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Indoor Air Quality Analysis for Detached Residences

For the

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SUMMARY

As houses become more air-tight, in order to reduce energy consumption, the threat of indoor pollution becomes an increasingly more important issue - effecting the health and comfort of the occupants.

A mathematical modelling analysis of the interaction of indoor pollutant source strengths and ventilation scenarios on the concentration of pollutants relative to human exposure limits and targets was carried out.

An extensive literature search was performed to determine pollutant emissions from building materials, whole house pollutant source strengths and pollutant health limits. Available information in all three of these areas is lacking, contradictory, or both.

Comfort and health limits, based on human comfort and health studies that account for toxicological, mutagenic and carcinogenic factors, need to be determined. Investigation should be carried out to determine if mass-based or volume-based limits better represent comfort and health effects. Because of the wide range of effects on comfort and health, we recommend that Total Volatile Organic Compound (TVOC) concentrations **not** be used to assess pollutant levels. The 'mix' of pollutants and their effects are too variable.

While some data is available, there is a need for accurate air-tightness and whole-house pollutant source strength data for the most prevalent Volatile Organic Compounds (VOC). A source strength prediction model should be developed and calibrated using this survey data. Extensive documentation **must** accompany the test data if it is to be used for this calibration process.

To expand available data on air-tightness, tests were carried out on 36 houses in the lower mainland of B.C.. The houses covered a range of construction dates ranging from 1920 to 1978. While houses in the lower mainland of B.C. are generally becoming more air-tight, they are also becoming larger. They still remain the loosest houses in Canada.

A simple Air Quality Simulation program was developed that was fast enough to enable large scale parametric analyses of the effects of changing many variables. This model should be developed to increase its accuracy and versatility.

The study focussed on the effects of Volatile Organic Compounds (VOC) because they are prevalent in homes but are amenable to control at source and by ventilation.

The monthly results of about a thousand annual runs have been combined into several databases to allow ease of access and formatted output. Based on surveyed pollutant source strengths, about 25% of the smallest and tightest houses in the Prairies and in B.C. have formaldehyde levels above the Action Limit provided by the Canadian Health Protection Branch during the critical shoulder season months. A similar number of Ontario houses exceeds the limit during the summer - a factor in air-conditioned houses.

Tables of maximum allowable pollutant source strength were developed for the cross-section of housing in three regions of Canada. They allow maximum allowable source strength to be calculated for the health limit of any pollutant.

With no mechanical ventilation, over 50% of new Prairie houses exceeded the formaldehyde target concentration of 0.05ppm. With a 25 L/s exhaust-only mechanical ventilation system running continuously, the number of houses exceeding the target dropped to 25% and with a balanced 25 L/s ventilation system, the number of houses dropped to less than 10%.

Exhaust-only ventilation systems were about 75% as effective as balanced ventilation systems of the same capacity.

RÉSUMÉ

À mesure que s'accroît l'étanchéité à l'air des maisons par souci de réduire la consommation d'énergie, la question de la pollution intérieure menace de plus en plus la santé et le confort des occupants.

On a effectué une analyse de modélisation de l'effet qu'ont les concentrations de polluants et les méthodes de ventilation à l'intérieur sur la teneur en polluants par rapport aux limites et niveaux cibles d'exposition chez l'être humain.

Une recherche documentaire étendue visait également à déterminer les émanations polluantes des matériaux de construction, les concentrations de polluants présentes dans toute la maison et les limites relatives à la santé. Les renseignements dans ces trois domaines sont inexistants ou contradictoires.

Il est nécessaire d'établir les limites relatives au confort et à la santé en fonction d'études tenant compte des facteurs toxicologiques, mutagènes et cancérigènes. On devra également déterminer s'il est préférable d'exprimer les limites selon la masse ou selon le volume pour représenter les effets sur le confort et la santé. En raison des conséquences variées sur le confort et la santé, nous recommandons de ne pas utiliser la concentration totale des composés organiques volatils (COV) pour évaluer les niveaux de polluants. Le «mélange» des polluants et leurs effets présentent trop de variations.

Bien que certaines données soient disponibles, nous devons obtenir des données précises sur l'étanchéité à l'air et les polluants de l'ensemble de la maison persiste en ce qui a trait aux composés organiques volatils (COV) les plus répandus. Un modèle de prévision des concentrations à la source devra être élaboré et étalonné à partir des données de l'enquête. Une documentation importante devra étayer les données des essais si l'on compte s'en servir à cette fin.

Pour augmenter la quantité de données disponibles relativement à l'étanchéité à l'air, des tests ont été effectués dans 36 maisons des basses terres continentales de la Colombie-Britannique. Les années de construction de l'échantillon s'échelonnaient de 1920 à 1978. Les maisons de cette région sont non seulement construites plus étanches mais aussi plus grandes. Elles demeurent cependant les maisons les moins étanches au Canada.

Un modèle simple de simulation de la qualité de l'air, suffisamment rapide pour permettre des analyses paramétriques des effets du changement de nombreuses variables, a été élaboré. On devra poursuivre l'élaboration de ce modèle afin d'en accroître la précision et la souplesse d'emploi.

L'étude a porté principalement sur les effets des composés organiques volatils (COV) étant donné qu'ils se retrouvent fréquemment dans les maisons et qu'ils peuvent être éliminés à la source et par ventilation.

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Les résultats mensuels d'environ mille essais annuels ont été regroupés en plusieurs bases de données afin d'en faciliter l'accès et la présentation.

Selon les concentrations de polluants relevées, environ 25 p. 100 des maisons les plus étanches et les plus petites des Prairies et de la C.-B. enregistrent des niveaux de formaldéhyde plus élevés que la limite d'intervention fixée par la Direction générale de la protection de la santé du Canada au cours des mois critiques de l'inter-saison. Un nombre équivalent de maisons ontariennes dépassent la norme pendant l'été, entre autres dans les maisons climatisées.

Des tableaux présentant les concentrations de polluants maximales admissibles ont été dressés à partir d'un échantillon de trois régions du Canada. Ils permettent de calculer les concentrations constituant la limite acceptable pour chaque substance polluante.

Sans ventilation mécanique, plus de 50 p. 100 des maisons neuves des Prairies dépassaient le concentration cible de formaldéhyde qui est de 0,05 ppm. Grâce à l'installation d'un système de ventilation mécanique par extraction de 25 L/s fonctionnant constamment, le nombre de maisons dépassant cette limite est tombé à 25 p. 100. Le recours à une installation de ventilation équilibrée de 25 L/s l'a ramené à moins de 10 p. 100.

Les installations de ventilation par extraction offraient 75 p. 100 de l'efficacité des installations de ventilation équilibrées de même capacité.

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1 BACKGROUND

1.1 Project Objectives

The purpose of this project was to carry out a mathematical modelling analysis of the interaction of indoor pollutant source strengths and ventilation scenarios on the concentration of pollutants, and compare them to human exposure limits and targets.

Several associated tasks were carried out in order to accomplish the overall project objective:

- Carry out a survey of building characteristic, pollutant sources and pollutant health limits;
- Develop a simple, fast indoor air quality simulation model;
- Determine representative housing characteristics to model (this required that we carry out air-tightness field tests in one region where data was lacking); and
- Perform over a thousand simulation runs to determine pollutant concentrations over a one year period - for three regions, several house types and various ventilation and control strategies.
- Compile simulation results into several databases for ease of access and to enable the output of formatted results.

1.2 Background

There is a long list of pollutants measured in residential environments. The pollutants break down into four broad categories, based on source.

Table 1.1 Residential Pollutants by Source

Combustion by-products	Outdoor pollutants	Biogenic particles	Volatile & semi-volatile organic compounds
• appliances • fireplaces • cigarettes	• soil gases (radon, methane, pesticides, etc.) • Industrial air pollutants (SO_2, NO_2, ozone, etc.)	• fungus • mites • bacteria • organic dust	• building materials • furnishings • consumer products • human bioeffluents • indoor activities (cooking, washing, hobbies and crafts)

Referring to the table above, combustion by-products have been well researched and a strong consensus is that combustion should not occur within the building envelope. There has been no suggestion that dilution, by ventilating the house, is a feasible solution for combustion related pollutants[1]

Also, soil-based research is on-going and models have already been developed to predict indoor concentrations. The primary control measure is the design of pressure difference control and an effective barrier to prevent entry into the below grade envelope (this concept includes sub-slab ventilation).

It is not possible, in residential systems, to control other outdoor source pollutants (SO_2, NO_2, etc.) through ventilation.

The presence or abundance of biogenic particles relates directly to how the occupant operates the house and high concentrations are usually a symptom of improper operation - in many cases relating to details of lifestyle (such as high relative humidity) and building construction (low surface temperatures leading to condensation). Therefore, ventilation scenarios are not likely to have a significant impact on this class of pollutant.

Unlike these other sources of pollutants, Volatile Organic Compounds (VOC) can be controlled at source (through design and material selection) and/or through ventilation.

For these reasons this study emphasizes Volatile Organic Compounds as the primary type of pollutants of concern for the Indoor Air Quality (IAQ) modelling.

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[1] e.g.: "In view of the carcinogenic properties of tobacco smoke, it is recommended that any exposure to tobacco smoke in indoor environments be avoided.", Exposure Guidelines for residential indoor air quality, Health and Welfare Canada, April 1987.

2 LITERATURE REVIEW

The objective of the literature review was to select a sub-set of pollutants that were well understood and a cause for concern. The following criteria were used to screen pollutants:

Table 2.1 Pollutant Selection Criteria

	Key Criteria
1.	Pollutant has been found in high concentration (greater than 5 $\mu g/m^3$) in surveys of residential environments.
2.	Sources of the pollutant have been well documented by small chamber testing
3.	Pollutant has been researched by the medical profession to establish health impacts and irritation potential and to set limits or guidelines for human exposure.

We used a 5 $\mu g/m^3$ cut-off point to narrow the selection of VOC. As more health and residential concentration data becomes available, the list of pollutants should be refined.

In addition to the above criteria, we wanted a mix of pollutants that were either odorous or irritating to the mucous membrane and either toxic or suspected/confirmed human carcinogens. This reflects our concern with both the health and comfort aspects of indoor air quality.

Table 2.2 Literature Review Tasks

1.	Review field surveys that identify and/or measure the concentration of pollutants in residential dwellings.
2.	Assemble an inventory of emission rates from building materials, . furnishings, and consumer products, and identify factors that influence their indoor concentration.
3.	Investigate current and proposed indoor guidelines and limits for the same pollutants identified in the second task.
4.	Create a list of critical indoor air pollutants based on the frequency of occurrence in the residential environment, the typical levels of concentration relative to current or proposed limits, and the known or suspected effect on occupant's health or perceived comfort.

2.1 Pollutants in Residential Dwellings

Survey data has been limited to residential construction. While the vast majority of indoor air quality surveys for volatile organics have been carried out in office buildings, this data has been excluded because of differences in the materials used, occupant activities and the operation of office equipment.

A poor correlation exists between the types of pollutants found in houses in different studies - a fact not acknowledged by the authors of these reports. It is likely that each group of researchers used different sampling and analyzing techniques, and were searching for different compounds. Also, the types of construction and the composition of consumer products may have been different. Age of products is another factor that is generally not documented. All this points to the necessity of **thorough documentation** of each dwelling.

While a number of residential studies were used for background and to assist in the selection of critical pollutants[2], work carried out for CMHC formed the basis of pollutant source strengths used in most of the IAQ simulations[3]. This data was sufficiently complete, including air change data, volume and pollutant concentrations to allow for the calculation of source strengths (see section 4.3 and Appendix, section 10.2).

2.2 Emission rates from Building Materials and Consumer Products

The data on emissions from residential building materials is extremely scarce. There is little or no data on how emissions from products vary by manufacturer or how emissions vary depending on temperature, humidity, age of product, or total loading of the ambient air. Just as significantly are the wide variety of testing and reporting methods which makes comparison of data from different sources difficult or impossible. Consequently, the available data (summarized in the Appendix, section 10.2), should be used with extreme caution until more extensive and consistent data becomes available.

Materials break down into "wet" and "dry" products. Wet products consist of a significant liquid fraction that dries, releasing the majority of its VOC in the first 10 to 100 hours after application. After about 100 hours these products can be considered dry products.

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[2] Krause, C., et al, "Occurrence of volatile organic compounds in the air of 500 homes in the Federal Republic of Germany", Indoor Air '87: Proceedings of the 4th International Conference on Indoor air Quality and Climate, Vol. 1, pp. 102-106.

Otson, Rein, "Surveys of Selected Organics in Residential Air", Health and Welfare Canada, Indoor Air Quality in Cold Climates, Hazards and Abatement Measures, Air Pollution Control Assoc., Ottawa (April 1985), pp. 224-236.

Wallace, Lance, "Volatile Organic Compounds in 600 US Homes: Major sources of personal exposure", Indoor Air '87: Proceedings of the 4th International Conference on Indoor Air Quality, Vol. 1, pp.183-187.

[3] Dumont, Rob, "Volatile Organic Compound Survey and Summarization of Results", January 1992, by Saskatchewan Research Council for CMHC. Surveys Rein Otson's 26 VOC compounds in 20 Saskatchewan and 24 Ontario houses. Volumes calculated and passive air change rates determined by PFT decay (concurrent with pollutant concentrations).

Dry products emit VOC at a steadily declining rate which can stretch from months to years. While emission rates generally decrease over time, changes in temperature and humidity can cause increases or accelerated decreases.

The Total Volatile Organic Compound (TVOC) rate of emissions is often used to characterize the VOC emissions from a material, however the suitability of TVOC as an indicator is still very much in question. The individual VOC vary considerably in their effect on health and comfort - ranging from no known effect at high concentrations through carcinogenic effects at low concentrations (see section 2.3).

Analysis of volatile organic compounds is accomplished using Gas Chromatograph/Mass Spectrometer (GC/MS) technology which is expensive and time consuming. A further step is required to go from identification to quantization of a compound. The result is that many of the researchers have economized and have only identified the most prevalent compounds. In some cases the total emission rate for a class of volatile compounds (e.g.: aromatic hydrocarbons) is determined. This drastically limits the usefulness of the data in determining the health and comfort effects of a VOC.

2.3 Health and Comfort Limits

VOC effect people in various ways. In Table 2.3, examples 1, 2 and 3 are usually subject to **concentration thresholds** below which their effect is negligible. However, carcinogenic effects are suspected to have **no threshold** and to be **cumulative** in their effect.

Table 2.3 Examples of VOC Health Effects

1.	Discomfort due to odor
2.	Irritation of mucous membranes leading to more frequent health problems
3.	Toxicity, singly or in groups, causing acute or long term health problems
4.	Carcinogenic (suspected or confirmed)

2.3.1 Odour Limits

Odour thresholds have been established for many compounds. Jon Ruth has compiled odour threshold data[4] for about 450 chemical

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[4] Ruth, Jon: "Odour Thresholds and Irritation Levels of Several Chemical Substances: A Review", Wausau Insurance Companies, 550 California St., San Francisco, CA.

substances. Ole Fanger has also concentrated on a broader definition of comfort which includes occupant's or a judging panel's perceptions[5].

Lars Gunnarsen, in his study on *Adaptation and Ventilation Requirements*, suggests that humans adapt differently to VOC from different sources. He concluded the following:

> Air quality is least acceptable immediately after entering a room with air pollution. After a few minutes, people adapt and the air is perceived as more acceptable.
>
> Adaptation improves acceptability for human bioeffluents, some for Environmental Tobacco Smoke (ETS), and least for building material sources.
>
> When defining ventilation requirements for adapted people, human bioeffluents may be neglected, ETS source strength may be reduced 50%, and building materials source strength may be reduced 30% compared to non-adapted people.

2.3.2 Irritant Limits

Molhave and others have concentrated on documenting the physical symptoms caused by exposure to a mixture of VOC that are commonly found in **office buildings** (also, see section 2.3.5).

2.3.3 Toxicity Limits

There is presently a major debate occurring as to whether existing occupational standards can be applied to residential indoor air. The consensus, however, is that occupational limits are too conservative (high) to be appropriate, perhaps in general[6], but definitely for determining allowable exposures for infants, the elderly, the sick and for pregnant women - all of whom are not only more susceptible, but also may spend up 100% of their time in the home environment.

Some existing and proposed VOC limits are summarized in section 10.3. The U.S. EPA found the following compounds to be toxic or mutagenic.

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[5] Fanger, Ole: "Hidden Olfs in Sick Buildings", ASHRAE Journal, November 1988

[6] S.A. Roach and S.M. Rappaport, "But They are Not Thresholds. A Critical Analysis of the Documentation of Threshold Limit Values." American Journal of Industrial Medicine, Volume 17 (1990), pp. 727-753.

In examining the documentation on 488 chemicals listed in the 1976 TLVs, the researchers found the following:

- TLVs were poorly correlated with the incidence of adverse effects
- TLVs were well correlated with the exposure levels which had to be reported at the time the limits were adopted
- Interpretation of exposure response relationships were inconsistent between the authors of studies cited in the 1976 Documentation and the TLV committee

Roach and Rappoport conjecture that the TLVs represent levels of exposure considered attainable at the time.

Table 2.4 Toxic or Mutagenic Compounds

Carbon Tetrachloride
Chlorobenzene
n-Decane
1,2-Dichloroethane
n-Dodecane
Ethylbenzene
1,1,2,2-Tetrachloroethane
1,1,1-Trichloroethane
Trichloroethylene
Undecane

2.3.4 Carcinogenic Limits

The introduction to the Canadian Health and Welfare Guidelines has the following to say about carcinogenic substances:

"There is evidence that for carcinogenic substances threshold levels may not exist. It follows in such cases that there is no level of exposure at which a hazard does not exist, although at very low concentrations the health risks may be so small as to be undetectable. For carcinogens, the derivation of acceptable exposure limits using experimentally derived LOAEL[7] and safety factors is considered inappropriate."

The following compounds are known or suspected carcinogens (U.S. EPA and others).

Table 2.5 Carcinogenic Compounds

Benzene
Chloroform
m,p-Dichlorobenzene
Styrene
Tetrachloroethylene
m,p,o-Xylene
Formaldehyde
Toluene

2.3.5 Summary of Limits

Molhave, Tucker and Seifert have each proposed different VOC standards for residential and commercial buildings.

Molhave based his proposed TVOC standard on the irritation response of his subjects to a mix of 25 compounds found in office buildings[8]. Molhave's guideline of 0.20 mg/m^3 is based on summing the signals from all VOC and reporting them as an equivalent concentration of Toluene. Molhave has attempted to provide a foundation based on the results of health effects studies, but he

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[7] LOAEL: Lowest Observable Adverse Effect Level

[8] The mixture of compounds used by Molhave consisted of:

n-Hexane
n-Nonane
n-Decane
n-Undecane
1-Octane
1-Decane
Cyclohexane
3-Xylene
Ethylbenzene
1,2,4-Trimethylbenzene
n-Propylbenzene
Pinene
n-Pentanal
n-Hexanal
Iso-propanol
n-butanol
2-butanone
3-Methyl-3-butanone
4-Methyl-2-pentanone
n-butylacetate
Ethoxyethylacetate
1,2-Dichloethane

also states that "field investigations and controlled experiments are, however, yet too few to allow a final conclusion" to VOC limits. Also, we believe that his approach is basically flawed, since it relies on a TVOC limit and, if the mix of compounds in buildings change (as they will), then the comfort/toxic/carcinogenic effects will also change.

Tucker proposes an allowable limit of 0.50 mg/m^3 from any single source, but scaled according to the number of sources present. He also sets limits according to the building material source - floors, furniture, etc. His limits are based on Molhave's work.

Seifert compares the ten most prevalent compounds with limits for each of several VOC compound classes.

Table 2.6 Seifert's Proposed VOC Limits

Chemical Class	Concentration (micrograms/m^3)
Alkanes	100
Aromatic Hydrocarbons	50
Terpenes	30
Halocarbons	30
Esters	20
Aldehydes & Ketones (except formaldehyde)	20
Formaldehyde	60
Other	50
Target guideline (sum of 10 most prevalent VOC)	300
Concentration of an individual compound should neither exceed 50% of its class limit nor 10% of the TVOC.	

While we feel that Seifert's approach has merit[9] in that it provides limits for **classes of compounds** rather than only for the TVOC, we feel that the best, long-term, approach would be to provide limits for selected **individual compounds**. The reason for this is that, with the wide range of effects that VOC have on health and comfort, it is impossible to reliably link TVOC to health or comfort effects (for example, air fresheners give off VOC but presumably have little or no effect on health or comfort for the general population). The only justification for limits of combinations of compounds (in addition to limits for individual compounds) would be to account for synergistic effects.

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[9] However, Seifert states that his "proposed target value is not based on toxicological considerations". This is not unreasonable since each class of compounds represents a mix of health effects.

At this time, therefore, we will use Seifert's proposed limits and assume that the compounds that we select are the most prevalent. With respect to formaldehyde, we will use the Canadian Health Protection Branch recommendations of 120 micrograms per m^3 (0.10 ppm) action level and 60 micrograms per m^3 (0.05 ppm) target level (the latter value coincides with Seifert's limit for formaldehyde).

The other change that we propose is that **volumetric limits** rather than **mass-based limits**[10] be used. This is in line with the fact that users of these limits - building scientists, ventilation system designers, etc. - deal with building volume, volumetric flow rates and volumetric air changes per hour. If limits for individual pollutants are used, then the compound molecular weight will be known and conversion from mass concentration will be easy. Also, there is some evidence that health effects may be linked more directly with volumetric concentrations (ppm or ppb), rather than to the mass concentrations of pollutants[11]. The fact that measured mass concentrations must be corrected for temperature and pressure to convert them to volumetric concentrations is of little relevance given the magnitude of other uncertainties already discussed.

Health limits from a variety of sources are summarized in Table 2.7 and in section 10.3. It is interesting to note that the range of limits proposed from various sources covers a range of about 10,000 to 1!

2.4 VOC Selected for Analysis

Considering that the simulations to be used will not account for individual compound characteristics (adsorption/desorption rates, concentration limiting factors, etc.), the actual list of compounds investigated is not too critical, except to illustrate the proximity of concentrations to limits and the effects of remedial methods. In fact, the database of simulated results is non pollutant specific (see section 4.4), so the results can be applied to other pollutants at any time.

After investigating lists of chemicals prevalent in residential construction, we have established the following list of compounds to include in our analysis.

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[10] The conversion from mass concentration limit to volume limit is:

$$Limit_{volume} = Limit_{mass} x \frac{0.02445}{(Molecular Weight)}$$

$Limit_{volume}$ in ppm
$Limit_{mass}$ in micrograms per m^3

[11] Girman (California Dept. of Health Services) makes this point in a letter to the "Indoor Air Quality Update" and also quotes Molhave as having a similar opinion.

Table 2.7 Selected VOC and their Characteristics

Compound	Mol. Wt.	Class	Effect	Sources	Available Limits	Proposed Limit
Formaldehyde	30	Aldehyde	suspected carcinogen	Plywood, particle board, carpets, panelling, upholstery fabric, urea foam insulation, wallpaper, caulking, floor varnish, adhesive, gypsum board, tobacco smoke	Dept. of Health & Welfare: ACGIH TLV:	0.1ppm 1.0ppm
Benzene	78	Aromatic Hydrocarbon	suspected carcinogen	Adhesives, spot cleaners, paint remover, particleboard, tobacco smoke	ACGIH TLV:	1.0ppm
Toluene	92	Aromatic Hydrocarbon	confirmed carcinogen	Solvent and water based adhesives, edge sealing, moulding tape, wallpaper, jointing compound, calcium silicate sheet, floor covering, vinyl coated wallpaper, caulking compounds, paint, chipboard, linoleum floor covering, kerosene heaters, tobacco smoke	Seifert: Aromatic Class: ACGIH TLV: ACGIH STEL:	~0.008 ppm 100ppm 150ppm
Xylene	106	Aromatic Hydrocarbon	mucous membrane irritant	Adhesives, jointing compound, wallpaper, caulking compounds, floor covering, floor lacquer, grease cleaners, shoe dye tobacco smoke, kerosene heaters, varnish, kerosene heaters.	ACGIH TLV: ACGIH STEL	100ppm 150ppm
Nonane	128	Alkane	mucous membrane irritant	Wallpaper, caulking, floor covering, chipboard, adhesives, cement flagstone, jointing compound, floor varnish, kerosene heaters, floor wax	Seifert: Alkane Class (ACGIH TLV)	~0.010 ppm 200ppm
Undecane	156	Alkane	mucous membrane irritant	Wallpaper, gypsum board, floor/wall covering, joint compound, chipboard, floor varnish, paints, paint removers		
Limonene	136	Terpene	short term irritant	Paint, adhesives, chipboard, detergents	Seifert: Terpene Class	~0.003 ppm
a-Pinene	208	Terpene	mucous membrane irritant	Cement flagstone, fibreboard, gypsum board, adhesive, insulation sheets, chipboard, calcium silicate sheet		
Ethylbenzene	106	Ether	skin & mucous membrane irritant	Floor/wall covering, insulation foam, chipboard, caulking, jointing compound, fibreboard, calcium silicate sheet, adhesives, floor lacquer, grease cleaners	Seifert: Ether Class (ACGIH TLV) (ACGIH STEL)	~0.002 ppm 100ppm 125ppm

Note: ACGIH TLV (Threshold Limit Values) and STEL (Short Term Exposure Limits) are occupational limits.

3 IAQ PROGRAMS

3.1 Background

Because of the uncertainties in health limits and microscale emission and air movement factors, residential IAQ modelling can be characterized as being at a preliminary stage. Most modelling work to date has used programs requiring extremely detailed inputs. Many of these inputs cannot be determined with sufficient accuracy to give credible results.

Until such time as VOC emission characteristics and the health effects of VOC pollution are known with better accuracy, there is little to be gained by very accurate modelling of pollutant concentrations. At this stage, what is required is a simple model to carry out hundreds of runs covering a range of climatic regions, housing types, ventilation types and ventilation operating scenarios to determine critical combinations of building and operating characteristics. As more accurate data and limits become available, further analysis, with more accurate modelling, can be focussed on known critical combinations.

