.6}$$

After substituting into Equation 3.3 and collecting terms:

$$\frac{dC_R}{dt} = -\frac{Q}{V}(E_{ahu} + E_{ac} - E_{ahu} \cdot E_{ac})C_R - \frac{\gamma_d}{V}C_R - \frac{\gamma_a}{V}C_R \qquad \text{Equation 3.7}$$

In the absence of an AHU or air cleaner (E_{ahu}=0, E_{ac}=0), Equation 3.7 reduces to:

$$\frac{dC_R}{dt} = -\frac{\dot{\gamma}_d}{V}C_R - \frac{\gamma_a}{V}C_R \qquad \text{Equation 3.8}$$

From equation 3.8, the rate constants for losses to interior surfaces (k_d) and air exchange (k_a) are:

$$k_d = -\frac{\dot{\gamma}_d}{V} \qquad \text{Equation 3.9}$$

$$k_a = -\frac{\dot{\gamma}_a}{V} \qquad \text{Equation 3.10}$$

In the presence of an AHU and absence of an air cleaner (E_{ac}=0), Equation 3.7 reduces to:

$$\frac{dC_R}{dt} = -\frac{Q}{V} E_{ahu} \cdot C_R - k_d \, C_R - k_a \, C_R \qquad \text{Equation 3.11}$$

From equation 3.11, the rate constant for losses by the AHU (k_{ahu}) is:

$$k_{ahu} = \frac{Q}{V} E_{ahu} C_R \qquad \text{Equation 3.12}$$

In the presence of an AHU and an air cleaner, Equation 3.7 can be expressed as:

$$\frac{dC_R}{dt} = \left(-\frac{Q}{V} E_{ac} - (1 - E_{ac}) k_{ahu} - k_d - k_a \right) C_R \qquad \text{Equation 3.13}$$

Based on this construct, the total aerosol removal rate for an individual test (k_t) was modeled as:

$$k_t = \frac{Q}{V} E_{ac} + (1 - E_{ac}) k_{ahu} + k_d + k_a \qquad \text{Equation 3.14}$$

K_t and k_a were determined from measurements made during each test. More specifically, k_t was estimated from the change in observed aerosol concentrations over time using the statistical methods described above and k_a was estimated by regressing natural log SF_6 concentrations against time. In Equation 3.14, k_d is the average deposition rate determined from multiple tests where neither the AHU nor an air cleaner were operated, identified henceforth as “No AHU, No Air Cleaner” tests. Similarly, k_{ahu} in Equation 3.14 is the average aerosol removal by the AHU determined from multiple tests conducted with the AHU operating but without an air cleaner (“No Air Cleaner” tests), accounting for k_d.

Finally, the rate loss constant for an air cleaner (k_{ac}) is computed by solving Equation 3.14 for E_{ac} and multiplying by Q/V:

$$k_{ac} = \frac{k_t - k_d - k_{ahu}}{\frac{Q}{V} - k_{ahu}} \times \frac{Q}{V} \qquad \text{Equation 3.15}$$

Whole House Clean Air Delivery Rate (WHCADR)

The WHCADR with units of cubic feet per minute was calculated as the product of k_{ac}

and the volume of the test home. WHCADR is analogous but not equivalent to the CADR associated with portable electric air cleaners as defined by the Association of Home Appliance Manufacturers (AHAM 2002). For example, WHCADR represents the efficacy of an air cleaning system throughout a typical sized-home accounting for ventilation by outdoor air, air movement among rooms, and particle loss in an AHU. CADR, in contrast, represents aerosol removal within a stagnant experimental chamber. WHCADR is the superior measure of how well an air cleaning device can control exposure to aerosols, including particulate matter and microorganisms, within an actual home. A more complete discussion of WHCADR and CADR is presented in Section 5.1.

Indoor-Outdoor Ratio

Steady-state aerosol concentrations indoors are a function of aerosol emission and removal rates. For a given emission rate, the steady-state concentration is inversely related to removal rate. To provide another metric for evaluating the efficacy of the air cleaners tested, EH&E determined the ratio of steady-state indoor to outdoor aerosol concentrations for each test. The indoor-outdoor ratio was calculated from data obtained by the Climet particle counter that collected sequential one-minute samples from the bathroom and outdoors. The indoor steady-state concentration was either determined from the non-linear model or estimated as the average concentration over the final 5 minutes of a test. The outdoor concentration used in computing the indoor-outdoor ratio was the average concentration over the duration of a test.

4.0 RESULTS

4.1 NOMINAL PARTICLE REMOVAL EFFICIENCY

The average particle removal efficiencies for each in-duct air cleaner are summarized in Table 4.1. The removal efficiency results for individual tests are tabulated in Appendix A. Note that because the downstream measurement was taken from a supply duct, the removal efficiencies reported here include filtration as well as deposition of particles within the AHU.

Table 4.1 Average nominal Particle Removal Efficiency (%) for In-duct Air Cleaner Configurations

Air Cleaner	N	Particle Size (microns)					
		0.3 – 0.5	**0.5 – 1**	**1 – 3**	**3 – 5**	**5 – 10**	**10 – 20**
No Filter	6	0.0	0.0	6.0	32.1	55.8	65.3
1-inch	9	0.0	2.5	20.7	55.3	74.3	78.8
5-inch	3	14.6	29.2	47.0	77.8	86.9	86.3
EAC	7	41.6	55.4	67.4	85.4	93.0	94.4
Trane CleanEffects™	7	90.1	90.7	91.8	96.5	98.4	96.2

N sample size
EAC electronic air cleaner

Removal efficiency was directly related to particle size for a given air cleaner. With the 1-inch in-duct filter, less than 1% of particles below 0.5 μm were removed, 3% of particles between 0.5 and 1 μm, 21% of particles between 1 and 3 μm, 55% of particles between 3 and 5 μm, 74% of particles between 5 and 10 μm, and 79% of particles between 10 and 20 μm. A similar trend was observed for each of the other in-duct air cleaners, although the range of efficiency across particle size bins differed among air cleaners. For instance, removal efficiency across particle size bins was most consistent for Trane CleanEffects™ compared to other in-duct air cleaners, varying from 90.1% for 0.3 – 0.5 μm aerosols to 98.4% for 5 – 10 μm aerosols.

The nominal removal efficiency varied among air cleaners for a given particle size as well. The in-duct air cleaners ranked from highest to lowest removal efficiency for a given particle size are as follows: Trane CleanEffects™, EAC, 5-inch, and 1-inch. This rank order is most apparent for the 0.3 – 0.5 μm size bin where the removal efficiencies are approximately 90%, 40%, 15%, and 0%, respectively. The differences among in-duct air cleaners were smaller for the larger particle size bins although the rank order was preserved.

4.2 WHOLE HOUSE AEROSOL REMOVAL RATE AND CLEAN AIR DELIVERY RATE

4.2.1 Fine Test Dust

The average whole house particle removal rates determined from tests with the fine dust standard are summarized in this section. Results for the 10 – 20 μm particles are not presented because the particle number concentrations were low and could not be quantified precisely.

Overall, the greatest whole house particle removal rates among the in-duct and portable air cleaners were observed for Trane CleanEffects™. Referring to results based upon particle number concentrations measured by the Climet instrument near the HVAC return (Table 4.2), the average k_{ac} of 0.3 – 0.5 micron particles for Trane CleanEffects™ was 7.2 per hour (hr^{-1}). The next greatest k_{ac} in the 0.3 – 0.5 μm range was achieved by the electronic air cleaner (4.6 hr^{-1}). A single HEPA-filtered portable air cleaner (1.4 hr^{-1}) and an in-duct 5-inch filter (1.5 hr^{-1}) had approximately identical k_{ac} for 0.3 – 0.5 micron particles. Operation of 5 HEPA-filtered portable air cleaners produced a whole house removal rate (3.9 hr^{-1}) for 0.3 – 0.5 micron particles that approached the performance of the EAC but was 3.3 hr^{-1} lower than Trane CleanEffects™. Representative decay curves for Trane CleanEffects™ versus the other in-duct air cleaners and portable air cleaners are shown in Figures 4.1 and 4.2.

Examination of the remaining portions of Table 4.2 shows that Trane CleanEffects™ achieved the greatest removal rate for each size category of particles. The 5-10 micron particle range was an exception where 5 portable HEPA units produced a particle removal rate slightly greater than Trane CleanEffects™. Operation of 3 portable ionic air cleaners yielded a removal rate that ranged from 0 to approximately 1 hr^{-1} depending upon particle size.

WHCADR for each combination of air cleaner and particle size is also summarized in Table 4.2 and is directly related to whole house k_{ac}. In the 0.3 – 0.5 μm category, Trane CleanEffects™ had an average WHCADR of 1,171 cfm, compared to the next highest WHCADR of 750 cfm attained by the EAC. Operation of a single HEPA-filter portable air cleaner produced an average WHCADR of approximately 230 cfm.

Detailed information on the particle removal rate and related parameters for each test are presented in Appendix D. As shown in Appendix E, whole house particle removal and clean air delivery rates determined from the APS measurements in the dining room were similar to those obtained from the Climet instrument with which it was collocated. Note that APS results for the 5 – 10 μm category are considered unreliable because of the low particle counts and small number of tests for which decay rates could be estimated.

Table 4.2 Whole House Particle Removal Rates and Clean Air Delivery Rate for Selected Air Cleaning Devices Based Upon Particle Number Concentration Measured by Climet Instrument in Dining Room of Test Home

Air Cleaner	N	Observed Removal Rate, $k_p+k_{AHU}+k_{ac}$ (hr^{-1})		Air Cleaner Removal Rate, k_{ac} (hr^{-1})		WHCADR (cfm)	
		Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
0.3 – 0.5 Microns							
No AHU, No Air Cleaner	6	0	0	NA	NA	NA	NA
No Air Cleaner	6	0	0	NA	NA	NA	NA
1-inch	10	0.02	0.05	0.02	0.05	3	8
5-inch	3	1.50	0.34	1.50	0.34	244	55
EAC	7	4.61	0.37	4.61	0.37	750	60
Trane CleanEffects™	6	7.20	1.27	7.20	1.27	1,171	207
Portable HEPA-Single	6	1.42	1.51	1.42	1.51	231	246
Portable HEPA-Multiple	2	3.85	0.58	3.85	0.58	626	94
Portable Ionic-Multiple	6	0	0	0	0	0	0
0.5 – 1 Microns							
No AHU, No Air Cleaner	6	0	0	NA	NA	NA	NA
No Air Cleaner	6	0.16	0.08	NA	NA	NA	NA
1-inch	8	0.46	0.19	0.35	0.15	57	24
5-inch	3	3.28	0.25	3.21	0.26	522	42
EAC	7	5.41	0.40	5.37	0.41	874	67
Trane CleanEffects™	7	7.25	0.70	7.24	0.72	1,178	117
Portable HEPA-Single	6	1.80	0.35	1.70	0.36	277	59
Portable HEPA-Multiple	2	4.02	0.81	3.96	0.82	644	133
Portable Ionic-Multiple	3	0.04	0.04	0	0	0	0

Table 4.2 Continued

Air Cleaner	N	Observed Removal Rate, $k_p+k_{AHU}+k_{ac}$ (hr^{-1})		Air Cleaner Removal Rate, k_{ac} (hr^{-1})		WHCADR (cfm)	
		Mean	SD	Mean	SD	Mean	SD
1 – 3 Microns							
No AHU, No Air Cleaner	6	0.53	0.24	NA	NA	NA	NA
No Air Cleaner	5	0.88	0.05	NA	NA	NA	NA
1-inch	[illegible]	1.72	0.52	0.91	0.44	148	72
5-inch	3	5.10	0.38	4.42	0.40	719	65
EAC	7	6.31	0.52	5.68	0.55	924	89
Trane CleanEffects™	7	7.63	0.77	7.06	0.80	1,149	130
Portable HEPA-Single	6	2.69	0.30	1.90	0.32	309	52
Portable HEPA-Multiple	2	4.84	0.95	4.15	0.99	675	161
Portable Ionic-Multiple	6	1.13	0.09	0.26	0.09	42	15
3 – 5 Microns							
No AHU, No Air Cleaner	3	0.87	0.21	NA	NA	NA	NA
No Air Cleaner	5	2.83	0.17	NA	NA	NA	NA
1-inch	10	4.10	1.26	1.92	1.19	312	194
5-inch	3	7.17	0.63	5.79	0.84	942	137
EAC	7	7.85	0.59	6.69	0.78	1,088	127
Trane CleanEffects™	7	8.32	1.02	7.32	1.37	1,191	223
Portable HEPA-Single	6	5.06	0.41	2.98	0.55	485	89
Portable HEPA-Multiple	2	7.41	0.73	6.10	0.97	992	158
Portable Ionic-Multiple	6	2.77	0.70	0.29	0.53	47	86
5 – 10 Microns							
No AHU, No Air Cleaner	2	2.56	0.85	NA	NA	NA	NA
No Air Cleaner	5	4.28	0.59	NA	NA	NA	NA
1-inch	10	5.27	2.66	1.78	2.85	290	464
5-inch	3	7.97	1.53	4.73	1.96	769	319
EAC	7	8.02	2.07	4.80	2.66	781	433
Trane CleanEffects™	7	9.18	1.81	6.28	2.32	1,022	377
Portable HEPA-Single	6	7.34	1.07	3.92	1.38	638	225
Portable HEPA-Multiple	2	9.92	0.35	7.23	0.45	1,176	73
Portable Ionic-Multiple	6	3.96	2.49	0.98	2.41	159	392
0.3 – 20 Microns							
No AHU, No Air Cleaner	6	0	0	NA	NA	NA	NA
No Air Cleaner	4	0.04	0.04	NA	NA	NA	NA
1-inch	8	0.11	0.16	0.09	0.14	15	23
5-inch	3	2.29	0.58	2.26	0.58	368	94
EAC	7	5.10	0.28	5.09	0.28	828	46
Trane CleanEffects™	7	7.16	0.98	7.16	0.99	1,165	161
Portable HEPA-Single	3	2.29	1.13	2.26	1.13	368	185
Portable HEPA-Multiple	2	4.12	0.71	4.10	0.72	667	117
Portable Ionic-Multiple	5	0	0	0	0	0	0

Table 4.2 Continued	
k_p	aerosol removal by losses to surfaces within the home
k_{AHU}	aerosol removal within the air handling unit
k_{ac}	aerosol removal by an air cleaner
hr^{-1}	per hour
WHCADR	whole house clean air delivery rate
cfm	cubic feet per minute
SD	standard deviation
NA	not applicable
EAC	electronic air cleaner
HEPA	high efficiency particle air

The sample size indicates the number of tests for which an aerosol removal rate was determined rather than the number of trials conducted.

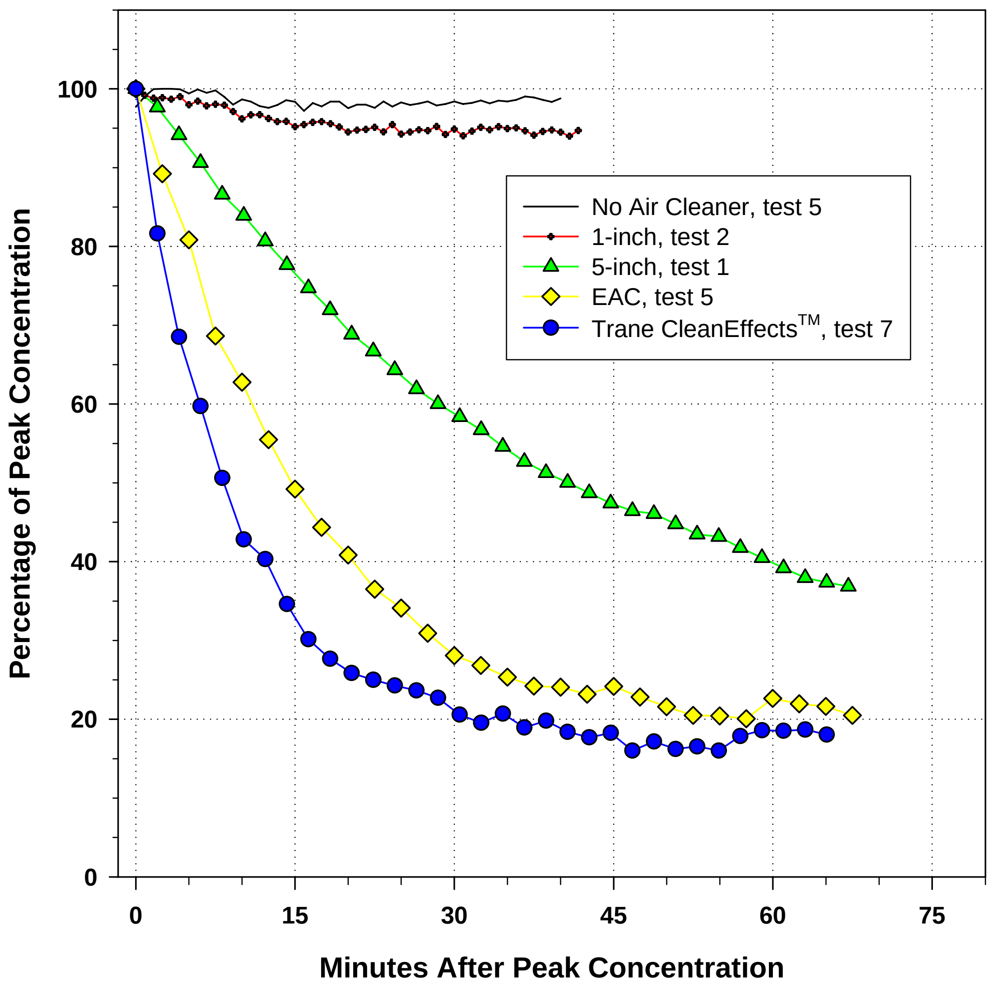


Figure 4.1 Normalized Concentrations of 0.3 – 0.5 μm Particles Over Time for Representative Tests of In-duct Air Cleaners

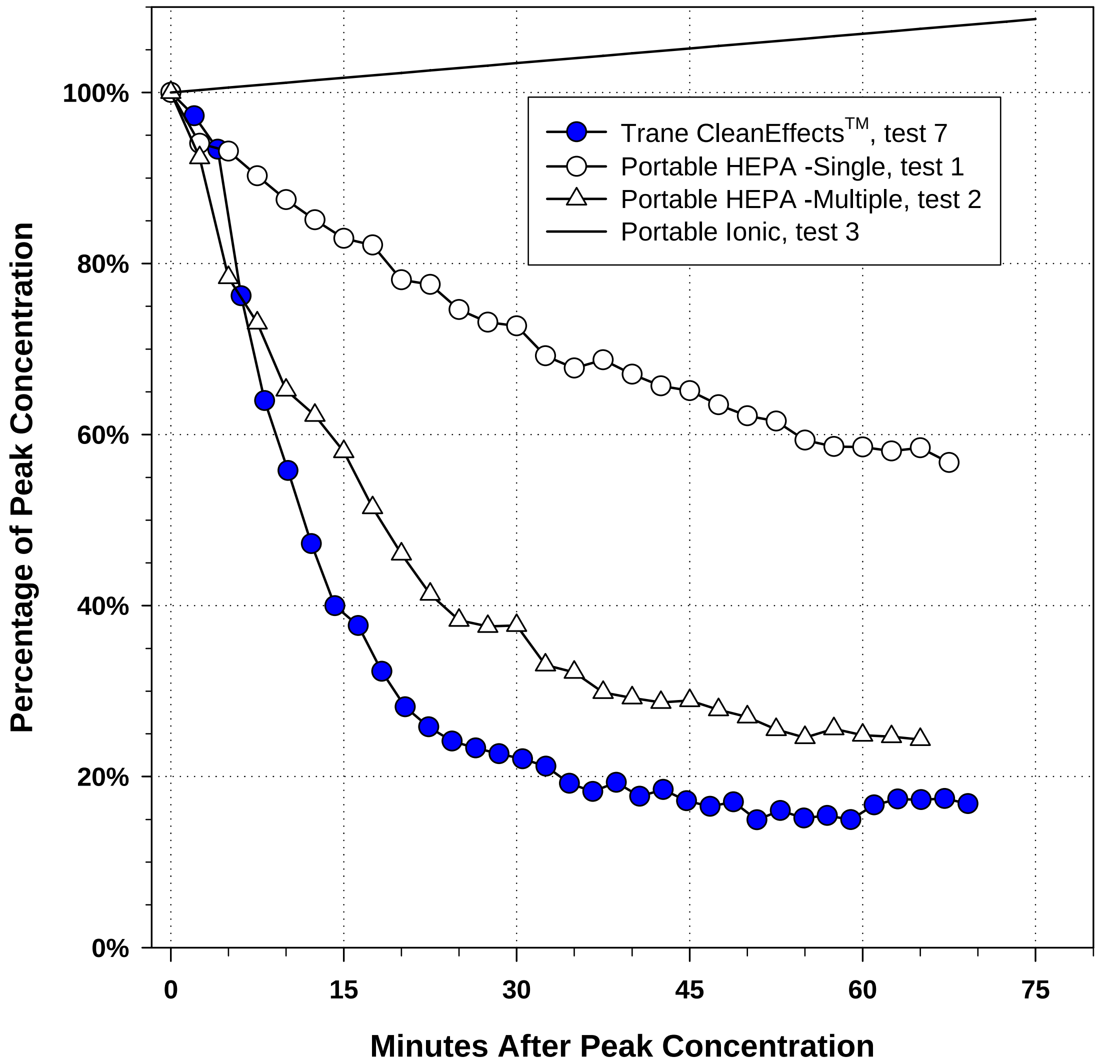


Figure 4.2 Normalized Concentrations of 0.3 – 0.5 μm Particles Over Time for Representative Tests of Trane CleanEffects™ and Portable Air Cleaners

Whole house particle removal rates for particle mass concentration are summarized in Table 4.3. Note that k_{ac} and WHCADR are not reported for particle mass concentrations because k_d was not determined for particle mass due to equipment constraints. The results for mass concentration parallel the removal rates based on particle number concentrations. The mass concentration results compare best to the larger particle size categories such as 3 – 5 μm that account for a majority of particle mass. As indicated by the standard deviation across tests shown in Table 4.3, particle removal rates based on the DustTrak are inherently more variable than those from the Climet, possibly because of the lower sampling flow rate. Total removal rates less than 4.7 hr^{-1} could not be determined reliably for particulate matter less than 2.5 micrometers in aerodynamic diameter ($PM_{2.5}$) mass concentrations. Therefore, the results shown for the No Air Cleaner, Portable HEPA-Single, and Portable Ionic-Multiple should be considered equivalent.

Table 4.3 Whole House Particle Removal Rate (hr^{-1}) and Clean Air Delivery Rate (cfm) for Selected Air Cleaning Devices Based Upon Particle Mass Concentrations Measured by a DustTrak Instrument in Dining Room of Test Home

Air Cleaner	Sample Size	Observed Removal Rate, k_p+k_{AHU}+k_{ac} (hr^{-1})	
		Mean	Standard Deviation
No Air Cleaner	1	4.73	--
1-inch	1	5.27	--
5-inch	5	8.63	3.28
EAC	5	7.12	3.30
Trane CleanEffects™	5	11.08	1.76
Portable HEPA-Single	4	2.20	0.35
Portable HEPA-Multiple	1	7.57	--
Portable Ionic-Multiple	5	3.87	1.82

hr^{-1} per hour
cfm cubic feet per minute
k_p aerosol removal by losses to surfaces within the home
k_{AHU} aerosol removal within the air handling unit
k_{ac} aerosol removal by an air cleaner
EAC electronic air cleaner

4.2.2 Fungal Spores

Whole house removal and clean air delivery rates for total fungal spore concentrations are shown in Table 4.4. Operation of Trane CleanEffects™ removed fungal spores at a greater rate than the other in-duct air cleaning configurations tested. The fungal spore removal rates are generally consistent with removal rates observed for the 3 – 5 μm particle size category. Note that k_{ac} and WHCADR are not reported for fungal spores because k_d was not determined due to time constraints.

Table 4.4 Whole House Fungal Spore Removal Rate (hr^{-1}) and Clean Air Delivery Rate (cfm) for Selected Air Cleaning Devices Based Upon Total Fungal Spore Concentrations Measured in Dining Room of Test Home

Filter	Sample Size	Observed Removal Rate, $k_p+k_{AHU}+k_{ac}$ (hr^{-1})	
		Mean	**Standard Deviation**
No Air Cleaner	5	3.70	0.48
1-inch	8	4.83	1.95
EAC	6	5.44	1.74
Trane CleanEffects™	5	6.64	2.39

hr^{-1} per hour
cfm cubic feet per minute
k_p aerosol removal by losses to surfaces within the home
k_{AHU} aerosol removal within the air handling unit
k_{ac} aerosol removal by an air cleaner
EAC electronic air cleaner

4.3 INDOOR-OUTDOOR RATIO

Steady-state indoor particle concentrations as a percentage of the average outdoor particle concentrations observed during the air cleaner tests are summarized in Table 4.5. The indoor-outdoor ratio is an important measure of performance because it indicates the ability of an air cleaner to remove particles of outdoor origin from indoor air.

Based upon an examination of the results for specific size categories, steady-state indoor-outdoor ratios were more variable than particle removal rates among tests of a given air cleaner. The increased variability may reflect differences in the absolute amount of particles released into the test home across tests as well as differences in particle concentrations in outdoor air over time. Steady-state indoor-outdoor ratios could be sensitive to those factors while particle removal rates are less so.

Despite the variability, certain patterns are apparent in the indoor-outdoor ratio data. These patterns are best represented by the total particle count results. Higher efficiency air cleaners, such as Trane CleanEffects™ and EAC produced indoor-outdoor ratios of 2% and 4%, respectively, for 0.3 – 0.5 μm particles. In contrast, an indoor-outdoor ratio of approximately 25% was produced by the lower efficiency systems such as the 1-inch filter (19%) and Portable Ionic-Multiple (28%). Five HEPA-filter portable devices yielded an indoor-outdoor ratio approximately equal to those of Trane CleanEffects™ and the

EAC. A single HEPA-filter portable air cleaner attained an indoor-outdoor ratio of 10%, probably reflecting its relatively high efficiency and low flow rate compared to the other device configurations tested.

Table 4.5 Steady-State Indoor Particle Concentrations as a Percentage of Average Outdoor Particle Concentrations for Selected Air Cleaning Devices

Air Cleaner	Sample Size	Mean	Standard Deviation
0.3 – 0.5 Microns			
No Air Cleaner	5	41%	0.11
1-inch	9	20%	0.10
5-inch	3	6%	0.01
EAC	6	4%	0.02
Trane CleanEffects™	5	2%	0.01
Portable HEPA-Single	6	10%	0.03
Portable HEPA-Multiple	2	2%	0.00
Portable Ionic-Multiple	6	29%	0.07
0.5 – 1 Microns			
No Air Cleaner	5	104%	0.24
1-inch	9	16%	0.07
5-inch	3	5%	0.02
EAC	6	5%	0.04
Trane CleanEffects™	5	4%	0.03
Portable HEPA-Single	6	4%	0.03
Portable HEPA-Multiple	2	2%	0.01
Portable Ionic-Multiple	6	15%	0.04
1 – 3 Microns			
No Air Cleaner	5	222%	1.37
1-inch	9	53%	0.37
5-inch	3	23%	0.09
EAC	6	11%	0.05
Trane CleanEffects™	5	40%	0.33
Portable HEPA-Single	6	15%	0.15
Portable HEPA-Multiple	2	3%	0.01
Portable Ionic-Multiple	6	47%	0.24

Table 4.5 Continued

Air Cleaner	Sample Size	Mean	Standard Deviation
3 – 5 Microns			
No Air Cleaner	5	188%	1.01
1-inch	9	60%	0.50
5-inch	3	6%	0.03
EAC	6	4%	0.02
Trane CleanEffects™	5	19%	0.09
Portable HEPA-Single	6	10%	0.07
Portable HEPA-Multiple	2	12%	0.05
Portable Ionic-Multiple	6	20%	0.15
5 – 10 Microns			
No Air Cleaner	5	134%	0.78
1-inch	9	46%	0.30
5-inch	3	5%	0.02
EAC	6	2%	0.01
Trane CleanEffects™	5	9%	0.02
Portable HEPA-Single	6	4%	0.04
Portable HEPA-Multiple	2	4%	0.05
Portable Ionic-Multiple	6	10%	0.11
10 – 20 Microns			
No Air Cleaner	5	70%	0.15
1-inch	9	100%	0.90
5-inch	3	12%	0.06
EAC	6	14%	0.29
Trane CleanEffects™	5	17%	0.14
Portable HEPA-Single	6	19%	0.12
Portable HEPA-Multiple	2	232%	3.28
Portable Ionic-Multiple	6	24%	0.34
0.3 – 20 Microns			
No Air Cleaner	5	42%	0.11
1-inch	9	19%	0.08
5-inch	3	7%	0.01
EAC	6	4%	0.02
Trane CleanEffects™	5	2%	0.01
Portable HEPA-Single	6	10%	0.02
Portable HEPA-Multiple	2	2%	0.00
Portable Ionic-Multiple	6	28%	0.05

EAC electronic air cleaner

4.4 OZONE

The potential presence of ozone indoors associated with operation of Trane CleanEffects™ was evaluated in the test home. Ozone levels were monitored continuously over two days on September 21 and 22, 2005, while Trane CleanEffects™ and air handler fan cycled on and off in accordance with the 70 degrees Fahrenheit set point. A recently calibrated Model 400-A Teledyne Ozone Analyzer located in the test home dining room was used to measure one-minute average ozone concentrations. A Hobo electronic data recorder connected to the AHU power source was used to determine when the fan and Trane CleanEffects™ were operating. Plots and summary statistics of ozone concentrations as a function of AHU/Trane CleanEffects™ operation generated to evaluate the potential presence of ozone indoors as a result of Trane CleanEffects™ operation.

