RESIDENTIAL COMBUSTION SPILLAGE MONITORING

Submitted to the
Research Division
Canada Mortgage and Housing Corporation

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ABSTRACT

Sixteen homes were continuously monitored to determine the frequency and duration of combustion product spillage from the furnaces and DHW systems. In the houses which did show spillage activity, event-controlled sampling was used to determine levels of air contaminants attributable to the spillage.

Additional testing of the sample houses included: air tightness testing, air change rate testing and "forced spillage" contaminant testing.

DISCLAIMER

This project was funded by the Canada Mortgage and Housing Corporation and the Panel for Energy Research and Development (PERD), but the views expressed are the personal views of the authors, and neither the Corporation nor PERD accepts responsibility for them.

EXECUTIVE SUMMARY

In a previous research contract, Canada Mortgage and Housing Corporation (CMHC) had simple monitors installed in approximately 900 houses to detect spillage of combustion products from fuel-fired furnaces and hot water heaters. In this study, CMHC found that a significant percentage of houses did have occurrences of combustion product spillage from these appliances.

Buchan, Lawton, Parent Ltd. was contracted by CMHC to carry out a more detailed monitoring programme on sample houses which had experienced incidents of combustion spillage.

The methodology incorporated two basic elements. The first, carried out on all sixteen houses covered under the test programme, was to monitor the mechanical systems and door and window operation of the houses to determine the frequency and duration of spillage incidents, and the status of exhausting equipment and envelope openings during these incidents. Testing and recording of house details, such as envelope air leakage and occupancy characteristics, were also done.

The second element was air sampling to determine contaminant levels attributable to combustion product spillage from the appliances. Two sampling technologies were employed. Tube sampling methods were used for NO, NO_2, and (in oil-heated houses and a limited number of gas-heated houses) SO_2. As well, bag samples were collected for later analysis by gas chromatography for CO, CO_2, methane and non-methane hydrocarbons. Three samples also underwent further analysis by mass spectrophotometry for a more complete analysis of organic compounds.

Air sampling was carried out in the houses as found, and during a period in which the combustion appliances were forced to spill by use of a high volume door fan. On those houses where significant 'naturally occurring' spillage events were recorded, a pump sampling package was installed, contralled by the monitoring system, which collected bag samples and, in a limited number of cases, NO_2 sorbant tube samples through two sampling trains. One sampling train collected only on spillage events and the other was activated on a time controlled basis, thus collecting an 'average' sample.

Monitoring activities were carried out in a total of sixteen houses, nine in Ottawa and seven in Winnipeg. Three of the Ottawa houses were oil-heated, the rest were heated by natural gas. Monitoring was done over a period of fourteen to thirty-five days on individual houses and a total of 322 days of usable monitoring data was gathered.

Of the sample sixteen houses, nine showed no spillage activity during the period they were monitored. Five gas-heated houses had significant spillage incidences and the remaining two houses, which were oil-heated, had brief, infrequent periods where spillage was detected.

In two of the houses which showed significant spillage occurrence, spillage was found to correlate with the operation of other exhausting appliances, a fireplace in one case and exhaust fans in the other. The three other spilled even without those aggrevating factors.

While some attempt has been made to correlate spillage data with atmospheric weather conditions (from Atmospheric Environment Service Weather Data), no direct correlation can be seen. This is not to say that there is no correlation, but rather, other factors such as exhaust appliance operation or poor chimney action overwhelmed weather effects.

Air quality sampling results indicate that there is some increase in contamination levels attributable to combustion spillage from the appliances, but that the increase was not dramatic.

It was found that during the forced spillage testing in some houses, contaminant levels, particularily carbon dioxide, did increase well above ambient levels (CO_2 concentrations up to 6636 ppm). In normal operation, even in those houses which spilled consistantly, the contaminant levels were below levels specified in existing standards and Health and Welfares proposed guidelines levels.

The study concludes that considering that the sample selection was limited to houses previously determined to have spillage occurrences, remarkably few had significant spillage incidents. Furthermore, while contaminant levels attributed to combustion product spillage were higher than ambient or average levels and in 'forced spillage' tests reached unacceptable levels, the contaminant levels from 'naturally occurring' spillage incidents were below Health and Welfare proposed guidelines.

It was noted, however, that the frequency and duration of combustion spillage and the levels of contaminants attributable to both 'forced' and 'naturally' occurring spillage were very house-specific. While hazardous levels of contaminants were not recorded from 'naturally' occurring spillage in the relatively few houses in which spillage was monitored, there is reason to suspect that in a limited number of cases, contamination levels could be a problem. The results would, however, indicate that this should be rare.

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1.0 INTRODUCTION AND BACKGROUND

During the course of a number of previous projects, Canada Mortgage and Housing Corporation (CMHC) has been attempting to define the prevalence and impact of combustion product spillage in Canadian Houses. The most significant project was one which surveyed approximately 900 houses across Canada (Reference 1). A simple temperature sensor was used to determine that combustion product spillage from furnace and hot water heaters had occurred in a significant percentage of the houses tested.

The technology used in the broad survey was limited in that it did not define the actual duration and number of occurrences of spillage, nor did it attempt to determine the effect of spillage on the indoor environment. These issues were addressed in the present project.

Buchan, Lawton, Parent Ltd.'s response to a CMHC request for proposals offered to carry out monitoring of a significant number of houses to determine the number and duration of spillage incidents, what household operation characteristics influenced spillage and the effect on the indoor environment. To meet objectives within CMHC's stated budget constraints required some innovation and planning, especially considering contract and heating season restraints limited all preliminary work and field monitoring to a period from contract award on January 16th 1987 until the end of the heating season which was deemed to be the end of March 1987.

This report is broken down into several sections. In section two one can find sub-sections discussing the selection of the case study houses, descriptions of the monitoring systems and methodology employed and a description of the air sampling methods used. Section three summarizes the field experience and the results of the program. Section four provides comments and conclusions.

Appendix A provides the data for each house on an individual basis.

2.0 PROCEDURES

The approach employed was to use "IBM PC clone" computer systems as an eight channel status data acquisition system by the use of a standard games controller card. Four of these channels were used to determine whether the combustion appliances were on or off and whether spillage was occurring. The other four determined house activity status, including whether or not windows and doors were open (on two sides split by orientation), whether exhaust fans were operating and whether the fireplace was in use.

This monitoring activity was carried out on nine houses in Ottawa and seven in Winnipeg. On those houses which showed significant spillage occurring, further work was undertaken to determine the effects of spillage on indoor air quality. This was done by using air sampling packages containing conventional aquarium pumps to draw air samples into mylar sample bags. The pumps were controlled by two output channels from the microcomputer. One pump was activated when a significant spillage event occurred and the other was on a regular time cycle so that "average" indoor contaminant levels could be determined.

Because of time and budget restraints, the project was limited to looking at "worst case" issues. The sample location was in an area near the furnace and near the ceiling (it was assumed that hot exhaust gases would tend to rise).

2.1 Unit Selection

The prime source of information on houses which had indications of spillage occurring was the data base built up by CMHC from previous projects. Initially, strong efforts were made to locate other spillage houses in the Ottawa area, as keeping the study within the Ottawa region would have a major impact on cost and flexibility.

CMHC supplied the names of nine houses that were "three dot failures" from their previous work (Reference 1). Of these, five agreed to the detailed monitoring program described in this report. Four other houses, with spillage frequencies, were found through contacts with the contractors who had carried out the previous study and through heating service firms. It soon became quite evident that finding additional houses was going to be a problem under the very tight time constraints of the contract, especially since these houses had to be found at the time of year when spillage was assumed less likely to occur (cold weather with frequent winds). Buchan, Lawton, Parent Ltd. was forced to look farther afield and made arrangements with G.K. Yuill and Associates in Winnipeg to contact some of the failure houses which had been located in Winnipeg during CMHC's previous work. Seven houses were found for the project in Winnipeg. BLP personnel went to Winnipeg to install the monitoring systems. On-site sampling and data gathering was carried out by personnel at G.K. Yuill and Associates.

House descriptions and data for each house covered in the program are included in Appendix A. Thirteen houses were gas heated and three were oil heated. Air quality monitoring was carried out in two of the oil heated houses and seven of the gas heated houses.

2.2 Monitoring Equipment

The key to providing the level of information required in this project at an acceptable cost was the use of standard microcomputers, specifically IBM PC clones, as the monitoring system. These were selected because they were readily available and inexpensive to rent. When equipped with dual floppy disk drives and a "multi-function card" (as they are normally available from suppliers), they have adequate storage capacity, the availability of a limited number of input channels (through the joystick controller portion of multi-function card), a real time clock (again on the multi-function card), and the ability to provide output signals (using the speaker connection and the "request to send" pin on the serial interface).

The monitoring systems and methods were designed around the capabilities and limitations of this building block. The games controller cards could provide four analog channels and four on-off status channels for data input. Because of some doubt about stability of the analog input, analog data recording was not attempted. On those sensors which provided analog signals, output was converted in software to status format based on field-settable threshold values. For example, when the measured resistance of a thermister fell below the set threshold, status was changed from off to on (cold to hot).

A description of the parameters measured and the type of sensors used are included in Table 2.1. It should be noted that some of the sensor selections were based on their availability within the time constraints, rather than selection of the best possible sensor for the application. If the equivalent system were to be used again, we would suggest some experimentation to see if thermistors could survive the undiluted flue

TABLE 2.1 MONITORING CHANNELS AND SENSORS	
Channel	Channel Description
1, 2	Door and Window Status: These are monitored on two channels (north/west and south/east side of the house) by non-contact magnetic switches with external wiring. All sensors are ganged so that the information recorded is limited to whether or not any one window or door is open on either of the two sides of the building.
3	Fireplace Status: Measured with a thermostatic switch placed in the chimney, approximately 1.2 metres from the top, on a length of pyrotenax cable. The wiring is again external.
4	Fan Status: Monitored with FM intercom transmitters wired in parallel to the fan. When the fan is turned on, a signal is sent from the intercom transmitter to the receiving unit housed in the data acquisition package. This approach eliminated the need for internal wiring.
5	Furnace Status: For liability reasons, a decision was made to keep our installation non-intrusive to the furnace systems themselves. Furnace status was being measured by a temperature sensor just upstream of the dilution air inlet. For simplicity and availability, a simple 100k resistor was chosen as the sensor. This provided adequate signal differential and response time although its absolute accuracy was obviously not the same as a more conventional temperature sensor. However, the repeatability was acceptable, so all this required was an on-site software calibration.
6	Furnace Spillage: For gas units, the spillage condition was detected by a thermister at the dilution air inlet. On all oil-fired units, a smoke detector unit was used.
7	Domestic Hot Water Status: Operation was done in the same manner as furnace operation.
8	Domestic Hot Water Spillage: Spillage was sensed in the same manner as furnace spillage.

temperatures used to determine combustion appliance status. The simple and readily available sensors used (standard 100k resistors) worked adequately, but were the most unreliable component in the system.

One novel technique used during this study proved successful beyond our wildest expectations. This was the use of the FM intercoms to monitor exhaust fan status. There was only one house out of the sixteen in which this approach was not possible. The use of the intercoms eliminated the need for any internal wiring in the house. Costs associated with using the intercom were probably equal to the cost of wiring but the benefits in terms of home owner co-operation and convenience were tremendous.

It should be noted that using the standard games controller to accept card inputs from sensors was not entirely straight forward, requiring software elements such as software filtering and minimum trapping to obtain adequate signal reliability and response times.

There was some concern about the risk of leaving an open, unattended computer system in the monitored houses. Consequently, painted plywood boxes were fabricated to house the microcomputer and keyboard. The monitor was left exposed on top of the box because it provided output information which the homeowner was requested to relay to us during phone calls. The box also housed a connection board which contained terminals for all connections, the intercom receiver and the electronic circuitry required for signal conditioning of the other sensors.

2.3 Monitoring Software

The monitoring software used was a relatively simple program. It was developed by D. Marshall at SRO for this project, and written in BASIC, the program scanned all eight input panels and the clock on a continuous basis. On the analog channels, the signal was compared against thresholds for conversion to status output. Data was only written to disk when a change in status was noted and at this time the status of all eight channels was written to disk in one line.

The program also controlled two output signals (the speaker and "Request to Send" channel of the serial interface), which we used to control the air sampling pump package described in Section 2.4. The control software had user-definable settings for on-delays, off-delays and sampling pump run times.

The threshold values used to convert analog signals to status were also user-settable.

The program was self-booting so that if there was a power failure or any other interruption, the system would self-boot, losing a minimum of data. Interruptions were recorded on a separate data file.

A sample of the data is shown as Figure 2.1. Each column represents one channel matching from left to right the channel definitions of Table 2.1.

Data analysis routines were developed to scan through this data at a rapid pace to find spillage incidents providing the edited data shown in Figure 2.2 and to produce the summary tables described in Section 3.2.1.

2.4 Air Sampling Equipment and Procedures

There were basically three types of air sampling carried out during the course of the project.

On all houses, usually during installation of the data acquisition system, Gastec absorption tubes were used to check for the presence of NO_2, NO_X and, in some cases, SO_2. This was done at two locations in the house, the basement near the furnace and in the living space, usually in the master bedroom. These samples were taken before and during a period of spillage forced by the use of a door fan or blocking of the flue. In cases where detectable quantities of any of these contaminants were found during the forced spillage tests, additional tube samples were carried out at the same locations a few minutes after the forced spillage was stopped. Samples of air were collected in mylar bags from near the furnace. These were shipped to Mann Testing Laboratories where gas chromatography analysis was used to determine concentrations of CO, CO_2, methane and non-methane hydrocarbons.

On houses which were showing spillage within the first two weeks of monitoring, an air sampling package was installed. In each package there were two aquarium-type diaphram pumps controlled by outputs from the data acquisition system via solid state relays. Air drawn by these two pumps was collected in ten litre, coated, mylar sample bags. One pump activated when the data acquisition system detected a spillage condition longer than a user settable time delay (usually set at 15 seconds). This pump ran for the duration of the spillage incident and over a settable "off" delay after

FIGURE 2.1 **Raw Data**

Time	Doors & Windows s/e	Doors & Windows n/w	Fireplace	Fans	Furnace Status	Furnace Spillage	DHW Status	DHW Spillage	Pump 1 (Spillage Furn)	Pump 2 (ambient indoor)
14:37:41	1	0	0	0	0	0	0	0	0	0
14:37:56	0	0	0	0	0	0	0	0	0	0
14:42:27	0	0	1	0	0	0	0	0	0	0
14:43:58	0	0	1	0	0	1	0	0	0	0
14:44:01	0	0	1	0	1	0	0	0	0	0
14:47:20	0	0	1	0	0	0	0	0	0	0
14:48:22	0	0	1	1	0	0	0	0	0	0
14:51:34	0	0	1	1	1	0	0	0	0	0
14:51:39	0	0	1	1	0	0	0	0	0	0
15:06:01	1	0	1	1	0	0	0	0	0	0
15:06:17	0	0	1	1	0	0	0	0	0	0
15:16:25	0	0	1	1	0	1	0	0	0	0
15:16:28	0	0	1	1	1	1	0	0	0	0
15:16:33	0	0	1	1	1	0	0	0	0	0
15:18:51	1	0	1	1	1	0	0	0	0	0
15:18:57	0	0	1	1	1	0	0	0	0	0
15:19:48	1	0	1	1	1	0	0	0	0	0
15:19:52	0	0	1	1	1	0	0	0	0	0
15:19:57	0	0	1	1	0	0	0	0	0	0
15:22:56	0	0	1	1	1	0	0	0	0	0
15:24:07	0	0	1	1	0	0	0	0	0	0
15:24:10	0	0	1	1	1	0	0	0	0	0
15:24:16	1	0	1	1	0	0	0	0	0	0
15:24:28	0	0	1	1	0	0	0	0	0	0
15:25:11	1	0	1	1	0	0	0	0	0	0
15:25:14	0	0	1	1	0	0	0	0	0	0
15:48:11	0	0	1	1	1	0	0	0	0	0
15:48:14	0	0	1	1	1	1	0	0	0	0
15:48:31	0	0	1	1	1	0	0	0	0	0
15:48:34	0	0	1	1	1	1	0	0	0	0
15:48:37	0	0	1	1	1	1	0	0	1	0
15:50:14	0	0	1	1	1	1	0	1	1	0
15:50:16	0	0	1	1	1	1	0	0	1	0
15:51:03	0	0	1	1	1	1	1	0	1	0
15:51:19	0	0	1	1	1	0	1	0	1	0
15:51:27	0	0	1	1	1	1	1	0	1	0
15:51:34	0	0	1	1	1	0	1	0	1	0
15:51:37	0	0	1	1	1	1	1	0	1	0
15:51:39	0	0	1	1	1	0	1	0	1	0
15:51:47	0	0	1	1	1	1	1	0	1	0
15:51:49	0	0	1	1	1	0	1	0	1	0
15:52:53	0	0	1	1	1	0	1	0	0	0
15:56:08	0	1	1	1	1	0	1	0	0	0

FIGURE 2.2 **Edited Data**

Time	Doors & Windows s/e	Doors & Windows n/w	Fireplace	Fans	Furnace Status	Furnace Spillage	DHW Status	DHW Spillage	Pump 1 (Spillage Furn)	Pump 2 (Ambient indoor)
03-14-1987	NEW DAY									
START EVENT					FURN!			DHW!PUMP!		
14:43:58	0	0	1	0	0	1	0	0	0	0
14:44:01	0	0	1	0	1	0	0	0	0	0
PUMP 1:EVENT		0.0	TOTAL		0.0	PUMP	2:TOTAL		0.0	
START EVENT					FURN!			DHW!PUMP!		
15:16:25	0	0	1	1	0	1	0	0	0	0
15:16:28	0	0	1	1	1	1	0	0	0	0
15:16:33	0	0	1	1	1	0	0	0	0	0
PUMP 1:EVENT		0.0	TOTAL		0.0	PUMP	2:TOTAL		0.0	
START EVENT					FURN!			DHW!PUMP!		
15:48:14	0	0	1	1	1	1	0	0	0	0
15:48:31	0	0	1	1	1	0	0	0	0	0
PUMP 1:EVENT		0.0	TOTAL		0.0	PUMP	2:TOTAL		0.0	
START EVENT					FURN!			DHW!PUMP!		
15:48:34	0	0	1	1	1	1	0	0	0	0
15:48:37	0	0	1	1	1	1	0	0	1	0
15:50:14	0	0	1	1	1	1	0	1	1	0
15:50:16	0	0	1	1	1	1	0	0	1	0
15:51:03	0	0	1	1	1	1	1	0	1	0
15:51:19	0	0	1	1	1	0	1	0	1	0
15:51:27	0	0	1	1	1	1	1	0	1	0
15:51:34	0	0	1	1	1	0	1	0	1	0
15:51:37	0	0	1	1	1	1	1	0	1	0
15:51:39	0	0	1	1	1	0	1	0	1	0
15:51:47	0	0	1	1	1	1	1	0	1	0
15:51:49	0	0	1	1	1	0	1	0	1	0

the incident ceased. The second pump was activated on a timed cycle and operated for 30 seconds every half hour. This pump was equipped with a metering valve and flow meter so that the flow rate could be set. The unrestricted flow rate of the pumps used was about one litre per minute which was deemed adequate for the spillage-controlled sample. For the timed sample it was adjusted to reduce this flow to approximately one half litre per minute to allow a 24 hour sample in the sample bag.

The bag samples were sent for analysis of CO, CO_2 and organics at Mann's testing lab in Toronto. A selected number of samples also underwent mass spectrography for a more complete analysis of the volatile organics.

It was recognized from the onset of this project that certain contaminants, notably nitrogen dioxide, could not be reliably analysed in a bag sample. Initial intentions were to draw samples through Gastec absorption tubes from the bags on-site, but even this was recognized as being somewhat unreliable because a sample could have been in the bag for up to 24 hours. With highly reactive nitrogen dioxide, this would be an excessive delay. While analysis for total oxides of nitrogen with Gastec tubes was also done, it was felt that, in those houses where significant spillage was occurring, it would be worthwhile to add additional effort to the nitrogen dioxide sampling. Consequently arrangements were made with the Ontario Research Foundation for the supply and analysis of a nitrogen dioxide sampler based on absorption of triethanolamine (TEA). These samplers are made up of three parts: the first contains a TEA impregnated molecular sieve which traps NO_2, the second is an oxidizer section which converts all NO to NO_2 and the last contains the impregnated mollecular sieve which traps the converted NO_2. Laboratory analysis to determine NO and NO_2 concentrations was done at ORF.

These tubes use a pump sampling approach and the procedure required modification of two sample packages by the addition of two pumps mounted parallel to the original two.

Flow rates were set using flow valves to approximately one half litre per minute. Pump sampling time was controlled by the same logic as the bag sampling trains.

The computer program automatically determined pump run time so that the required sample volume calculation could be readily made. There was some startup instability in the pump flow rates. The flow meters used for setting flow rates had a specified accuracy of +10% so there is some sample volume errors but we judge it to be well within +20% accuracy levels desired for this project.

2.5 Other Testing

Two other procedures were carried out to provide support data for the spillage monitoring and air quality monitoring activities.

Each house was subject to a fan depressurization test according to CGSB/CAN 149.10M86. In the Ottawa houses, this was done by Buchan, Lawton, Parent Ltd. technologists and in Winnipeg the work was sub-contracted to NRG Industries Ltd. Results of the testing were recorded on the house data sheets in Appendix A.

As support for the air quality data, it is desirable to know the actual air change rate of the buildings during the monitoring period, consequently, a time-averaged tracer gas testing procedure developed by Brookhaven National Labs was employed. In this procedure, two sources of a perfluorocarbon tracer gas were located in each of two zones of the building, in the basement and in the master bedroom. The sources used in the two zones emit, at a relatively constant rate, different tracer gases so that inter-zone mixing can also be determined. A sampler which absorbs the tracer gases was mounted in the same rooms as the sources and left in place for the entire period that air quality monitoring was taking place. These samplers are analysed by a thermal desorption/mass spectrographic process, from which one can calculate a time-averaged air change rate and inter-zone mixing.

Supply and analysis of the samplers was sub-contracted to the National Association of Home Builders' (NAHB) Research Center in Upper Marlboro, MD.

3.0 RESULTS

3.1 Field Experiences and Problems

As with any project of this magnitude, a number of problems had to be overcome during the course of the monitoring program. It is worth noting them in order to facilitate future use of equivalent techniques and as a reference to help in explaining any data irregularities. Problems that were encountered included:

3.1.1 Appliance Status Sensors

Appliance status was monitored by measuring the resistance of 100k resistors placed in the flue, upstream of the dilution air inlet. The signal varied enough over the temperature range of a flue that a discrete status symbol could be obtained.

