RESEARCH REPORT

Penetration of Outdoor Particles into a Residence: Appendices

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Penetration of Outdoor Particles into a Residence APPENDICES

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A HOUSE DESCRIPTION

- single family detached residence
- continuously occupied during tests (i.e. not vacant)
- forced air system
- no smokers
- no pets

Table 1
House Characteristics

Volume	429 m^3
Floor Area (including basement)	168 m^2
Internal Surface Area (Estimate)	809 m^2
% of Floor Carpeted	71%
Draft Type	Direct Vent
Fuel	Gas
Cooking Appliances	Electric
Adults	2
Children	0
Pets	0
Location	Suburban
ela_{10}	733 cm^2
ACH50	2.1
Age	24 years

B TESTING

B.1 General Arrangement

The house was equipped with a ducting arrangement which allowed more precise measurement of in-duct particles and airflow than would be possible in a typical Canadian central forced air ductwork system. Although the "test duct section" for this house is specially configured for filter testing, it is connected to a more or less conventional heating and air conditioning duct system with an air turn-over rate of 2.2 air turnovers per hour. This is above the minimum 1.5 turnovers per hour recommended by the HRAI Residential air systems design manual (Ref 14).

The general ducting arrangement provides for:

a) precision air flow measurement of airflow introduced into the return air duct directly from outside.

b) precision air flow measurement of the total return airflow (air from living space mixed with outdoor air);

c) variation of airflow by means of both total; airflow and incoming outside airflow via blower speed and damper adjustment.

B.2 Airflow testing

1) All of the tests were taken with the turning vanes in place at the bottom elbow (see test duct diagram).

2) All pressure measurements were taken with an Energy Conservatory Automated Performance Testing (APT) data-acquisition system. The system pressure gauges are accurate to +/- 0.1 Pa (0.004 in. w.g.)

3) Airflow was measured using an Environmental Control Technologies Airflow Measuring Station mounted upstream of the filter station. The station had been previously calibrated using a precision pitot-tube traverse at the same location.

4) The airflow as well as upstream and downstream static pressures were recorded continuously during the experiments.

C INSTRUMENTATION

C.1 Sampling Rig

C.1.1 Components

1) vacuum pump:
   - Gast # 1532 carbon-vane rotary oil-less type
   - exit air from pump (& system) is passed through a HEPA filter before return to the house.

2) sample lines:
   - 9 mm flexible soft copper (7.9 mm i.d.) with maximum length of 50 ft. (velocity of 1.73 metres/second at 5 Lpm flow)
   - short lengths of 6.5 mm i.d. teflon-lined flexible connector tubing
   - isokinetic inlets of 19 mm diameter are used giving an intake velocity of 0.30 metres/second

3) flow-regulation:
   - Dwyer MMA rotameter with integral flow-regulating valve.
   - each rotameter was calibrated to an accuracy level of +/- 5% of the indicated flow against a primary airflow calibration device.
   - flows are measured;
     - -total system flow (25 Lpm)
     - -each bypass line (5 Lpm when not sampling)
     - -particle counter exit flow (2.8 Lpm)
     - -sampling line bypass flow (2.2 Lpm)

4) Valves & timers:
   - brass-body diaphragm type solenoid actuated valves, 25 mm nominal, 8 mm port size.
   - trigger interlock timer , using a 90 second sample period with a 15 second purge period

5) Impact separator;
   - Air-metrics, 10 µm greased plate separator @ 5 Lpm flowrate

6) Particle counter: Bio-Test APC 1000, laser particle counter with continuous data collection in four channels:
   - 0.3 to 0.5 µm
   - 0.5 to 1.0 µm
   - 1.0 to 5.0 µm
   - 5.0 µm & above

7) The particle counter was calibrated using Latex-Polystyrene spheres by their respective approved calibration lab.

C.1.2 Sampling Airflow

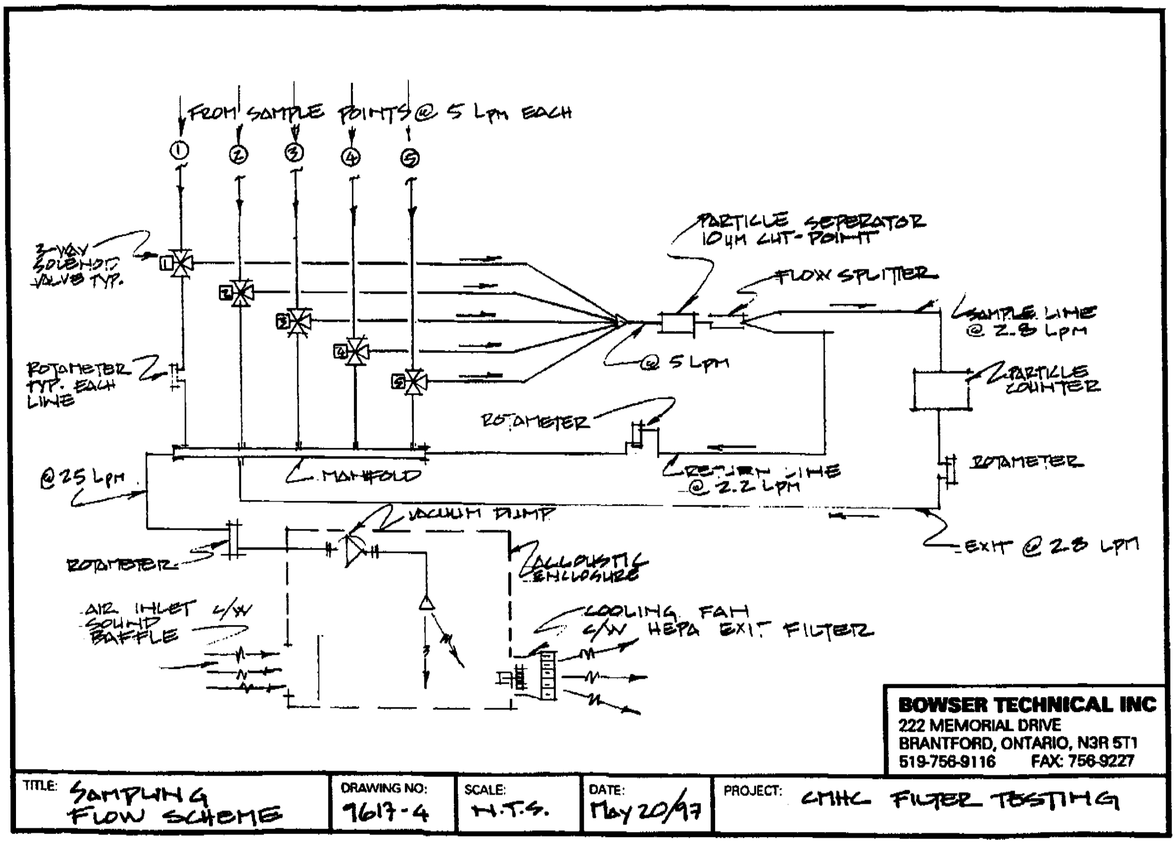
1) The rig generates a continuous flow of 5 Lpm (Litres per minute) from each location and switches the active sampling line on an interval of 90 or 105 seconds.

