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INFILTRATION AND AIR QUALITY IN WELL-INSULATED HOMES: 2. EFFECT OF CONSERVATION MEASURES ON AIR EXCHANGE AND ENERGY USE

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Abstract

Air infiltration in two well-insulated houses is being investigated to determine its effect on energy use and indoor air quality. The first paper of this series provides a general perspective on the problem being investigated and a detailed description of the study design. This paper reports on the effect on conservation measures taken, including the installation of an air-to-air heat exchanger, on air exchange and energy use. A third paper presents pollutant measurements and modeling results.

Experimental Setup

Under this project, sponsored by the Electric Power Research Institute, two identical bilevel houses were constructed on adjacent lots in a suburban area near Washington, D.C. (1). Both houses are well insulated and have the same orientation and wind exposure. Baseline fan pressurization/depressurization tests indicated that the two houses had very similar air change rates, i.e., approximately 10 air changes per hour (ACH) at 50 Pa. One of the houses, termed the experimental house, was retrofitted to achieve a 40 percent reduction in air leakage. An air-to-air heat exchanger with a capacity of 2.8 m^3 per minute at a pressure drop of 90 Pa was installed in the retrofitted house. The heat exchanger was configured to supply partially conditioned outside air to the main supply duct of the central forced-air system for heating and cooling. The other house, termed the control house, was left in its initial state of construction for comparative purposes.

The retrofit for tightness was carried out in late spring of 1983. Prior to retrofit, the houses were monitored for infiltration rates, energy consumption, and air pollution levels over a period of several weeks. Since the retrofit, the houses have been monitored over three seasons--summer, fall, and winter. Continuous studies of tracer gas (SF_6) decay are used to calculate infiltration rates in the upstairs and downstairs levels of each house. Total energy consumption, as well as energy use for air conditioning or heating, is also monitored continuously for each house. This paper reports the measured effects of the retrofit and heat exchanger operation on air exchange and energy use.

Air Exchange Measurements

In both houses, infiltration rates measured in the lower level were always greater than or equal to those measured in the upper level (2). The difference between the two zones was dependent on the activity of the circulation fan associated with the forced-air system. When this fan was operated constantly, each house behaved as a single homogeneous zone with respect to infiltration patterns. In Table 1, average infiltration rates for 1-week monitoring periods during spring, summer, and fall are shown for each house. During these periods, the circulation fan was operated constantly. The error bands attached to each rate in Table 1 represent 95 percent confidence intervals for the mean. The error bands are relatively small because each average is based on between 70 and 200 hourly measurements.

Table 1. Effects of retrofit and season on average air infiltration rates in ACH.

	Spring (preretrofit)	Summer*	Fall*
Control house	0.33 ± 0.03	0.22 ± 0.02 (33% reduction)	0.33 ± 0.02 (no reduction)
Experimental house	0.31 ± 0.03	0.20 ± 0.02 (35% reduction)	0.23 ± 0.02 (26% reduction)

* Percent reduction from spring indicated in parentheses.

Table 1 indicates that the two houses experienced similar infiltration rate reductions for the transition from spring to summer, even though only one house was retrofitted. Apparently, the reduction in air infiltration through lower indoor-outdoor temperature differences dampened out the potential differences due to retrofit. During the fall season, the control house returned to its baseline infiltration rate but the experimental house did not; its fall rate was 26 percent lower than the spring rate.

For most weekly sets of measurements, the circulation fan was operated only when heating or cooling was demanded. With this fan setting, the effects of four heat exchanger flow-rate settings--off, low, medium, and high--were studied. The outdoor supply and exhaust ducts for the heat exchanger were closed by taping the inlet and outlet when it was off. The high setting represents the maximum flow rate for the heat exchanger, whereas low and medium reflect intermediate settings.

The effect of the heat exchanger on summer and fall infiltration rates is shown in Table 2. The infiltration rates for each house are a volume-weighted average of the upstairs and downstairs zones. During both seasons, the experimental house had a lower infiltration rate than the control house when the heat exchanger was off. When the heat exchanger was operated, the experimental house had higher levels of air exchange. The magnitude of the difference in air change rates was related to the heat exchanger flow rate. The relative excess at each flow-rate setting was somewhat less in fall than in summer. By comparing the differences between the two houses at the flow-rate extremes (off and high) one can see that the heat exchanger added about 0.4 ACH at its full setting.

Table 2. Effect of heat exchanger operation on average air change rates, in ACH.

Heat exchanger setting	Control house	Experimental house	Difference*
Summer			
Off	0.16	0.13	-0.03
Low	0.22	0.32	0.10
Medium	0.20	0.48	0.28
High	0.22	0.59	0.37
Fall			
Off	0.32	0.23	-0.09
Low	0.29	0.39	0.10
Medium	0.37	0.58	0.21
High	0.42	0.72	0.30

* Difference between average infiltration rates in experimental and control houses.

Energy Use Measurements

In Figure 1, energy use comparisons are given for two heat exchanger settings--off and medium--during the summer period. These two settings were chosen because associated weekly cooling loads were almost identical. Comparisons between the two houses are provided both in terms of energy use for air conditioning only and total energy use. When the heat exchanger was off, the experimental house used about 3 percent less energy (i.e., 0.5 kWh/day less for air conditioning and 1.0 kWh/day less in total). With the heat exchanger at medium, the experimental house used about 5 percent more energy (1.0 kWh/day) for air conditioning and about 11 percent more energy (3.3 kWh/day) in total. The higher excess for total energy reflects power consumption by the heat exchanger itself.