While a more direct acting sensor such as the relay on the furnace would seem more appropriate, there were real concerns over liability issues. Any problems with the furnace systems whether or not they were directly caused by our actions could be blamed on the monitoring system. It was decided to use temperature as the status indicator.

The resistors were chosen after some experimentation because they were available in the very short time frames required, they could be measured with the games controller card and they could survive the undiluted flue temperatures.

With hindsight, we feel that the high temperature thermistors (600°C), could be a more appropriate sensor but the only supplier of these sensors had too few thermistors in stock for both the status and spillage indicators needed.

The resistor's reaction time was much slower than the tiny thermistors (which were virtually instantaneous) used for the spillage indicators, so there was some sensor delay (in general about 15 seconds on both the on and off cycle). This delay has to be taken into account in any data analysis.

The change in resistance with temperature was not great (about 10 percent) between exposure to ambient and flue temperatures. There was a certain amount of trial and error in finding the correct threshold settings to obtain a positive response to status change. Otherwise, in a plateau region the computer recorded an event every two or three seconds which rapidly filled up the disk with data. This problem was accented by the fact that the resistance sensors did drift significantly with time so field checking and calibration was necessary during site visits.

3.1.2 Inconsistent Output Signals

In this program sixteen different computers from three different suppliers were used at various times. All were IBM-PC clones, but there were some differences in how they were set up internally, notably with the speaker channel which was used as an output channel for the program. In the initial group of computers, we found that the output signal was strong, stable and acceptable for driving the solid state relay which turned on the sampling pumps.

In one of the latter systems in Ottawa and all of the systems in Winnipeg, it was found that this was not true. This channel produced a inconsistent signal creating varying pump flow rate. For the bag sampling this was not much of a problem since the measurement of bag samples were done based on concentration, so the absolute volume of samples didn't matter. On those houses where NO_2 sampling with the sorbent tube was used, knowledge of the actual pumped volume was critical. Plans included sampling for NO_2 on both spillage-controlled and timer-controlled sample trains. The inconsistent flow on the output used for the timer-controlled sample train reduced the NO_2 sampling to only one channel on two Winnipeg houses.

3.1.3 Sample Sizes

With the spillage controlled sample one can expect a great variation in sample size. A balance had to be drawn between sample volume flow and storage capacity. Ten and fifteen litre mylar bags were use for storage even though only about one litre was required for analysis. While there was some capacity to adjust the sample time delays and to a lesser extent, the flow rates, the time constraints of the project allowed only limited refinement of these parameters on an individual house. Because of the variation in sampling time, in some cases, unusably small samples were collected and, in other cases, bags were filled relatively rapidly, perhaps over one or two major spillage occurrences.

3.1.4 Lost Data

There were periods where data was lost. This can be traced to two sources.

In some cases, due to the problem described in section 3.1.1, disks were filled up much more rapidly than expected, and there was some elapsed time between the filling of the disks and site visits to replace them.

The second problem was encountered with the Winnipeg systems. On at least three occasions, the data could not be read from the disks. We suspect that it was some software compatibility problems in the operating system between the DOS system used in Ottawa and Winnipeg. In these cases, it was found that data was resident on the disks and could be read in a "block by block" fashion, however, the blocks were not always in chronological order. Procedures were set up to process the data in order to determine what happened over a period but the actual time of events was difficult to determine.

3.2 Monitoring Results

The basic data obtained in this project can be broken down into three categories: house and occupant characteristics, spillage frequency and duration data, and air quality data.

A summary of all data on a case study basis is included, by house, in Appendix A. For each house one will find:

- a description of the house and occupant characteristics including the floor plan,
- a series of tables analysing the operation and spillage data, and
- air quality sampling results.

Three types of tables are included to summarize operation and spillage data.

The first table shows the frequency and duration of significant spillage events. A significant spillage event was defined as 10 seconds of spillage (as determined from the spillage sensor) for a gas heated house and 5 seconds for an oil heated house.

The second table shows the effect of aggrevating conditions during spillage. In this table, the number of events and total time is binned in combinations of the aggrevating appliance status. These were defined as operation of the fireplace or woodstove, operation of any exhaust fans and the operation of the other fuel-fired appliance (furnace or DHW tank). The percentage of time that the house operated in any of the eight bin conditions is also shown. This allows assessment of the significance of the spillage data in relation to total time. The last column in this table shows the number of spillage occurrences recorded when any of the windows or doors were open. This information should be used very carefully since the normal operation of the house in the winter is, of course, with the windows closed.

Air quality data is presented in a single table for each house. On this chart, you will find the results of all contaminant sampling, including results of tube-type sampling, bag samples or the pumped sorbent tube sampling far NO_2.

3.2.1. Operation and Spillage Data

Table 3.1 summarizes the number of monitored days, the number of days of data available and the number of days that were analysed in the above described charts of frequency, duration and aggrevating factors. A total of 363 days of monitoring was done. Approximately eleven percent of the data was lost due to problems mentioned in Section 3.1. Analysis for duration and aggrevating conditions data was only done on those disks where some spillage was recorded. This accounted for 96 days of data.

Of the five houses with spillage, it was very obvious that one (location code 02) spillage was almost exclusively driven by the fireplace. In fact, since the flue for the fireplace and the gas appliances are side by side, the fireplace smoke would get drawn down the appliance stack and into the house through the dilution air inlet of the gas DHW system.

In one other location (W1), the spillage seemed driven by other exhausting appliances, notably exhaust fans.

In three houses 03, 06 and W4, spillage occurred regularly, even in the absence of aggrevating conditions.

In two of the oil heated houses (05, 07), only short spillage incidents were recorded. This is consistent with the "startup puffs" one would expect with a powered burner system. There was some statistical correlation with aggrevating factors on a percentage of time basis but this spillage still occurred when the aggrevating factors were not present.

Figures 3.1 and 3.2 show how spillage occurrences correlate with AES weather data. On these plots, daily maximum and minimum temperature and

TABLE 3.1
MONITORING HISTORY

OTTAWA

Location Code	Oil Heated Houses	Spillage occurrence (N/Y)	Total Days Monitored	Days Data Available	Days Data Analysed
01		N	16	16	0
02		Y	28	27	12
03		Y	19	12	12
04	0	N	14	14	0
05	0	Y	29	19	10
06		Y	35	30	19
07	0	Y	27	21	17
08		N	16	16	0
09		N	16	16	0
	Ottawa Totals		200	171	70

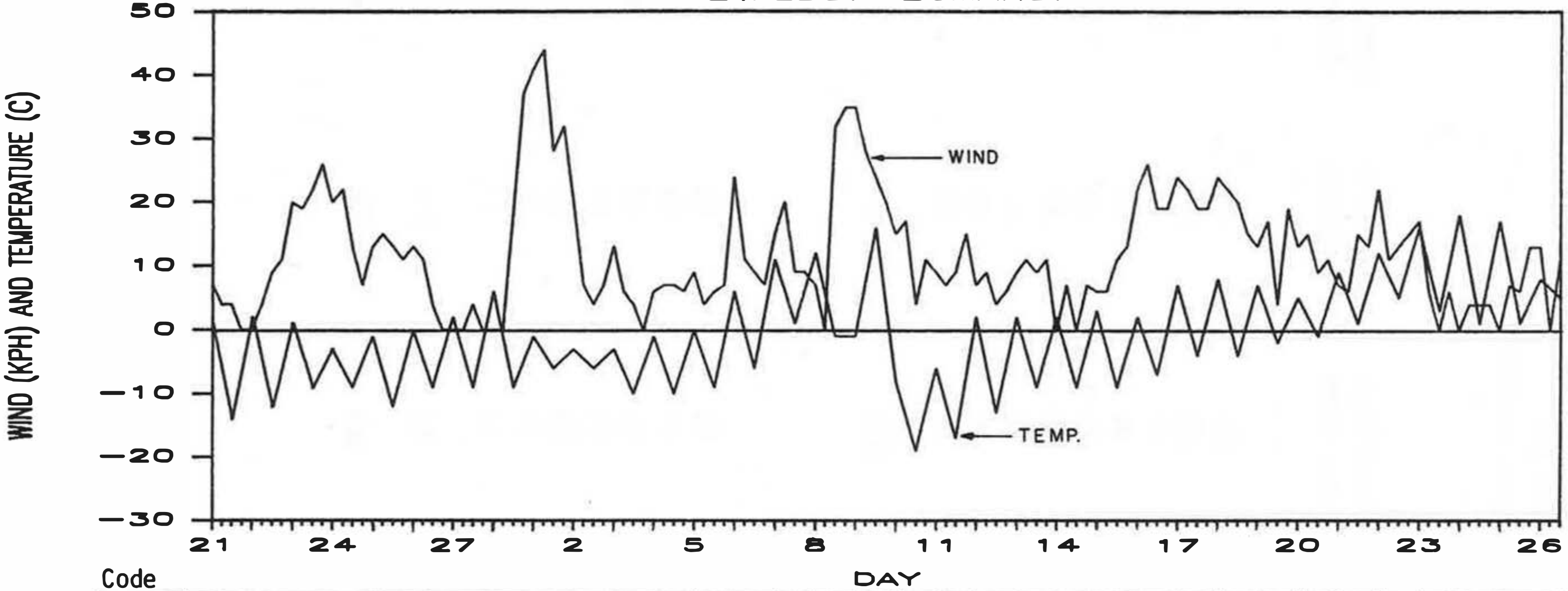
WINNIPEG

W1		Y	33	33	11
W2		N	29	29	0
W3		N	16	16	0
W4		Y	25	19	15
W5		N	28	28	0
W6		N	19	15	0
W7		N	13	11	0
	Winnipeg Totals		163	151	26
	Project Totals		363	322	96

FIGURE 3.1

OTTAWA WEATHER DATA

21FEB87—26MAR87



Code		21	22	23	24	25	26	27	28	1	2	3	4	5	6	7	8
02	N		34														
	D																
03	N	/	/	/	8	7		8	11		/	/	/	/	19	12	3
	D	/	/	/	7	31		3	27	1	/	/	/	/	11	19	18
05	N	/	/	/	/	/	/	/	/	/	/	/	/	/	2		2
	D	/	/	/	/	/	/	/	/	/	/	/	/	/	1		
06	N	/	/	/	/	/	/	/	/	/	/	20	13	17	8	11	
	D	/	/	/	/	/	/	/	/	/	/	9	18	14	14	9	9
07	N	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
	D	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/

Code		9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
02	N								/	/	/	/	/	/	/	/	/	/	/
	D			4	2			2	/	/	/	/	/	/	/	/	/	/	/
03	N	14	9	7	22	14	12		/	/	/	/	/	/	/	/	/	/	/
	D	25	17	19	28	32	29	8	/	/	/	/	/	/	/	/	/	/	/
05	N																/	/	/
	D	7	1	3	2		1										/	/	/
06	N	/	/	/	/	23	25	24	36	32	9	13	14	7	3	3	1	2	8
	D	/	/	/	/		12	10	24	18	10	11	17	12	4	5	3	7	14
07	N	/																	
	D	/	2		6	1			1	1	1	2				1			

Chart shows number of spillage occurrences in the Ottawa sample per 12 hour period

/ Indicates no monitoring

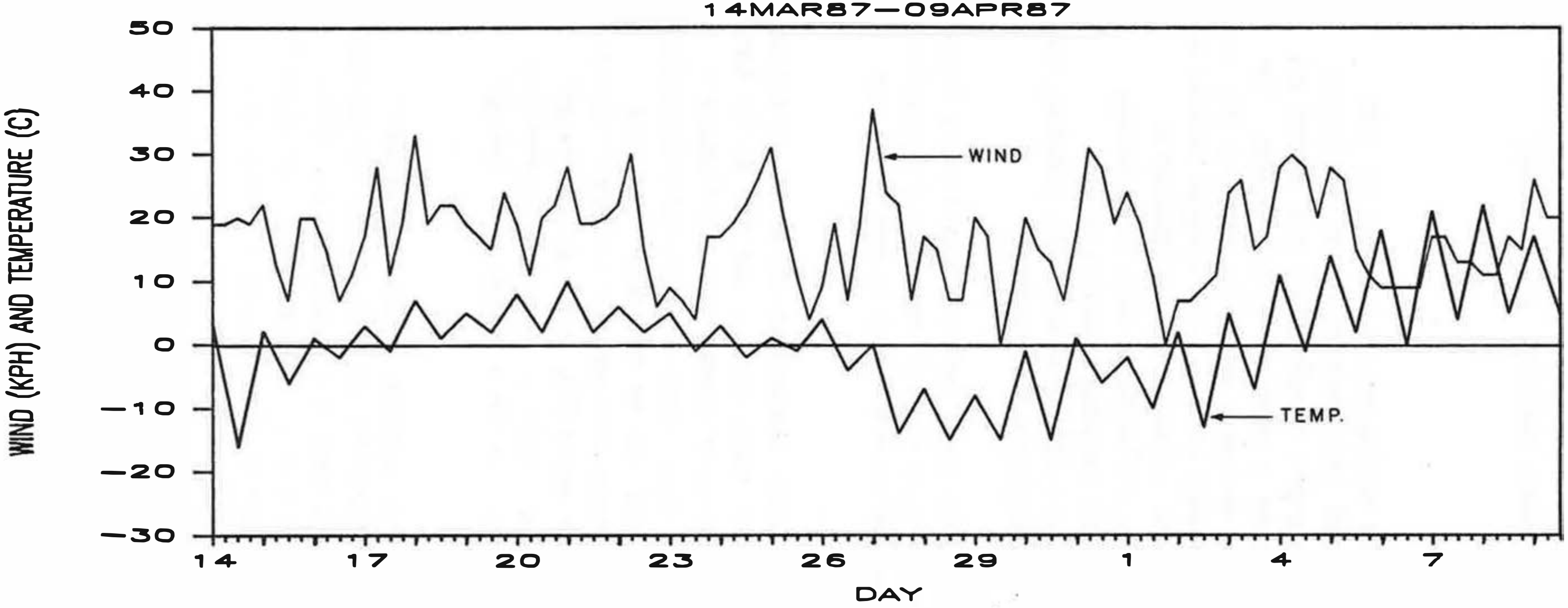
D = Day 07:00hr. — 19:00hr.

N = Night 19:00hr. — 07:00hr.

FIGURE 3.2

WINNIPEG WEATHER DATA

14MAR87—09APR87



Code

WI	N																											
	D				26		3			11		9																
W4	N	/	/	/	/	11		14	8	63	20	10	/	/	/	/	/			6	5	2	9	4	4	1		
	D	/	/	/	/	2	22			5	4	4	/	/	/	/	/			3	16	22	6	31	15	3	5	

Chart shows total number of spillage occurrences in the Winnipeg sample per 12 hour period

/ Indicates no monitoring

D = Day 07:00hr. — 19:00hr

N = Night 19:00hr. — 07:00hr.

wind speed every six hours is plotted. Any direct correlation to wind and temperature is indiscernible with the data available. It is probably overwhelmed by other factors.

3.2.2 Air Quality Testing Results

Appendix A has a summary of quality testing results included for each house. The first three sections of this table show results of the Gastec tube-type sampling and gas chromotography sampling that was carried out before, during, and in some cases, after a period of forced spillage. The last two sections show results of the computer controlled sampling that was carried out in those houses which showed spillage. The samples labelled as "controlled" were drawn during spillage incidents and one labelled as "timed" was on a regular time cycling and could be considered average indoor levels. The computer controlled sampling consisted of gas chromotography analysis, in some cases NO/NO_2 sorbent tube sampling, and in three cases a more complete scan using mass spectography.

In a number of cases, it was impossible to do both a pre-spill and a forced spill bag sample because the long delivery time of bags from the supplier. In these cases only one sample was taken, the forced sample which was deemed more important.

Table 3.2 presents the maximum readings recorded on any of the 16 houses covered under the program. From this table, one can see that in the forced spillage tests, a fairly high reading of some contaminants, particularly CO_2 and SO_2, were recorded but, in cases where naturally occurring spillage was monitored, contaminant levels would not be considered hazardous according to current standards and proposed Health and Welfare Guidelines. Interestingly, in many houses with the worst CO_2 levels during "forced" spillage did not spill during monitoring. Table 3.3 provides a comparison of "forced" and "natural" spillage results on those houses which did spill "naturally".

The results of the three samples which underwent mass spectographic analysis (Houses O2, O3, W4) are included in Appendix A with the relevant house. In general, levels of all VOC's were in the sub-parts per billion range, and no "concern" levels of any compound were found. The Mann Testing Laboratories' report is included as Appendix B. It should be noted, when viewing the sample results, that the SO_2 peak is the result of a system contaminant from the thermal desorption process and does not indicate the presence of this contaminant in the sample.

3.2.3 Air Change Testing Results

The NAHB-produced results of the long term tracer gas testing are included in Appendix C. The measured, overall air change for the tested houses were:

House	AC/h
02	.263
03	.239
05	.010 *
06	.688
07	.449
W1	.329
W4	.378
W7	.229

* Impurities found in sample. Ignore result.

For detailed results, including inter-zone exchange rates, refer to Appendix C.

TABLE 3.2

MAXIMUM CONTAMINANT READINGS

Spillage Type	Location	SORBENT TUBES NO_2 (ppm)	SORBENT TUBES NO (ppm)	GASTEC TUBES NO_2 (ppm)	GASTEC TUBES NO_x (ppm)	GASTEC TUBES SO_2 (ppm)	BAG SAMPLES CO (ppm)	BAG SAMPLES CO_2 (ppm)	BAG SAMPLES CH_4 (ppm)	BAG SAMPLES H.C* (ppm)
Pre-spill	near furnace			0	0	0	1.9	1249	4	2.7
	living space			0	0	0				
Forced	near furnace			0.6	7.5	0.2	5.3	6634	4.4	2.9
	living space			Trace	Trace	0.25				
Post Spill	near furnace			0	Trace	0.1				
	living space			0	Trace	0.13				
Controlled	at furnace	0.76	0.366	-	-	-	3.7	1590	12.9	9.9
Timed	at furnace	0.58	0.079	-	-	-	2.7	983	7.7	5.1

* H.C. - non methane hydrocarbons.

TABLE 3.3

COMPARISON OF 'FORCED' AND 'NATURAL' SPILLAGE CONTAMINANT LEVELS

House Code	Forced/ Controlled	CO	CO_2	CH_4	H.C.
02	Forced	1.2	1826	2.5	1.7
	Controlled	2.9-3.7	697-1045	1.9-2.2	1.5-2.1
03	Forced	Bag Damaged in Transit			
	Controlled	0.8-2.8	621-968	1.6-4.6	1.4-6.0
05	Forced	1.6	528	1.5	0.9
	Controlled	1.0	462	1.6	2.1
06	Forced	0.8	838	4.4	1.2
	Controlled	1.1-2.4	702-827	8.5-12.9	1.4-1.5
W1	Forced	0.1	503	2.8	2.9
	Controlled	0.8	646	2.5	2.7
W4	Forced	5.3	1998	2.9	1.4
	Controlled	0.5	570-1590	1.7-3.8	1.5-1.9

4.0 COMMENTS AND CONCLUSIONS

Although there were some problems expected during first time use of any field system, the low-cost, PC-based monitoring system used in the project worked remarkably well. We feel that this approach could be very useful for equivalent research projects, which require a limited amount of status-type data over a period in which capital and installation costs of a more complex data acquisition system are difficult to justify.

Considering that the houses monitored were pre-selected to be those in which spillage incidents were thought to have occurred, remarkably few actually had significant spillage events. While one could hypothesize that this was due to misleading data from the previous surveys, it is also likely that, for a large number of cases, the combination of environmental and house operation characteristics most condusive to the spillage are relatively rare, and that in the monitoring period, these conditions did not present themselves.

In examining the contributing factors to spillage problems, we are somewhat limited in our data. The possible correlation with temperature and wind effects is not immediately evident. The airtightness and air change testing data was collected to allow analysis of these effects. There has been no attempts at employing the results in correlations, as the effects of outside temperature and wind were marginal in the monitored houses. Applicance or venting system configuration and the effect of exhausting appliances are more strongly related to spillage incidents.

In two houses, spillage was directly related to the use of exhausting appliances. In three others, spillage commonly occurred even when exhausting appliances were off, suggesting that poor chimney action is the most important contributing factor.

In examining the effect of spillage on the indoor air quality, it is apparent, from the forced spillage testing that unacceptably high levels of some contaminants, particularily CO_2 and SO_2, are possible when full spillage is occurring, as it was in our forced tests.

On the other hand, the observed effects of naturally occurring spillage were not dramatic. Results indicate a percentage rather than multiple increase in the levels of contaminants. None of the readings exceeded industrial standards or proposed Health and Welfare Guidelines for residential indoor air contaminant levels.

Therefore, while the forced testing would indicate that the potential for hazardous levels is possible, the monitoring results indicate that such hazardous levels should be rare.

