Results of Field Measurements and CONTAM Simulation

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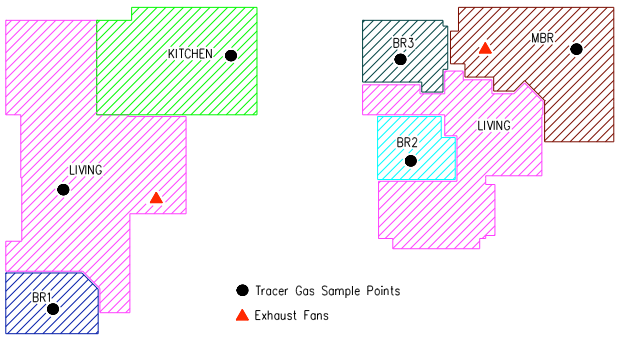
- Tracer gas test of a production Building America house in Sacramento
- 2-story, 4 bedrooms, ~2500 square feet
- Ventilation systems tested: supply and exhaust ventilation, with and without mixing via central air handler

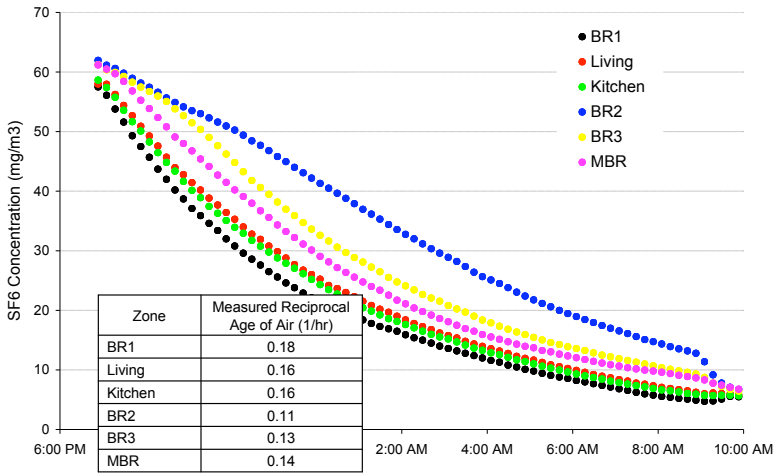
Zones – 2 Story House



- Tracer gas decay tests—establish uniform concentration of tracer gas and then activate ventilation system to remove it
- Reciprocal age-of-air can be calculated from decay curves (if weather conditions are sufficiently constant)

Example Results of Tracer Gas Testing

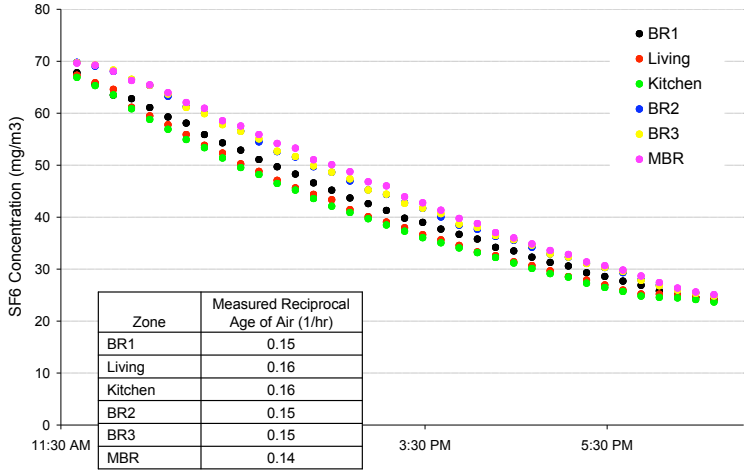
Laundry Exhaust, 100% of 62.2 Rate, Doors Closed, Transfer Grills Open, No Mixing



Zone	Measured Reciprocal Age of Air (1/hr)
BR1	0.18
Living	0.16
Kitchen	0.16
BR2	0.11
BR3	0.13
MBR	0.14

Example Results of Tracer Gas Testing

Laundry Exhaust, 100% of 62.2 Rate, Doors Closed, Transfer Grills Open, 33% Mixing