Ozone concentrations indoors ranged from 0 to 3 parts per billion (ppb) throughout the testing period. As shown in Table 4.6, the average ozone concentration was approximately 0.8 ppb when Trane CleanEffects™ was both on and off. Based on these results, operation of Trane CleanEffects™ does not produce elevated or detectable concentrations of ozone indoors.

Table 4.6 Summary Statistics for One-minute Average Ozone Concentrations Indoors as a Function of Trane CleanEffects™ Operation

Parameter	Trane CleanEffects™ Operation	
	Off	**On**
Sample Size	182	317
Mean	0.863	0.801
Standard Deviation	0.4792	0.708

4.5 PARTICLE REMOVAL IN NON-CENTRAL ROOMS

As described in the Methods section, continuous particle count measurements were made in bedroom 2 and bathroom of the test home in addition to the dining room. Room-specific average total aerosol removal rates adjusted for k_a are plotted by in-duct air cleaner in Figure 4.3. The average aerosol removal rates were approximately equal across rooms, suggesting that clean air delivery associated with in-duct air cleaners was homogeneous throughout the test home.

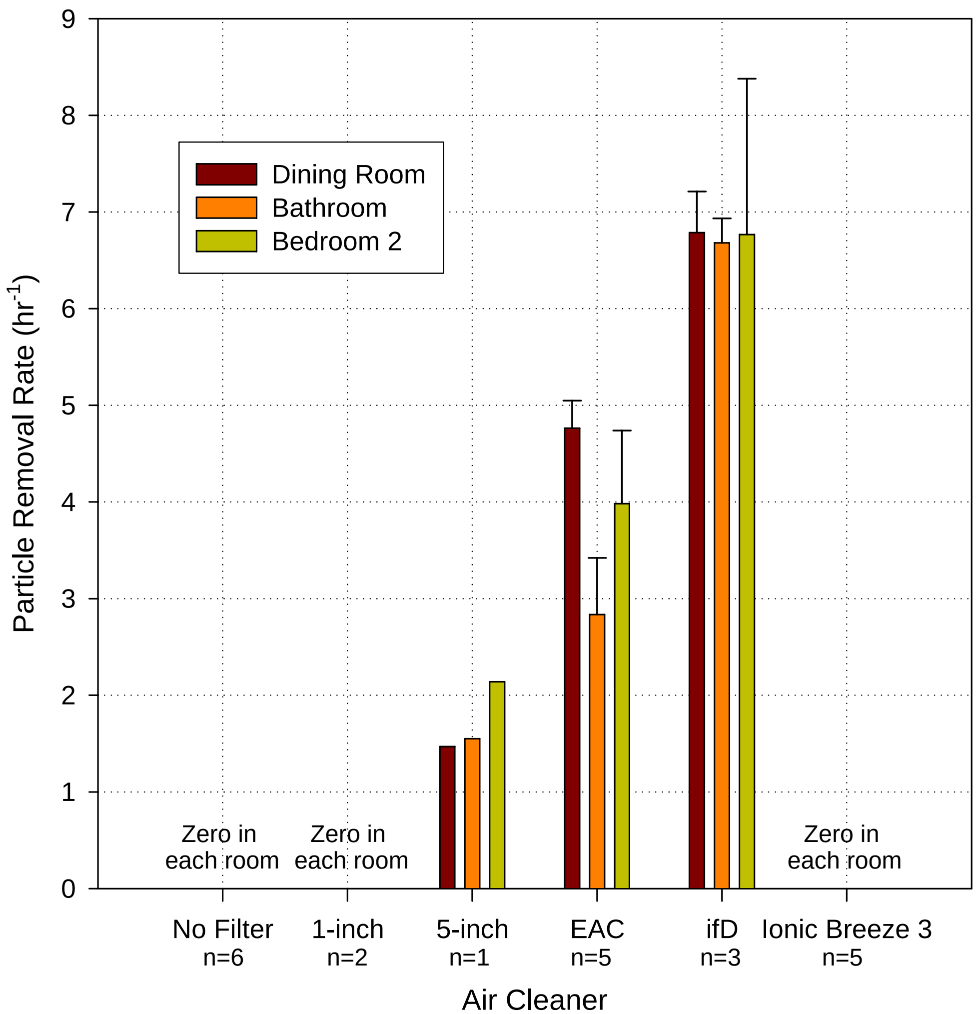


Figure 4.3 Average Whole House Total Particle Removal Rates (k_p+k_{AHU}+k_{ac}) by Room for In-duct Air Cleaners Accounting for Particle Removal by Air Exchange. Error Bars Represent One Standard Deviation.

5.0 DISCUSSION

5.1 TESTING RESULTS

The performance of four in-duct air cleaners and three configurations of portable electric air cleaners was evaluated in a whole house setting under controlled. The EH&E test home was selected and configured to be comparable to the multi-room test facility operated by NIST for studies of building ventilation and related parameters (Persily 2003).

The primary empirical measure that resulted from the performance testing was the whole house aerosol removal rate. The whole house aerosol removal rate for each test was determined by using statistical software to fit a first-order decay function to the particle concentrations observed following the introduction of an aerosol into the test home. The Pearson correlation between the observed concentrations and concentrations predicted by the fitted decay function represents the precision of the aerosol removal rate estimated for a test. The precision of estimated aerosol removal rates for individual tests was high as indicated by the distribution of correlation coefficients. The mean correlation coefficient was 0.98 (SD 0.02). In addition, half of the correlation coefficients were greater than 0.99 and 90% of the correlation coefficients were greater than 0.95.

Aerosol removal rates were also consistent among replicate trials of an air cleaner. Inspection of Table 4.2 shows that results of individual trials were generally within 10 – 20% of each other, the exceptions occurring for low efficiency air cleaners and the large particle sizes. The trial-to-trial precision observed in the EH&E test home is similar to the repeatability of tests for particles in these size ranges reported by other investigators (Emmerich and Nabinger 2000; Howard-Reed et al. 2003; Wallace et al. 2004).

The ratio of steady-state indoor particle concentrations to outdoor particle concentrations is another important empirical measure derived from the whole house performance testing. In the presence of constant particle emissions indoors, the indoor-outdoor ratio indicates the ability of an air cleaner to control indoor exposure to particles of outdoor origin. With respect to this metric, Trane CleanEffects™ performed the best of the single air cleaners tested. Results for the EAC and multiple (5) portable air cleaner scenarios were similar.

As detailed in the Methods section, WHCADR was calculated as the product of k_{ac} and the volume of the test home. As described in Section 3, k_{ac} was derived from results of tests conducted with air cleaners and the AHU operating, only the AHU operating, and without operation of the AHU or an air cleaner. The methodology employed to calculate k_{ac} allows performance of the air cleaner to be distinguished from particle removal by the AHU. Other investigators have used the differences among the various fan operation and air cleaner conditions to estimate k_{ac} (Howard-Reed et al. 2003; Wallace et al. 2004), although that approach does not account for the AHU and air cleaner being in series.

Particle removal rates measured in the EH&E test home for air cleaners are comparable to those reported in the scientific literature as well. In a single-zone building equipped with a forced air system and a conventional 1-inch filter, removal rates of approximately 0.7, 1, and 2 hr^{-1} were observed for 0.3 – 0.5, 0.5 – 1, and 1 – 5 μm particles, respectively (Emmerich et al. 2000). In an occupied townhouse, the deposition rates for 0.3 – 0.5, 0.5 – 1, 1 – 2.5, and 2.5 – 5 μm particles were approximately 0.8, 1.4, 2, and 3 hr^{-1}, respectively during operation of a 1-inch filter (Howard-Reed et al. 2003). In the same townhouse, an electrostatic precipitator achieved a particle removal rate of approximately 1.1 hr^{-1} for 0.5 to 1 μm particles and 1.7 hr^{-1} for 1 to 2.5 μm particles. Particle removal rates from those studies are generally within 1 hr^{-1} of the rates observed in the EH&E test home.

As noted earlier, WHCADR is analogous but not equivalent to the CADR metric associated with the AHAM protocol for evaluation of portable electric air cleaners (AHAM 2002). Key differences between the EH&E whole house and AHAM chamber testing protocols are summarized in Table 5.1.

Table 5.1 Key Differences Between EH&E Whole House and AHAM Single Room Protocols for Evaluating the Efficacy of Air Cleaners

Parameter	EH&E	AHAM
Clean air delivery rate limit	1,273 cfm	400 cfm
Test space scale	Whole house	Room size
Test space volume	9761 ft^3	1008 ft^3
Air exchange rate	~0.15 hr^{-1}	<0.03 hr^{-1}
Background particle levels	Ambient	< Detection limit
Ventilation during test	Central AHU in operation	No ventilation
Principal particle loss processes	Impaction on surfaces, deposition in AHU, exfiltration, air cleaner removal, infiltration	Impaction on surfaces, air cleaner removal

EH&E Environmental Health & Engineering, Inc.
AHAM Association of Home Appliance Manufacturers
cfm cubic feet per minute
ft^3 cubic feet
hr^{-1} per hour
AHU air handling unit

WHCADR is determined under more dynamic and realistic conditions than CADR. These conditions include air flow associated with the forced air system and exfiltration rates. Turbulence can influence the settling rate of particles by aiding suspension of particles in updrafts and by increasing impaction in other cases. Although variable in the whole house setting, exfiltration rates were measured during each trial and accounted for in determination of whole house removal rates and WHCADR. In addition to creating turbulence, operation of the forced air system during the air cleaner tests influenced particle removal directly through impaction of particles on AHU components such as the fan and fan box. The AHAM methodology for determination of k_{ac} does not account for particle losses in the AHU.

5.2 PARTICLE SIZE AND PARTICULATE MATTER EXPOSURE

The aerodynamic diameter of airborne particles is a key determinant of filtration, exposure, and deposition in human airways. In this section, these factors are discussed in consideration of the results of the air cleaner testing presented above.

5.2.1 Filtration

Particles with an aerodynamic diameter of approximately 0.3 μm are the most difficult to remove from airstreams for fibrous filters. As a result, particles of this size have historically been the focus of efficiency testing and air cleaner performance standards.

Fibrous filters remove aerosols from an air stream when particles collide with and attach to the surface of the filter. Particles come in contact with fibrous filters by four basic mechanisms: (1) diffusion; (2) interception; (3) inertial impaction; and (4) gravitational settling. Diffusion occurs when particles deviate from their general streamline due to Brownian motion. Particles less than 0.1 μm are the most influenced by Brownian motion. The effectiveness of diffusion is increased when the velocity is lower, as particles have more time to deviate from their streamlines. Interception occurs when a particle follows the gas streamline that happens to come within one particle radius of the surface of the filter fiber. Interception is effective for particles larger than 0.5 μm. Inertial impaction occurs when a particle is unable to adjust to abrupt changes in the streamlines near the fiber filter and collides with the fiber. Impaction increases with increasing particle inertia (due to greater diameter or density), increasing particle velocity, or with abrupt changes in the streamlines. Impaction is effective for particles larger than 0.5 μm depending on air velocity and the fiber size of the filter. Gravitational settling is only an important mechanism of deposition when the particle size is large (greater than 5 μm) and the velocity through the filter is low.

Diffusion is greatest for particles smaller than one tenth of a micron (μm), while interception, impaction, and settling are most effective for particles larger than 0.5 μm. Therefore, the minimum collection efficiency occurs for particles between 0.1 and 0.5 μm. Depending on the filter type, the efficiency for 0.3 μm particles can range from a few percent for typical disposable filters used in air handling units to 99.97% for HEPA filters.

Among the air cleaners tested by EH&E, Trane CleanEffects™ was shown to have the greatest removal rate, WHCADR, and nominal removal efficiency for 0.3 – 0.5 μm particles, the size known to be the most difficult to remove from airstreams using fibrous filters.

5.2.2 Exposure

Particle sizes are generally divided among three modes: nuclei, accumulation, and coarse (Seinfeld and Pandis 1998). The nuclei mode refers to particles with an aerodynamic diameter less than 0.1 μm. As shown in Figure 5.1, the nuclei mode contains the greatest number of particles in the atmosphere. Nuclei particles are generated from nucleation in the gas phase as well as through coagulation and condensation. Nuclei particles are relatively short-lived in the atmosphere as they are lost by coagulation with larger particles.

Particles in the accumulation mode (0.1 μm – 2.5 μm) account for the majority of particle surface area and a major fraction of particle volume (and therefore mass) in the atmosphere (Figure 5.1). With a mode of approximately 0.3 μm, accumulation mode particles are among the most difficult to remove from indoor air. Accumulation mode particles result from coagulation of nuclei mode particles and condensation of vapors onto existing particles. The major components of particles in the accumulation mode emanate from anthropogenic sources, the primary source being combustion of fossil fuels. Accordingly, sulfate, elemental carbon, organic species, and heavy metals are the principal constituents of accumulation mode particles.

The coarse particle mode (>2.5 μm) accounts for approximately one-half of the particle volume and mass in the atmosphere. Coarse particles are generated from mechanical processes including crushing, grinding, and re-suspension.

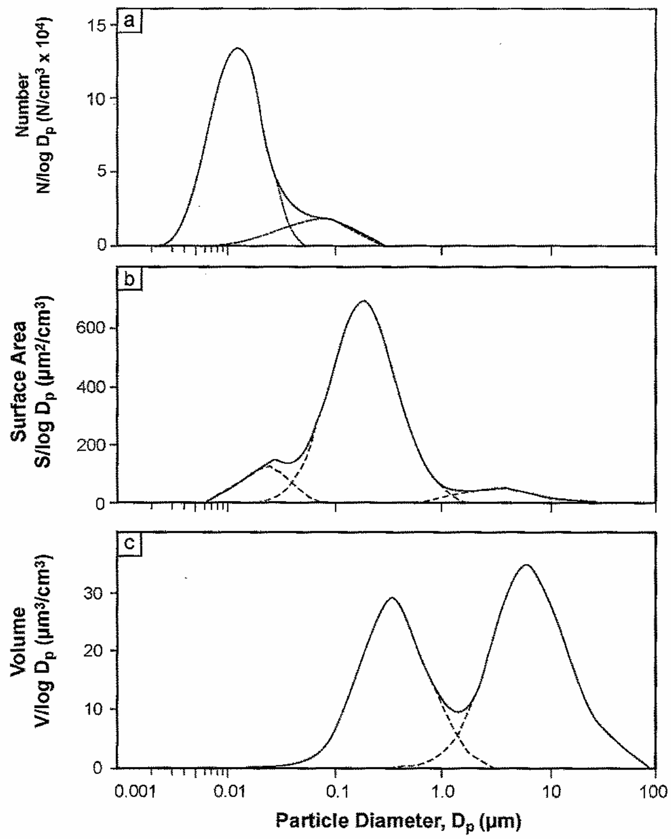


Figure 5.1 Particle Size Distributions of Coarse, Accumulation, and Nuclei Mode Particles by Three Characteristics: (a) Number, N; (b) Surface Area, S; and (c) Volume, V. Source: EPA. 2004. *Air Quality Criteria for Particulate Matter*. Research Triangle Park, NC: U.S. Environmental Protection Agency Office of Air Quality Planning and Standards.

Based on the whole house testing results reported here, Trane CleanEffects™ is differentiated from the other air cleaners evaluated by its rapid removal and control of accumulation mode particles. Particles in this mode are strongly associated with industrial and motor vehicle pollutant emissions.

5.2.3 Airways Deposition

Analogous to air cleaners and indoor air, the respiratory system removes particles from the inhaled air stream. The airways of the head region, which include the nose, mouth, pharynx, and larynx, remove the majority of inhaled coarse mode and nucleation mode particles, due to impaction and diffusion, respectively (EPA 2004).

For particles ranging in size from approximately 0.1 to 0.4 μm, the alveoli are the primary location of deposition. Alveolar deposition is relevant to health because the alveoli are thin walled sacs in the lung where gas exchange with the blood takes place. Some insoluble particles that deposit in the alveoli can be retained in the deep tissues of the lung for years, while soluble particles that may contain toxic components may be absorbed into the bloodstream and carried to other parts of the body (Lippmann et al. 2003).

Among the devices tested, Trane CleanEffects™ has been shown to be the most effective air cleaner for particles that would deposit in the alveoli of the human lung.

5.3 HEALTH EFFECTS OF PARTICULATE MATTER

The potential impacts of indoor air contamination on human health have received considerable public and scientific attention. In addition to infiltration of ambient pollutants, pollutants generated or released indoors can contaminate indoor air.

Airborne particulate matter can be classified as either of non-biological or biological origin. This section provides information related to health effects associated with non-biological particulate matter and particulate matter of biological origin, such as mold and allergens that are present in indoor air.

5.3.1 Non-Biological Particulate Matter

Non-biological particulate matter (PM) is a complex mixture of solid and liquid particles that are suspended in air. These particles typically consist of a mixture of inorganic and organic chemicals, including carbon, sulfates, nitrates, metals, acids, and semi-volatile compounds. PM less than 2.5 μm in aerodynamic diameter is of primary concern for health because these particles can deposit in the alveoli as described above. Fossil fuel combustion is the primary source of ambient $PM_{2.5}$. $PM_{2.5}$ also forms from condensation of gases or droplets in the atmosphere.

In addition to ambient $PM_{2.5}$ that infiltrates indoors, people are exposed to $PM_{2.5}$ generated from indoor sources such as cooking, home heating, tobacco smoke, and the disturbance of settled PM (EPA 2004). Indoor levels of $PM_{2.5}$ are often greater than outdoor levels because of emissions from indoor sources.

Depending upon the magnitude of emissions form indoor sources, the toxicological properties of indoor PM may differ from those of ambient PM. In at least one study, alveolar cells exposed to $PM_{2.5}$ collected inside of residential buildings produced more markers of inflammation than the same cells exposed to ambient $PM_{2.5}$ (Long et al. 2001).

With respect to ambient $PM_{2.5}$, a large number of studies report associations between the levels of $PM_{2.5}$ in the air and adverse respiratory and cardiovascular effects, including premature mortality (Pope et al. 1995; Krewski et al. 2000; Pope et al. 2002), infant mortality (Bobak and Leon 1992; Woodruff et al. 1997; Bobak and Leon 1999; Lipfert et al. 2000; Ha et al. 2003), hospital admissions (Pope 1991; Thurston et al. 1992; Delfino et al. 1994; Thurston et al. 1994; Burnett et al. 1995; Morris et al. 1995; Schwartz and Morris 1995; Anderson et al. 1997; Schwartz 1997), nonfatal myocardial infarctions (Poloniecki et al. 1997; Peters et al. 2001), emergency room visits (Samet et al. 1981; Schwartz et al. 1993; Weisel et al. 1995; Lipsett et al. 1997; Yang et al. 1997), chronic bronchitis (Abbey et al. 1995), acute bronchitis (Dockery et al. 1989; Dockery et al. 1996), asthma attacks (Whittemore and Korn 1980; Pope 1991; Roemer et al. 1993; Dusseldorp et al. 1995; Delfino et al. 1997; Peters et al. 1997), lower respiratory symptoms (Schwartz and Neas 2000), and minor restricted activity days (Ostro and Rothschild 1989).

Scientists have observed $PM_{2.5}$ exposure-response associations at ambient levels that are prevalent in the U.S. and Western Europe. In addition, a level of PM exposure below which health effects are not evident has yet to be identified. The American Cancer Society (ACS) cohort study (Pope et al. 1995; Krewski et al. 2000; Pope et al. 2002) was a retrospective analysis of a cohort of more than 500,000 individuals in all U.S. states, who were matched to air pollution data from the nearest ambient monitor. The relative risk of premature mortality ranged from 1.04 to 1.06 per 10 micrograms per cubic meter ($\mu g/m^3$) increase of $PM_{2.5}$ concentrations, a 0.5% increase in mortality per $\mu g/m^3$ increase of $PM_{2.5}$ concentrations. The magnitude of the association suggests that controlling exposure to $PM_{2.5}$ pollution would result in thousands fewer early deaths per year.

Home ventilation has been demonstrated to have an influence on personal exposure to $PM_{2.5}$ (Suh et al. 1992; Suh et al. 1994; Sarnat et al. 2000). People living in homes with air conditioning appear to be exposed to lower levels of ambient PM than individuals in the same area that do not have air conditioning. A recent analysis of air pollution and health data from 14 U.S. cities demonstrated that the prevalence of air conditioning was inversely related to the risk of cardiovascular disease, pneumonia, and hospital admissions for chronic obstructive pulmonary disease associated with $PM_{2.5}$ exposure (Janssen et al. 2002). Because most AHU are equipped with disposable one-inch filters, common use of advanced filtration systems such as Trane CleanEffects™ could further reduce exposure to $PM_{2.5}$ of outdoor origin and thereby, reduce the risk of various health outcomes.

In summary, the demonstrated ability of Trane CleanEffects™ to remove particles rapidly from indoor and to achieve low steady-state levels of particles indoors is anticipated to have a health benefit.

5.3.2 Biological Particulate Matter

5.3.2.1 Fungi

Fungal material is an important class of biological aerosols present in indoor environments and includes spores, hyphae, and structural fragments. Fungal spores typically enter indoor environments by infiltration from outdoor air and are tracked in by humans and animals. Concentrations of fungal spores in outdoor air are typically greater than levels indoors except in cases where moisture conditions indoors support rapid fungal propagation. Outdoor fungal spore levels vary by location and season and can range from essentially zero to the tens of thousands per cubic meter of air (MacIntosh et al. 2006).

Fungal material can act as an irritant or allergen in humans. Approximately 8% of the overall U.S. population and 50% of people with allergies are estimated to be sensitized to fungal allergens (IOM 2000). Sensitized individuals may experience an allergic reaction when exposed to mold spores or related materials (Lopez and Salvaggio 1985; Lopez and Salvaggio 1987). Allergic rhinitis (runny or stuffy nose, scratchy throat), allergic conjunctivitis (eye irritation) and asthma are common manifestations of these reactions (IOM 2004). Because of individual variability no threshold has been established below which sensitized individuals will not have symptoms.

The Institute of Medicine (IOM) has concluded that exposure to fungal material is associated with asthma exacerbation in sensitized asthmatics (IOM 2000). In one study that helped to form the IOM opinion, the authors detected a relationship between daily levels of ambient mold spores and corresponding changes in asthma severity. The authors noted that higher ambient temperatures were protective, probably due to air conditioning use, lowering infiltration of outdoor fungal material (Delfino et al. 1997). As with $PM_{2.5}$, advanced air cleaning devices such as Trane CleanEffects™ could reduce indoor fungal levels to levels substantially below outdoors, and thereby, reduce the risk of allergic reactions in sensitive individuals.

5.3.2.2 Allergens

Indoor exposure to cat, dog and dust mite allergen is a risk factor for respiratory symptoms and impaired respiratory function (Norman et al. 1996; Gehring et al. 2001). The IOM determined that there was sufficient scientific evidence to implicate cat and dust mite allergen as causal agents of asthma exacerbation in sensitive individuals, and dog allergen exposure as associated with asthma exacerbation (IOM 2000). Dust mite and animal allergens can also induce allergic and asthmatic symptoms, decrements in lung function, and increased airway reactivity in sensitized asthmatics (Langley et al. 2003).

Cat and dog allergen is associated with particles less than 5 μm in aerodynamic diameter and therefore easily aerosolized and widely disseminated in dust and air (Bollinger et al. 1996; Custovic et al. 1997; Custovic et al. 1998). The allergens originate in the sebaceous glands in cats and the salivary glands in dogs. As all cats and dogs have sweat and salivary glands there are no breeds that do not contain allergens, although the amount of allergen released can vary between breeds. Among the air cleaners tested by EH&E, Trane CleanEffects™ demonstrated the greatest removal rate for particles in the size range associated with cat and dog allergen.

The majority of dust mite allergen is associated with fecal particles approximately 10 – 20 μm in aerodynamic diameter (Tovey et al. 1981). Mite allergen is too large to stay airborne for an extended amount of time and the principal exposure route is inhalation immediately after a disturbance of a mite allergen reservoir such as bedding or furniture (Platts-Mills et al. 1986; Platts-Mills 2001). Because mite allergen does not remain airborne, a central ventilation system may not have a substantive effect on mite allergen levels in the home due to filtration. However, dust mites thrive in high humidity environments; therefore, central cooling systems may influence mite allergen levels in the home by reducing relative humidity levels although this effect has not been demonstrated (Hyndman et al. 2000).

Levels of cat and mite allergen in dust greater than 2 micrograms per gram (μg/g) have generally been thought to create a risk for sensitization and levels greater than 10 μg/g are thought to create a risk for acute asthma exacerbations (Platts-Mills et al. 1992). Thresholds are expressed as allergen levels in dust because airborne concentrations are more variable and difficult to measure. There are reports, however, of increased risk at exposures below those threshold levels (Price et al. 1990; Warner et al. 1996). In addition, an experimental study demonstrated that cat-sensitive individuals exposed to airborne cat allergen at levels typical in locations without cats (less than 0.1 $\mu g/m^3$) can exhibit upper and lower respiratory symptoms (Bollinger et al. 1996).

Efficient and high volume central air cleaners such as Trane CleanEffects™ can mitigate indoor exposure to animal allergen by reducing concentrations in indoor air relative to control achieved by conventional in-duct and portable air cleaning systems. Because sensitized individuals can exhibit symptoms at low environmental concentrations of allergens, use of Trane CleanEffects™ has the potential to reduce the burden of allergy-related symptoms and disease in people who are allergic to cats and dogs.

6.0 CONCLUSIONS

EH&E evaluated the performance of the Trane CleanEffects™ whole house air cleaning system through comparison to industry standards, the performance of alternative systems, and health-based considerations. The primary metrics of analysis were the whole house aerosol removal rate, WHCADR, indoor-outdoor ratio of particle concentrations, and nominal particle removal efficiency.

Among the air cleaners tested, Trane CleanEffects™ demonstrated the:

- Greatest whole house aerosol removal rate for particles and fungal spores
- Greatest WHCADR for particles and fungal spores
- Lowest ratio of indoor-outdoor particle concentrations
- Greatest nominal removal efficiency for particles.

The average Trane CleanEffects™ whole house aerosol removal rate was 7.2 hr^{-1} for 0.3 – 0.5 μm particles and the corresponding whole house clean air delivery rate was 1,171 cfm. At these rates, Trane CleanEffects™ delivered over 7 house volumes of clean air each hour. The WHCADR achieved by Trane CleanEffects™ for 0.3 – 0.5 μm particles was more than 400 cfm greater than the next largest WHCADR. Trane CleanEffects™ WHCADR was more than five times greater than the WHCADR achieved by a single portable air cleaner with an AHAM-rated CADR of approximately 220 cfm. Moreover, Trane CleanEffects™ WHCADR was nearly two times larger than the WHCADR achieved by five portable air cleaners operated simultaneously even though the total AHAM-rated CADR for the air cleaner was approximately equal to Trane CleanEffects™ WHCADR.