REFERENCES

1. RESIDENTIAL COMBUSTION VENTING FAILURE - A SYSTEMS APPROACH
   Scanada Sheltair Consortium, for CMHC, 1987

APPENDIX A

House Data

LEGEND FOR AIR QUALITY

NO = Nitric Oxide
NO_2 = Nitrogen Dioxide
NO_x = other Oxides of Nitrogen
SO_2 = Sulpher Dioxide
CO = Carbon Monoxide
CO_2 = Carbon Dioxide
CH_4 = Methane
H.C.= Non Methane Hydrocarbons
O_2 = Oxygen

HOME PROFILE

1. HOUSE IDENTIFICATION: No. O-1

2. HOUSE DESCRIPTION:

   Total Floor Area: 206 m^2, two storey, semi-detached

3. SPACE HEATING:

   Fuel: natural gas
   Heat Distribution: forced air
   Location: open basement

4. DOMESTIC HOT WATER HEATING:

   Fuel: natural gas
   Location: adjacent to furnace

5. SUPPLEMENTARY COMBUSTION SYSTEMS:

   Type: fireplace
   Fuel: wood
   Frequency of Use: once per winter month
   Chimney Type: masonry

6. EXHAUST FANS FREQUENTLY USED:

   clothes dryer
   bathroom
   central vacuum

7. DOORS/WINDOWS FREQUENTLY USED:

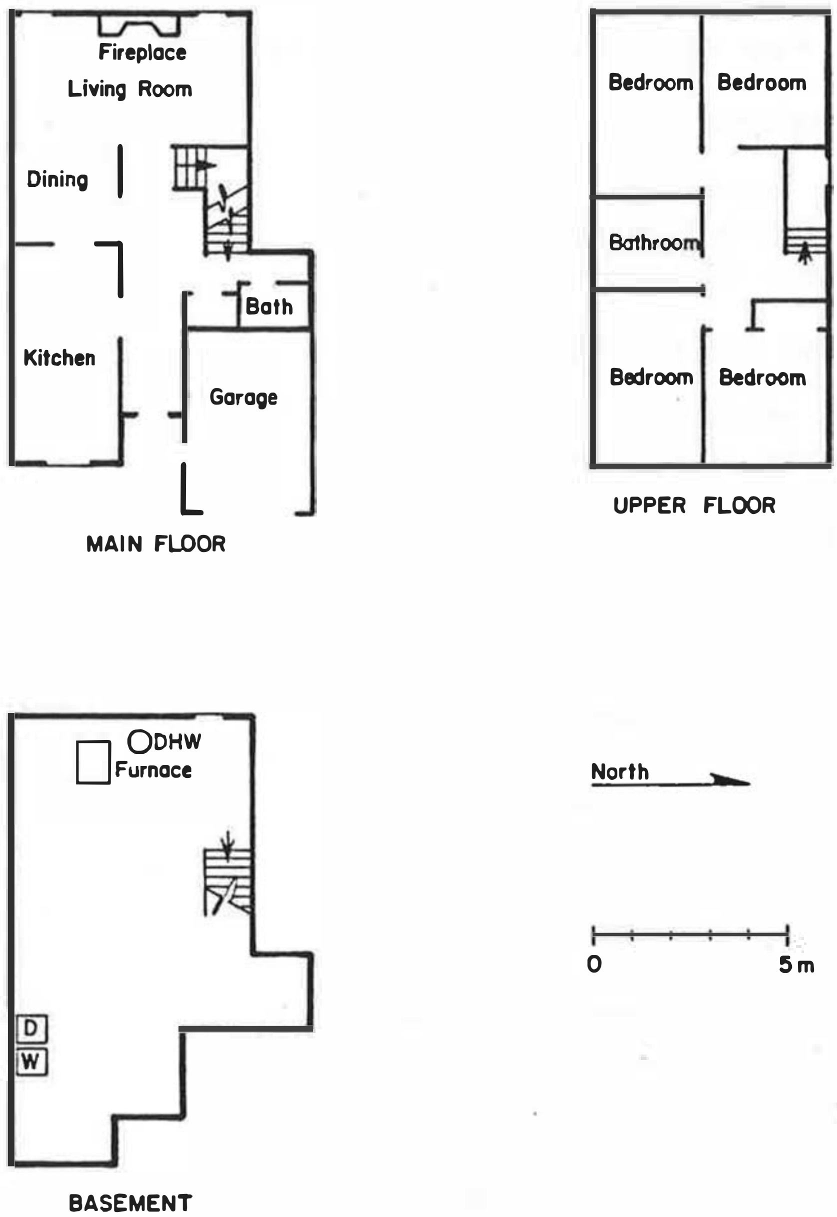
   main entrance
   back door

8. FAN TEST CHARACTERISTICS:

   6.81 Air Changes per Hour (@ 50 Pa)
   0.098 Equivalent Leakage Area (m^2)

9. HOMEOWNER PROFILE:

   Occupants 18 years and older: 4
   Occupants under 18 years: 1
   Number of occupants who smoke: 1


Fireplace
Living Room
Dining
Kitchen
Bath
Garage
MAIN FLOOR
Bedroom
Bedroom
Bathroom
Bedroom
Bedroom
UPPER FLOOR
DHW
Furnace
D
W
BASEMENT
North
0
5 m

HOUSE O-1

Air Analysis Results of Residential Combustion Spillage Monitoring

Address: 01 City: Ottawa Fuel Type: Gas

SPILLAGE TYPE	Date	---Location---	---GASTEC Tubes--- NO2 (ppm)	NOx (ppm)	SO2 (ppm)	---Bag Samples--- CO (ppm)	CO2 (ppm)	CH4 (ppm)	H.C (ppm)	O2 (%)	Sorbent Tubes NO2 (ppm)	NO (ppm)	Pump Time (sec.)
PRE SPILL	Feb 11	At furnace	0	0									
		Opp.end of bsmt	0	0									
FORCED	Feb 11	At furnace	0	0		1.1	750	4.4	0.9	21			
		Opp.end of bsmt	0	0									
POST SPILL	Feb 11	At furnace	0	0									
		Opp.end of bsmt.											

HOME PROFILE

1. HOUSE IDENTIFICATION: No. O-2

2. HOUSE DESCRIPTION:

   Total Floor Area: 204 m^2, two storey, single detached

3. SPACE HEATING:

   Fuel: natural gas
   Heat Distribution: forced air
   Location: open basement

4. DOMESTIC HOT WATER HEATING:

   Fuel: natural gas
   Location: adjacent to furnace

5. SUPPLEMENTARY COMBUSTION SYSTEMS:

   Type: fireplace
   Fuel: wood
   Frequency of Use: once per winter week
   Chimney Type: masonry

6. EXHAUST FANS FREQUENTLY USED:

   clothes dryer
   master bedroom bathroom
   upstairs bathroom

7. DOORS/WINDOWS FREQUENTLY USED:

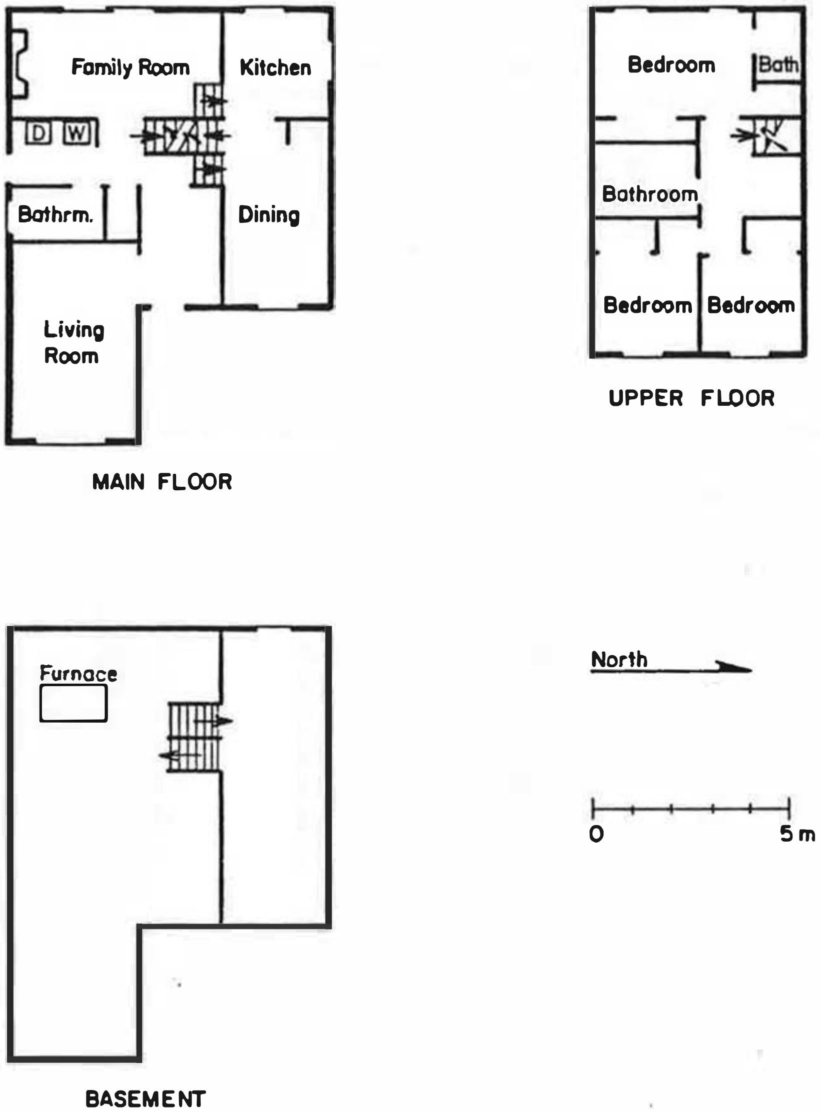
   main entrance
   side door
   kitchen windows

8. FAN TEST CHARACTERISTICS:

   3.79 Air Changes per Hour (@ 50 Pa)
   0.070 Equivalent Leakage Area (m^2)

9. HOMEOWNER PROFILE:

   Occupants 18 years and older: 2
   Occupants under 18 years: 0
   Number of occupants who smoke: 1


Family Room
Kitchen
D
W
Bathrm.
Dining
Living Room
MAIN FLOOR
Bedroom
Bath
Bathroom
Bedroom
Bedroom
UPPER FLOOR
Furnace
BASEMENT
North
0
5 m

HOUSE O-2

Location Code:02
Start date:10FEB87   End date:22FEB87
Total Number of Days Analyzed in these Tables: 4
Total Number of Days Monitored for this House:28

TABLE1:FREQUENCY AND DURATION OF SPILLAGE EVENTS

Spillage time Interval (sec)	Total Spillage Events Furnace	DHW	Total
10-29	0	21	21
30-120	0	9	9
>120	0	4	4
Total	0	34	34

TABLE 2:AGGRAVATING CONDITIONS DURING SPILLAGE EVENTS

List of Conditions Fireplace	Fan	Other Devices	% Time Condition True	Spillage Events Totals	Time(min)	Total Window Open Occurrences
OFF	OFF	OFF	87.724	0	0.00	0
OFF	ON	OFF	6.962	0	0.00	0
OFF	OFF	ON	0.746	0	0.00	0
OFF	ON	ON	0.717	0	0.00	0
ON	OFF	OFF	3.737	31	34.25	1
ON	ON	OFF	0.075	1	19.92	0
ON	OFF	ON	0.037	1	0.18	0
ON	ON	ON	0.000	1	1.88	0
			TOTAL:	34	56	

note:column '% Time Condition True' has device status forced on if device is spilling

Location Code: 02
Start date:07MAR87   End date:15MAR87
Total Number of Days Analyzed in these Tables: 9
Total Number of Days Monitored for this House:28

TABLE1:FREQUENCY AND DURATION OF SPILLAGE EVENTS

Spillage time Interval (sec)	Total Spillage Events Furnace	DHW	Total
10-29	2	2	4
30-120	0	0	0
>120	2	2	4
Total	4	4	8

TABLE 2:AGGRAVATING CONDITIONS DURING SPILLAGE EVENTS

List of Conditions Fireplace	Fan	Other Devices	% Time Condition True	Spillage Events Totals	Time(min)	Total Window Open Occurrences
OFF	OFF	OFF	80.388	1	0.25	0
OFF	ON	OFF	4.401	0	0.00	0
OFF	OFF	ON	0.222	0	0.00	0
OFF	ON	ON	0.481	0	0.00	0
ON	OFF	OFF	11.217	0	0.00	0
ON	ON	OFF	3.034	4	22.50	2
ON	OFF	ON	0.000	0	0.00	0
ON	ON	ON	0.257	3	41.37	2
			TOTAL:	8	64	

note:column '% Time Condition True' has device status forced on if device is spilling

Air Analysis Results of Residential Combustion Spillage Monitoring

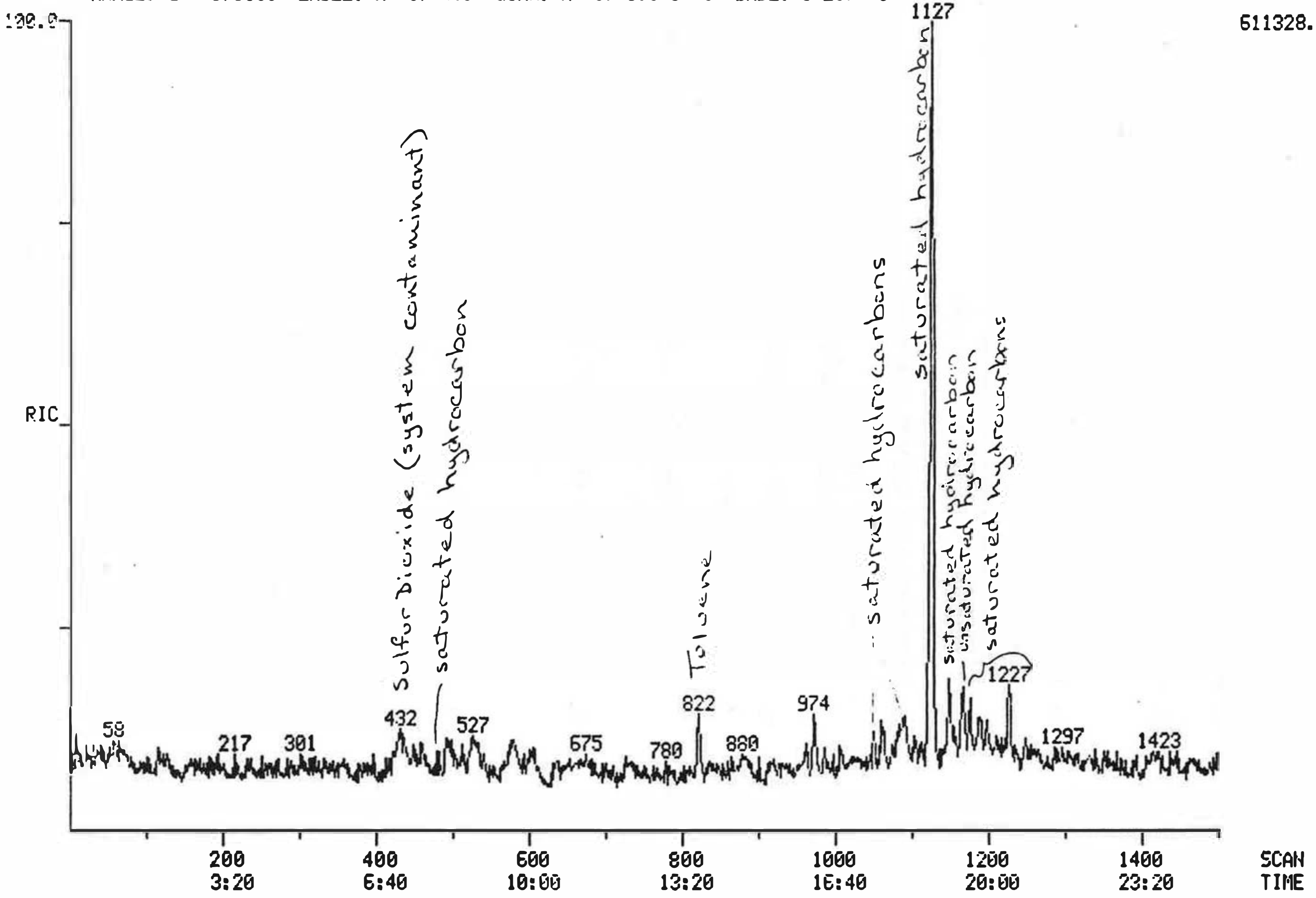
Address: 02 City: Ottawa Fuel Type: Gas

SPILLAGE TYPE	Date	---Location----	---GASTEC Tubes---- NO2 (ppm)	NOx (ppm)	SO2 (ppm)	------------Bag Samples-------- CO (ppm)	CO2 (ppm)	CH4 (ppm)	H.C (ppm)	O2 (%)	Sorbent Tubes NO2 (ppm)	NO (ppm)	Pump Time (sec.)
PRE SPILL	Feb.16	beside furnace	0	0	0								
		master bedroom											
FORCED	Feb.16	At furnace	0	0	0	1.2	1826	2.5	1.7	21			
		master bedroom	0	0									
POST SPILL	Feb.16	At furnace	0	0									
		master bedroom											
CONTROLLED	Mar.12-14	At furnace				2.9	697	1.9	2.1	21			71
	Mar.14-16	"	* M.S.*			3.7	1045	2.2	1.5	21			255
					AVG.	3.3	871	2.05	1.8	21			
TIMED	Mar.12-14	At furnace				1.2	595	1.9	1.2	21			300
	Mar.14-16	"				1.3	600	1.9	1.7	21			480
					AVG.	1.25	598	1.9	1.45	21			

NOTE : M.S. = MASS SPECTROMETER DONE.

HOUSE O-2

RIC   DATA: HQ5158 #1   SCANS   1 TO 1500
03/29/87 0:04:00   CALI: CQ5146 #10
SAMPLE: SAMPLE BAG #34 - 50ML INJECTED
CONDS.: SE30 30M, 50-200C @ 10C/MIN INIT. HOLD FOR 4MIN
RANGE: G   1,1500 LABEL: N 0, 4.0 QUAN: A 0, 1.0 J 0 BASE: U 20, 3



HOME PROFILE

1. HOUSE IDENTIFICATION: No. O-3

2. HOUSE DESCRIPTION:

   Total Floor Area: 186 m^2, one storey, single detached

3. SPACE HEATING:

   Fuel: natural gas
   Heat Distribution: forced air
   Location: enclosed furnace room

4. DOMESTIC HOT WATER HEATING:

   Fuel: natural gas
   Location: adjacent to furnace

5. SUPPLEMENTARY COMBUSTION SYSTEMS:

   Type: fireplace
   Fuel: wood
   Frequency of Use: once per year
   Chimney Type: masonry

   Type: woodstove
   Fuel: wood
   Frequency of use: daily
   Chimney Type: insulated metal

6. EXHAUST FANS FREQUENTLY USED:

   clothes dryer
   kitchen range

7. DOORS/WINDOWS FREQUENTLY USED:

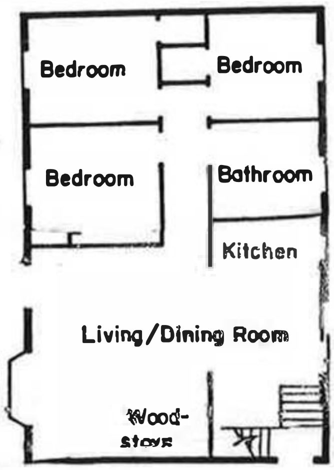
   main entrance
   side door
   kitchen door
   front bedroom

8. FAN TEST CHARACTERISTICS:

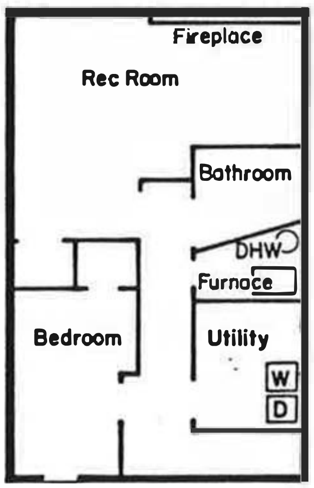
   5.3 Air Changes per Hour (@ 50 Pa)
   0.082 Equivalent Leakage Area (m^2)

9. HOMEOWNER PROFILE:

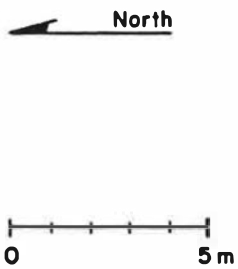
   Occupants 18 years and older: 4
   Occupants under 18 years: 1
   Number of occupants who smoke: 0



MAIN FLOOR



BASEMENT



HOUSE O-3

Location Code: 03
Start date:24FEB87 End date:26FEB87
Total Number of Days Analyzed in these Tables: 2
Total Number of Days Monitored for this House:19

TABLE1:FREQUENCY AND DURATION OF SPILLAGE EVENTS

Spillage time Interval (sec)	Total Spillage Events Furnace	DHW	Total
10-29	11	22	33
30-120	0	5	5
>120	1	14	15
Total	12	41	53

TABLE 2:AGGRAVATING CONDITIONS DURING SPILLAGE EVENTS

List of Conditions Fireplace	Fan	Other Devices	% Time Condition True	Spillage Events Totals	Time(min)	Total Window Open Occurrences
OFF	OFF	OFF	14.650	3	0.73	0
OFF	ON	OFF	6.449	7	37.48	2
OFF	OFF	ON	0.855	1	0.17	1
OFF	ON	ON	0.650	0	0.00	0
ON	OFF	OFF	28.820	4	1.47	0
ON	ON	OFF	46.436	24	61.50	3
ON	OFF	ON	1.887	9	15.27	3
ON	ON	ON	0.253	5	49.28	1
			TOTAL:	53	166	

note:column '% Time Condition True' has device status forced on if device is spilling

Location Code:03
Start date:27FEB87   End date:01 MAR87
Total Number of Days Analyzed in these Tables: 2
Total Number of Days Monitored for this House:19

TABLE1:FREQUENCY AND DURATION OF SPILLAGE EVENTS

Spillage time Interval (sec)	Total Spillage Events Furnace	DHW	Total
10-29	15	17	32
30-120	1	8	9
>120	0	9	9
Total	16	34	50

TABLE 2:AGGRAVATING CONDITIONS DURING SPILLAGE EVENTS

List of Conditions Fireplace	Fan	Other Devices	% Time Condition True	Spillage Events Totals	Time(min)	Total Window Open Occurrences
OFF	OFF	OFF	29.355	7	37.02	3
OFF	ON	OFF	28.465	7	2.22	1
OFF	OFF	ON	0.235	5	2.82	0
OFF	ON	ON	0.131	2	20.43	0
ON	OFF	OFF	16.375	6	1.63	0
ON	ON	OFF	25.203	20	46.27	9
ON	OFF	ON	0.028	0	0.00	0
ON	ON	ON	0.208	3	3.28	0
			TOTAL:	50	114	

note:column '% Time Condition True' has device status forced on if device is spilling.

