

Subject Focus on Energy Public Benefits Evaluation

WISCONSIN ENERGY STAR® HOMES INFILTRATION ANALYSIS

To Oscar Bloch, Wisconsin DOA

Cc Rick Morgan, WECC

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Background and Method

This memorandum presents findings from the residential evaluation team's analysis of trends in infiltration rates among homes certified through the Wisconsin ENERGY STAR® Homes (WESH) program.

As stated in the CY4 Detailed Evaluation Plan, the primary intent of this analysis is to confirm that the verified gross estimate of 100 therms for WESH home space heating savings is still reasonable.¹ This estimate is based on an Energy Center of Wisconsin (ECW) study that compared energy use and savings for 87 WESH homes built in 1999 and 2000 to a control group of 157 new, non-WESH homes.² We refer to this study as the ECW WESH Study throughout the remainder of this memo. Because the ECW WESH Study found a statistically significant relationship between blower-door based infiltration rates and heating gas use among WESH homes, our approach involves comparing infiltration rates for all 4,637 WESH homes certified program-to-date (through December 31, 2004) to the infiltration rates for the 87 WESH homes that were part of the ECW WESH Study. Comparable infiltration rates between WESH homes overall and WESH homes in the ECW WESH Study would indicate that the 100 therms estimate is still reasonable. Significant differences in the infiltration rates between these two groups, on the other hand, would imply that the 100 therms estimate is no longer reasonable. This assumes that baseline infiltration practices during the years following the ECW WESH Study have not changed. This analysis does not address trends in nonparticipant infiltration practices.

A secondary goal of this analysis is to look at trends in infiltration rates of WESH homes across all WESH builders. A decline in infiltration rates would signify that WESH is having an ongoing effect at improving infiltration-related practices among WESH builders above and beyond the improvements initially made to qualify for the program. Stagnant or increasing infiltration rates, on the other hand, would suggest that WESH's influence on infiltration-related practices is limited to the improvements initially made to qualify for the program.

¹ State of Wisconsin, Department of Administration, Division of Energy. Focus on Energy Public Benefits Evaluation. *Contract Year 4 Detailed Evaluation Plan*. May 28, 2004.

² Energy Savings from the Wisconsin ENERGY STAR Homes Program, *Research Report 211-1*, Energy Center of Wisconsin, October 2002.



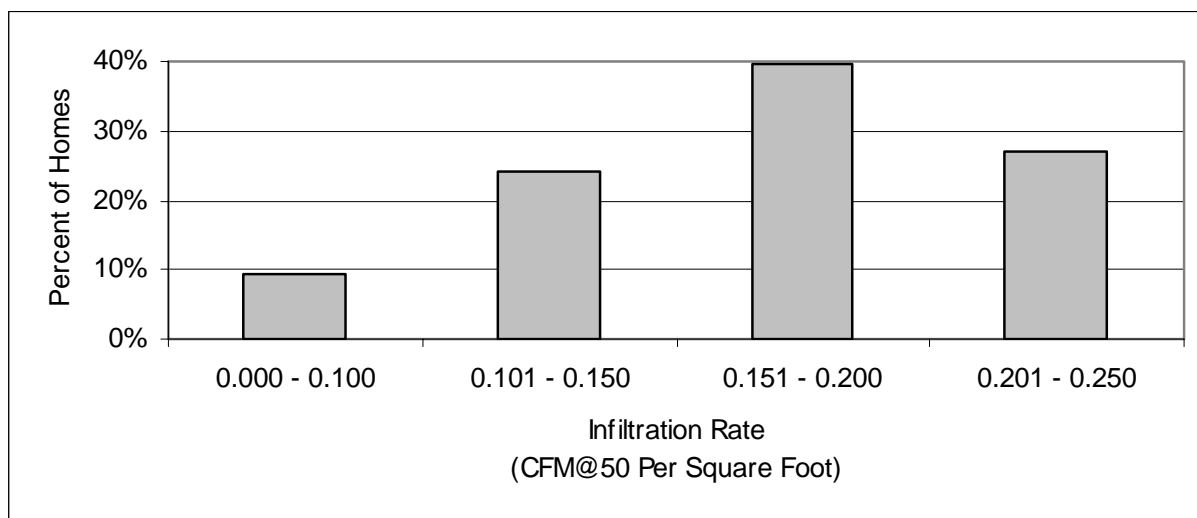
Verified Gross Estimate Confirmation

Our approach to verify that WESH's 100 therm savings estimate for space heating savings involves comparing infiltration rates for all 4,637 WESH homes certified program-to-date (through December 31, 2004) to the infiltration rates for the 87 WESH homes that were part of the ECW WESH Study. Comparable infiltration rates between these two groups would indicate that the 100 therms estimate is still reasonable. Significant differences in the infiltration rates between these two groups, on the other hand, would imply that the 100 therms estimate is no longer reasonable.