Zone	Measured Reciprocal Age of Air (1/hr)
BR1	0.15
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Kitchen	0.16
BR2	0.15
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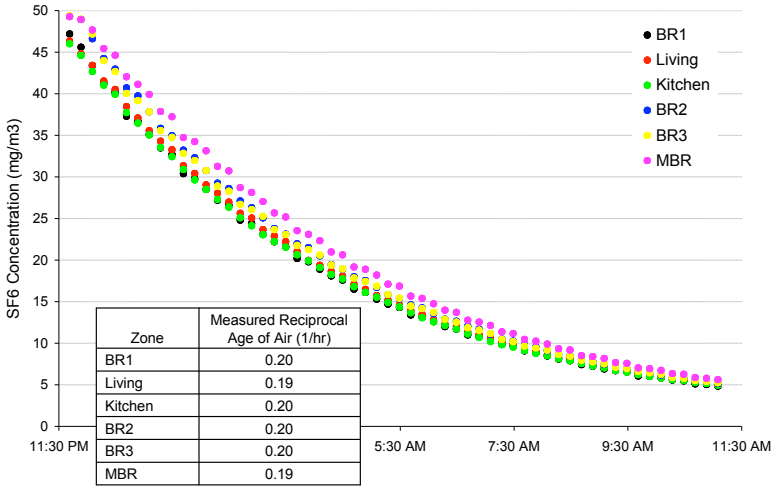
Example Results of Tracer Gas Testing

CFI, 100% of 62.2 Rate, Doors Closed, Transfer Grills Open, 33% Mixing

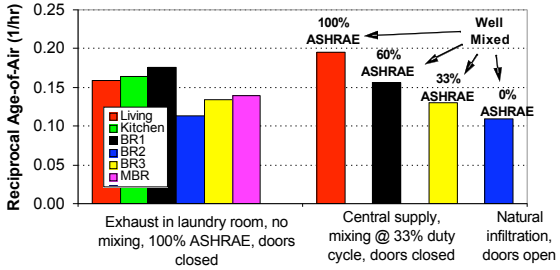


Zone	Measured Reciprocal Age of Air (1/hr)
BR1	0.20
Living	0.19
Kitchen	0.20
BR2	0.20
BR3	0.20
MBR	0.19

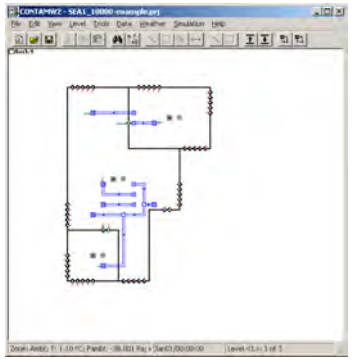
Conclusions From Tracer Gas Testing

- Mixing is very important to whole-house and individual zone pollutant decay rate
- Supply ventilation is slightly more effective than exhaust ventilation, even with mixing
- The location of a single-point ventilation system affects the performance but the effect is not predictable

Simple Exhaust vs Central Fan Integrated Supply with Lower Ventilation Rates



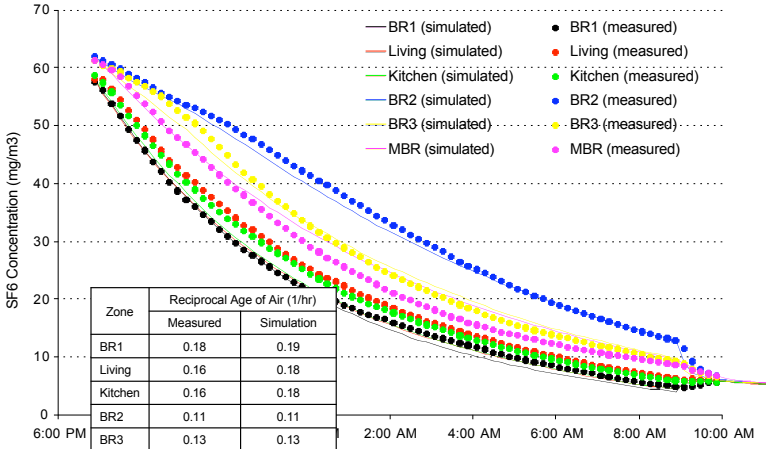
Tuned CONTAM Model



Computer modeling used to replicate field testing (tune the model) and predict performance of systems not tested in the field

Example Results of Tuned CONTAM Model

Laundry Exhaust, 100% of 62.2 Rate, Doors Closed, Transfer Grills Open, No Mixing



Zone	Reciprocal Age of Air (1/hr)	
	Measured	Simulation
BR1	0.18	0.19
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MBR	0.14	0.13