A variety of IAQ models were surveyed, but none were deemed to be suitable for our requirements. A good review of IAQ models is contained in the paper by Bruce Weir[12].

3.2 AQ1 Program

The Indoor Air Quality program, AQ1, created for this analysis is described and documented fully in the Appendix, section 9.

The program AQ1 is an indoor air quality model for a one-zone building. It uses weather, pollutant and building characteristics to calculate hourly infiltration/ventilation rates and pollutant concentration rates.

The program uses the AIM-2 infiltration model[13] to calculate natural infiltration. Ventilation added by exhaust and supply fans is calculated using a fan model developed by Ecotope.

Source and sink effects are not modelled, nor are concentration dependant emission rates. The calculated concentrations can therefore be scaled with actual emission rates during post-processing.

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[12] Weir, Bruce, et al "Specification of Indoor Air model characteristics", Indoor Air 90, Toronto, Ontario, volume 3, pp. 231-236.

[13] Walker, I.S. and Wilson, D.J., The Alberta Air Infiltration Model, AIM-2", The University of Alberta Dept. of Mech. Engineering Report 71, January 1990.

4 IAQ SIMULATION RESULTS

4.1 AQ1 Testing

A number of trial runs were carried out with data provided by CMHC in order to:

- compare calculated with measured air change and pollutant concentrations
- perform a parametric analysis to see the effect of changing detailed model inputs.

Two houses were analyzed and the results are presented in section 9.5). Generally the distribution of holes in the building envelope is unknown and must be estimated. By changing unknown factors, such as the infiltration coefficients describing the locations of holes in the walls, roof, floor and flue (R,X,Y in the AIM-2 model), building height, shelter factors, etc. we were able to model changes in infiltration of over two to one. This points to a need for more complete documentation of test results - shelter factors, building heights, etc.

Using March weather to match the test period, predicted infiltration and concentration could be brought to within 20% of measured values with a 'reasonable' mix of estimated building coefficients.

4.2 Weather Data

In the simulations to follow, one year of hourly weather was used for the following cities. The following table shows a comparison of the yearly means of this hourly data and long-term weather.

Table 4.1 Annual Average Summary of Weather Data

City	Hourly Temp. (C)	Long-term Temp (C)	Hourly Wind (m/s)	Long-term Wind (m/s)
Vancouver, B.C.*	9.1	9.8	3.9	3.3
Edmonton, Alberta	1.8	3.1	4.0	3.9
Winnipeg, Manitoba*	1.6	2.2	4.6	5.2
Toronto, Ontario*	6.8	7.4	4.2	4.4
Montreal, Quebec	5.7	6.2	4.1	3.3

*Used in this analyses for Pacific (B.C.), Prairie and West Central (Ontario) regions, respectively. Edmonton and Montreal files were used during the AQ1 testing (section 4.1).

Hourly winds for Vancouver averaged 18% higher than long-term, while winds for Winnipeg averaged 12% lower than long-term.

The hourly temperature data resulted in annual mean temperatures that were slightly lower than long term for all three cities - but typically by about 0.6C.

These weather files are therefore close enough to long-term that infiltration calculations will be sufficiently accurate.

4.3 House Characteristics

A set of representative house types was developed from available data (see section 10.1).

Descriptive and fan-door air-tightness test results were obtained for over 400 houses. Output from the database of houses was obtained to provide statistical groupings of data by region and age of house. For older houses in B.C., field data was obtained for the lower mainland (see section 11).

There was not sufficient data available to be able to develop separate data for houses with and without flues. The simulations were carried out in pairs with the same volume and air-tightness, but for one house with a flue and one without.

Averages of building heights and air-tightness exponent were used for each age group and region. Percentile distributions were obtained for volume and air leakage coefficients for four age groups in each of three regions (Table 4.2).

Table 4.2 House Characteristics

		B.C.		Prairies *		Ontario	
Age	Percentile	Volume m^3	C m3/Pa^n	Volume m^3	C m3/Pa^n	Volume m^3	C m3/Pa^n
pre 1946	50	600	597	425	261	533	360
	75	481	408	315	175	385	193
	90	426	360	283	115	375	190
1946-1960	50	472	513	360	145	548	163
	75	389	279	291	102	449	135
	90	384	210	226	91	375	125
1961-1980	50	490	386	531	118	518	166
	75	362	204	421	97	462	114
	90	327	190	333	85	409	91
1981-1990	50	721	275	553	82	836	214
	75	539	248	494	50	725	169
	90	452	168	397	40	577	132

The 90th percentile results represent the smallest and tightest 10% of the housing stock surveyed.

4.4 Database of Results

Several spreadsheet databases of monthly results were set up, each consisting of 250 to 400 runs. This was done, not for speed (annual simulations take under 5 seconds on a 486 computer), but to provide a formatted and graphic output (see Figures 5.1 and 5.2 plus samples in the Appendix, section 10.4.1).

The databases are set up to allow for input of the region (Ontario, Prairies or BC), age category (pre 1946, 1946-1960, 1961-1980 or 1981-1990), building characteristic percentile (50, 75 or 90), and ventilation scenario (none, continuous balanced ventilation of 25L/s or 50L/s, continuous exhaust of 25L/s or intermittent exhaust for 2 hours per day at 50L/s). One database was devoted to runs using inside to outside temperature difference ventilation control. In each case, the output is the average of two runs - with and without a flue. In the future, if the building characteristics can be disaggregated for flue and non-flue houses, the database could be updated to allow separate outputs for this characteristic.

In the databases, pollutant sources[14] for formaldehyde, benzene, toluene, xylene, nonane, undecane, limone, a-pinene and ethylbenzene can be input in several different ways:

- Using whole house survey data provided (formaldehyde for new houses only, other VOC for new and older houses in Saskatchewan and Ontario)
- Using user specified quantities (areas) of various materials
  - particle board
  - plywood
  - gyproc
  - wallpaper
  - carpet plus underlay
  - vinyl flooring
- Using user input source strengths
- Using sums of any of the above

---

[14] Note that, since the simulation runs are not specific to a particular pollutant, the results can be applied to any pollutant, simply by scaling the output (actual source strength/simulation source strength). The simulations were run using 1,000 mL/h as a source strength.

5 ANALYSIS OF RESULTS

The following figures show sample outputs for 75th percentile houses (75% of houses are larger and have higher leakage coefficients) in each region, with **average pollutant source strengths.**

If the houses are assumed to be open during the summer, then the critical periods occur when the infiltration driving forces are least - typically in the 'shoulder seasons' between the heating season and summer. March and October are likely to be critical for pollutant concentration for houses that are opened in the summer. Summer will be critical for houses that are kept closed year around.

With average (5.5 mL/h) formaldehyde source strength, the 75th percentile Prairie house averaged 0.116 ppm in October - just over the 0.10 ppm Action Limit. If the house were kept closed during the summer, the non-ventilated house would average 0.162 ppm in July - almost twice the Action Limit for formaldehyde. Figure 5.1 is for a Prairies base case with no ventilation[15] and Figure 5.2 is for the same building with continuous balanced fans at 25 L/s. In the latter case, formaldehyde concentrations are below the action and target levels.

With average formaldehyde emissions, the new 75th percentile houses in B.C. and the Prairies exceeded the formaldehyde action limit of 0.10ppm (Table 5.1). This would indicate that over 25% of the houses have critical months averaging higher than the action limit and considerably higher than the target of 0.05ppm.

Table 5.1 Formaldehyde concentration in 1981-1990 houses (75th percentile)

	B.C.		Prairies		Ontario	
Ventilation system	October	August	October	July	October	July
Volume (m^3)	539		494		725	
None	0.118	0.170	0.116	0.162	0.060	0.093
25L/s exhaust; fans on if temp. diff. <8C	0.100	0.090	0.090	0.057	0.043	0.040
25L/s continuous exhaust			0.055	0.057		
25L/s continuous balanced flow	0.070	0.089	0.039	0.045	0.029	0.036

Notes: For formaldehyde, the ACTION LIMIT is 0.10ppm (target limit is 0.05ppm)

Concentrations are based on survey determined average source strengths of 17.1 mL/h for B.C. and 5.5 mL/h for the other two regions. Temperature difference controller turns fan on if dT < 8C.

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[15] Runs with two hours of exhaust ventilation at 50L/s showed virtually no change in average pollutant concentrations compared to the no ventilation case (section 10.4.1).

Figure 5.1

Indoor Air Quality Profile

Description:

Region: PRAI
Age: 1981 to 1990
Percentile: 75
Ventilation Type: None
Ventilation Flow: 0 L/s

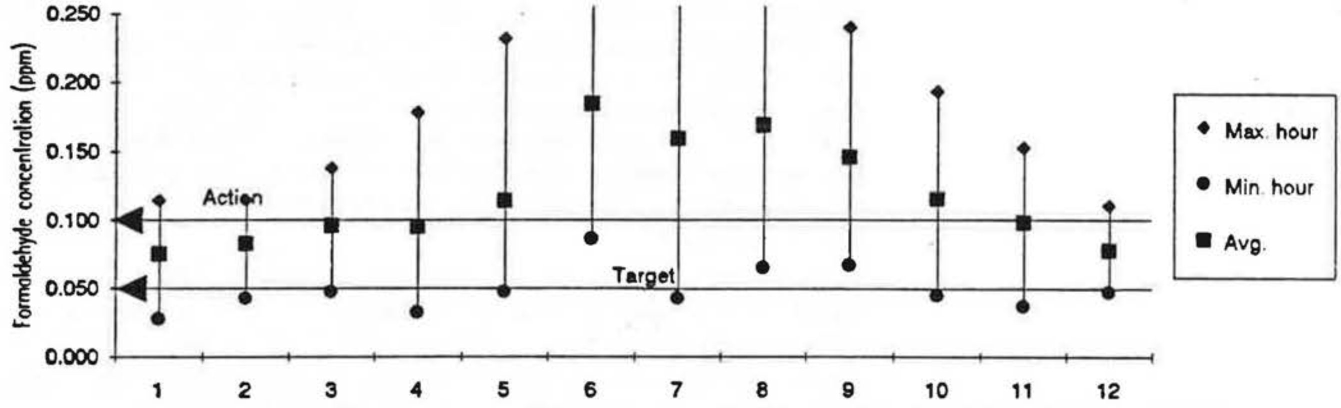
Volume 494 m^3
Bldg. Ht. 4.5 m
Flue Ht. 6.0 m
Foundation Bsmt
C 50 L/sPa^n
n 0.71
ELA 1,030 cm^2

	No Flue		Flue
Run ID #	3630	and	3730
Infil. Coeff:			
R	0.60		0.43
X	0.00		0.00
Y	0.00		0.39
Shelter:			
Building	0.90		0.90
Flue	0.00		0.95

Pollutant Source Strengths:

Whole house source strengths based on: 22 houses

	Formaldehyde	Benzene	Toluene	Xylene	Nonane (mL/hr)	Undecane	Limonene	A-pinene	Ethylbenzene	Source strengths:
House	5.500	0.985	0.856	1.162	N/A	N/A	0.521	0.805	0.385	SRC avg. meas. (whole house) Formaldehyde meas. (CMHC)



Note: Graph shown is for formaldehyde, other pollutant curves will be the same shape.

Pollutant Health Limits (ppm)

	Formaldehyde	Benzene	Toluene	Xylene	Nonane	Undecane	Limonene	a-Pinene	Ethylbenzene	
Classes:	Aldehyde	Aromatic Hydrocarbons			Alkanes		Terpenes		Ether	Class limits are from Seifert
Class Limits:	0.10	0.008	0.007	0.006	0.010	0.008	0.003	0.002	0.002	Aldehyde limit is from EHD
ACGIH TLV	1.00	9	100	100	200	N/A	N/A	N/A	100	(Canada) for formaldehyde.
Predicted Pollutant Concentrations (ppm)										
Avg: Year	0.118	0.021	0.018	0.025	not avail.	not avail.	0.011	0.017	0.008	Highest monthly average for each period
Max: Oct-Apr	0.116	0.021	0.018	0.024	not avail.	not avail.	0.011	0.017	0.008	
May-Sep	0.185	0.033	0.029	0.039	not avail.	not avail.	0.018	0.027	0.013	
Max. hour	0.316	0.057	0.049	0.067	not avail.	not avail.	0.030	0.046	0.022	

Infiltration & Ventilation (ach)

Month	1	2	3	4	5	6	7	8	9	10	11	12
Max.	0.473	0.330	0.332	0.438	0.328	0.214	0.385	0.262	0.235	0.337	0.345	0.307
Min.	0.073	0.070	0.063	0.021	0.012	0.012	0.012	0.005	0.012	0.024	0.060	0.074
Avg.	0.155	0.138	0.120	0.134	0.105	0.066	0.078	0.071	0.081	0.107	0.128	0.148
Infiltration & Ventilation (L/s)												
Avg.	21	19	16	18	14	9	11	10	11	15	18	20

Temperatures (C)

Outside	-21.7	-19.0	-9.0	3.1	10.5	17.8	16.7	19.1	13.2	6.9	-5.0	-14.7
Inside	20.0	20.0	20.0	20.0	20.5	21.7	21.3	22.6	20.7	20.0	20.0	20.0

Winds (m/s)

AES Station	4.6	3.8	4.2	6.0	5.3	3.9	4.4	4.2	4.3	5.0	4.7	5.1
Building	3.5	2.9	3.2	4.5	4.0	2.9	3.3	3.2	3.2	3.8	3.6	3.9

Figure 5.2

Indoor Air Quality Profile

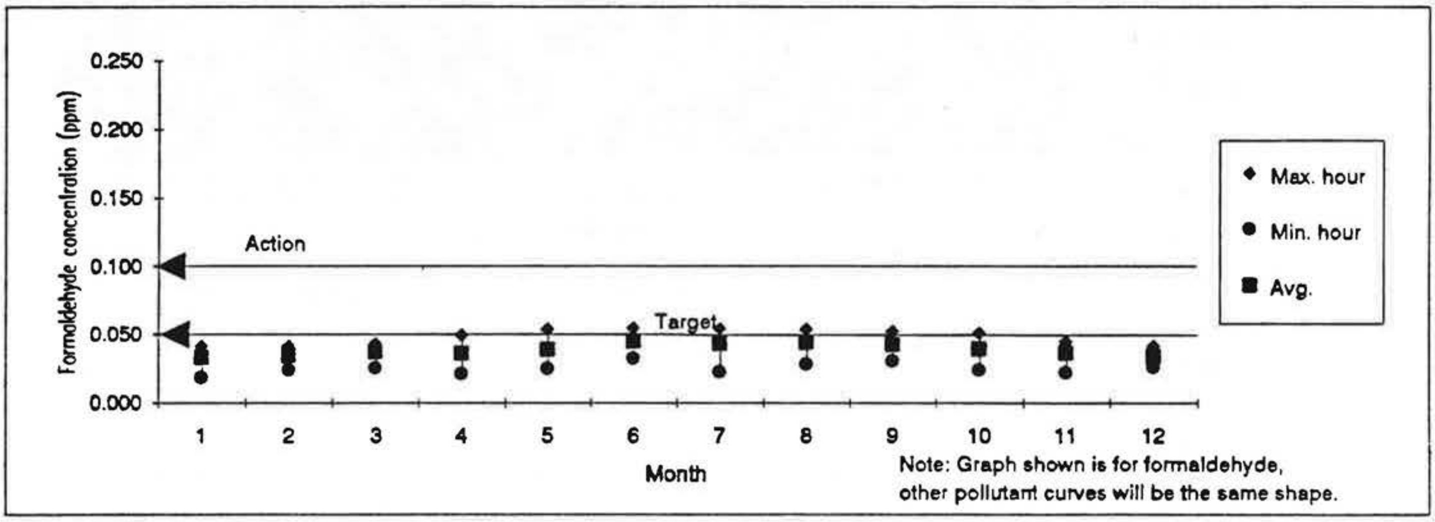
Description:

					No Flue		Flue
Region:	PRAI	Volume	494 m^3	Run ID #	3631	and	3731
Age:	1981 to 1990	Bldg. Ht.	4.5 m	Infil. Coeff:			
Percentile:	75	Flue Ht.	6.0 m	R	0.60		0.43
Ventilation Type:	Continuous flow, balanced	Foundation	Bsmt	X	0.00		0.00
Ventilation Flow:	25 L/s	C	50 L/sPa^n	Y	0.00		0.39
		n	0.71	Shelter:			
		ELA	1,030 cm^2	Building	0.90		0.90
				Flue	0.00		0.95

Pollutant Source Strengths:

Whole house source strengths based on: 22 houses

	Formaldehyde	Benzene	Toluene	Xylene	Nonane	Undecane	Limonene	A-pinene	Ethylbenzene	Source strengths:
					(mL/hr)					
House	5.500	0.985	0.856	1.162	N/A	N/A	0.521	0.805	0.385	SRC avg. meas. (whole house) Formaldehyde meas. (CMHC)



Note: Graph shown is for formaldehyde, other pollutant curves will be the same shape.

Pollutant Health Limits (ppm)

	Formaldehyde	Benzene	Toluene	Xylene	Nonane	Undecane	Limonene	a-Pinene	Ethylbenzene	
Classes:	Aldehyde	Aromatic Hydrocarbons			Alkanes		Terpenes		Ether	Class limits are from Seifert
Class Limits:	0.10	0.008	0.007	0.006	0.010	0.008	0.003	0.002	0.002	Aldehyde limit is from EHD
ACGIH TLV	1.00	9	100	100	200	N/A	N/A	N/A	100	(Canada) for formaldehyde.
Predicted Pollutant Concentrations (ppm)										
Avg: Year	0.039	0.007	0.006	0.008	not avail.	not avail.	0.004	0.006	0.003	
Max: Oct-Apr	0.039	0.007	0.006	0.008	not avail.	not avail.	0.004	0.006	0.003	Highest monthly average for
May-Sep	0.045	0.008	0.007	0.010	not avail.	not avail.	0.004	0.007	0.003	each period
Max. hour	0.055	0.010	0.009	0.012	not avail.	not avail.	0.005	0.008	0.004	

Infiltration & Ventilation (ach) Month

	1	2	3	4	5	6	7	8	9	10	11	12
Max.	0.655	0.513	0.514	0.621	0.510	0.396	0.567	0.445	0.417	0.519	0.527	0.490
Min.	0.255	0.252	0.245	0.204	0.194	0.194	0.194	0.187	0.194	0.206	0.242	0.256
Avg.	0.337	0.320	0.302	0.316	0.288	0.248	0.260	0.253	0.264	0.289	0.310	0.330
Infiltration & Ventilation (L/s)												
Avg.	46	44	41	43	39	34	36	35	36	40	43	45

Temperatures (C)

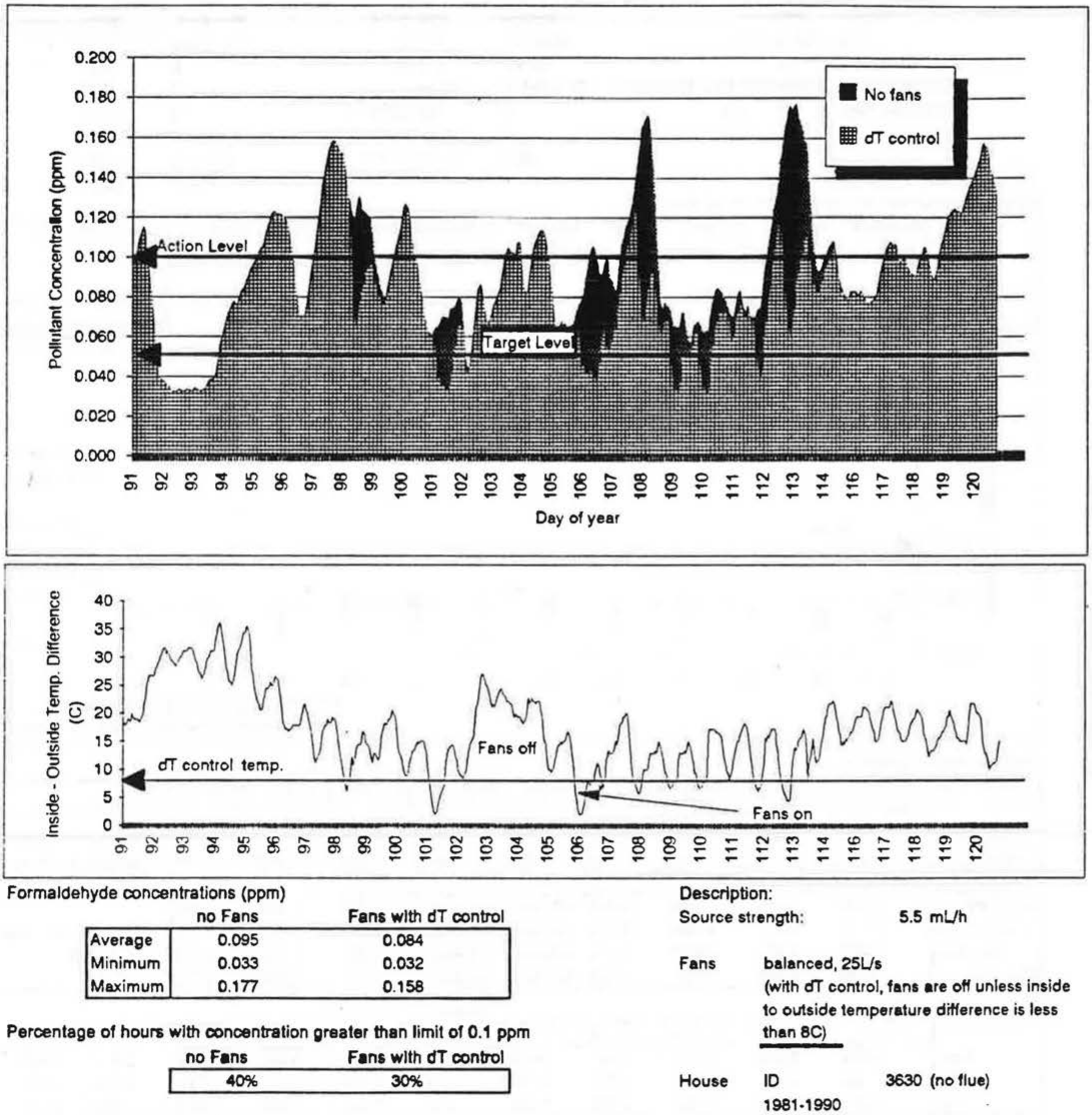
Outside	-21.7	-19.0	-9.0	3.1	10.5	17.8	16.7	19.1	13.2	6.9	-5.0	-14.7
Inside	20.0	20.0	20.0	20.0	20.5	21.7	21.3	22.6	20.7	20.0	20.0	20.0

Winds (m/s)

AES Station	4.6	3.8	4.2	6.0	5.3	3.9	4.4	4.2	4.3	5.0	4.7	5.1
Building	3.5	2.9	3.2	4.5	4.0	2.9	3.3	3.2	3.2	3.8	3.6	3.9

Figure 5.3 Prairies 1980-1990 houses (75th percentile): Temperature difference controlled ventilation

April



Formaldehyde concentrations (ppm)

	no Fans	Fans with dT control
Average	0.095	0.084
Minimum	0.033	0.032
Maximum	0.177	0.158

Percentage of hours with concentration greater than limit of 0.1 ppm

no Fans	Fans with dT control
40%	30%

Total infiltration and ventilation

	no Fans		Fans with dT control	
	(ach)	(L/s)	(ach)	(L/s)
Average	0.13	18	0.15	21
Minimum	0.02	3	0.04	5
Maximum	0.44	60	0.44	60

Fan operation:	0 hours	78 hours

Description:

Source strength: 5.5 mL/h

Fans balanced, 25L/s
(with dT control, fans are off unless inside to outside temperature difference is less than 8C)

House	ID	3630 (no flue)
	1981-1990	
	75th percentile	
	Volume	494 m^3
	C	50 L/sPa^n
	n	0.71
	ELA	1,030 cm^2
	Basement foundation	

Various pollution abatement measures were simulated, resulting in concentrations approaching or below the formaldehyde action limit of 0.10 ppm. For example, with 25L/s balanced fans turned on whenever the inside to outside temperature difference was less than 8C, the October average dropped to 0.043 ppm to 0.100, depending on the region[16] (also see Figure 5.3 for hourly output for a Prairies example). The percentage of hours greater than 0.10 ppm dropped from 40% to about 30% - fans operated only 10% of the time but reduced hours exceeding the limit by 25%.

In B.C., activating ventilation below an 8C inside to outside temperature difference reduced the number of March hours exceeding 0.1ppm from 45% to 40% (fans operated only 5% of the time). Increasing the controlling temperature difference to 14C, operated the fans 60% of the time and reduced the number of hours exceeding 0.1ppm by 87% (from 45% to 6% of hours in the month).

In Ontario, activating ventilation below an 8C inside to outside temperature difference reduced the number of July hours exceeding 0.1ppm from 34% to 0% (and exceeding 0.05ppm from 100% to 0%), with the fans operating 94% of the time.

Balanced ventilation of 25 L/s reduced concentrations in the new 75 percentile houses by 41% in B.C., 66% in the Prairies, and 52% in Ontario (Table 5.1) - the differences largely due to the different size and air-tightness of houses in the three regions.

In the Appendix, section 10.4.1, additional base and abatement outputs are shown for Prairie and Ontario houses with higher than average formaldehyde concentrations.

With regard to the other VOC investigated, it is no surprise that concentrations are much less than the conservative ACGIH Threshold Limit Values (TLV). In fact, the ratio of TLV to concentration ranges from about 500 to 12,000 - indicating that we are not even close to the limits for these pollutants.