Because the infiltration rate measures the air tightness of the home, the lower the infiltration rate is, the tighter the home. WESH standards require that certified homes have an infiltration rate—measured in cubic feet per minute at 50 Pascals pressure difference (CFM@50)—of no more than 25 percent the total shell area of the home (0.25 CFM@50 per square foot).

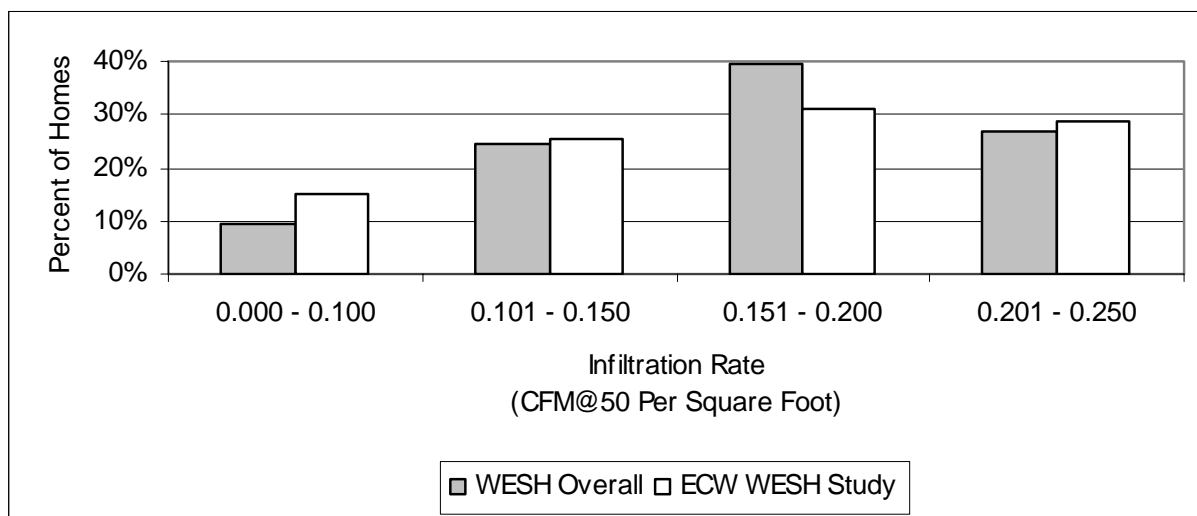
The mean infiltration rate is 0.169 CFM@50 per square foot for all 4,637 WESH homes certified program-to-date. Figure 1 shows the distribution of infiltration rates among these homes. About 27 percent of WESH homes have an infiltration rate greater than 0.20 but less than or equal to 0.25 CFM@50 per square foot, 40 percent have an infiltration rate between 0.15 and 0.20 CFM@50 per square foot, 24 percent have an infiltration rate between 0.10 and 0.15 CFM@50 per square foot, and 9 percent have an infiltration rate of 0.10 CFM@50 per square foot or below.

Figure 1. Distribution of Infiltration Rates—WESH Homes Overall



The mean infiltration rate for the 87 WESH homes that were part of the ECW WESH Study is 0.162 CFM@50 per square foot, which is lower than that for WESH homes overall. Figure 2 compares the distribution of infiltration rates for the 87 WESH homes that were part of the ECW WESH Study to the distribution of WESH homes overall. Compared to WESH homes overall, a higher percentage of WESH homes that were part of the ECW WESH Study have an infiltration rate of 0.10 CFM@50 per square foot or below (9 vs. 15 percent) and a lower percentage have an infiltration rate between 0.15 and 0.20 CFM@50 per square foot (40 vs. 31 percent).