Example Results of Tuned CONTAM Model

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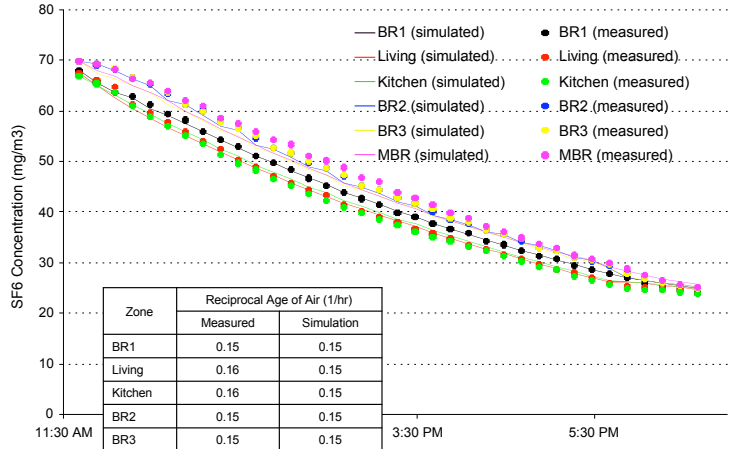

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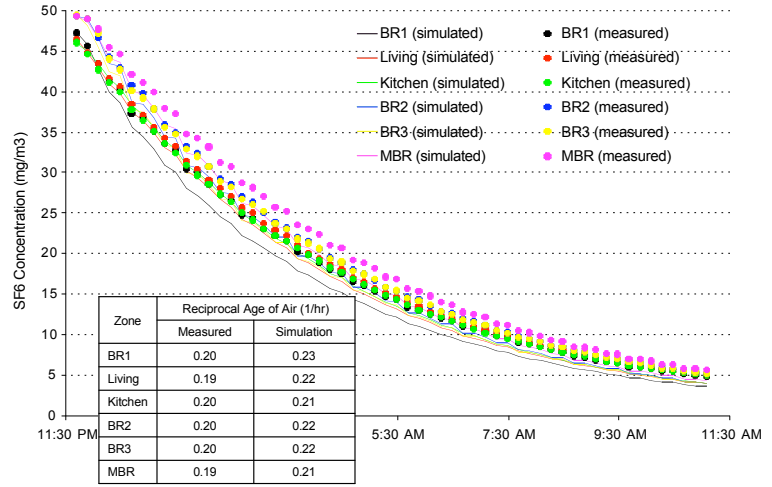
Example Results of Tuned CONTAM Model

CFI, 100% of 62.2 Rate, Doors Closed, Transfer Grills Open, 33% Mixing

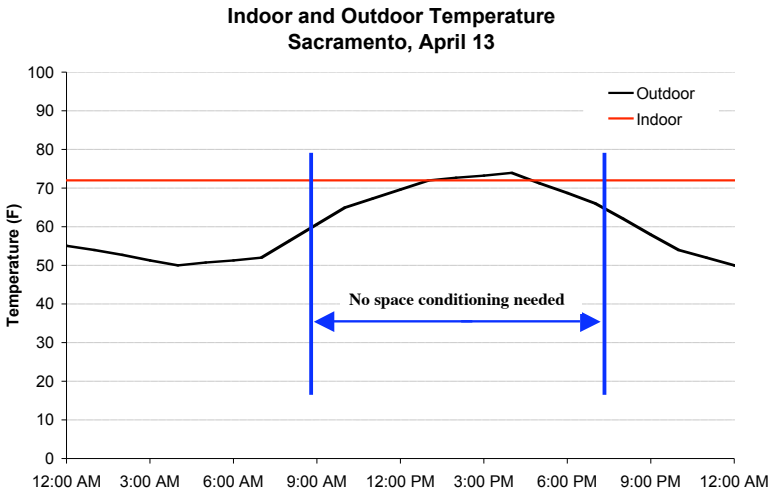


Zone	Reciprocal Age of Air (1/hr)	
	Measured	Simulation
BR1	0.20	0.23
Living	0.19	0.22
Kitchen	0.20	0.21
BR2	0.20	0.22
BR3	0.20	0.22
MBR	0.19	0.21

