

# **Window Usage, Ventilation, and Formaldehyde Concentrations in New California Homes: Summer Field Sessions**

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## Window usage

- People opened their windows about the same amount in houses with no mechanical ventilation system as they did in houses with supply ventilation (outdoor air ducted to the central return).
- People in houses with HRV ventilation systems opened their windows about twice as much as people in houses with either no mechanical ventilation or supply ventilation.

Table 2. Window and door opening expressed as the average opening in square feet over the 24-hour air quality sampling period and the average of the previous seven 24-hour periods in new single-family detached homes in California; with and without mechanical outdoor air ventilation.

	No Mechanical Outdoor Air <sup>a</sup> Homes (n=42)		DOA Mechanical Outdoor Air <sup>b</sup> Homes (n=8)		HRV Mechanical Outdoor Air <sup>c</sup> Homes (n=3)	
	Test Day 24 hr Average (ft <sup>2</sup> )	Week 24 hr Average (ft <sup>2</sup> )	Test Day 24 hr Average (ft <sup>2</sup> )	Week 24 hr Average (ft <sup>2</sup> )	Test Day 24 hr Average (ft <sup>2</sup> )	Week 24 hr Average (ft <sup>2</sup> )
Minimum	0.0	0.0	0.0	0.2	12.1	14.2
25% Quartile	1.7	1.9	3.3	5.0	16.4	16.5
50% Median	7.9	8.5	10.4	7.8	20.7	18.8
75% Quartile	17.5	19.2	19.2	23.9	33.6	28.7
Maximum	102.0	52.5	52.8	43.7	46.4	38.6

- a.) 42 homes with no mechanical outdoor air systems and no nighttime ventilation cooling systems.
- b.) 8 homes with operational mechanical ducted outdoor air (DOA) ventilation systems and no nighttime ventilation cooling systems.
- c.) 3 homes with operational mechanical heat recovery ventilator (HRV) outdoor air ventilation systems and no nighttime ventilation cooling systems.

## Building enclosure leakage

- All of the house groups had about the same range of building air tightness as tested by blower door, about 4 to 5 ach50, or 2 to 3 SLA.

Table 4. Building envelope air leakage area as calculated from building envelope depressurization tests and as expressed as ACH<sub>50</sub> and SLA in new single-family detached homes in California with and without mechanical outdoor air ventilation.

	No Mechanical Outdoor Air <sup>a</sup> Homes (n=42)		DOA Mechanical Outdoor Air <sup>b</sup> Homes (n=7)		HRV Mechanical Outdoor Air <sup>c</sup> Homes (n=3)	
	ACH <sub>50</sub> (ach)	SLA	ACH <sub>50</sub> (ach)	SLA	ACH <sub>50</sub> (ach)	SLA
Minimum	3.5	1.7	3.2	1.4	4.3	2.1
25% Quartile	4.0	2.4	4.0	2.5	4.4	2.2
50% Median	4.7	2.7	4.3	2.8	4.6	2.4
75% Quartile	5.3	3.0	5.0	3.0	4.8	2.6
Maximum	8.4	5.5	6.1	3.7	4.9	2.8

- a.) 42 homes with no mechanical outdoor air systems and no nighttime ventilation cooling systems.  
 b.) 7 homes with operational mechanical ducted outdoor air (DOA) ventilation systems and no nighttime ventilation cooling systems (one home without blower door measurements excluded)  
 c.) 3 homes with operational mechanical heat recovery ventilator (HRV) outdoor air ventilation systems and no nighttime ventilation cooling systems.

# Ventilation flow rates

- Houses with supply ventilation had about the same estimated outside air exchange rate as houses with no mechanical ventilation.
- Only one of the eight supply ventilation houses had a fan cycling control to assure a minimum fan duty cycle (11 minutes every 30). That house was lumped with all the others for reporting the air exchange results so there was no way to differentiate performance due to a programmed minimum fan duty cycle.
- The median estimated outside air flow rate for the supply systems was 40 cfm, and the median fan runtime was 18%. That was the equivalent of 7 cfm continuous.

## Ventilation flow rates (cont.)

- The median outside air flow rate for the HRV houses was 153 cfm and 100% runtime. Therefore, the median HRV system delivered about 20 times more outside air than the median supply ventilation system over the test period.
- The median house size was 2,260 ft<sup>2</sup>, assuming 3 bedrooms, the median HRV ventilation rate was 3 times the 62.2 rate.

Table 3. Exhaust and outdoor air fan ventilation as expressed as the average air changes per hour (ach) over the 24-hour air quality sampling period as well as the average of the previous seven 24-hour periods in new single-family detached homes in California with and without mechanical outdoor air ventilation.