Figure 2. Distribution of Infiltration Rates—WESH Homes Overall vs. ECW WESH Study



Although the mean infiltration rate for WESH homes that were part of the ECW WESH Study is lower than that for WESH homes overall, this does not imply that the means between these two groups are statistically different. A 95% confidence interval around the sample mean from the ECW WESH Study is 0.162 ± 0.012 CFM@50 per square foot, or 0.15 to 0.174 CFM@50 per square foot. Because the mean for WESH homes overall (0.169 CFM@50 per square foot) is within this interval, we conclude that the mean infiltration rate for WESH homes that were part of the WESH Study is not statistically different from the mean infiltration rate for WESH homes overall.

Table 1. Comparison of Mean Infiltration Rates—ECW Study vs. Overall

WESH Home Group	Mean ¹	Standard Deviation	N	Statistically Significant Difference ²
ECW WESH Study	0.162	0.056	87	No
Overall	0.169	0.047	4,637	

¹ CFM@50 per square foot.

² At 95% level.

Based on these results, we conclude that the verified gross estimate of 100 therms for WESH home space heating savings is still reasonable. Again, this assumes that baseline infiltration practices during the years following the ECW WESH Study have not changed.

Infiltration Rate Trends

In the remainder of this memo, we analyze trends in infiltration rates of WESH homes to investigate whether or not WESH is having an ongoing effect at improving infiltration-related practices among WESH builders above and beyond the improvements initially made to qualify for the program. Our hypothesis is that a declining infiltration rate with each subsequent home, or group of homes, built indicates that WESH is having an ongoing effect. To test this hypothesis, we conducted three sets of analysis, which are each described below.

- In the first set, we divided the homes built by each builder into two equal temporal groups (halves temporal grouping). We refer to this as the halves temporal grouping. The first group (group 1) is comprised of the first 50 percent of homes built through WESH, and the second group (group 2) is comprised of the last 50 percent of homes. For example, a builder who built 10 WESH homes would have the first 5 homes built through WESH in the first group and the next 5 homes in the second group. Builders who built only 1 WESH home are excluded from this analysis.
- In the second set, we divided the homes built by each builder into four equal temporal groups (quarters temporal grouping). The first group (group 1) is comprised of the first 25 percent of homes built through WESH, and so on (groups 2-4). Builders who built less than 4 WESH homes are excluded from this analysis.
- In the third set, we divided the homes built by each builder into ten equal temporal groups (tenths temporal grouping). The first group (group 1) is comprised of the first 10 percent of homes built through WESH, and so on (groups 2-10). Builders who built less than 10 WESH homes are excluded from this analysis.

Figure 3 shows the trend lines corresponding to each of the three sets of analysis. For each temporal grouping, the analysis shows a declining trend in infiltration rates with subsequent groups of homes built through WESH. For the halves temporal grouping, the infiltration rate declines from 0.175 CFM@50 per square foot for group 1 to 0.164 CFM@50 per square foot for group 2. For the quarters temporal grouping, the infiltration rate declines from 0.182 CFM@50 per square foot for group 1 to 0.163 CFM@50 per square foot for group 4. For the tenths temporal grouping, the infiltration rate declines from 0.187 CFM@50 per square foot for group 1 to 0.165 CFM@50 per square foot for group 10.