However, if **Seifert's pollutant limits** are used, it is a completely different story. For the non-ventilated 75th percentile Prairie house (Fig. 5.1) the individual aromatic hydrocarbons averaged from 0.018 ppm to 0.025 ppm for the year (worse in critical months) - much **greater than Seifert's limit** of about 0.007 ppm. Total aromatic hydrocarbon concentration shows a similar trend[17]. The other VOC show a similar problem. Even with balanced fans running con-

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[16] The results for temperature difference controlled ventilation should be taken as indicative, rather than absolute, since AQ1 is not a thermal modelling program (temperature differences due to internal and solar gains are assumed constant).

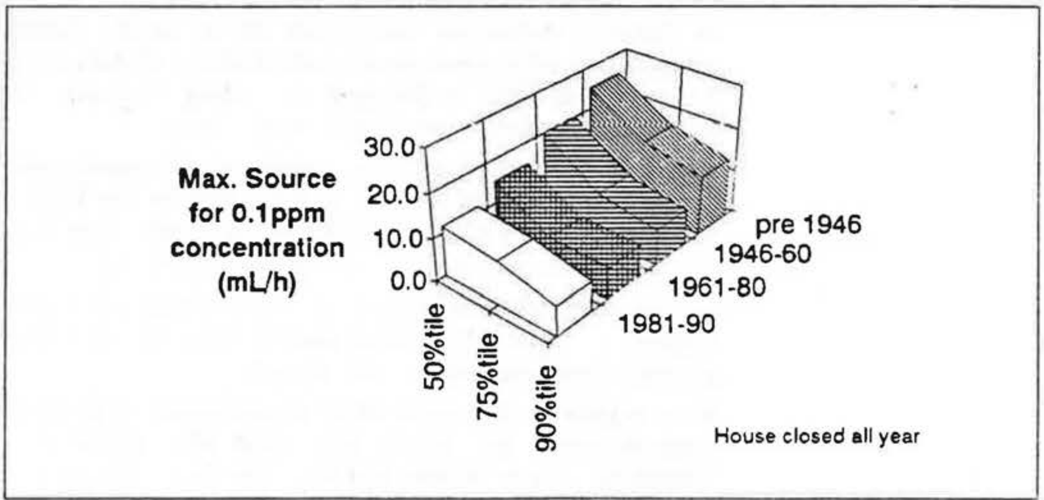
[17] Seifert uses mass-based limits and these compounds have different molecular weights. If the comparison is done using mass concentrations, the total annual average for the three aromatic hydrocarbons equals 243 $\mu g/m^3$ versus the Seifert class limit of 50 $\mu g/m^3$ - about five times (even higher than the volumetric comparison for each compound alone).

tinuously (Fig. 5.2), the annual average concentration of individual aromatic hydrocarbons meets Seifert's limit (and the total would exceed Seifert's limit).

Keep in mind, however that Seifert's limits are not based on toxicological studies - section 2.3.5. Health limits must be defined with reasonable certainty before we can determine what pollution abatement measures are required - if any are required at all. **It has been shown, with formaldehyde, that health limits can be determined if the effort is made.**

Figure 5.4 Maximum Allowable Pollutant Source Strength: B.C.

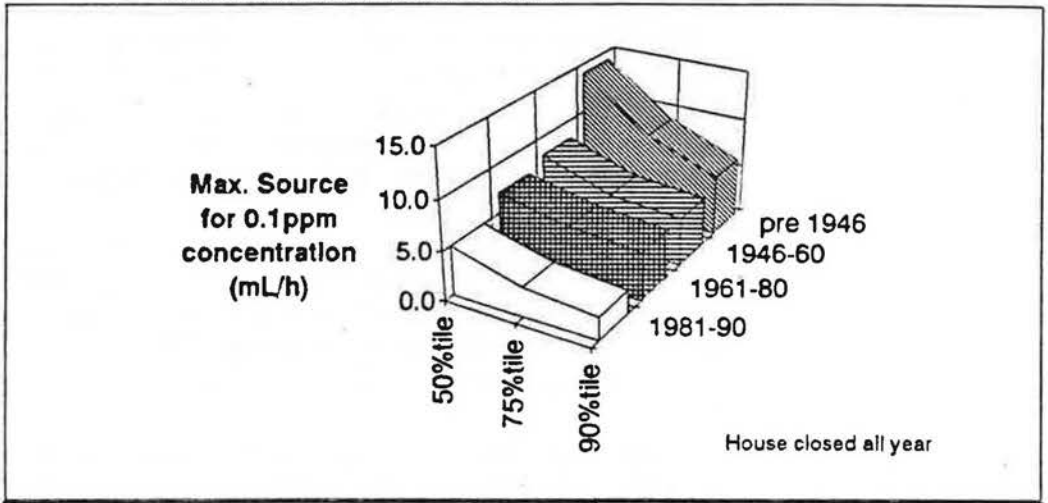
Maximum house emissions to maintain maximum monthly concentration below health limit of 0.1ppm



	Maximum Source Strength (mL/h) House closed all year			Maximum Source Strength (mL/h) House closed Oct - Apr		
	50%tile	75%tile	90%tile	50%tile	75%tile	90%tile
1981-90	11.5	10.0	6.8	17.2	14.9	10.1
1961-80	15.0	7.8	7.2	18.4	9.6	8.8
1946-60	20.0	11.0	8.3	24.5	13.5	10.2
pre 1946	25.0	17.0	13.8	31.9	20.9	16.9

Figure 5.5 Maximum Allowable Pollutant Source Strength: Prairies

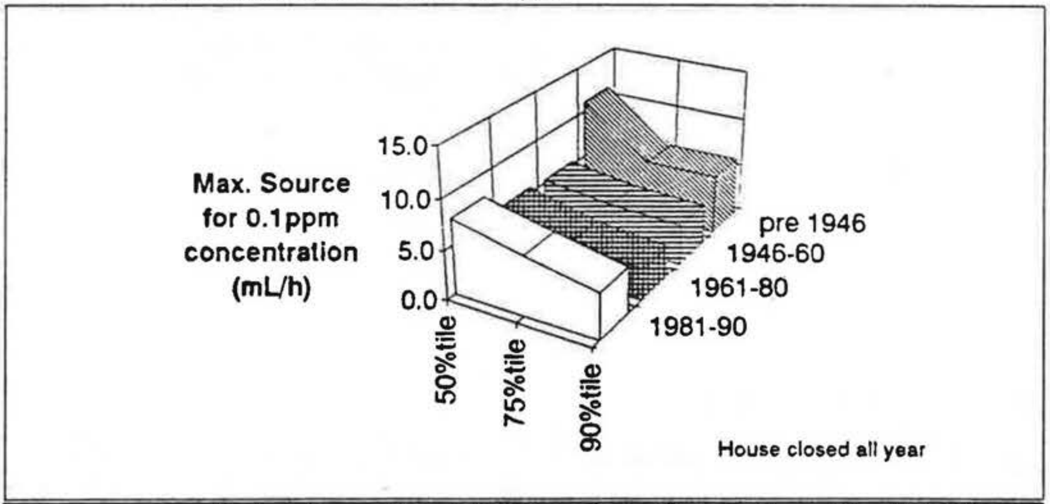
Maximum house emissions to maintain maximum monthly concentration below health limit of 0.1ppm



	Maximum Source Strength (mL/h) House closed all year			Maximum Source Strength (mL/h) House closed Oct - Apr		
	50%tile	75%tile	90%tile	50%tile	75%tile	90%tile
1981-90	5.0	3.0	2.3	8.2	4.8	3.6
1961-80	7.0	5.5	4.9	11.1	9.0	7.7
1946-60	8.0	5.5	4.9	12.3	8.9	7.8
pre 1946	14.0	9.0	6.1	21.5	14.5	9.8

Figure 5.6 Maximum Allowable Pollutant Source Strength: Ontario

Maximum house emissions to maintain maximum monthly concentration below health limit of 0.1ppm



	Maximum Source Strength (mL/h) House closed all year			Maximum Source Strength (mL/h) House closed Oct - Apr		
	50%tile	75%tile	90%tile	50%tile	75%tile	90%tile
1981-90	7.6	6.0	4.6	12.2	9.6	7.5
1961-80	5.5	3.8	3.1	8.5	5.9	4.7
1946-60	5.3	4.4	4.1	8.0	6.7	6.2
pre 1946	11.0	6.0	6.1	17.5	9.4	9.2

Reduction of B.C.'s very high formaldehyde source strengths (17.1 mL/h) should be investigated before using fans to reduce formaldehyde concentrations. The accuracy of the source strength should also be checked, since it is based on only five new houses.

This type of result illustrates the importance of using regional and age specific survey data in simulations (volumes, air-tightness, pollutant source strengths, etc.), rather than relying on arbitrarily selected values.

Since formaldehyde source strengths were unknown for older houses, maximum source strengths were determined for each age group and percentile group that would result in a maximum monthly average concentration at or below a limit of 0.10 ppm[18]. The results are detailed in section 10.4.1 and summarized in Figures 5.4, 5.5 and 5.6.

The graphs and left side of each table in Figures 5.4 to 5.6 show the maximum allowable source strength, for a concentration of 0.1ppm, if the house is closed all year (for security and/or cooling), while the right side of each table present maximum source strengths if the house is closed only for the October to April heating season.

These tables can be used to calculate allowable maximum source strengths for other pollutants with different health limits, using the following relationship:

$$Max.SourceStrength_{pollutant} = \frac{(HealthLimit_{pollutant})}{0.1} x (Sourcestrength from tables)$$

Max. Source Strength has units of mL/h

Health Limit has units of ppm

The table values in Figures 5.4 to 5.6, and Tables 5.2 and 5.3 are for specific house characteristics of volume and air-tightness (see Table 4.2)

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[18] With no ventilation, the ratio of maximum hourly concentration to maximum monthly concentration (used to define the values in the following tables) was as follows - B.C.: 156% to 195% (average 174%); Prairies: 171% to 242% (average 206%); Ontario: 150% to 176% (average 163%). Low values were in smaller and tighter houses (new, 90 percentile) and high values in the larger and looser houses (old, 50 percentile).

With ventilation (Tables 5.2 and 5.3), the ratio of maximum hourly concentration to maximum monthly concentration was lower - B.C.: 124% to 182% (average 152%); Prairies: 101% to 185% (average 136%); Ontario: 102% to 152% (average 120%). Again, the smaller ratios occurred with smaller and tighter houses. The exhaust-only systems had greater variability in this ratio than the balanced systems.

Table 5.2 Maximum Allowable Source Strength: Continuous 25 L/s Exhaust Ventilation

Maximum house emissions to maintain maximum monthly concentration below 0.1ppm limit

	Maximum Source Strength (mL/h) House closed all year			Maximum Source Strength (mL/h) House closed Oct - Apr		
B.C.	50%tile	75%tile	90%tile	50%tile	75%tile	90%tile
1981-90	16.1	14.7	11.6	21.7	20.0	14.9
1961-80	19.6	12.5	12.1	26.3	15.6	14.9
1946-60	25.0	15.6	13.0	32.3	19.6	15.9
pre 1946	30.3	21.3	18.5	41.7	27.8	23.3
Prairies						
1981-90	10.5	9.4	9.1	13.0	10.1	9.4
1961-80	12.3	11.1	10.5	15.9	13.9	12.7
1946-60	13.2	11.1	10.6	17.2	13.9	12.8
pre 1946	18.5	14.5	11.6	26.3	19.6	14.7
Ontario						
1981-90	12.3	10.9	9.9	16.9	14.5	12.3
1961-80	10.4	9.4	9.2	13.3	10.9	9.9
1946-60	10.3	9.7	9.5	12.8	11.5	11.1
pre 1946	16.1	11.1	11.0	22.2	14.3	14.1

Table 5.3 Maximum Allowable Source Strength: Continuous 25 L/s Balanced Ventilation

Maximum house emissions to maintain maximum monthly concentration below 0.1ppm limit

	Maximum Source Strength (mL/h) House closed all year			Maximum Source Strength (mL/h) House closed Oct - Apr		
B.C.	50%tile	75%tile	90%tile	50%tile	75%tile	90%tile
1981-90	20.4	19.2	15.9	26.3	24.4	19.6
1961-80	24.4	17.0	16.4	31.3	20.4	19.6
1946-60	29.4	20.4	17.5	37.0	24.4	20.4
pre 1946	35.7	26.3	23.3	45.4	33.3	28.6
Prairies						
1981-90	14.3	12.0	11.4	17.5	13.9	12.8
1961-80	16.4	14.9	14.1	20.8	18.5	17.2
1946-60	17.2	14.9	14.3	22.2	18.5	17.5
pre 1946	23.3	18.9	15.6	31.3	24.4	19.2
Ontario						
1981-90	16.7	15.1	13.7	21.7	18.9	16.9
1961-80	14.5	12.8	12.0	17.9	15.1	13.9
1946-60	14.3	13.5	13.2	17.2	15.9	15.4
pre 1946	20.4	15.4	15.1	27.0	18.9	18.5

For comparison, the tables also show maximum source strengths for 1981-90 houses. These values can be compared to measured values. The average formaldehyde source strength for B.C. houses of 17.1 mL/h exceeds October to April values for the 75th and 90th percentiles - indicating that at least 25% of these new houses have formaldehyde concentrations of over 0.10ppm (the formaldehyde Action Limit). In the Prairies, the average formaldehyde source strength of 5.5 mL/h in new houses is slightly higher than the October to April 75th percentile value of 4.8mL/h, so over 25% of these houses would have formaldehyde concentrations exceeding 0.1ppm. If the formaldehyde target value of 0.05ppm is used, the maximum allowable source strength values in the table would have to be halved (For example, the 50th percentile new Prairies house has a $Max.\ Source\ Strength_{target} = (0.05/0.1) \times 8.2 = 4.1\ mL/h$ for a house that is closed from October to April. Average actual formaldehyde source strength of 5.5 mL/h exceeds this value, so over 50% of new houses will have formaldehyde concentrations exceeding the 0.05ppm target).

Tables 5.2 and 5.3 present similar values for 25 L/s exhaust-only ventilation and balanced 25 L/s ventilation. For the new Prairies housing example used previously, with 25 L/s continuous exhaust ventilation, the maximum allowable source strength (for the 75th percentile) would be 10.1 mL/h for a 0.1ppm concentration, or 5.5 mL/h for 0.05ppm concentration. This equals the average measured source strength, indicating that 25% of these houses would exceed the formaldehyde target concentration with a 25 L/s exhaust-only system. From Table 5.3, for new Prairies housing, the 90th percentile value of 12.8 for 0.1ppm or 6.4 mL/h for 0.05ppm exceeds the measured source strength, so fewer than 10% of these houses would exceed the 0.05ppm formaldehyde target limit with a 25 L/s balanced ventilation system.

The ratio of allowable maximum source strength with the house closed all year to that if the house were closed from October to April (with no ventilation), varied from 64% (Prairies and Ontario) to 78% (B.C.). With 25 L/s ventilation (exhaust-only or balanced), this ratio averaged 80% across all regions and age categories (from a low of 70% to a high of 97%).

The ratio of allowable maximum source strength with 25 L/s of exhaust-only ventilation to that with a balanced 25 L/s ventilation averaged 80% in B.C. (73% to 92%); 76% in the Prairies (73% to 84%); and 74% in Ontario (71% to 82%). The ratio did not show any pattern according to age or tightness of house.

6 CONCLUSIONS & RECOMMENDATIONS

6.1 General

An extensive literature search was performed to determine pollutant emissions from building materials, whole house pollutant source strengths and pollutant health limits. Available information in all three of these areas is lacking, contradictory, or both.

To expand available data on air-tightness, tests were carried out on 36 houses in the lower mainland of B.C.. The houses covered a range of construction dates ranging from 1920 to 1978.

Houses in the lower mainland of B.C. are gradually becoming more air-tight. Pre and post war houses had NLAs of about 6 cm^2/m^2 - decreasing to 4.4 cm^2/m^2 in the 1961-80 houses, and decreasing further to 2.8 cm^2/m^2 in the 1989 houses (CMHC cross-Canada new merchant house survey). Compared with houses in the rest of Canada, these are still quite loose, however.

A simple Air Quality Simulation program was developed that was fast enough to enable large scale parametric analyses of the effects of changing many variables.

Comfort and health limits, based on human comfort and health studies that account for toxicological, mutagenic and carcinogenic factors. Investigation should be carried out to determine if mass-based or volume-based limits better represent comfort and health effects. Because of the wide range of effects on comfort and health, we recommend that Total Volatile Organic Compound (TVOC) concentrations **not** be used to assess pollutant levels. The 'mix' of pollutants and their effects is too variable.

While some data is available, there is a need for accurate air-tightness and whole-house pollutant source strength data for the most prevalent VOC. A source strength prediction model should be developed and calibrated using this survey data. Extensive documentation **must** accompany the test data if it is to be used for this calibration process.

Wherever possible, simulations should use real building data from statistically significant surveys. This highlights regional and age-specific problems. Remedial measures based on source strength reduction and/or ventilation can then be tailored to the specific needs of the region and type of house.

Results should include the 'tails' of the housing distribution (75th, 90th percentile, etc.) - averages often do not show the problem houses.

Exhaust-only ventilation systems were about 75% as effective as balanced ventilation systems of the same capacity.

6.2 Simulation Program Changes

Some recommendations for change include:

Near term...

- Allow for multiple "starts" of a decaying pollutant over a one year period (maintenance: waxes, etc.)
- Allow for hourly output for specified series of months (February to April, for example)
- Output hours of operation of fan(s).

At a later date...

- Incorporate simple thermal modelling to predict inside temperatures and heating requirements (enabling effect of ventilation control scenarios on heating energy consumption to be determined)
- Incorporate adsorption and concentration limiting factors (when accuracy of health limits justifies).

7 ACKNOWLEDGEMENTS

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We would like to thank Anil Parekh of Scanada and Rob Dumont of SRC for providing survey data without which much of the validity of our results would have been undermined.

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9 APPENDIX: IAQ SIMULATION PROGRAM

9.1 AQ1 Program Description

The program AQ1 is an indoor air quality model for a one-zone building written in Turbo Pascal. It uses weather, pollutant and building characteristics to calculate hourly infiltration/ventilation rates and pollutant concentration rates.

The program uses the AIM-2 infiltration model to calculate natural infiltration (Walker and Wilson, 1990). Ventilation added by exhaust and supply fans is calculated using a fan model developed by Ecotope[19]. The program produces either hourly values or an annual summary of infiltration and pollutant concentration.

Program behavior is controlled from the command line and from four input text files. The command line asks for a filename, which is the prefix of the master input file and of all output files. The filename entered by the user must contain no extensions, but it can include the pathname where the file is located. If a pathname is entered, the output files will be written to that location.

Figure 1 below shows the AQ1 program in mid-operation. To execute the program, type "AQ1" and press ENTER. Enter the input filename with no extension; in the example shown in Figure 1, this file was called "AIMHOUSE.in", and the filename "AIM-HOUSE" was entered. The program then begins running and the screen shows the run number in progress.

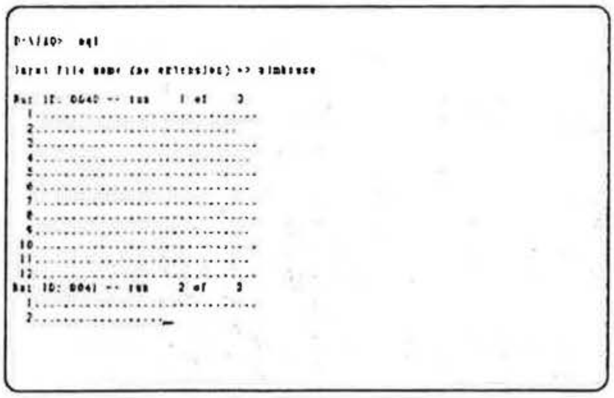

Figure 9.1 Operation of the AQ1 program. The screen output was captured in the middle of a run.

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[19] L. Palmiter, T. Bond: "Field Measurement of Interaction of Mechanical System and Natural Infiltration", Proceedings of AIVC Conference, September 24-27, 1991, Vol. 1: Air Movement and Control in Buildings.

9.2 Program Input Files

AQ1 uses four input files: a master file which has a user-specified name, a weather station data file (WEAREC.dat), a building description file which contains parameters relevant for calculating infiltration (BLDREC.dat), and a weekly schedule file used for supply and exhaust fans, pollutant emissions, and occupancy schedules (SCHREC.dat). The command line requires a filename, which is the prefix of the master input file and of all output files.

The four input files are discussed in detail in the next sections. The master input file may be located in any directory, but the three other input files must be in the disk directory containing the AQ1 program. Table 1 lists a few suggestions for simulating various effects.

Table 9.1 Simulation of various effects using AQ1

Desired Effect	Input
No natural infiltration	Set building leakage coefficient to 0 in building information file.
No wind infiltration	Set building shelter coefficient to 0 in building information file.
No stack infiltration	Set heating set-point lower than the lowest outdoor temperature; set cooling set-point above the highest outdoor temperature; set DT to 0. Building will remain at outdoor temperature.
No mechanical ventilation	Set supply and exhaust fan flow rates to 0 in master input file.
Occupant-generated pollutants	Use same schedule for pollutant emission and occupancy.
Occupant-operated ventilation	Use same schedule for fan operation and occupancy.
Decaying pollutant (e.g., formaldehyde)	Enter pollutant time constant in master input file.

9.2.1 Master Input File

The master input file has a user-specified name, but the extension must be ".in". The name of the file, without an extension, is entered when the AQ1 program asks for the input file name. This name is also used to create all of the output files.

Figure 9.2 shows an example of a master input file. The file can begin with as many comment lines as needed, designated with a asterisk-space combination in the first and second positions. Input data follows the comments, one line per building. The input fields are listed in Table 9.2. Each item must be separated with a space, and no spaces are allowed at the beginning of a line of data.

Table 9.2 Master input file structure

Run ID	A string of no more than 8 characters and no spaces.
Elevation (m)	Elevation above sea level of the building
Set Points (C):	Heating set point and cooling set point
DT (C)	Minimum house temperature rise over ambient unless pinned by the cooling set point.
Fan DT (C)	Minimum difference between outdoor and indoor temperature to keep ventilation fans from operating. If the DT during an hour is smaller than this entry, both supply and exhaust fans operate regardless of schedule. Otherwise, the fans are controlled by the fan schedules.
Station #	Weather station number in weather station data file (WEAREC.dat).
Building #	Building number with house infiltration characteristics in infiltration data file (BLDREC.dat).
Efan Sch	Schedule number for exhaust fan operation.
Sfan Sch	Schedule number for supply fan operation.
Efan flow (m^3/h)	Exhaust fan flow.
Sfan flow (m^3/h)	Supply fan flow.
Occ Sch	Schedule number for exposure (zero to disregard). If zero is entered, data is summarized 24 hours per day (normal operation). If a schedule is entered, all variables in the annual summary are summarized only over the hours when occupants are present. This does not affect the hourly output.
Poll Sch	Schedule number for emission; used only if the emission time constant is set to zero.
Emission rate (mL/hr)	Peak emission rate of pollutant, or initial emission rate if decaying pollutant is used.
Time constant	Emission time constant (hrs) if decaying pollutant is used; 0 otherwise. If set to 0, the emission schedule is used (normal operation). The time constant is the number of hours after which the pollutant reaches 37%, or 1/e, of the initial value.
Output Freq	Frequency and type of output: 0 for annual summary; 1-12 for hourly output for that month; 13 for year of hourly; 20 for annual summary including weather. Mixing annual with hourly output is not a desirable strategy because the output files will not have a consistent structure.

```
* This is a main input file.
* As long as the first character is an asterisk and the second a space
* the line is considered a comment.  The format of this file is as follows:
*
*        setpts    Fan  Sta Bld Efan Sfan Rfan Sfan Occ Poll  -Pollut--  Out
* ID# Elv ht cl dt  dt   #   #    Sch  Sch Flow Flow Sch  Sch  Pk  tcons  Frq
*
001    0 18 40  2    4   4   3     3    3  200  200  0     4 1000     0    1
002    0 18 40  2    2   1   1     3    3  200  200  0     4 1000     0    1
```

Figure 9.2 A master input file for AQ1

For all of the above inputs which reference other data files, the schedule, building or weather station number is the first number on each line of the data file, not the line number in the file. In the other data files, these numbers can be non-sequential, but they must be unique.

9.2.2 Weather Information File

The weather information file, WEAREC.dat, contains information on weather stations, one per line. No spaces are allowed before each line of data, but any number of spaces can appear between fields. Comments are not allowed in this file.

The structure of each line is listed in Table 9.3.

Table 9.3 Structure of weather information file

Station #	Unique number of weather station, referenced by master input file. No leading spaces are allowed.
Station Name	File name of an Ecotope packed-format file. This is the complete file name of a weather station which must be present in the subdirectory.
Units flag	The units used in the weather file (1=English; 0=metric). All Ecotope weather files are in English units.
Tower ht (m)	Height of the weather tower at the station.
Low speed terrain factor	Tower exponent for adjusting wind speeds below 3 m/s to site wind speeds (see paper on AIM-2 infiltration model, Walker and Wilson, 1990, Table 1).
Hi speed terrain factor	Tower exponent for adjusting wind speeds over 3 m/s to site wind speeds (see AIM-2 infiltration model, Table 1).

Figure 9.3 below shows a weather information file which contains the Canadian sites available from Ecotope as well as three U.S. sites.

```
 1 vancoubc.bin  1 10    0.34  0.12
 2 windsoon.bin  1 10    0.34  0.12
 3 winnipmt.bin  1 10    0.34  0.12
 4 summerbc.bin  1 10    0.34  0.12
 5 swiftcsk.bin  1 10    0.34  0.12
 6 toronton.bin  1 10    0.34  0.12
 7 edmontal.bin  1 10    0.34  0.12
 8 montrequ.bin  1 10    0.34  0.12
 9 ottawaon.bin  1 10    0.34  0.12
10 Seattle.bin   1 6.096 0.34  0.12
11 spokanwa.bin  1 6.096 0.34  0.12
12 bangorme.bin  1 6.096 0.34  0.12
```

Figure 9.3 A weather information file for AQ1 (WEAREC.dat)

9.2.3 Building Information File

The infiltration data file contains building parameters which relate to infiltration, one record per line. The file name is always BLDREC.dat. The file format is listed in Table 9.4; each item must be separated by spaces, and no spaces are allowed at the beginning of a line of data. Comments are not allowed in this file.

