

***Final Report on the Expert Meeting for
Ventilation Effectiveness in Residential Systems***

Building Science Corporation Industry Team

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EXECUTIVE SUMMARY

1. **Title:** Final Report on the Expert Meeting for Ventilation Effectiveness in Residential Systems (Gate 1B)
2. **Overview:** The Building Science Consortium held an Expert Meeting on Ventilation Air Distribution Effectiveness in Residential Systems on 23 January 2009 at the Hilton Hotel in Chicago, Illinois. The expert meeting was held immediately before the ASHRAE SSPC 62.2 meetings in advance of the ASHRAE technical program. Invited speakers gave presentations in their particular area of expertise. Speakers included Dr. Jeffrey Siegel and Dr. Atila Novoselac of the University of Texas at Austin and Aaron Townsend of Building Science Corporation.
3. **Key Results:** Key results from this meeting were a greater buy-in from the ASHRAE 62.2 community that BSC's approach to ventilation effectiveness is producing meaningful results and with appropriate modifications can reach results that can be adopted by the 62.2 committee.
4. **Gate Status:** This project meets the "must meet" and "should meet" criteria for Gate 1B. The project provides source energy and whole building performance benefits by incentivizing efficient ventilation systems and tight enclosures, thereby reducing the source energy needed to condition the house. The project also meets the performance-based safety, health, and building code requirements for use in new homes, as it directly attempts to improve the ventilation code, which will likely be adopted by building codes at some point in the future. For the same reason, this project meets the prescriptive-based code requirements. The project will be cost-neutral for new homes, as builders will still be free to choose from a variety of ventilation systems. The project will increase reliability by increasing the likelihood of uniform indoor air quality. Finally, the project does not require any new products to be manufactured, and suppliers, manufactures, and builders will continue responding to market forces as they always do.
5. **Conclusions:** The key gaps that remain are concerns by certain members of the 62.2 committee to certain aspects of the proposed changes, particularly assumptions about the contaminant sources and decisions regarding the appropriate magnitude of the system coefficients, and drafting and approval of a change to the ASHRAE Standard 62.2. The next steps involve continuing the dialogue with the committee members to further identify and address their concerns, and drafting and submission of a change proposal to the 62.2 committee. After these steps are complete, the ASHRAE 62.2 committee will be given the opportunity to adopt the suggested revisions into the 62.2 standard. Expected benefits include energy savings (due to credit given to ducted ventilation systems), reliability (due to improved indoor air quality), durability (due to guaranteed ventilation and therefore lower chances of moisture damage), and expected value to builders, contractors, and homeowners (due to improved homeowner satisfaction with their homes, which also benefits builders and contractors).

INTRODUCTION

The Building Science Consortium held an Expert Meetings on Ventilation Air Distribution Effectiveness in Residential Systems on 23 January 2009 at the Hilton Hotel in Chicago, Illinois. The expert meeting was held immediately before the ASHRAE SSPC 62.2 meetings in advance of the ASHRAE technical program in order to make it easier for experts who had already traveled there to participate. There were 31 in attendance. Invited speakers gave presentations in their particular area of expertise. The presentations were followed by discussion with the expert audience.

A summary of the individual presentations and major discussion points is provided in the sections below.

The final agenda for the meeting is listed in Appendix A. A list of attendees for the meeting is given in Appendix B. The presentations are included in Appendices C through F.

PRESENTATIONS

Speaker 1: Dr. Jeffrey Siegel, Department of Civil, Architectural, and Environmental Engineering, the University of Texas at Austin

Presenter bio: Dr. Jeffrey A. Siegel is an associate professor in the Department of Civil, Architectural, and Environmental Engineering at The University of Texas at Austin. He received his B.S. in Engineering from Swarthmore College in 1995 and his Ph.D. from U.C. Berkeley in Mechanical Engineering in 2002. Dr. Siegel and his research team have ongoing research on HVAC filtration, portable and passive air cleaners, particle resuspension, human exposure, and particle transport and deposition in HVAC systems. He is the recipient of the Early Career Award from the International Society for Exposure Assessment /American Chemistry Council, the 3M Non-Tenured Faculty Grant, and the ASHRAE New Investigator Award. He is the co-director of the National Science Foundation funded Integrative Graduate Education and Research Traineeship (IGERT) graduate program in Indoor Environmental Science and Engineering at The University of Texas. He is a voting member of TC 2.4, TC 6.3, SSPC 52.2, research subcommittee chair of TC2.4, and PI of RP1299 (Energy Implications of Filters in Residential and Light Commercial Buildings).

Presentation Title: *Pollutant Sources and Occupant Activities*

Presentation Summary:

Dr. Siegel presented the results of a literature review of indoor air contaminant sources. He gave examples of different categories of contaminant sources, such as area sources, point sources, and occupant-associated sources.