Figure 3. Infiltration Rate Trends by Temporal Groupings

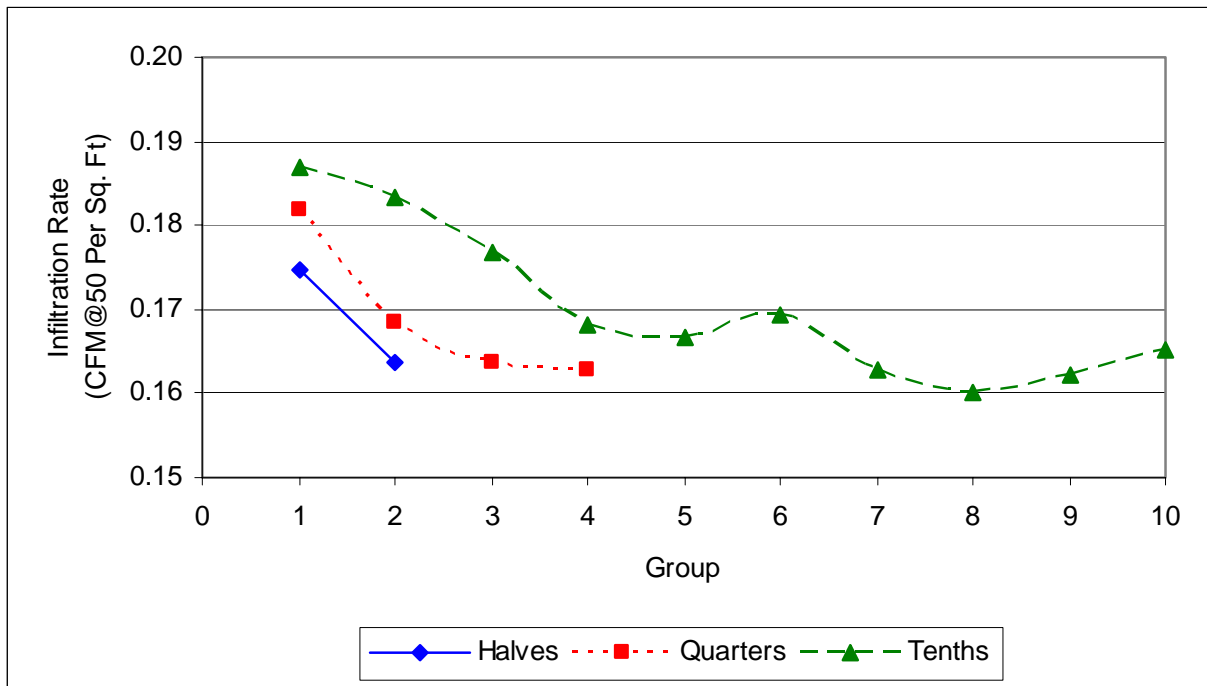


Table 2 shows the mean infiltration rate, standard deviation, and number of homes for each temporal group. The table also compares the mean infiltration rate of each subsequent group to (1) the infiltration rate of the first group and (2) the infiltration rate of the previous group.

Table 2. Significance of Temporal Trends

Temporal Grouping		Mean ¹	Standard Deviation	N	Downward Trend	
					From First Group	From Previous Group
Halves	1	0.175	0.047	2,103	–	–
	2	0.164	0.046	2,235	Yes	Yes
Quarters	1	0.182	0.047	947	–	–
	2	0.168	0.046	1,027	Yes	Yes
	3	0.164	0.046	1,078	Yes	Yes
	4	0.163	0.047	978	Yes	Yes
Tenths	1	0.187	0.047	311	–	–
	2	0.183	0.048	340	Yes	Yes
	3	0.177	0.045	360	Yes	Yes
	4	0.168	0.046	340	Yes	Yes
	5	0.167	0.045	341	Yes	Yes
	6	0.169	0.045	362	Yes	No
	7	0.163	0.045	353	Yes	Yes
	8	0.160	0.046	347	Yes	Yes
	9	0.162	0.047	353	Yes	No
	10	0.165	0.048	318	Yes	No

¹ CFM@50 per square foot.

For the halves temporal grouping, the infiltration rate for the second half of homes (0.164 CFM@50 per square foot) is lower than the infiltration rate for the first half (0.175 CFM@50 per square foot).

For the quarters temporal grouping, the infiltration rates for the second quarter (0.168 CFM@50 per square foot), third quarter (0.164 CFM@50 per square foot), and fourth quarter (0.163 CFM@50 per square foot) are all lower than the infiltration rate for the first quarter (0.182 CFM@50 per square foot). In addition, the infiltration rate declines for each subsequent quarter.

For the tenths temporal grouping, the infiltration rates for the second through tenth groups are all lower than the infiltration rate for the first group. In addition, the infiltration rate declines in all but the sixth, ninth, and tenth groups.

Based on this analysis, we conclude WESH is having an ongoing effect at improving infiltration-related practices among WESH builders above and beyond the improvements initially made to qualify for the program. Although we find ongoing improvements in infiltration rates, the scale of improvements diminishes and begins to level off as more homes are certified through WESH. Specifically, the analysis for the quarter and tenth temporal groupings (Figure 3) indicates a sharp decline in the initial groups of homes, and then a leveling off in subsequent groups. This pattern is not surprising and entirely consistent with a program like WESH, which is predicated on consultants providing builders on-site training. In this type of ongoing applied training program, the fastest progress in moving up the learning curve occurs during the initial stages, and then, as trainees become more familiar with applying the trained practices, subsequent progress increase at a decreasing rate and eventually levels off as trainees gain proficiency.