Operation of Trane CleanEffects™ did not produce detectable increases in ozone concentrations within the test home.

Trane CleanEffects™ is differentiated from the other devices tested by the combination of high air flow rate and high particle removal efficiency for all sizes of particles. Trane CleanEffects™ is unique among the air cleaners tested for rapid and efficient removal of accumulation mode particles—particles with aerodynamic diameter between 0.1 and

2.5 μm. These performance characteristics correspond to rapid removal of particulate air pollutants that are generated indoors and that penetrate building envelopes from outdoors. Overall, the testing results indicate that operation of a Trane CleanEffects™ system will reduce the burden of indoor air pollution relative to the use of portable air cleaners and other in-duct air cleaners.

The effective control of accumulation mode particles by Trane CleanEffects™ is of special interest because particulate air pollutants of anthropogenic origin are ubiquitous in this size range. Particles of anthropogenic origin are emitted directly from sources or formed from interactions among gases emitted from various sources. Examples of anthropogenic sources of accumulation mode particles emitted to outdoor air include cars and trucks, electric power plants, and manufacturing operations. Because of their small size, accumulation mode particles in outdoor air easily enter homes by moving through and around doors, windows, and other penetrations in the building envelope. Common indoor sources of accumulation mode particles include cooking and cigarette smoking. Accumulation mode particles also include constituents of biological origin such as mold spores, cat and dog allergen, bacteria, virus, and some pollen.

The control of particulate air pollution in the accumulation mode is important for public health because non-biological and biological particles in this size class have been associated with increased risks of a variety of adverse health outcomes. Particle concentrations are associated with increased risk of premature mortality and a variety of cardiopulmonary effects, including myocardial infarction (heart attack) and respiratory effects such as bronchitis and asthma attacks. Exposure to mold and certain animal allergens has been associated with asthma exacerbations and lower respiratory symptoms. Notably, a threshold for response of sensitized individuals to particle and allergen exposure has not been demonstrated. For these reasons, the demonstrated ability of Trane CleanEffects™ to remove particles rapidly from indoor and to achieve low steady-state levels of particles indoors is anticipated to have a health benefit.

7.0 REFERENCES

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APPENDIX A

FINE TEST DUST PROTOCOL

FINE TEST DUST PROTOCOL

SAMPLING CRITERIA

The air sample collection strategy involves particle sampling four locations inside and one outside. Fine dust is released over a one-minute duration. Decay is measured over approximately one hour.

The test home is closed up and the heating, ventilating, and air-conditioning (HVAC) unit will be set to run continuously (fan only).

EQUIPMENT AND SUPPLIES NEEDED

- Pitt 3 acoustical speaker aerosol generator
- Sampling tables (6)
- Air compressor to supply air to Pitt Generator and pneumatic actuator valves
- Fine dust standard, fine grade
- Rotameter to measure airflow to Pitt Generator
- Stopwatch
- Drill

For general sampling during all testing:

- Climets—five locations
  - Outdoor
  - Indoor—dining room
  - Indoor—bathroom
  - Indoor—supply duct
  - Indoor—bedroom 2
- (2) TSI APS—aerodynamic particle sizer
  - Indoor—bedroom 2
  - Indoor—kitchen
- Dustrak—one location in dining room

- Data collector
  - Outdoor air temperature
  - Outdoor air relative humidity (RH)
  - Pressure—three locations
  - Wind speed
  - Wind direction
- HOBOs—eight locations: Temp, RH
- HOBO—fan amperage
- B & K / Sulfur hexafluoride (SF_6)—two locations
  - Bedroom 2
  - Bathroom

SET-UP AND SAMPLING

Pre-Test Preparation

Unplug HVAC compressor disconnect (located on outside of test home near entrance) to prevent compressor operation during test. Remove all filter media from air handler. Remove upper two panels from air handler (using drill to remove sheet metal screws). Remove panel covering cooling coil. Remove water build up from accessible part of drain pan (black plastic in front area). Soak up water with paper towels. Replace air handling unit (AHU) panels. Ensure upper filter cover retainers are locked in place; adjust retainers if necessary.

Test Home Cleaning/Cooling Coil Drying

Install 5-inch pleated filter marked for general cleaning (marked "General cleaning only"). Set thermostat for 15 degrees lower than ambient to allow continuous fan operation. Set thermostat to "cooling" mode. Cooling coil will begin to dry off from continuous airflow. Monitor temperature/RH sensor mounted in supply ductwork. Coil is dry when output temperature is greater or equal to return air temperature.

While coil is drying (approximately 20 – 30 minutes), vacuum floor areas with high efficiency particle air (HEPA)-equipped vacuum. Run AHU an additional 10 minutes after vacuuming is complete to remove particles stirred up during vacuuming. Replace 5-inch cleaning filter with appropriate test filter in AHU.

General Sampling

Prior to starting each fine dust test verify that HOBO loggers, data collector and B & K are sampling. Ensure adequate pressure is in air compressor tank (>100 pounds per square inch [psi]). Run air compressor if necessary and shut off when tank is fully pressurized, open yellow ball valve on compressor. Shut off air compressor after tank is fully pressurized. Place “Testing in Progress” sign on exterior door of test home. Plug in orange extension cord in AHU room. Turn on Climets in bathroom, dining room, and bedroom 2. Verify that all Climets are set to collect infinite samples. Clear the memory on each Climet. Press start on dining room and bathroom Climets simultaneously (requires two people), then immediately start bedroom 2 Climet. Record which valve samples first on each Climet. Note: the valve is open when the yellow band is in the vertical position. Start APS units. Start Dustrak and note general background level. Allow samplers to run at least 10 minutes before releasing fine dust.

Verify that all interior doors in the test home are open.

Fine Dust Standard Sampling

Set up six tables: one in the living room, one in bedroom 2, one in the bathroom, one in the kitchen, and one in the dining room. Climets are located on tables in the bathroom, dining room, and bedroom 2. The Pitt 3 fine dust generator is located in the living room. The APSs are located in bedroom 2 and the dining room. The DustTrak is in the dining room.

SF_6 Release SF_6 injection does not need to be performed prior to each test, as long as concentrations are above 4 parts per million (ppm) inside the test home at the start of each test. Verify that the red tubing lead to outside is in the return air grill of the AHU. Place the SF_6 tank outside the test home, near the compressor where the red tubing tail to the AHU return grille is located. Ensure that the regulator on the SF_6 tank is equipped with the blue capillary tube. Turn the SF_6 Tank on and adjust pressure to 60 psi.

Connect regulator to red tubing tail. Start stop watch. Wait 5 minutes and close SF_6 tank. Remove red tubing from the regulator.

Fine Dust Standard Release

Enter test home and approach the Pitt 3 Table. Open air shut off valve to filter unit. Set air flow to 2 liters per minute (rotameter reading: 40) and allow to stabilize. Turn on voltage source on green rheostat (set at 10 volts). Connect air line from Pitt 3 to upper connection on rotameter. Wait for visible dust to exhaust the generator and start stop watch. After one minute, shut off fine dust generator by disconnecting air line to generator. Then, close air shut off valve to filter units and turn off voltage generator switch. While fine dust is releasing use black vacuum without a bag installed and vacuum the carpet area in front of the return diffuser.

Return to computers in kitchen area and move as little as possible to avoid re-suspension of dust during the duration of the test. Run test for 80 minutes and stop Climets, APS, and DustTrak instruments. Download these instruments immediately after each test and place on project folder drive.

Download HOBOs, B&K and Data Collector at the end of the sampling day.

APPENDIX B

FUNGAL SPORE PROTOCOL

FUNGAL SPORE PROTOCOL

SAMPLING CRITERIA

The air sample collection strategy involves sampling three locations inside, six samples each location, over a one-hour duration. An outdoor sample will be taken at the beginning and end of each test.

The test home will be purged with outside air before each test. The test home will then be closed up and the heating, ventilating, and air-conditioning (HVAC) unit will be set to run continuously.

EQUIPMENT AND SUPPLIES NEEDED

For collecting air samples from inside and outside test home:

- Four Burkard samplers (3 inside, 1 outside)
- Four tables
- 20 Burkard slides
- Empty slide box
- Air sampling data sheets
- One window fan
- Isopropyl alcohol
- Stop watch

For general sampling during all testing

- Climets—four ocations
  - Outdoor
  - Indoor—dining room
  - Indoor—bathroom
  - Indoor—supply duct
- Data collector
  - Outdoor air temperature
  - Outdoor air relative humidity (RH)

- Pressure—three locations
- Wind speed
- Wind direction

- HOBOs—eight locations
- B & K / Sulfur hexafluoride (SF_6)—two locations
  - Bedroom 2
  - Dining room

SET-UP AND SAMPLING

General Sampling

Prior to starting mold-sampling test verify that HOBO loggers, data collector and B & K are sampling. Plug in orange extension chord in air handling unit (AHU) room. Turn on compressor and open yellow ball valve on compressor. Turn on Climets in bathroom and dining room. Verify that both Climets are set to collect infinite samples. Clear the memory on each Climet. Press start on each Climet simultaneously (requires two people). Record which valve samples first on each Climet. Note: the valve is open when the yellow band is in the vertical position.

Verify that all interior doors in the test home are open.

AHU Set Up

Remove all filter media from the AHU. Verify that the red tubing lead to outside is in the return air grill of the AHU. Set the AHU over-ride temperature on the thermostat inside the test home to either 15 degrees Fahrenheit (°F) above or below the current test home temperature. Turn off compressor outside the test home, by pulling the breaker plug out and replacing it in the off position.

Mold Sampling

Set up four tables; one outside; one in the dining room; one in bedroom 2; one in the bathroom. Verify that the four Burkards are charged. Place one Burkard on each table. Clean each Burkard with an alcohol wipe and allow sampler to run for one minute in its sampling location. Load each Burkard with a slide. Set each Burkard for five minute samples. Place air sampling data sheet on outside table.

Open all windows in the test home. Place window fan in the open window in the den. Turn the fan on so that it is blowing air out the window (exhaust at speed 3). Allow fan to run for 15 minutes. While fan is operating, collect one five-minute outdoor air sample with the outdoor Burkard. Record sampling data on field data sheet. After 15 minutes, shut off fan and close all windows. Start one five-minute sample from each indoor Burkard location before going outside to start SF6 injection.

Inject test home with SF_6. Place the SF_6 tank outside the test home, near the compressor where the red tubing tail to the AHU return grille is located. Ensure that the regulator on the SF_6 tank is equipped with the blue capillary tube. Turn the SF_6 Tank on and adjust pressure to 60 pounds per square inch (psi). Connect regulator to red tubing tail. Start stop watch. Wait five minutes and close SF_6 tank. Remove red tubing from the regulator.

Enter test home with field data sheet and lock door. Change slide an start Burkard in bedroom 2. Record sampling data on field data sheet. Change slide and start Burkard in dining room. Record sampling data on field data sheet. Change slide and start Burkard in bathroom. Wait for five- minute sample to collect.

At the end of each sample remove slide from Burkard and replace with a blank slide. Start a next sample in each location immediately. Repeat until six samples have been taken at each indoor location.

Stop Climet sampling and download data. Stop B & K sampling and download data. Download HOBOs and Data Collector at the end of the sampling day.

Collect second outdoor air sample after B & K and Climets have been stopped.

Pack Burkard samples in cases and fill out chain of custody at the end of each sampling day. Send the samples to a laboratory for analysis.

Appendix B

SAMPLING LOCATIONS

Samples will be collected in the:

- Dining room—six samples
- Bedroom 2—six samples
- Bathroom—six samples
- Outside—two samples

APPENDIX C

NOMINAL PARTICLE REMOVAL EFFICIENCY

Table C.1 Nominal Particle Removal Efficiency

Air Cleaner	Test ID	0.3 – 0.5 Microns	0.5 – 1 Microns	1 – 3 Microns	3 – 5 Microns	5 – 10 Microns	10 – 20 Microns	0.3 – 20 Microns
No Filter	T1	0	0	2	28	56	72	25
No Filter	T2	0	0	2	27	51	67	23
No Filter	T3	0	0	9	35	55	66	27
No Filter	T4	0	0	8	35	56	68	27
No Filter	T5	0	0	6	32	56	56	24
No Filter	T6	0	0	9	36	61	63	28
1-inch	TA	0	4	24	60	79	93	43
1-inch	TB	0	0	22	56	76	89	40
1-inch	T1	1	5	21	59	78	75	40
1-inch	T2	0	5	21	57	77	76	39
1-inch	T3	0	0	20	60	78	78	39
1-inch	T4	0	0	16	51	73	78	36
1-inch	T5	0	3	21	55	74	73	37
1-inch	T6	0	5	25	59	74	70	39
1-inch	TD	0	3	15	40	60	77	32
5-inch	T1	11	22	36	59	69	64	44
5-inch	T2	15	31	50	85	95	97	62
5-inch	T3	18	35	56	89	96	98	65
Electronic	T1	34	52	66	85	92	95	71
Electronic	T2	36	54	68	87	90	90	71
Electronic	T4	46	57	67	85	92	91	73
Electronic	T5	46	59	70	85	95	93	75
Electronic	T6	42	54	67	85	92	94	72
Electronic	T1	46	56	67	86	97	99	75
Electronic	T2	41	55	67	85	95	99	74
Trane CleanEffects™	T2	88	89	91	96	98	89	92
Trane CleanEffects™	T4	90	90	91	96	98	98	94
Trane CleanEffects™	T5	89	89	89	96	98	98	93
Trane CleanEffects™	T7	87	88	89	94	97	95	92
Trane CleanEffects™	T8	89	90	91	97	98	98	94
Trane CleanEffects™	TO	94	92	95	98	100	96	96
Trane CleanEffects™	TP	94	96	97	99	99	100	97

APPENDIX D

WHOLE HOUSE DECAY RATE:
PARTICLE COUNTS BY CLIMET INSTRUMENTS

Table D.1 Whole House Decay Rate: Particle Counts by Climet Instruments

Air Cleaner	PM (μm)	Location	Test	k_t	Fit	k_a	$k_t - k_a$	C_{ss}
No Filter	0.3 to 0.5	Bathroom	T1	0.0	-99	0.10	0.0	.
No Filter	0.3 to 0.5	Bathroom	T2	0.0	-99	0.10	0.0	103503544
No Filter	0.3 to 0.5	Bathroom	T3	0.0	-99	0.17	0.0	83086105
No Filter	0.3 to 0.5	Bathroom	T4	0.1	0.91	0.17	0.0	77724602
No Filter	0.3 to 0.5	Bathroom	T5	0.0	-99	0.17	0.0	74244376
No Filter	0.3 to 0.5	Bathroom	T6	0.0	-99	0.17	0.0	92903846
No Filter	0.3 to 0.5	Bedroom2	T1	0.0	-99	0.10	0.0	.
No Filter	0.3 to 0.5	Bedroom2	T2	0.0	-99	0.10	0.0	.
No Filter	0.3 to 0.5	Bedroom2	T3	0.0	-99	0.17	0.0	.
No Filter	0.3 to 0.5	Bedroom2	T4	0.0	-99	0.17	0.0	.
No Filter	0.3 to 0.5	Bedroom2	T5	0.0	-99	0.17	0.0	.
No Filter	0.3 to 0.5	Bedroom2	T6	0.0	-99	0.17	0.0	.
No Filter	0.3 to 0.5	Dining Room	T1	0.0	-99	0.10	0.0	.
No Filter	0.3 to 0.5	Dining Room	T2	0.0	-99	0.10	0.0	.
No Filter	0.3 to 0.5	Dining Room	T3	0.1	0.97	0.17	0.0	.
No Filter	0.3 to 0.5	Dining Room	T4	0.1	0.98	0.17	0.0	.
No Filter	0.3 to 0.5	Dining Room	T5	0.0	-99	0.17	0.0	.
No Filter	0.3 to 0.5	Dining Room	T6	0.0	-99	0.17	0.0	.
No Filter	0.5 to 1	Bathroom	T1	0.0	-99	0.10	0.0	.
No Filter	0.5 to 1	Bathroom	T2	0.0	-99	0.10	0.0	4795993
No Filter	0.5 to 1	Bathroom	T3	0.3	0.98	0.17	0.1	3958026
No Filter	0.5 to 1	Bathroom	T4	0.4	0.97	0.17	0.2	4236023
No Filter	0.5 to 1	Bathroom	T5	0.2	0.94	0.17	0.1	3780071
No Filter	0.5 to 1	Bathroom	T6	0.4	0.97	0.17	0.2	5085298
No Filter	0.5 to 1	Bedroom2	T1	0.0	-99	0.10	0.0	.
No Filter	0.5 to 1	Bedroom2	T2	0.0	-99	0.10	0.0	.
No Filter	0.5 to 1	Bedroom2	T3	0.2	0.98	0.17	0.1	.
No Filter	0.5 to 1	Bedroom2	T4	0.3	0.98	0.17	0.1	.
No Filter	0.5 to 1	Bedroom2	T5	.	-99	0.17	.	.
No Filter	0.5 to 1	Bedroom2	T6	0.2	0.97	0.17	0.1	.
No Filter	0.5 to 1	Dining Room	T1	0.0	-99	0.10	0.0	.
No Filter	0.5 to 1	Dining Room	T2	0.3	0.98	0.10	0.2	.
No Filter	0.5 to 1	Dining Room	T3	0.4	0.98	0.17	0.2	.
No Filter	0.5 to 1	Dining Room	T4	0.4	0.99	0.17	0.2	.
No Filter	0.5 to 1	Dining Room	T5	0.3	0.97	0.17	0.1	.
No Filter	0.5 to 1	Dining Room	T6	0.3	0.99	0.17	0.2	.
No Filter	1 to 3	Bathroom	T1	.	-99	0.10	.	.
No Filter	1 to 3	Bathroom	T2	.	-99	0.10	.	554586
No Filter	1 to 3	Bathroom	T3	0.9	0.99	0.17	0.7	476730
No Filter	1 to 3	Bathroom	T4	0.8	0.99	0.17	0.7	407103
No Filter	1 to 3	Bathroom	T5	0.8	0.98	0.17	0.6	383173
No Filter	1 to 3	Bathroom	T6	0.8	0.96	0.17	0.6	507481
No Filter	1 to 3	Bedroom2	T1	.	-99	0.10	.	.
No Filter	1 to 3	Bedroom2	T2	0.8	0.99	0.10	0.7	.

Table D.1 Continued

Air Cleaner	PM (μm)	Location	Test	k_t	Fit	k_a	$k_t - k_a$	C_{ss}
No Filter	1 to 3	Bedroom2	T3	1.0	1.00	0.17	0.8	.
No Filter	1 to 3	Bedroom2	T4	0.8	1.00	0.17	0.7	.
No Filter	1 to 3	Bedroom2	T5	0.9	1.00	0.17	0.7	.
No Filter	1 to 3	Bedroom2	T6	0.8	0.99	0.17	0.7	.
No Filter	1 to 3	Dining Room	T1	.	-99	0.10	.	.
No Filter	1 to 3	Dining Room	T2	1.0	1.00	0.10	0.9	.
No Filter	1 to 3	Dining Room	T3	1.1	0.99	0.17	0.9	.
No Filter	1 to 3	Dining Room	T4	1.0	0.99	0.17	0.8	.
No Filter	1 to 3	Dining Room	T5	1.0	0.99	0.17	0.9	.
No Filter	1 to 3	Dining Room	T6	1.1	1.00	0.17	0.9	.
No Filter	3 to 5	Bathroom	T1	.	-99	0.10	.	.
No Filter	3 to 5	Bathroom	T2	.	-99	0.10	.	48197
No Filter	3 to 5	Bathroom	T3	1.9	0.97	0.17	1.8	27434
No Filter	3 to 5	Bathroom	T4	1.8	0.95	0.17	1.6	22553
No Filter	3 to 5	Bathroom	T5	.	-99	0.17	.	21052
No Filter	3 to 5	Bathroom	T6	1.7	0.96	0.17	1.5	26192
No Filter	3 to 5	Bedroom2	T1	.	-99	0.10	.	.
No Filter	3 to 5	Bedroom2	T2	2.9	0.98	0.10	2.8	.
No Filter	3 to 5	Bedroom2	T3	4.4	0.95	0.17	4.2	.
No Filter	3 to 5	Bedroom2	T4	2.7	0.97	0.17	2.5	.
No Filter	3 to 5	Bedroom2	T5	2.4	0.90	0.17	2.2	.
No Filter	3 to 5	Bedroom2	T6	3.1	0.99	0.17	3.0	.
No Filter	3 to 5	Dining Room	T1	.	-99	0.10	.	.
No Filter	3 to 5	Dining Room	T2	2.8	0.99	0.10	2.7	.
No Filter	3 to 5	Dining Room	T3	3.1	0.99	0.17	3.0	.
No Filter	3 to 5	Dining Room	T4	2.8	0.99	0.17	2.7	.
No Filter	3 to 5	Dining Room	T5	2.9	0.99	0.17	2.8	.
No Filter	3 to 5	Dining Room	T6	3.2	0.99	0.17	3.1	.
No Filter	5 to 10	Bathroom	T1	.	-99	0.10	.	.
No Filter	5 to 10	Bathroom	T2	.	-99	0.10	.	9950
No Filter	5 to 10	Bathroom	T3	2.8	0.92	0.17	2.6	3661
No Filter	5 to 10	Bathroom	T4	.	-99	0.17	.	4290
No Filter	5 to 10	Bathroom	T5	.	-99	0.17	.	3931
No Filter	5 to 10	Bathroom	T6	.	-99	0.17	.	4717
No Filter	5 to 10	Bedroom2	T1	.	-99	0.10	.	.
No Filter	5 to 10	Bedroom2	T2	.	-99	0.10	.	.
No Filter	5 to 10	Bedroom2	T3	12.5	0.95	0.17	12.3	644
No Filter	5 to 10	Bedroom2	T4	2.2	0.89	0.17	2.1	.
No Filter	5 to 10	Bedroom2	T5	.	-99	0.17	.	.
No Filter	5 to 10	Bedroom2	T6	9.8	0.96	0.17	9.6	712
No Filter	5 to 10	Dining Room	T1	.	-99	0.10	.	.
No Filter	5 to 10	Dining Room	T2	3.8	0.95	0.10	3.7	.
No Filter	5 to 10	Dining Room	T3	4.9	0.98	0.17	4.7	.
No Filter	5 to 10	Dining Room	T4	3.8	0.97	0.17	3.6	.

Table D.1 Continued								
Air Cleaner	**PM (μm)**	**Location**	**Test**	**k_t**	**Fit**	**k_a**	**$k_t - k_a$**	**C_{ss}**
No Filter	5 to 10	Dining Room	T5	5.0	0.98	0.17	4.8	.
No Filter	5 to 10	Dining Room	T6	4.7	0.97	0.17	4.5	.
No Filter	10 to 20	Bathroom	T1	.	-99	0.10	.	.
No Filter	10 to 20	Bathroom	T2	.	-99	0.10	.	372
No Filter	10 to 20	Bathroom	T3	.	-99	0.17	.	219
No Filter	10 to 20	Bathroom	T4	.	-99	0.17	.	240
No Filter	10 to 20	Bathroom	T5	.	-99	0.17	.	262
No Filter	10 to 20	Bathroom	T6	.	-99	0.17	.	197
No Filter	10 to 20	Bedroom2	T1	.	-99	0.10	.	.
No Filter	10 to 20	Bedroom2	T2	.	-99	0.10	.	.
No Filter	10 to 20	Bedroom2	T3	.	-99	0.17	.	.
No Filter	10 to 20	Bedroom2	T4	.	-99	0.17	.	.
No Filter	10 to 20	Bedroom2	T5	.	-99	0.17	.	.
No Filter	10 to 20	Bedroom2	T6	.	-99	0.17	.	.
No Filter	10 to 20	Dining Room	T1	.	-99	0.10	.	.
No Filter	10 to 20	Dining Room	T2	.	-99	0.10	.	.
No Filter	10 to 20	Dining Room	T3	.	-99	0.17	.	.
No Filter	10 to 20	Dining Room	T4	.	-99	0.17	.	.
No Filter	10 to 20	Dining Room	T5	.	-99	0.17	.	.
No Filter	10 to 20	Dining Room	T6	.	-99	0.17	.	.
No Filter	Total	Bathroom	T1	.	-99	0.10	.	.
No Filter	Total	Bathroom	T2	.	-99	0.10	.	108912642
No Filter	Total	Bathroom	T3	.	-99	0.17	.	87552174
No Filter	Total	Bathroom	T4	0.1	0.94	0.17	0.0	82394813
No Filter	Total	Bathroom	T5	.	-99	0.17	.	78432865
No Filter	Total	Bathroom	T6	.	-99	0.17	.	98527730
No Filter	Total	Bedroom2	T1	.	-99	0.10	.	.
No Filter	Total	Bedroom2	T2	.	0.99	0.10	.	.
No Filter	Total	Bedroom2	T3	0.2	0.99	0.17	0.0	.
No Filter	Total	Bedroom2	T4	0.2	0.99	0.17	0.0	.
No Filter	Total	Bedroom2	T5	.	-99	0.17	.	.
No Filter	Total	Bedroom2	T6	0.1	0.95	0.17	0.0	.
No Filter	Total	Dining Room	T1	.	-99	0.10	.	.
No Filter	Total	Dining Room	T2	.	-99	0.10	.	.
No Filter	Total	Dining Room	T3	0.2	0.98	0.17	0.1	.
No Filter	Total	Dining Room	T4	0.3	0.99	0.17	0.1	.
No Filter	Total	Dining Room	T5	0.2	0.94	0.17	0.0	.
No Filter	Total	Dining Room	T6	0.2	0.96	0.17	0.0	.
1-inch	0.3 to 0.5	Bathroom	T1	0.2	0.98	0.07	0.1	77288311
1-inch	0.3 to 0.5	Bathroom	T2	0.0	-99	0.07	0.0	78455686
1-inch	0.3 to 0.5	Bathroom	T3	0.0	-99	0.07	0.0	102173107
1-inch	0.3 to 0.5	Bathroom	T4	0.0	-99	0.09	0.0	75178613
1-inch	0.3 to 0.5	Bathroom	T5	0.1	0.91	0.09	0.0	95568089
1-inch	0.3 to 0.5	Bathroom	T6	0.0	-99	0.09	0.0	48264639

Table D.1 Continued								
Air Cleaner	**PM (μm)**	**Location**	**Test**	**k_t**	**Fit**	**k_a**	**k_t – k_a**	**C_{ss}**
1-inch	0.3 to 0.5	Bathroom	TA	0.0	-99	0.10	0.0	127319184
1-inch	0.3 to 0.5	Bathroom	TB	0.0	-99	0.11	0.0	220448196
1-inch	0.3 to 0.5	Bathroom	TC	0.0	-99	0.13	0.0	232006859
1-inch	0.3 to 0.5	Bedroom2	T1	0.2	0.99	0.07	0.1	.
1-inch	0.3 to 0.5	Bedroom2	T2	0.0	-99	0.07	0.0	.
1-inch	0.3 to 0.5	Bedroom2	T3	0.0	-99	0.07	0.0	.
1-inch	0.3 to 0.5	Bedroom2	T4	0.0	-99	0.09	0.0	.
1-inch	0.3 to 0.5	Bedroom2	T5	0.0	-99	0.09	0.0	.
1-inch	0.3 to 0.5	Bedroom2	T6	0.0	-99	0.09	0.0	.
1-inch	0.3 to 0.5	Bedroom2	TA	0.0	-99	0.10	0.0	.
1-inch	0.3 to 0.5	Bedroom2	TB	0.0	-99	0.11	0.0	.
1-inch	0.3 to 0.5	Bedroom2	TC	0.0	-99	0.13	0.0	.
1-inch	0.3 to 0.5	Dining Room	T1	0.2	0.97	0.07	0.2	.
1-inch	0.3 to 0.5	Dining Room	T2	0.2	0.90	0.07	0.1	.
1-inch	0.3 to 0.5	Dining Room	T3	0.0	-99	0.07	0.0	.
1-inch	0.3 to 0.5	Dining Room	T4	0.0	-99	0.09	0.0	.
1-inch	0.3 to 0.5	Dining Room	T5	0.0	-99	0.09	0.0	.
1-inch	0.3 to 0.5	Dining Room	T6	0.0	-99	0.09	0.0	.
1-inch	0.3 to 0.5	Dining Room	TB	0.0	-99	0.11	0.0	.
1-inch	0.3 to 0.5	Dining Room	TC	0.0	-99	0.13	0.0	.
1-inch	0.3 to 0.5	Dining Room	TD	0.0	-99	0.10	0.0	.
1-inch	0.3 to 0.5	Dining Room	TE	0.0	-99	0.11	0.0	.
1-inch	0.5 to 1	Bathroom	T1	0.6	0.99	0.07	0.6	3385516
1-inch	0.5 to 1	Bathroom	T2	0.5	0.98	0.07	0.5	3449928
1-inch	0.5 to 1	Bathroom	T3	0.5	0.98	0.07	0.4	3813374
1-inch	0.5 to 1	Bathroom	T4	0.4	0.94	0.09	0.3	3327614
1-inch	0.5 to 1	Bathroom	T5	0.5	0.99	0.09	0.4	3613081
1-inch	0.5 to 1	Bathroom	T6	0.6	0.97	0.09	0.5	2815884
1-inch	0.5 to 1	Bathroom	TA	0.2	0.98	0.10	0.1	2863832
1-inch	0.5 to 1	Bathroom	TB	0.1	0.90	0.11	0.0	6870025
1-inch	0.5 to 1	Bathroom	TC	.	-99	0.13	.	6047694
1-inch	0.5 to 1	Bedroom2	T1	0.5	0.99	0.07	0.4	.
1-inch	0.5 to 1	Bedroom2	T2	0.4	1.00	0.07	0.4	.
1-inch	0.5 to 1	Bedroom2	T3	0.3	0.99	0.07	0.2	.
1-inch	0.5 to 1	Bedroom2	T4	0.4	0.99	0.09	0.3	.
1-inch	0.5 to 1	Bedroom2	T5	0.3	0.99	0.09	0.3	.
1-inch	0.5 to 1	Bedroom2	T6	0.3	0.99	0.09	0.2	.
1-inch	0.5 to 1	Bedroom2	TA	0.4	0.99	0.10	0.3	.
1-inch	0.5 to 1	Bedroom2	TB	0.1	0.95	0.11	0.0	.
1-inch	0.5 to 1	Bedroom2	TC	0.2	0.98	0.13	0.0	.
1-inch	0.5 to 1	Dining Room	T1	0.7	0.98	0.07	0.6	.
1-inch	0.5 to 1	Dining Room	T2	0.6	0.98	0.07	0.5	.
1-inch	0.5 to 1	Dining Room	T3	0.6	0.95	0.07	0.5	.
1-inch	0.5 to 1	Dining Room	T4	0.6	0.98	0.09	0.5	.

