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VARIATIONS IN INTERZONAL AIRFLOW RATES IN A DETACHED HOUSE USING TRACER GAS TECHNIQUES

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ABSTRACT

It is well known that indoor air quality in buildings is influenced by the ventilation and infiltration of ambient air as well as air contaminant sources. Airflow rates between zones in a building are often large enough to alter the concentration of an air contaminant within any one zone. For detached houses, ventilation, air infiltration, and contaminant source strengths may differ significantly from one zone to another. To predict air contaminant concentrations in any one zone, there is a need to quantify the air exchange rate between one zone (eg. the house basement) and the adjacent zone (eg. the main floor). Airflow rates between adjacent zones can be measured using tracer gas techniques. Although previous studies have successfully used these tracer gas techniques to validate interzonal airflow rate models of tracer gas movement between interconnected rooms with controlled airflow rates, little work has been done to evaluate the interzonal airflow rates in buildings such as detached houses.

In recent years, several computer models have been developed to predict air contaminant concentrations in multi-zone buildings. Although these models assume a uniform contaminant distribution within each zone, variations of airborne contaminant concentrations within a space or zone can occur due to time varying source strengths, room size and geometry, air circulation, and ventilation and infiltration rates. Consequently, assuming a uniform concentration in any zone and constant air exchange rates between zones may lead to large errors between simulation results and measured data.

This paper describes a study conducted to compute, using tracer gas data, the air exchange rates between the basement and main level and between the ambient surroundings and an unoccupied single-storey detached house located in Saskatoon, Saskatchewan. The building envelope is constructed to good energy conservation standards. Heating is supplied by means of a forced-air gas furnace. To obtain data for the calculation of interzonal airflow rates, different tracer gases were injected into each zone. Nitrous oxide (N_2O) was released into the basement and, at the same time, carbon dioxide (CO_2) was released into the upstairs region, both as pulse injections. Experiments were conducted to measure the time variation of each tracer gas in each zone for three test conditions. These are:

1) the forced-air recirculation furnace fan is used to enhance air circulation between the two zones while air mixing within each zone is by auxiliary fans set on each floor,
2) the air exchange between zones is by natural or free convection only, and air circulation within each zone is enhanced by operating the auxiliary mixing fans, and
3) air exchange between the two zones of the house is by natural or free convection only, and no mixing fans are used to circulate the air within each zone.

Experimental results on the rise or decay of each tracer gas were compared with results generated by a computer program written to simulate the time variation of these tracer gas concentrations for a two zone building with air infiltration from outside. That is, based on the mass-conservation and mass-balance equations for well-mixed, isothermal zones, the model predicts tracer gas concentrations in each zone. The experimental technique, accuracy of the calculated airflow rates, and sensitivity of tracer gas concentrations under various test conditions are presented and discussed.

Results obtained from this study indicate that tracer gas methods used to quantify air exchange rates between the basement and main floor of the house may be inaccurate, especially if tracer gas concentrations in each zone are not well-mixed. Typical tracer gas profiles, for the test condition (3) with no mixing fans or furnace fan operating, are presented in Figure 1. The other tracer gas response curves were somewhat similar which are also similar to other data in the literature. In this paper, we use these experimental tracer gas data obtained under typical operating conditions to deduce the air exchange rates between each of the zones.

For a two zone building, there are six airflow components. They include: from outside to basement (F_{ob}), from the basement to outside (F_{bo}), from the outside to the main level of the house (F_{om}), from the main level of the house to outside (F_{mo}), from the basement to the main level of the house (F_{bm}), and from the main level of the house to the basement (F_{mb}). The corresponding airflow rates, calculated at various time intervals, are presented in Figure 2. Only tracer gas data obtained 48 minutes after initial injection were included in Figures 1 and 2, since prior to this time, the tracer gas concentrations in each zone were inadequately mixed. The mean value, F_{mean}, maximum relative error, RE_{max}, standard deviation, S, and ratio of the standard deviation to mean airflow rate are presented for each airflow rate in Table 1 for the three test conditions. For the case with no mixing fans or furnace fan operating, repeatability of the calculated airflow rates is poor. On average, variations in the computed time variable airflow rates between zones for this case were nearly three to five times greater than the other two test conditions where mixing fans were used to mix the tracer gas within each zone. However, even with mixing fans in operation, large variations at various times in the computed air exchange rates are indicated using this technique to compute these airflow rates. Due to the complexity of the situation, the actual airflow rates were not measured directly. It is not expected that the actual variation in airflow rates would be nearly as large as the tracer gas computed values reported here, especially when the furnace fan was used.

These results on computed air exchange rates inferred from tracer gas data suggest that great care must be given in the use of models that assume well mixed air in each zone for air pollutant dispersion between zones. Furthermore, more experimental tracer gas testing should be done to compare simulation models with measured data and to characterize tracer gas distributions in zones that are not well mixed.

