



# ENVIRONMENTAL HEALTH & ENGINEERING



## PERFORMANCE TESTING OF TRANE CLEAN EFFECTS WHOLE HOUSE AIR CLEANING SYSTEM

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Prepared for:

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## 1.0 EXECUTIVE SUMMARY

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### 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 ( $\text{hr}^{-1}$ ) for 0.3 – 0.5 micrometer ( $\mu\text{m}$ ) particles. In other words, Trane CleanEffects™ removed 12% of the 0.3 – 0.5  $\mu\text{m}$  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  $\mu\text{m}$  particles at a rate of 0.02  $\text{hr}^{-1}$  and therefore removed 0.03% of the particles each minute. The removal of 0.3 – 0.5  $\mu\text{m}$  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  $\mu\text{m}$ ) achieved by Trane CleanEffects™ was 1,158 cfm. The corresponding WHCADR for a typical 1-inch disposable filter and 0.3 – 20  $\mu\text{m}$  particles was 15 cfm. Thus, Trane CleanEffects™ delivered approximately 80 times more air free of 0.3 – 20  $\mu\text{m}$  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  $\mu\text{m}$  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.