These findings support the continued use of WESH's inspection requirements, in which the number of required inspections decrease as builders certify more homes and as the homes a builder certifies become tighter. Specifically, WESH requires that the first three homes that a builder certifies have three on-site inspections (two pre-drywall and one final). Subsequent to the third home, WESH requires two onsite inspections (one pre-drywall and one final). Finally, only the final site visit is required for builders consistently certifying homes that have an infiltration rate less than 0.15 CFM@50 per square foot.³

It is important to note that the trend analysis is across all WESH builders and that the extent of WESH's ongoing effects varies among builders. To illustrate this variation, we present, in an attachment to this memo, trend analysis for the five builders who have the highest volume of certified WESH homes. These five builders have certified 1,806 WESH homes, or roughly 40 percent of the 4,637 WESH homes certified program-to-date (through December 31, 2004). In order to maintain confidentiality for each builder, we do not present the individual builder's name or volume. The analysis shows sustained improvement among two of the five builders (Builders A and D) and fluctuating performance among the remaining three (Builders B, C, and E).⁴

³ WESH's standard for consistency is at least 80 percent of a builder's homes having an infiltration rate less than 0.15 CFM@50 per square foot.

⁴ We have presented the analysis to the WESH program manager, who is working with the consultants of these builders to investigate reasons for these fluctuations.

Attachment A Top Five Builder Trends

Builder A

Figure A-1. Distribution of Infiltration Rates—Builder A

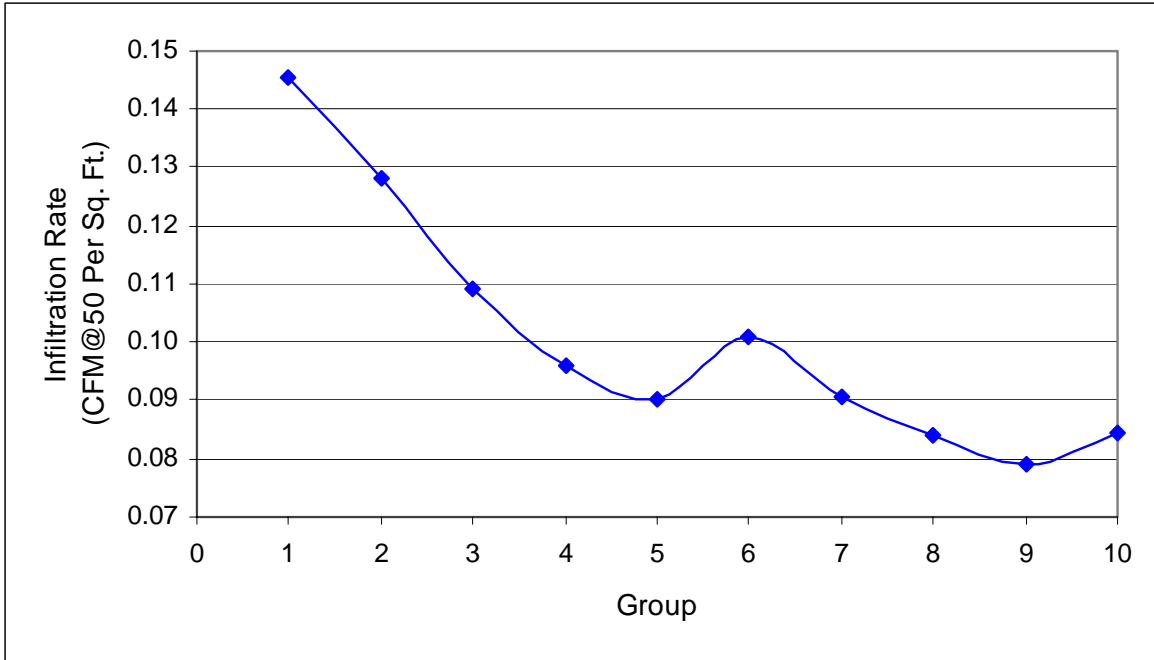


Table A-1. Significance of Temporal Trends—Builder A

Temporal Grouping		Mean ¹	Standard Deviation	Downward Trend	
				From First Group	From Previous Group
Tenths	1	0.146	0.053	–	–
	2	0.128	0.056	Yes	Yes
	3	0.109	0.041	Yes	Yes
	4	0.096	0.030	Yes	Yes
	5	0.090	0.031	Yes	Yes
	6	0.101	0.038	Yes	No
	7	0.091	0.023	Yes	Yes
	8	0.084	0.016	Yes	Yes
	9	0.079	0.016	Yes	Yes
	10	0.085	0.022	Yes	No

¹ CFM@50 per square foot.