Location Code:03
Start date:06MAR87 End date:16MAR87
Total Number of Days Analyzed in these Tables: 9
Total Number of Days Monitored for this House:19

TABLE1:FREQUENCY AND DURATION OF SPILLAGE EVENTS

Spillage time Interval (sec)	Total Spillage Events Furnace	DHW	Total
10-29	88	123	211
30-120	2	25	27
>120	0	80	80
Total	90	228	318

TABLE 2:AGGRAVATING CONDITIONS DURING SPILLAGE EVENTS

List of Conditions Fireplace	Fan	Other Devices	% Time Condition True	Spillage Events Totals	Time(min)	Total Window Open Occurrences
OFF	OFF	OFF	70.229	182	490.02	42
OFF	ON	OFF	2.977	21	57.88	2
OFF	OFF	ON	0.348	19	70.30	3
OFF	ON	ON	0.029	6	24.75	0
ON	OFF	OFF	22.640	57	177.83	6
ON	ON	OFF	3.602	21	61.00	1
ON	OFF	ON	0.144	12	28.65	5
ON	ON	ON	0.031	0	0.00	0
		TOTAL:		318	910	

note:column '% Time Condition True' has device status forced on if device is spilling

Air Analysis Results of Residential Combustion Spillage Monitoring

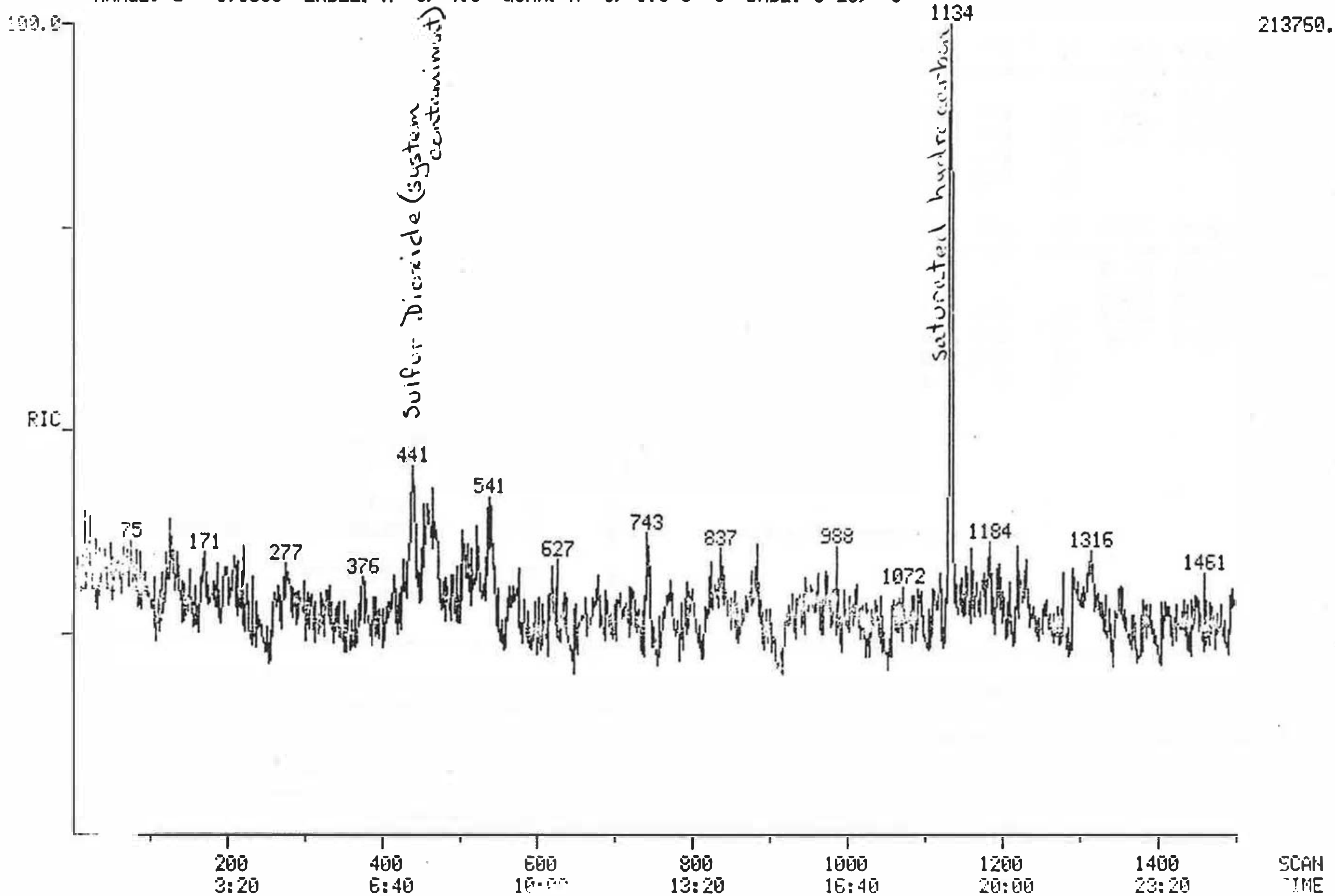
Address: 03 City: Ottawa Fuel Type: Gas

SPILLAGE TYPE	Date	---Location----	---GASTEC Tubes---- NO2 (ppm)	NOx (ppm)	SO2 (ppm)	------------Bag Samples-------- CO (ppm)	CO2 (ppm)	CH4 (ppm)	H.C (ppm)	O2 (%)	Sorbent Tubes NO2 (ppm)	NO (ppm)	Pump Time (sec.)
PRE SPILL	Feb.24	At furnace	0	0		Trace	774	1.6	0.6	21			
		Living room	0	0									
FORCED	Feb.24	At furnace	0.3	0		Sample bag damaged in transit							
		Living room	0	0									
POST SPILL	Feb.24	At furnace	0										
		Living room											
CONTROLLED	Mar.5-7	At furnace				2.8	937	4.3	6	21			3000
	Mar.7-9	"				1.8	968	4.6	5.1	21			10420
	Mar.9-12	"	* M.S.*			0.8	621	1.6	1.8	21	N.D.	0.034	1254
	Mar.12-13	"				1.1	690	1.8	1.4	21	0.014	0.102	3483
	Mar.13-14	"									0.025	0.116	3724
	Mar.14-16	"									0.006	0.093	1244
					AVG.	1.625	804	3.1	3.6	21	0.011	0.086	
TIMED	Mar.5-7	At furnace				2.7	876	2.7	5.1	21			
	Mar.7-9	"				0.9	791	3	4.3	21			570
	Mar.9-12	"				0	534	3	1.5	21	N.D.	0.023	270
	Mar.12-13	"				1.1	687	2.4	1.5	21	0.007	0.058	660
	Mar.13-14	"									N.D.	0.079	600
					AVG.	1.2	722	2.85	3.1	21	0.007	0.053	

NOTE: N.D. = NONE DETECTED
M.S. = MASS SPECTROMETER DONE.

HOUSE 0-3

RIC
03/28/87 20:55:00
DATA: HQ5162 #1
CALI: CQ5146 #10
SCANS 1 TO 1500
SAMPLE: SAMPLE BAG #22 - 50ML INJECTED
CONDS.: SE30 30M, 50-200C @ 10C/MIN INIT. HOLD FOR 4MIN
RANGE: G 1,1500 LABEL: N 0, 4.0 QUAN: A 0, 1.0 J 0 BASE: U 20, 3



HOME PROFILE

1. HOUSE IDENTIFICATION: No. O-4

2. HOUSE DESCRIPTION:

   Total Floor Area: 250 m^2, one storey, single detached

3. SPACE HEATING:

   Fuel: oil
   Heat Distribution: forced air
   Location: open basement

4. DOMESTIC HOT WATER HEATING:

   Fuel: electric
   Location: basement

5. SUPPLEMENTARY COMBUSTION SYSTEMS:

   Type: fireplace
   Fuel: wood
   Frequency of Use: once per winter week
   Chimney Type: masonry

6. EXHAUST FANS FREQUENTLY USED:

   none

7. DOORS/WINDOWS FREQUENTLY USED:

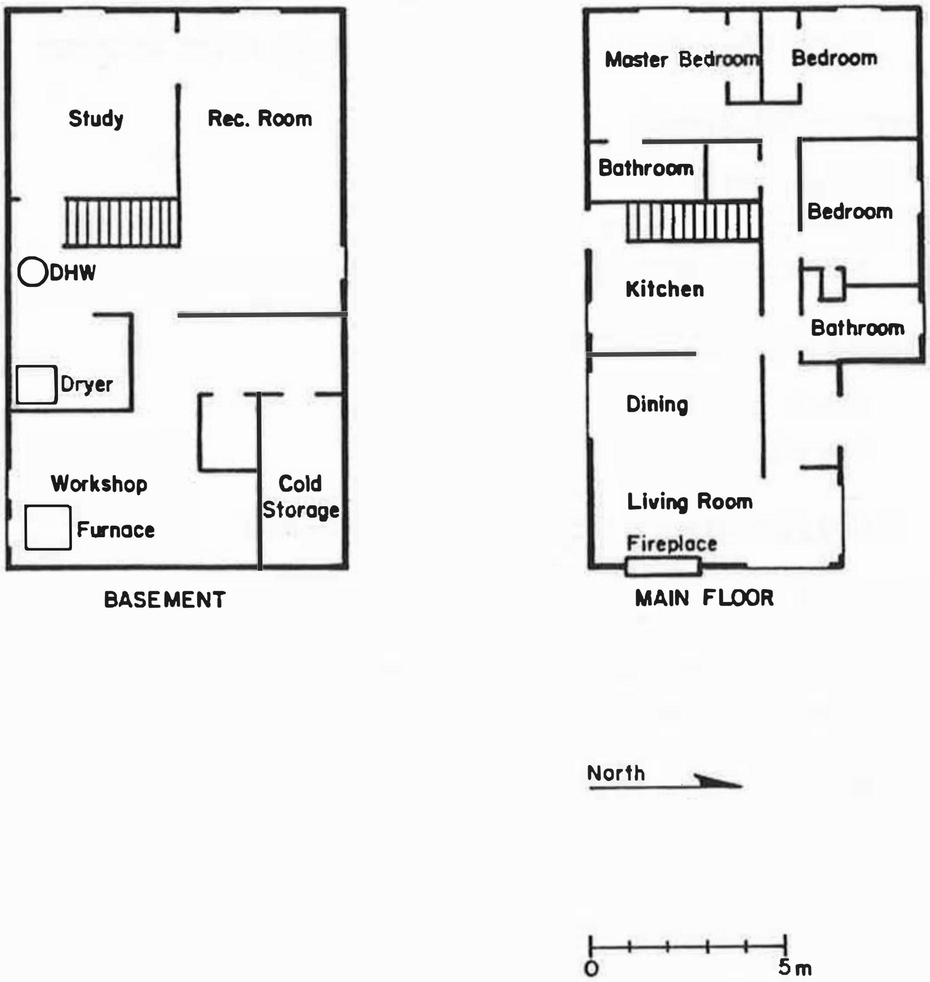
   main entrance
   side door

8. FAN TEST CHARACTERISTICS:

   4.26 Air Changes per Hour (@ 50 Pa)
   0.082 Equivalent Leakage Area (m^2)

9. HOMEOWNER PROFILE:

   Occupants 18 years and older: 3
   Occupants under 18 years: 0
   Number of occupants who smoke: 0


Study
Rec. Room
DHW
Dryer
Workshop
Furnace
Cold Storage
BASEMENT
Master Bedroom
Bedroom
Bathroom
Bedroom
Kitchen
Bathroom
Dining
Living Room
Fireplace
MAIN FLOOR
North
0
5 m

HOUSE O-4

Air Analysis Results of Residential Combustion Spillage Monitoring

Address: 04 City: Ottawa Fuel Type: Oil

SPILLAGE TYPE	Date	---Location---	---GASTEC Tubes--- NO2 (ppm)	NOx (ppm)	SO2 (ppm)	---Bag Samples--- CO (ppm)	CO2 (ppm)	CH4 (ppm)	H.C (ppm)	O2 (%)	Sorbent Tubes NO2 (ppm)	NO (ppm)	Pump Time (sec.)
PRE SPILL	Feb.27	At furnace	0	0	0								
		Living room	0	0	0								
FORCED	Feb.27	At furnace	0	0	0.2	1.6	1904	1.1	0.9	21			
		Living room	0	0	0.25								
POST SPILL	Feb.27	At furnace			0.1								
		Living room			0.13								

HOME PROFILE

1. HOUSE IDENTIFICATION: No. O-5

2. HOUSE DESCRIPTION:

   Total Floor Area: 180 m^2, suburban, two storey, semi-detached

3. SPACE HEATING:

   Fuel: oil
   Heat Distribution: forced air
   Location: enclosed basement

4. DOMESTIC HOT WATER HEATING:

   Fuel: oil
   Location: adjacent to furnace

5. SUPPLEMENTARY COMBUSTION SYSTEMS:

   Type: fireplace
   Fuel: wood
   Frequency of Use: never
   Chimney Type: masonry

6. EXHAUST FANS FREQUENTLY USED:

   main bathroom
   basement bathroom
   range hood
   clothes dryer

7. DOORS/WINDOWS FREQUENTLY USED:

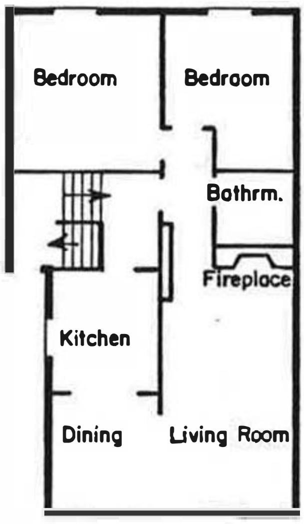
   main entrance
   garage door
   back bedroom window

8. FAN TEST CHARACTERISTICS:

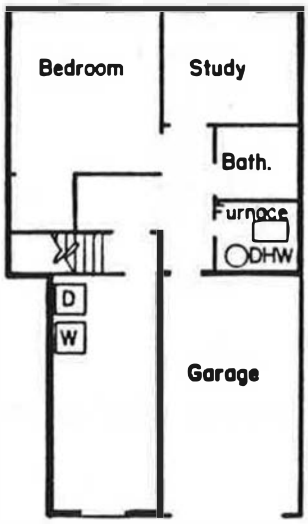
   7.98 Air Changes per Hour (@ 50 Pa)
   0.137 Equivalent Leakage Area (m^2)

9. HOMEOWNER PROFILE:

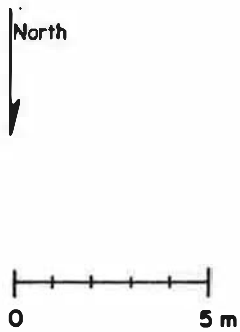
   Occupants 18 years and older: 3
   Occupants under 18 years: 0
   Number of occupants who smoke: 1



MAIN FLOOR



BASEMENT



HOUSE O-5

Location Code:05
Start date:06MAR87   End date:09MAR87
Total Number of Days Analyzed in these Tables: 3
Total Number of Days Monitored for this House:29

TABLE1:FREQUENCY AND DURATION OF SPILLAGE EVENTS

Spillage time Interval (sec)	Total Spillage Events Furnace	DHW	Total
5-29	11	0	11
30-120	0	0	0
>120	0	0	0
Total	11	0	11

TABLE 2:AGGRAVATING CONDITIONS DURING SPILLAGE EVENTS

List of Conditions Fireplace	Fan	Other Devices	% Time Condition True	Spillage Events Totals	Time(min)	Total Window Open Occurrences
OFF	OFF	OFF	94.005	7	0.90	1
OFF	ON	OFF	5.995	4	0.62	4
OFF	OFF	ON	0.000	0	0.00	0
OFF	ON	ON	0.000	0	0.00	0
ON	OFF	OFF	0.000	0	0.00	0
ON	ON	OFF	0.000	0	0.00	0
ON	OFF	ON	0.000	0	0.00	0
ON	ON	ON	0.000	0	0.00	0
			TOTAL:	11	2	

note:column '% Time Condition True' has device status forced on if device is spilling

Location Code:05
Start date:09MAR87 End date:15MAR87
Total Number of Days Analyzed in these Tables: 6
Total Number of Days Monitored for this House:29

TABLE1:FREQUENCY AND DURATION OF SPILLAGE EVENTS

Spillage time Interval (sec)	Total Spillage Events Furnace	DHW	Total
5-29	5	3	8
30-120	0	0	0
>120	0	0	0
Total	5	3	8

TABLE 2:AGGRAVATING CONDITIONS DURING SPILLAGE EVENTS

List of Conditions Fireplace	Fan	Other Devices	% Time Condition True	Spillage Events Totals	Time(min)	Total Window Open Occurrences
OFF	OFF	OFF	97.893	1	0.10	0
OFF	ON	OFF	1.950	0	0.00	0
OFF	OFF	ON	0.156	6	0.55	0
OFF	ON	ON	0.001	1	0.13	0
ON	OFF	OFF	0.000	0	0.00	0
ON	ON	OFF	0.000	0	0.00	0
ON	OFF	ON	0.000	0	0.00	0
ON	ON	ON	0.000	0	0.00	0
			TOTAL:	8	1	

note:column '% Time Condition True' has device status forced on if device is spilling

Air Analysis Results of Residential Combustion Spillage Monitoring

Address: 05 City: Ottawa Fuel Type: Oil

SPILLAGE TYPE	Date	---Location---	---GASTEC Tubes---- NO2 (ppm)	NOx (ppm)	SO2 (ppm)	------------Bag Samples-------- CO (ppm)	CO2 (ppm)	CH4 (ppm)	H.C (ppm)	O2 (%)	Sorbent Tubes NO2 (ppm)	NO (ppm)	Pump Time (sec.)
PRE SPILL	Feb.25	At furnace	0	0	0	1.2	639	1.6	0.6	21			
		Dining room	0	0	0								
FORCED	Feb.25	At furnace	0	0	0	1.6	528	1.5	0.9	21			
		Dining room	0	0	0								
POST SPILL													
CONTROLLED	Mar.9-20	At furnace				1	462	1.6	2.1	21			70
TIMED	Mar.9-20	At furnace				1.9	513	1.7	3.6	21			120

HOME PROFILE

1. HOUSE IDENTIFICATION: No. O-6

2. HOUSE DESCRIPTION:

   Total Floor Area: 317 m^2, two storey, single detached

3. SPACE HEATING:

   Fuel: natural gas
   Heat Distribution: forced air
   Location: enclosed furnace room

4. DOMESTIC HOT WATER HEATING:

   Fuel: natural gas
   Location: adjacent to furnace

5. SUPPLEMENTARY COMBUSTION SYSTEMS:

   Type: fireplace
   Fuel: wood
   Frequency of Use:
   once per winter month
   Chimney Type: masonry

   Type: wood stove
   Fuel: wood
   Frequency of use:
   three times per winter
   Chimney Type: insulated metal

6. EXHAUST FANS FREQUENTLY USED:

   main bathroom
   kitchen - Jenn Air
   range hood
   clothes dryer

7. DOORS/WINDOWS FREQUENTLY USED:

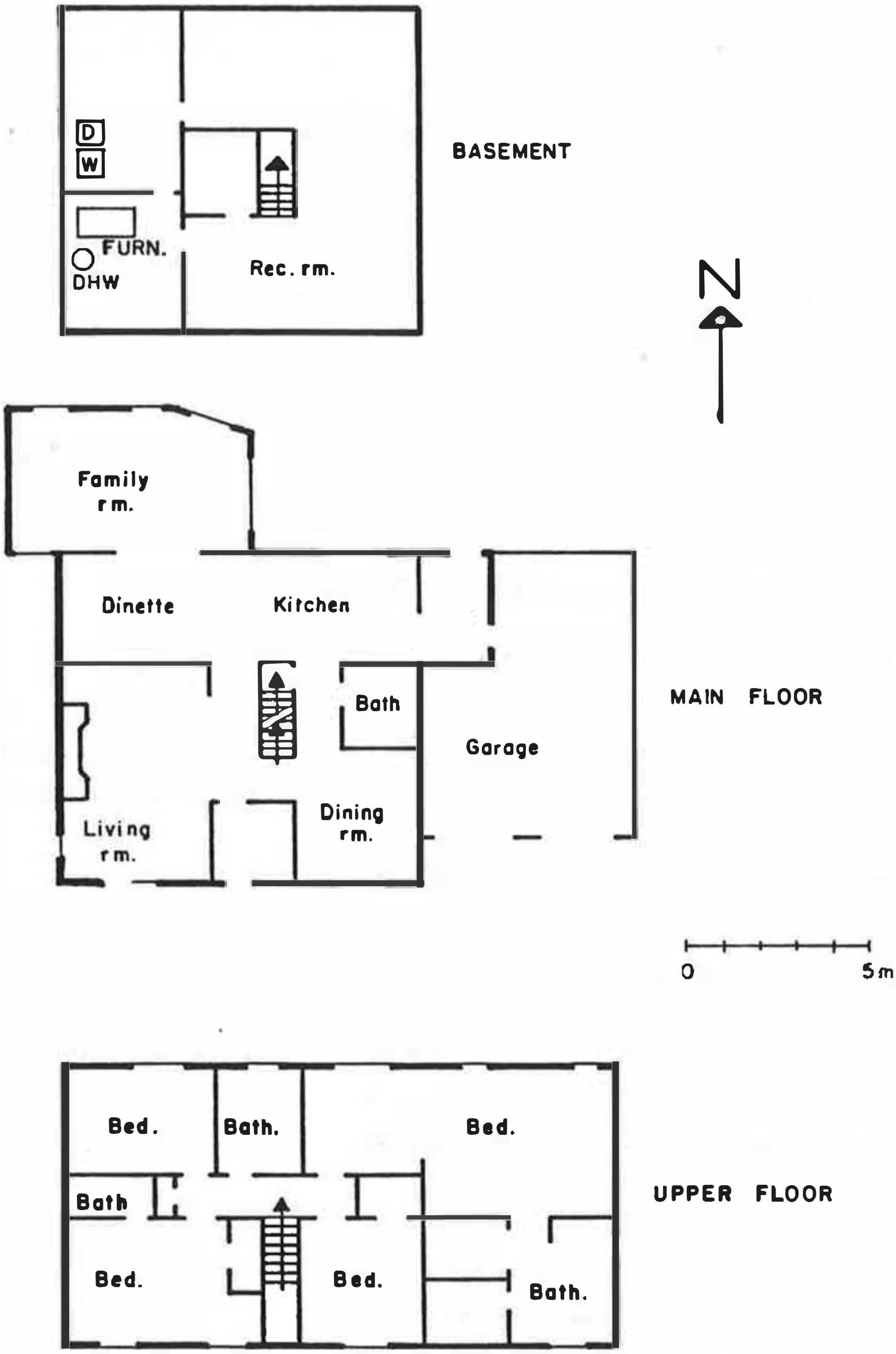
   main entrance
   garage door
   back door
   five windows

8. FAN TEST CHARACTERISTICS:

   7.01 Air Changes per Hour (@ 50 Pa)
   0.176 Equivalent Leakage Area (m^2)

9. HOMEOWNER PROFILE:

   Occupants 18 years and older: 2
   Occupants under 18 years: 2
   Number of occupants who smoke: 0


D
W
FURN.
DHW
Rec. rm.
BASEMENT
N
Family rm.
Dinette
Kitchen
Bath
Garage
Living rm.
Dining rm.
MAIN FLOOR
0
5m
Bed.
Bath.
Bed.
Bath
Bed.
Bed.
Bath.
UPPER FLOOR