Table 9.4a Windspeed Power Law Exponent

Windspeed exponent for adjusting meteorological tower windspeeds to local building sites[20]

Terrain class	Terrain roughness	U_{met} > 3m/s	U_{met} < 3m/s
1	Open flat terrain; Rural grassland	0.12	0.34
2	Suburban detached housing; Mixed woods and fields	0.16	0.32
3	Dense urban housing with multi-storey buildings; Heavy forest	0.27	0.38
4	High rise urban centers		

Table 9.4b Estimates of Shelter Coefficient

(for no flue[21])

Shelter Coefficient S_{WO}	Description
1.00	No obstructions or local shielding
0.90	Light local shielding with few obstructions within two house heights
0.70	Heavy shielding, many large obstructions within two house heights
0.50	Very heavy shielding, many large obstructions within one house height
0.30	Complete shielding, with large buildings immediately adjacent

---

[20] From the "Alberta Infiltration Model (AIM-2)", Table 1

[21] From the "Alberta Infiltration Model (AIM-2)", Table 2

Table 9.4c Structure of building information file

Building #	Unique number of building, referenced by master input file. No leading spaces are allowed.
Infiltration model	1 for AIM model, 2 for LBL model. As of this time, the LBL model has not been implemented, so this number should always be 1.
Record label	Character description of the building record with no spaces. This is for reference only and is not output.
Volume (m^3)	Volume of conditioned space.
Building height (m)	Height of the building used for infiltration calculations. For Ecotope calculations, the average stack height of the building is used.
Flue height (m)	Height of the top of the flue. This must be non-zero if a flue fraction (Y) is entered.
Crawlspace flag	0=no crawl; 1=crawl. This affects only the AIM-2 wind model, which is different for buildings with and without crawlspaces.
C (m^3/h)	Building leakage coefficient (C) from blower door test.
n	Building leakage exponent (n) from blower door test.
R	Floor/ceiling leakage fraction $(A_{\text{ceil}} + A_{\text{floor}})/A_{\text{total}}$
X	Floor/ceiling difference fraction $(A_{\text{ceil}} - A_{\text{floor}})/A_{\text{total}}$
Y	Flue leakage fraction $A_{\text{flue}}/A_{\text{total}}$. If 0, no flue calculations are done.
Shelter factor	Building shelter factor for local shielding; used to convert site wind speed to speed actually seen by the building (Table 9.4b).
Flue shelter factor	Shelter coefficient for the flue; 0 if no flue (Table 9.4b)
Low speed terrain factor	Building exponent for adjusting wind speeds below 3 m/s to site wind speeds (Table 9.4a).
Hi speed terrain factor	Tower exponent for adjusting wind speeds over 3 m/s to site wind speeds (Table 9.4a).

Figure 9.4 shows a building information file. The sites numbered 1, 2 and 4 are three sites studied under the EPRI project (Palmiter and Bond, 1991). The lines numbered 10 through 12 are three test cases studied in the AIM-2 report (Walker and Wilson, 1990). AIM Site #4 was tested with the flue both sealed and open.

```
1  1 EPRI1          350 4.18 0   1  216.5  0.629 0.5 0 0   0.5  0 0.38 0.27
2  1 EPRI2          498 4.12 0   1  404.5  0.66  0.5 0 0   0.5  0 0.38 0.27
4  1 EPRI4          269 2.46 0   1  108.7  0.643 0.5 0 0   0.5  0 0.38 0.27
40 1 AIM4_no_flu    209 3    0   0  23     0.7   0.5 0 0   0.75 1 0.32 0.16
41 1 AIM4_flu       209 3    4.5 0  35     0.66  0.3 0 0.4 0.75 1 0.32 0.16
51 1 AIM5_flu       209 3    4.5 0  66     0.58  0.1 0 0.6 0.75 1 0.32 0.16
```

Figure 9.4 A building information file for AQ1 (BLDREC.dat)

9.2.4 Schedule File

The schedule data file contains one schedule record on each line. Each record can be referenced by any number of input cases and by more than one schedule type (exhaust fan, pollutant concentration, etc). The file name is always SCHREC.dat. Comments are not allowed in this file. The format is given in Table 9.5.

The first entry is the hour which will be output as 1:00AM. January 1 is taken as a Monday.

Table 9.5 Structure of schedule file

Schedule #	Unique number of schedule, referenced by master input file. No leading spaces are allowed.
Weekday schedule	24 space-separated values which should be between 0 and 1.
Weekend schedule	24 space-separated values which should be between 0 and 1.

For fan and pollutant schedules, the values entered are used as multipliers for the fan flow or pollutant emission entered in the master input file. We suggest that values of 0 through 1 be used so that the master input file contains the maximum and the schedule values are scaling factors.

For an occupant schedule, any non-zero value is taken to mean that occupants are home for that hour.

A sample schedule file is given in Figure 9.5. Interpretations of the schedules given are as follows:

Schedule documentation:

Schedule Number	Description - weekday	Description - weekend
1	off all hours	on all hours
2	on 0000 to 0700 hours; off 0700 to 1800; on 1800 to 2400	on all hours
3	off all hours	off all hours
4	on all hours	on all hours
5	off 0000 to 0600 hours; on 0600 to 1800; off 1800 to 2400	off 0000 to 0600 hours; on 0600 to 1800; off 1800 to 2400
6	on 0000 to 0600 hours; off 0600 to 1800; on 1800 to 2400	on 0000 to 0600 hours; off 0600 to 1800; on 1800 to 2400
7	on 1900 to 2000 hours; off rest of time	on 1900 to 2000 hours; off rest of time
8	on 0700 to 0800; on 1900 to 2000 hours	on 0700 to 0800; on 1900 to 2000 hours
9	on one hour 0100 to 0200 & every 6 hours thereafter	on one hour 0100 to 0200 & every 6 hours thereafter
10	on one hour 0300 to 0400 & every 4 hours thereafter	on one hour 0300 to 0400 & every 4 hours thereafter
11	on one hour 0100 to 0200 & every 2 hours thereafter	on one hour 0100 to 0200 & every 2 hours thereafter
12	on 1800 to 2000 hours; off rest of time	on 1800 to 2000 hours; off rest of time
13	on 1600 to 2000 hours; off rest of time	on 1600 to 2000 hours; off rest of time
14	on 1400 to 2000 hours; off rest of time	on 1400 to 2000 hours; off rest of time
15	off all hours	on all hours
16	on all hours	off all hours

Used in simulations:

Schedule 3	Never on
Schedule 4	Always on
Schedule 8	On for one hour each of morning and evening

```
                          Weekday                                                Weekend

Hr:1 2 3 4 5 6 7 8 9 10 12  14  16  18  20  22  24   1 2 3 4 5 6 7 8 9 10 12  14  16  18  20  22  24

1   0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0   1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2   1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
3   0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
4   1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
10  0 0 0 1 0 0 0 1 0 0 0 1 0 0 0 1 0 0 0 1 0 0 0 1   0 0 0 1 0 0 0 1 0 0 0 1 0 0 0 1 0 0 0 1 0 0 0 1
14  0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 0 0 0 0   0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 0 0 0 0
```

Figure 9.5 A schedule file for AQ1 (SCHREC.dat)

9.3 Program Output Files

The program output for all buildings in the input file is written to output files. At the command line, the user specifies a name, without an extension. The output files created are listed in Table 9.6, along with the output frequencies that will produce them. The following sections give the structure of these files.

Only files required for the buildings in the input file are created; that is, if all buildings have annual output specified, no hourly file is created. If a file needed for output already exists, it is overwritten.

It is possible to specify buildings with different output frequencies-- hourly, annual, and annual with weather-- in a single input file. However, we recommend that input files contain buildings with a single type of output so that input and output lines can be easily matched.

Table 9.6 Output files created by AQ1. In each case, "FILENAME" is specified by the user at the beginning of a run.

Output file	Contents	Output Freq	# Columns
FILENAME.hou	Hourly output.	1-13	11
FILENAME.inf	Mean, minimum and maximum infiltration for 12 months.	0 or 20	37
FILENAME.con	Mean, minimum and maximum pollutant concentrations for 12 months.	0 or 20	37
FILENAME.win	Mean weather station and building wind speeds for 12 months.	20	25
FILENAME.tem	Mean outdoor and indoor temperatures for 12 months.	20	25

9.3.1 Hourly Output

If hourly output is specified, one line of output is written for each hour to the file FILENAME.hou. Table 9.7 lists the format of this file. If hourly output is requested for more than one building, the output for each building is appended to the file, so it is important that each building have a unique run ID.

Table 9.7 File structure for hourly output (FILENAME.hou)

Field#	Contents	Description
1	Run ID	ID from the master input file
2	Day of year	January 1 is Day 1.
3	Hour of day	Hour 1 is 1:00 a.m.
4	Ambient temperature (C)	Outside temperature, taken directly from the weather file.
5	House temperature (C)	Interior temperature.
6	Building wind speed (m/s)	Building wind speed obtained from adjusting the weather station wind speed by the terrain and shielding coefficients.
7	Station wind speed (m/s)	Wind speed recorded at the weather station.
8	Natural infiltration (m^3/h)	Infiltration due to natural driving forces (wind and temperature differences) only.
9	Total infiltration (m^3/h)	Infiltration produced by the combination of natural driving forces and mechanical ventilation.
10	Pollutant concentration (ppm)	Average pollutant concentration for the hour.
11	Emission rate (mL/hr)	Pollutant emission rate, taken as constant for that hour.

9.3.2 Annual Output

If annual output (frequency 0 or 20) is specified for the input building, the infiltration and pollutant concentration for each month are written as a single line per building in each of two files, FILENAME.inf and FILENAME.con. The format of these two files is given in Tables 9.8 and 9.9. For the pollutant concentration and total infiltration, a mean, minimum and maximum value, in that order, are given for each month, beginning with January.

If annual output with weather data (frequency 20) is specified, wind speeds and temperatures are written to two additional output files, FILENAME.win and FILENAME.tem. Again, the output is a single line per building in each file. The structures of these files are listed in Tables 9.10 and 9.11.

Table 9.8 File structure for annual output of pollutant concentration (FILENAME.con)

Field #	Contents	Description
1	Run ID	ID from the master input file
2	Mean pollutant concentration (ppm), Jan.	Mean pollutant concentration for January, based on hourly averages.
3	Minimum pollutant concentration (ppm), Jan.	Minimum hourly average pollutant concentration during January.
4	Maximum pollutant concentration (ppm), Jan.	Maximum hourly average pollutant concentration during January.
5-37	Pollutant concentrations (ppm), remaining months	Mean, minimum and maximum pollutant concentration, in that order, for the remaining months of the year in order.

Table 9.9 File structure for annual output of total infiltration (FILENAME.inf)

Field #	Contents	Description
1	Run ID	ID from the master input file
2	Mean infiltration (m3/h), January	Mean infiltration for January, based on hourly averages.
3	Minimum infiltration (m3/h), January	Minimum hourly average infiltration during January.
4	Maximum infiltration (m3/h), January	Maximum hourly average infiltration during January.
5-37	Infiltration (m3/h), remaining months	Mean, minimum and maximum infiltration, in that order, for the remaining months of the year in order.

Table 9.10 File structure for annual output of wind speed (FILENAME.win)

Field #	Contents	Description
1	Run ID	ID from the master input file
2	Building wind speed (m/s), January	Average building wind speed for January. This is the station wind speed, adjusted hourly for terrain height and shelter coefficient, and then averaged. This is the wind speed actually used in the AIM-2 infiltration model.
3	Building wind speed (m/s), February	Average building wind speed for February.
4-13	Building wind speed (m/s), remaining months	Average building wind speed for March through December, in order.
14	Station wind speed (m/s), January	Average recorded station wind speed for January.
15	Station wind speed (m/s), February	Average recorded station wind speed for February.
16-25	Building wind speed (m/s), remaining months	Average weather station wind speed for March through December, in order.

Table 9.11 File structure for annual output of temperature (FILENAME.tem)

Field #	Contents	Description
1	Run ID	ID from the master input file
2	Outdoor temperature (C), January	Average outside temperature for January, summarized from weather station data.
3	Outdoor temperature (C), February	Average outside temperature for February.
4-13	Outdoor temperature (C), remaining months	Average outside temperature for March through December, in order.
14	Indoor temperature (C), January	Average indoor temperature for January, calculated hourly as either the heating or cooling set-point or minimum DT above ambient and then averaged.
15	Indoor temperature (C), February	Average indoor temperature for February.
16-25	Indoor temperature (C), remaining months	Average indoor temperature for March through December, in order.

9.4 Calculation Method

The AQI program uses weather-station wind speed and dry-bulb temperature read from Ecotope packed-format weather files. The hourly station wind speed is adjusted to an hourly site wind speed using the method outlined in the AIM-2 report, and the outside temperature is taken as that measured at the weather station. The weather data, as well as the fan flows, are assumed to be piecewise constant over the entire hour.

The natural infiltration is calculated using a full implementation of the AIM-2 infiltration model developed at the University of Alberta (Walker and Wilson, 1990). The stack and wind effects are computed separately and then combined using the AIM-2 rule.

The AQI program first reads the four input files to get the building parameters and weather station information. It calculates the multiplicative factors for the wind and stack models (*fw* and *fs*) given in the AIM paper. The density of air at the site at 59°F, or 15°C, is calculated using the equation

$$\rho(\mathrm{kg/m^3}) = 1.225\left(1 - \frac{0.0064997\,z}{288.15}\right)^{5.256}$$

where z is the elevation in meters, 1.225 kg/m^3 is the density of air at sea level at 15°C, and 0.0064997 is the mean temperature drop with elevation. The outside density, which is used in the AIM-2 stack and wind models, is calculated hourly from the outside temperature.

The total ventilation rate of the building is a combination of the natural and mechanical ventilation[22]. Using the fan schedules set by the user and the minimum DT for fan operation, the program determines whether either an exhaust or supply fan, or both, are running during an hour. Each fan runs if its schedule so dictates or if the indoor - outdoor temperature difference is below the minimum DT for fan operation. These are then combined using the fan model developed by Palmiter and Bond (1991) according to the following equations:

$$Q_{max} = \max(Q_{supply}, Q_{exhaust})$$

$$Q_{min} = \min(Q_{supply}, Q_{exhaust})$$

If there is only one exhaust fan then $Q_{\min} = 0$.

The total infiltration is:

$$Q_{tot} = Q_{nat} + F_a Q_{max}$$

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[22] L. Palmiter: "Field Measurement of Interaction of Mechanical System and Natural Infiltration", Proceedings of AIVC Conference, September 24-27, 1991, Vol. 1: Air Movement and Control in Buildings

where

$$F_a = \frac{1}{2}\left(1 + \frac{Q_{min}}{Q_{max}}\right)$$

if $Q_{max} - Q_{min} \leq 2\ Q_{nat}$

or

$$F_a = 1 - \frac{Q_{nat}}{Q_{max}}$$

if $Q_{max} - Q_{min} \geq 2\ Q_{nat}$

The program checks the schedule to determine whether pollutants are emitted for the hour in question. If so, the emission rate is either scaled according to the factor in the schedule file or a decayed emission rate is calculated. This emission rate is assumed to be constant for that hour.

Pollutant concentrations are calculated for the end of each hour, assuming that total infiltration is constant through that hour. The new concentration is given by

$$c_1 = c_0 e^{-a\Delta t} + \frac{s}{f}(1 - e^{-a\Delta t})$$

if the air-change rate is greater than 0.0001, or

$$c_1 = c_0 e^{-a\Delta t} + \frac{s}{v}(1 - a(0.50 + a/6))$$

if it is less. In the above equations, c_1 is the new concentration, c_0 is the original concentration, a is the air-change rate per hour, Dt is 1 hour, s is the emission rate in mL/h, f is the flow rate in m^3/h, and v is the volume of the building.

The concentration output is the average concentration over the hour. This is calculated from the equation

$$c_{avg} = \frac{c_0 - c_1}{a} + \frac{s}{f}$$

if the air-change rate is greater than 0.0001 h^{-1}, or the arithmetic mean of c_0 and c_1 if the air-change rate is less.

Before output begins, the concentration is initialized by running the program for the week prior to the first week of data to be output.

9.5 AQ1 Testing

9.5.1 Trial Simulations

A set of 40 trial runs were performed using data for two houses from the air-tightness and indoor air quality surveys[23]. The series of runs were performed in order to test the program and to determine the sensitivity of indoor air quality to changes in the various input parameters.

The results for 40 simulation runs are summarized in the following figures: 27 runs for house Q9001002m, located in Montreal, PQ (except one run in Vancouver), and 13 runs for house Edm_09_A, located in Edmonton, Alberta (except one run in Vancouver).

The house in Montreal is electrically heated, while the one in Edmonton is heated with a forced-air natural gas system. The base case for Montreal assumed the house to be two storeys high, with natural air leakage evenly divided between walls and floor/ceiling (R=0.5). Floor and ceiling leakage was assumed to be equal (X=0).

Pollutant source strength for each house was calculated from the formaldehyde test results, PFT infiltration and house volume, using the following equation:

Source strength = (Air change rate) x *(Vol.)* x *Pollutant Conc., (mL/h)*

Air change rate = AIMS PFT measured air change rate (tested in March, 1991)

Volume = heated house volume (m^3)

Pollutant Concentration Measured Formaldehyde concentration (ppm)

All of these runs assumed a maximum emission of 1,000 units. This value is arbitrary, since pollutant levels are scaled according to the actual emission rates. This assumes emission rates are independent of concentration. Also, the "base case" runs used values for building height, R, X, Y and shelter factors that were "reasonable" or "middle of the road", since they were not known.

The resulting ASCII data files were then loaded into a spreadsheet for further analysis. The following figures show the variation in pollutant concentration and infiltration plus ventilation with variations in various parameters.

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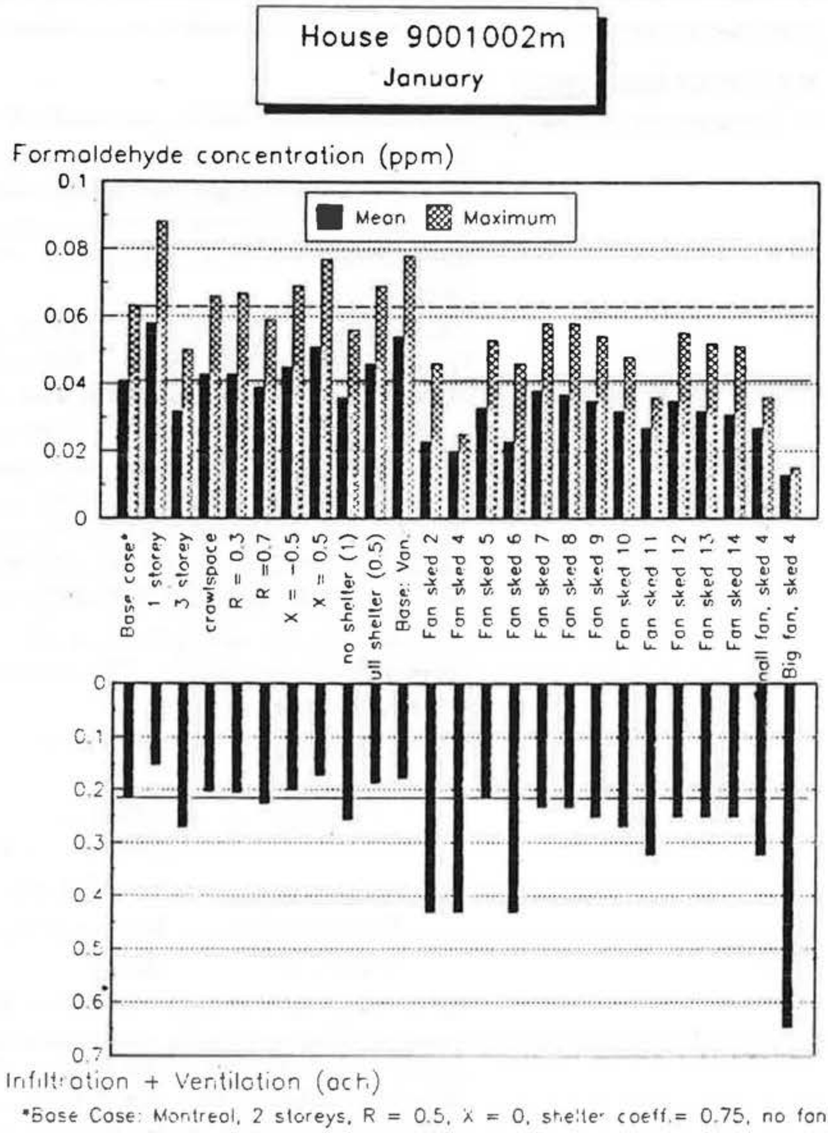
[23] Supplied by Tom Hamlin: house Q9001002m (Montreal) which had electric heat and no flue; house EDM_09_A with gas heat (see Appendix, section 7.3).



*Base Case: Montreal, 2 storeys, R = 0.5, X = 0, shelter coeff.= 0.75, no fans

Figure 9.6 House 9001002m Parametric Analysis (for January)

For house with no flue:

For the Montreal house, with all other factors remaining constant, a two storey configuration had 41% higher infiltration than a one storey house - with the one storey house therefore having 41% higher pollutant concentration. A three storey configuration had 22% lower concentration of pollutant.

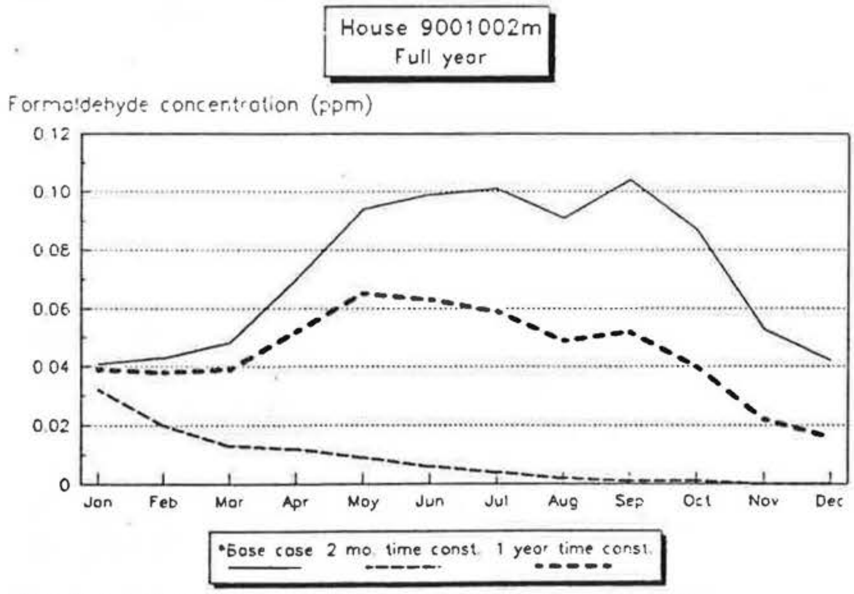
Changing to a crawlspace configuration caused only a 5% increase in pollutant concentration due to slightly reduced infiltration.

Changing the distribution of holes from evenly split between walls and floor-ceiling (R=0.5) to 20% less or more in the floor-ceiling resulted in 5% more or less in pollutant concentration.

With 50% of the holes in the walls and the remainder in the rest in the floor (X=-0.5), pollutant concentration increased 10%. With 50% of the holes in the walls and the remainder in the ceiling (X=0.5), pollutant concentration increased 24% (both changes resulted in reduced infiltration).

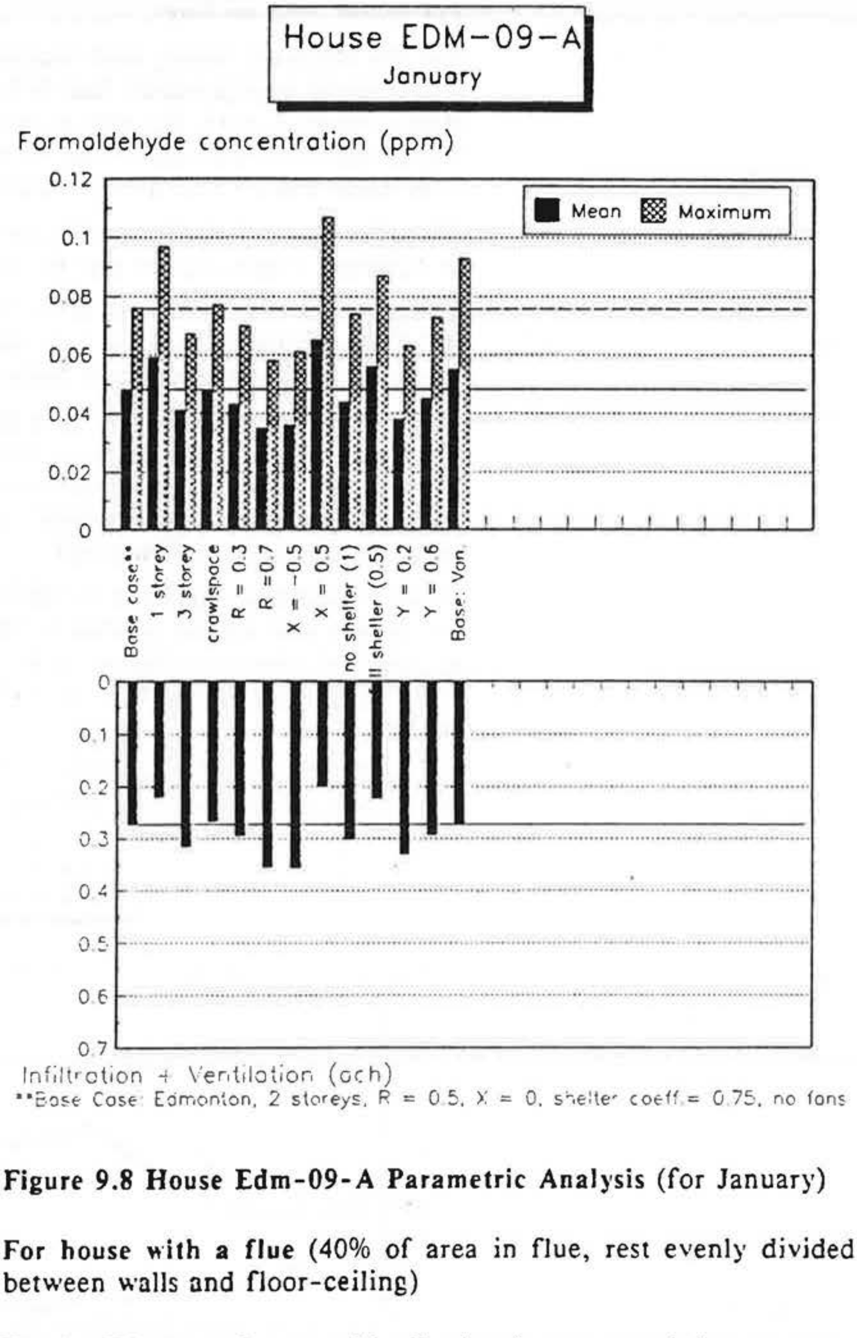
From a partially sheltered condition (shelter factor of 0.75) to completely unsheltered (shelter factor of 1.0) resulted in a decrease in pollutant concentration of 12%. With a completely sheltered building (shelter factor of 0.5), pollutant concentration increased by 12%.