Table D.1 Continued

Air Cleaner	PM (μm)	Location	Test	k_t	Fit	k_a	$k_t - k_a$	C_{ss}
1-inch	0.5 to 1	Dining Room	T5	0.5	0.99	0.09	0.4	.
1-inch	0.5 to 1	Dining Room	T6	0.6	0.96	0.09	0.6	.
1-inch	0.5 to 1	Dining Room	TB	.	-99	0.11	.	.
1-inch	0.5 to 1	Dining Room	TC	.	-99	0.13	.	.
1-inch	0.5 to 1	Dining Room	TD	0.1	0.96	0.10	0.0	.
1-inch	0.5 to 1	Dining Room	TE	0.7	1.00	0.11	0.6	.
1-inch	1 to 3	Bathroom	T1	1.7	0.98	0.07	1.6	230075
1-inch	1 to 3	Bathroom	T2	1.7	0.99	0.07	1.7	204756
1-inch	1 to 3	Bathroom	T3	1.9	0.98	0.07	1.8	219907
1-inch	1 to 3	Bathroom	T4	1.5	0.97	0.09	1.4	239692
1-inch	1 to 3	Bathroom	T5	1.5	0.97	0.09	1.4	214823
1-inch	1 to 3	Bathroom	T6	1.7	0.97	0.09	1.6	206451
1-inch	1 to 3	Bathroom	TA	1.3	1.00	0.10	1.2	122481
1-inch	1 to 3	Bathroom	TB	1.5	0.98	0.11	1.4	313663
1-inch	1 to 3	Bathroom	TC	1.1	0.99	0.13	0.9	197204
1-inch	1 to 3	Bedroom2	T1	1.6	1.00	0.07	1.5	.
1-inch	1 to 3	Bedroom2	T2	1.6	1.00	0.07	1.5	.
1-inch	1 to 3	Bedroom2	T3	1.7	1.00	0.07	1.7	.
1-inch	1 to 3	Bedroom2	T4	1.5	1.00	0.09	1.4	.
1-inch	1 to 3	Bedroom2	T5	1.5	0.99	0.09	1.4	.
1-inch	1 to 3	Bedroom2	T6	1.5	0.99	0.09	1.4	.
1-inch	1 to 3	Bedroom2	TA	2.0	1.00	0.10	1.9	.
1-inch	1 to 3	Bedroom2	TB	0.9	0.94	0.11	0.8	.
1-inch	1 to 3	Bedroom2	TC	1.2	0.99	0.13	1.1	.
1-inch	1 to 3	Dining Room	T1	2.0	0.99	0.07	2.0	.
1-inch	1 to 3	Dining Room	T2	2.1	0.99	0.07	2.0	.
1-inch	1 to 3	Dining Room	T3	2.2	0.99	0.07	2.2	.
1-inch	1 to 3	Dining Room	T4	2.0	0.99	0.09	2.0	.
1-inch	1 to 3	Dining Room	T5	1.9	0.99	0.09	1.9	.
1-inch	1 to 3	Dining Room	T6	2.2	0.99	0.09	2.1	.
1-inch	1 to 3	Dining Room	TB	0.6	0.92	0.11	0.5	.
1-inch	1 to 3	Dining Room	TC	1.3	0.99	0.13	1.1	.
1-inch	1 to 3	Dining Room	TD	1.8	0.99	0.10	1.7	.
1-inch	1 to 3	Dining Room	TE	1.9	1.00	0.11	1.8	.
1-inch	3 to 5	Bathroom	T1	2.8	0.97	0.07	2.8	9818
1-inch	3 to 5	Bathroom	T2	3.4	0.96	0.07	3.3	9385
1-inch	3 to 5	Bathroom	T3	3.1	0.97	0.07	3.0	10136
1-inch	3 to 5	Bathroom	T4	2.8	0.98	0.09	2.7	10280
1-inch	3 to 5	Bathroom	T5	2.7	0.97	0.09	2.6	9732
1-inch	3 to 5	Bathroom	T6	3.4	0.99	0.09	3.3	10425
1-inch	3 to 5	Bathroom	TA	2.1	0.96	0.10	2.0	4312
1-inch	3 to 5	Bathroom	TB	3.3	0.96	0.11	3.2	14581
1-inch	3 to 5	Bathroom	TC	1.9	0.96	0.13	1.8	5930
1-inch	3 to 5	Bedroom2	T1	4.3	0.99	0.07	4.2	.

Table D.1 Continued

Air Cleaner	PM (μm)	Location	Test	k_t	Fit	k_a	$k_t - k_a$	C_{ss}
1-inch	3 to 5	Bedroom2	T2	2.9	0.92	0.07	2.8	.
1-inch	3 to 5	Bedroom2	T3	3.9	0.98	0.07	3.8	.
1-inch	3 to 5	Bedroom2	T4	3.1	0.94	0.09	3.0	.
1-inch	3 to 5	Bedroom2	T5	4.2	0.98	0.09	4.1	.
1-inch	3 to 5	Bedroom2	T6	4.3	0.98	0.09	4.2	.
1-inch	3 to 5	Bedroom2	TA	4.6	0.97	0.10	4.5	.
1-inch	3 to 5	Bedroom2	TB	2.4	0.93	0.11	2.3	.
1-inch	3 to 5	Bedroom2	TC	2.5	0.96	0.13	2.3	.
1-inch	3 to 5	Dining Room	T1	4.7	0.99	0.07	4.7	.
1-inch	3 to 5	Dining Room	T2	4.4	0.97	0.07	4.3	.
1-inch	3 to 5	Dining Room	T3	4.7	0.98	0.07	4.7	.
1-inch	3 to 5	Dining Room	T4	4.9	0.99	0.09	4.8	.
1-inch	3 to 5	Dining Room	T5	4.6	0.98	0.09	4.5	.
1-inch	3 to 5	Dining Room	T6	6.1	0.99	0.09	6.0	.
1-inch	3 to 5	Dining Room	TB	1.3	0.92	0.11	1.2	.
1-inch	3 to 5	Dining Room	TC	3.3	0.99	0.13	3.2	.
1-inch	3 to 5	Dining Room	TD	2.9	0.92	0.07	2.8	.
1-inch	3 to 5	Dining Room	TE	3.9	0.98	0.07	3.8	.
1-inch	5 to 10	Bathroom	T1	3.1	0.94	0.09	3.0	1550
1-inch	5 to 10	Bathroom	T2	4.2	0.98	0.09	4.1	2201
1-inch	5 to 10	Bathroom	T3	4.3	0.98	0.09	4.2	1774
1-inch	5 to 10	Bathroom	T4	4.6	0.97	0.10	4.5	1819
1-inch	5 to 10	Bathroom	T5	2.4	0.93	0.11	2.3	1970
1-inch	5 to 10	Bathroom	T6	2.5	0.96	0.13	2.3	1494
1-inch	5 to 10	Bathroom	TA	4.7	0.99	0.07	4.7	393
1-inch	5 to 10	Bathroom	TB	4.4	0.97	0.07	4.3	1866
1-inch	5 to 10	Bathroom	TC	4.7	0.98	0.07	4.7	1006
1-inch	5 to 10	Bedroom2	T1	4.9	0.99	0.09	4.8	.
1-inch	5 to 10	Bedroom2	T2	4.6	0.98	0.09	4.5	.
1-inch	5 to 10	Bedroom2	T3	6.1	0.99	0.09	6.0	.
1-inch	5 to 10	Bedroom2	T4	1.3	0.92	0.11	1.2	.
1-inch	5 to 10	Bedroom2	T5	3.3	0.99	0.13	3.2	.
1-inch	5 to 10	Bedroom2	T6	2.9	0.92	0.07	2.8	.
1-inch	5 to 10	Bedroom2	TA	3.9	0.98	0.07	3.8	.
1-inch	5 to 10	Bedroom2	TB	3.1	0.94	0.09	3.0	.
1-inch	5 to 10	Bedroom2	TC	4.2	0.98	0.09	4.1	558
1-inch	5 to 10	Dining Room	T1	4.3	0.98	0.09	4.2	.
1-inch	5 to 10	Dining Room	T2	4.6	0.97	0.10	4.5	.
1-inch	5 to 10	Dining Room	T3	2.4	0.93	0.11	2.3	1626
1-inch	5 to 10	Dining Room	T4	2.5	0.96	0.13	2.3	.
1-inch	5 to 10	Dining Room	T5	4.7	0.99	0.07	4.7	.
1-inch	5 to 10	Dining Room	T6	4.4	0.97	0.07	4.3	.
1-inch	5 to 10	Dining Room	TB	4.7	0.98	0.07	4.7	.
1-inch	5 to 10	Dining Room	TC	4.9	0.99	0.09	4.8	.

Table D.1 Continued

Air Cleaner	PM (μm)	Location	Test	k_t	Fit	k_a	$k_t - k_a$	C_{ss}
1-inch	5 to 10	Dining Room	TD	3.9	0.98	0.10	3.8	.
1-inch	5 to 10	Dining Room	TE	4.0	0.99	0.11	3.9	.
1-inch	10 to 20	Bathroom	T1	3.4	0.91	0.07	3.3	175
1-inch	10 to 20	Bathroom	T2	3.9	0.93	0.07	3.8	896
1-inch	10 to 20	Bathroom	T3	3.6	0.92	0.07	3.5	568
1-inch	10 to 20	Bathroom	T4	.	-99	0.09	.	111
1-inch	10 to 20	Bathroom	T5	.	-99	0.09	.	199
1-inch	10 to 20	Bathroom	T6	3.8	0.94	0.09	3.7	219
1-inch	10 to 20	Bathroom	TA	2.3	0.93	0.10	2.3	82
1-inch	10 to 20	Bathroom	TB	.	-99	0.11	.	388
1-inch	10 to 20	Bathroom	TC	2.0	0.92	0.13	1.8	306
1-inch	10 to 20	Bedroom2	T1	4.6	0.93	0.07	4.5	.
1-inch	10 to 20	Bedroom2	T2	.	-99	0.07	.	.
1-inch	10 to 20	Bedroom2	T3	.	-99	0.07	.	.
1-inch	10 to 20	Bedroom2	T4	6.0	0.94	0.09	6.0	.
1-inch	10 to 20	Bedroom2	T5	.	-99	0.09	.	.
1-inch	10 to 20	Bedroom2	T6	4.4	0.95	0.09	4.4	.
1-inch	10 to 20	Bedroom2	TA	.	-99	0.10	.	19
1-inch	10 to 20	Bedroom2	TB	.	-99	0.11	.	.
1-inch	10 to 20	Bedroom2	TC	11.4	0.95	0.13	11.3	.
1-inch	10 to 20	Dining Room	T1	4.8	0.93	0.07	4.8	.
1-inch	10 to 20	Dining Room	T2	4.6	0.90	0.07	4.5	604
1-inch	10 to 20	Dining Room	T3	11.6	1.00	0.07	11.5	.
1-inch	10 to 20	Dining Room	T4	5.0	0.94	0.09	4.9	.
1-inch	10 to 20	Dining Room	T5	4.7	0.92	0.09	4.6	226
1-inch	10 to 20	Dining Room	T6	7.1	0.95	0.09	7.0	.
1-inch	10 to 20	Dining Room	TB	1.5	0.94	0.11	1.4	.
1-inch	10 to 20	Dining Room	TC	3.2	0.93	0.13	3.1	.
1-inch	10 to 20	Dining Room	TD	6.2	0.96	0.10	6.1	.
1-inch	10 to 20	Dining Room	TE	5.0	0.99	0.11	4.9	.
1-inch	Total	Bathroom	T1	.	-99	0.07	.	80915445
1-inch	Total	Bathroom	T2	.	-99	0.07	.	82122852
1-inch	Total	Bathroom	T3	.	-99	0.07	.	106218866
1-inch	Total	Bathroom	T4	.	-99	0.09	.	78758131
1-inch	Total	Bathroom	T5	.	-99	0.09	.	99407893
1-inch	Total	Bathroom	T6	.	-99	0.09	.	51299123
1-inch	Total	Bathroom	TA	.	-99	0.10	.	130310284
1-inch	Total	Bathroom	TB	22.0	0.99	0.11	21.9	227648718
1-inch	Total	Bathroom	TC	.	-99	0.13	.	238258999
1-inch	Total	Bedroom2	T1	.	-99	0.07	.	.
1-inch	Total	Bedroom2	T2	.	-99	0.07	.	.
1-inch	Total	Bedroom2	T3	.	-99	0.07	.	.
1-inch	Total	Bedroom2	T4	.	-99	0.09	.	.
1-inch	Total	Bedroom2	T5	.	-99	0.09	.	.

Table D.1 Continued

Air Cleaner	PM (μm)	Location	Test	k_t	Fit	k_a	$k_t - k_a$	C_{ss}
1-inch	Total	Bedroom2	T6	0.2	0.97	0.09	0.1	.
1-inch	Total	Bedroom2	TA	.	0.99	0.10	.	.
1-inch	Total	Bedroom2	TB	.	0.96	0.11	.	.
1-inch	Total	Bedroom2	TC	.	0.98	0.13	.	.
1-inch	Total	Dining Room	T1	0.4	0.96	0.07	0.4	.
1-inch	Total	Dining Room	T2	0.0	-99	0.07	0.0	.
1-inch	Total	Dining Room	T3	0.0	-99	0.07	0.0	.
1-inch	Total	Dining Room	T4	0.0	-99	0.09	0.0	.
1-inch	Total	Dining Room	T5	0.0	-99	0.09	0.0	.
1-inch	Total	Dining Room	T6	0.4	0.93	0.09	0.3	.
1-inch	Total	Dining Room	TB	0.0	-99	0.11	0.0	.
1-inch	Total	Dining Room	TC	.	0.96	0.13	.	.
1-inch	Total	Dining Room	TD	.	0.99	0.10	.	.
1-inch	Total	Dining Room	TE	0.3	0.99	0.11	0.2	.
5-inch	0.3 to 0.5	Bathroom	T1	1.7	1.00	0.12	1.6	29181874
5-inch	0.3 to 0.5	Bathroom	T2	.	-99	0.11	.	26301391
5-inch	0.3 to 0.5	Bathroom	T3	.	-99	0.10	.	24897082
5-inch	0.3 to 0.5	Bathroom	T4	1.6	0.99	0.07	1.5	12719577
5-inch	0.3 to 0.5	Bathroom	T5	.	-99	0.07	.	21851531
5-inch	0.3 to 0.5	Bathroom	T6	1.5	1.00	0.11	1.4	25838859
5-inch	0.3 to 0.5	Bedroom2	T1	.	-99	0.12	.	.
5-inch	0.3 to 0.5	Bedroom2	T2	.	-99	0.11	.	.
5-inch	0.3 to 0.5	Bedroom2	T3	.	-99	0.10	.	.
5-inch	0.3 to 0.5	Bedroom2	T4	.	-99	0.07	.	.
5-inch	0.3 to 0.5	Bedroom2	T5	.	-99	0.07	.	.
5-inch	0.3 to 0.5	Bedroom2	T6	.	-99	0.11	.	.
5-inch	0.3 to 0.5	Dining Room	T1	1.6	1.00	0.12	1.5	2265455
5-inch	0.3 to 0.5	Dining Room	T2	1.3	1.00	0.11	1.2	1347741
5-inch	0.3 to 0.5	Dining Room	T3	2.0	1.00	0.10	1.9	1724283
5-inch	0.5 to 1	Bathroom	T1	2.4	1.00	0.12	2.3	314339
5-inch	0.5 to 1	Bathroom	T2	2.2	1.00	0.11	2.1	130601
5-inch	0.5 to 1	Bathroom	T3	2.6	1.00	0.10	2.5	195296
5-inch	0.5 to 1	Bathroom	T4	3.0	0.99	0.07	2.9	133681
5-inch	0.5 to 1	Bathroom	T5	.	-99	0.07	.	193235
5-inch	0.5 to 1	Bathroom	T6	2.2	1.00	0.11	2.0	73206
5-inch	0.5 to 1	Bedroom2	T1	.	-99	0.12	.	.
5-inch	0.5 to 1	Bedroom2	T2	.	-99	0.11	.	.
5-inch	0.5 to 1	Bedroom2	T3	.	-99	0.10	.	.
5-inch	0.5 to 1	Bedroom2	T4	.	-99	0.07	.	.
5-inch	0.5 to 1	Bedroom2	T5	.	-99	0.07	.	.
5-inch	0.5 to 1	Bedroom2	T6	.	-99	0.11	.	.
5-inch	0.5 to 1	Dining Room	T1	3.2	1.00	0.12	3.1	152404
5-inch	0.5 to 1	Dining Room	T2	3.3	1.00	0.11	3.2	107273
5-inch	0.5 to 1	Dining Room	T3	3.7	1.00	0.10	3.6	133513

Table D.1 Continued

Air Cleaner	PM (μm)	Location	Test	k_t	Fit	k_a	$k_t – k_a$	C_{ss}
5-inch	1 to 3	Bathroom	T1	3.8	1.00	0.12	3.7	44816
5-inch	1 to 3	Bathroom	T2	3.4	1.00	0.11	3.2	18608
5-inch	1 to 3	Bathroom	T3	3.4	1.00	0.10	3.3	31783
5-inch	1 to 3	Bathroom	T4	.	-99	0.07	.	9910
5-inch	1 to 3	Bathroom	T5	.	-99	0.07	.	5503
5-inch	1 to 3	Bathroom	T6	.	-99	0.11	.	9891
5-inch	1 to 3	Bedroom2	T1	.	-99	0.12	.	.
5-inch	1 to 3	Bedroom2	T2	.	-99	0.11	.	.
5-inch	1 to 3	Bedroom2	T3	.	-99	0.10	.	.
5-inch	1 to 3	Bedroom2	T4	.	-99	0.07	.	.
5-inch	1 to 3	Bedroom2	T5	.	-99	0.07	.	.
5-inch	1 to 3	Bedroom2	T6	.	-99	0.11	.	.
5-inch	1 to 3	Dining Room	T1	4.9	1.00	0.12	4.8	15119
5-inch	1 to 3	Dining Room	T2	5.1	1.00	0.11	5.0	16988
5-inch	1 to 3	Dining Room	T3	5.6	1.00	0.10	5.5	25231
5-inch	3 to 5	Bathroom	T1	5.3	1.00	0.12	5.2	1614
5-inch	3 to 5	Bathroom	T2	5.5	1.00	0.11	5.4	1013
5-inch	3 to 5	Bathroom	T3	6.1	1.00	0.10	6.0	1926
5-inch	3 to 5	Bathroom	T4	.	-99	0.07	.	960
5-inch	3 to 5	Bathroom	T5	.	-99	0.07	.	455
5-inch	3 to 5	Bathroom	T6	4.5	0.99	0.11	4.4	0
5-inch	3 to 5	Bedroom2	T1	.	-99	0.12	.	.
5-inch	3 to 5	Bedroom2	T2	.	-99	0.11	.	.
5-inch	3 to 5	Bedroom2	T3	.	-99	0.10	.	.
5-inch	3 to 5	Bedroom2	T4	.	-99	0.07	.	.
5-inch	3 to 5	Bedroom2	T5	.	-99	0.07	.	.
5-inch	3 to 5	Bedroom2	T6	.	-99	0.11	.	.
5-inch	3 to 5	Dining Room	T1	6.7	1.00	0.12	6.6	413
5-inch	3 to 5	Dining Room	T2	7.1	1.00	0.11	7.0	790
5-inch	3 to 5	Dining Room	T3	8.0	1.00	0.10	7.9	1756
5-inch	5 to 10	Bathroom	T1	5.6	0.99	0.12	5.5	431
5-inch	5 to 10	Bathroom	T2	7.2	1.00	0.11	7.1	385
5-inch	5 to 10	Bathroom	T3	6.6	0.98	0.10	6.5	468
5-inch	5 to 10	Bathroom	T4	.	-99	0.07	.	537
5-inch	5 to 10	Bathroom	T5	.	-99	0.07	.	183
5-inch	5 to 10	Bathroom	T6	5.2	0.99	0.11	5.1	0
5-inch	5 to 10	Bedroom2	T1	.	-99	0.12	.	.
5-inch	5 to 10	Bedroom2	T2	.	-99	0.11	.	.
5-inch	5 to 10	Bedroom2	T3	.	-99	0.10	.	.
5-inch	5 to 10	Bedroom2	T4	.	-99	0.07	.	.
5-inch	5 to 10	Bedroom2	T5	.	-99	0.07	.	.
5-inch	5 to 10	Bedroom2	T6	.	-99	0.11	.	.
5-inch	5 to 10	Dining Room	T1	7.3	0.99	0.12	7.2	442
5-inch	5 to 10	Dining Room	T2	7.1	1.00	0.11	7.0	0

Table D.1 Continued

Air Cleaner	PM (μm)	Location	Test	k_t	Fit	k_a	$k_t - k_a$	C_{ss}
5-inch	5 to 10	Dining Room	T3	9.8	1.00	0.10	9.7	749
5-inch	10 to 20	Bathroom	T1	.	-99	0.12	.	61
5-inch	10 to 20	Bathroom	T2	.	-99	0.11	.	194
5-inch	10 to 20	Bathroom	T3	.	-99	0.10	.	102
5-inch	10 to 20	Bathroom	T4	.	-99	0.07	.	562
5-inch	10 to 20	Bathroom	T5	.	-99	0.07	.	51
5-inch	10 to 20	Bathroom	T6	.	-99	0.11	.	73
5-inch	10 to 20	Bedroom2	T1	.	-99	0.12	.	.
5-inch	10 to 20	Bedroom2	T2	.	-99	0.11	.	.
5-inch	10 to 20	Bedroom2	T3	.	-99	0.10	.	.
5-inch	10 to 20	Bedroom2	T4	.	-99	0.07	.	.
5-inch	10 to 20	Bedroom2	T5	.	-99	0.07	.	.
5-inch	10 to 20	Bedroom2	T6	.	-99	0.11	.	.
5-inch	10 to 20	Dining Room	T1	.	-99	0.12	.	.
5-inch	10 to 20	Dining Room	T2	.	-99	0.11	.	.
5-inch	10 to 20	Dining Room	T3	.	-99	0.10	.	.
5-inch	Total	Bathroom	T1	.	-99	0.12	.	44095601
5-inch	Total	Bathroom	T2	.	-99	0.11	.	26669210
5-inch	Total	Bathroom	T3	.	-99	0.10	.	25354421
5-inch	Total	Bathroom	T4	1.7	1.00	0.07	1.6	13154828
5-inch	Total	Bathroom	T5	.	-99	0.07	.	22052305
5-inch	Total	Bathroom	T6	1.3	1.00	0.11	1.2	24569174
5-inch	Total	Bedroom2	T1	.	-99	0.12	.	.
5-inch	Total	Bedroom2	T2	.	-99	0.11	.	.
5-inch	Total	Bedroom2	T3	.	-99	0.10	.	.
5-inch	Total	Bedroom2	T4	.	-99	0.07	.	.
5-inch	Total	Bedroom2	T5	.	-99	0.07	.	.
5-inch	Total	Bedroom2	T6	.	-99	0.11	.	.
5-inch	Total	Dining Room	T1	1.8	0.99	0.12	1.7	2349922
5-inch	Total	Dining Room	T2	2.4	1.00	0.11	2.3	2015248
5-inch	Total	Dining Room	T3	3.0	1.00	0.10	2.9	2180111
Electronic	0.3 to 0.5	Bathroom	T1	3.4	1.00	0.15	3.3	3053058
Electronic	0.3 to 0.5	Bathroom	T2	3.7	1.00	0.15	3.6	3666797
Electronic	0.3 to 0.5	Bathroom	T3	2.3	1.00	0.14	2.1	6166761
Electronic	0.3 to 0.5	Bathroom	T4	2.6	0.99	0.12	2.5	8947693
Electronic	0.3 to 0.5	Bathroom	T5	.	-99	0.09	.	12435963
Electronic	0.3 to 0.5	Bathroom	T6	2.8	0.99	0.10	2.7	13296825
Electronic	0.3 to 0.5	Dining Room	T1	4.7	1.00	0.15	4.6	226086
Electronic	0.3 to 0.5	Dining Room	T2	5.2	1.00	0.15	5.1	258903
Electronic	0.3 to 0.5	Dining Room	T3	5.2	1.00	0.14	5.1	258903
Electronic	0.3 to 0.5	Dining Room	T4	4.8	1.00	0.12	4.7	992480
Electronic	0.3 to 0.5	Dining Room	T5	4.1	1.00	0.09	4.0	858679
Electronic	0.3 to 0.5	Dining Room	T6	4.6	1.00	0.10	4.5	1058249
Electronic	0.3 to 0.5	Dining Room	TB	4.6	0.99	0.13	4.5	694809