Tuned CONTAM Model Applied to Other Systems

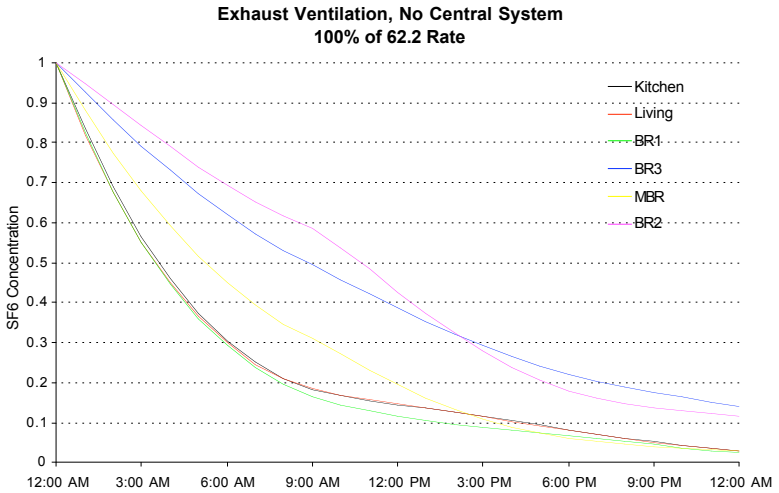
Six Systems Evaluated & Compared:

1. Exhaust ventilation, without central duct system
2. Supply ventilation, without central duct system
3. Exhaust ventilation, with central ducts, standard Tstat
4. Exhaust ventilation, with central ducts, Tstat with timer
5. Supply ventilation, with central ducts, Tstat with timer
6. Balanced ventilation system with fully distributed supply, without central duct system



Simulation allows identical weather conditions for each system (generally not possible in field tests).

Results of Tuned CONTAM Model



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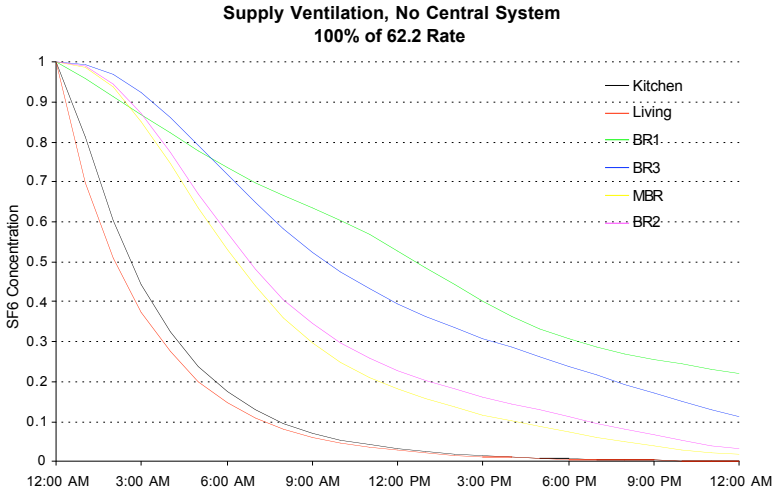

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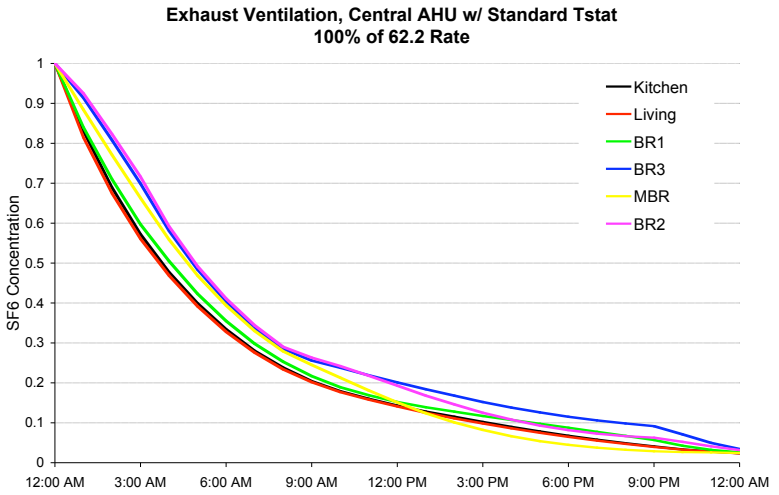