Dr. Siegel made the following key points during his presentation:

- Sources can roughly be divided into three categories: area sources, point sources, and occupant-associated sources; however these areas are roughly defined and some sources could be grouped in more than one category depending on the specific criteria used.
- The effect of an exposure to a contaminant depends on the contaminant and for many contaminants on the individual exposed as well. Because of this it is difficult to compare the impact of different contaminants.
- Area sources can be the dominant source of certain contaminants. These types of sources often decline in strength over time.
- Depending on the specific contaminant, point sources may decline over time or may remain constant.
- Occupant sources are very activity and contaminant dependent. The source strength of contaminants associated with an occupant's activities varies widely. The sources due to one occupant appear to be a point source from other occupants' perspectives.
- The National Human Activity Survey (NHAPS) is a significant resource for analyzing effects of human sources.
- The occupants are disproportionately exposed to occupant-generated sources due to their proximity and non-uniform mixing in the zone.
- There is little in the literature to suggest that fugitive emissions from items stored in kitchens and bathrooms (cleaning products, for example) are a significant source. Many of the emissions that occur in kitchens and bathrooms are a result of the occupant's activities while in those rooms. Cleaning products, etc, generally need ozone to react with to form harmful byproducts, and there is generally little ozone in the cabinets where they are stored.
- There is evidence that increasing ventilation rates causes higher emission rates from formaldehyde sources, such that the formaldehyde concentration does not change substantially.
- Dr. Siegel concludes that occupant-associated sources are often the dominant cause of exposure in homes.
- Dr. Siegel would like to see actual pollutants modeled instead of a single tracer-gas contaminant.
- Dr. Siegel would currently assume occupant activities account for 50-75% of total exposure.

Questions and discussion during and after the presentation:

The audience had several questions and comments during and after the discussion, which Dr. Siegel answered or discussed. The questions and comments were as follows:

- Q: How did the work presented define pollutant? A: Chemicals that are known to be harmful to humans.
- Q: How does one differentiate between emissions from humans themselves and emissions from their activities? A: It is mostly the activities, very little we personally emit is harmful.
- Q: How aggressive or conservative is this analysis? A: 50% would be the absolute lowest percentage exposure Dr. Siegel would expect to be due to occupant-generated sources.
- Q: What size particles did the analysis consider? A: PM10, PM2.5, ultrafine (1 nm)
- Q: Which contaminant species are the current dominant long-term health risks in residential settings? A: Formaldehyde and paradichlorobenzene.

- Q: Is there disproportionate exposure to either of these chemicals? A: Studies indicate no disproportionate exposure to formaldehyde but the Hispanic population is disproportionately exposed to paradichlorobenze, presumably due to higher tendencies to use the types of products that contain the chemical
- Q: How much difference is there between the occupant-generated emissions based on the actual activity level? Are the emissions while sleeping and moving around substantially different? A: The emissions rates are substantially higher while moving around but it is difficult to quantify how much. The NHAPS might be a good resource to try to determine occupant activities and typical locations.
- Q: Is the higher exposure of the Hispanic population due to increased use of moth crystals? A: Only one study looked at this question and it suggested that increased use of toilet bowl deodorizers was the most likely reason.

Speaker 2: Dr. Atila Novoselac, Department of Civil, Architectural, and Environmental Engineering, the University of Texas at Austin

Presenter bio: Dr. Atila Novoselac is an assistant professor in the Department of Civil, Architectural, and Environmental Engineering at The University of Texas at Austin. His research encompasses analysis of pollutant transport in indoor environments, human exposure studies, and development and experimental validation of models for air and particle dynamics. He has developed several indoor air quality indicators for evaluation of various air mixing and stratified ventilation systems. His current work includes studies related to the effects that the human microenvironment and ventilation type have on human exposure to gaseous and particulate contaminants. Dr. Novoselac is very active in ASHRAE indoor environmental modeling and room air distribution technical committees (voting member in TCs 5.3 and 4.10). He is also a corresponding member of TCs 4.3 and 4.7, and PI on the RP1416 project sponsored by ASHRAE (Development of Internal Surface Convection Correlations for Energy and Load Calculation Methods).

Presentation Title: *Contaminant Generation and Spatial Ventilation Effectiveness: How do Sources Relate to Human Exposure?*

Presentation Summary:

Dr. Novoselac presented data on the impact of the thermal plume that exists around a person sitting in a still air environment. This thermal plume draws contaminants into the person's breathing zone that would otherwise remain outside the breathing zone.

Dr. Novoselac made the following key points during his presentation:

- Personal exposure depends on the local concentration of the pollutants in a person's breathing zone.
- The local concentration of pollutants in a person's breathing zone can be different than the average concentration in the room, due to the thermal plume caused by the person's body heat.
- The thermal plume is important when the air is still, but is not when there is a fan or other mechanism for actively moving air within the space.