HOUSE O-6

Location Code:06
Start date:03MAR87   End date:08MAR87
Total Number of Days Analyzed in these Tables: 5
Total Number of Days Monitored for this House:35

TABLE1:FREQUENCY AND DURATION OF SPILLAGE EVENTS

Spillage time Interval (sec)	Total Spillage Events Furnace	DHW	Total
10-29	45	10	55
30-120	87	0	87
>120	0	0	0
Total	132	10	142

TABLE 2:AGGRAVATING CONDITIONS DURING SPILLAGE EVENTS

List of Conditions Fireplace	Fan	Other Devices	% Time Condition True	Spillage Events Totals	Time(min)	Total Window Open Occurrences
OFF	OFF	OFF	89.747	129	67.53	22
OFF	ON	OFF	6.356	9	4.57	2
OFF	OFF	ON	2.455	1	0.23	0
OFF	ON	ON	1.443	3	0.80	0
ON	OFF	OFF	0.000	0	0.00	0
ON	ON	OFF	0.000	0	0.00	0
ON	OFF	ON	0.000	0	0.00	0
ON	ON	ON	0.000	0	0.00	0
			TOTAL:	142	73	

note:column "% Time Condition True" has device status forced on if device is spilling

Location Code:06
Start date:13MAR87   End date:27MAR87
Total Number of Days Analyzed in these Tables:14
Total Number of Days Monitored for this House:35

TABLE1:FREQUENCY AND DURATION OF SPILLAGE EVENTS

Spillage time Interval (sec)	Total Spillage Events Furnace	DHW	Total
10-29	121	20	141
30-120	204	4	208
>120	0	0	0
Total	325	24	349

TABLE 2:AGGRAVATING CONDITIONS DURING SPILLAGE EVENTS

List of Conditions Fireplace	Fan	Other Devices	% Time Condition True	Spillage Events Totals	Time(min)	Total Window Open Occurrences
OFF	OFF	OFF	94.364	319	166.78	60
OFF	ON	OFF	4.250	11	4.50	7
OFF	OFF	ON	0.831	16	8.82	8
OFF	ON	ON	0.555	3	1.52	3
ON	OFF	OFF	0.000	0	0.00	0
ON	ON	OFF	0.000	0	0.00	0
ON	OFF	ON	0.000	0	0.00	0
ON	ON	ON	0.000	0	0.00	0
			TOTAL:	349	182	

note:column '% Time Condition True' has device status forced on if device is spilling

Air Analysis Results of Residential Combustion Spillage Monitoring

Address: 06 City: Ottawa Fuel Type: Gas

SPILLAGE TYPE	Date	---Location---	---GASTEC Tubes----			------------Bag Samples--------					Sorbent Tubes		Pump
			NO2 (ppm)	NOx (ppm)	SO2 (ppm)	CO (ppm)	CO2 (ppm)	CH4 (ppm)	H.C (ppm)	O2 (%)	NO2 (ppm)	NO (ppm)	Time (sec.)
PRE SPILL	Feb.21	At furnace	0	0		0.8	845	4	1.2	21			
		Master bedroom	0	0									
FORCED	Feb.21	At furnace	0	0	0	0.8	838	4.4	1.2	21			
		Master bedroom		0									
POST SPILL													
CONTROLLED	Mar.18-19	At furnace				1.6	762	12.9	1.5	21	0.019	0.187	957
	Mar.19-21	"				2.4	827	7.3	1.4	21	0.006	0.022	3321
	Mar.21-23	"				1.1	702	8.5	1.4	21	0.025	0.125	1242
					AVG.	1.7	764	9.6	1.4	21	0.017	0.111	
TIMED	Mar.19-21	At furnace				1.1	578	7.7	1.7	21			720
											0.0006	0.068	570

HOME PROFILE

1. HOUSE IDENTIFICATION: No. O-7

2. HOUSE DESCRIPTION:

   Total Floor Area: 288 m^2, duplex (upper floor, lower floor)

3. SPACE HEATING:

   Fuel: oil
   Heat Distribution: forced air
   Location: enclosed furnace room

4. DOMESTIC HOT WATER HEATING:

   Fuel: electric
   Location: in basement

5. SUPPLEMENTARY COMBUSTION SYSTEMS:

   Type: fireplaces (2)
   Fuel: wood
   Frequency of Use: twice per winter month
   Chimney Type: masonry

6. EXHAUST FANS FREQUENTLY USED:

   none

7. DOORS/WINDOWS FREQUENTLY USED:

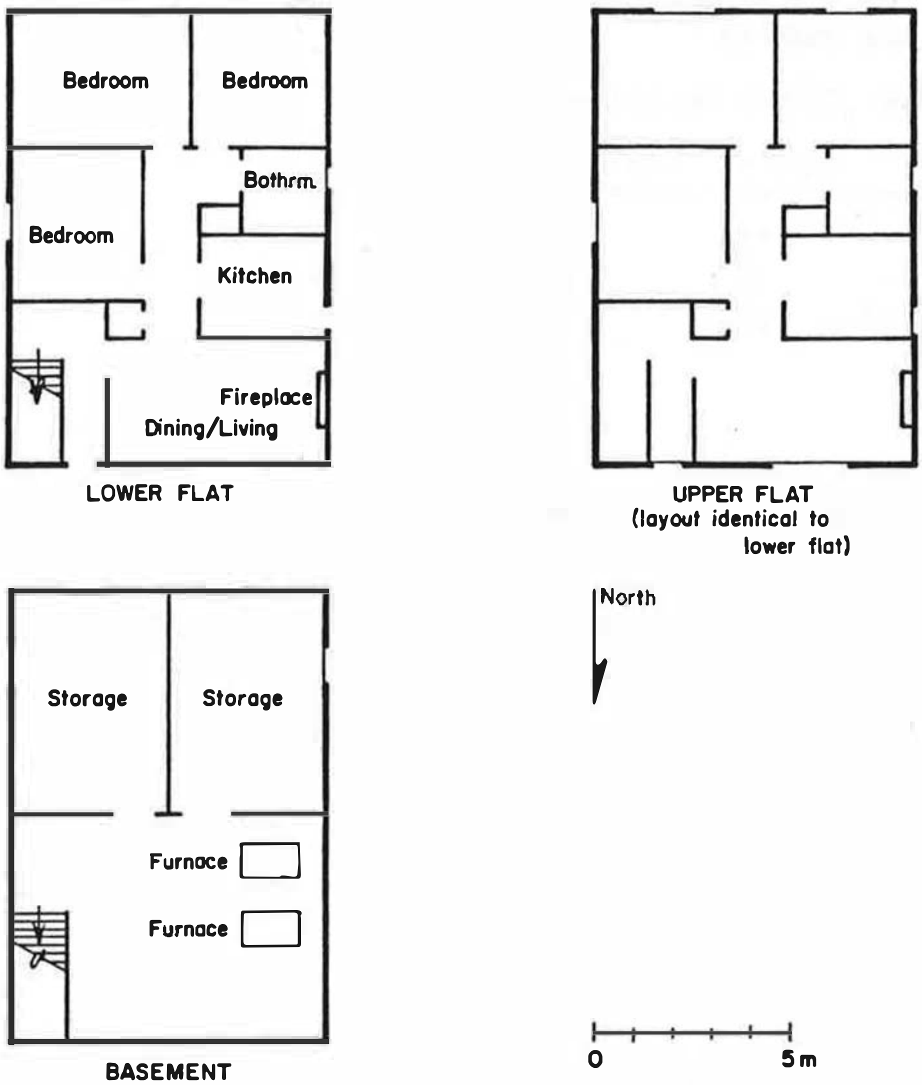
   main entrance door
   lower unit - side door

8. FAN TEST CHARACTERISTICS:

   Access Refused For One Time Testing

9. HOMEOWNER PROFILE:

   Occupants 18 years and older: 3
   Occupants under 18 years: 0
   Number of occupants who smoke: 2


Bedroom
Bedroom
Bathrm.
Bedroom
Kitchen
Fireplace
Dining/Living
LOWER FLAT
UPPER FLAT
(layout identical to
lower flat)
North
Storage
Storage
Furnace
Furnace
BASEMENT
0
5 m

HOUSE O–7

Location Code:07
Start date:10MAR87   End date:27MAR87
Total Number of Days Analyzed in these Tables:17
Total Number of Days Monitored for this House:27

TABLE1:FREQUENCY AND DURATION OF SPILLAGE EVENTS

Spillage time Interval (sec)	Total Spillage Events Furn1	Furn2	Total
5-29	14	0	14
30-120	1	0	1
>120	0	0	0
Total	15	0	15

TABLE 2:AGGRAVATING CONDITIONS DURING SPILLAGE EVENTS

List of Conditions Fireplace	Fan	Other Devices	% Time Condition True	Spillage Events Totals	Time(min)	Total Window Open Occurrences
OFF	OFF	OFF	99.591	13	1.77	0
OFF	ON	OFF	0.000	0	0.00	0
OFF	OFF	ON	0.409	2	0.22	0
OFF	ON	ON	0.000	0	0.00	0
ON	OFF	OFF	0.000	0	0.00	0
ON	ON	OFF	0.000	0	0.00	0
ON	OFF	ON	0.000	0	0.00	0
ON	ON	ON	0.000	0	0.00	0
			TOTAL:	15	2	

note:column '% Time Condition True' has device status forced on if device is spilling

Air Analysis Results of Residential Combustion Spillage Monitoring

Address: 07 City: Ottawa Fuel Type: Oil

SPILLAGE TYPE	Date	---Location----	---GASTEC Tubes---- NO2 (ppm)	NOx (ppm)	SO2 (ppm)	------------Bag Samples-------- CO (ppm)	CO2 (ppm)	CH4 (ppm)	H.C (ppm)	O2 (%)	Sorbent Tubes NO2 (ppm)	NO (ppm)	Pump Time (sec.)
PRE SPILL													
FORCED													
POST SPILL													

Access Refused For One Time Testing

HOME PROFILE

1. HOUSE IDENTIFICATION: No. O-8

2. HOUSE DESCRIPTION:

   Total Floor Area: 278 m^2, one storey, single detached

3. SPACE HEATING:

   Fuel: natural gas
   Heat Distribution: forced air
   Location: enclosed furnace room

4. DOMESTIC HOT WATER HEATING:

   Fuel: natural gas
   Location: adjacent to furnace

5. SUPPLEMENTARY COMBUSTION SYSTEMS:

   Type: fireplace
   Fuel: wood
   Frequency of Use: never
   Chimney Type: masonry

6. EXHAUST FANS FREQUENTLY USED:

   clothes dryer

7. DOORS/WINDOWS FREQUENTLY USED:

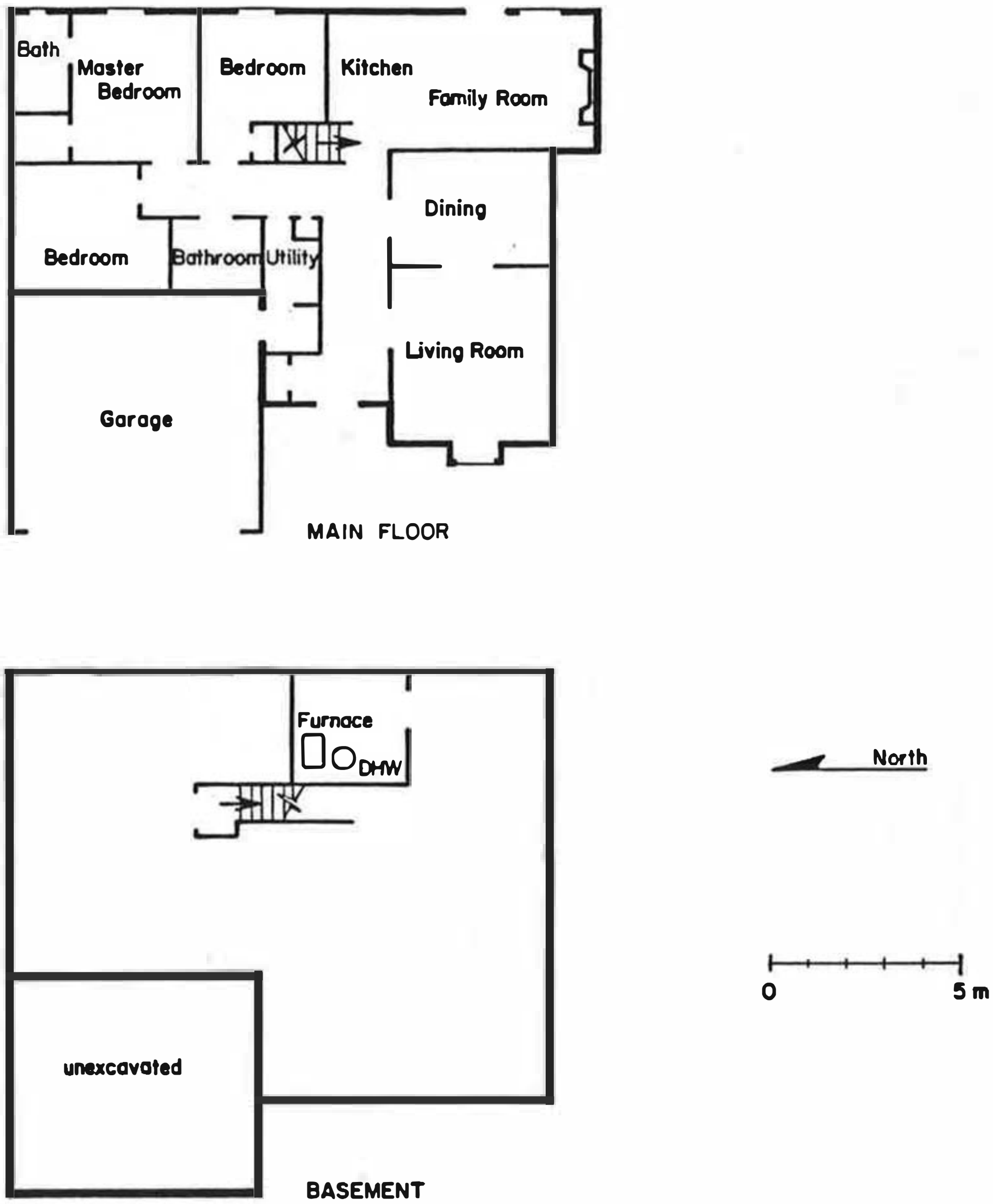
   main entrance
   garage door

8. FAN TEST CHARACTERISTICS:

   2.29 Air Changes per Hour (@ 50 Pa)
   0.056 Equivalent Leakage Area (m^2)

9. HOMEOWNER PROFILE:

   Occupants 18 years and older: 2
   Occupants under 18 years: 0
   Number of occupants who smoke: 0


Bath
Master Bedroom
Bedroom
Kitchen
Family Room
Dining
Bedroom
Bathroom
Utility
Living Room
Garage
MAIN FLOOR
Furnace
DHW
unexcavated
BASEMENT
North
0
5 m

HOUSE O-8

Air Analysis Results of Residential Combustion Spillage Monitoring

Address: 08 City: Ottawa Fuel Type: Gas

SPILLAGE TYPE	Date	---Location----	---GASTEC Tubes---- NO2 (ppm)	NOx (ppm)	SO2 (ppm)	------------Bag Samples-------- CO (ppm)	CO2 (ppm)	CH4 (ppm)	H.C (ppm)	O2 (%)	Sorbent Tubes NO2 (ppm)	NO (ppm)	Pump Time (sec.)
PRE SPILL	Mar.4	At furnace	0	0		trace	696	2.6	1.2	21			
		Living room	0	0									
FORCED	Mar.4	At furnace	0.1	4		ND	>6634	1.4	1.2	21			
		Living room	0	0									
POST SPILL	Mar.4	At furnace	0	0									
		By HRV vent	0	trace									

ND = None Detected

HOME PROFILE

1. HOUSE IDENTIFICATION: No. O-9

2. HOUSE DESCRIPTION:

   Total Floor Area: 132 m^2, two storey, single detached

3. SPACE HEATING:

   Fuel: natural gas
   Heat Distribution: forced air
   Location: enclosed furnace room

4. DOMESTIC HOT WATER HEATING:

   Fuel: natural gas
   Location: adjacent to furnace

5. SUPPLEMENTARY COMBUSTION SYSTEMS:

   Type: fireplace
   Fuel: wood
   Frequency of Use: twice per winter week
   Chimney Type: insulated metal

6. EXHAUST FANS FREQUENTLY USED:

   clothes dryer — main bathroom
   upstairs bathroom — range hood

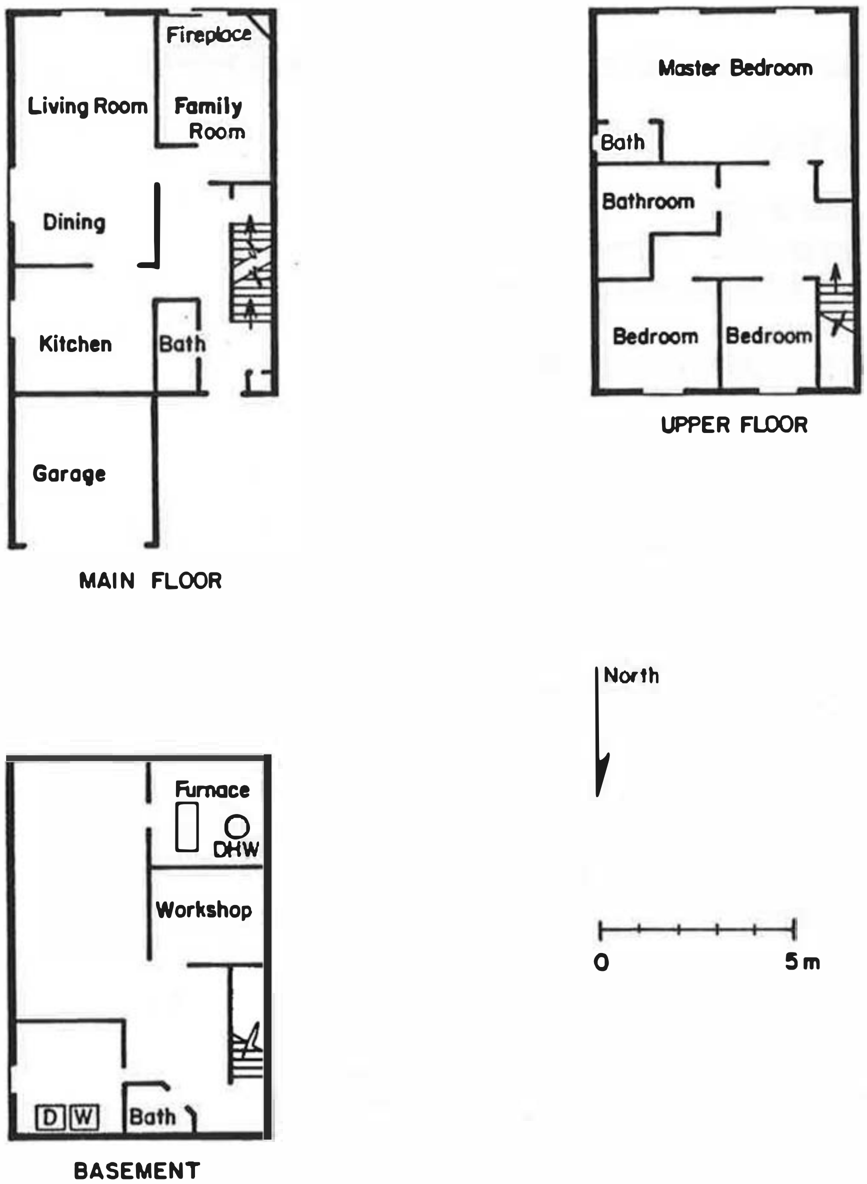
7. DOORS/WINDOWS FREQUENTLY USED:

   main entrance — rear door
   kitchen window — two bedroom windows

8. FAN TEST CHARACTERISTICS:
   3.97 Air Changes per Hour (@ 50 Pa)
   0.067 Equivalent Leakage Area (m^2)

9. HOMEOWNER PROFILE:

   Occupants 18 years and older: 2
   Occupants under 18 years: 0
   Number of occupants who smoke: 0


Fireplace
Living Room
Family Room
Dining
Kitchen
Bath
Garage
MAIN FLOOR
Master Bedroom
Bath
Bathroom
Bedroom
Bedroom
UPPER FLOOR
North
Furnace
DHW
Workshop
D
W
Bath
BASEMENT
0
5 m

HOUSE O-9

Air Analysis Results of Residential Combustion Spillage Monitoring

Address: 09 City: Ottawa Fuel Type: Gas

SPILLAGE TYPE	Date	---Location---	---GASTEC Tubes---- NO2 (ppm)	NOx (ppm)	SO2 (ppm)	------------Bag Samples-------- CO (ppm)	CO2 (ppm)	CH4 (ppm)	H.C (ppm)	O2 (%)	Sorbent Tubes NO2 (ppm)	NO (ppm)	Pump Time (sec.)
PRE SPILL	Mar.2	At furnace	0	0		trace	593	2.2	1.7	21			
		Main floor hall	0	0									
FORCED	Mar.2	At furnace	0	0		trace	>2594	2.2	1.7	21			
		Main floor hall	0	0									
POST SPILL	Mar.2	At furnace											
		Main floor hall											

PROFILE PAGE

1. HOUSE IDENTIFICATION: No. W-1

2. HOUSE DESCRIPTION:

   Total Floor Area: 150 m^2, two storey, semi-detached

3. SPACE HEATING:

   Fuel: natural gas
   Heat Distribution: forced air
   Location: open basement

4. DOMESTIC HOT WATER HEATING:

   Fuel: natural gas
   Location: adjacent to furnace

5. SUPPLEMENTARY COMBUSTION SYSTEMS:

   Type: fireplace
   Fuel: wood
   Frequency of Use: once per winter month
   Chimney Type: masonry

6. EXHAUST FANS FREQUENTLY USED:

   first floor bathroom
   second floor bathroom
   clothes dryer

7. DOORS/WINDOWS FREQUENTLY USED:

   main entrance
   kitchen window

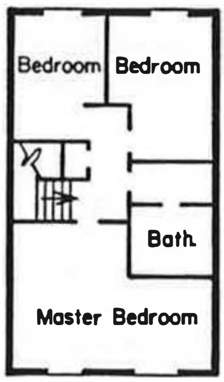
8. FAN TEST CHARACTERISTICS:

   4.51 Air Changes per Hour (@ 50 Pa)
   0.046 Equivalent Leakage Area (m^2)

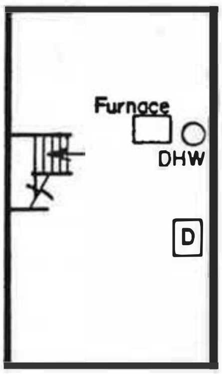
9. HOMEOWNER PROFILE:

   Occupants 18 years and older: 2
   Occupants under 18 years: 3
   Number of occupants who smoke: 2

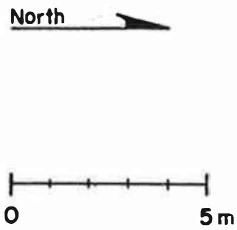
MAIN FLOOR



UPPER FLOOR



BASEMENT



HOUSE W-1

Location Code: W I
Start date: 14mar87   End date: 25mar87
Total Number of Days Analyzed in these Tables: 11
Total Number of Days Monitored for this House: 33

TABLE1: FREQUENCY AND DURATION OF SPILLAGE EVENTS

Spillage time Interval (sec)	Total Spillage Events Furnace	DHW	Total
10-29	0	33	33
30-120	0	10	10
>120	0	6	6
Total	0	49	49

TABLE 2: AGGRAVATING CONDITIONS DURING SPILLAGE EVENTS

List of Conditions Fireplace	Fan	Other Devices	% Time Condition True	Spillage Events Totals	Time(min)	Total Window Open Occurrences
OFF	OFF	OFF	89.998	0	0.00	0
OFF	ON	OFF	8.183	26	14.82	0
OFF	OFF	ON	1.195	4	2.45	0
OFF	ON	ON	0.623	19	34.57	1
ON	OFF	OFF	0.000	0	0.00	0
ON	ON	OFF	0.000	0	0.00	0
ON	OFF	ON	0.002	0	0.00	0
ON	ON	ON	0.000	0	0.00	0
		TOTAL:		49	52	

note: column "% Time Condition True" has device status forced on if device is spilling

Air Analysis Results of Residential Combustion Spillage Monitoring

Address: W1 City: Winnipeg Fuel Type: Gas

SPILLAGE TYPE	Date	---Location---	GASTEC Tubes NO2 (ppm)	GASTEC Tubes NOx (ppm)	GASTEC Tubes SO2 (ppm)	Bag Samples CO (ppm)	Bag Samples CO2 (ppm)	Bag Samples CH4 (ppm)	Bag Samples H.C (ppm)	Bag Samples O2 (%)	Sorbent Tubes NO2 (ppm)	Sorbent Tubes NO (ppm)	Pump Time (sec.)
PRE SPILL	Mar.14	At furnace	0	0		0.5	744	1.9	1.5	21			
		In living room	0	0									
FORCED	Mar.14	At furnace	0	0		0.1	563	2.8	2.9	21			
		In living room	0	0									
POST SPILL	Mar.14	At furnace	0	0									
		In living room	0	0									
CONTROLLED	Mar.31 - Apr.2	At furnace				0.8	646	2.5	2.7	21	0.032	0.088	225
	Apr.2-16	"									0.038	0.111	1398
										AVG.	0.035	0.1	
TIMED	Mar.31 - Apr.2	At furnace				1.4	593	2.6	2.5	21			120

HOME PROFILE

1. HOUSE IDENTIFICATION: No. W-2

2. HOUSE DESCRIPTION:

   Total Floor Area: 170 m^2, one storey, single

3. SPACE HEATING:

   Fuel: natural gas
   Heat Distribution: forced air
   Location: open basement

4. DOMESTIC HOT WATER HEATING:

   Fuel: natural gas
   Location: adjacent to furnace

5. SUPPLEMENTARY COMBUSTION SYSTEMS:

   Type: none
   Fuel: n/a
   Frequency of Use: n/a
   Chimney Type: n/a

6. EXHAUST FANS FREQUENTLY USED:

   bathroom
   central vacuum
   clothes dryer

7. DOORS/WINDOWS FREQUENTLY USED:

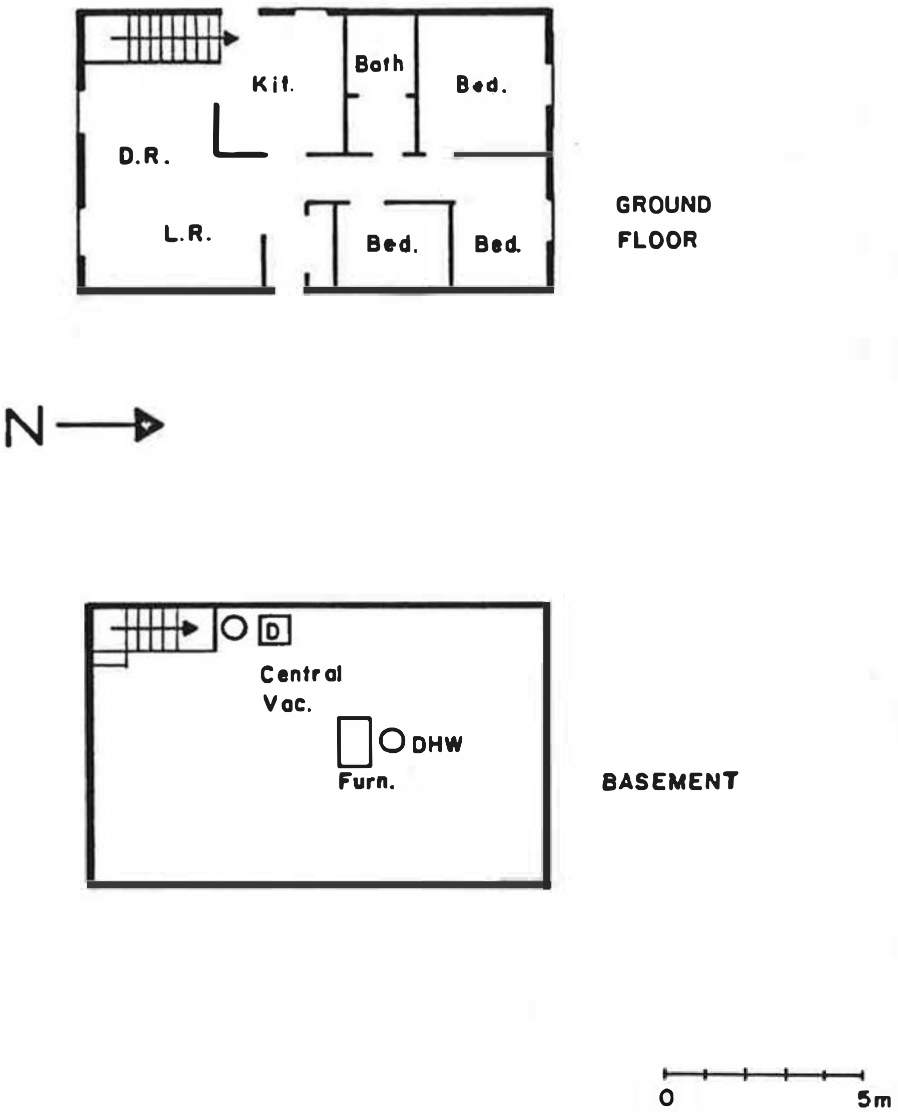
   main entrance
   kitchen entrance

8. FAN TEST CHARACTERISTICS:

   2.07 Air Changes per Hour (@ 50 Pa)
   0.034 Equivalent Leakage Area (m^2)

9. HOMEOWNER PROFILE:

   Occupants 18 years and older: 2
   Occupants under 18 years: 2
   Number of occupants who smoke: 0


Kit.
Bath
Bed.
D.R.
L.R.
Bed.
Bed.
GROUND
FLOOR
N
D
Central
Vac.
DHW
Furn.
BASEMENT
0
5m

HOUSE W-2

Air Analysis Results of Residential Combustion Spillage Monitoring

Address: W2 City: WINNIPEG Fuel Type: Gas

SPILLAGE TYPE	Date	---Location----	---GASTEC Tubes----			------------Bag Samples--------					Sorbent Tubes		Pump
			NO2 (ppm)	NOx (ppm)	SO2 (ppm)	CO (ppm)	CO2 (ppm)	CH4 (ppm)	H.C (ppm)	O2 (%)	NO2 (ppm)	NO (ppm)	Time (sec.)
PRE SPILL	Mar 16	near furnace	0	0		0.5	1076	1.7	1.2	21			
		living room	0	0									
FORCED	Mar 16	near furnace	0.6	0		0.5	963	1.8	1.5	21			
		living room	0	0									
POST SPILL	Mar 16	near furnace	0	0									
		living room	0	0									

HOME PROFILE

1. HOUSE IDENTIFICATION: No. W-3

2. HOUSE DESCRIPTION:

   Total Floor Area: 321 m^2, one storey, single detached

3. SPACE HEATING:

   Fuel: natural gas
   Location: open basement
   Heat Distribution: forced air

4. DOMESTIC HOT WATER HEATING:

   Fuel: natural gas
   Location: adjacent to furnace

5. SUPPLEMENTARY COMBUSTION SYSTEMS:

   Type: fireplace
   Fuel: wood
   Frequency of Use: once per week
   Chimney Type: insulated metal

6. EXHAUST FANS FREQUENTLY USED:

   main bathroom
   central vacuum
   master bedroom bathroom

7. DOORS/WINDOWS FREQUENTLY USED:

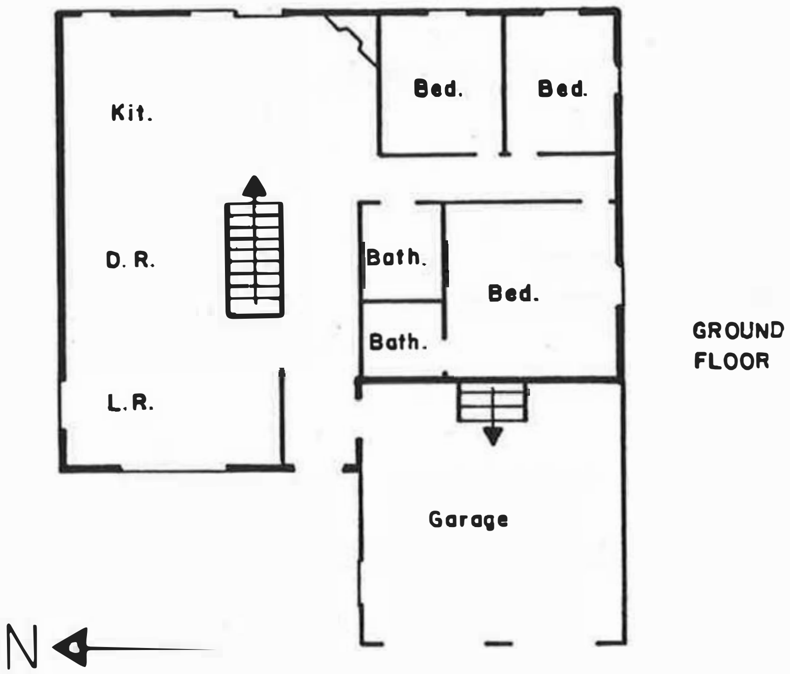
main entrance	basement door
kitchen window	garage door

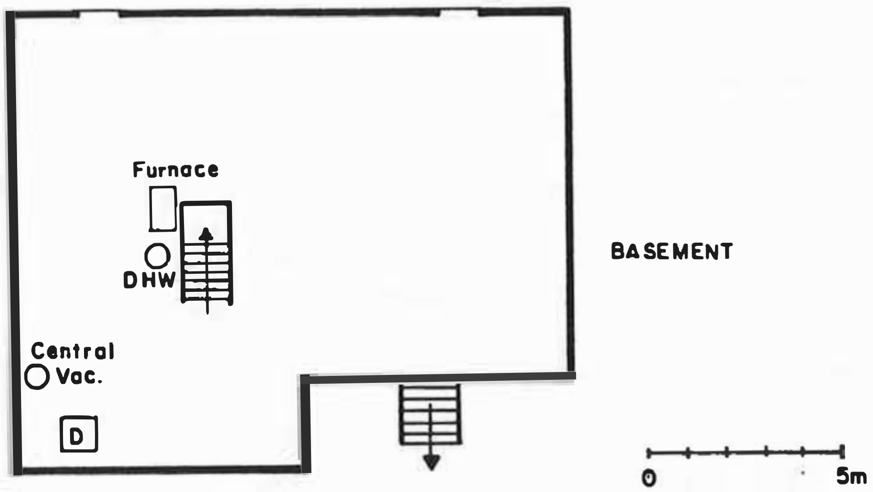
8. FAN TEST CHARACTERISTICS:

   1.88 Air Changes per Hour (@ 50 Pa)
   0.051 Equivalent Leakage Area (m^2)

9. HOMEOWNER PROFILE:

   Occupants 18 years and older: 2
   Occupants under 18 years: 1
   Number of occupants who smoke: 2


Kit.
D. R.
L.R.
Bed.
Bed.
Bath.
Bath.
Bed.
Garage
N
GROUND
FLOOR


Furnace
DHW
Central
Vac.
D
BASEMENT
0
5m

HOUSE W-3

Air Analysis Results of Residential Combustion Spillage Monitoring

Address: W3 City: Winnipeg Fuel Type: Gas

SPILLAGE TYPE	Date	---Location---	GASTEC Tubes NO2 (ppm)	GASTEC Tubes NOx (ppm)	GASTEC Tubes SO2 (ppm)	Bag Samples CO (ppm)	Bag Samples CO2 (ppm)	Bag Samples CH4 (ppm)	Bag Samples H.C (ppm)	Bag Samples O2 (%)	Sorbent Tubes NO2 (ppm)	Sorbent Tubes NO (ppm)	Pump Time (sec.)
PRE SPILL	Mar 17	near furnace	0	0		1.9	669	3.1	2.7	21			
		living room	0	0									
FORCED	Mar 17	near furnace	0	trace		1.1	1268	2.7	2.1	21			
		living room	0	0									
POST SPILL	Mar 17	near furnace	0	0									
		living room	0	0									

HOME PROFILE

1. HOUSE IDENTIFICATION: No. W-4

2. HOUSE DESCRIPTION:

   Total Floor Area: 237 m^2, one storey, single detached

3. SPACE HEATING:

   Fuel: natural gas
   Heat Distribution: forced air
   location: enclosed furnace room

4. DOMESTIC HOT WATER HEATING:

   Fuel: natural gas
   Location: adjacent to furnace

5. SUPPLEMENTARY COMBUSTION SYSTEMS:

   Type: fireplace
   Fuel: wood
   Frequency of Use: twice per season
   Chimney Type: masonry

6. EXHAUST FANS FREQUENTLY USED:

   clothes dryer
   master bedroom bathroom
   main floor bathroom

7. DOORS/WINDOWS FREQUENTLY USED:

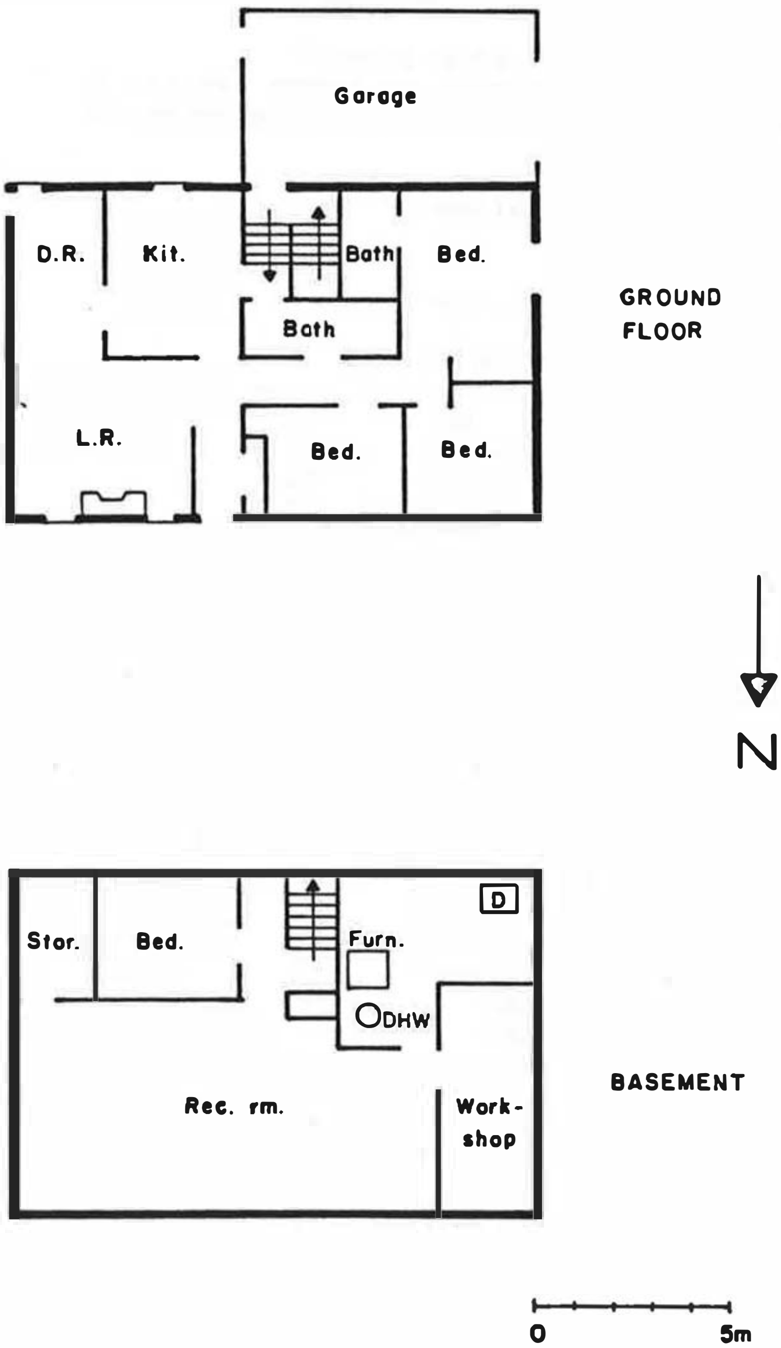
   main entrance
   garage door
   workshop window

8. FAN TEST CHARACTERISTICS:

   3.18 Air Changes per Hour (@ 50 Pa)
   0.072 Equivalent Leakage Area (m^2)

9. HOMEOWNER PROFILE:

   Occupants 18 years and older: 4
   Occupants under 18 years: 1
   Number of occupants who smoke: 3


Garage
D.R.
Kit.
Bath
Bed.
Bath
L.R.
Bed.
Bed.
GROUND
FLOOR
N
Stor.
Bed.
Furn.
D
DHW
Rec. rm.
Work-
shop
BASEMENT
0
5m

HOUSE W-4

Location Code: W4
Start date: 18mar87 End date: 24mar87
Total Number of Days Analyzed in these Tables: 6
Total Number of Days Monitored for this House: 19

TABLE1: FREQUENCY AND DURATION OF SPILLAGE EVENTS

Spillage time Interval (sec)	Total Spillage Events Furnace	DHW	Total
10-29	0	57	57
30-120	0	47	47
>120	0	59	59
Total	0	163	163

TABLE 2: AGGRAVATING CONDITIONS DURING SPILLAGE EVENTS

List of Conditions Fireplace	Fan	Other Devices	% Time Condition True	Spillage Events Totals	Time(min)	Total Window Open Occurrences
OFF	OFF	OFF	84.743	71	604.88	23
OFF	ON	OFF	14.845	78	620.77	18
OFF	OFF	ON	0.411	14	36.15	3
OFF	ON	ON	0.000	0	0.00	0
ON	OFF	OFF	0.000	0	0.00	0
ON	ON	OFF	0.000	0	0.00	0
ON	OFF	ON	0.000	0	0.00	0
ON	ON	ON	0.000	0	0.00	0
			TOTAL:	163	1262	

note: column "% Time Condition True" has device status forced on if device is spilling

Location Code:W4
Start date:01APR87 End date:08APR87
Total Number of Days Analyzed in these Tables: 7
Total Number of Davs Monitored for this House:19

TABLE1:FREQUENCY AND DURATION OF
SPILLAGE EVENTS

Spillage time Interval (sec)	Total Spillage Events Furnace	DHW	Total
10-29	0	34	34
30-120	0	32	32
>120	0	66	66
Total	0	132	132

TABLE 2:AGGRAVATING CONDITIONS DURING SPILLAGE EVENTS

List of Conditions Fireplace	Fan	Other Devices	% Time Condition True	Spillage Events Totals	Time(min)	Total Window Open Occurrences
OFF	OFF	OFF	85.783	53	587.47	17
OFF	ON	OFF	13.691	72	708.15	29
OFF	OFF	ON	0.506	5	67.88	1
OFF	ON	ON	0.017	2	56.10	2
ON	OFF	OFF	0.000	0	0.00	0
ON	ON	OFF	0.000	0	0.00	0
ON	OFF	ON	0.003	0	0.00	0
ON	ON	ON	0.000	0	0.00	0
		TOTAL:		132	1420	

note:column '% Time Condition True' has device status forced on if device is spilling