Builder B

Figure A-2. Distribution of Infiltration Rates—Builder B

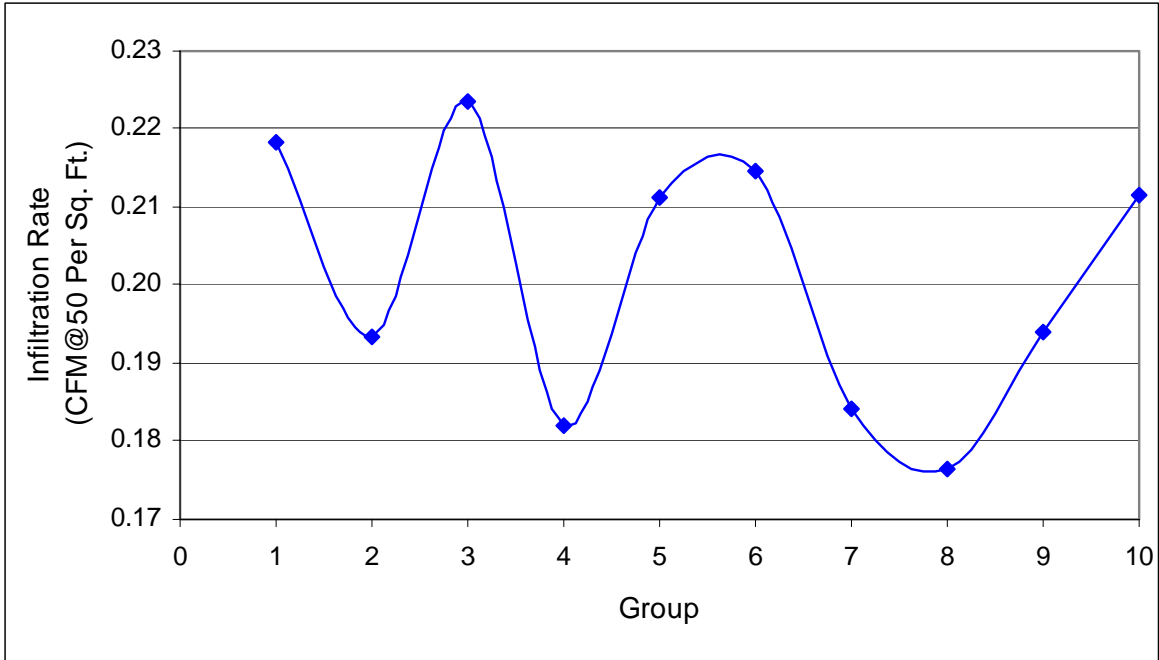


Table A-2. Significance of Temporal Trends—Builder B

Temporal Grouping		Mean ¹	Standard Deviation	Downward Trend	
				From First Group	From Previous Group
Tenths	1	0.218	0.032	–	–
	2	0.193	0.029	Yes	Yes
	3	0.223	0.015	No	No
	4	0.182	0.019	Yes	Yes
	5	0.211	0.025	Yes	No
	6	0.215	0.019	Yes	No
	7	0.184	0.025	Yes	Yes
	8	0.177	0.017	Yes	Yes
	9	0.194	0.030	Yes	No
	10	0.212	0.030	Yes	No

¹ CFM@50 per square foot.