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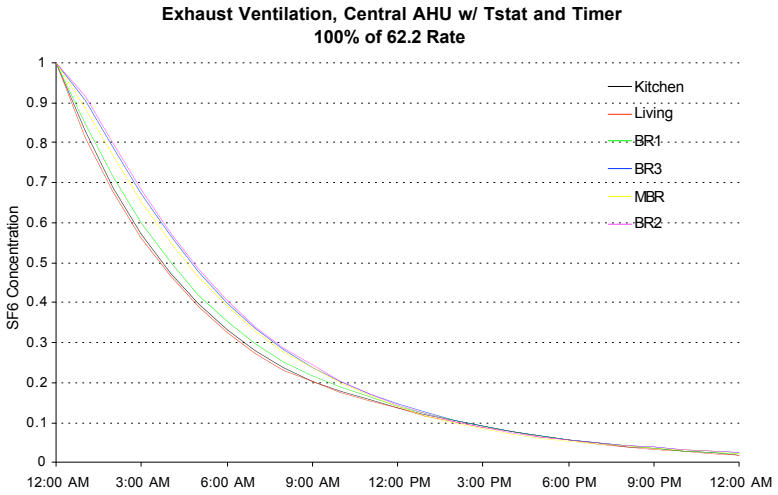

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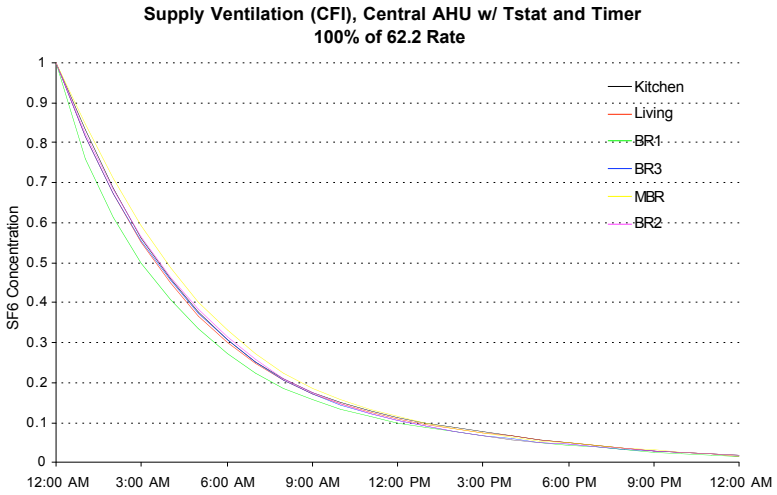

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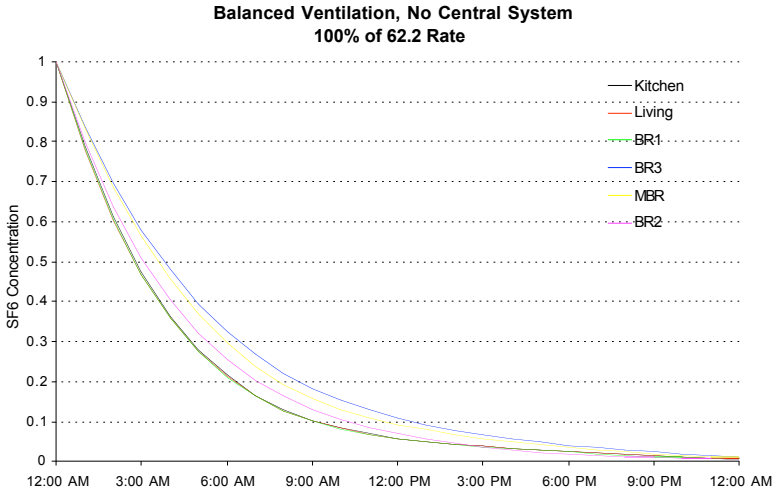
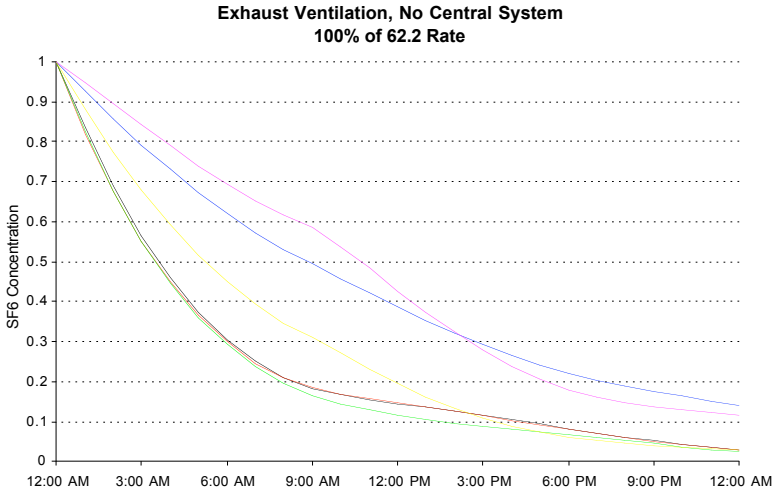