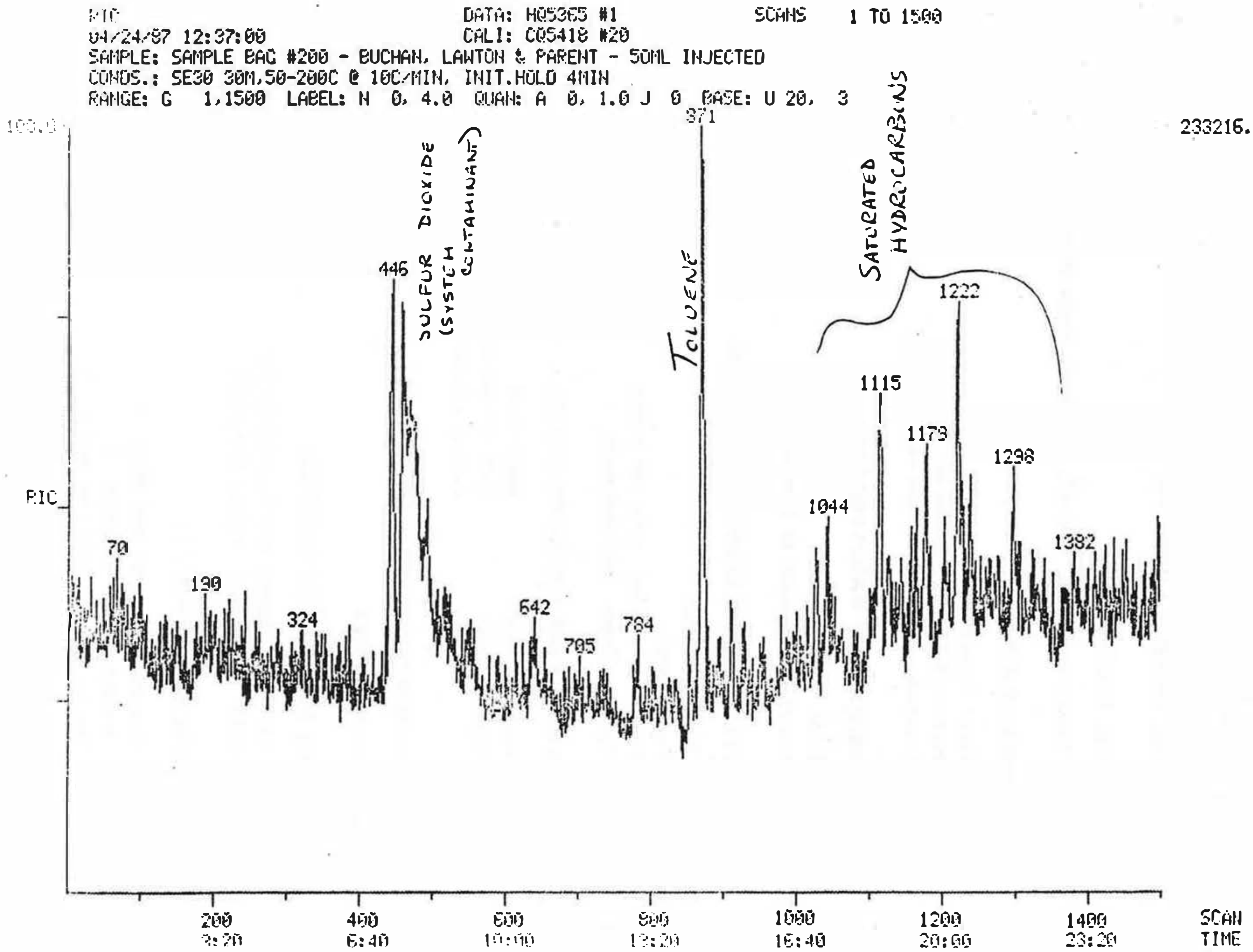
Air Analysis Results of Residential Combustion Spillage Monitoring

Address: W4 City: Winnipeg Fuel Type: Gas

SPILLAGE TYPE	Date	---Location----	---GASTEC Tubes---- NO2 (ppm)	NOx (ppm)	SO2 (ppm)	------------Bag Samples-------- CO (ppm)	CO2 (ppm)	CH4 (ppm)	H.C (ppm)	O2 (%)	Sorbent Tubes NO2 (ppm)	NO (ppm)	Pump Time (sec.)
PRE SPILL	Mar 18	near furnace	0	0		0.5	919	2.1	1.2	21			
		kitchen	0	0									
FORCED	Mar 18	near furnace	0.25	0		5.3	1998	2.9	1.4	21			
		kitchen	trace	0									
POST SPILL	Mar 18	near furnace	0	0									
		kitchen	0	0									
CONTROLLED	Mar.31 - Apr.1	near furnace				1	1118	1.7	3.3	21	0.012	0.094	10359
	Apr.1-2	"				0.5	1056	2	3.3	21	0.049	0.366	4595
	Apr.2-3	"				1.1	1361	2.3	1.8	21	0.057	0.207	8167
	Apr.3-4	"				0.5	520	3.8	1.6	21	0.056	0.264	9524
	Apr.4-5	"				1.1	1215	2.3	1.6	21			
	Apr.5-6	"									0.066	0.269	15214
	Apr.6-7	"				1.1	1590	1.9	2	21			
	Apr.7-8	"				0.8	1383	1.7	1.5	21	0.076	0.159	9537
	Apr.17-19	"	* M.S.*			0.9	1342	1.8	9.9	21			
					AVG.	0.88	1198	2.2	3.1	21	0.053	0.227	
TIMED	Mar.31 - Apr.1	near furnace				0.5	655	2.4	2.7	21			1170
	Apr.1-2	"				1	695	2.3	3.8	21			450
	Apr.2-3	"				2.2	568	2.3	2.2	21			450
	Apr.3-4	"				0.8	772	2.3	1.9	21			390
	Apr.4-5	"				1.6	822	2.6	1.5	21			300
	Apr.5-6	"				1.1	735	3.6	2.4	21			150
	Apr.6-7	"				1.1	983	2.2	2.3	21			240
	Apr.7-8	"				0.8	824	1.9	1.5	21			270
					AVG.	1.1	757	2.45	2.3	21			

NOTE: M.S. = MASS SPECTROMETER DONE.

HOUSE W-4


RIC
04/24/87 12:37:00
DATA: HQ5365 #1
CALI: CQ5418 #20
SCANS 1 TO 1500
SAMPLE: SAMPLE BAG #200 - BUCHAN, LAWTON & PARENT - 50ML INJECTED
CONDS.: SE30 30M,50-200C @ 10C/MIN, INIT.HOLD 4MIN
RANGE: G 1,1500 LABEL: N 0, 4.0 QUAN: A 0, 1.0 J 0 BASE: U 20, 3
100.0
233216.
RIC
70
190
324
446
SULFUR DIOXIDE (SYSTEM CONTAMINANT)
642
705
784
871
TOLUENE
1044
1115
1173
1222
1298
1382
SATURATED HYDROCARBONS
200 3:20
400 6:40
600 10:00
800 13:20
1000 16:40
1200 20:00
1400 23:20
SCAN TIME

HOME PROFILE

1. HOUSE IDENTIFICATION: No. W-5

2. HOUSE DESCRIPTION:

   Total Floor Area: 216 m^2, split-level, single detached

3. SPACE HEATING:

   Fuel: natural gas
   Heat Distribution: forced air
   Location: enclosed furnace room

4. DOMESTIC HOT WATER HEATING:

   Fuel: natural gas
   Location: adjacent to furnace

5. SUPPLEMENTARY COMBUSTION SYSTEMS:

   Type: fireplace
   Fuel: wood
   Frequency of Use: once per season
   Chimney Type: insulated metal

6. EXHAUST FANS FREQUENTLY USED:

   main bathroom
   clothes dryer
   range hood
   both upstairs bathrooms
   central vacuum

7. DOORS/WINDOWS FREQUENTLY USED:

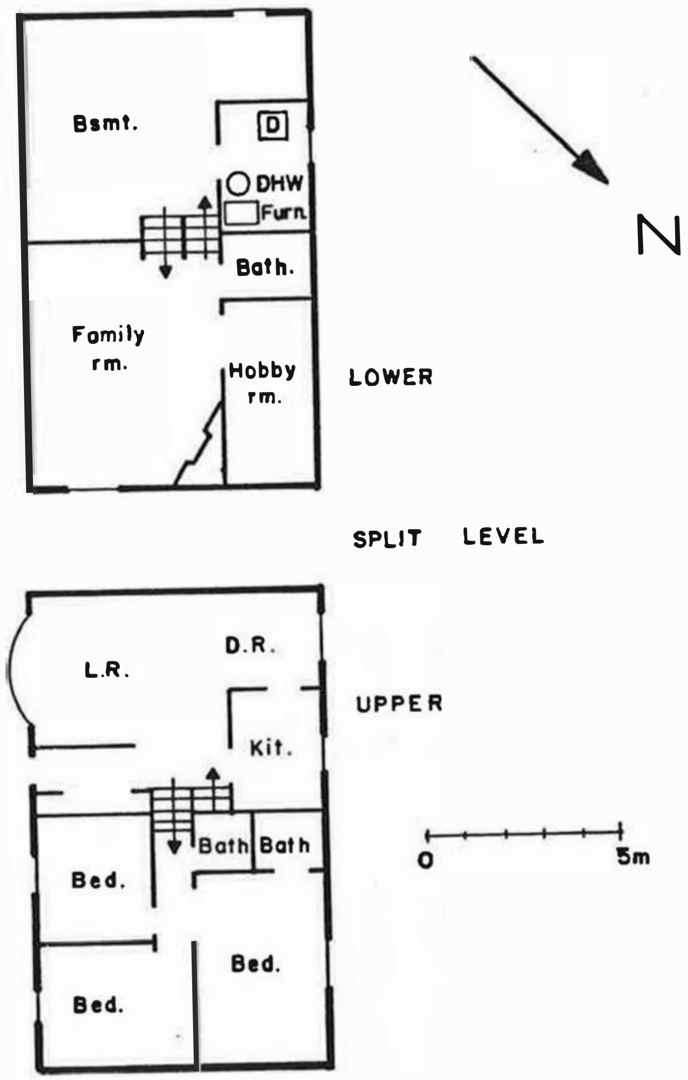
   main entrance

8. FAN TEST CHARACTERISTICS:

   1.83 Air Changes per Hour (@ 50 Pa)
   0.034 Equivalent Leakage Area (m^2)

9. HOMEOWNER PROFILE:

   Occupants 18 years and older: 2
   Occupants under 18 years: 2
   Number of occupants who smoke: 0



Bsmt.
D
DHW
Furn.
Bath.
Family rm.
Hobby rm.
LOWER
N
SPLIT LEVEL
L.R.
D.R.
UPPER
Kit.
Bath
Bath
Bed.
Bed.
Bed.
0
5m

HOUSE W-5

Air Analysis Results of Residential Combustion Spillage Monitoring

Address: W5 City: Winnipeg Fuel Type: Gas

SPILLAGE TYPE	Date	---Location----	---GASTEC Tubes---- NO2 (ppm)	NOx (ppm)	SO2 (ppm)	------------Bag Samples-------- CO (ppm)	CO2 (ppm)	CH4 (ppm)	H.C (ppm)	O2 (%)	Sorbent Tubes NO2 (ppm)	NO (ppm)	Pump Time (sec.)
PRE SPILL	Mar 19	near furnace	0	0		1.9	1249	2	2.1	21			
		living room	0	0									
FORCED	Mar 19	near furnace	trace	7.5		0.8	3568	1.5	2	21			
		living room	0	trace									
POST SPILL	Mar 19	near furnace	0	trace									
		living room	0	0									

HOME PROFILE

1. HOUSE IDENTIFICATION: No. W-6

2. HOUSE DESCRIPTION:

   Total Floor Area: 235 m^2, single storey, single detached

3. SPACE HEATING:

   Fuel: natural gas
   Heat Distribution: forced air
   Location: open basement

4. DOMESTIC HOT WATER HEATING:

   Fuel: natural gas
   Location: adjacent to furnace

5. SUPPLEMENTARY COMBUSTION SYSTEMS:

   Type: none
   Fuel: n/a
   Frequency of Use: n/a
   Chimney Type: n/a

6. EXHAUST FANS FREQUENTLY USED:

   main bathroom
   clothes dryer
   master bedroom bathroom

7. DOORS/WINDOWS FREQUENTLY USED:

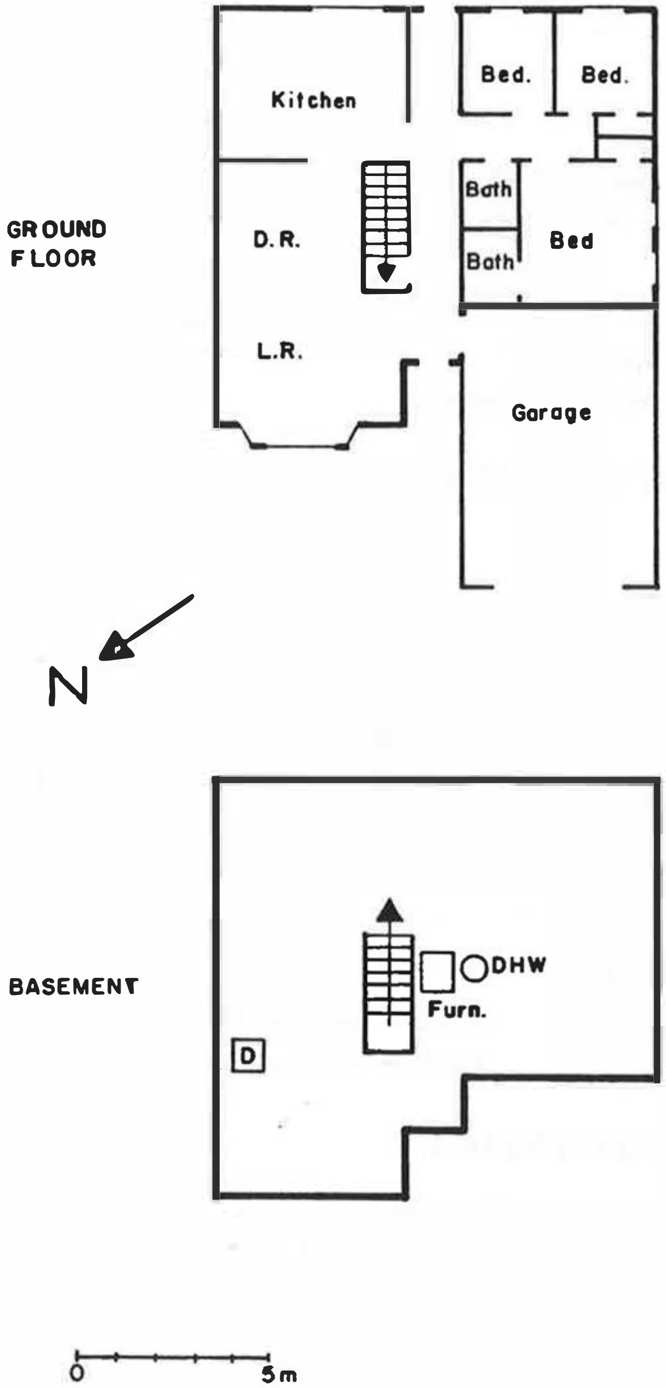
main entrance	living room window
garage door	kitchen window

8. FAN TEST CHARACTERISTICS:

   1.95 Air Changes per Hour (@ 50 Pa)
   0.041 Equivalent Leakage Area (m^2)

9. HOMEOWNER PROFILE:

   Occupants 18 years and older: 2
   Occupants under 18 years: 1
   Number of occupants who smoke: 2


GROUND FLOOR
Kitchen
D.R.
L.R.
Bed.
Bed.
Bath
Bath
Bed
Garage
N
BASEMENT
DHW
Furn.
D
0
5m

HOUSE W-6

Air Analysis Results of Residential Combustion Spillage Monitoring

Address: W6   City: Winnipeg   Fuel Type: Gas

SPILLAGE TYPE	Date	---Location----	---GASTEC Tubes----			------------Bag Samples--------					Sorbent Tubes		Pump
			NO2 (ppm)	NOx (ppm)	SO2 (ppm)	CO (ppm)	CO2 (ppm)	CH4 (ppm)	H.C (ppm)	O2 (%)	NO2 (ppm)	NO (ppm)	Time (sec.)
PRE SPILL	Mar 20	near furnace	0	0									
		living room	0	0									
FORCED	Mar 20	near furnace	0.2	2.5		3.6	2592	3.3	2	21			
		living room	0	0									
POST SPILL	Mar 20	near furnace	0	0									
		living room	0	0									

HOME PROFILE

1. HOUSE IDENTIFICATION: No. W-7

2. HOUSE DESCRIPTION:

   Total Floor Area: 213 m^2, two storey, single detached

3. SPACE HEATING:

   Fuel: natural gas
   Heat Distribution: forced air
   Location: enclosd furnace room

4. DOMESTIC HOT WATER HEATING:

   Fuel: natural gas
   Location: adjacent to furnace

5. SUPPLEMENTARY COMBUSTION SYSTEMS:

   Type: fireplace
   Fuel: wood
   Frequency of Use: once per winter month
   Chimney Type: insulated metal

6. EXHAUST FANS FREQUENTLY USED:

   clothes dryer

7. DOORS/WINDOWS FREQUENTLY USED:

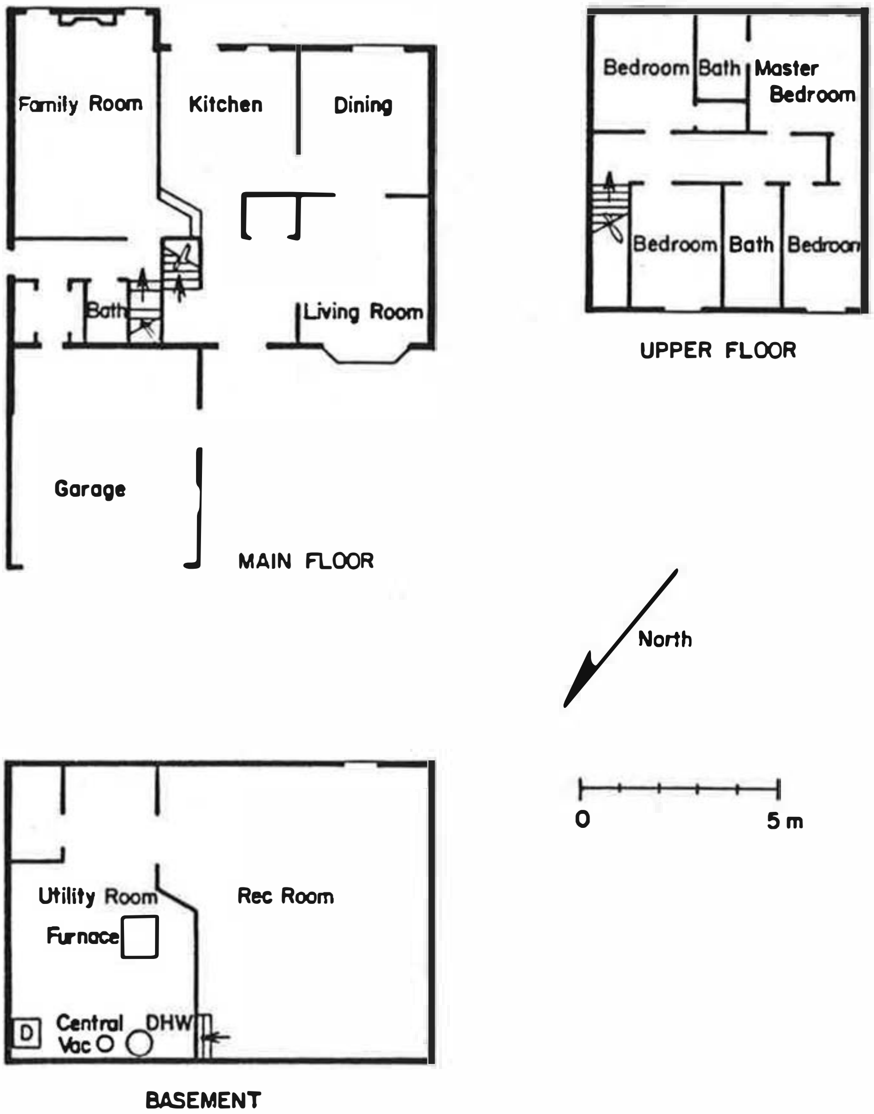
main entrance	kitchen door
garage door	kitchen window
	side door

8. FAN TEST CHARACTERISTICS:

   2.34 Air Changes per Hour (@ 50 Pa)
   0.062 Equivalent Leakage Area (m^2)

9. HOMEOWNER PROFILE:

   Occupants 18 years and older: 2
   Occupants under 18 years: 3
   Number of occupants who smoke: 2


Family Room
Kitchen
Dining
Bath
Living Room
Garage
MAIN FLOOR
Bedroom
Bath
Master Bedroom
Bedroom
Bath
Bedroom
UPPER FLOOR
North
0
5 m
Utility Room
Rec Room
Furnace
D
Central Vac
DHW
BASEMENT

HOUSE W-7

Air Analysis Results of Residential Combustion Spillage Monitoring

Address: W7 City: Winnipeg Fuel Type: Gas

SPILLAGE TYPE	Date	---Location----	GASTEC Tubes NO2 (ppm)	GASTEC Tubes NOx (ppm)	GASTEC Tubes SO2 (ppm)	Bag Samples CO (ppm)	Bag Samples CO2 (ppm)	Bag Samples CH4 (ppm)	Bag Samples H.C (ppm)	Bag Samples O2 (%)	Sorbent Tubes NO2 (ppm)	Sorbent Tubes NO (ppm)	Pump Time (sec.)
PRE SPILL	Mar 22	near furnace	0	0									
		living room	0	0									
FORCED	Mar 22	near furnace	0.3	trace		1.1	2567	3.2	1.5	21			
		living room	0	trace									
POST SPILL	Mar 22	near furnace	0	0									
		living room	0	0									
CONTROLLED	Mar.31 - Apr.1	At furnace				1	535	3.8	2.7	21			198
TIMED	Mar.31 - Apr.1	At furnace				0.5	473	4.1	3.5	21			540

APPENDIX B

Mann Testing Laboratories Report

MANN TESTING LABORATORIES LTD.
5550 McADAM ROAD, MISSISSAUGA, ONTARIO L4Z 1P1
PHONE: 890-2555 • TELEX: 06-960496

June 15, 1987

Buchan, Lawton & Parent Ltd.
5370 Canotek Road
Ottawa, Ontario
K1J 8X7

Attention: Mr. Mark Lawton

RE: MASS SPECTROMETER INFORMATION

In response to your telephone call of June 5th, 1987, I am pleased to submit the following information to assist you with the interpretation of your project results.

There are limitations inherent in both the method of sampling and the mass spectrometer itself. The mass spectrometer has a lower detection limit of low to sub ppb and detects only compounds with a molecular weight greater than 40. The use of the bag sample technique limits the analytical detectability to volatile organics.

All of the samples submitted for GC/MS qualitative screening were analyzed for total volatile hydrocarbon and found to be under 10 ppm methane equivalents; with samples #22 and #34 under 2 ppm methane equivalents. As an example, if 1 ppm of toluene (C_7H_8) was present it would translate approximately to 7 ppm methane equilvalents (i.e. toluene 7 carbons to methane 1 carbon).

The samples, therefore all contain ppb levels of the compounds found.

If you have any further questions please contact either Betsy Cliffe or myself.

Yours truly,

MANN TESTING LABORATORIES LTD.

W.R. Burgess, B.Sc., C. Chem.
Manager, Occupational Health

WRB/vs

MANN

MANN TESTING LABORATORIES LTD.
5550 McADAM ROAD, MISSISSAUGA, ONTARIO L4Z 1P1
PHONE: 890-2555 • TELEX: 06-960496

April 23, 1987

Buchan, Lawton & Parent Ltd.
5370 Canotek Road
Ottawa, Ontario
K1J 8X7

Attention: Mr. Mark Lawton

RE: MANN TESTING FILES 876723/876728
MASS SPECTROMETER RESULTS
BAG SAMPLES 22/34

Dear Mr. Lawton:

Your two bag samples were analyzed by Gas Chromatography/Mass Spectrometer (GC/MS) under the following conditions:

Injection Volume:	50 mL
Initial Temperature:	50°C
Initial Hold Time:	4 min.
Final Temperature:	200°C
Temperature Ramp:	10°C/min
Column:	30M, SE30

The samples were analyzed using a Universal Automated Concentrator Instrument Model 780, which passes the released organics through two sorbent traps of large and small bore. The latter trap serves to reduce the sample to a small concentrated plug prior to its separation with a 30 meter Superox GC capillary column, and subsequent analysis by a Finnigan Model 3200 Mass Spectrometer.