Builder C

Figure A-3. Distribution of Infiltration Rates—Builder C

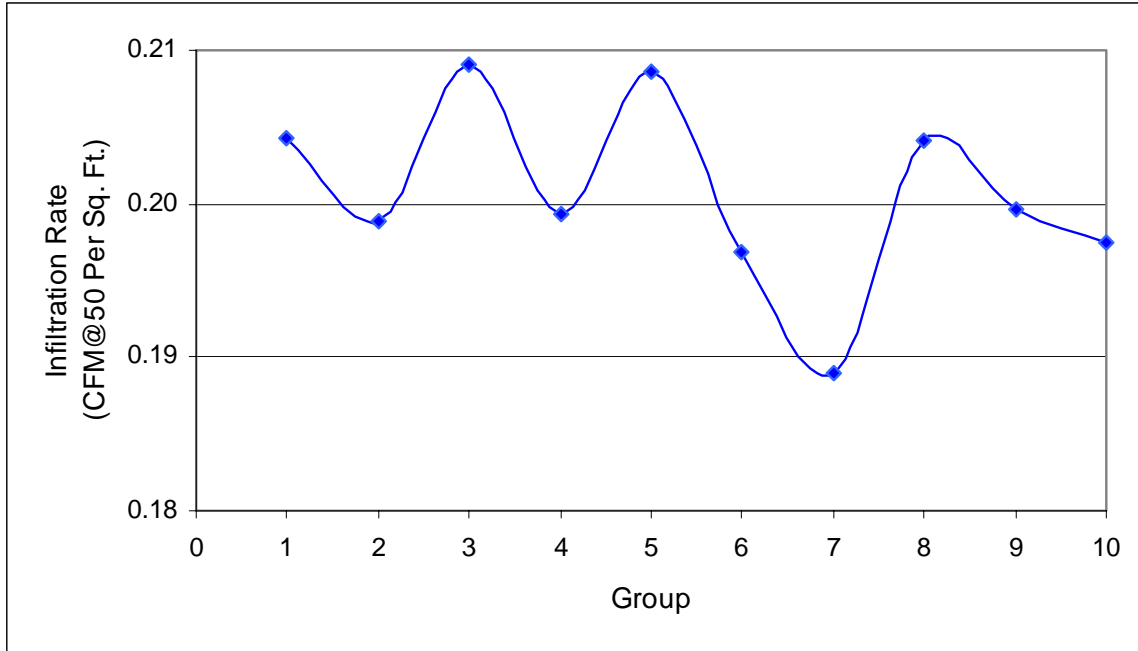


Table A-3. Significance of Temporal Trends—Builder C

Temporal Grouping	Mean ¹	Standard Deviation	Downward Trend		
			From First Group	From Previous Group	
Tenths	1	0.204	0.041	–	–
	2	0.199	0.033	Yes	Yes
	3	0.209	0.036	No	No
	4	0.199	0.025	Yes	Yes
	5	0.209	0.030	No	No
	6	0.197	0.023	Yes	Yes
	7	0.189	0.035	Yes	Yes
	8	0.204	0.032	No	No
	9	0.200	0.033	Yes	Yes
	10	0.197	0.033	Yes	Yes

¹ CFM@50 per square foot.