In Figure 2, similar energy use comparisons are made for the fall season. With the heat exchanger off, the experimental house used 19 percent less energy (5.3 kWh/day) for heating and 16 percent less energy (5.9 kWh/day) in total. With the heat exchanger at medium, the experimental house used 12 percent less energy (3.4 kWh/day) for heating and 4 percent less energy (1.5 kWh/day) in total. Thus, unlike the summer case, there was some energy savings during the fall with the heat exchanger at medium, even though the air exchange rate at this setting was 0.2 ACH higher than the corresponding rate for the control house.

The importance of making energy comparisons during periods of similar heating or cooling loads is illustrated in Table 3. This table shows differences between the houses during two different portions of the same week when the heat exchanger was not operated. During the first part of the week, when the heating load was lighter, the experimental house used 30 percent less (3.6 kWh/day) heating energy. During the period with a higher heating load, the difference between the houses was smaller in percentage terms (19 percent) but larger in absolute terms (5.3 kWh/day).

Table 3. Effect of heating load on relative energy use.

Heating load	Energy use for heating, in kWh/day: Control house	Experimental house	Absolute difference	Percentage difference
Lighter	12.0	8.4	3.6	30
Heavier	28.1	22.8	5.3	19

Conclusions

The air leakage reduction in the experimental house due to retrofit, as measured by blower door tests, was not evidenced during the summer in terms of air infiltration rates. Energy use accompanying the heat exchanger operation during summer was higher than for the control house. By comparison, a reduction in air infiltration rates due to the retrofit was observed in the fall season. Some energy savings due to the retrofit were seen even with the heat exchanger in operation. It is anticipated that greater savings from the retrofit will be experienced during the more extreme winter weather conditions.

Acknowledgment

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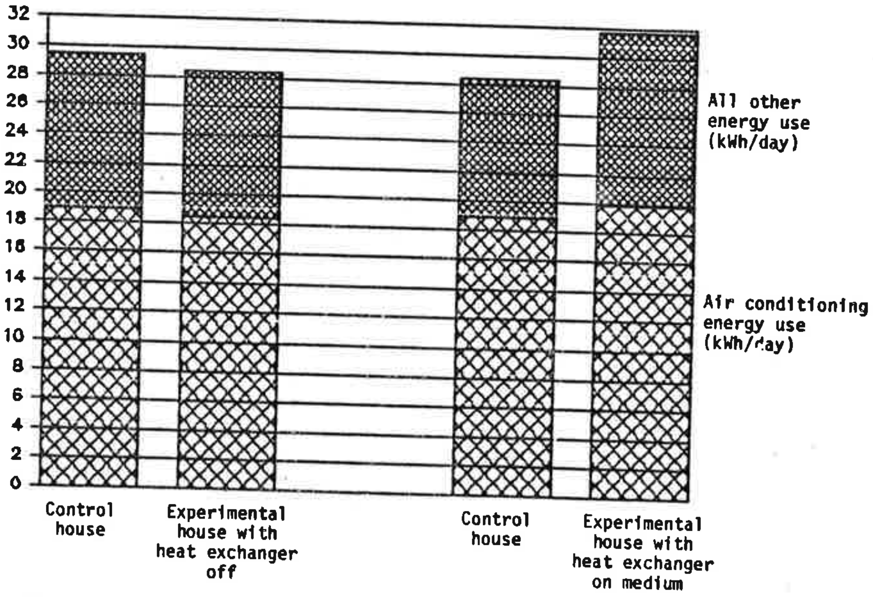

Fig. 1. Effect of heat exchanger on summer energy use.

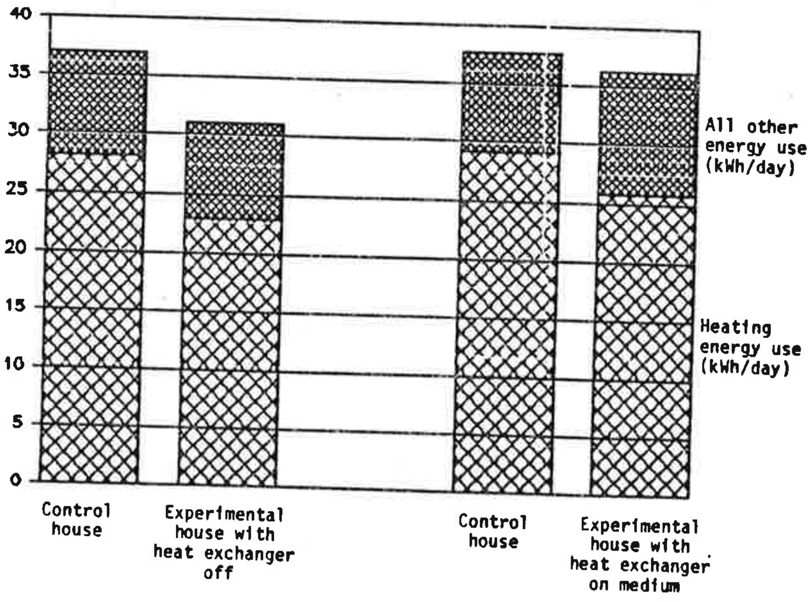

Fig. 2. Effect of heat exchanger on fall energy use.

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