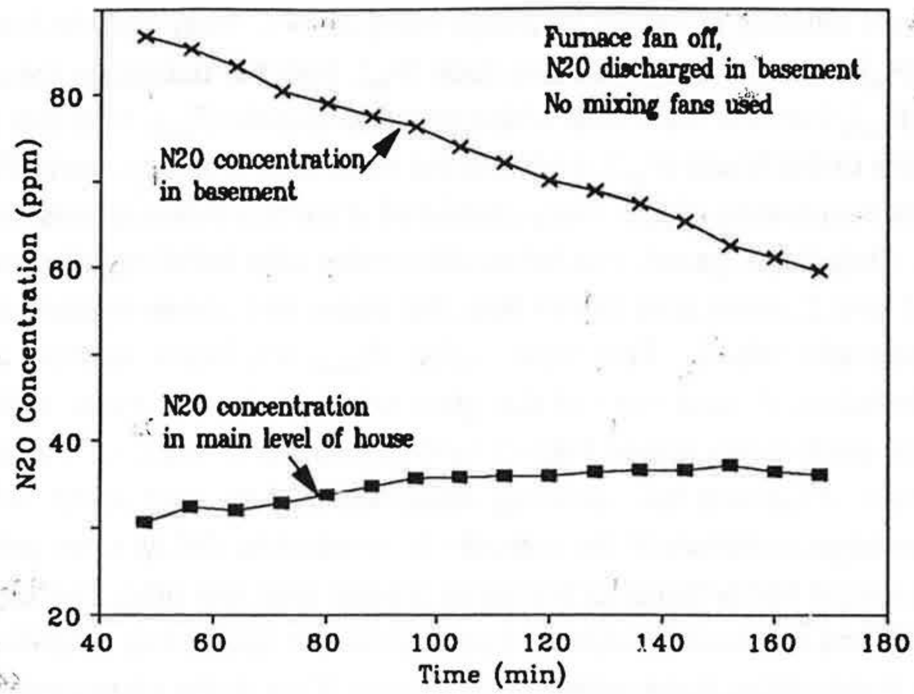

Figure 1. N_2O tracer gas concentration in the basement and main level zones for a pulse input of N_2O in the basement with furnace fan and mixing fans off.

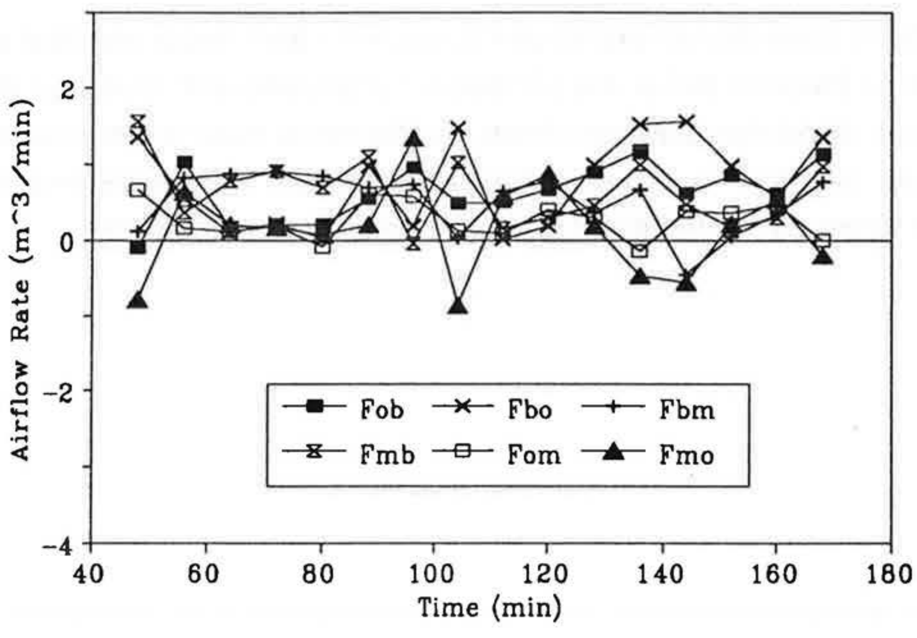

Figure 2. Calculated airflow rates versus time with both the furnace fan and mixing fans off.

Table 1. Mean value, maximum relative error, and standard deviation of calculated airflow rates.

TEST CONDITION		F_{ob}	F_{bo}	F_{bm}	F_{mb}	F_{om}	F_{mo}
Furnace Fan On	F_{mean}	0.98	2.09	13.34	14.45	1.70	0.59
Mixing Fans On	RE_{max}	0.16	0.37	0.41	0.35	0.14	1.66
	S	0.08	0.62	4.01	3.66	0.15	0.70
	S/F_{mean}	0.08	0.29	0.30	0.25	0.09	1.18
Furnace Fan Off	F_{mean}	0.88	1.01	1.64	1.84	0.52	0.33
Mixing Fans On	RE_{max}	0.37	0.49	0.41	0.31	0.48	1.84
	S	0.14	0.27	0.38	0.28	0.11	0.26
	S/F_{mean}	0.16	0.27	0.23	0.15	0.22	0.78
Furnace Fan Off	F_{mean}	0.62	0.75	0.51	0.64	0.27	0.14
Mixing Fans Off	RE_{max}	1.15	1.05	1.89	1.44	1.51	8.91
	S	0.37	0.58	0.39	0.43	0.24	0.60
	S/F_{mean}	0.60	0.77	0.77	0.68	0.92	4.44