2) The active sampling flow is first passed through the impact separator which removes particles above 10 µm before passing into the particle counting instrument.

3) The particle-counter flow-rate is 2.8 Lpm. This lower flow is separated from the 5 Lpm flow is separated using a low-angle (15°) equal-velocity flow-separator.

4) Flow is maintained at a constant 5 Lpm in all sampling lines, whether or not a sample is being taken.

Figure A-1
Schematic, Sampling Rig



C.2 Weather Station

1) Weather data was obtained with a portable, on-site weather station (Davis Instruments Monitor II) which records:
   a) indoor % RH and temperature
   b) barometric pressure
   c) outdoor temperature
   d) wind-speed and direction

2) Wind-speeds are recorded at the eave height of the house, at a point approximately two house-heights away from the house, in an area which avoids obstructions as much as possible.

3) The airtightness of the house was measured using a blower-door test apparatus according to the CGSB 149.1 test method. [Ref 2]

4) Ventilation flows are measured directly with an in-line flow measuring station. (Environmental Control Technologies type)

C.3 Carbon Dioxide Measurement

1) Ozone monitoring was conducted using a Young Environmental System Model; 206 Ambient CO_2 Monitor .and a Honeywell model C7242A ambient CO_2 monitor. The monitors were cross-calibrated by co-location at the beginning and end of the experiments. Inter-unit drift was adjusted using straight-line interpolation varying with time.

2) The YES 206 unit had been factory calibrated immediately prior to use in this project.

D CALCULATIONS

D.1 System Airflow

The system airflow for a given data period was calculated using the average of the calculated airflow during each 8 min. 45s cycle. The calculated airflow obtained by assigning each 1 min. 45 sec. data sub-cycle a status of "high" "Low" or "Off" according to the time-mark of the data-logger. The airflow measured at "high" or "low" for the furnace filter combination under test was assigned to each sub-cycle according it's status. Refer to B.2 for a description of the airflow measurement methods.

D.2 Air-Change Calculations

1) The air-change rate was estimated using monitored weather data and the airtightness characteristics of the house using the AIM-2 [Ref 5] analysis method. Validation of this model using continuous SF_6 air-change monitoring has shown a bias error 10% and scatter error of 3% (total error approximately 13%) for an unsheltered house with no flue. [Ref 5]

2) Combined natural and mechanical ventilation effects were modeled using the a modified Keil-Wilson [Ref 6] relationship. The model is shown in the following equation as suggested by Prof Wilson in personal correspondence dated January 9th, 1991. The modifications allow for both supply and exhaust mechanical ventilation flows.

$$Q_{total} = Q_{bal} + \{(Q_{inf})^{1/n} + (Q_{unbal}/2)^{1/n}\}^{n} + (Q_{unbal}/2)$$

Where:

Q_{total}	=	Total air exchange flow
Q_{bal}	=	Balanced mechanical ventilation flow
Q_{inf}	=	Infiltration flow from AIM2 model
Q_{unbal}	=	Unbalanced ventilation flow
n	=	Flow exponent from CGSB 149.1 test method. [Ref 2]

3) Windows and doors remained closed during data acquisition.

4) Data were collected and air change calculations are carried out at 15 minute intervals.

5) The model based on weather data and measured flows was validated using a CO_2 decay technique where by a quality of CO_2 was released into the house and then all occupants left for a period of at least 1 hour. The resulting CO_2 decay curve was analyzed by applying linear regression with time to the natural log of the differential values between indoor and outdoor measurements. The slope of the sum-of-squares regression (time in hours) is taken as the actual air changes per hour. Six such experiments were carried out with an aggregate correlation between the modeled and measured CO_2 - Decay air change rates of r=0.989 (standard error 5.6%).

The following table sets out the results of each experiment

Table A-2

Experiment	Modeled ACH	CO_2 Decay ACH	Correlation (R^2)	Standard Error
Supply Only # 1	1.54	1.60	0.938	6%
Supply Only # 2	1.13	1.04	0.988	7%
Balanced # 1	0.75	0.74	0.781	7%
Balanced # 2	0.69	0.69	0.990	6%
Balanced # 3	0.72	0.72	0.947	14%
Exhaust Only	0.76	0.76	0.987	3%