The same house in Vancouver's milder climate resulted in reduced infiltration which increased pollutant concentrations by 32%.



*Base Case Montreal, 2 storeys, R = 0.5, X = 0, shelter coeff.= 0.75, no fans

Figure 9.7 House 9001002m: Effect of Varying Time Constant



**Base Case: Edmonton, 2 storeys, R = 0.5, X = 0, shelter coeff.= 0.75, no fans

Figure 9.8 House Edm-09-A Parametric Analysis (for January)

For house with a flue (40% of area in flue, rest evenly divided between walls and floor-ceiling)

For the Edmonton house, with all other factors remaining constant, the one storey house had 23% higher pollutant concentration. A three storey configuration had 15% lower concentration of pollutant.

Changing to a crawlspace configuration caused no change in pollutant concentration.

Changing the distribution of holes from evenly split between walls and floor-ceiling (Y=0.4, R=0.3) to 20% more in the floor-ceiling (R=0.5, Y=0.3) resulted in 10% less pollutant concentration. Increasing the proportion of holes in the floor-ceiling (R=0.7, Y=0.1) resulted in a further reduction in pollutant concentration (27% less than base case).

With 50% of the building holes in the walls and the remainder in the floor (X=-0.3, Y=0.4), pollutant concentration decreased 25% (note that this change is opposite to that encountered with the no flue house). With 50% of the building holes in the walls and the remainder in the ceiling (X=0.3, Y=0.4), pollutant concentration **increased** 35%.

From a partially sheltered building (shelter factor of 0.75) and unsheltered flue, to completely unsheltered (shelter factor of 1.0) resulted in a decrease in pollutant concentration of 8%. With a completely sheltered building (shelter factor of 0.5), and partially sheltered flue (shelter factor of 0.7) pollutant concentration increased by 17%.

9.5.2 Comparison with Test Results

Comparisons were made using March weather data (the formaldehyde and AIMS air change tests were carried out in March). Two runs were performed with unknown parameters selected to attempt to approximate the test results.

A comparison with monthly summary results is shown in Table 9.12.

Note that by selecting air change parameters[24] (R, X, etc.) we were able to obtain a change in calculated air change, and therefore pollutant concentration, of over two to one.

Table 9.12 Comparison with Test Results

House	Measured Air change (ac/h)	Calculated Air change (ac/h)	Measured HCHO conc. (ppm)	Calculated HCHO conc. (ppm)	Remarks
9001002m	0.08	0.19	0.105	0.048	base case
	0.08	0.10	0.105	0.118	Match Run: Bldg Height = 5m R=0.3, X=0.15, shelter = 0.50
EDM-09-A	0.34	0.24	0.035	0.055	base case
	0.34	0.35	0.035	0.036	Match Run: Bldg Height = 6m Flue Height = 6.5m R=0.6, X=-0.3, Y=0.2 shelter = 0.9

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[24] These parameters in the base case runs were arbitrarily selected as "middle of the road" values since they were not known.

10 APPENDIX: SIMULATIONS

10.1 House Types

Descriptive and fan-door air-tightness test results were obtained from Scanada Consulting for over 400 houses, with varying degrees of data completeness. Where possible, missing data was "filled in" with values calculated from other data supplied. Output from the database was obtained to provide statistical groupings of data by region and age of house. For older houses, there was no data for either of Canada's maritime regions. Field data was obtained for the lower mainland of B.C. to help fill this void (see section 11).

Unfortunately, there was not sufficient data available to be able to develop separate data for houses with and without flues. While we acknowledge that houses with flues have a higher leakage coefficient than those without flues, we could not quantify the difference for all age groups and regions. The simulations were carried out in pairs with the same volume and air-tightness, but for one house with a flue and one without.

For the simulation of natural air change rates, critical inputs included Volume, air-tightness coefficients, and height of heated space and flue.

Averages of building heights and air-tightness exponent were used for each age group and region. Volume and air leakage coefficients did not generally follow a normal distribution so the house characteristic database output was binned to provide percentile information. This procedure was carried out for four age groups in each of three regions for Volume and air-tightness coefficients. The following graphs and tables summarize these results.

For the simulations, the 50th, 75th and 90th percentile results (Figures 10.1, 10.2 and 10.3) were used since we wanted to investigate that portion of the housing stock likely to have air quality problems (smaller and tighter). For each region and age category, three housing types were used.

The 90th percentile results represent the smallest and tightest 10% of the housing stock surveyed (an analysis of air-tightness coefficient versus volume showed that, as one would expect, there was a significant, though not perfect, correlation of the two characteristics - smaller houses tended to have smaller leakage coefficients). Because of the small size of the data sets, the accuracy of the 90th percentile data is relatively low.

Figure 10.1 B.C. Volume and Air-tightness

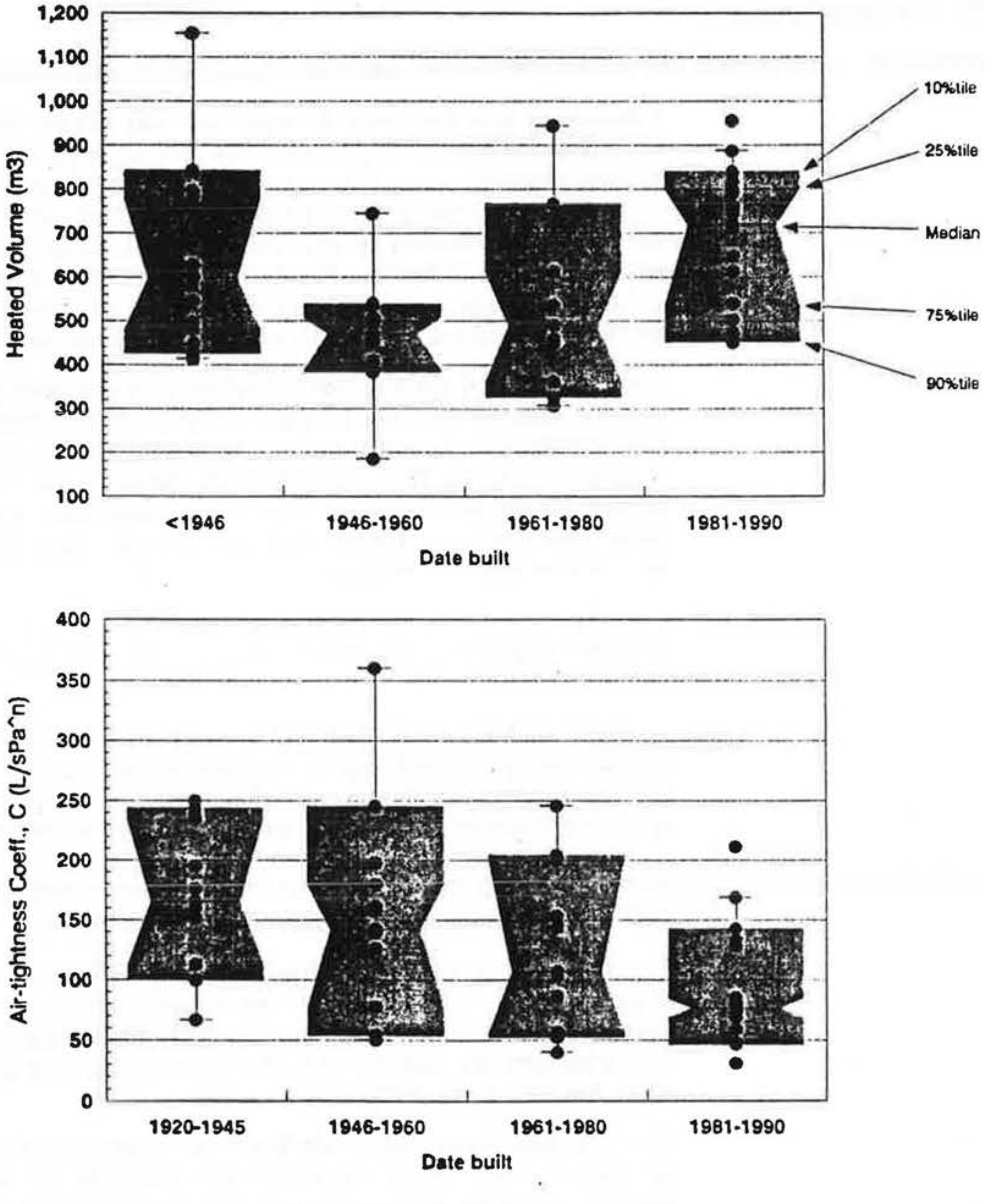
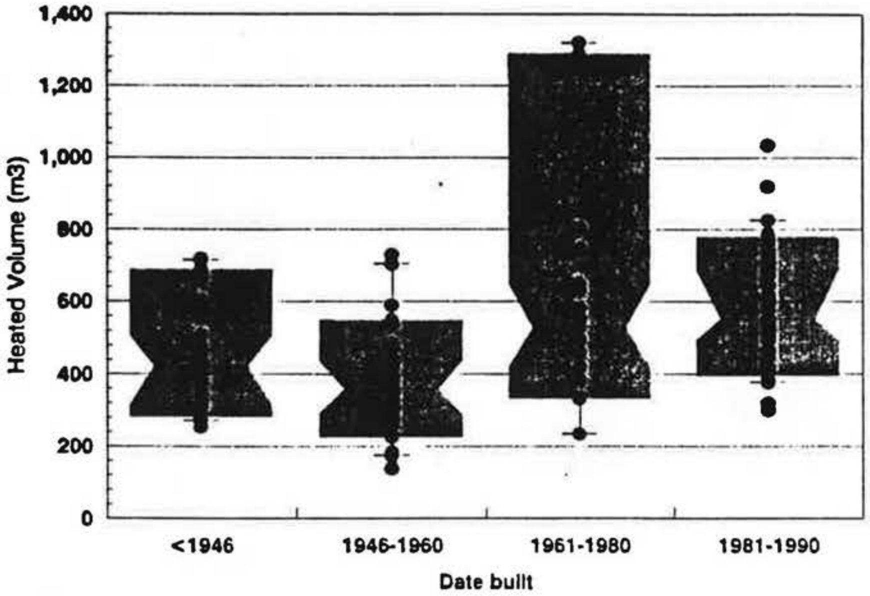


Figure 10.2 Prairies Volume and Air-tightness



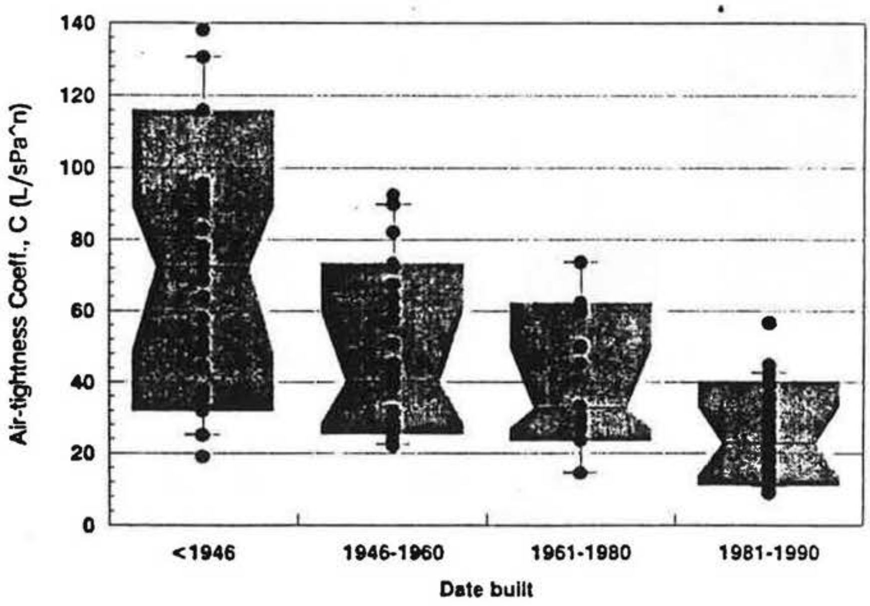
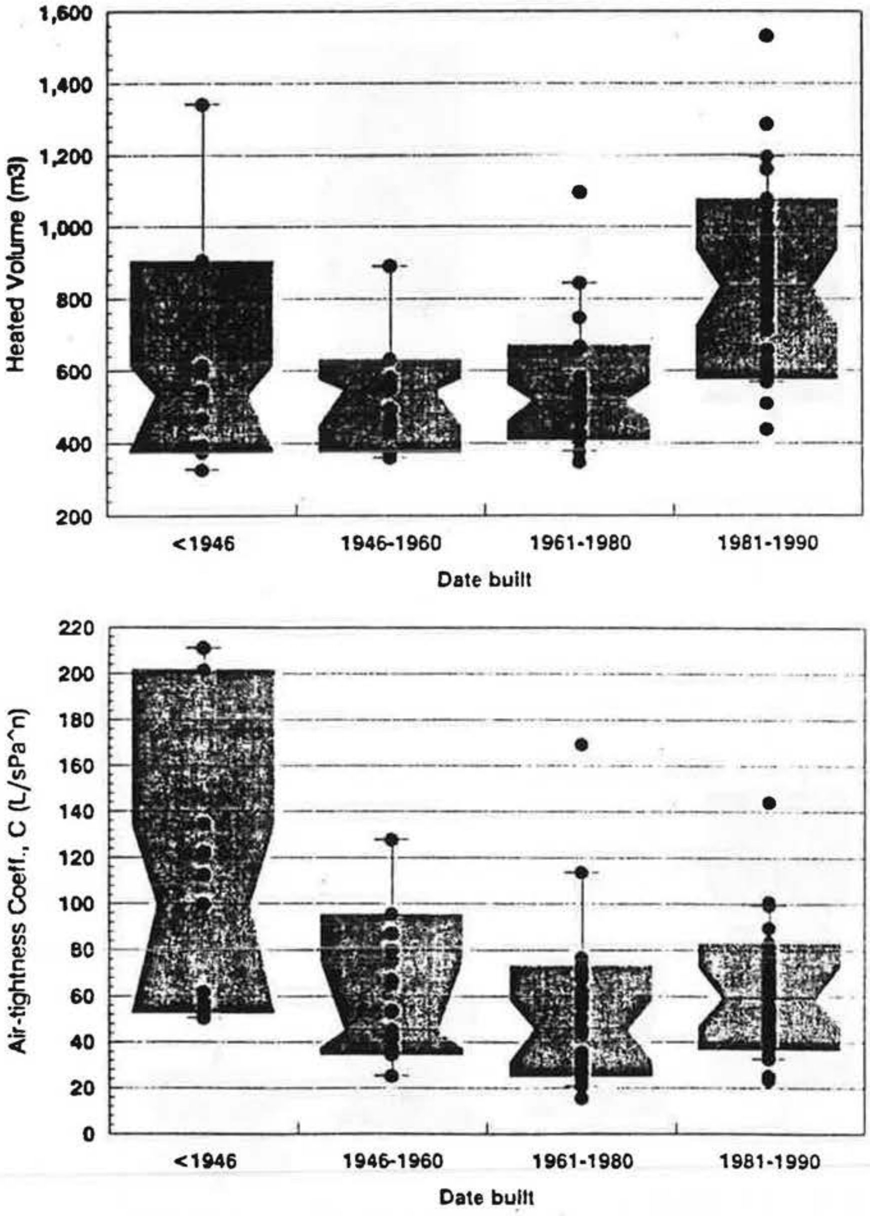


Figure 10.3 Ontario Volume and Air-tightness



10.2 Air quality survey data

We obtained VOC concentration and infiltration data from the Saskatchewan Research Council[25] for new and existing houses in Saskatchewan and Ontario. Formaldehyde and infiltration data was obtained from CMHC for new houses across Canada.

This data was processed further to obtain source strengths of the pollutants, using the following relationship:

Source strength = *Concentration* x *ACH* x *Volume*

Source strength	Whole house rate of emission of a pollutant, averaged over test period - typically one day (mL/h).
Concentration	Average pollutant concentration over test period (ppm)
ACH	Measured air changes per hour, using PFT or other tracer gas (h^{-1})
Volume	Heated house volume (m^3)

In the case of formaldehyde, the results were broken down to yield source strengths for the Pacific Region (B.C.) of 17.1 mL/h and the rest of Canada (5.5 mL/h). It is interesting to note that formaldehyde source strengths range from 0.9 mL/h to 24.6 mL/h in new merchant houses. Unfortunately, the documentation of house characteristics is not adequate to enable one to determine why there is such a tremendous range in source strengths (why do formaldehyde source strengths for B.C. houses average over three times those in the rest of Canada, for example?).

Pollutant emissions data for some materials used in residential construction and operation was obtained from a variety of sources and is summarized in Table 10.1.

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[25] Dr. Rob Dumont and Lawrence Snodgrass, "Volatile Organic Compound Survey and Summarization of Results" for CMHC, SRC Publication No. I-4800-1-C-92, January, 1992. In addition to data on 26 VOC and the TVOC, extensive documentation data was collected on materials used in each house.

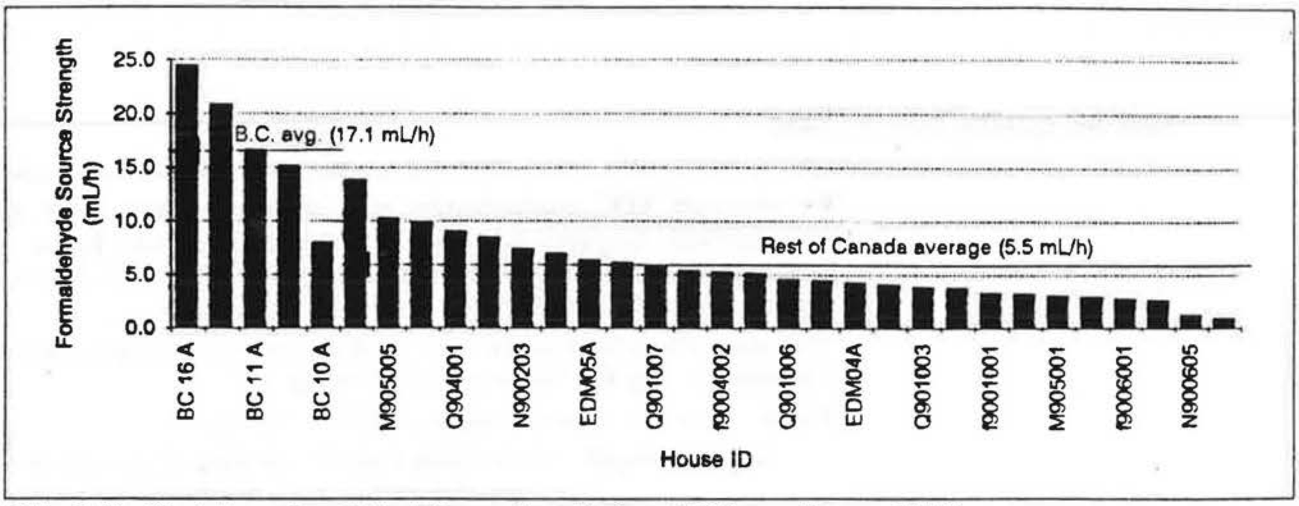

Table 10.1A Whole House Formaldehyde Source Strengths from 1989 Houses (Source: CMHC)

House I.D. Number	TEST RESULTS: AIMS (ach)	HCHO (ppm)	Source Strength (mL/h)	House Volume (m3)	Envelope Area (m2)	Volume/ Area (m)	Flow Coeff. (L/sPa ^ n)	Flow Exp. (n)	ELA (m2)	NLA (cm2/m2)	ACH @ 50 Pa (ach)
BC 16 A	0.58	0.055	24.6	770	564	1.37	211.9	0.502	0.270	4.79	7.06
BC 17 A	0.80	0.057	20.9	458	411	1.11	73.6	0.664	0.136	3.32	7.77
BC 11 A	0.62	0.059	16.7	457	411	1.11	68.9	0.683	0.133	3.24	7.86
BC 18 A	0.34	0.064	15.3	702	526	1.33	80.0	0.647	0.142	2.71	5.15
BC 10 A	0.49	0.027	8.1	609	498	1.22	31.5	0.698	0.063	1.27	2.86
M905003	0.27	0.071	13.9	726	551	1.32	34.4	0.651	0.062	1.12	2.18
M905005	0.16	0.117	10.4	553	438	1.26	12.0	0.648	0.021	0.49	0.98
M905004	0.16	0.112	9.9	555	439	1.26	10.0	0.708	0.021	0.47	1.04
Q904001	0.26	0.070	9.1	501	409	1.22	14.3	0.756	0.033	0.80	1.99
Q904002	0.28	0.059	8.6	518	483	1.07	32.3	0.767	0.076	1.57	4.50
N900203	0.12	0.141	7.4	440	358	1.23	38.9	0.657	0.071	1.98	4.16
EDM09A*	0.34	0.035	7.1	594	454	1.31	38.8	0.744	0.086	1.91	4.32
EDM05A	0.20	0.046	6.5	703			41.8	0.679	0.080		3.04
EDM03A	0.17	0.085	6.2	427	370	1.15	23.1	0.643	0.041	1.10	2.40
Q901007	0.16	0.084	5.9	437	357	1.22	9.1	0.800	0.023	0.65	1.71
N900201	0.14	0.079	5.5	493	378	1.30	18.9	0.787	0.046	1.23	3.00
f9004002	0.18	0.040	5.3	742	514	1.44	56.9	0.686	0.111	2.16	4.05
M903001	0.08	0.119	5.3	552	440	1.25	9.1	0.797	0.023	0.52	1.34
Q901006	0.18	0.063	4.7	413	326	1.27	13.5	0.841	0.038	1.16	3.17
f9004001	0.08	0.072	4.6	793	562	1.41	57.1	0.671	0.107	1.91	3.57
EDM04A	0.25	0.025	4.4	697	539	1.29	42.7	0.692	0.084	1.57	3.31
M907006	0.14	0.100	4.2	300	290	1.03	14.0	0.641	0.025	0.85	2.07
Q901003	0.11	0.077	3.9	464	378	1.23	16.7	0.770	0.039	1.04	2.62
Q901002*	0.08	0.105	3.9	464	378	1.23	19.4	0.756	0.045	1.18	2.90
f9001001	0.12	0.064	3.4	442	397	1.11	39.8	0.623	0.067	1.69	3.71
Q904004	0.15	0.062	3.4	362	325	1.11	17.1	0.768	0.040	1.24	3.44
M905001	0.09	0.049	3.1	710	530	1.34	33.5	0.691	0.066	1.25	2.54
M907005	0.09	0.085	3.0	394	358	1.10	17.9	0.639	0.031	0.88	2.00
f9006001	0.08	0.089	2.8	398	352	1.13	32.9	0.609	0.054	1.53	3.22
f9002001	0.14	0.042	2.7	464	384	1.21	28.6	0.628	0.049	1.27	2.59
N900605	0.05	0.035	1.3	771	726	1.06	85.7	0.690	0.169	2.32	5.96
M904002	0.02	0.085	0.9	552	443	1.25	18.6	0.723	0.040	0.89	2.05
Average	0.22	0.071	7.3	546	438	1.23	38.9	0.696	0.072	1.55	3.39
Std. Dev.	0.18	0.028	5.5	135	92	0.10	37.5	0.069	0.052	0.93	1.74
Minimum	0.02	0.025	0.9	300	290	1.03	9.1	0.502	0.021	0.47	0.98
Maximum	0.80	0.141	24.6	793	726	1.44	211.9	0.841	0.270	4.79	7.86

* Used in AQ1 test simulations (see section 9.5)