- His research includes both computer modeling (CFD) and physical testing.
- The location of a source in relation to the person and thermal plume has an important impact on the person's exposure to the contaminant.
- In a test house, their work determined that buoyancy-driven flow (i.e. the thermal plume) was the dominant flow mechanism when the central air handler was not operating.
- An assumption of well-mixed zones may be a bad assumption in a house without an operating air handler. Non-uniform mixing will generally increase the exposure to the occupant.

Questions and discussion during and after the presentation:

Dr. Novoselac answered the following questions and comments after his presentation:

- Q: What is a typical air velocity in the thermal plume? A: Approximately 0.5 feet per second.

Speaker 3: Aaron Townsend, Building Science Corporation

Presenter bio: Aaron Townsend is an Associate with Building Science Corporation. He has worked for Building Science for five years, where he focuses on energy efficiency, building durability, and indoor air quality. Aaron holds a bachelor's degree in mechanical engineering from the University of Texas and a master's degree in mechanical engineering from Stanford University.

Presentation Title: *System Coefficients: Where Have We Been and Where Are We Going?*

Presentation Summary:

Townsend reviewed the work to date towards establishing a system coefficient for the 62.2 standard. This history includes:

- Development of a CONTAM airflow network model and comparison to measurements from field tests of a production Building America house in Sacramento in January 2006
- Presentation of these results at the ventilation expert meeting in January 2006
- Modification and presentation of results for and after expert meetings in January and June 2007 as well as in January and June 2008
- Conference calls in between meetings to consult with participating 62.2 committee members and present results of additional work

Townsend also presented the results of one additional ventilation system that was modeled since the previous meeting. This system was a two-point exhaust system with an exhaust point on each of the two floors in the house. Townsend then presented a sensitivity analysis on effect of the source scenario on the ventilation system coefficients. Townsend made the following points during this part of the presentation:

- The sensitivity analysis examined the effect of mixing the three initial (or "pure") source assumptions in different ratios.
- The first pure scenario (volume-weighted sources) has about 25% of the emissions in the kitchens and bathrooms.
- The third pure scenario (occupant-generated sources) has about 15% of the emissions in the kitchens and bathrooms.

- Seven blends of the pure scenarios were presented. The blends chosen ranged from heavily dominated by volume-weighted and occupant-generated contaminants (50-50 split) to evenly divided between the volume-weighted, kitchens and bathrooms, and occupant-generated sources (1/3 each).
- The resulting coefficient tables for each of the pure and blended scenarios were presented and discussed. Increasing the ratio of occupant-generated contaminants resulted in lower system coefficients for ventilation systems with minimum turnover requirements and higher system coefficients for ventilation systems without a central air handling system.

Questions and discussion during and after the presentation:

Townsend answered the following questions and comments after his presentation:

- Q: Have there been more houses compared to this model? A: Yes, the results presented by Max Sherman and Iain Walker of LBNL were compared to results from this model, with good agreement given the differences in approach.
- Q: The sources in the model do not vary with time? A: Correct, the sources in the current model do not vary with time. It is within the model's capabilities but was not done in order to keep the results independent of a particular contaminant species.

GENERAL DISCUSSION

The general open discussion period was moderated by Joseph Lstiburek, Principal of Building Science Corporation.

- A proposal was made to assign system coefficient values simply: all systems with minimum turnover or balanced ventilation get values of 1.0 and all others get values of 1.5. The general response to this proposal was that it was too general and ignored some of the differences between systems, such as the effect of ducting.
- A proposal was made to use the blended scenario with 1/3 of each of the pure scenarios, but to scale the coefficients down such that all the values of 1.33 became 1.25 and all the values of 1.65 became 1.5. The general response to this proposal was positive, in that the audience was receptive to the idea of reducing the penalty of the poorer-performing systems.
- Another proposal was made to have 3 categories: a balanced ventilation system with a minimum turnover has a coefficient of 1.0; a system that is either balanced or has a minimum turnover (but not both) has a coefficient of 1.25; and a system with neither balanced nor minimum turnover has a coefficient of 1.5. The general response to this proposal was mixed, as it ignores some differences seen in the presented results.

FOLLOW-UP WORK

Further discussion and work occurred after the SSPC 62.2 meeting. The concept of scaling back the magnitude of the coefficients to the range of 1.0 to 1.5 is being pursued. BSC is collaborating with Bruce Wilcox and Steve Emmerich to present the data in different ways (as requested by the committee) and to advance the proposed change to the 62.2 standard.

Appendix A: Expert Meeting Agenda

Appendix B: Expert Meeting Attendee List (based on sign-in sheet)

Appendix C: Introductory Presentation

Appendix D: Presentation 1

Appendix E: Presentation 2

Appendix F: Presentation 3