Adjusting Ventilation Rate to Achieve Equivalent Performance



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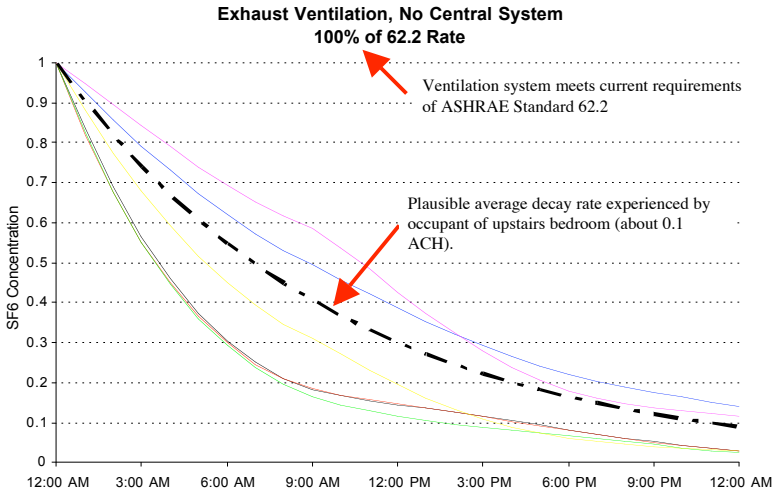

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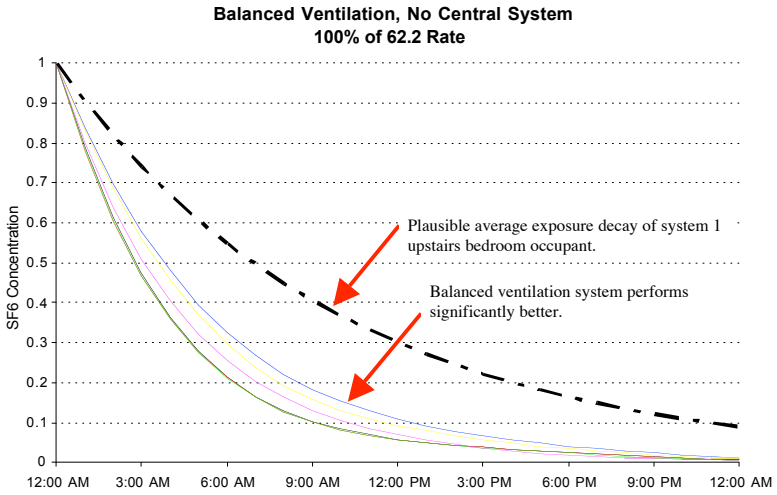

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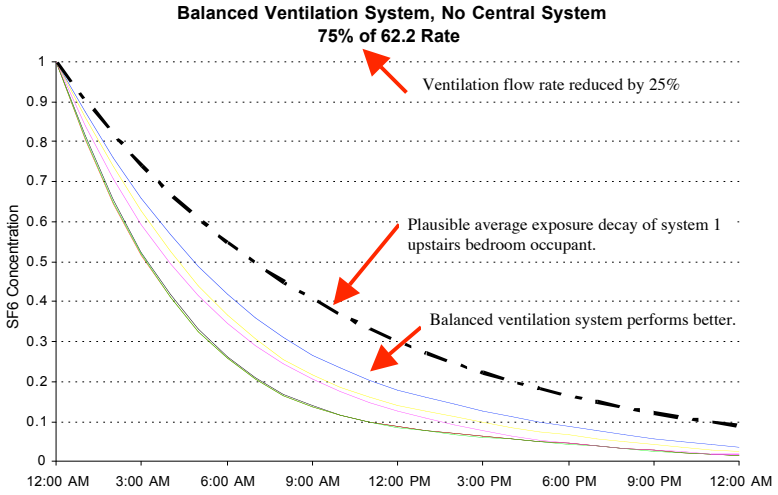