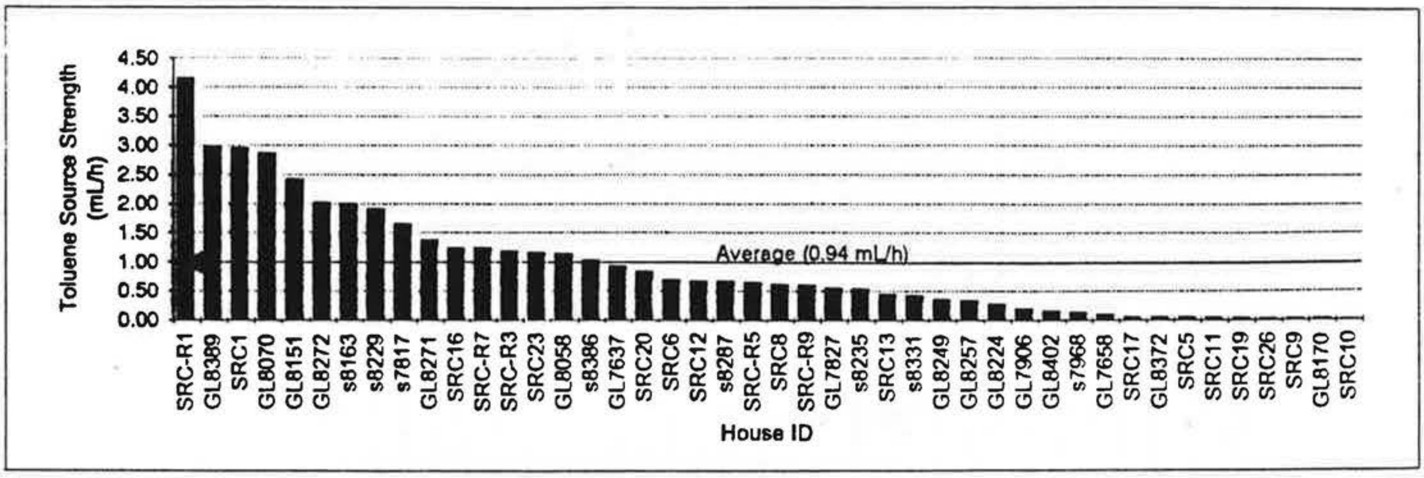

Table 10.1B VOC Whole House Source Strengths (Source: SRC)

	TVOC	SumVOC	PFTach	Volume	DateBuilt	Benzene	aPinene	Toluene	EthBenzen	pXylene	mXylene	oXylene	Limonen
Avg.	557	248	0.34	545	1,974	0.85	0.54	0.94	0.37	0.29	0.53	0.22	0.56
StdDev	466	131	0.18	137		0.62	0.57	0.98	0.23	0.19	0.37	0.14	0.44
Min	40	15	0.09	325	1,891	0.03	0.01	0.01	0.02	0.02	0.03	0.02	0.02
Max	1,913	647	1.06	905	1,990	2.22	2.83	4.17	0.90	0.83	1.29	0.66	2.13
House	(ug/m3)		(ac/h)	(m3)		(mL/hr)	(mL/hr)	(mL/hr)	(mL/hr)	(mL/hr)	(mL/hr)	(mL/hr)	(mL/hr)
SRC-R1	749	647	0.235	604	1989	1.88	2.83	4.17	0.47	0.37	0.74	0.35	0.96
GL8389	461	94	0.728	508	1920	0.12	0.04	2.97	0.18	0.09	0.09	0.09	0.07
SRC1	1,678	602	0.210	674	1989	1.56	0.86	2.97	0.65	0.50	1.24	0.66	1.09
GL8070	499	341	0.303	340		0.67	0.24	2.88	0.16	0.06	0.27	0.10	0.56
GL8151	1,174	446	0.207	483	1950	0.03	0.40	2.43	0.71	0.35	1.02	0.35	0.45
GL8272	1,478	199	0.189	408	1975	0.17	0.08	2.03	0.02	0.02	0.04	0.02	0.43
s8163	1,187	315	0.440	506	1973	1.26	0.03	2.00	0.62	0.52	1.00	0.29	0.41
s8229	1,913	230	0.659	405	1936	1.17	0.12	1.92	0.61	0.53	0.94	0.20	0.55
s7817	231	237	0.479	551	1974	0.99	0.13	1.66	0.59	0.47	0.93	0.18	0.78
GL8271	488	296	0.281	420	1985	0.56	0.66	1.39	0.47	0.43	0.46	0.22	0.43
SRC16	727	490	0.094	750	1986	0.68	0.56	1.25	0.35	0.23	0.61	0.21	0.44
SRC-R7	544	254	0.329	778	1989	0.91	1.06	1.25	0.55	0.51	0.82	0.45	0.64
SRC-R3	1,387	310	0.293	700	1989	2.10	0.78	1.19	0.54	0.45	0.74	0.39	0.55
SRC23	291	257	0.307	654	1988	0.87	0.46	1.17	0.40	0.38	0.50	0.31	1.10
GL8058	83	214	0.293	493	1980	0.69	0.61	1.15	0.30	0.39	0.41	0.25	0.30
s8386	298	177	1.063	545	1891	2.22	1.12	1.03	0.90	0.83	1.24	0.13	0.90
GL7637	158	251	0.386	528	1974	0.85	0.28	0.94	0.42	0.36	0.45	0.35	0.64
SRC20	406	281	0.371	836	1990	2.06	2.05	0.85	0.53	0.49	0.75	0.46	1.04
SRC6	468	378	0.194	500	1984	0.37	0.88	0.70	0.73	0.49	1.17	0.30	0.23
SRC12	1,340	315	0.286	545	1989	1.20	1.53	0.68	0.39	0.28	0.68	0.31	0.34
s8287	602	303	0.168	420	1976	0.42	0.01	0.68	0.15	0.12	0.21	0.02	0.26
SRC-R5	1,009	270	0.249	698	1989	1.47	0.75	0.66	0.35	0.33	0.45	0.26	0.60
SRC8	507	172	0.261	638	1989	0.89	0.22	0.62	0.85	0.60	1.29	0.30	0.33
SRC-R9	755	228	0.242	558	1989	0.75	0.24	0.61	0.27	0.25	0.36	0.21	0.40
GL7827	40	111	0.228	905	1990	0.66	0.76	0.56	0.17	0.18	0.19	0.14	0.38
s8235	278	257	0.426	493	1962	0.65	0.22	0.55	0.54	0.43	0.76	0.14	2.03
SRC13	361	214	0.263	618	1988	1.14	0.57	0.45	0.47	0.34	0.78	0.25	0.47
s8331	332	198	0.562	458	1962	0.93	0.15	0.43	0.34	0.33	0.44	0.06	2.13
GL8249	150	180	0.587	388	1978	1.77	0.23	0.37	0.31	0.05	0.53	0.18	0.34
GL8257	618	101	0.255	355	1978	0.08	0.06	0.35	0.06	0.02	0.17	0.04	0.26
GL8224	308	264	0.401	448	1952	0.41	0.72	0.29	0.31	0.27	0.34	0.29	1.10
GL7906	638	290	0.101	540	1978	0.05	0.43	0.21	0.10	0.09	0.13	0.09	0.17
GL8402	850	437	0.310	435	1967	0.04	0.66	0.17	0.03	0.03	0.03	0.03	0.02
s7968	236	300	0.308	444	1957	0.41	0.25	0.15	0.70	0.52	1.02	0.29	0.30
GL7658	40	126	0.564	745	1935	2.17	0.32	0.11	0.45	0.10	0.57	0.35	0.65
SRC17	415	138	0.383	693	1984	1.42	0.57	0.07	0.34	0.21	0.52	0.31	0.52
GL8372	55	15	0.448	565	1900	0.08	0.03	0.07	0.06	0.06	0.06	0.06	0.05
SRC5	334	134	0.390	613	1989	0.59	1.48	0.06	0.21	0.30	0.32	0.24	0.51
SRC11	654	174	0.227	398	1989	0.42	0.63	0.06	0.18	0.09	0.34	0.09	0.27
SRC19	56	99	0.388	435	1985	0.92	0.09	0.04	0.16	0.12	0.23	0.14	0.78
SRC26	198	220	0.254	465	1989	0.66	0.42	0.03	0.20	0.19	0.23	0.14	0.24
SRC9	159	83	0.166	659	1988	0.38	0.15	0.03	0.12	0.15	0.16	0.10	0.05
GL8170	40	119	0.328	325	1974	0.45	0.13	0.03	0.07	0.02	0.09	0.07	0.68
SRC10	328	140	0.124	455	1989	0.20	0.17	0.01	0.06	0.08	0.09	0.08	0.09

Note: SumVOC is the sum of mass concentrations of 26 VOCs, including the 8 shown here

Table 10.2 VOC Emissions (by Volume)

Building Component		Aldehyde	Aromatics			Alkane		Terpene		Ether	Row
		Formaldehyde	Benzene	Toluene	Xylene	Nonane	Undecane	Limonene	A-pinene	Ethylebenzene	Index
	Materials	Emissions (mL/m^2.hr)									
Flooring		D	E	F	G	H	I	J	K	L	
	Particle Board	0.244				0.002			0.003		7
	Plywood	0.016									8
	Vinyl Flooring	0.024								0.009	9
	Carpet and Underpad	0.008		0.016	0.000		0.002				10
	Adhesive							0.034			11
Walls											
	drywall				0.001		0.014				13
	paint		0.002	0.040				0.009			14
	cove base adhesive		0.016					0.034		0.154	15
	caulking		0.002	0.005	0.009					0.000	16
	wallpaper	0.012		0.013		0.002	0.003				17
Ceiling											
	drywall				0.001		0.014				19
	paint		0.002	0.040				0.009			20
Utilities											
	PVC Plumbing				0.000						22
	Wiring				0.001		0.001			0.001	23
Furniture & Cabinets											
	particle board	0.244				0.002					25
	plywood	0.016									26
	paint		0.002	0.040							27
Consumer products (wet)											
	floor wax							0.027	0.006		29
	grease cleaners						0.010				30

Molecular Weights	30	78	92	106	128	156	136	208	106

Notes: Conversion factor for ug/hr to mL/hr is 0.02445/molecular weight of compound

Blank cells indicate that information is unavailable, however emission rate is unlikely to be significant

10.3 Health Limits

Table 10.3 IAQ HEALTH LIMITS

	Aldehyde	Aromatics					Alkane		Terpene		Ether	
	Formaldehyde	Benzene	Toluene		Xylene		Nonano	Undecane	Limonene	A-pinene	Ethylebenxene	
Source	Suspected Carcinogen	Suspected Carcinogen	Confirmed Carcinogen		mucuous membrane irritant		mucuous membrane irritant	mucuous membrane irritant	short term irritant	mucuous membrane irritant	skin & mucuous membrane irritant	
	TLV	TLV	TLV	STEL	TLV	STEL	TLV	TLV	TLV	TLV	TLV	STEL
							(ug/m ^ 3)					
Seifert	60	25	25		25		50	50	15	15	10	
							(ppm)					
Seifert	0.049	0.008	0.007		0.006		0.010	0.008	0.003	0.002	0.002	
ACGIH	1.0	~1	100	150	100	150	200				100	125
ANSI		10	200		100							
NIOSH			100									
Australia	2.0											
Belgium	2.0											
Finland	2.0											
Japan	2.0											
Netherlands	2.0											
Sweden	2.0	10	100		100							
Czechoslovakia	1.6	16	50		45						45	
East Germany	1.6	16	50		45							
Poland	1.6										25	
Switzerland	1.0											
West Germany	1.0	minimize	200		200							
Italy	1.0											
Bulgaria	0.8											
Hungary	0.8											
Yugoslavia	0.8											
USSR	0.4	1.6	14		11							

TLV	Threshold Limit Value based on a long term TWA (time weighted average)
STEL	Short Term Exposure Limit (usually about 15 minutes duration)
ACGIH	American Conference of Governmental Industrial Hygenists
NIOSH	National Institute for Occupational Safety and Health

10.4 Simulation results

10.4.1 Annual results

The monthly and annual results of the following runs are presented here:

Table 10.4 List of Annual Result Runs

	Output No.	Region	Age	%tile	Ventilation	Remarks
BASE RUNS:						
	1-3	Ontario	1981-90	50, 75, 90	none	Average of surveyed levels of VOC
	4-5	Prairies	1981-90	50, 75	none	Average of surveyed levels of VOC
	7-8	Pacific	1981-90	50, 75	none	Average of surveyed levels of VOC
Pollutant abatement of Base Houses:						
	12	Ontario	1981-90	75	25 L/s Balanced	Average of surveyed levels of VOC
	13	Ontario	1981-90	75	25 L/s exhaust, dT controlled (<8C)	Average of surveyed levels of VOC
	14-18	Prairies	1981-90	75	25 L/s Balanced 25 L/s Exhaust, on & dT controlled (<8, 10, 12C)	Average of surveyed levels of VOC
	19	Pacific	1981-90	75	25 L/s Balanced	Average of surveyed levels of VOC
	$21_{a,b}$				25 L/s exhaust, dT controlled (<8, 10, 12C)	Average of surveyed levels of VOC

Note that this is not a thermal simulation model so actual inside temperatures are not calculated. The results due to fan control by inside to outside temperature difference[26] therefore show an **indication of the potential** of this type of control, rather than its absolute potential.

The **Output #** is on the top right corner of each page of printout (bold) - numbers are **not** continuous.

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[26] dT fan control: fans on if inside to outside temperature difference less than a specified amount (8C to 12C), otherwise fans off.

Table 10.4 List of Annual Results Runs (cont'd)

	Output No.	Region	Age	%tile	Ventilation	Remarks
Increased source strength:	22	Ontario	1981-90	75	none	HCHO source increased 5mL/h
Pollutant abatement with increased source strength:	31	Ontario	1981-90	75	25 L/s Balanced	HCHO source increased 5mL/h
BASE RUNS:	51	Ontario	pre 1946	75	none	HCHO max. for conc.<Limit
	54		1946-60			Average of surveyed levels
	57		1961-80			of other VOC
	61	Prairies	pre 1946	75	none	HCHO max. for conc.<Limit
	64		1946-60			Average of surveyed levels
	67		1961-80			of other VOC
	71	Pacific	pre 1946	75	none	HCHO max. for conc.<Limit
	74		1946-60			Average of surveyed levels
	77		1961-80			of other VOC

Indoor Air Quality Profile

1

Description:

Region: ONT
Age: 1981 to 1990
Percentile: 50
Ventilation Type: None
Ventilation Flow: 0 L/s

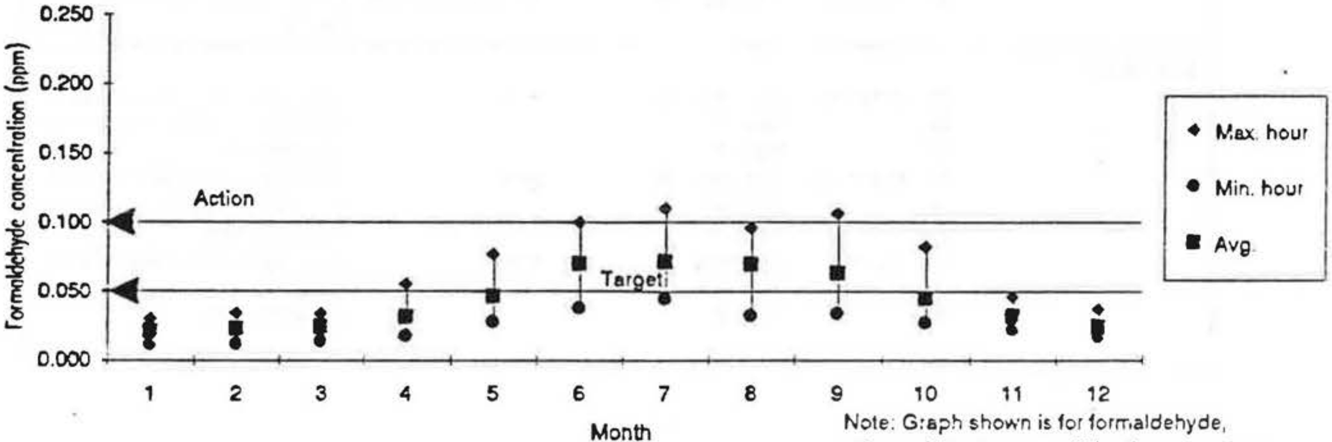
Volume 836 m^3
Bldg. Ht. 6.5 m
Flue Ht. 8.0 m
Foundation Bsmt
C 214 L/sPa^n
n 0.69
ELA 4,208 cm^2

	No Flue		Flue
Run ID #	6600	and	6700
Infil. Coeff:			
R	0.60		0.55
X	0.00		0.00
Y	0.00		0.10
Shelter:			
Building	0.80		0.80
Flue	0.00		0.85

Pollutant Source Strengths:

Whole house source strengths based on: 22 houses

	Formaldehyde	Benzene	Toluene	Xylene	Nonane (mL/hr)	Undecane	Limonene	A-pinene	Ethylbenzene	Source strengths:
House	5.500	0.985	0.856	1.162	N/A	N/A	0.521	0.805	0.385	SRC avg. meas. (whole house) Formaldehyde meas (CMHC)



Note: Graph shown is for formaldehyde, other pollutent curves will be the same shape.

Pollutant Health Limits (ppm)

	Formaldehyde	Benzene	Toluene	Xylene	Nonane	Undecane	Limonene	a-Pinene	Ethylbenzene	
Classes:	Aldehyde	Aromatic Hydrocarbons			Alkanes		Terpenes •		Ether	Class limits are from Seifert
Limits:	0.10	0.008	0.007	0.006	0.010	0.008	0.003	0.002	0.002	Aldehyde limit is from EHD
ACGIH TLV	1.00	9	100	100	200	N/A	N/A	N/A	100	(Canada) for formaldehyde.
Predicted Pollutant Concentrations (ppm)										
Avg: Year	0.044	0.008	0.007	0.009	not avail.	not avail.	0.004	0.006	0.003	
Max: Oct-Apr	0.045	0.008	0.007	0.009	not avail.	not avail.	0.004	0.007	0.003	Highest monthly average for each period
May-Sep	0.072	0.013	0.011	0.015	not avail.	not avail.	0.007	0.011	0.005	
Max. hour	0.110	0.020	0.017	0.023	not avail.	not avail.	0.010	0.016	0.008	

Infiltration & Ventilation (ach) Month

	1	2	3	4	5	6	7	8	9	10	11	12
Max.	0.649	0.604	0.511	0.485	0.326	0.289	0.220	0.290	0.321	0.300	0.366	0.459
Min.	0.193	0.175	0.168	0.066	0.042	0.038	0.041	0.041	0.041	0.044	0.116	0.163
Avg.	0.318	0.299	0.273	0.219	0.147	0.098	0.095	0.098	0.114	0.158	0.212	0.279
Infiltration & Ventilation (L/s)												
Avg.	74	69	63	51	34	23	22	23	26	37	49	65

Temperatures (C)

Outside	-8.8	-4.7	-3.0	4.2	12.0	18.2	19.4	19.0	15.6	9.6	4.6	-4.8
Inside	20.0	20.0	20.0	20.0	20.5	22.2	22.6	22.6	21.1	20.1	20.0	20.0

Winds (m/s)

AES Station	5.3	5.8	4.8	4.8	4.0	3.1	3.5	3.5	3.3	3.6	4.8	4.4
Building	2.2	2.4	2.0	2.0	1.7	1.4	1.5	1.5	1.5	1.6	2.0	1.9

Indoor Air Quality Profile

2

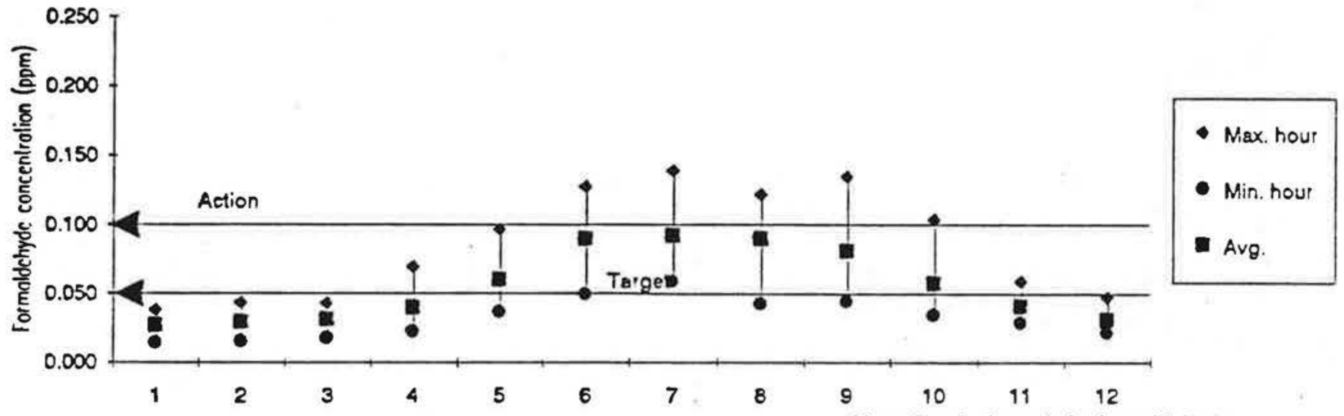
Description:

Region:	ONT	Volume	725 m^3		No Flue	Flue
Age:	1981 to 1990	Bldg. Ht.	6.5 m	Run ID #	6630 and	6730
Percentile:	75	Flue Ht.	8.0 m	Infil. Coeff:		
Ventilation Type:	None	Foundation	Bsmt	R	0.60	0.54
Ventilation Flow:	0 L/s	C	169 L/sPa^n	X	0.00	0.00
		n	0.69	Y	0.00	0.12
		ELA	3,323 cm^2	Shelter:		
				Building	0.80	0.80
				Flue	0.00	0.85

Pollutant Source Strengths:

Whole house source strengths based on: 22 houses

	Formaldehyde	Benzene	Toluene	Xylene	Nonane (mL/hr)	Undecane	Limonene	A-pinene	Ethylbenzene	Source strengths:
House	5.500	0.985	0.856	1.162	N/A	N/A	0.521	0.805	0.385	SRC avg. meas. (whole house) Formaldehyde meas. (CMHC)



Note: Graph shown is for formaldehyde, other pollutant curves will be the same shape.

Pollutant Health Limits (ppm)

	Formaldehyde	Benzene	Toluene	Xylene	Nonane	Undecane	Limonene	a-Pinene	Ethylbenzene	
Classes:	Aldehyde	Aromatic Hydrocarbons			Alkanes		Terpenes		Ether	Class limits are from Seifert
Limits:	0.10	0.008	0.007	0.006	0.010	0.008	0.003	0.002	0.002	Aldehyde limit is from EHD
ACGIH TLV	1.00	9	100	100	200	N/A	N/A	N/A	100	(Canada) for formaldehyde.
Predicted Pollutant Concentrations (ppm)										
Avg: Year	0.056	0.010	0.009	0.012	not avail.	not avail.	0.005	0.008	0.004	
Max: Oct-Apr	0.058	0.010	0.009	0.012	not avail.	not avail.	0.005	0.008	0.004	Highest monthly average for each period
May-Sep	0.093	0.017	0.014	0.020	not avail.	not avail.	0.009	0.014	0.006	
Max. hour	0.139	0.025	0.022	0.029	not avail.	not avail.	0.013	0.020	0.010	

Infiltration & Ventilation (ach) Month

	1	2	3	4	5	6	7	8	9	10	11	12
Max.	0.578	0.538	0.455	0.431	0.289	0.256	0.195	0.258	0.285	0.267	0.326	0.409
Min.	0.174	0.158	0.151	0.059	0.038	0.035	0.037	0.037	0.037	0.040	0.105	0.146
Avg.	0.286	0.268	0.245	0.196	0.132	0.087	0.084	0.088	0.102	0.142	0.190	0.250
Infiltration & Ventilation (L/s)												
Avg.	58	54	49	40	27	18	17	18	20	29	38	50

Temperatures (C)

Outside	-6.8	-4.7	-3.0	4.2	12.0	18.2	19.4	19.0	15.6	9.6	4.6	-4.8
Inside	20.0	20.0	20.0	20.0	20.5	22.2	22.6	22.6	21.1	20.1	20.0	20.0

Winds (m/s)

AES Station	5.3	5.8	4.8	4.8	4.0	3.1	3.5	3.5	3.3	3.6	4.8	4.4
Building	2.2	2.4	2.0	2.0	1.7	1.4	1.5	1.6	1.5	1.6	2.0	1.9

Indoor Air Quality Profile

3

Description:

Region: ONT
Age: 1981 to 1990
Percentile: 90
Ventilation Type: None
Ventilation Flow: 0 L/s

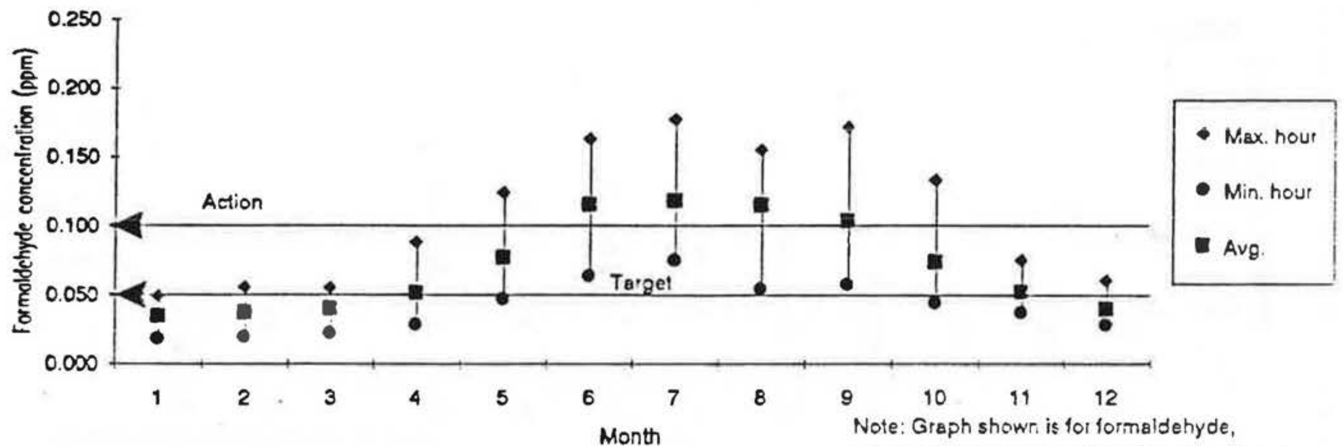
Volume 577 m^3
Bldg. Ht. 6.5 m
Flue Ht. 8.0 m
Foundation Bsmt
C 132 L/sPa^n
n 0.69
ELA 2,596 cm^2

	No Flue		Flue
Run ID #	6660	and	6760
Infil. Coeff:			
R	0.60		0.52
X	0.00		0.00
Y	0.00		0.15
Shelter:			
Building	0.80		0.80
Flue	0.00		0.85

Pollutant Source Strengths:

Whole house source strengths based on: 22 houses

	Formaldehyde	Benzene	Toluene	Xylene	Nonane (mL/hr)	Undecane	Limonene	A-pinene	Ethylbenzene	Source strengths:
House	5.500	0.985	0.856	1.162	N/A	N/A	0.521	0.805	0.385	SRC avg. meas. (whole house) Formaldehyde meas. (CMHC)



Note: Graph shown is for formaldehyde, other pollutant curves will be the same shape.