Table D.1 Continued

Air Cleaner	PM (μm)	Location	Test	k_t	Fit	k_a	$k_t - k_a$	C_{ss}
Electronic	0.3 to 0.5	Dining Room	TC	.	-99	0.11	.	.
Electronic	0.5 to 1	Bathroom	T1	4.5	1.00	0.15	4.3	82027
Electronic	0.5 to 1	Bathroom	T2	3.9	1.00	0.15	3.8	74597
Electronic	0.5 to 1	Bathroom	T3	3.2	1.00	0.14	3.0	57749
Electronic	0.5 to 1	Bathroom	T4	3.9	1.00	0.12	3.7	73179
Electronic	0.5 to 1	Bathroom	T5	4.5	1.00	0.09	4.4	106551
Electronic	0.5 to 1	Bathroom	T6	4.3	1.00	0.10	4.2	97025
Electronic	0.5 to 1	Dining Room	T1	5.4	1.00	0.15	5.3	30694
Electronic	0.5 to 1	Dining Room	T2	5.4	1.00	0.15	5.2	29259
Electronic	0.5 to 1	Dining Room	T3	5.6	1.00	0.14	5.5	31941
Electronic	0.5 to 1	Dining Room	T4	4.8	1.00	0.12	4.7	37094
Electronic	0.5 to 1	Dining Room	T5	5.7	1.00	0.09	5.6	66952
Electronic	0.5 to 1	Dining Room	T6	5.8	1.00	0.10	5.7	47820
Electronic	0.5 to 1	Dining Room	TB	6.1	0.99	0.13	5.9	67851
Electronic	0.5 to 1	Dining Room	TC	.	-99	0.11	.	.
Electronic	1 to 3	Bathroom	T1	4.8	0.99	0.15	4.6	17026
Electronic	1 to 3	Bathroom	T2	5.4	1.00	0.15	5.2	16862
Electronic	1 to 3	Bathroom	T3	3.5	1.00	0.14	3.3	3523
Electronic	1 to 3	Bathroom	T4	3.8	0.99	0.12	3.7	4542
Electronic	1 to 3	Bathroom	T5	5.4	1.00	0.09	5.3	12725
Electronic	1 to 3	Bathroom	T6	5.3	1.00	0.10	5.2	12431
Electronic	1 to 3	Dining Room	T1	6.0	1.00	0.15	5.9	11166
Electronic	1 to 3	Dining Room	T2	6.4	1.00	0.15	6.3	11059
Electronic	1 to 3	Dining Room	T3	6.5	1.00	0.14	6.4	10169
Electronic	1 to 3	Dining Room	T4	5.6	1.00	0.12	5.4	5854
Electronic	1 to 3	Dining Room	T5	6.6	1.00	0.09	6.5	19073
Electronic	1 to 3	Dining Room	T6	7.0	1.00	0.10	6.9	11300
Electronic	1 to 3	Dining Room	TB	7.0	1.00	0.13	6.9	7838
Electronic	1 to 3	Dining Room	TC	.	-99	0.11	.	.
Electronic	3 to 5	Bathroom	T1	4.1	0.96	0.15	3.9	918
Electronic	3 to 5	Bathroom	T2	6.3	0.97	0.15	6.2	1086
Electronic	3 to 5	Bathroom	T3	4.9	0.99	0.14	4.8	204
Electronic	3 to 5	Bathroom	T4	6.0	1.00	0.12	5.9	756
Electronic	3 to 5	Bathroom	T5	6.3	1.00	0.09	6.2	785
Electronic	3 to 5	Bathroom	T6	6.6	1.00	0.10	6.5	811
Electronic	3 to 5	Dining Room	T1	7.4	0.99	0.15	7.2	1389
Electronic	3 to 5	Dining Room	T2	8.1	1.00	0.15	7.9	1018
Electronic	3 to 5	Dining Room	T3	8.3	1.00	0.14	8.1	1059
Electronic	3 to 5	Dining Room	T4	7.1	1.00	0.12	7.0	902
Electronic	3 to 5	Dining Room	T5	7.8	1.00	0.09	7.7	1192
Electronic	3 to 5	Dining Room	T6	8.4	1.00	0.10	8.3	1122
Electronic	3 to 5	Dining Room	TB	8.8	1.00	0.13	8.7	411
Electronic	3 to 5	Dining Room	TC	.	-99	0.11	.	.
Electronic	5 to 10	Bathroom	T1	4.4	0.95	0.15	4.3	155

Table D.1 Continued

Air Cleaner	PM (μm)	Location	Test	k_t	Fit	k_a	$k_t - k_a$	C_{ss}
Electronic	5 to 10	Bathroom	T2	4.7	0.94	0.15	4.6	122
Electronic	5 to 10	Bathroom	T3	5.8	0.99	0.14	5.6	76
Electronic	5 to 10	Bathroom	T4	6.5	0.99	0.12	6.4	235
Electronic	5 to 10	Bathroom	T5	5.9	0.99	0.09	5.8	88
Electronic	5 to 10	Bathroom	T6	6.5	0.98	0.10	6.4	125
Electronic	5 to 10	Dining Room	T1	6.4	0.95	0.15	6.3	447
Electronic	5 to 10	Dining Room	T2	6.1	0.99	0.15	5.9	155
Electronic	5 to 10	Dining Room	T3	6.4	0.98	0.14	6.3	183
Electronic	5 to 10	Dining Room	T4	7.7	1.00	0.12	7.6	408
Electronic	5 to 10	Dining Room	T5	8.8	1.00	0.09	8.7	295
Electronic	5 to 10	Dining Room	T6	11.2	1.00	0.10	11.1	469
Electronic	5 to 10	Dining Room	TB	10.4	0.99	0.13	10.3	108
Electronic	5 to 10	Dining Room	TC	.	-99	0.11	.	.
Electronic	10 to 20	Bathroom	T1	.	-99	0.15	.	61
Electronic	10 to 20	Bathroom	T2	10.7	0.95	0.15	10.6	20
Electronic	10 to 20	Bathroom	T3	4.2	0.91	0.14	4.1	7
Electronic	10 to 20	Bathroom	T4	5.9	0.96	0.12	5.8	12
Electronic	10 to 20	Bathroom	T5	4.0	0.94	0.09	3.9	0
Electronic	10 to 20	Bathroom	T6	.	-99	0.10	.	535
Electronic	10 to 20	Dining Room	T1	.	-99	0.15	.	.
Electronic	10 to 20	Dining Room	T2	13.6	1.00	0.15	13.5	170
Electronic	10 to 20	Dining Room	T3	13.6	1.00	0.14	13.5	170
Electronic	10 to 20	Dining Room	T4	10.4	0.99	0.12	10.3	189
Electronic	10 to 20	Dining Room	T5	5.9	0.96	0.09	5.8	16
Electronic	10 to 20	Dining Room	T6	10.9	0.94	0.10	10.8	63
Electronic	10 to 20	Dining Room	TB	.	-99	0.13	.	.
Electronic	10 to 20	Dining Room	TC	.	-99	0.11	.	.
Electronic	Total	Bathroom	T1	3.3	1.00	0.15	3.1	3059344
Electronic	Total	Bathroom	T2	3.5	1.00	0.15	3.4	3692687
Electronic	Total	Bathroom	T3	.	-99	0.14	.	9097776
Electronic	Total	Bathroom	T4	2.7	0.99	0.12	2.6	8959231
Electronic	Total	Bathroom	T5	.	-99	0.09	.	12618423
Electronic	Total	Bathroom	T6	2.5	0.99	0.10	2.4	13013846
Electronic	Total	Dining Room	T1	5.1	1.00	0.15	4.9	271890
Electronic	Total	Dining Room	T2	5.5	1.00	0.15	5.4	306695
Electronic	Total	Dining Room	T3	5.5	1.00	0.14	5.4	306695
Electronic	Total	Dining Room	T4	4.7	1.00	0.12	4.6	1011930
Electronic	Total	Dining Room	T5	5.1	1.00	0.09	5.0	1020664
Electronic	Total	Dining Room	T6	5.3	1.00	0.10	5.2	1130957
Electronic	Total	Dining Room	TB	5.4	0.99	0.13	5.3	785336
Electronic	Total	Dining Room	TC	.	-99	0.11	.	.
CleanEffects™	0.3 to 0.5	Bathroom	T2	.	-99	0.10	.	18597188
CleanEffects™	0.3 to 0.5	Bathroom	T4	6.5	0.99	0.10	6.4	12376936
CleanEffects™	0.3 to 0.5	Bathroom	T5	6.9	0.98	0.12	6.8	11166470

Table D.1 Continued

Air Cleaner	PM (μm)	Location	Test	k_t	Fit	k_a	$k_t - k_a$	C_{ss}
CleanEffects™	0.3 to 0.5	Bathroom	T7	7.0	1.00	0.10	6.9	11152123
CleanEffects™	0.3 to 0.5	Bathroom	T8	3.8	0.99	0.09	3.7	12022734
CleanEffects™	0.3 to 0.5	Bedroom2	T2	5.8	1.00	0.10	5.7	410526
CleanEffects™	0.3 to 0.5	Bedroom2	T4	6.0	1.00	0.10	5.9	226922
CleanEffects™	0.3 to 0.5	Bedroom2	T5	5.6	0.98	0.12	5.5	297251
CleanEffects™	0.3 to 0.5	Bedroom2	T7	5.7	1.00	0.10	5.6	562643
CleanEffects™	0.3 to 0.5	Bedroom2	T8	5.0	1.00	0.09	4.9	475086
CleanEffects™	0.3 to 0.5	Dining Room	T2	9.5	1.00	0.10	9.4	594925
CleanEffects™	0.3 to 0.5	Dining Room	T4	7.0	0.99	0.10	6.9	569757
CleanEffects™	0.3 to 0.5	Dining Room	T5	7.3	0.99	0.12	7.2	525794
CleanEffects™	0.3 to 0.5	Dining Room	T7	6.4	1.00	0.10	6.3	626290
CleanEffects™	0.3 to 0.5	Dining Room	T8	.	-99	0.09	.	.
CleanEffects™	0.3 to 0.5	Dining Room	TO	5.9	1.00	0.12	5.8	107231
CleanEffects™	0.3 to 0.5	Dining Room	TP	7.8	0.99	0.11	7.7	1328915
CleanEffects™	0.5 to 1	Bathroom	T2	.	-99	0.10	.	308582
CleanEffects™	0.5 to 1	Bathroom	T4	6.5	0.99	0.10	6.4	303302
CleanEffects™	0.5 to 1	Bathroom	T5	4.3	0.99	0.12	4.2	308734
CleanEffects™	0.5 to 1	Bathroom	T7	4.3	1.00	0.10	4.2	276154
CleanEffects™	0.5 to 1	Bathroom	T8	5.8	0.99	0.09	5.7	355672
CleanEffects™	0.5 to 1	Bedroom2	T2	4.2	1.00	0.10	4.1	9887
CleanEffects™	0.5 to 1	Bedroom2	T4	3.4	0.99	0.10	3.3	9832
CleanEffects™	0.5 to 1	Bedroom2	T5	5.1	1.00	0.12	4.9	11150
CleanEffects™	0.5 to 1	Bedroom2	T7	4.3	0.99	0.10	4.2	47342
CleanEffects™	0.5 to 1	Bedroom2	T8	3.3	1.00	0.09	3.2	20079
CleanEffects™	0.5 to 1	Dining Room	T2	8.4	1.00	0.10	8.3	46800
CleanEffects™	0.5 to 1	Dining Room	T4	7.8	1.00	0.10	7.7	40371
CleanEffects™	0.5 to 1	Dining Room	T5	7.0	1.00	0.12	6.9	29489
CleanEffects™	0.5 to 1	Dining Room	T7	6.7	1.00	0.10	6.6	65065
CleanEffects™	0.5 to 1	Dining Room	T8	7.3	1.00	0.09	7.2	59778
CleanEffects™	0.5 to 1	Dining Room	TO	6.5	1.00	0.12	6.3	3357
CleanEffects™	0.5 to 1	Dining Room	TP	7.9	1.00	0.11	7.8	86061
CleanEffects™	1 to 3	Bathroom	T2	.	-99	0.10	.	38801
CleanEffects™	1 to 3	Bathroom	T4	.	-99	0.10	.	88635
CleanEffects™	1 to 3	Bathroom	T5	4.6	0.96	0.12	4.5	76635
CleanEffects™	1 to 3	Bathroom	T7	.	-99	0.10	.	42345
CleanEffects™	1 to 3	Bathroom	T8	7.5	0.97	0.09	7.4	65577
CleanEffects™	1 to 3	Bedroom2	T2	.	-99	0.10	.	.
CleanEffects™	1 to 3	Bedroom2	T4	.	-99	0.10	.	.
CleanEffects™	1 to 3	Bedroom2	T5	5.3	1.00	0.12	5.2	0
CleanEffects™	1 to 3	Bedroom2	T7	.	-99	0.10	.	.
CleanEffects™	1 to 3	Bedroom2	T8	3.5	1.00	0.09	3.4	0
CleanEffects™	1 to 3	Dining Room	T2	8.7	1.00	0.10	8.6	8861
CleanEffects™	1 to 3	Dining Room	T4	8.2	1.00	0.10	8.1	11067
CleanEffects™	1 to 3	Dining Room	T5	7.3	1.00	0.12	7.2	5770

Table D.1 Continued

Air Cleaner	PM (μm)	Location	Test	k_t	Fit	k_a	$k_t - k_a$	C_{ss}
CleanEffects™	1 to 3	Dining Room	T7	7.0	1.00	0.10	6.9	9520
CleanEffects™	1 to 3	Dining Room	T8	7.9	1.00	0.09	7.8	10320
ifD	1 to 3	Dining Room	TO	6.6	1.00	0.12	6.5	0
CleanEffects™	1 to 3	Dining Room	TP	8.3	1.00	0.11	8.2	8247
CleanEffects™	3 to 5	Bathroom	T2	.	-99	0.10	.	1914
CleanEffects™	3 to 5	Bathroom	T4	10.9	0.98	0.10	10.8	4362
CleanEffects™	3 to 5	Bathroom	T5	6.8	0.99	0.12	6.7	4070
CleanEffects™	3 to 5	Bathroom	T7	5.0	1.00	0.10	4.9	2755
CleanEffects™	3 to 5	Bathroom	T8	8.2	0.97	0.09	8.1	4157
CleanEffects™	3 to 5	Bedroom2	T2	5.0	0.99	0.10	4.9	0
CleanEffects™	3 to 5	Bedroom2	T4	5.8	0.97	0.10	5.7	487
CleanEffects™	3 to 5	Bedroom2	T5	8.4	0.99	0.12	8.2	0
CleanEffects™	3 to 5	Bedroom2	T7	5.6	0.98	0.10	5.5	58
CleanEffects™	3 to 5	Bedroom2	T8	9.5	0.97	0.09	9.4	925
CleanEffects™	3 to 5	Dining Room	T2	9.5	1.00	0.10	9.4	955
CleanEffects™	3 to 5	Dining Room	T4	9.1	1.00	0.10	9.0	1567
CleanEffects™	3 to 5	Dining Room	T5	8.2	1.00	0.12	8.1	923
CleanEffects™	3 to 5	Dining Room	T7	7.8	1.00	0.10	7.7	1200
CleanEffects™	3 to 5	Dining Room	T8	8.5	1.00	0.09	8.4	1144
CleanEffects™	3 to 5	Dining Room	TO	6.6	1.00	0.12	6.4	0
CleanEffects™	3 to 5	Dining Room	TP	9.3	1.00	0.11	9.1	924
CleanEffects™	5 to 10	Bathroom	T2	.	-99	0.10	.	419
CleanEffects™	5 to 10	Bathroom	T4	7.9	0.95	0.10	7.8	658
CleanEffects™	5 to 10	Bathroom	T5	6.0	0.92	0.12	5.9	862
CleanEffects™	5 to 10	Bathroom	T7	5.5	0.99	0.10	5.4	549
CleanEffects™	5 to 10	Bathroom	T8	8.1	0.94	0.09	8.0	764
CleanEffects™	5 to 10	Bedroom2	T2	.	-99	0.10	.	.
CleanEffects™	5 to 10	Bedroom2	T4	.	-99	0.10	.	.
CleanEffects™	5 to 10	Bedroom2	T5	9.2	0.98	0.12	9.1	39
CleanEffects™	5 to 10	Bedroom2	T7	8.4	0.95	0.10	8.3	76
CleanEffects™	5 to 10	Bedroom2	T8	10.0	0.99	0.09	9.9	135
CleanEffects™	5 to 10	Dining Room	T2	11.3	1.00	0.10	11.2	348
CleanEffects™	5 to 10	Dining Room	T4	9.4	0.99	0.10	9.3	630
CleanEffects™	5 to 10	Dining Room	T5	8.2	1.00	0.12	8.1	280
CleanEffects™	5 to 10	Dining Room	T7	8.8	1.00	0.10	8.7	629
CleanEffects™	5 to 10	Dining Room	T8	9.2	0.99	0.09	9.1	584
CleanEffects™	5 to 10	Dining Room	TO	6.4	1.00	0.12	6.3	0
CleanEffects™	5 to 10	Dining Room	TP	11.8	0.98	0.11	11.7	404
CleanEffects™	10 to 20	Bathroom	T2	.	-99	0.10	.	0
CleanEffects™	10 to 20	Bathroom	T4	.	-99	0.10	.	204
CleanEffects™	10 to 20	Bathroom	T5	.	-99	0.12	.	102
CleanEffects™	10 to 20	Bathroom	T7	.	-99	0.10	.	204
CleanEffects™	10 to 20	Bathroom	T8	11.5	0.94	0.09	11.4	133
CleanEffects™	10 to 20	Bedroom2	T2	.	-99	0.10	.	.

Table D.1 Continued

Air Cleaner	PM (μm)	Location	Test	k_t	Fit	k_a	$k_t - k_a$	C_{ss}
CleanEffects™	10 to 20	Bedroom2	T4	.	-99	0.10	.	.
CleanEffects™	10 to 20	Bedroom2	T5	.	-99	0.12	.	.
CleanEffects™	10 to 20	Bedroom2	T7	.	-99	0.10	.	.
CleanEffects™	10 to 20	Bedroom2	T8	.	-99	0.09	.	.
CleanEffects™	10 to 20	Dining Room	T2	.	-99	0.10	.	.
CleanEffects™	10 to 20	Dining Room	T4	.	-99	0.10	.	.
CleanEffects™	10 to 20	Dining Room	T5	.	-99	0.12	.	.
CleanEffects™	10 to 20	Dining Room	T7	.	-99	0.10	.	.
CleanEffects™	10 to 20	Dining Room	T8	.	-99	0.09	.	.
CleanEffects™	10 to 20	Dining Room	TO	.	-99	0.12	.	.
CleanEffects™	10 to 20	Dining Room	TP	.	-99	0.11	.	.
CleanEffects™	Total	Bathroom	T2	.	-99	0.10	.	18946903
CleanEffects™	Total	Bathroom	T4	6.4	0.99	0.10	6.3	12947676
CleanEffects™	Total	Bathroom	T5	6.5	0.98	0.12	6.4	11663738
CleanEffects™	Total	Bathroom	T7	6.8	1.00	0.10	6.7	11633725
CleanEffects™	Total	Bathroom	T8	3.7	0.99	0.09	3.6	12297580
CleanEffects™	Total	Bedroom2	T2	.	-99	0.10	.	.
CleanEffects™	Total	Bedroom2	T4	5.9	1.00	0.10	5.8	273893
CleanEffects™	Total	Bedroom2	T5	4.3	0.98	0.12	4.2	288942
CleanEffects™	Total	Bedroom2	T7	5.6	1.00	0.10	5.5	651053
CleanEffects™	Total	Bedroom2	T8	4.9	1.00	0.09	4.8	552254
CleanEffects™	Total	Dining Room	T2	8.9	1.00	0.10	8.8	653880
CleanEffects™	Total	Dining Room	T4	7.5	1.00	0.10	7.4	624303
CleanEffects™	Total	Dining Room	T5	7.2	1.00	0.12	7.1	562712
CleanEffects™	Total	Dining Room	T7	6.7	1.00	0.10	6.6	704145
CleanEffects™	Total	Dining Room	T8	6.8	1.00	0.09	6.7	676222
CleanEffects™	Total	Dining Room	TO	5.9	1.00	0.12	5.8	101698
CleanEffects™	Total	Dining Room	TP	7.9	1.00	0.11	7.8	1424949
Portable: 1	0.3 to 0.5	Bathroom	T1	.	-99	0.12	.	131842782
Portable: 1	0.3 to 0.5	Bathroom	T2	.	-99	0.13	.	87853891
Portable: 1	0.3 to 0.5	Bathroom	T3	.	-99	0.10	.	56666348
Portable: 1	0.3 to 0.5	Bathroom	T4	3.2	0.98	0.08	3.1	57712507
Portable: 1	0.3 to 0.5	Bathroom	T5	.	-99	0.11	.	92307682
Portable: 1	0.3 to 0.5	Bathroom	T6	.	-99	0.08	.	50343184
Portable: 1	0.3 to 0.5	Dining Room	T1	1.2	1.00	0.12	1.1	6426652
Portable: 1	0.3 to 0.5	Dining Room	T2	0.4	0.99	0.13	0.3	0
Portable: 1	0.3 to 0.5	Dining Room	T3	1.5	1.00	0.10	1.4	3327757
Portable: 1	0.3 to 0.5	Dining Room	T4	4.4	1.00	0.08	4.3	5070224
Portable: 1	0.3 to 0.5	Dining Room	T5	0.3	0.99	0.11	0.2	0
Portable: 1	0.3 to 0.5	Dining Room	T6	1.4	1.00	0.08	1.3	3240878
Portable: 1	0.5 to 1	Bathroom	T1	1.4	1.00	0.12	1.3	1747230
Portable: 1	0.5 to 1	Bathroom	T2	1.0	1.00	0.13	0.9	173040
Portable: 1	0.5 to 1	Bathroom	T3	1.6	1.00	0.10	1.5	423879
Portable: 1	0.5 to 1	Bathroom	T4	1.8	1.00	0.08	1.8	959448

Table D.1 Continued

Air Cleaner	PM (μm)	Location	Test	k_t	Fit	k_a	$k_t - k_a$	C_{ss}
Portable: 1	0.5 to 1	Bathroom	T5	1.2	1.00	0.11	1.1	165582
Portable: 1	0.5 to 1	Bathroom	T6	1.5	1.00	0.08	1.5	446413
Portable: 1	0.5 to 1	Dining Room	T1	2.1	1.00	0.12	2.0	833197
Portable: 1	0.5 to 1	Dining Room	T2	1.5	1.00	0.13	1.4	374380
Portable: 1	0.5 to 1	Dining Room	T3	2.1	1.00	0.10	2.0	346699
Portable: 1	0.5 to 1	Dining Room	T4	2.4	1.00	0.08	2.3	477663
Portable: 1	0.5 to 1	Dining Room	T5	1.6	1.00	0.11	1.5	325593
Portable: 1	0.5 to 1	Dining Room	T6	1.8	1.00	0.08	1.7	271440
Portable: 1	1 to 3	Bathroom	T1	1.5	1.00	0.12	1.4	2820
Portable: 1	1 to 3	Bathroom	T2	1.9	1.00	0.13	1.7	14819
Portable: 1	1 to 3	Bathroom	T3	2.3	1.00	0.10	2.2	28372
Portable: 1	1 to 3	Bathroom	T4	2.0	1.00	0.08	1.9	18332
Portable: 1	1 to 3	Bathroom	T5	2.0	1.00	0.11	1.9	22471
Portable: 1	1 to 3	Bathroom	T6	2.4	1.00	0.08	2.3	48015
Portable: 1	1 to 3	Dining Room	T1	3.2	0.99	0.12	3.1	104961
Portable: 1	1 to 3	Dining Room	T2	2.7	1.00	0.13	2.6	49277
Portable: 1	1 to 3	Dining Room	T3	3.0	1.00	0.10	2.9	58214
Portable: 1	1 to 3	Dining Room	T4	2.9	1.00	0.08	2.8	58720
Portable: 1	1 to 3	Dining Room	T5	2.4	1.00	0.11	2.3	63805
Portable: 1	1 to 3	Dining Room	T6	2.6	1.00	0.08	2.5	65350
Portable: 1	3 to 5	Bathroom	T1	3.4	1.00	0.12	3.3	1868
Portable: 1	3 to 5	Bathroom	T2	3.1	1.00	0.13	3.0	608
Portable: 1	3 to 5	Bathroom	T3	4.5	1.00	0.10	4.4	2747
Portable: 1	3 to 5	Bathroom	T4	3.2	0.99	0.08	3.2	975
Portable: 1	3 to 5	Bathroom	T5	3.8	1.00	0.11	3.7	3486
Portable: 1	3 to 5	Bathroom	T6	3.5	1.00	0.08	3.4	1665
Portable: 1	3 to 5	Dining Room	T1	5.6	1.00	0.12	5.5	5209
Portable: 1	3 to 5	Dining Room	T2	5.7	1.00	0.13	5.5	3134
Portable: 1	3 to 5	Dining Room	T3	5.4	1.00	0.10	5.3	3164
Portable: 1	3 to 5	Dining Room	T4	4.9	1.00	0.08	4.8	2565
Portable: 1	3 to 5	Dining Room	T5	4.7	1.00	0.11	4.6	5676
Portable: 1	3 to 5	Dining Room	T6	4.8	1.00	0.08	4.7	4485
Portable: 1	5 to 10	Bathroom	T1	5.0	0.99	0.12	4.9	566
Portable: 1	5 to 10	Bathroom	T2	3.9	0.97	0.13	3.7	318
Portable: 1	5 to 10	Bathroom	T3	3.7	0.98	0.10	3.6	22
Portable: 1	5 to 10	Bathroom	T4	4.6	0.99	0.08	4.6	468
Portable: 1	5 to 10	Bathroom	T5	4.8	1.00	0.11	4.7	66
Portable: 1	5 to 10	Bathroom	T6	4.7	1.00	0.08	4.7	420
Portable: 1	5 to 10	Dining Room	T1	8.7	0.99	0.12	8.6	832
Portable: 1	5 to 10	Dining Room	T2	8.4	0.99	0.13	8.3	573
Portable: 1	5 to 10	Dining Room	T3	8.0	1.00	0.10	7.9	342
Portable: 1	5 to 10	Dining Room	T4	6.0	0.99	0.08	5.9	386
Portable: 1	5 to 10	Dining Room	T5	6.6	1.00	0.11	6.5	209
Portable: 1	5 to 10	Dining Room	T6	7.0	1.00	0.08	6.9	613

Table D.1 Continued

Air Cleaner	PM (μm)	Location	Test	k_t	Fit	k_a	$k_t - k_a$	C_{ss}
Portable: 1	10 to 20	Bathroom	T1	.	-99	0.12	.	61
Portable: 1	10 to 20	Bathroom	T2	.	-99	0.13	.	382
Portable: 1	10 to 20	Bathroom	T3	.	-99	0.10	.	143
Portable: 1	10 to 20	Bathroom	T4	.	-99	0.08	.	102
Portable: 1	10 to 20	Bathroom	T5	.	-99	0.11	.	82
Portable: 1	10 to 20	Bathroom	T6	.	-99	0.08	.	163
Portable: 1	10 to 20	Dining Room	T1	13.1	0.94	0.12	13.0	176
Portable: 1	10 to 20	Dining Room	T2	13.6	0.99	0.13	13.5	108
Portable: 1	10 to 20	Dining Room	T3	10.2	0.98	0.10	10.1	72
Portable: 1	10 to 20	Dining Room	T4	.	-99	0.08	.	.
Portable: 1	10 to 20	Dining Room	T5	4.5	0.96	0.11	4.4	78
Portable: 1	10 to 20	Dining Room	T6	.	-99	0.08	.	.
Portable: 1	Total	Bathroom	T1	.	-99	0.12	.	134718030
Portable: 1	Total	Bathroom	T2	.	-99	0.13	.	89594818
Portable: 1	Total	Bathroom	T3	.	-99	0.10	.	57903756
Portable: 1	Total	Bathroom	T4	.	-99	0.08	.	63029072
Portable: 1	Total	Bathroom	T5	.	-99	0.11	.	94441205
Portable: 1	Total	Bathroom	T6	.	-99	0.08	.	51822693
Portable: 1	Total	Dining Room	T1	.	-99	0.12	.	.
Portable: 1	Total	Dining Room	T2	.	-99	0.13	.	.
Portable: 1	Total	Dining Room	T3	1.8	1.00	0.10	1.7	3915253
Portable: 1	Total	Dining Room	T4	3.7	1.00	0.08	3.6	5730946
Portable: 1	Total	Dining Room	T5	.	-99	0.11	.	.
Portable: 1	Total	Dining Room	T6	1.7	1.00	0.08	1.6	3813383
Portable: 5	0.3 to 0.5	Bathroom	T2	3.4	0.99	0.13	3.3	6404495
Portable: 5	0.3 to 0.5	Bathroom	T3	3.4	0.98	0.12	3.3	3976704
Portable: 5	0.3 to 0.5	Dining Room	T2	3.6	1.00	0.13	3.4	923178
Portable: 5	0.3 to 0.5	Dining Room	T3	4.4	1.00	0.12	4.3	550942
Portable: 5	0.5 to 1	Bathroom	T2	3.8	1.00	0.13	3.6	59515
Portable: 5	0.5 to 1	Bathroom	T3	4.3	1.00	0.12	4.2	37460
Portable: 5	0.5 to 1	Dining Room	T2	3.6	1.00	0.13	3.5	28768
Portable: 5	0.5 to 1	Dining Room	T3	4.7	1.00	0.12	4.6	31179
Portable: 5	1 to 3	Bathroom	T2	4.4	1.00	0.13	4.2	2596
Portable: 5	1 to 3	Bathroom	T3	4.8	1.00	0.12	4.7	1417
Portable: 5	1 to 3	Dining Room	T2	4.3	1.00	0.13	4.2	2094
Portable: 5	1 to 3	Dining Room	T3	5.6	1.00	0.12	5.5	11536
Portable: 5	3 to 5	Bathroom	T2	6.6	1.00	0.13	6.5	346
Portable: 5	3 to 5	Bathroom	T3	7.5	0.99	0.12	7.4	298
Portable: 5	3 to 5	Dining Room	T2	7.0	1.00	0.13	6.9	858
Portable: 5	3 to 5	Dining Room	T3	8.0	1.00	0.12	7.9	394
Portable: 5	5 to 10	Bathroom	T2	6.0	0.99	0.13	5.9	40
Portable: 5	5 to 10	Bathroom	T3	5.8	0.95	0.12	5.7	0
Portable: 5	5 to 10	Dining Room	T2	10.3	1.00	0.13	10.2	429
Portable: 5	5 to 10	Dining Room	T3	9.8	1.00	0.12	9.7	248