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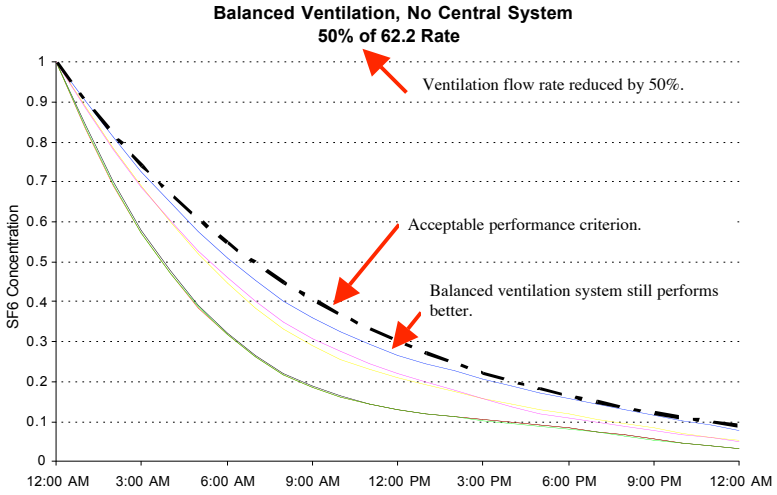


Conclusions from Tuned CONTAM Model

1. Ventilation systems do not perform equally just because they have equal nominal airflow
2. Airflow requirements can be adjusted based on performance of each system
3. Further simulations were needed to predict year-round performance for general guidance
4. Can we create a “distribution coefficient” to modify the required airflow?

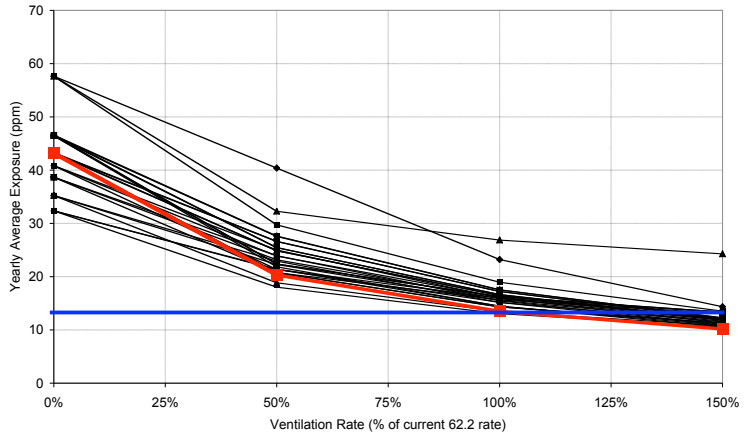
Next Steps

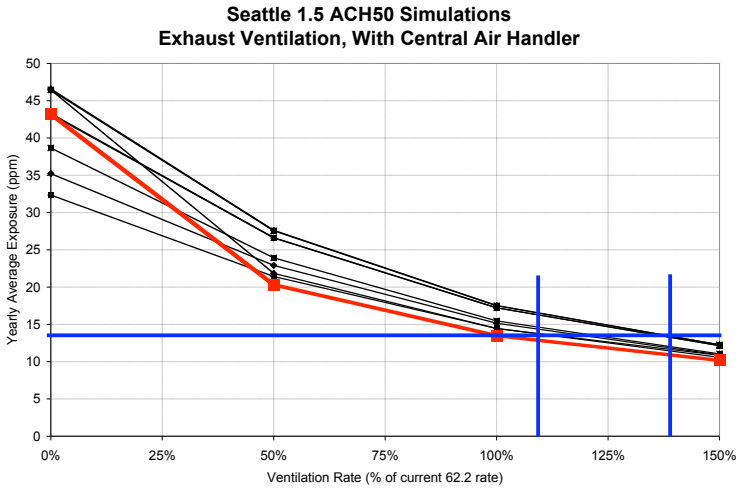
1. Expand modeling from 1 day in 1 house in 1 climate to full year, various house characteristics, different climates
2. Methodology of simulations changed from decay to exposure
   1. Uniform generation of pollutant within house
   2. Assumed occupancy schedule
   3. Calculated occupant exposure based on concentration in the zone where they are each hour

Reference System

- Reference system is a balanced ventilation system with fully ducted supply side and a single return
- Compare other systems to this system: what ratio of airflows do other systems need to provide equal yearly average exposure?