RECEIVED APR 2 8 1987

The data thus produced are stored in the memory of the computer and matched with the spectra from the United States Environmental Protection Agency/National Institute of Health library, which contains mass spectra of over 40,000 compounds.

The enclosed GC/MS chromatograms have been labelled with the compounds found in the respective samples. The most abundant compounds are saturated hydrocarbons which are aliphatic straight chained hydrocarbons (e.g. C_xH_{2x+2}).

If you have any questions concerning this data, please contact Betsy Cliffe or myself.

Yours truly,

MANN TESTING LABORATORIES LTD.

W.R. Burgess, B.Sc.,C.Chem.
Manager, Occupational Health

WRB/jh,
Encl.

MANN TESTING LABORATORIES LTD.
5550 McADAM ROAD, MISSISSAUGA, ONTARIO L4Z 1P1
PHONE: 890-2555 • TELEX: 06-960496

May 4, 1987

Buchan, Lawton & Parent Ltd.
5370 Canotek Road
Ottawa, Ontario
K1J 8X7

Attention: Mr. Mark Lawton

RE: MANN TESTING FILE NO. 876954
MASS SPECTROMETER RESULTS
SAMPLE BAG NO. 200

Dear Mr. Lawton:

Your bag sample was analyzed by Gas Chromatography/Mass Spectrometer (GC/MS) under the following conditions:

Injection Volume:	50 mL
Initial Temperature:	50°C
Initial Hold Time:	4 min.
Final Temperature:	200°C
Temperature Ramp:	10°C/min
Column:	30M, SE30

The sample was analyzed using a Universal Automated Concentrator Instrument Model 780, which passes the released organics through two sorbent traps of large and small bore. The latter trap serves to reduce the sample to a small concentrated plug prior to its separation with a 30 meter Superox GC capillary column, and subsequent analysis by a Finnigan Model 3200 Mass Spectrometer.

The data thus produced are stored in the memory of the computer and matched with the spectra from the United States Environmental Protection Agency/National Institute of Health library, which contains mass spectra of over 40,000 compounds.

The enclosed GC/MS chromatogram has been labelled with the compounds found in the sample. The most abundant compounds are saturated hydrocarbons which are aliphatic straight chained hydrocarbons (e.g. C_xH_{2x+2}).

If you have any questions concerning this data, please contact Betsy Cliffe or myself.

Yours truly,

MANN TESTING LABORATORIES LTD.

W.R. Burgess, B.Sc.,C.Chem.
Manager, Occupational Health

WRB/bc,
Encl.

APPENDIX C

Tracer Gas Sampler Analysis

General Description of the NAHB Research Foundation/
AIMS Output Format

June 1987

The top portion of the sheet shows the project title, house identification, start and stop times and dates for sampling, final date that computations were made, and date of the analysis.

The Rates Section gives the overall infiltration rate in cubic meters per hour (m^3/hr) for all zones, and the air change rate per hour (ACH), obtained by dividing the air infiltration rate by the total volume. For each zone, the zone location, source information (gravimetric calibration rate at 25 degrees C., quantity, total emission rate adjusted for temperature, assuming an enthalpy of 6.8 kcal/mole), and exfiltration and infiltration rates with their standard deviations (SD's) are given, followed by the zone-to-zone air flow rates and SDs, and total flow in or out of each zone.

The Analysis Section gives, for each zone, the volume, source type, and average tracer concentration with SD's, followed by the individual capillary absorption tracer (CATS) analyses by zone with correction factors.

The Notes Section gives the SD's assigned to the source rates and volumes. Conditions or results that should not exist are flagged by printing in capital letters.

The current PFT tracer codes are:

Type	Tracer Name	Abbreviation
1	Perfluorodimethylcyclobutane	PDCB
8	Perfluoromethylcyclopentane	PMCP
2	Perfluoromethylcyclohexane	PMCH
3	Perfluorodimethylcyclohexane	PDCH

NAHB-RESEARCH FOUNDATION

AIMS

07-01-1987

PROJECT: RES COMB.S START: 18:00 (02-26-1987) FILE: 1BUCH
HOUSE: 02 STOP: 15:00 (03-16-1987) ANALYZED: 06-30-1987

************************************** RATES **

OVERALL INFILTRATION RATE = 133.6 ± 12.7(m^3/h)
OVERALL AIR EXCHANGE RATE = 0.263 ± 0.027(1/h)

ZONE	ZONE LOCATION	SOURCE RATE @25C (nL/m)	QTY	@T (nL/h)	EXFILTRATION RATE (m^3/h)	SD	INFILTRATION RATE (m^3/h)	SD	ACH (/h)	SD
1	UPPER ZONE	35.9	2	3272	88.9	16.6	85.4	13.5	0.440	0.073
2	BASEMENT	24.7	2	2253	44.7	11.2	48.2	8.3	0.153	0.027

ZONE-ZONE	RATE	± SD (m^3/h)	ZONE-ZONE	RATE	± SD (m^3/h)
1 - 2	33.7	7.5	2 - 1	37.2	8.3

TOTAL FLOW IN OR OUT

ZONE	RATE	± SD (m^3/h)	ACH	± SD(/h)	ZONE	RATE	± SD (m^3/h)	ACH	± SD(/h)
1	122.6	18.9	0.632	0.102	2	81.9	12.6	0.261	0.042

************************************* ANALYSIS *************************************

AVG. TRACER CONC. (pL/L) ± SD

ZONE	VOL m^3	SOURCE TYPE	PMCP	± SD	PMCH	± SD
1	194	PMCP	30.49	3.05	9.54	0.95
2	314	PMCH	12.54	1.25	31.45	3.14

CONCENTRATION(pL/L)

ZONE	CATS#	PMCP	PMCH	PDCB	PDCH
1	4	30.492	9.539	0.022	0.202
2	130	12.542	31.447	0.018	0.237

C.F.:	PDCB	PMCP	PMCH	PDCH	COEFFICIENTS FILE
	0.89	0.89	0.97	0.97	3AIM2FMA

************************************** NOTES **************************************

The standard deviation in the source strength has been set at 10 %.
The standard deviation in the volume measurement has been set at 5 %.

NAHB-RESEARCH FOUNDATION
AIMS

07-01-1987

PROJECT: RFS COMB.S
HOUSE: **03**

START: 10:00 (03-06-1987)
STOP: 15:30 (03-16-1987)

FILE: 1BUCH
ANALYZED: 06-30-1987

** RATES **

OVERALL INFILTRATION RATE = 108.3 ± 15.0(m^3/h)
OVERALL AIR EXCHANGE RATE = 0.239 ± 0.034(1/h)

ZONE	ZONE LOCATION	SOURCE RATE @25C (nL/m)	QTY	@T (nL/h)	EXFILTRATION RATE (m^3/h)	EXFILTRATION SD	INFILTRATION RATE (m^3/h)	INFILTRATION SD	INFILTRATION ACH (/h)	INFILTRATION SD
1	BED	35.9	2	3272	66.5	25.6	-11.9	27.8	-0.053	0.123
2	BASEMENT	24.7	2	2253	41.9	36.6	120.3	29.5	0.531	0.133

ZONE-ZONE	RATE	± SD (m^3/h)	ZONE-ZONE	RATE	± SD (m^3/h)
1 - 2	105.3	39.3	2 - 1	183.7	68.6

TOTAL FLOW IN OR OUT

ZONE	RATE	± SD (m^3/h)	ACH	± SD(/h)	ZONE	RATE	± SD (m^3/h)	ACH	± SD(/h)
1	171.7	48.5	0.759	0.217	2	225.5	63.7	0.996	0.286

** ANALYSIS **

AVG. TRACER CONC. (pL/L) ± SD

ZONE	VOL m^3	SOURCE TYPE	PMCP	± SD	PMCH	± SD
1	226	PMCP	38.05	3.80	21.34	2.13
2	225	PMCH	17.76	1.78	19.95	2.00

CONCENTRATION (pL/L)

ZONE	CATS#	PMCP	PMCH	PDCB	PDCH
1	417	38.049	21.338	0.033	0.043
2	161	17.761	19.952	0.058	0.000

C.F.:	PDCB	PMCP	PMCH	PDCH
	0.89	0.89	0.97	0.97

COEFFICIENTS FILE 3AIM2FMA

** NOTES **

The standard deviation in the source strength has been set at 10 %.
The standard deviation in the volume measurement has been set at 5 %.
C22 IS LESS THAN C21
INFILTRATION RATE FOR ZONE 1 IS NEGATIVE

NAHB-RESEARCH FOUNDATION
AIMS

07-02-1987

PROJECT: 2332 START: 17:00 (03-09-1987) FILE: 1BUCH
HOUSE: **05** STOP: 12:10 (03-26-1987) ANALYZED: 06-30-1987

************************************ RATES ************************************

OVERALL INFILTRATION RATE = 74.2 ± 10.4(m^3/h)
OVERALL AIR EXCHANGE RATE = 0.010 ± 0.001(1/h)

ZONE	ZONE LOCATION	SOURCE RATE @25C (nL/m)	QTY	@T (nL/h)	EXFILTRATION RATE (m^3/h)	EXFILTRATION SD	INFILTRATION RATE (m^3/h)	INFILTRATION SD	ACH (/h)	SD
1	BED	35.9	2	3272	73.6	10.5	73.7	10.4	0.010	0.002
2	BASEMENT	24.7	2	2253	0.6	0.1	0.6	0.1	0.004	0.001

ZONE-ZONE	RATE	± SD (m^3/h)	ZONE-ZONE	RATE	± SD (m^3/h)
1 - 2	0.4	0.1	2 - 1	0.4	0.1

TOTAL FLOW IN OR OUT

ZONE	RATE	± SD (m^3/h)	ACH	± SD(/h)	ZONE	RATE	± SD (m^3/h)	ACH	± SD(/h)
1	74.1	10.5	0.010	0.002	2	1.0	0.1	0.007	[illegible]

************************************ ANALYSIS ************************************

AVG. TRACER CONC. (pL/L) ± SD

ZONE	VOL m^3	SOURCE TYPE	PMCP	± SD	PMCH	± SD
1	7224	PMCP	44.29	± 4.43	12.33	± 1.23
2	151	PMCH	18.72	± 1.87	2249.29	± %224.93

CONCENTRATION(pL/L)

	CATS#	PMCP	PMCH	PDCB	PDCH
1	[illegible]	44.286	12.326	0.033	0.000
2	* 465	18.720	2249.289	0.000	25.251

CAL :	PDCB	PMCP	PMCH	PDCH	COEFFICIENTS FILE
	0.89	0.89	0.97	0.97	341M2FMA

************************************ NOTES ************************************

The standard deviation in the source strength has been set at 10 %.
The standard deviation in the volume measurement has been set at 7 %.

* Impurities were found on tube # 465 (Spare Room) and this caused the ACH 0.010 to be low and may not be reliable. The actual ACH for this house should be higher than 0.010.

NAHB-RESEARCH FOUNDATION
AIMS
07-02-1987

PROJECT: 2332　　START: 10:00 (03-19-1987)　　FILE: 1BUCH
HOUSE: 06　　STOP: 11:30 (03-27-1987)　　ANALYZED: 06-30-1987

************************************* RATES *************************************

OVERALL INFILTRATION RATE = 318.4 ± 28.5(m^3/h)
OVERALL AIR EXCHANGE RATE = 0.688 ± 0.066(1/h)

ZONE	ZONE LOCATION	SOURCE RATE @25C (nL/m)	QTY	@T (nL/h)	EXFILTRATION RATE (m^3/h)	SD	INFILTRATION RATE (m^3/h)	SD	ACH (/h)	SD
1	BOYS BED	35.9	2	3272	221.7	58.8	161.3	38.8	0.576	0.141
2	BASEMENT	24.7	2	2253	96.7	54.1	157.1	33.5	0.862	0.189

ZONE-ZONE	RATE	± SD (m^3/h)	ZONE-ZONE	RATE	± SD (m^3/h)
1 - 2	192.2	54.6	2 - 1	252.7	71.7

TOTAL FLOW IN OR OUT

ZONE	RATE	± SD (m^3/h)	ACH	± SD(/h)	ZONE	RATE	± SD (m^3/h)	ACH	± SD(/h)
1	414.0	83.1	1.477	0.306	2	349.3	70.2	1.916	0.397

************************************* ANALYSIS *************************************

ZONE	VOL m^3	SOURCE TYPE	AVG. TRACER CONC. (pL/L) ± SD PMCP		PMCH	
1	280	PMCP	11.90 ±	1.19	5.93 ±	0.59
2	182	PMCH	6.55 ±	0.65	9.71 ±	0.97

ZONE	CATS#	CONCENTRATION(pL/L) PMCP	PMCH	PDCB	PDCH
1	147	11.901	5.927	0.078	0.000
2	32[illegible]	6.549	9.711	0.065	0.000

C.F.:	PDCB	PMCP	PMCH	PDCH
	0.8[illegible]	0.89	0.97	0.97

COEFFICIENTS F[illegible]
3A1M2PMA

************************************* NOTES *************************************

The standard deviation in the source strength has been set at 10 %.
The standard deviation in the volume measurement has been set at 5 %.

NAHB-RESEARCH FOUNDATION
AIMS 07-01-1987

PROJECT: RES COMR.S   START: 13:30 (03-10-1987)   FILE: 1BUCH
HOUSE: 07   STOP: 14:00 (03-27-1987)   ANALYZED: 06-30-1987

************************************ RATES ************************************

OVERALL INFILTRATION RATE = 210.0 ± 22.3(m^3/h)
OVERALL AIR EXCHANGE RATE = 0.449 ± 0.050(1/h)

ZONE	ZONE LOCATION	SOURCE @25C (nL/m)	QTY	RATE @T (nL/h)	EXFILTRATION RATE (m^3/h)	SD	INFILTRATION RATE (m^3/h)	SD	ACH (/h)	SD
1	UP. HALL	35.9	2	3272	35.2	15.8	52.8	10.1	0.226	0.045
2	BASEMENT	24.7	2	2253	174.8	31.2	157.2	25.1	0.672	0.112

ZONE-ZONE	RATE	± SD (m^3/h)	ZONE-ZONE	RATE	± SD (m^3/h)
1 - 2	68.4	15.5	2 - 1	50.8	11.5

TOTAL FLOW IN OR OUT

ZONE	RATE	± SD (m^3/h)	ACH	± SD(/h)	ZONE	RATE	± SD (m^3/h)	ACH	± SD(/h)
1	103.5	16.3	0.443	0.073	2	225.6	35.5	0.964	0.159

************************************ ANALYSIS ************************************

AVG.TRACER CONC. (pL/L) ± SD

ZONE	VOL m^3	SOURCE TYPE	PMCP	± SD	PMCH	± SD
1	234	PMCP	37.12	± 3.71	5.75	± 0.58
2	234	PMCH	11.25	± 1.13	11.73	± 1.17

CONCENTRATION(pL/L)

	CATS#	PMCP	PMCH	PDCB	PDCH
1	233	37.119	5.754	0.015	0.000
2	312	11.250	11.734	0.010	0.000

C.F.:	PDCB	PMCP	PMCH	PDCH	COEFFICIENTS FILE
	0.69	0.89	0.97	0.97	3AIM2FMA

************************************ NOTES ************************************

The standard deviation in the source strength has been set at 10 %.
The standard deviation in the volume measurement has been set at 5 %.

NAHB—RESEARCH FOUNDATION

AIMS

07-02-1987

PROJECT: 2332
HOUSE: **W4**

START: 15:00 (03-31-1987)
STOP: 18:00 (04-19-1987)

FILE: 1BUCH
ANALYZED: 06-30-1987

************************************** RATES **************************************

OVERALL INFILTRATION RATE = 218.4 ± 26.5(m^3/h)
OVERALL AIR EXCHANGE RATE = 0.378 ± 0.048(1/h)

ZONE	ZONE LOCATION	SOURCE RATE @25C (nL/m)	QTY	@T (nL/h)	EXFILTRATION RATE (m^3/h)	EXFILTRATION SD	INFILTRATION RATE (m^3/h)	INFILTRATION SD	ACH (/h)	SD
1	BASEMENT	24.7	2	2440	206.1	45.0	189.3	34.5	0.655	0.124
2	MASTER BED	35.9	2	3544	12.3	24.2	29.1	13.9	0.101	0.048

ZONE-ZONE	RATE	± SD (m^3/h)	ZONE-ZONE	RATE	± SD (m^3/h)
1 - 2	103.3	28.0	2 - 1	120.1	32.6

TOTAL FLOW IN OR OUT

ZONE	RATE	± SD (m^3/h)	ACH	± SD(/h)	ZONE	RATE	± SD (m^3/h)	ACH	± SD(/h)
1	309.4	58.9	1.071	0.211	2	132.5	25.2	0.458	0.090

************************************** ANALYSIS **************************************

AVG. TRACER CONC. (pL/L) ± SD

ZONE	VOL m^3	SOURCE TYPE	PMCH	± SD	PMCP	± SD
1	289	PMCH	11.31	1.13	14.90	1.49
2	289	PMCP	8.82	0.88	38.37	3.84

CONCENTRATION (pL/L)

ZONE	CATS#	PMCH	PMCP	PDCB	PDCH
1	[illegible]	11.312	14.899	0.077	0.000
2	51[illegible]	8.824	38.374	0.049	0.000

C.F.:	PDCB	PMCP	PMCH	PDCH
	0.89	0.89	0.97	0.97

COEFFICIENTS FILE
3AIM2FMA

************************************** NOTES **************************************

The standard deviation in the source strength has been set at 10 %.
The standard deviation in the volume measurement has been set at 5 %.

NAHB—RESEARCH FOUNDATION

AIMS 07-02-1987

PROJECT: 2332 START: 12:00 (03-31-1987) FILE: 1BUCH
HOUSE: WI STOP: 18:00 (04-16-1987) ANALYZED: 06-30-1987

************************************ RATES ************************************

OVERALL INFILTRATION RATE = 128.3 ± 12.3(m^3/h)
OVERALL AIR EXCHANGE RATE = 0.329 ± 0.034(1/h)

ZONE	ZONE LOCATION	SOURCE RATE @25C (nL/m)	QTY	@T (nL/h)	EXFILTRATION RATE (m^3/h)	SD	INFILTRATION RATE (m^3/h)	SD	ACH (/h)	SD
1	BASEMENT	24.7	2	2440	85.9	15.7	83.7	13.0	0.644	0.105
2	MASTER BED	35.9	2	3544	42.4	10.2	44.6	7.6	0.172	0.030

ZONE-ZONE	RATE	± SD (m^3/h)	ZONE-ZONE	RATE	± SD (m^3/h)
1 - 2	30.5	6.7	2 - 1	32.7	7.2

TOTAL FLOW IN OR OUT

ZONE	RATE	± SD (m^3/h)	ACH	± SD(/h)	ZONE	RATE	± SD (m^3/h)	ACH	± SD(/h)
1	116.4	17.7	0.895	0.144	2	75.1	11.4	0.289	0.046

************************************ ANALYSIS ************************************

ZONE	VOL m^3	SOURCE TYPE	AVG. TRACER CONC. (pL/L) ± SD: PMCH	PMCP
1	130	PMCH	23.66 ± 2.37	14.95 ± 1.49
2	280	PMCP	9.61 ± 0.96	53.27 ± 5.33

ZONE	CATS#	CONCENTRATION (pL/L): PMCH	PMCP	PDCB	PDCH
1	26	23.662	14.947	0.210	0.000
2	33	9.605	53.272	0.084	0.000

C.F.:	PDCB	PMCP	PMCH	PDCH
	0.89	0.89	0.97	0.97

COEFFICIENTS FILE
3AIM2PMA

************************************ NOTES ************************************

The standard deviation in the source strength has been set at 10 %.
The standard deviation in the volume measurement has been set at 2 %.

NAHB—RESEARCH FOUNDATION

AIMS

07-02-1987

PROJECT: 2332 | START: 17:40 (03-30-1987) | FILE: 1BUCH
HOUSE: **W 7** | STOP: 16:00 (04-16-1987) | ANALYZED: 06-30-1987

************************************** RATES **************************************

OVERALL INFILTRATION RATE = 143.9 ± 16.5(m^3/h)
OVERALL AIR EXCHANGE RATE = 0.229 ± 0.028(1/h)

ZONE	ZONE LOCATION	SOURCE RATE @25C (nL/m)	QTY	@T (nL/h)	EXFILTRATION RATE (m^3/h)	SD	INFILTRATION RATE (m^3/h)	SD	ACH (/h)	SD
1	BASEMENT	35.9	2	3544	117.2	18.8	119.9	17.6	0.588	0.091
2	MASTER BED	24.7	2	2440	26.7	6.0	23.9	4.4	0.057	0.011

ZONE-ZONE	RATE	± SD (m^3/h)	ZONE-ZONE	RATE	± SD (m^3/h)
1 - 2	20.5	4.3	2 - 1	17.7	3.7

TOTAL FLOW IN OR OUT

ZONE	RATE	± SD (m^3/h)	ACH	± SD(/h)	ZONE	RATE	± SD (m^3/h)	ACH	± SD(/h)
1	137.7	20.2	0.675	0.104	2	44.4	[illegible].5	0.105	0.016

************************************** ANALYSIS **************************************

ZONE	VOL m^3	SOURCE TYPE	AVG. TRACER CONC. (pL/L) ± SD PMCP		PMCH	
1	204	PMCP	27.36 ±	2.74	7.53 ±	0.75
2	423	PMCH	12.62 ±	1.26	58.43 ±	5.84

ZONE	CATS#	CONCENTRATION(pL/L) PMCP	PMCH	PDCB	PDCH
1	210	27.362	7.531	0.082	0.017
2	248	12.618	58.433	0.059	0.053

C.F.:	PDCB	PMCP	PMCH	PDCH	COEFFICIENTS FILE
	0.89	0.89	0.97	0.97	3AIMZFM4

************************************** NOTES **************************************

The standard deviation in the source strength has been set at 10 %.
The standard deviation in the volume measurement has been set at 5 %.