Table D.1 Continued

Air Cleaner	PM (μm)	Location	Test	k_t	Fit	k_a	$k_t – k_a$	C_{ss}
Portable: 5	10 to 20	Bathroom	T2	.	-99	0.13	.	0
Portable: 5	10 to 20	Bathroom	T3	.	-99	0.12	.	102
Portable: 5	10 to 20	Dining Room	T2	.	-99	0.13	.	.
Portable: 5	10 to 20	Dining Room	T3	.	-99	0.12	.	.
Portable: 5	Total	Bathroom	T2	3.1	0.99	0.13	3.0	6165908
Portable: 5	Total	Bathroom	T3	3.0	0.97	0.12	2.9	3724820
Portable: 5	Total	Dining Room	T2	3.7	1.00	0.13	3.6	970897
Portable: 5	Total	Dining Room	T3	4.7	1.00	0.12	4.6	607166
Ionic Breeze: 3	0.3 to 0.5	Bathroom	T1	0.1	0.99	0.15	0.0	327813050
Ionic Breeze: 3	0.3 to 0.5	Bathroom	T2	0.0	-99	0.13	0.0	289126321
Ionic Breeze: 3	0.3 to 0.5	Bathroom	T3	0.0	-99	0.13	0.0	247113084
Ionic Breeze: 3	0.3 to 0.5	Bathroom	T4	0.0	-99	0.11	0.0	273292786
Ionic Breeze: 3	0.3 to 0.5	Bathroom	T5	0.0	-99	0.12	0.0	185187024
Ionic Breeze: 3	0.3 to 0.5	Bathroom	T6	0.0	-99	0.11	0.0	166678510
Ionic Breeze: 3	0.3 to 0.5	Dining Room	T1	0.1	0.99	0.15	0.0	.
Ionic Breeze: 3	0.3 to 0.5	Dining Room	T2	0.0	-99	0.13	0.0	.
Ionic Breeze: 3	0.3 to 0.5	Dining Room	T3	0.0	-99	0.13	0.0	.
Ionic Breeze: 3	0.3 to 0.5	Dining Room	T4	0.0	-99	0.11	0.0	.
Ionic Breeze: 3	0.3 to 0.5	Dining Room	T5	0.0	-99	0.12	0.0	.
Ionic Breeze: 3	0.3 to 0.5	Dining Room	T6	0.0	-99	0.11	0.0	.
Ionic Breeze: 3	0.5 to 1	Bathroom	T1	0.2	1.00	0.15	0.1	7823975
Ionic Breeze: 3	0.5 to 1	Bathroom	T2	0.3	0.99	0.13	0.1	7251515
Ionic Breeze: 3	0.5 to 1	Bathroom	T3	0.2	0.98	0.13	0.0	5120733
Ionic Breeze: 3	0.5 to 1	Bathroom	T4	.	-99	0.11	.	6122329
Ionic Breeze: 3	0.5 to 1	Bathroom	T5	.	-99	0.12	.	3351871
Ionic Breeze: 3	0.5 to 1	Bathroom	T6	.	-99	0.11	.	2623042
Ionic Breeze: 3	0.5 to 1	Dining Room	T1	0.2	0.99	0.15	0.0	.
Ionic Breeze: 3	0.5 to 1	Dining Room	T2	0.2	0.99	0.13	0.1	.
Ionic Breeze: 3	0.5 to 1	Dining Room	T3	0.2	0.94	0.13	0.0	.
Ionic Breeze: 3	0.5 to 1	Dining Room	T4	.	-99	0.11	.	.
Ionic Breeze: 3	0.5 to 1	Dining Room	T5	.	-99	0.12	.	.
Ionic Breeze: 3	0.5 to 1	Dining Room	T6	.	-99	0.11	.	.
Ionic Breeze: 3	1 to 3	Bathroom	T1	1.2	1.00	0.15	1.0	166884
Ionic Breeze: 3	1 to 3	Bathroom	T2	1.0	1.00	0.13	0.8	235357
Ionic Breeze: 3	1 to 3	Bathroom	T3	1.1	1.00	0.13	1.0	156441
Ionic Breeze: 3	1 to 3	Bathroom	T4	1.0	0.99	0.11	0.9	154173
Ionic Breeze: 3	1 to 3	Bathroom	T5	1.1	1.00	0.12	1.0	107940
Ionic Breeze: 3	1 to 3	Bathroom	T6	1.2	1.00	0.11	1.1	65462
Ionic Breeze: 3	1 to 3	Dining Room	T1	1.4	0.99	0.15	1.2	.
Ionic Breeze: 3	1 to 3	Dining Room	T2	1.1	1.00	0.13	1.0	.
Ionic Breeze: 3	1 to 3	Dining Room	T3	1.4	0.99	0.13	1.2	.
Ionic Breeze: 3	1 to 3	Dining Room	T4	1.2	0.99	0.11	1.1	.
Ionic Breeze: 3	1 to 3	Dining Room	T5	1.2	1.00	0.12	1.1	.
Ionic Breeze: 3	1 to 3	Dining Room	T6	1.3	0.99	0.11	1.2	.

Table D.1 Continued

Air Cleaner	PM (μm)	Location	Test	k_t	Fit	k_a	$k_t - k_a$	C_{ss}
Ionic Breeze: 3	3 to 5	Bathroom	T1	2.6	0.99	0.15	2.4	4232
Ionic Breeze: 3	3 to 5	Bathroom	T2	2.4	0.99	0.13	2.2	8032
Ionic Breeze: 3	3 to 5	Bathroom	T3	2.7	0.99	0.13	2.6	3692
Ionic Breeze: 3	3 to 5	Bathroom	T4	2.2	0.98	0.11	2.1	4555
Ionic Breeze: 3	3 to 5	Bathroom	T5	2.0	0.97	0.12	1.9	2803
Ionic Breeze: 3	3 to 5	Bathroom	T6	2.0	0.97	0.11	1.9	1671
Ionic Breeze: 3	3 to 5	Dining Room	T1	3.0	0.98	0.15	2.9	.
Ionic Breeze: 3	3 to 5	Dining Room	T2	3.0	1.00	0.13	2.9	.
Ionic Breeze: 3	3 to 5	Dining Room	T3	4.0	0.99	0.13	3.9	.
Ionic Breeze: 3	3 to 5	Dining Room	T4	3.1	0.99	0.11	3.0	.
Ionic Breeze: 3	3 to 5	Dining Room	T5	2.2	0.98	0.12	2.1	.
Ionic Breeze: 3	3 to 5	Dining Room	T6	2.0	0.96	0.11	1.9	.
Ionic Breeze: 3	5 to 10	Bathroom	T1	2.4	0.93	0.15	2.2	839
Ionic Breeze: 3	5 to 10	Bathroom	T2	2.5	0.97	0.13	2.4	1887
Ionic Breeze: 3	5 to 10	Bathroom	T3	2.7	0.95	0.13	2.6	587
Ionic Breeze: 3	5 to 10	Bathroom	T4	2.8	0.95	0.11	2.7	566
Ionic Breeze: 3	5 to 10	Bathroom	T5	1.7	0.94	0.12	1.6	524
Ionic Breeze: 3	5 to 10	Bathroom	T6	1.9	0.93	0.11	1.8	293
Ionic Breeze: 3	5 to 10	Dining Room	T1	4.2	0.95	0.15	4.1	.
Ionic Breeze: 3	5 to 10	Dining Room	T2	2.5	0.91	0.13	2.4	.
Ionic Breeze: 3	5 to 10	Dining Room	T3	3.0	0.95	0.13	2.9	.
Ionic Breeze: 3	5 to 10	Dining Room	T4	3.0	0.97	0.11	2.9	.
Ionic Breeze: 3	5 to 10	Dining Room	T5	2.7	0.96	0.12	2.6	.
Ionic Breeze: 3	5 to 10	Dining Room	T6	9.0	1.00	0.11	8.9	957
Ionic Breeze: 3	10 to 20	Bathroom	T1	2.9	0.90	0.15	2.8	790
Ionic Breeze: 3	10 to 20	Bathroom	T2	.	-99	0.13	.	795
Ionic Breeze: 3	10 to 20	Bathroom	T3	8.7	0.93	0.13	8.5	32
Ionic Breeze: 3	10 to 20	Bathroom	T4	.	-99	0.11	.	82
Ionic Breeze: 3	10 to 20	Bathroom	T5	.	-99	0.12	.	61
Ionic Breeze: 3	10 to 20	Bathroom	T6	6.5	0.96	0.11	6.4	18
Ionic Breeze: 3	10 to 20	Dining Room	T1	4.2	0.94	0.15	4.1	.
Ionic Breeze: 3	10 to 20	Dining Room	T2	.	-99	0.13	.	.
Ionic Breeze: 3	10 to 20	Dining Room	T3	.	-99	0.13	.	.
Ionic Breeze: 3	10 to 20	Dining Room	T4	.	-99	0.11	.	.
Ionic Breeze: 3	10 to 20	Dining Room	T5	.	-99	0.12	.	.
Ionic Breeze: 3	10 to 20	Dining Room	T6	.	-99	0.11	.	.
Ionic Breeze: 3	Total	Bathroom	T1	0.1	0.99	0.15	0.0	335809769
Ionic Breeze: 3	Total	Bathroom	T2	0.0	-99	0.13	0.0	296623907
Ionic Breeze: 3	Total	Bathroom	T3	0.0	-99	0.13	0.0	252394579
Ionic Breeze: 3	Total	Bathroom	T4	0.0	-99	0.11	0.0	279574490
Ionic Breeze: 3	Total	Bathroom	T5	0.0	-99	0.12	0.0	188650224
Ionic Breeze: 3	Total	Bathroom	T6	0.0	-99	0.11	0.0	169369060
Ionic Breeze: 3	Total	Dining Room	T1	0.1	0.99	0.15	0.0	.
Ionic Breeze: 3	Total	Dining Room	T2	0.0	-99	0.13	0.0	.

Table D.1 Continued

Air Cleaner	PM (μm)	Location	Test	k_t	Fit	k_a	$k_t - k_a$	C_{ss}
Ionic Breeze: 3	Total	Dining Room	T3	.	0.93	0.13	.	.
Ionic Breeze: 3	Total	Dining Room	T4	0.0	-99	0.11	0.0	.
Ionic Breeze: 3	Total	Dining Room	T5	0.0	-99	0.12	0.0	.
Ionic Breeze: 3	Total	Dining Room	T6	0.0	-99	0.11	0.0	.

PM particulate matter
μm micrometer
k_t total aerosol removal rate
Fit Pearson correlation between observed and predicted aerosol concentrations
k_a aerosol removal by air exchange or exfiltration
$K_t - k_a$ total aerosol removal rate minus the aerosol removal by air exchange or exfiltration
C_{ss} concentration at steady-state

APPENDIX E

WHOLE HOUSE DECAY RATE:
PARTICLE COUNTS BY APS INSTRUMENTS

Table E.1 Whole House Decay Rate: Particle Counts by APS Instruments

Air Cleaner	PM (μm)	Location	Test	k_t	Fit	k_a	$k_t - k_a$	C_{ss}
No Filter	0.3 to 0.5	Bedroom2	T1	0.0	-99	0.10	0.0	.
No Filter	0.3 to 0.5	Bedroom2	T2	0.0	-99	0.10	0.0	.
No Filter	0.3 to 0.5	Bedroom2	T3	0.0	-99	0.17	0.0	.
No Filter	0.3 to 0.5	Bedroom2	T4	0.0	-99	0.17	0.0	.
No Filter	0.3 to 0.5	Bedroom2	T5	0.0	-99	0.17	0.0	.
No Filter	0.3 to 0.5	Bedroom2	T6	0.0	-99	0.17	0.0	.
No Filter	0.3 to 0.5	Dining Room	T1	0.0	-99	0.10	0.0	.
No Filter	0.3 to 0.5	Dining Room	T2	0.0	-99	0.10	0.0	.
No Filter	0.3 to 0.5	Dining Room	T3	0.0	-99	0.17	0.0	.
No Filter	0.3 to 0.5	Dining Room	T4	0.0	-99	0.17	0.0	.
No Filter	0.3 to 0.5	Dining Room	T5	0.0	-99	0.17	0.0	.
No Filter	0.3 to 0.5	Dining Room	T6	0.0	-99	0.17	0.0	.
No Filter	0.5 to 1	Bedroom2	T1	0.0	-99	0.10	0.0	.
No Filter	0.5 to 1	Bedroom2	T2	0.0	-99	0.10	0.0	.
No Filter	0.5 to 1	Bedroom2	T3	0.0	-99	0.17	0.0	.
No Filter	0.5 to 1	Bedroom2	T4	.	-99	0.17	.	.
No Filter	0.5 to 1	Bedroom2	T5	0.0	-99	0.17	0.0	.
No Filter	0.5 to 1	Bedroom2	T6	0.0	-99	0.17	0.0	.
No Filter	0.5 to 1	Dining Room	T1	.	-99	0.10	.	.
No Filter	0.5 to 1	Dining Room	T2	.	-99	0.10	.	.
No Filter	0.5 to 1	Dining Room	T3	0.2	0.91	0.17	0.1	.
No Filter	0.5 to 1	Dining Room	T4	0.3	0.90	0.17	0.1	.
No Filter	0.5 to 1	Dining Room	T5	.	-99	0.17	.	.
No Filter	0.5 to 1	Dining Room	T6	.	-99	0.17	.	.
No Filter	1 to 3	Bedroom2	T1	0.7	0.92	0.10	0.6	.
No Filter	1 to 3	Bedroom2	T2	.	-99	0.10	.	.
No Filter	1 to 3	Bedroom2	T3	.	-99	0.17	.	.
No Filter	1 to 3	Bedroom2	T4	.	-99	0.17	.	.
No Filter	1 to 3	Bedroom2	T5	.	-99	0.17	.	.
No Filter	1 to 3	Bedroom2	T6	.	-99	0.17	.	.
No Filter	1 to 3	Dining Room	T1	1.1	0.96	0.10	1.0	.
No Filter	1 to 3	Dining Room	T2	1.0	0.97	0.10	0.9	.
No Filter	1 to 3	Dining Room	T3	1.1	0.97	0.17	0.9	.
No Filter	1 to 3	Dining Room	T4	.	-99	0.17	.	.
No Filter	1 to 3	Dining Room	T5	.	-99	0.17	.	.
No Filter	1 to 3	Dining Room	T6	1.2	0.97	0.17	1.0	.
No Filter	3 to 5	Bedroom2	T1	.	-99	0.10	.	.
No Filter	3 to 5	Bedroom2	T2	.	-99	0.10	.	.
No Filter	3 to 5	Bedroom2	T3	.	-99	0.17	.	.
No Filter	3 to 5	Bedroom2	T4	.	-99	0.17	.	.
No Filter	3 to 5	Bedroom2	T5	.	-99	0.17	.	.
No Filter	3 to 5	Bedroom2	T6	.	-99	0.17	.	.
No Filter	3 to 5	Dining Room	T1	3.9	0.91	0.10	3.8	.
No Filter	3 to 5	Dining Room	T2	.	-99	0.10	.	.

Table E.1 Continued

Air Cleaner	PM (μm)	Location	Test	k_t	Fit	k_a	$k_t - k_a$	C_{ss}
No Filter	3 to 5	Dining Room	T3	5.8	0.95	0.17	5.6	.
No Filter	3 to 5	Dining Room	T4	5.0	0.93	0.17	4.9	.
No Filter	3 to 5	Dining Room	T5	.	-99	0.17	.	.
No Filter	3 to 5	Dining Room	T6	5.2	0.91	0.17	5.0	.
No Filter	5 to 10	Bedroom2	T1	.	-99	0.10	.	.
No Filter	5 to 10	Bedroom2	T2	.	-99	0.10	.	.
No Filter	5 to 10	Bedroom2	T3	.	-99	0.17	.	.
No Filter	5 to 10	Bedroom2	T4	.	-99	0.17	.	.
No Filter	5 to 10	Bedroom2	T5	.	-99	0.17	.	.
No Filter	5 to 10	Bedroom2	T6	.	-99	0.17	.	.
No Filter	5 to 10	Dining Room	T1	.	-99	0.10	.	.
No Filter	5 to 10	Dining Room	T2	.	-99	0.10	.	.
No Filter	5 to 10	Dining Room	T3	.	-99	0.17	.	.
No Filter	5 to 10	Dining Room	T4	.	-99	0.17	.	.
No Filter	5 to 10	Dining Room	T5	.	-99	0.17	.	.
No Filter	5 to 10	Dining Room	T6	.	-99	0.17	.	.
No Filter	10 to 20	Bedroom2	T1	.	-99	0.10	.	.
No Filter	10 to 20	Bedroom2	T2	.	-99	0.10	.	.
No Filter	10 to 20	Bedroom2	T3	.	-99	0.17	.	.
No Filter	10 to 20	Bedroom2	T4	.	-99	0.17	.	.
No Filter	10 to 20	Bedroom2	T5	.	-99	0.17	.	.
No Filter	10 to 20	Bedroom2	T6	.	-99	0.17	.	.
No Filter	10 to 20	Dining Room	T1	.	-99	0.10	.	.
No Filter	10 to 20	Dining Room	T2	.	-99	0.10	.	.
No Filter	10 to 20	Dining Room	T3	.	-99	0.17	.	.
No Filter	10 to 20	Dining Room	T4	.	-99	0.17	.	.
No Filter	10 to 20	Dining Room	T5	.	-99	0.17	.	.
No Filter	10 to 20	Dining Room	T6	.	-99	0.17	.	.
No Filter	Total	Bedroom2	T1	0.0	-99	0.10	0.0	.
No Filter	Total	Bedroom2	T2	0.0	-99	0.10	0.0	.
No Filter	Total	Bedroom2	T3	0.0	-99	0.17	0.0	.
No Filter	Total	Bedroom2	T4	0.2	0.94	0.17	0.1	.
No Filter	Total	Bedroom2	T5	0.0	-99	0.17	0.0	.
No Filter	Total	Bedroom2	T6	0.0	-99	0.17	0.0	.
No Filter	Total	Dining Room	T1	0.0	-99	0.10	0.0	.
No Filter	Total	Dining Room	T2	0.0	-99	0.10	0.0	.
No Filter	Total	Dining Room	T3	0.3	0.97	0.17	0.2	.
No Filter	Total	Dining Room	T4	0.0	-99	0.17	0.0	.
No Filter	Total	Dining Room	T5	0.0	-99	0.17	0.0	.
No Filter	Total	Dining Room	T6	0.0	-99	0.17	0.0	.
1-inch	0.3 to 0.5	Bedroom1	T1	0.0	-99	0.07	0.0	.
1-inch	0.3 to 0.5	Bedroom1	T2	0.0	-99	0.07	0.0	.
1-inch	0.3 to 0.5	Bedroom1	T3	0.0	-99	0.07	0.0	.
1-inch	0.3 to 0.5	Bedroom1	T4	0.0	-99	0.09	0.0	.

Table E.1 Continued

Air Cleaner	PM (μm)	Location	Test	k_t	Fit	k_a	$k_t – k_a$	C_{ss}
1-inch	0.3 to 0.5	Bedroom1	T5	0.0	-99	0.09	0.0	.
1-inch	0.3 to 0.5	Bedroom1	T6	0.0	-99	0.09	0.0	.
1-inch	0.3 to 0.5	Bedroom2	TA	0.0	-99	0.10	0.0	.
1-inch	0.3 to 0.5	Bedroom2	TB	0.0	-99	0.11	0.0	.
1-inch	0.3 to 0.5	Bedroom2	TC	0.0	-99	0.13	0.0	.
1-inch	0.3 to 0.5	Dining Room	TA	0.0	-99	0.10	0.0	.
1-inch	0.3 to 0.5	Dining Room	TB	0.0	-99	0.11	0.0	.
1-inch	0.3 to 0.5	Dining Room	TC	0.0	-99	0.13	0.0	.
1-inch	0.5 to 1	Bedroom1	T1	.	-99	0.07	.	.
1-inch	0.5 to 1	Bedroom1	T2	0.3	0.90	0.07	0.2	.
1-inch	0.5 to 1	Bedroom1	T3	.	-99	0.07	.	.
1-inch	0.5 to 1	Bedroom1	T4	.	-99	0.09	.	.
1-inch	0.5 to 1	Bedroom1	T5	.	-99	0.09	.	.
1-inch	0.5 to 1	Bedroom1	T6	.	-99	0.09	.	.
1-inch	0.5 to 1	Bedroom2	TA	.	-99	0.10	.	.
1-inch	0.5 to 1	Bedroom2	TB	.	-99	0.11	.	.
1-inch	0.5 to 1	Bedroom2	TC	.	-99	0.13	.	.
1-inch	0.5 to 1	Dining Room	TA	.	-99	0.10	.	.
1-inch	0.5 to 1	Dining Room	TB	.	-99	0.11	.	.
1-inch	0.5 to 1	Dining Room	TC	.	-99	0.13	.	.
1-inch	1 to 3	Bedroom1	T1	.	-99	0.07	.	.
1-inch	1 to 3	Bedroom1	T2	1.8	0.98	0.07	1.7	.
1-inch	1 to 3	Bedroom1	T3	1.9	0.99	0.07	1.9	.
1-inch	1 to 3	Bedroom1	T4	1.7	0.99	0.09	1.6	.
1-inch	1 to 3	Bedroom1	T5	1.8	0.99	0.09	1.7	.
1-inch	1 to 3	Bedroom1	T6	1.8	0.98	0.09	1.8	.
1-inch	1 to 3	Bedroom2	TA	1.6	0.99	0.10	1.6	.
1-inch	1 to 3	Bedroom2	TB	0.7	0.93	0.11	0.6	.
1-inch	1 to 3	Bedroom2	TC	1.0	0.98	0.13	0.9	.
1-inch	1 to 3	Dining Room	TA	1.7	0.99	0.10	1.6	.
1-inch	1 to 3	Dining Room	TB	.	-99	0.11	.	.
1-inch	1 to 3	Dining Room	TC	1.2	0.98	0.13	1.0	.
1-inch	3 to 5	Bedroom1	T1	.	-99	0.07	.	.
1-inch	3 to 5	Bedroom1	T2	.	-99	0.07	.	.
1-inch	3 to 5	Bedroom1	T3	.	-99	0.07	.	.
1-inch	3 to 5	Bedroom1	T4	.	-99	0.09	.	.
1-inch	3 to 5	Bedroom1	T5	.	-99	0.09	.	.
1-inch	3 to 5	Bedroom1	T6	.	-99	0.09	.	.
1-inch	3 to 5	Bedroom2	TA	.	-99	0.10	.	.
1-inch	3 to 5	Bedroom2	TB	.	-99	0.11	.	.
1-inch	3 to 5	Bedroom2	TC	.	-99	0.13	.	.
1-inch	3 to 5	Dining Room	TA	6.2	0.93	0.10	6.1	.
1-inch	3 to 5	Dining Room	TB	.	-99	0.11	.	.
1-inch	3 to 5	Dining Room	TC	4.4	0.91	0.13	4.3	.

Table E.1 Continued

Air Cleaner	PM (μm)	Location	Test	k_t	Fit	k_a	$k_t - k_a$	C_{ss}
1-inch	5 to 10	Bedroom1	T1	.	-99	0.07	.	.
1-inch	5 to 10	Bedroom1	T2	.	-99	0.07	.	.
1-inch	5 to 10	Bedroom1	T3	.	-99	0.07	.	.
1-inch	5 to 10	Bedroom1	T4	.	-99	0.09	.	.
1-inch	5 to 10	Bedroom1	T5	.	-99	0.09	.	.
1-inch	5 to 10	Bedroom1	T6	.	-99	0.09	.	.
1-inch	5 to 10	Bedroom2	TA	.	-99	0.10	.	.
1-inch	5 to 10	Bedroom2	TB	.	-99	0.11	.	.
1-inch	5 to 10	Bedroom2	TC	.	-99	0.13	.	.
1-inch	5 to 10	Dining Room	TA	.	-99	0.10	.	.
1-inch	5 to 10	Dining Room	TB	.	-99	0.11	.	.
1-inch	5 to 10	Dining Room	TC	.	-99	0.13	.	.
1-inch	10 to 20	Bedroom1	T1	.	-99	0.07	.	.
1-inch	10 to 20	Bedroom1	T2	.	-99	0.07	.	.
1-inch	10 to 20	Bedroom1	T3	.	-99	0.07	.	.
1-inch	10 to 20	Bedroom1	T4	.	-99	0.09	.	.
1-inch	10 to 20	Bedroom1	T5	.	-99	0.09	.	.
1-inch	10 to 20	Bedroom1	T6	.	-99	0.09	.	.
1-inch	10 to 20	Bedroom2	TA	.	-99	0.10	.	.
1-inch	10 to 20	Bedroom2	TB	.	-99	0.11	.	.
1-inch	10 to 20	Bedroom2	TC	.	-99	0.13	.	.
1-inch	10 to 20	Dining Room	TA	.	-99	0.10	.	.
1-inch	10 to 20	Dining Room	TB	54.0	0.91	0.11	53.9	0
1-inch	10 to 20	Dining Room	TC	.	-99	0.13	.	.
1-inch	Total	Bedroom1	T1	.	-99	0.07	.	.
1-inch	Total	Bedroom1	T2	0.4	0.97	0.07	0.4	.
1-inch	Total	Bedroom1	T3	0.4	0.94	0.07	0.3	.
1-inch	Total	Bedroom1	T4	0.4	0.94	0.09	0.3	.
1-inch	Total	Bedroom1	T5	.	-99	0.09	.	.
1-inch	Total	Bedroom1	T6	0.5	0.98	0.09	0.4	.
1-inch	Total	Bedroom2	TA	.	0.94	0.10	.	.
1-inch	Total	Bedroom2	TB	.	-99	0.11	.	.
1-inch	Total	Bedroom2	TC	.	-99	0.13	.	.
1-inch	Total	Dining Room	TA	.	-99	0.10	.	.
1-inch	Total	Dining Room	TB	.	-99	0.11	.	.
1-inch	Total	Dining Room	TC	.	-99	0.13	.	.
5-inch	0.3 to 0.5	Bedroom2	T1	1.8	1.00	0.12	1.7	1507053
5-inch	0.3 to 0.5	Bedroom2	T2	.	-99	0.11	.	.
5-inch	0.3 to 0.5	Bedroom2	T3	.	-99	0.10	.	.
5-inch	0.3 to 0.5	Bedroom2	T4	.	-99	0.07	.	.
5-inch	0.3 to 0.5	Bedroom2	T5	1.6	0.99	0.07	1.5	800751
5-inch	0.3 to 0.5	Bedroom2	T6	.	-99	0.11	.	.
5-inch	0.3 to 0.5	Dining Room	T1	2.3	1.00	0.12	2.1	1825327
5-inch	0.3 to 0.5	Dining Room	T2	.	-99	0.11	.	.