Builder D

Figure A-4. Distribution of Infiltration Rates—Builder D

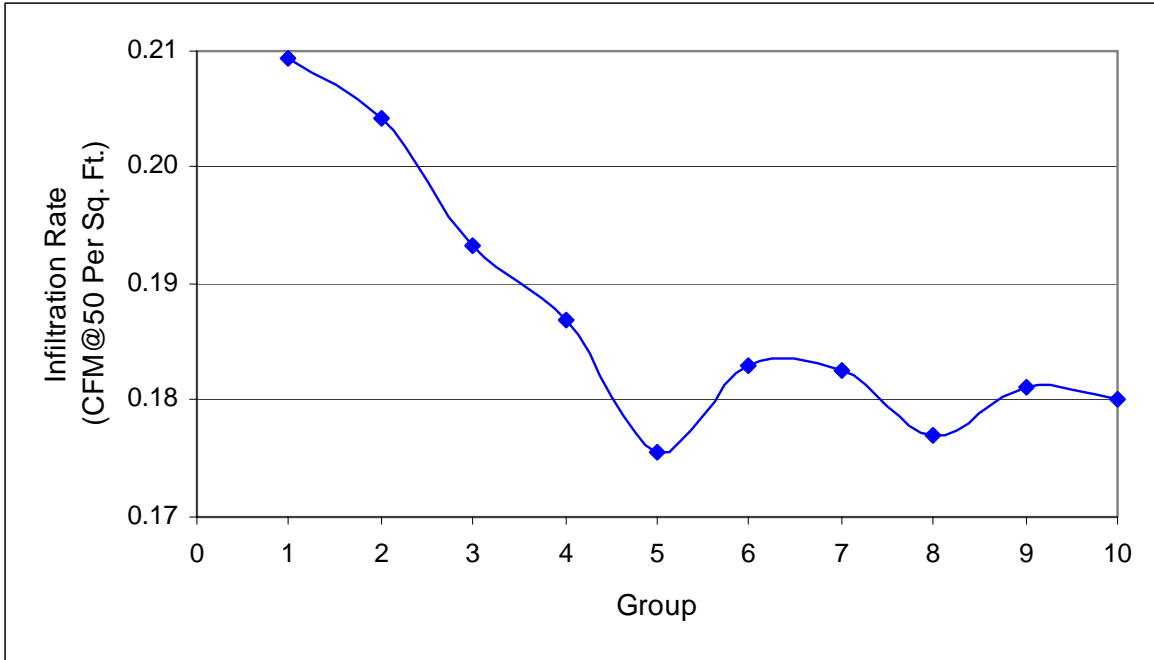


Table A-4. Significance of Temporal Trends—Builder D

Temporal Grouping		Mean ¹	Standard Deviation	Downward Trend	
				From First Group	From Previous Group
Tenths	1	0.209	0.032	–	–
	2	0.204	0.030	Yes	Yes
	3	0.193	0.028	Yes	Yes
	4	0.187	0.029	Yes	Yes
	5	0.176	0.028	Yes	Yes
	6	0.183	0.026	Yes	No
	7	0.183	0.032	Yes	No
	8	0.177	0.029	Yes	Yes
	9	0.181	0.035	Yes	No
	10	0.180	0.031	Yes	Yes

¹ CFM@50 per square foot.

Builder E

Figure A-5. Distribution of Infiltration Rates—Builder E

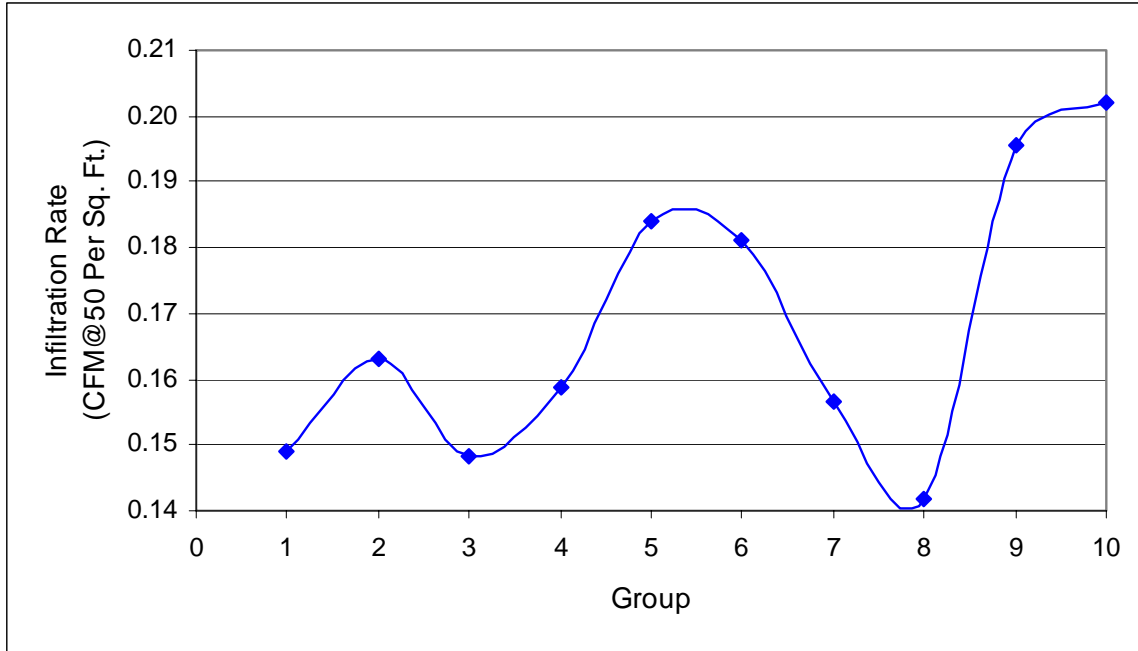


Table A-5. Significance of Temporal Trends—Builder E

Temporal Grouping		Mean ¹	Standard Deviation	Downward Trend	
				From First Group	From Previous Group
Tenths	1	0.149	0.022	—	—
	2	0.163	0.042	No	No
	3	0.148	0.043	Yes	Yes
	4	0.159	0.040	No	No
	5	0.184	0.027	No	No
	6	0.181	0.043	No	Yes
	7	0.157	0.032	No	Yes
	8	0.142	0.036	Yes	Yes
	9	0.196	0.031	No	No
	10	0.202	0.037	No	No

¹ CFM@50 per square foot.