Pollutant Health Limits (ppm)

	Formaldehyde	Benzene	Toluene	Xylene	Nonane	Undecane	Limonene	a-Pinene	Ethylbenzene	
Classes:	Aldehyde	Aromatic Hydrocarbons			Alkanes		Terpenes		Ether	Class limits are from Seifen
Limits:	0.10	0.008	0.007	0.006	0.010	0.008	0.003	0.002	0.002	Aldehyde limit is from EHD
ACGIH TLV	1.00	9	100	100	200	N/A	N/A	N/A	100	(Canada) for formaldehyde.
Predicted Pollutant Concentrations (ppm)										
Avg: Year	0.072	0.013	0.011	0.015	not avail.	not avail.	0.007	0.011	0.005	
Max: Oct-Apr	0.074	0.013	0.012	0.016	not avail.	not avail.	0.007	0.011	0.005	Highest monthly average for each period
May-Sep	0.119	0.021	0.018	0.025	not avail.	not avail.	0.011	0.017	0.008	
Max. hour	0.178	0.032	0.026	0.038	not avail.	not avail.	0.017	0.026	0.012	

Infiltration & Ventilation (ach) Month

	1	2	3	4	5	6	7	8	9	10	11	12
Max.	0.567	0.528	0.447	0.424	0.284	0.252	0.192	0.253	0.280	0.262	0.320	0.401
Min.	0.170	0.154	0.148	0.058	0.037	0.034	0.036	0.036	0.036	0.039	0.102	0.143
Avg.	0.279	0.262	0.239	0.192	0.129	0.085	0.083	0.086	0.100	0.139	0.186	0.245
Infiltration & Ventilation (L/s)												
Avg.	45	42	38	31	21	14	13	14	16	22	30	39

Temperatures (C)

Outside	-8.8	-4.7	-3.0	4.2	12.0	18.2	19.4	19.0	15.6	9.6	4.6	-4.8
Inside	20.0	20.0	20.0	20.0	20.5	22.2	22.6	22.6	21.1	20.1	20.0	20.0

Winds (m/s)

AES Station	5.3	5.8	4.8	4.8	4.0	3.1	3.5	3.5	3.3	3.6	4.8	4.4
Building	2.2	2.4	2.0	2.0	1.7	1.4	1.6	1.6	1.5	1.6	2.0	1.9

Indoor Air Quality Profile

4

Description:

Region: PRAI
Age: 1981 to 1990
Percentile: 50
Ventilation Type: None
Ventilation Flow: 0 L/s

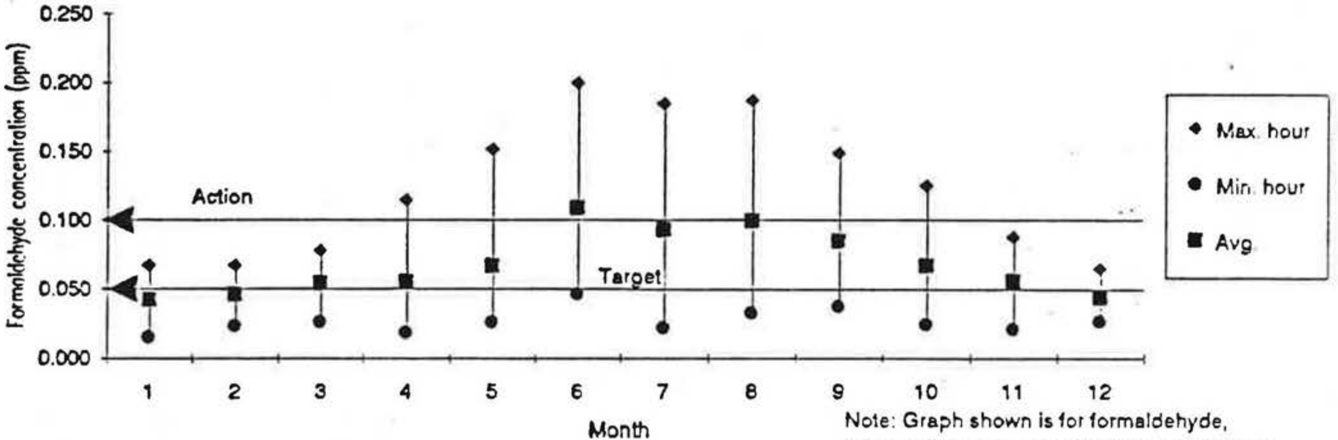
Volume 553 m^3
Bldg. Ht. 5 m
Flue Ht. 6.5 m
Foundation Bsmt
C 82 L/sPa^n
n 0.71
ELA 1,688 cm^2

	No Flue		Flue
Run ID #	3600	and	3700
Infil. Coeff:			
R	0.60		0.49
X	0.00		0.00
Y	0.00		0.24
Shelter:			
Building	0.90		0.90
Flue	0.00		0.95

Pollutant Source Strengths:

Whole house source strengths based on: 22 houses

	Formaldehyde	Benzene	Toluene	Xylene	Nonane (mL/hr)	Undecane	Limonene	A-pinene	Ethylbenzene	Source strengths:
House	5.500	0.985	0.856	1.162	N/A	N/A	0.521	0.805	0.385	SRC avg. meas. (whole house) Formaldehyde meas. (CMHC)



Note: Graph shown is for formaldehyde, other pollutant curves will be the same shape.

Pollutant Health Limits (ppm)

	Formaldehyde	Benzene	Toluene	Xylene	Nonane	Undecane	Limonene	a-Pinene	Ethylbenzene	
Classes:	Aldehyde	Aromatic Hydrocarbons			Alkanes		Terpenes		Ether	Class limits are from Seifert
Limits:	0.10	0.008	0.007	0.006	0.010	0.008	0.003	0.002	0.002	Aldehyde limit is from EHD
ACGIH TLV	1.00	9	100	100	200	N/A	N/A	N/A	100	(Canada) for formaldehyde.
Predicted Pollutant Concentrations (ppm)										
Avg: Year	0.068	0.012	0.011	0.014	not avail.	not avail.	0.006	0.010	0.005	
Max: Oct-Apr	0.067	0.012	0.010	0.014	not avail.	not avail.	0.006	0.010	0.005	Highest monthly average for each period
May-Sep	0.109	0.020	0.017	0.023	not avail.	not avail.	0.010	0.016	0.008	
Max. hour	0.200	0.036	0.031	0.042	not avail.	not avail.	0.019	0.029	0.014	

Infiltration & Ventilation (ach) Month

	1	2	3	4	5	6	7	8	9	10	11	12
Max.	0.729	0.511	0.511	0.674	0.502	0.328	0.590	0.402	0.360	0.519	0.532	0 477
Min.	0.119	0.115	0.102	0.035	0.020	0.019	0.019	0.008	0.020	0.039	0.099	0.121
Avg.	0.247	0.221	0.191	0.209	0.164	0.102	0.121	0.110	0.127	0.167	0.202	0.235
Infiltration & Ventilation (L/s)												
Avg.	38	34	29	32	25	16	19	17	20	26	31	36

Temperatures (C)

Outside	-21.7	-19.0	-9.0	3.1	10.5	17.8	16.7	19.1	13.2	6.9	-5.0	-14.7
Inside	20.0	20.0	20.0	20.0	20.5	21.7	21.3	22.6	20.7	20.0	20.0	20.0

Winds (m/s)

AES Station	4.6	3.8	4.2	6.0	5.3	3.9	4.4	4.2	4.3	5.0	4.7	5.1
Building	3.4	2.9	3.2	4.4	3.9	2.9	3.3	3.1	3.2	3.7	3.5	3.8

Indoor Air Quality Profile

5

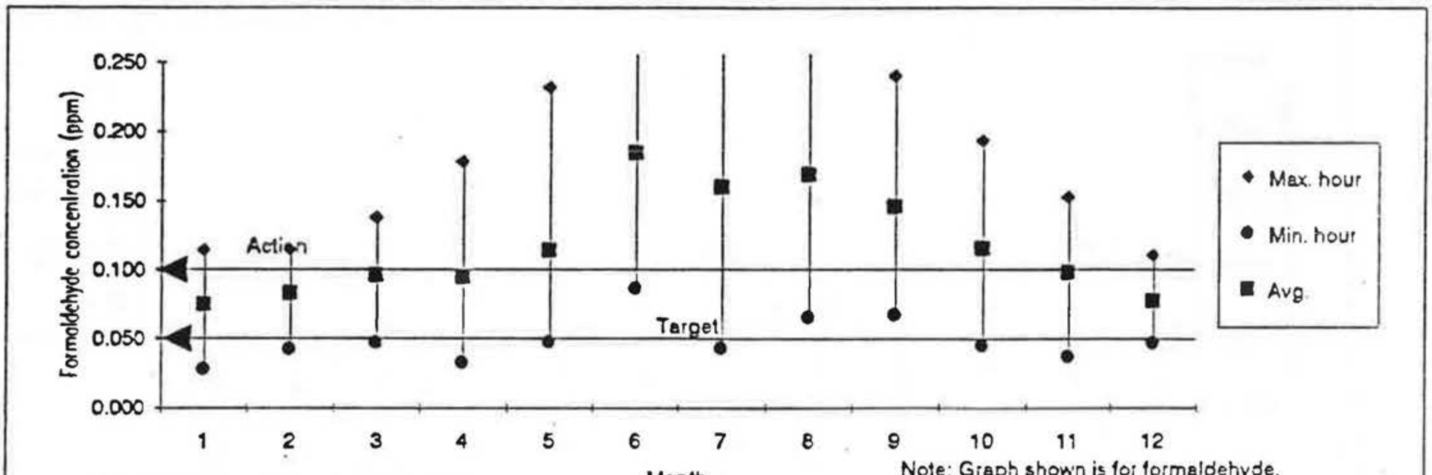
Description:

Region:	PRAI	Volume	494 m^3		No Flue		Flue
Age:	1981 to 1990	Bldg. Ht.	4.5 m	Run ID #	3630	and	3730
Percentile:	75	Flue Ht.	6.0 m	Infil. Coeff:			
Ventilation Type:	None	Foundation	Bsmt	R	0.60		0.43
Ventilation Flow:	0 L/s	C	50 L/sPa^n	X	0.00		0.00
		n	0.71	Y	0.00		0.39
		ELA	1,030 cm^2	Shelter:			
				Building	0.90		0.90
				Flue	0.00		0.95

Pollutant Source Strengths:

Whole house source strengths based on: 22 houses

	Formaldehyde	Benzene	Toluene	Xylene	Nonane (mL/hr)	Undecane	Limonene	A-pinene	Ethylbenzene	Source strengths:
House	5.500	0.985	0.856	1.162	N/A	N/A	0.521	0.805	0.385	SRC avg. meas. (whole house) Formaldehyde meas. (CMHC)



Note: Graph shown is for formaldehyde, other pollutant curves will be the same shape.

Pollutant Health Limits (ppm)

	Formaldehyde	Benzene	Toluene	Xylene	Nonane	Undecane	Limonene	a-Pinene	Ethylbenzene	
Classes:	Aldehyde	Aromatic Hydrocarbons			Alkanes		Terpenes		Ether	Class limits are from Seifert
Limits:	0.10	0.008	0.007	0.006	0.010	0.008	0.003	0.002	0.002	Aldehyde limit is from EHD
ACGIH TLV	1.00	9	100	100	200	N/A	N/A	N/A	100	(Canada) for formaldehyde.
Predicted Pollutant Concentrations (ppm)										
Avg: Year	0.118	0.021	0.018	0.025	not avail.	not avail.	0.011	0.017	0.008	
Max: Oct-Apr	0.116	0.021	0.018	0.024	not avail.	not avail.	0.011	0.017	0.008	Highest monthly average for each period
May-Sep	0.185	0.033	0.029	0.039	not avail.	not avail.	0.018	0.027	0.013	
Max. hour	0.316	0.057	0.049	0.067	not avail.	not avail.	0.030	0.046	0.022	

Infiltration & Ventilation (ach) Month

	1	2	3	4	5	6	7	8	9	10	11	12
Max.	0.473	0.330	0.332	0.438	0.328	0.214	0.385	0.262	0.235	0.337	0.345	0.307
Min.	0.073	0.070	0.063	0.021	0.012	0.012	0.012	0.005	0.012	0.024	0.060	0.074
Avg.	0.155	0.138	0.120	0.134	0.105	0.066	0.078	0.071	0.081	0.107	0.128	0.146
Infiltration & Ventilation (L/s)												
Avg.	21	19	16	18	14	9	11	10	11	15	18	20

Temperatures (C)

Outside	-21.7	-19.0	-9.0	3.1	10.5	17.8	16.7	19.1	13.2	6.9	-5.0	-14.7
Inside	20.0	20.0	20.0	20.0	20.5	21.7	21.3	22.6	20.7	20.0	20.0	20.0

Winds (m/s)

AES Station	4.6	3.8	4.2	6.0	5.3	3.9	4.4	4.2	4.3	5.0	4.7	5.1
Building	3.5	2.9	3.2	4.5	4.0	2.9	3.3	3.2	3.2	3.8	3.6	3.9

Indoor Air Quality Profile

7

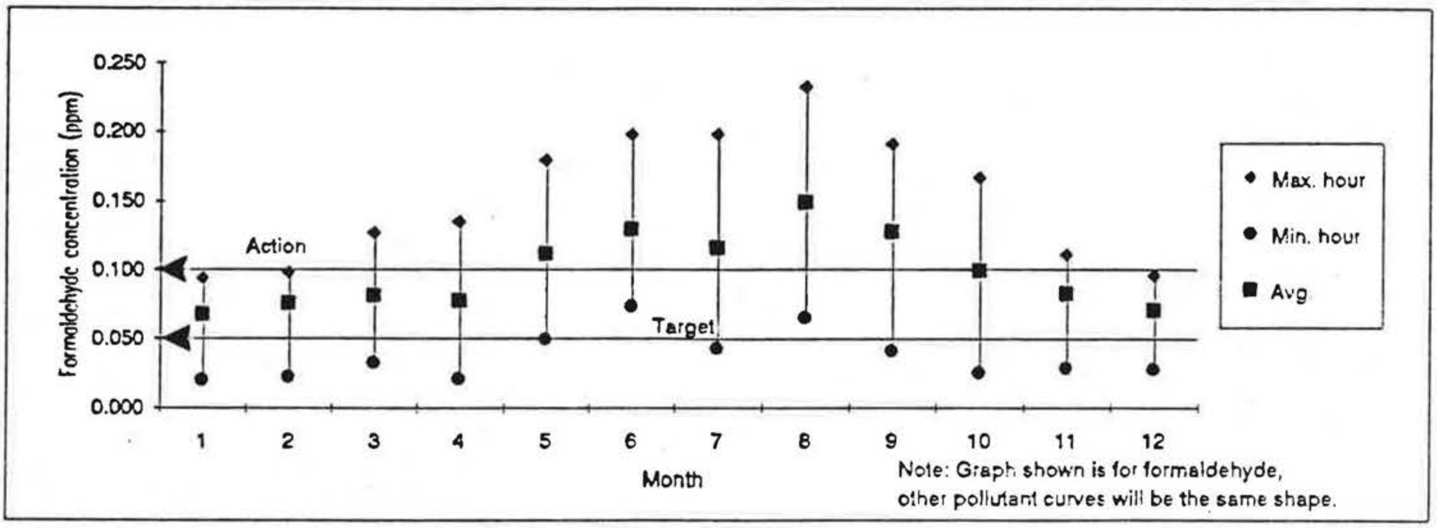
Description:

Region:	BC	Volume	721 m^3		No Flue		Flue
Age:	1981 to 1990	Bldg. Ht.	5.5 m	Run ID #	1600	and	1700
Percentile:	50	Flue Ht.	7.0 m	Infil. Coeff:			
Ventilation Type:	None	Foundation	C/space	R	0.60		0.56
Ventilation Flow:	0 L/s	C	275 L/sPa^n	X	0.00		0.00
		n	0.66	Y	0.00		0.08
		ELA	5,047 cm^2	Shelter:			
				Building	0.80		0.80
				Flue	0.00		0.85

Pollutant Source Strengths:

Whole house source strengths based on: 5 houses

	Formaldehyde	Benzene	Toluene	Xylene	Nonane (mL/hr)	Undecane	Limonene	A-pinene	Ethylbenzene	Source strengths:
House	17.100	0.985	0.856	1.162	N/A	N/A	0.521	0.805	0.385	SRC avg. meas. (whole house) Formaldehyde meas. (CMHC)



Note: Graph shown is for formaldehyde, other pollutant curves will be the same shape.

Pollutant Health Limits (ppm)

	Formaldehyde	Benzene	Toluene	Xylene	Nonane	Undecane	Limonene	a-Pinene	Ethylbenzene	
Classes:	Aldehyde	Aromatic Hydrocarbons			Alkanes		Terpenes		Ether	Class limits are from Seifert
Limits:	0.10	0.006	0.007	0.006	0.010	0.008	0.003	0.002	0.002	Aldehyde limit is from EHD
ACGIH TLV	1.00	9	100	100	200	N/A	N/A	N/A	100	(Canada) for formaldehyde.
Predicted Pollutant Concentrations (ppm)										
Avg. Year	0.099	0.006	0.005	0.007	not avail.	not avail.	0.003	0.005	0.002	
Max: Oct-Apr	0.100	0.006	0.005	0.007	not avail.	not avail.	0.003	0.005	0.002	Highest monthly average for each period
May-Sep	0.149	0.009	0.007	0.010	not avail.	not avail.	0.005	0.007	0.003	
Max. hour	0.233	0.013	0.012	0.016	not avail.	not avail.	0.007	0.011	0.005	

Infiltration & Ventilation (ach) Month

	1	2	3	4	5	6	7	8	9	10	11	12
Max.	1.306	1.182	0.982	1.267	0.600	0.426	0.624	0.516	0.658	1.062	0.995	0.991
Min.	0.217	0.173	0.139	0.111	0.060	0.059	0.060	0.059	0.060	0.060	0.182	0.211
Avg.	0.377	0.323	0.305	0.333	0.224	0.189	0.228	0.170	0.200	0.268	0.301	0.347
Infiltration & Ventilation (L/s)												
Avg.	75	65	61	67	45	38	46	34	40	54	60	69

Temperatures (C)

Outside	0.5	3.9	6.7	7.1	12.4	14.5	16.9	17.8	13.1	9.0	6.3	0.6
Inside	20.0	20.0	20.0	20.0	20.2	20.1	21.0	21.3	20.0	20.0	20.0	20.0

Winds (m/s)

AES Station	4.5	4.1	4.5	5.1	3.5	3.2	4.4	3.3	2.9	3.6	4.0	3.9
Building	2.9	2.7	2.9	3.2	2.3	2.1	2.9	2.2	1.9	2.3	2.6	2.5

Indoor Air Quality Profile

8

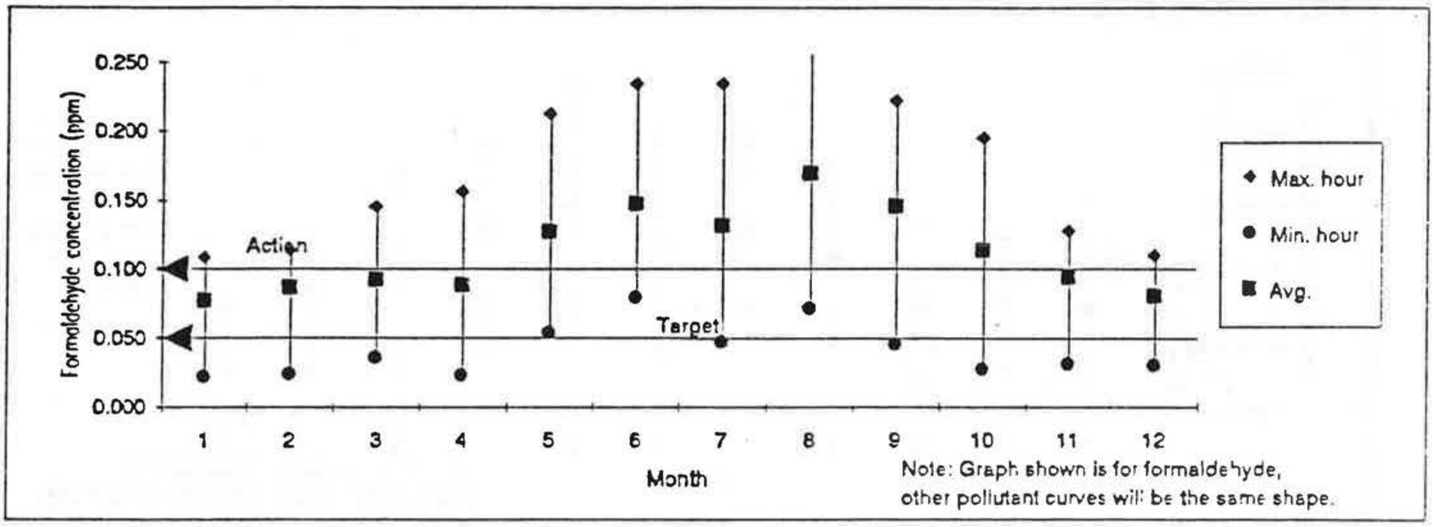
Description:

					No Flue	Flue
Region:	BC	Volume	539 m^3	Run ID #	1630 and	1730
Age:	1981 to 1990	Bldg. Ht.	5.2 m	Infil. Coeff:		
Percentile:	75	Flue Ht.	6.7 m	R	0.60	0.55
Ventilation Type:	None	Foundation	C/space	X	0.00	0.00
Ventilation Flow:	0 L/s	C	248 L/sPa^n	Y	0.00	0.09
		n	0.66	Shelter:		
		ELA	4,551 cm^2	Building	0.80	0.80
				Flue	0.00	0.85

Pollutant Source Strengths:

Whole house source strengths based on: 5 houses

	Formaldehyde	Benzene	Toluene	Xylene	Nonane (mL/hr)	Undecane	Limonene	A-pinene	Ethylbenzene	Source strengths:
House	17.100	0.985	0.856	1.162	N/A	N/A	0.521	0.805	0.385	SRC avg. meas. (whole house) Formaldehyde meas. (CMHC)



Note: Graph shown is for formaldehyde, other pollutant curves will be the same shape.

Pollutant Health Limits (ppm)

	Formaldehyde	Benzene	Toluene	Xylene	Nonane	Undecane	Limonene	a-Pinene	Ethylbenzene	
Classes:	Aldehyde	Aromatic Hydrocarbons			Alkanes		Terpenes		Ether	Class limits are from Seifert
Limits:	0.10	0.008	0.007	0.006	0.010	0.008	0.003	0.002	0.002	Aldehyde limit is from EHD
ACGIH TLV	1.00	9	100	100	200	N/A	N/A	N/A	100	(Canada) for formaldehyde.
Predicted Pollutant Concentrations (ppm)										
Avg: Year	0.113	0.007	0.006	0.008	not avail.	not avail.	0.003	0.005	0.003	
Max: Oct-Apr	0.114	0.007	0.006	0.008	not avail.	not avail.	0.003	0.005	0.003	Highest monthly average for
May-Sep	0.170	0.010	0.009	0.012	not avail.	not avail.	0.005	0.008	0.004	each period
Max. hour	0.271	0.016	0.014	0.018	not avail.	not avail.	0.008	0.013	0.006	

Infiltration & Ventilation (ach) Month

	1	2	3	4	5	6	7	8	9	10	11	12
Max.	1.564	1.415	1.175	1.518	0.718	0.511	0.747	0.617	0.788	1.272	1.191	1.165
Min.	0.253	0.202	0.165	0.130	0.070	0.069	0.070	0.069	0.070	0.070	0.213	0.246
Avg.	0.444	0.381	0.360	0.395	0.265	0.223	0.271	0.201	0.236	0.316	0.355	0.408
Infiltration & Ventilation (L/s)												
Avg.	67	57	54	59	40	33	41	30	35	47	53	61

Temperatures (C)

Outside	0.5	3.9	6.7	7.1	12.4	14.5	16.9	17.8	13.1	9.0	6.3	0.6
Inside	20.0	20.0	20.0	20.0	20.2	20.1	21.0	21.3	20.0	20.0	20.0	20.0

Winds (m/s)

AES Station	4.5	4.1	4.5	5.1	3.5	3.2	4.4	3.3	2.9	3.6	4.0	3.9
Building	2.9	2.6	2.9	3.2	2.3	2.1	2.8	2.2	1.9	2.3	2.6	2.5

Indoor Air Quality Profile

12

Description:

Region: ONT
Age: 1981 to 1990
Percentile: 75
Ventilation Type: Continuous flow, balanced
Ventilation Flow: 25 L/s

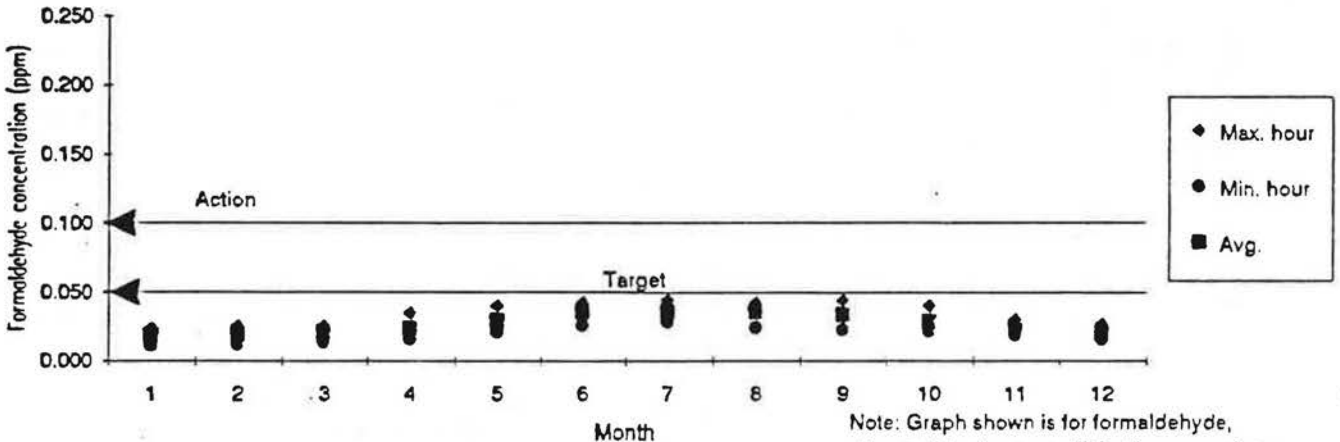
Volume 725 m^3
Bldg. Ht. 6.5 m
Flue Ht. 8.0 m
Foundation Bsmt
C 169 L/sPa^n
n 0.69
ELA 3,323 cm^2

	No Flue		Flue
Run ID #	6631	and	6731
Infil. Coeff:			
R	0.60		0.54
X	0.00		0.00
Y	0.00		0.12
Shelter:			
Building	0.80		0.80
Flue	0.00		0.85

Pollutant Source Strengths:

Whole house source strengths based on: 22 houses

	Formaldehyde	Benzene	Toluene	Xylene	Nonane (mL/hr)	Undecane	Limonene	A-pinene	Ethylbenzene	Source strengths:
House	5.500	0.985	0.856	1.162	N/A	N/A	0.521	0.805	0.385	SRC avg. meas. (whole house) Formaldehyde meas. (CMHC)



Note: Graph shown is for formaldehyde, other pollutant curves will be the same shape.