Table E.1 Continued

Air Cleaner	PM (μm)	Location	Test	k_t	Fit	k_a	$k_t - k_a$	C_{ss}
5-inch	0.3 to 0.5	Dining Room	T3	1.9	0.99	0.10	1.8	933448
5-inch	0.3 to 0.5	Dining Room	T4	2.4	0.99	0.07	2.3	910263
5-inch	0.3 to 0.5	Dining Room	T5	2.5	0.99	0.07	2.5	1243380
5-inch	0.3 to 0.5	Dining Room	T6	2.7	0.99	0.11	2.6	1500878
5-inch	0.5 to 1	Bedroom2	T1	1.2	0.99	0.12	1.1	0
5-inch	0.5 to 1	Bedroom2	T2	.	-99	0.11	.	.
5-inch	0.5 to 1	Bedroom2	T3	1.7	1.00	0.10	1.6	0
5-inch	0.5 to 1	Bedroom2	T4	.	-99	0.07	.	.
5-inch	0.5 to 1	Bedroom2	T5	0.7	0.99	0.07	0.7	0
5-inch	0.5 to 1	Bedroom2	T6	0.9	0.99	0.11	0.8	0
5-inch	0.5 to 1	Dining Room	T1	2.8	1.00	0.12	2.7	677289
5-inch	0.5 to 1	Dining Room	T2	3.1	1.00	0.11	2.9	381454
5-inch	0.5 to 1	Dining Room	T3	.	-99	0.10	.	.
5-inch	0.5 to 1	Dining Room	T4	3.9	1.00	0.07	3.8	349343
5-inch	0.5 to 1	Dining Room	T5	4.0	0.99	0.07	3.9	259287
5-inch	0.5 to 1	Dining Room	T6	3.0	0.99	0.11	2.9	491552
5-inch	1 to 3	Bedroom2	T1	.	-99	0.12	.	.
5-inch	1 to 3	Bedroom2	T2	.	-99	0.11	.	.
5-inch	1 to 3	Bedroom2	T3	.	-99	0.10	.	.
5-inch	1 to 3	Bedroom2	T4	.	-99	0.07	.	.
5-inch	1 to 3	Bedroom2	T5	.	-99	0.07	.	.
5-inch	1 to 3	Bedroom2	T6	.	-99	0.11	.	.
5-inch	1 to 3	Dining Room	T1	4.9	1.00	0.12	4.8	42958
5-inch	1 to 3	Dining Room	T2	5.6	1.00	0.11	5.5	58884
5-inch	1 to 3	Dining Room	T3	7.9	0.97	0.10	7.8	164918
5-inch	1 to 3	Dining Room	T4	6.7	1.00	0.07	6.6	99371
5-inch	1 to 3	Dining Room	T5	6.2	0.99	0.07	6.2	45299
5-inch	1 to 3	Dining Room	T6	4.4	1.00	0.11	4.3	25178
5-inch	3 to 5	Bedroom2	T1	.	-99	0.12	.	.
5-inch	3 to 5	Bedroom2	T2	.	-99	0.11	.	.
5-inch	3 to 5	Bedroom2	T3	.	-99	0.10	.	.
5-inch	3 to 5	Bedroom2	T4	.	-99	0.07	.	.
5-inch	3 to 5	Bedroom2	T5	.	-99	0.07	.	.
5-inch	3 to 5	Bedroom2	T6	.	-99	0.11	.	.
5-inch	3 to 5	Dining Room	T1	7.7	0.98	0.12	7.6	1007
5-inch	3 to 5	Dining Room	T2	8.6	0.97	0.11	8.5	1014
5-inch	3 to 5	Dining Room	T3	14.0	0.95	0.10	13.9	3734
5-inch	3 to 5	Dining Room	T4	11.8	0.97	0.07	11.8	4410
5-inch	3 to 5	Dining Room	T5	10.7	0.95	0.07	10.7	595
5-inch	3 to 5	Dining Room	T6	8.0	0.97	0.11	7.8	485
5-inch	5 to 10	Bedroom2	T1	.	-99	0.12	.	.
5-inch	5 to 10	Bedroom2	T2	.	-99	0.11	.	.
5-inch	5 to 10	Bedroom2	T3	.	-99	0.10	.	.
5-inch	5 to 10	Bedroom2	T4	.	-99	0.07	.	.

Table E.1 Continued

Air Cleaner	PM (μm)	Location	Test	k_t	Fit	k_a	$k_t - k_a$	C_{ss}
5-inch	5 to 10	Bedroom2	T5	18.6	0.91	0.07	18.5	18
5-inch	5 to 10	Bedroom2	T6	.	-99	0.11	.	.
5-inch	5 to 10	Dining Room	T1	.	-99	0.12	.	.
5-inch	5 to 10	Dining Room	T2	.	-99	0.11	.	.
5-inch	5 to 10	Dining Room	T3	16.6	0.94	0.10	16.5	381
5-inch	5 to 10	Dining Room	T4	.	-99	0.07	.	.
5-inch	5 to 10	Dining Room	T5	.	-99	0.07	.	.
5-inch	5 to 10	Dining Room	T6	.	-99	0.11	.	.
5-inch	10 to 20	Bedroom2	T1	.	-99	0.12	.	.
5-inch	10 to 20	Bedroom2	T2	.	-99	0.11	.	.
5-inch	10 to 20	Bedroom2	T3	.	-99	0.10	.	.
5-inch	10 to 20	Bedroom2	T4	.	-99	0.07	.	.
5-inch	10 to 20	Bedroom2	T5	.	-99	0.07	.	.
5-inch	10 to 20	Bedroom2	T6	.	-99	0.11	.	.
5-inch	10 to 20	Dining Room	T1	.	-99	0.12	.	.
5-inch	10 to 20	Dining Room	T2	.	-99	0.11	.	.
5-inch	10 to 20	Dining Room	T3	.	-99	0.10	.	.
5-inch	10 to 20	Dining Room	T4	.	-99	0.07	.	.
5-inch	10 to 20	Dining Room	T5	.	-99	0.07	.	.
5-inch	10 to 20	Dining Room	T6	.	-99	0.11	.	.
5-inch	Total	Bedroom2	T1	1.8	1.00	0.12	1.7	1706508
5-inch	Total	Bedroom2	T2	.	-99	0.11	.	.
5-inch	Total	Bedroom2	T3	1.6	1.00	0.10	1.5	586476
5-inch	Total	Bedroom2	T4	.	-99	0.07	.	.
5-inch	Total	Bedroom2	T5	.	-99	0.07	.	.
5-inch	Total	Bedroom2	T6	.	-99	0.11	.	.
5-inch	Total	Dining Room	T1	.	-99	0.12	.	.
5-inch	Total	Dining Room	T2	2.4	0.99	0.11	2.3	1477130
5-inch	Total	Dining Room	T3	2.9	1.00	0.10	2.8	1466233
5-inch	Total	Dining Room	T4	3.9	1.00	0.07	3.8	1553711
5-inch	Total	Dining Room	T5	4.0	0.99	0.07	3.9	1656713
5-inch	Total	Dining Room	T6	3.4	1.00	0.11	3.3	2072955
Electronic	0.3 to 0.5	Bedroom2	T1	2.8	1.00	0.15	2.7	125130
Electronic	0.3 to 0.5	Bedroom2	T2	3.4	1.00	0.15	3.2	157630
Electronic	0.3 to 0.5	Bedroom2	T3	3.0	1.00	0.14	2.9	307207
Electronic	0.3 to 0.5	Bedroom2	T4	.	-99	0.12	.	.
Electronic	0.3 to 0.5	Bedroom2	T5	3.6	0.99	0.09	3.5	503135
Electronic	0.3 to 0.5	Bedroom2	T6	3.4	1.00	0.10	3.3	2355991
Electronic	0.3 to 0.5	Dining Room	T1	4.6	1.00	0.15	4.5	139693
Electronic	0.3 to 0.5	Dining Room	T2	2.8	0.99	0.15	2.7	87198
Electronic	0.3 to 0.5	Dining Room	T3	4.3	0.99	0.14	4.1	432888
Electronic	0.3 to 0.5	Dining Room	T4	4.6	0.99	0.12	4.5	595543
Electronic	0.3 to 0.5	Dining Room	T5	4.7	0.99	0.09	4.6	624708
Electronic	0.3 to 0.5	Dining Room	T6	4.3	0.99	0.10	4.2	706733

Table E.1 Continued

Air Cleaner	PM (μm)	Location	Test	k_t	Fit	k_a	$k_t - k_a$	C_{ss}
Electronic	0.5 to 1	Bedroom2	T1	2.6	0.99	0.15	2.5	0
Electronic	0.5 to 1	Bedroom2	T2	2.9	0.98	0.15	2.8	0
Electronic	0.5 to 1	Bedroom2	T3	.	-99	0.14	.	.
Electronic	0.5 to 1	Bedroom2	T4	1.9	0.99	0.12	1.8	27058
Electronic	0.5 to 1	Bedroom2	T5	2.3	0.99	0.09	2.3	35966
Electronic	0.5 to 1	Bedroom2	T6	2.4	0.99	0.10	2.3	1100151
Electronic	0.5 to 1	Dining Room	T1	5.7	1.00	0.15	5.5	50810
Electronic	0.5 to 1	Dining Room	T2	5.3	0.99	0.15	5.2	43598
Electronic	0.5 to 1	Dining Room	T3	4.5	1.00	0.14	4.4	184282
Electronic	0.5 to 1	Dining Room	T4	5.1	1.00	0.12	5.0	225076
Electronic	0.5 to 1	Dining Room	T5	6.3	1.00	0.09	6.2	236359
Electronic	0.5 to 1	Dining Room	T6	6.6	0.99	0.10	6.5	169685
Electronic	1 to 3	Bedroom2	T1	.	-99	0.15	.	.
Electronic	1 to 3	Bedroom2	T2	.	-99	0.15	.	.
Electronic	1 to 3	Bedroom2	T3	.	-99	0.14	.	.
Electronic	1 to 3	Bedroom2	T4	.	-99	0.12	.	.
Electronic	1 to 3	Bedroom2	T5	.	-99	0.09	.	.
Electronic	1 to 3	Bedroom2	T6	.	-99	0.10	.	.
Electronic	1 to 3	Dining Room	T1	7.0	1.00	0.15	6.9	20795
Electronic	1 to 3	Dining Room	T2	6.1	0.99	0.15	6.0	12354
Electronic	1 to 3	Dining Room	T3	5.5	1.00	0.14	5.4	9725
Electronic	1 to 3	Dining Room	T4	5.8	1.00	0.12	5.7	13827
Electronic	1 to 3	Dining Room	T5	7.7	1.00	0.09	7.6	50208
Electronic	1 to 3	Dining Room	T6	8.2	0.99	0.10	8.1	32129
Electronic	3 to 5	Bedroom2	T1	.	-99	0.15	.	.
Electronic	3 to 5	Bedroom2	T2	.	-99	0.15	.	.
Electronic	3 to 5	Bedroom2	T3	.	-99	0.14	.	.
Electronic	3 to 5	Bedroom2	T4	.	-99	0.12	.	.
Electronic	3 to 5	Bedroom2	T5	.	-99	0.09	.	.
Electronic	3 to 5	Bedroom2	T6	.	-99	0.10	.	.
Electronic	3 to 5	Dining Room	T1	.	-99	0.15	.	.
Electronic	3 to 5	Dining Room	T2	.	-99	0.15	.	.
Electronic	3 to 5	Dining Room	T3	.	-99	0.14	.	.
Electronic	3 to 5	Dining Room	T4	7.8	0.98	0.12	7.7	362
Electronic	3 to 5	Dining Room	T5	11.1	0.98	0.09	11.0	621
Electronic	3 to 5	Dining Room	T6	10.8	0.97	0.10	10.7	1042
Electronic	5 to 10	Bedroom2	T1	.	-99	0.15	.	.
Electronic	5 to 10	Bedroom2	T2	.	-99	0.15	.	.
Electronic	5 to 10	Bedroom2	T3	.	-99	0.14	.	.
Electronic	5 to 10	Bedroom2	T4	.	-99	0.12	.	.
Electronic	5 to 10	Bedroom2	T5	.	-99	0.09	.	.
Electronic	5 to 10	Bedroom2	T6	.	-99	0.10	.	.
Electronic	5 to 10	Dining Room	T1	.	-99	0.15	.	.
Electronic	5 to 10	Dining Room	T2	19.3	0.92	0.15	19.2	201

Table E.1 Continued

Air Cleaner	PM (μm)	Location	Test	k_t	Fit	k_a	$k_t - k_a$	C_{ss}
Electronic	5 to 10	Dining Room	T3	24.0	0.94	0.14	23.9	558
Electronic	5 to 10	Dining Room	T4	.	-99	0.12	.	.
Electronic	5 to 10	Dining Room	T5	.	-99	0.09	.	.
Electronic	5 to 10	Dining Room	T6	.	-99	0.10	.	.
Electronic	10 to 20	Bedroom2	T1	.	-99	0.15	.	.
Electronic	10 to 20	Bedroom2	T2	.	-99	0.15	.	.
Electronic	10 to 20	Bedroom2	T3	.	-99	0.14	.	.
Electronic	10 to 20	Bedroom2	T4	.	-99	0.12	.	.
Electronic	10 to 20	Bedroom2	T5	.	-99	0.09	.	.
Electronic	10 to 20	Bedroom2	T6	.	-99	0.10	.	.
Electronic	10 to 20	Dining Room	T1	.	-99	0.15	.	.
Electronic	10 to 20	Dining Room	T2	.	-99	0.15	.	.
Electronic	10 to 20	Dining Room	T3	.	-99	0.14	.	.
Electronic	10 to 20	Dining Room	T4	.	-99	0.12	.	.
Electronic	10 to 20	Dining Room	T5	.	-99	0.09	.	.
Electronic	10 to 20	Dining Room	T6	.	-99	0.10	.	.
Electronic	Total	Bedroom2	T1	1.8	0.99	0.15	1.7	1013
Electronic	Total	Bedroom2	T2	1.9	0.99	0.15	1.7	6379
Electronic	Total	Bedroom2	T3	1.6	0.99	0.14	1.5	37663
Electronic	Total	Bedroom2	T4	.	-99	0.12	.	.
Electronic	Total	Bedroom2	T5	.	-99	0.09	.	.
Electronic	Total	Bedroom2	T6	.	-99	0.10	.	.
Electronic	Total	Dining Room	T1	5.8	1.00	0.15	5.6	223202
Electronic	Total	Dining Room	T2	.	-99	0.15	.	.
Electronic	Total	Dining Room	T3	3.4	0.99	0.14	3.3	400674
Electronic	Total	Dining Room	T4	4.4	0.99	0.12	4.3	648710
Electronic	Total	Dining Room	T5	6.5	1.00	0.09	6.4	955684
Electronic	Total	Dining Room	T6	.	-99	0.10	.	.
CleanEffects™	0.3 to 0.5	Bedroom2	T1	6.0	1.00	0.14	5.8	207740
CleanEffects™	0.3 to 0.5	Bedroom2	T2	7.5	1.00	0.10	7.4	258631
CleanEffects™	0.3 to 0.5	Bedroom2	T4	6.3	1.00	0.10	6.2	145501
CleanEffects™	0.3 to 0.5	Bedroom2	T5	6.3	1.00	0.12	6.2	212268
CleanEffects™	0.3 to 0.5	Bedroom2	T7	6.1	1.00	0.10	6.0	274821
CleanEffects™	0.3 to 0.5	Bedroom2	T8	4.6	0.99	0.09	4.5	240010
CleanEffects™	0.3 to 0.5	Dining Room	T1	.	-99	0.14	.	.
CleanEffects™	0.3 to 0.5	Dining Room	T4	6.4	0.99	0.10	6.3	431283
CleanEffects™	0.3 to 0.5	Dining Room	T5	8.7	0.99	0.12	8.6	384357
CleanEffects™	0.3 to 0.5	Dining Room	T7	5.6	0.99	0.10	5.5	389380
CleanEffects™	0.3 to 0.5	Dining Room	T8	.	-99	0.09	.	.
CleanEffects™	0.5 to 1	Bedroom2	T1	.	-99	0.14	.	.
CleanEffects™	0.5 to 1	Bedroom2	T2	5.0	0.99	0.10	4.9	96887
CleanEffects™	0.5 to 1	Bedroom2	T4	6.0	0.99	0.10	5.9	77964
CleanEffects™	0.5 to 1	Bedroom2	T5	5.7	0.99	0.12	5.6	43798
CleanEffects™	0.5 to 1	Bedroom2	T7	6.1	1.00	0.10	6.0	296583

Table E.1 Continued

Air Cleaner	PM (μm)	Location	Test	k_t	Fit	k_a	$k_t - k_a$	C_{ss}
CleanEffects™	0.5 to 1	Bedroom2	T8	4.1	0.99	0.09	4.0	141654
CleanEffects™	0.5 to 1	Dining Room	T1	7.1	1.00	0.14	7.0	111667
CleanEffects™	0.5 to 1	Dining Room	T4	8.3	1.00	0.10	8.2	129356
CleanEffects™	0.5 to 1	Dining Room	T5	8.3	1.00	0.12	8.2	91089
CleanEffects™	0.5 to 1	Dining Room	T7	6.8	1.00	0.10	6.7	256540
CleanEffects™	0.5 to 1	Dining Room	T8	7.0	1.00	0.09	6.9	183957
CleanEffects™	1 to 3	Bedroom2	T1	4.0	0.99	0.14	3.9	0
CleanEffects™	1 to 3	Bedroom2	T2	.	-99	0.10	.	.
CleanEffects™	1 to 3	Bedroom2	T4	.	-99	0.10	.	.
CleanEffects™	1 to 3	Bedroom2	T5	5.2	0.99	0.12	5.1	0
CleanEffects™	1 to 3	Bedroom2	T7	.	-99	0.10	.	.
CleanEffects™	1 to 3	Bedroom2	T8	.	-99	0.09	.	.
CleanEffects™	1 to 3	Dining Room	T1	7.5	1.00	0.14	7.4	3086
CleanEffects™	1 to 3	Dining Room	T4	9.2	1.00	0.10	9.1	15976
CleanEffects™	1 to 3	Dining Room	T5	8.7	1.00	0.12	8.5	15629
CleanEffects™	1 to 3	Dining Room	T7	7.8	1.00	0.10	7.7	21144
CleanEffects™	1 to 3	Dining Room	T8	8.4	1.00	0.09	8.3	17300
CleanEffects™	3 to 5	Bedroom2	T1	.	-99	0.14	.	.
CleanEffects™	3 to 5	Bedroom2	T2	.	-99	0.10	.	.
CleanEffects™	3 to 5	Bedroom2	T4	.	-99	0.10	.	.
CleanEffects™	3 to 5	Bedroom2	T5	.	-99	0.12	.	.
CleanEffects™	3 to 5	Bedroom2	T7	.	-99	0.10	.	.
CleanEffects™	3 to 5	Bedroom2	T8	.	-99	0.09	.	.
CleanEffects™	3 to 5	Dining Room	T1	8.7	0.97	0.14	8.6	398
CleanEffects™	3 to 5	Dining Room	T4	10.5	0.99	0.10	10.4	1299
CleanEffects™	3 to 5	Dining Room	T5	10.1	0.97	0.12	10.0	673
CleanEffects™	3 to 5	Dining Room	T7	10.1	0.98	0.10	10.0	1806
CleanEffects™	3 to 5	Dining Room	T8	10.3	0.96	0.09	10.3	1503
CleanEffects™	5 to 10	Bedroom2	T1	.	-99	0.14	.	.
CleanEffects™	5 to 10	Bedroom2	T2	.	-99	0.10	.	.
CleanEffects™	5 to 10	Bedroom2	T4	.	-99	0.10	.	.
CleanEffects™	5 to 10	Bedroom2	T5	.	-99	0.12	.	.
CleanEffects™	5 to 10	Bedroom2	T7	.	-99	0.10	.	.
CleanEffects™	5 to 10	Bedroom2	T8	.	-99	0.09	.	.
CleanEffects™	5 to 10	Dining Room	T1	.	-99	0.14	.	.
CleanEffects™	5 to 10	Dining Room	T4	.	-99	0.10	.	.
CleanEffects™	5 to 10	Dining Room	T5	.	-99	0.12	.	.
CleanEffects™	5 to 10	Dining Room	T7	.	-99	0.10	.	.
CleanEffects™	5 to 10	Dining Room	T8	.	-99	0.09	.	.
CleanEffects™	10 to 20	Bedroom2	T1	.	-99	0.14	.	.
CleanEffects™	10 to 20	Bedroom2	T2	.	-99	0.10	.	.
CleanEffects™	10 to 20	Bedroom2	T4	.	-99	0.10	.	.
CleanEffects™	10 to 20	Bedroom2	T5	.	-99	0.12	.	.
CleanEffects™	10 to 20	Bedroom2	T7	.	-99	0.10	.	.

Table E.1 Continued

Air Cleaner	PM (μm)	Location	Test	k_t	Fit	k_a	$k_t - k_a$	C_{ss}
CleanEffects™	10 to 20	Bedroom2	T8	.	-99	0.09	.	.
CleanEffects™	10 to 20	Dining Room	T1	.	-99	0.14	.	.
CleanEffects™	10 to 20	Dining Room	T4	.	-99	0.10	.	.
CleanEffects™	10 to 20	Dining Room	T5	.	-99	0.12	.	.
CleanEffects™	10 to 20	Dining Room	T7	.	-99	0.10	.	.
CleanEffects™	10 to 20	Dining Room	T8	.	-99	0.09	.	.
CleanEffects™	Total	Bedroom2	T1	.	-99	0.14	.	.
CleanEffects™	Total	Bedroom2	T2	.	-99	0.10	.	.
CleanEffects™	Total	Bedroom2	T4	6.0	1.00	0.10	5.9	246838
CleanEffects™	Total	Bedroom2	T5	.	-99	0.12	.	.
CleanEffects™	Total	Bedroom2	T7	5.7	1.00	0.10	5.6	607599
CleanEffects™	Total	Bedroom2	T8	3.9	0.99	0.09	3.8	382853
CleanEffects™	Total	Dining Room	T1	7.3	1.00	0.14	7.2	483035
CleanEffects™	Total	Dining Room	T4	.	-99	0.10	.	.
CleanEffects™	Total	Dining Room	T5	.	-99	0.12	.	.
CleanEffects™	Total	Dining Room	T7	.	-99	0.10	.	.
CleanEffects™	Total	Dining Room	T8	7.3	1.00	0.09	7.3	664994
Portable: 1	0.3 to 0.5	Bedroom2	T1	1.1	1.00	0.12	1.0	2285545
Portable: 1	0.3 to 0.5	Bedroom2	T2	.	-99	0.13	.	.
Portable: 1	0.3 to 0.5	Bedroom2	T3	1.8	1.00	0.10	1.7	1939765
Portable: 1	0.3 to 0.5	Bedroom2	T4	3.1	0.98	0.08	3.0	3407176
Portable: 1	0.3 to 0.5	Bedroom2	T5	.	-99	0.11	.	.
Portable: 1	0.3 to 0.5	Bedroom2	T6	1.6	1.00	0.08	1.6	2312121
Portable: 1	0.3 to 0.5	Dining Room	T1	.	-99	0.12	.	.
Portable: 1	0.3 to 0.5	Dining Room	T2	.	-99	0.13	.	.
Portable: 1	0.3 to 0.5	Dining Room	T3	.	-99	0.10	.	.
Portable: 1	0.3 to 0.5	Dining Room	T4	.	-99	0.08	.	.
Portable: 1	0.3 to 0.5	Dining Room	T5	.	-99	0.11	.	.
Portable: 1	0.3 to 0.5	Dining Room	T6	.	-99	0.08	.	.
Portable: 1	0.5 to 1	Bedroom2	T1	0.6	1.00	0.12	0.4	0
Portable: 1	0.5 to 1	Bedroom2	T2	.	-99	0.13	.	.
Portable: 1	0.5 to 1	Bedroom2	T3	1.0	1.00	0.10	0.9	0
Portable: 1	0.5 to 1	Bedroom2	T4	.	-99	0.08	.	.
Portable: 1	0.5 to 1	Bedroom2	T5	.	-99	0.11	.	.
Portable: 1	0.5 to 1	Bedroom2	T6	0.7	0.99	0.08	0.7	0
Portable: 1	0.5 to 1	Dining Room	T1	.	-99	0.12	.	.
Portable: 1	0.5 to 1	Dining Room	T2	.	-99	0.13	.	.
Portable: 1	0.5 to 1	Dining Room	T3	2.0	0.99	0.10	1.9	969556
Portable: 1	0.5 to 1	Dining Room	T4	.	-99	0.08	.	.
Portable: 1	0.5 to 1	Dining Room	T5	1.8	0.99	0.11	1.7	1465073
Portable: 1	0.5 to 1	Dining Room	T6	1.9	1.00	0.08	1.8	827966
Portable: 1	1 to 3	Bedroom2	T1	.	-99	0.12	.	.
Portable: 1	1 to 3	Bedroom2	T2	.	-99	0.13	.	.
Portable: 1	1 to 3	Bedroom2	T3	.	-99	0.10	.	.

Table E.1 Continued

Air Cleaner	PM (μm)	Location	Test	k_t	Fit	k_a	$k_t - k_a$	C_{ss}
Portable: 1	1 to 3	Bedroom2	T4	.	-99	0.08	.	.
Portable: 1	1 to 3	Bedroom2	T5	.	-99	0.11	.	.
Portable: 1	1 to 3	Bedroom2	T6	.	-99	0.08	.	.
Portable: 1	1 to 3	Dining Room	T1	.	-99	0.12	.	.
Portable: 1	1 to 3	Dining Room	T2	2.6	0.99	0.13	2.5	142878
Portable: 1	1 to 3	Dining Room	T3	3.3	0.99	0.10	3.2	194423
Portable: 1	1 to 3	Dining Room	T4	2.5	0.99	0.08	2.5	92945
Portable: 1	1 to 3	Dining Room	T5	2.7	1.00	0.11	2.6	258906
Portable: 1	1 to 3	Dining Room	T6	2.7	1.00	0.08	2.6	175872
Portable: 1	3 to 5	Bedroom2	T1	.	-99	0.12	.	.
Portable: 1	3 to 5	Bedroom2	T2	.	-99	0.13	.	.
Portable: 1	3 to 5	Bedroom2	T3	.	-99	0.10	.	.
Portable: 1	3 to 5	Bedroom2	T4	.	-99	0.08	.	.
Portable: 1	3 to 5	Bedroom2	T5	.	-99	0.11	.	.
Portable: 1	3 to 5	Bedroom2	T6	.	-99	0.08	.	.
Portable: 1	3 to 5	Dining Room	T1	.	-99	0.12	.	.
Portable: 1	3 to 5	Dining Room	T2	.	-99	0.13	.	.
Portable: 1	3 to 5	Dining Room	T3	7.8	0.96	0.10	7.7	1446
Portable: 1	3 to 5	Dining Room	T4	.	-99	0.08	.	.
Portable: 1	3 to 5	Dining Room	T5	6.1	0.97	0.11	6.0	564
Portable: 1	3 to 5	Dining Room	T6	6.0	0.98	0.08	5.9	82
Portable: 1	5 to 10	Bedroom2	T1	.	-99	0.12	.	.
Portable: 1	5 to 10	Bedroom2	T2	25.6	0.94	0.13	25.5	323
Portable: 1	5 to 10	Bedroom2	T3	.	-99	0.10	.	.
Portable: 1	5 to 10	Bedroom2	T4	.	-99	0.08	.	.
Portable: 1	5 to 10	Bedroom2	T5	.	-99	0.11	.	.
Portable: 1	5 to 10	Bedroom2	T6	.	-99	0.08	.	.
Portable: 1	5 to 10	Dining Room	T1	.	-99	0.12	.	.
Portable: 1	5 to 10	Dining Room	T2	.	-99	0.13	.	.
Portable: 1	5 to 10	Dining Room	T3	19.2	0.90	0.10	19.1	184
Portable: 1	5 to 10	Dining Room	T4	.	-99	0.08	.	.
Portable: 1	5 to 10	Dining Room	T5	.	-99	0.11	.	.
Portable: 1	5 to 10	Dining Room	T6	.	-99	0.08	.	.
Portable: 1	10 to 20	Bedroom2	T1	.	-99	0.12	.	.
Portable: 1	10 to 20	Bedroom2	T2	.	-99	0.13	.	.
Portable: 1	10 to 20	Bedroom2	T3	.	-99	0.10	.	.
Portable: 1	10 to 20	Bedroom2	T4	.	-99	0.08	.	.
Portable: 1	10 to 20	Bedroom2	T5	.	-99	0.11	.	.
Portable: 1	10 to 20	Bedroom2	T6	.	-99	0.08	.	.
Portable: 1	10 to 20	Dining Room	T1	.	-99	0.12	.	.
Portable: 1	10 to 20	Dining Room	T2	.	-99	0.13	.	.
Portable: 1	10 to 20	Dining Room	T3	.	-99	0.10	.	.
Portable: 1	10 to 20	Dining Room	T4	.	-99	0.08	.	.
Portable: 1	10 to 20	Dining Room	T5	.	-99	0.11	.	.