	No Mechanical Outdoor Air <sup>a</sup> Homes (n=42)	DOA Mechanical Outdoor Air <sup>b</sup> Homes (n=8)		HRV Mechanical Outdoor Air <sup>c</sup> Homes (n=3)	
	Exhaust Fan 24 hr Average (ach)	Exhaust Fan 24 hr Average (ach)	Mechanical Outdoor Air 24 hr Average (ach) / (%ON) / (cfm)	Exhaust Fan 24 hr Average (ach)	Mechanical Outdoor Air 24 hr Average (ach) / (%ON) / (cfm)
Minimum	0.00	0.00	0.00 / 0 / 27	0.11	0.12 / 32 / 149
25% Quartile	0.00	0.00	0.01 / 0 / 30	0.23	0.38 / 66 / 151
50% Median	0.01	0.00	0.02 / 18 / 40	0.35	0.44 / 100 / 153
75% Quartile	0.01	0.02	0.04 / 25 / 48	0.43	0.46 / 100 / 156
Maximum	0.10	0.03	0.07 / 40 / 71	0.51	0.47 / 100 / 159

- a.) 42 homes with no mechanical outdoor air systems and no nighttime ventilation cooling systems.
- b.) 8 homes with operational mechanical ducted outdoor air (DOA) ventilation systems and no nighttime ventilation cooling systems.
- c.) 3 homes with operational mechanical heat recovery ventilator (HRV) outdoor air ventilation systems and no nighttime ventilation cooling systems.

## PFT measured air change rate

- As measured by PFT, houses with the supply ventilation system had a slightly higher 24 hour average air exchange rate compared to houses with no mechanical outdoor air, 0.36 ach compared to 0.33 ach.
- Houses with HRV systems had four times that amount, 1.43 ach.
- In all, 50% of the 62 homes with PFT measurements had outdoor air exchanges rates below 0.35 ach.

Table 5. Average 24-hour outdoor air exchange rates as calculated from passive PFT tracer gas measurements in new single-family detached homes in California with and without mechanical outdoor air ventilation.

	No Mechanical Outdoor Air <sup>a</sup> Homes (n=41)	DOA Mechanical Outdoor Air <sup>b</sup> Homes (n=8)	HRV Mechanical Outdoor Air <sup>c</sup> Homes (n=3)
	Outdoor Air Exchange Rate (ach)	Outdoor Air Exchange Rate (ach)	Outdoor Air Exchange Rate (ach)
Minimum	0.13	0.10	0.33
25% Quartile	0.20	0.20	0.88
50% Median	0.33	0.36	1.43
75% Quartile	0.66	0.46	2.86
Maximum	6.47	0.58	4.28

- a.) 41 homes with no mechanical outdoor air systems and no nighttime ventilation cooling systems (one home without a PFT measurement excluded).
- b.) 8 homes with operational mechanical ducted outdoor air (DOA) ventilation systems and no nighttime ventilation cooling systems.
- c.) 3 homes with operational mechanical heat recovery ventilator (HRV) outdoor air ventilation systems and no nighttime ventilation cooling systems.

# Formaldehyde concentrations

- The median 24 hour average formaldehyde concentration was  $38 \mu\text{g}/\text{m}^3$  for the 42 houses with no mechanical ventilation. It was about 50% higher for the 7 houses with supply ventilation ( $59 \mu\text{g}/\text{m}^3$ ), and about four times less for the 3 HRV houses ( $10 \mu\text{g}/\text{m}^3$ ).
- In all, 62% of the 61 homes with formaldehyde measurements had indoor concentrations that exceeded the California Air Resources Board exposure guideline of  $33 \mu\text{g}/\text{m}^3$ .

Table 6. Average 24-hour indoor formaldehyde concentrations in new single-family detached homes in California with and without mechanical outdoor air ventilation.

	No Mechanical Outdoor Air <sup>a</sup> Homes (n=42)	DOA Mechanical Outdoor Air <sup>c</sup> Homes (n=7)	HRV Mechanical Outdoor Air <sup>c</sup> Homes (n=3)	Outdoor All <sup>d</sup> Homes (n=23)
	Indoor Formaldehyde Concentrations ( $\mu\text{g}/\text{m}^3$ )	Indoor Formaldehyde Concentrations ( $\mu\text{g}/\text{m}^3$ )	Indoor Formaldehyde Concentrations ( $\mu\text{g}/\text{m}^3$ )	Outdoor Formaldehyde Concentrations ( $\mu\text{g}/\text{m}^3$ )
Minimum	4.7	34.6	7.8	0.7
25% Quartile	22.2	42.2	8.9	1.5
50% Median	38.3	58.5	10.0	2.2
75% Quartile	73.8	87.0	23.4	3.1
Maximum	143.6	135.5	36.7	8.0

- a.) 42 homes with no mechanical outdoor air systems and no nighttime ventilation cooling systems.  
 b.) 7 homes with operational mechanical ducted outdoor air (DOA) ventilation systems and no nighttime ventilation cooling systems (one home with a formaldehyde sample failure excluded)  
 c.) 3 homes with operational mechanical heat recovery ventilator (HRV) outdoor air ventilation systems and no nighttime ventilation cooling systems.

This presentation was by Armin Rudd of Building Science Corporation in Mr. Offerman's absence. The Tables were excerpted with permission from "Window Usage, Ventilation, and Formaldehyde Concentrations in New California Homes: Summer Field Sessions," by Francis Offermann PE CIH, Principal Investigator, Jonathan Robertson CIH and Teresa Woo EIT, of Indoor Environmental Engineering, San Francisco, CA [www.iee-sf.com](http://www.iee-sf.com); and Steve Brennan PE and Dave Springer of Davis Energy Group, Davis, CA