Seattle 1.5 ACH50 Simulations





Airflow Ratios—Preliminary Results

System Type	Preliminary Results
Fully ducted balanced ventilation system, with or without central duct system	1.0
Non-fully ducted balanced ventilation, with central duct system, and central air handler unit controlled to a minimum runtime of at least 10 minutes per hour	1.0
Supply or exhaust ventilation, with central duct system, and central air handler unit controlled to a minimum runtime of at least 10 minutes per hour	1.25
Supply or exhaust ventilation, with central duct system, and central air handler unit not controlled to a minimum runtime of at least 10 minutes per hour	1.5
Supply or exhaust ventilation, without central duct system	1.75

Model Assumptions: Weather

1. Temperature
   1. Outdoor temperature from TMY2 data
   2. Indoor temperature constant at 72 F (with minor variation between rooms)
2. Wind
   1. Wind speed and direction from TMY2 data
   2. Wind shielding model and modifiers as described in ASHRAE Fundamentals 2005 Chapters 16 and 27 for typical suburban surroundings

Model Assumptions: Air Handler

1. Sizing per Manual J for each climate
2. Duty cycle each hour based on temperature and design temperature for the climate
   1. Maximum 80% runtime at design conditions
   2. Heating balance point = 65 F
   3. Cooling balance point = 75 F
3. Two cycles per hour
   1. Cycles rounded to nearest 5 minute increment (simulation time step = 5 minutes)

Model Assumptions: Envelope Leakage

1. Distribution
   1. Leakage distribution per ASHRAE Fundamentals Chapter 27
      1. Walls, windows, doors: 62%
      2. Ceilings & nonoperating exhaust vents: 23%
      3. Ducts: 15%
2. Total leakage varied as described later

Model Assumptions: Pollutant Generation

1. Uniform generation of unique pollutant in each room
   1. Generation rate arbitrarily set at 1 mg/hr/sf
   2. Can be scaled as desired

Model Assumptions: Occupant Schedules

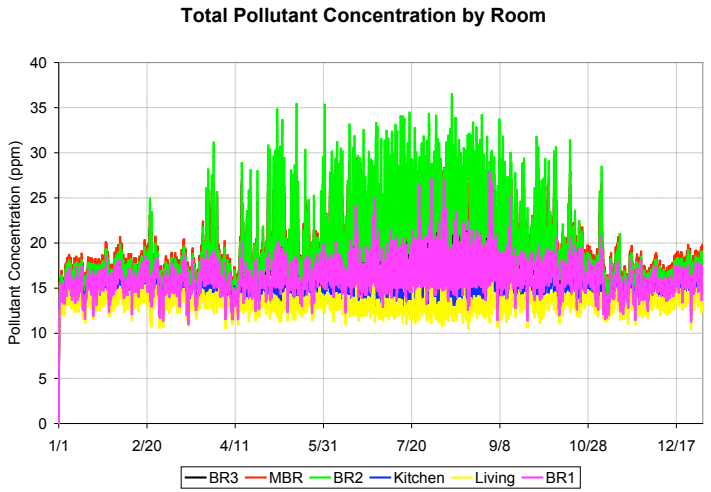
1. Assume similar schedule for each occupant:
   1. 10 PM to 7 AM: in bedroom with door closed
   2. 7 AM to 9 AM: in kitchen
   3. 9 AM to 12 PM: in living room
   4. 12 PM to 1 PM: in kitchen
   5. 1 PM to 6 PM: in living room
   6. 6 PM to 10 PM: in other bedrooms
2. Bedroom doors open except during sleeping period 10 PM to 7 AM

Varied Parameters

1. Climate
   1. Minneapolis, Seattle, Phoenix, Raleigh, Daytona Beach
2. Envelope leakage
   1. 1.5, 3.5, 7 ACH50
3. Central AHU System
   1. Not present, in conditioned space, outside of conditioned space
4. AHU Schedule
   1. Standard Tstat, Tstat with minimum runtime (10 minutes per half-hour)
5. Duct Leakage
   1. 6% & 12% of air handler flow

Varied Parameters

6. Ventilation System
   1. Single-point exhaust
   2. Single-point supply
   3. Dual-point balanced
   4. Fully-ducted balanced
7. Ventilation Rate
   1. 0, 50, 100, 150, 200% of current 62.2 rate



Exposure Calculation

- Yearly average hourly exposure
- Sum of pollutant concentration in the zone occupied by the occupant each hour of the year, divided by 8760 hr/yr