Table E.1 Continued

Air Cleaner	PM (μm)	Location	Test	k_t	Fit	k_a	$k_t – k_a$	C_{ss}
Portable: 1	10 to 20	Dining Room	T6	.	-99	0.08	.	.
Portable: 1	Total	Bedroom2	T1	.	-99	0.12	.	.
Portable: 1	Total	Bedroom2	T2	0.6	0.99	0.13	0.4	0
Portable: 1	Total	Bedroom2	T3	.	-99	0.10	.	.
Portable: 1	Total	Bedroom2	T4	.	-99	0.08	.	.
Portable: 1	Total	Bedroom2	T5	.	-99	0.11	.	.
Portable: 1	Total	Bedroom2	T6	.	-99	0.08	.	.
Portable: 1	Total	Dining Room	T1	.	-99	0.12	.	.
Portable: 1	Total	Dining Room	T2	.	-99	0.13	.	.
Portable: 1	Total	Dining Room	T3	2.2	0.99	0.10	2.1	3703742
Portable: 1	Total	Dining Room	T4	.	-99	0.08	.	.
Portable: 1	Total	Dining Room	T5	2.0	1.00	0.11	1.9	5891073
Portable: 1	Total	Dining Room	T6	2.1	1.00	0.08	2.0	3750237
Portable: 5	0.3 to 0.5	Bedroom2	T1	6.5	0.99	99.00	0.0	381727
Portable: 5	0.3 to 0.5	Bedroom2	T2	5.1	0.99	0.13	5.0	244846
Portable: 5	0.3 to 0.5	Bedroom2	T3	.	-99	0.12	.	.
Portable: 5	0.3 to 0.5	Bedroom3	T1	.	-99	99.00	.	.
Portable: 5	0.3 to 0.5	Bedroom3	T2	.	-99	0.13	.	.
Portable: 5	0.3 to 0.5	Bedroom3	T3	.	-99	0.12	.	.
Portable: 5	0.5 to 1	Bedroom2	T1	4.5	1.00	99.00	0.0	255423
Portable: 5	0.5 to 1	Bedroom2	T2	4.0	0.99	0.13	3.8	171813
Portable: 5	0.5 to 1	Bedroom2	T3	3.5	0.99	0.12	3.4	54485
Portable: 5	0.5 to 1	Bedroom3	T1	.	-99	99.00	.	.
Portable: 5	0.5 to 1	Bedroom3	T2	3.8	0.99	0.13	3.7	311327
Portable: 5	0.5 to 1	Bedroom3	T3	3.8	0.99	0.12	3.7	140650
Portable: 5	1 to 3	Bedroom2	T1	5.5	0.99	99.00	0.0	7063
Portable: 5	1 to 3	Bedroom2	T2	4.8	1.00	0.13	4.7	4714
Portable: 5	1 to 3	Bedroom2	T3	5.0	1.00	0.12	4.8	1319
Portable: 5	1 to 3	Bedroom3	T1	.	-99	99.00	.	.
Portable: 5	1 to 3	Bedroom3	T2	4.3	1.00	0.13	4.2	0
Portable: 5	1 to 3	Bedroom3	T3	4.3	0.99	0.12	4.2	0
Portable: 5	3 to 5	Bedroom2	T1	.	-99	99.00	.	.
Portable: 5	3 to 5	Bedroom2	T2	.	-99	0.13	.	.
Portable: 5	3 to 5	Bedroom2	T3	.	-99	0.12	.	.
Portable: 5	3 to 5	Bedroom3	T1	.	-99	99.00	.	.
Portable: 5	3 to 5	Bedroom3	T2	.	-99	0.13	.	.
Portable: 5	3 to 5	Bedroom3	T3	.	-99	0.12	.	.
Portable: 5	5 to 10	Bedroom2	T1	.	-99	99.00	.	.
Portable: 5	5 to 10	Bedroom2	T2	.	-99	0.13	.	.
Portable: 5	5 to 10	Bedroom2	T3	.	-99	0.12	.	.
Portable: 5	5 to 10	Bedroom3	T1	.	-99	99.00	.	.
Portable: 5	5 to 10	Bedroom3	T2	.	-99	0.13	.	.
Portable: 5	5 to 10	Bedroom3	T3	.	-99	0.12	.	.
Portable: 5	10 to 20	Bedroom2	T1	.	-99	99.00	.	.

Table E.1 Continued

Air Cleaner	PM (μm)	Location	Test	k_t	Fit	k_a	$k_t - k_a$	C_{ss}
Portable: 5	10 to 20	Bedroom2	T2	.	-99	0.13	.	.
Portable: 5	10 to 20	Bedroom2	T3	.	-99	0.12	.	.
Portable: 5	10 to 20	Bedroom3	T1	.	-99	99.00	.	.
Portable: 5	10 to 20	Bedroom3	T2	.	-99	0.13	.	.
Portable: 5	10 to 20	Bedroom3	T3	.	-99	0.12	.	.
Portable: 5	Total	Bedroom2	T1	.	-99	99.00	.	.
Portable: 5	Total	Bedroom2	T2	.	-99	0.13	.	.
Portable: 5	Total	Bedroom2	T3	4.7	1.00	0.12	4.6	211494
Portable: 5	Total	Bedroom3	T1	.	-99	99.00	.	.
Portable: 5	Total	Bedroom3	T2	.	-99	0.13	.	.
Portable: 5	Total	Bedroom3	T3	.	-99	0.12	.	.
Ionic Breeze: 3	0.3 to 0.5	Bedroom2	T1	0.0	-99	0.15	0.0	.
Ionic Breeze: 3	0.3 to 0.5	Bedroom2	T2	0.0	-99	0.13	0.0	.
Ionic Breeze: 3	0.3 to 0.5	Bedroom2	T3	0.0	-99	0.13	0.0	.
Ionic Breeze: 3	0.3 to 0.5	Bedroom2	T4	0.0	-99	0.11	0.0	.
Ionic Breeze: 3	0.3 to 0.5	Bedroom2	T5	0.0	-99	0.12	0.0	.
Ionic Breeze: 3	0.3 to 0.5	Bedroom2	T6	0.0	-99	0.11	0.0	.
Ionic Breeze: 3	0.3 to 0.5	Bedroom3	T6	0.0	-99	0.11	0.0	.
Ionic Breeze: 3	0.3 to 0.5	Dining Room	T1	0.0	-99	0.15	0.0	.
Ionic Breeze: 3	0.3 to 0.5	Dining Room	T2	0.0	-99	0.13	0.0	.
Ionic Breeze: 3	0.3 to 0.5	Dining Room	T3	0.0	-99	0.13	0.0	.
Ionic Breeze: 3	0.3 to 0.5	Dining Room	T4	0.0	-99	0.11	0.0	.
Ionic Breeze: 3	0.3 to 0.5	Dining Room	T5	0.0	-99	0.12	0.0	.
Ionic Breeze: 3	0.5 to 1	Bedroom2	T1	0.1	0.93	0.15	0.0	.
Ionic Breeze: 3	0.5 to 1	Bedroom2	T2	.	-99	0.13	.	.
Ionic Breeze: 3	0.5 to 1	Bedroom2	T3	.	-99	0.13	.	.
Ionic Breeze: 3	0.5 to 1	Bedroom2	T4	.	-99	0.11	.	.
Ionic Breeze: 3	0.5 to 1	Bedroom2	T5	.	-99	0.12	.	.
Ionic Breeze: 3	0.5 to 1	Bedroom2	T6	.	-99	0.11	.	.
Ionic Breeze: 3	0.5 to 1	Bedroom3	T6	0.1	0.91	0.11	0.0	.
Ionic Breeze: 3	0.5 to 1	Dining Room	T1	.	-99	0.15	.	.
Ionic Breeze: 3	0.5 to 1	Dining Room	T2	.	-99	0.13	.	.
Ionic Breeze: 3	0.5 to 1	Dining Room	T3	.	-99	0.13	.	.
Ionic Breeze: 3	0.5 to 1	Dining Room	T4	.	-99	0.11	.	.
Ionic Breeze: 3	0.5 to 1	Dining Room	T5	.	-99	0.12	.	.
Ionic Breeze: 3	1 to 3	Bedroom2	T1	1.1	0.98	0.15	0.9	.
Ionic Breeze: 3	1 to 3	Bedroom2	T2	0.9	0.98	0.13	0.8	.
Ionic Breeze: 3	1 to 3	Bedroom2	T3	1.1	0.99	0.13	0.9	.
Ionic Breeze: 3	1 to 3	Bedroom2	T4	1.0	0.98	0.11	0.9	.
Ionic Breeze: 3	1 to 3	Bedroom2	T5	1.0	1.00	0.12	0.8	.
Ionic Breeze: 3	1 to 3	Bedroom2	T6	1.1	1.00	0.11	1.0	.
Ionic Breeze: 3	1 to 3	Bedroom3	T6	1.0	0.99	0.11	0.9	.
Ionic Breeze: 3	1 to 3	Dining Room	T1	.	-99	0.15	.	.
Ionic Breeze: 3	1 to 3	Dining Room	T2	1.1	0.99	0.13	1.0	.

Table E.1 Continued

Air Cleaner	PM (μm)	Location	Test	k_t	Fit	k_a	k_t – k_a	C_{ss}
Ionic Breeze: 3	1 to 3	Dining Room	T3	1.2	0.99	0.13	1.1	.
Ionic Breeze: 3	1 to 3	Dining Room	T4	1.2	0.99	0.11	1.1	.
Ionic Breeze: 3	1 to 3	Dining Room	T5	1.0	0.99	0.12	0.9	.
Ionic Breeze: 3	3 to 5	Bedroom2	T1	.	-99	0.15	.	.
Ionic Breeze: 3	3 to 5	Bedroom2	T2	.	-99	0.13	.	.
Ionic Breeze: 3	3 to 5	Bedroom2	T3	.	-99	0.13	.	.
Ionic Breeze: 3	3 to 5	Bedroom2	T4	.	-99	0.11	.	.
Ionic Breeze: 3	3 to 5	Bedroom2	T5	.	-99	0.12	.	.
Ionic Breeze: 3	3 to 5	Bedroom2	T6	.	-99	0.11	.	.
Ionic Breeze: 3	3 to 5	Bedroom3	T6	.	-99	0.11	.	.
Ionic Breeze: 3	3 to 5	Dining Room	T1	.	-99	0.15	.	.
Ionic Breeze: 3	3 to 5	Dining Room	T2	8.2	0.97	0.13	8.1	4051
Ionic Breeze: 3	3 to 5	Dining Room	T3	3.5	0.93	0.13	3.4	.
Ionic Breeze: 3	3 to 5	Dining Room	T4	.	-99	0.11	.	.
Ionic Breeze: 3	3 to 5	Dining Room	T5	3.1	0.91	0.12	2.9	.
Ionic Breeze: 3	5 to 10	Bedroom2	T1	.	-99	0.15	.	.
Ionic Breeze: 3	5 to 10	Bedroom2	T2	.	-99	0.13	.	.
Ionic Breeze: 3	5 to 10	Bedroom2	T3	.	-99	0.13	.	.
Ionic Breeze: 3	5 to 10	Bedroom2	T4	.	-99	0.11	.	.
Ionic Breeze: 3	5 to 10	Bedroom2	T5	.	-99	0.12	.	.
Ionic Breeze: 3	5 to 10	Bedroom2	T6	.	-99	0.11	.	.
Ionic Breeze: 3	5 to 10	Bedroom3	T6	.	-99	0.11	.	.
Ionic Breeze: 3	5 to 10	Dining Room	T1	.	-99	0.15	.	.
Ionic Breeze: 3	5 to 10	Dining Room	T2	.	-99	0.13	.	.
Ionic Breeze: 3	5 to 10	Dining Room	T3	.	-99	0.13	.	.
Ionic Breeze: 3	5 to 10	Dining Room	T4	.	-99	0.11	.	.
Ionic Breeze: 3	5 to 10	Dining Room	T5	.	-99	0.12	.	.
Ionic Breeze: 3	10 to 20	Bedroom2	T1	.	-99	0.15	.	.
Ionic Breeze: 3	10 to 20	Bedroom2	T2	.	-99	0.13	.	.
Ionic Breeze: 3	10 to 20	Bedroom2	T3	.	-99	0.13	.	.
Ionic Breeze: 3	10 to 20	Bedroom2	T4	.	-99	0.11	.	.
Ionic Breeze: 3	10 to 20	Bedroom2	T5	.	-99	0.12	.	.
Ionic Breeze: 3	10 to 20	Bedroom2	T6	.	-99	0.11	.	.
Ionic Breeze: 3	10 to 20	Bedroom3	T6	.	-99	0.11	.	.
Ionic Breeze: 3	10 to 20	Dining Room	T1	.	-99	0.15	.	.
Ionic Breeze: 3	10 to 20	Dining Room	T2	.	-99	0.13	.	.
Ionic Breeze: 3	10 to 20	Dining Room	T3	.	-99	0.13	.	.
Ionic Breeze: 3	10 to 20	Dining Room	T4	.	-99	0.11	.	.
Ionic Breeze: 3	10 to 20	Dining Room	T5	.	-99	0.12	.	.
Ionic Breeze: 3	Total	Bedroom2	T1	0.1	0.97	0.15	0.0	.
Ionic Breeze: 3	Total	Bedroom2	T2	0.0	-99	0.13	0.0	.
Ionic Breeze: 3	Total	Bedroom2	T3	0.0	-99	0.13	0.0	.
Ionic Breeze: 3	Total	Bedroom2	T4	0.0	-99	0.11	0.0	.
Ionic Breeze: 3	Total	Bedroom2	T5	0.0	-99	0.12	0.0	.

Table E.1 Continued

Air Cleaner	PM (μm)	Location	Test	k_t	Fit	k_a	$k_t - k_a$	C_{ss}
Ionic Breeze: 3	Total	Bedroom2	T6	0.0	-99	0.11	0.0	.
Ionic Breeze: 3	Total	Bedroom3	T6	0.0	-99	0.11	0.0	.
Ionic Breeze: 3	Total	Dining Room	T1	0.0	-99	0.15	0.0	.
Ionic Breeze: 3	Total	Dining Room	T2	0.2	0.95	0.13	0.0	.
Ionic Breeze: 3	Total	Dining Room	T3	0.0	-99	0.13	0.0	.
Ionic Breeze: 3	Total	Dining Room	T4	0.0	-99	0.11	0.0	.
Ionic Breeze: 3	Total	Dining Room	T5	0.0	-99	0.12	0.0	.

PM particulate matter
μm micrometer
k_t total aerosol removal rate
Fit Pearson correlation between observed and predicted aerosol concentrations
k_a aerosol removal by air exchange or exfiltration
$K_t - k_a$ total aerosol removal rate minus the aerosol removal by air exchange or exfiltration
C_{ss} concentration at steady-state

APPENDIX F

WHOLE HOUSE DECAY RATE: $PM_{2.5}$ MASS

Table F.1 Whole House Decay Rate: $PM_{2.5}$ Mass

Air Cleaner	PM	Location	Test	k_t	Fit	k_a	$k_t - k_a$	Css
No Filter	$PM_{2.5}$	Dining Room	T2	.	.	0.10	.	12.7
No Filter	$PM_{2.5}$	Dining Room	T3	4.9	0.90	0.17	4.7	9.8
No Filter	$PM_{2.5}$	Dining Room	T4	.	.	0.17	.	11.6
No Filter	$PM_{2.5}$	Dining Room	T5	.	.	0.17	.	10.9
No Filter	$PM_{2.5}$	Dining Room	T6	.	.	0.17	.	12.1
1-inch	$PM_{2.5}$	Dining Room	TA	.	.	0.10	.	4.5
1-inch	$PM_{2.5}$	Dining Room	TB	.	.	0.11	.	12.1
1-inch	$PM_{2.5}$	Dining Room	TC	5.4	0.92	0.13	5.3	11
5-inch	$PM_{2.5}$	Dining Room	T1	4.7	0.97	0.12	4.6	0.4
5-inch	$PM_{2.5}$	Dining Room	T2	7.1	0.95	0.11	7.0	1.5
5-inch	$PM_{2.5}$	Dining Room	T3	13.4	0.97	0.10	13.3	2.8
5-inch	$PM_{2.5}$	Dining Room	T4	10.1	0.97	0.07	10.0	1.5
5-inch	$PM_{2.5}$	Dining Room	T5	8.3	0.96	0.07	8.2	2.1
5-inch	$PM_{2.5}$	Dining Room	T6	.	.	0.11	.	0
Electronic	$PM_{2.5}$	Dining Room	T1	5.1	0.93	0.15	5.0	0
Electronic	$PM_{2.5}$	Dining Room	T2	11.5	0.96	0.15	11.4	0
Electronic	$PM_{2.5}$	Dining Room	T3	3.5	0.95	0.14	3.4	0
Electronic	$PM_{2.5}$	Dining Room	T4	.	.	0.12	.	0
Electronic	$PM_{2.5}$	Dining Room	T5	9.7	0.98	0.09	9.6	1.3
Electronic	$PM_{2.5}$	Dining Room	T6	6.4	0.97	0.10	6.3	0.2
Trane CleanEffects™	$PM_{2.5}$	Dining Room	T2	10.7	0.97	0.10	10.6	0.5
Trane CleanEffects™	$PM_{2.5}$	Dining Room	T4	10.6	0.98	0.10	10.5	0
Trane CleanEffects™	$PM_{2.5}$	Dining Room	T5	13.6	0.97	0.12	13.5	0.2
Trane CleanEffects™	$PM_{2.5}$	Dining Room	T7	8.9	0.96	0.10	8.8	0
Trane CleanEffects™	$PM_{2.5}$	Dining Room	T8	12.1	0.96	0.09	12.0	0.6
Portable: 1	$PM_{2.5}$	Dining Room	T1	.	.	0.12	.	5.9
Portable: 1	$PM_{2.5}$	Dining Room	T2	2.2	0.95	0.13	2.1	0.7
Portable: 1	$PM_{2.5}$	Dining Room	T3	2.8	0.94	0.10	2.7	0.8
Portable: 1	$PM_{2.5}$	Dining Room	T4	.	.	0.08	.	4
Portable: 1	$PM_{2.5}$	Dining Room	T5	2.2	0.97	0.11	2.1	2.6
Portable: 1	$PM_{2.5}$	Dining Room	T6	2	0.95	0.08	1.9	0
Portable: 5	$PM_{2.5}$	Dining Room	T2	7.7	0.99	0.13	7.6	0.9
Portable: 5	$PM_{2.5}$	Dining Room	T3	.	.	0.12	.	0
Ionic Breeze: 3	$PM_{2.5}$	Dining Room	T1	5.1	0.95	0.15	5.0	16
Ionic Breeze: 3	$PM_{2.5}$	Dining Room	T2	1.8	0.90	0.13	1.7	10.1
Ionic Breeze: 3	$PM_{2.5}$	Dining Room	T3	6.5	0.94	0.13	6.4	7.5
Ionic Breeze: 3	$PM_{2.5}$	Dining Room	T4		.	0.11	.	9.2
Ionic Breeze: 3	$PM_{2.5}$	Dining Room	T5	3.4	0.96	0.12	3.3	10
Ionic Breeze: 3	$PM_{2.5}$	Dining Room	T6	3.2	0.96	0.11	3.1	7.6

PM particulate matter
$PM_{2.5}$ particulate matter less than 2.5 micrometers in aerodynamic diameter
k_t total aerosol removal rate
Fit Pearson correlation between observed and predicted aerosol concentrations
k_a aerosol removal by air exchange or exfiltration
$K_t - k_a$ total aerosol removal rate minus the aerosol removal by air exchange or exfiltration
C_{ss} concentration at steady-state

APPENDIX G

WHOLE HOUSE DECAY RATE: MOLD SPORES

Table G.1 Whole House Decay Rate: Mold Spores

Filter	Test	Location	K_t	Fit	K_a	$K_t – k_a$
No Filter	1	Bedroom 2	2.6	0.72	0.10	2.4
No Filter	2	Bedroom 2	4.9	0.98	0.17	4.7
No Filter	3	Bedroom 2	4.1	0.99	0.15	3.9
No Filter	4	Bedroom 2	4.5	0.85	0.14	4.4
No Filter	5	Bedroom 2	4.7	0.98	0.10	4.6
No Filter	1	Bathroom	1.5	0.83	0.10	1.4
No Filter	2	Bathroom	3.8	0.80	0.17	3.6
No Filter	3	Bathroom	5.9	0.86	0.15	5.7
No Filter	4	Bathroom	4.4	0.81	0.14	4.2
No Filter	5	Bathroom	4.2	0.97	0.10	4.1
No Filter	1	Dining Room	3.1	0.96	0.10	3.0
No Filter	2	Dining Room	4.5	0.94	0.17	4.3
No Filter	3	Dining Room	3.8	0.98	0.15	3.6
No Filter	4	Dining Room	4.2	0.99	0.14	4.0
No Filter	5	Dining Room	3.6	0.97	0.10	3.5
1 Inch	1	Bedroom 2	3.8	0.93	0.28	3.5
1 Inch	2	Bedroom 2	2.9	0.90	0.19	2.7
1 Inch	3	Bedroom 2	4.2	0.90	0.34	3.9
1 Inch	4	Bedroom 2	5.3	0.94	0.33	5.0
1 Inch	6	Bedroom 2	6.9	0.96	0.11	6.8
1 Inch	7	Bedroom 2	7.9	1.00	0.16	7.7
1 Inch	8	Bedroom 2	5.9	0.97	0.08	5.8
1 Inch	9	Bedroom 2	8.0	0.99	0.21	7.8
1 Inch	1	Bathroom	2.4	0.76	0.00	2.1
1 Inch	2	Bathroom	2.9	0.96	0.28	2.7
1 Inch	3	Bathroom	4.2	0.95	0.19	3.9
1 Inch	4	Bathroom	6.0	0.94	0.34	5.6
1 Inch	6	Bathroom	8.6	0.89	0.33	8.5
1 Inch	7	Bathroom	2.9	0.82	0.11	2.7
1 Inch	8	Bathroom	5.4	0.81	0.16	5.3
1 Inch	9	Bathroom	9.8	0.88	0.21	9.6
1 Inch	1	Dining Room	2.2	0.86	0.28	2.0
1 Inch	2	Dining Room	4.2	0.93	0.19	4.1
1 Inch	3	Dining Room	4.2	0.97	0.34	3.9
1 Inch	4	Dining Room	5.3	0.98	0.33	5.0
1 Inch	6	Dining Room	8.7	0.99	0.11	8.6
1 Inch	7	Dining Room	6.4	0.94	0.16	6.2
1 Inch	8	Dining Room	4.8	0.98	0.08	4.7
1 Inch	9	Dining Room	4.4	0.80	0.21	4.2
EAC	1	Bedroom 2	3.9	1.00	0.16	3.7
EAC	2	Bedroom 2	7.0	1.00	0.03	7.0
EAC	3	Bedroom 2	9.2	0.96	0.03	9.2
EAC	5	Bedroom 2	8.2	0.99	0.10	8.1
EAC	6	Bedroom 2	8.6	0.99	0.07	8.5

Table G.1 Continued

Filter	Test	Location	K_t	Fit	K_a	$K_t - k_a$
EAC	1	Bathroom	3.4	0.99	0.16	3.3
EAC	2	Bathroom	8.6	0.98	0.03	8.5
EAC	3	Bathroom	7.9	0.99	0.03	7.9
EAC	4	Bathroom	5.7	0.99	0.27	5.4
EAC	5	Bathroom	7.6	0.96	0.10	7.5
EAC	6	Bathroom	8.3	0.99	0.07	8.2
EAC	1	Dining Room	6.2	0.97	0.16	6.1
EAC	2	Dining Room	8.3	0.99	0.03	8.3
EAC	3	Dining Room	3.4	0.84	0.03	3.3
EAC	4	Dining Room	4.6	0.97	0.27	4.3
EAC	5	Dining Room	4.7	0.99	0.10	4.6
EAC	6	Dining Room	6.1	0.97	0.07	6.0
Trane CleanEffects™	1	Bedroom 2	5.2	0.46	0.04	5.1
Trane CleanEffects™	2	Bedroom 2	5.5	0.50	0.04	5.4
Trane CleanEffects™	4	Bedroom 2	7.2	0.49	0.34	6.8
Trane CleanEffects™	5	Bedroom 2	9.9	0.50	0.14	9.8
Trane CleanEffects™	1	Bathroom	4.5	0.43	0.04	4.5
Trane CleanEffects™	2	Bathroom	4.7	0.48	0.04	4.6
Trane CleanEffects™	4	Bathroom	8.1	0.31	0.34	7.7
Trane CleanEffects™	5	Bathroom	8.3	0.48	0.14	8.1
Trane CleanEffects™	6	Bathroom	9.0	0.47	0.05	8.9
Trane CleanEffects™	1	Dining Room	8.5	0.44	0.04	8.5
Trane CleanEffects™	2	Dining Room	2.9	0.37	0.04	2.9
Trane CleanEffects™	4	Dining Room	6.1	0.46	0.34	5.7
Trane CleanEffects™	5	Dining Room	7.6	0.44	0.14	7.5
Trane CleanEffects™	6	Dining Room	8.7	0.49	0.05	8.6

k_t total aerosol removal rate
Fit Pearson correlation between observed and predicted aerosol concentrations
k_a aerosol removal by air exchange or exfiltration
$k_t - k_a$ total aerosol removal rate minus the aerosol removal by air exchange or exfiltration
EAC electronic air cleaner

APPENDIX H

LIMITATIONS

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1. Environmental Health & Engineering, Inc.'s (EH&E) indoor environmental quality assessment described in the attached report number 13603, *Trane Residential Systems Phase II Efficacy Demonstration of Trane's Whole House Air Cleaning System* (hereafter "the Report"), was performed in accordance with generally accepted practices employed by other consultants undertaking similar studies at the same time and in the same geographical area; and EH&E observed that degree of care and skill generally exercised by such other consultants under similar circumstances and conditions. The observations described in the Report were made under the conditions stated therein. The conclusions presented in the Report were based solely upon the services described therein, and not on scientific tasks or procedures beyond the scope of described services, nor beyond the time and budgetary constraints imposed by the client.

2. Observations were made of the site as indicated within the Report. Where access to portions of the site was unavailable or limited, EH&E renders no opinion as to the condition of that portion of the site.

3. The observations and recommendations contained in the Report are based on limited environmental sampling and visual observation and were arrived at in accordance with generally accepted standards of industrial hygiene practice. The sampling and observations conducted at the site were limited in scope and, therefore, cannot be considered representative of areas not sampled or observed.

4. When an outside laboratory conducted sample analyses, EH&E relied upon the data provided and did not conduct an independent evaluation of the reliability of these data.

5. The purpose of the Report was to assess the characteristics of the subject site as stated within the Report. No specific attempt was made to verify compliance by any party with all federal, state, or local laws and regulations.

Bel-Aire
ElectronicAirCleaners.com

ENVIRONMENTAL HEALTH & ENGINEERING

60 Wells Avenue
Newton, MA 02459
Tel: 800.825.5343
617.964.8550
Fax: 617.964.8556
Web: www.eheinc.com

7270 NW 12th Street, PH-9
Miami, FL 33126
Tel: 800.825.5343
305.594.0061
Fax: 305.591.8404
Web: www.eheinc.com