Pollutant Health Limits (ppm)

	Formaldehyde	Benzene	Toluene	Xylene	Nonane	Undecane	Limonene	a-Pinene	Ethylbenzene	
Classes:	Aldehyde	Aromatic Hydrocarbons			Alkanes		Terpenes		Ether	Class limits are from Seifert
Limits:	0.10	0.008	0.007	0.006	0.010	0.008	0.003	0.002	0.002	Aldehyde limit is from EHD
ACGIH TLV	1.00	9	100	100	200	N/A	N/A	N/A	100	(Canada) for formaldehyde.
Predicted Pollutant Concentrations (ppm)										
Avg: Year	0.027	0.005	0.004	0.006	not avail.	not avail.	0.003	0.004	0.002	
Max: Oct-Apr	0.029	0.005	0.004	0.006	not avail.	not avail.	0.003	0.004	0.002	Highest monthly average for each period
May-Sep	0.036	0.007	0.006	0.008	not avail.	not avail.	0.003	0.005	0.003	
Max. hour	0.044	0.008	0.007	0.009	not avail.	not avail.	0.004	0.006	0.003	

Infiltration & Ventilation (ach)

Month	1	2	3	4	5	6	7	8	9	10	11	12
Max.	0.716	0.675	0.590	0.567	0.421	0.388	0.325	0.389	0.417	0.398	0.458	0.543
Min.	0.301	0.264	0.278	0.184	0.163	0.159	0.162	0.162	0.162	0.164	0.230	0.272
Avg.	0.415	0.397	0.373	0.324	0.259	0.213	0.210	0.214	0.228	0.268	0.318	0.378
Infiltration & Ventilation (L/s)												
Avg.	83	80	75	65	52	43	42	43	46	54	64	76

Temperatures (C)

Outside	-8.8	-4.7	-3.0	4.2	12.0	18.2	19.4	19.0	15.6	9.6	4.6	-4.8
Inside	20.0	20.0	20.0	20.0	20.5	22.2	22.6	22.6	21.1	20.1	20.0	20.0

Winds (m/s)

AES Station	5.3	5.8	4.8	4.8	4.0	3.1	3.5	3.5	3.3	3.6	4.8	4.4
Building	2.2	2.4	2.0	2.0	1.7	1.4	1.5	1.6	1.5	1.6	2.0	1.9

13

Indoor Air Quality Profile

Description:

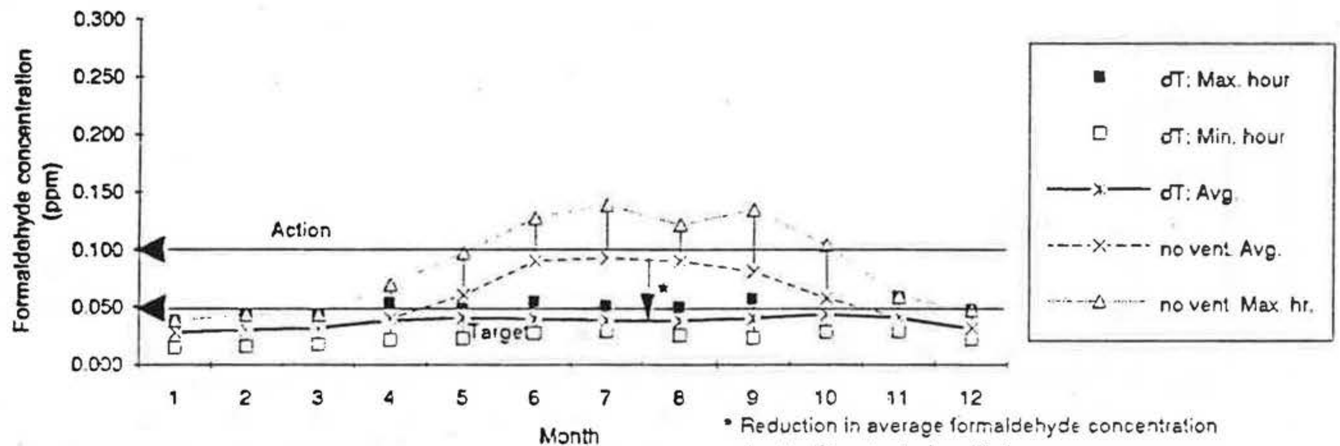
Region:	ONT	Volume	725 m^3	Run ID #	66302	66331
Age:	1981 to 1990	Bldg Ht.	6.5 m	Infil. Coeff:		
Percentile:	75	Flue	none	R	0.60	0.60
Ventilation Type:	Exhaust	Foundation	Bsmt	X	0.00	0.00
Ventilation Flow:	25 L/s	C	169 L/sPa^n	Y	0.00	0.00
	(Ventilation on if temp. difference	n	0.69	Shelter:		
	to outside <8C, off otherwise)	ELA	3,323 cm^2	Building	0.80	0.80

(Run ID columns: dT control / no vent.)

Pollutant Source Strengths:

Whole house source strengths based on: 22 houses

	Formaldehyde	Benzene	Toluene	Xylene	Nonane (mL/hr)	Undecane	Limonene	A-pinene	Ethylbenzene	Source strengths:
House	5.500	0.985	0.856	1.162	N/A	N/A	0.521	0.805	0.385	SRC avg. meas. (whole house)



* Reduction in average formaldehyde concentration due to dT controlled ventilation

Pollutant Health Limits (ppm)

	Formaldehyde	Benzene	Toluene	Xylene	Nonane	Undecane	Limonene	a-Pinene	Ethylbenzene	
Classes:	Aldehyde	Aromatic Hydrocarbons			Alkanes		Terpenes		Ether	Class limits are from Seifert
Limits:	0.05	0.008	0.007	0.006	0.010	0.008	0.003	0.002	0.002	Aldehyde limit is from EHD
ACGIH TLV	1.00	9	100	100	200	N/A	N/A	N/A	100	(Canada) for formaldehyde.
Predicted Pollutant Concentrations with dT controlled ventilation (ppm)										
Avg: Year	0.037	0.007	0.008	0.008	not avail.	not avail.	0.003	0.005	0.003	
Max: Oct-Apr	0.043	0.008	0.009	0.009	not avail.	not avail.	0.004	0.006	0.003	Highest monthly average for
May-Sep	0.043	0.008	0.009	0.009	not avail.	not avail.	0.004	0.006	0.003	each period
Max. hour	0.059	0.011	0.012	0.012	not avail.	not avail.	0.006	0.009	0.004	

Infiltration & Ventilation: dT control (ac/h) Month

	1	2	3	4	5	6	7	8	9	10	11	12
Max.	0.581	0.541	0.457	0.434	0.416	0.383	0.321	0.384	0.411	0.326	0.327	0.429
Min.	0.173	0.157	0.151	0.104	0.104	0.102	0.102	0.102	0.104	0.102	0.104	0.145
Avg.	0.285	0.267	0.244	0.206	0.191	0.195	0.201	0.201	0.193	0.178	0.191	0.250
Infiltration with no Ventilation (ac/h)												
Avg.	0.285	0.267	0.244	0.196	0.132	0.087	0.085	0.088	0.102	0.141	0.190	0.249

Monthly Average Temperatures (C)

Outside	-8.8	-4.7	-3.0	4.2	12.0	18.2	19.4	19.0	15.6	9.6	4.6	-4.6
Inside	20.0	20.0	20.0	20.0	20.5	22.2	22.6	22.6	21.1	20.1	20.0	20.0

Monthly Average Winds (m/s)

AES Station	5.3	5.8	4.8	4.8	4.0	3.1	3.5	3.5	3.3	3.6	4.8	4.4
Building	2.1	2.3	2.0	1.9	1.7	1.4	1.5	1.5	1.4	1.5	1.9	1.6

Indoor Air Quality Profile

14

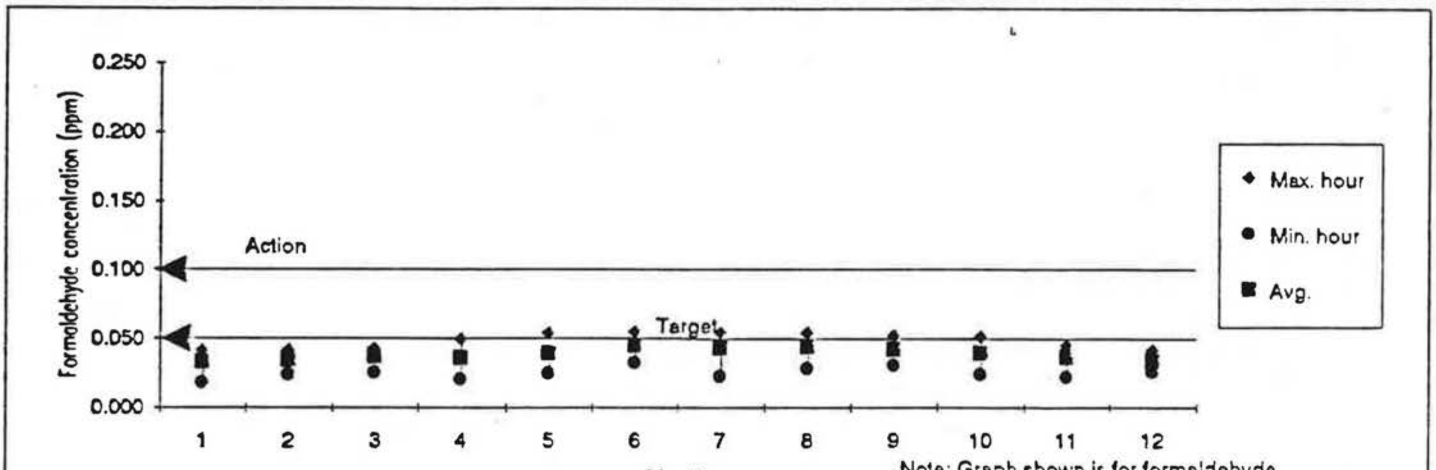
Description:

					No Flue	Flue
Region:	PRAI	Volume	494 m^3	Run ID #	3631 and	3731
Age:	1981 to 1990	Bldg. Ht.	4.5 m	Infil. Coeff:		
Percentile:	75	Flue Ht.	6.0 m	R	0.60	0.43
Ventilation Type:	Continuous flow, balanced	Foundation	Bsmt	X	0.00	0.00
Ventilation Flow:	25 L/s	C	50 L/sPa^n	Y	0.00	0.39
		n	0.71	Shelter:		
		ELA	1,030 cm^2	Building	0.90	0.90
				Flue	0.00	0.95

Pollutant Source Strengths:

Whole house source strengths based on: 22 houses

	Formaldehyde	Benzene	Toluene	Xylene	Nonane (mL/hr)	Undecane	Limonene	A-pinene	Ethylbenzene	Source strengths:
House	5.500	0.985	0.856	1.162	N/A	N/A	0.521	0.805	0.385	SRC avg. meas. (whole house) Formaldehyde meas. (CMHC)



Note: Graph shown is for formaldehyde, other pollutant curves will be the same shape.

Pollutant Health Limits (ppm)

	Formaldehyde	Benzene	Toluene	Xylene	Nonane	Undecane	Limonene	a-Pinene	Ethylbenzene	
Classes:	Aldehyde	Aromatic Hydrocarbons			Alkanes		Terpenes		Ether	Class limits are from Seifert
Limits:	0.10	0.008	0.007	0.006	0.010	0.008	0.003	0.002	0.002	Aldehyde limit is from EHD
ACGIH TLV	1.00	9	100	100	200	N/A	N/A	N/A	100	(Canada) for formaldehyde.
Predicted Pollutant Concentrations (ppm)										
Avg: Year	0.039	0.007	0.006	0.008	not avail.	not avail.	0.004	0.006	0.003	Highest monthly average for each period
Max: Oct-Apr	0.039	0.007	0.006	0.008	not avail.	not avail.	0.004	0.006	0.003	
May-Sep	0.045	0.008	0.007	0.010	not avail.	not avail.	0.004	0.007	0.003	
Max. hour	0.055	0.010	0.009	0.012	not avail.	not avail.	0.005	0.008	0.004	

Infiltration & Ventilation (ach)

	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
Max.	0.655	0.513	0.514	0.621	0.510	0.396	0.567	0.445	0.417	0.519	0.527	0.490
Min.	0.255	0.252	0.245	0.204	0.194	0.194	0.194	0.187	0.194	0.206	0.242	0.256
Avg.	0.337	0.320	0.302	0.316	0.288	0.248	0.260	0.253	0.264	0.289	0.310	0.330
Infiltration & Ventilation (L/s)												
Avg.	46	44	41	43	39	34	36	35	36	40	43	45

Temperatures (C)

Outside	-21.7	-19.0	-9.0	3.1	10.5	17.8	16.7	19.1	13.2	6.9	-5.0	-14.7
Inside	20.0	20.0	20.0	20.0	20.5	21.7	21.3	22.6	20.7	20.0	20.0	20.0

Winds (m/s)

AES Station	4.6	3.8	4.2	6.0	5.3	3.9	4.4	4.2	4.3	5.0	4.7	5.1
Building	3.5	2.9	3.2	4.5	4.0	2.9	3.3	3.2	3.2	3.8	3.6	3.9

Indoor Air Quality Profile

15

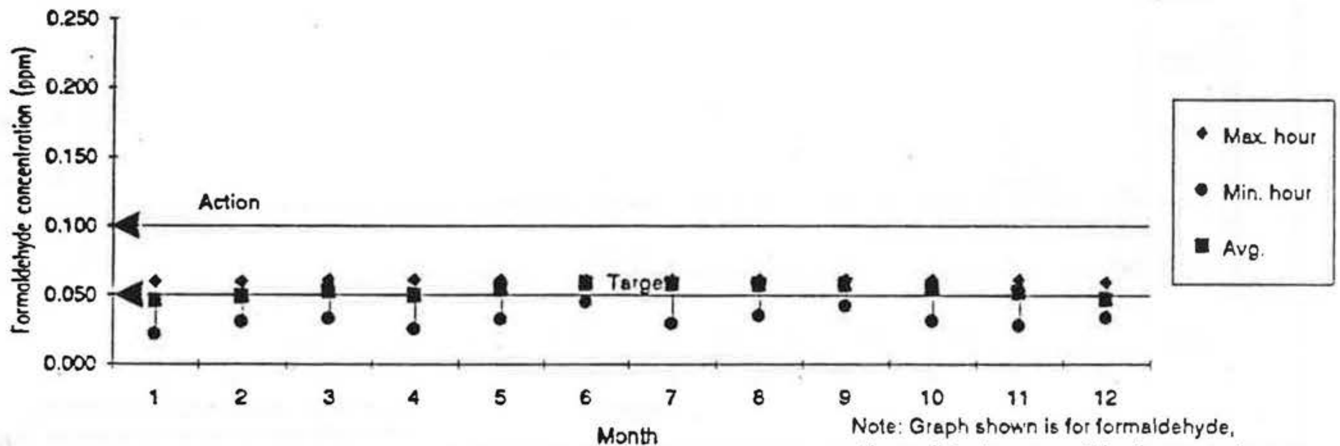
Description:

Region:	PRAI	Volume	494 m^3		No Flue		Flue
Age:	1981 to 1990	Bldg. Ht.	4.5 m	Run ID #	3635	and	3735
Percentile:	75	Flue Ht.	6.0 m	Infil. Coeff:			
Ventilation Type:	Continuous Exhaust	Foundation	Bsmt	R	0.60		0.43
Ventilation Flow:	25 L/s	C	50 L/sPa^n	X	0.00		0.00
		n	0.71	Y	0.00		0.39
		ELA	1,030 cm^2	Shelter:			
				Building	0.90		0.90
				Flue	0.00		0.95

Pollutant Source Strengths:

Whole house source strengths based on: 22 houses

	Formaldehyde	Benzene	Toluene	Xylene	Nonane (mL/hr)	Undecane	Limonene	A-pinene	Ethylbenzene	Source strengths:
House	5.500	0.985	0.856	1.162	N/A	N/A	0.521	0.805	0.385	SRC avg. meas. (whole house) Formaldehyde meas. (CMHC)



Note: Graph shown is for formaldehyde, other pollutant curves will be the same shape.

Pollutant Health Limits (ppm)

	Formaldehyde	Benzene	Toluene	Xylene	Nonane	Undecane	Limonene	a-Pinene	Ethylbenzene	
Classes:	Aldehyde	Aromatic Hydrocarbons			Alkanes		Terpenes		Ether	Class limits are from Seifert
Limits:	0.10	0.008	0.007	0.006	0.010	0.008	0.003	0.002	0.002	Aldehyde limit is from EHD
ACGIH TLV	1.00	9	100	100	200	N/A	N/A	N/A	100	(Canada) for formaldehyde.
Predicted Pollutant Concentrations (ppm)										
Avg: Year	0.053	0.010	0.008	0.011	not avail.	not avail.	0.005	0.008	0.004	
Max: Oct-Apr	0.054	0.010	0.008	0.011	not avail.	not avail.	0.005	0.008	0.004	Highest monthly average for each period
May-Sep	0.059	0.011	0.009	0.012	not avail.	not avail.	0.006	0.009	0.004	
Max. hour	0.061	0.011	0.010	0.013	not avail.	not avail.	0.006	0.009	0.004	

Infiltration & Ventilation (ach) Month

	1	2	3	4	5	6	7	8	9	10	11	12
Max.	0.564	0.421	0.423	0.530	0.419	0.305	0.476	0.420	0.326	0.428	0.436	0.399
Min.	0.182	0.182	0.182	0.182	0.182	0.182	0.182	0.182	0.182	0.182	0.182	0.182
Avg.	0.246	0.229	0.213	0.231	0.209	0.190	0.194	0.195	0.194	0.210	0.223	0.239
Infiltration & Ventilation (L/s)												
Avg.	34	31	29	32	29	26	27	27	27	29	31	33

Temperatures (C)

Outside	-21.7	-19.0	-9.0	3.1	10.5	17.8	16.7	19.1	13.2	6.9	-5.0	-14.7
Inside	20.0	20.0	20.0	20.0	20.5	21.7	21.3	22.6	20.7	20.0	20.0	20.0

Winds (m/s)

AES Station	4.6	3.8	4.2	6.0	5.3	3.9	4.4	4.2	4.3	5.0	4.7	5.1
Building	3.5	2.9	3.2	4.5	4.0	2.9	3.3	3.2	3.2	3.8	3.6	3.9

16

Indoor Air Quality Profile

Description:

Region: PRAI
Age: 1981 to 1990
Percentile: 75
Ventilation Type: Exhaust
Ventilation Flow: 25 L/s
(Ventilation on if temp. difference
to outside <8C, off otherwise)

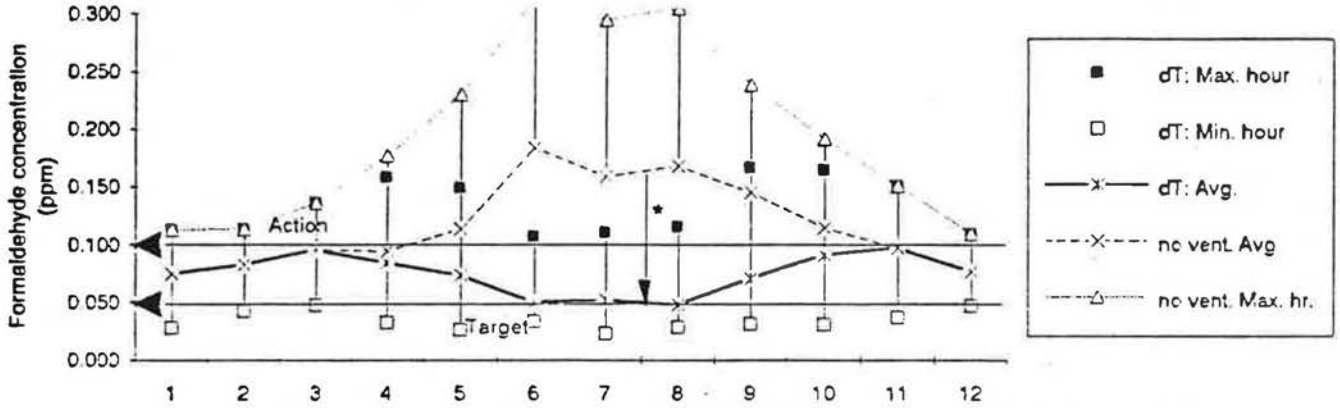
Volume 494 m^3
Bldg. Ht. 4.5 m
Flue none
Foundation Bsmt
C 50 L/sPa^n
n 0.71
ELA 1,030 cm^2

	dT control	no vent.
Run ID #	36302	36331
Infil. Coeff:		
R	0.60	0.60
X	0.00	0.00
Y	0.00	0.00
Shelter:		
Building	0.90	0.90

Pollutant Source Strengths:

Whole house source strengths based on: 22 houses

	Formaldehyde	Benzene	Toluene	Xylene	Nonane (mL/hr)	Undecane	Limonene	A-pinene	Ethylbenzene	Source strengths:
House	5.500	0.985	0.856	1.162	N/A	N/A	0.521	0.805	0.385	SRC avg. meas. (whole house)



* Reduction in average formaldehyde concentration due to dT controlled ventilation

Pollutant Health Limits (ppm)

	Formaldehyde	Benzene	Toluene	Xylene	Nonane	Undecane	Limonene	a-Pinene	Ethylbenzene	
Classes:	Aldehyde	Aromatic Hydrocarbons*			Alkanes		Terpenes		Ether	Class limits are from Seifert
Limits:	0.05	0.008	0.007	0.005	0.010	0.008	0.003	0.002	0.002	Aldehyde limit is from EHD
ACGIH TLV	1.00	9	100	100	200	N/A	N/A	N/A	100	(Canada) for formaldehyde.
Predicted Pollutant Concentrations with dT controlled ventilation (ppm)										
Avg: Year	0.075	0.013	0.016	0.016	not avail.	not avail.	0.007	0.011	0.005	
Max: Oct-Apr	0.097	0.017	0.021	0.021	not avail.	not avail.	0.009	0.014	0.007	Highest monthly average for each period
May-Sep	0.097	0.017	0.021	0.021	not avail.	not avail.	0.009	0.014	0.007	
Max. hour	0.167	0.030	0.035	0.035	not avail.	not avail.	0.016	0.024	0.012	

Infiltration & Ventilation: dT control (ac/h) Month

	1	2	3	4	5	6	7	8	9	10	11	12
Max.	0.475	0.332	0.333	0.440	0.511	0.397	0.569	0.446	0.418	0.501	0.347	0.309
Min.	0.074	0.071	0.063	0.036	0.035	0.034	0.034	0.034	0.034	0.034	0.061	0.075
Avg.	0.156	0.139	0.121	0.154	0.174	0.231	0.234	0.241	0.192	0.144	0.129	0.149

Infiltration with no Ventilation (ac/h)

Avg.	0.156	0.139	0.121	0.135	0.106	0.066	0.079	0.072	0.082	0.107	0.129	0.149

Monthly Average Temperatures (C)

Outside	-21.7	-19.0	-9.0	3.1	10.5	17.6	16.7	19.1	13.2	6.9	-5.0	-14.7
Inside	20.0	20.0	20.0	20.0	20.5	21.7	21.3	22.6	20.7	20.0	20.0	20.0

Monthly Average Winds (m/s)

AES Station	4.6	3.8	4.2	6.0	5.3	3.9	4.4	4.2	4.3	5.0	4.7	5.1
Building	3.2	2.6	2.9	4.0	3.6	2.6	3.0	2.9	2.9	3.4	3.2	3.5

17

Indoor Air Quality Profile

Description:

Region: PRAI
Age: 1981 to 1990
Percentile: 75
Ventilation Type: Exhaust
Ventilation Flow: 25 L/s
(Ventilation on if temp. difference
to outside <10C, off otherwise)

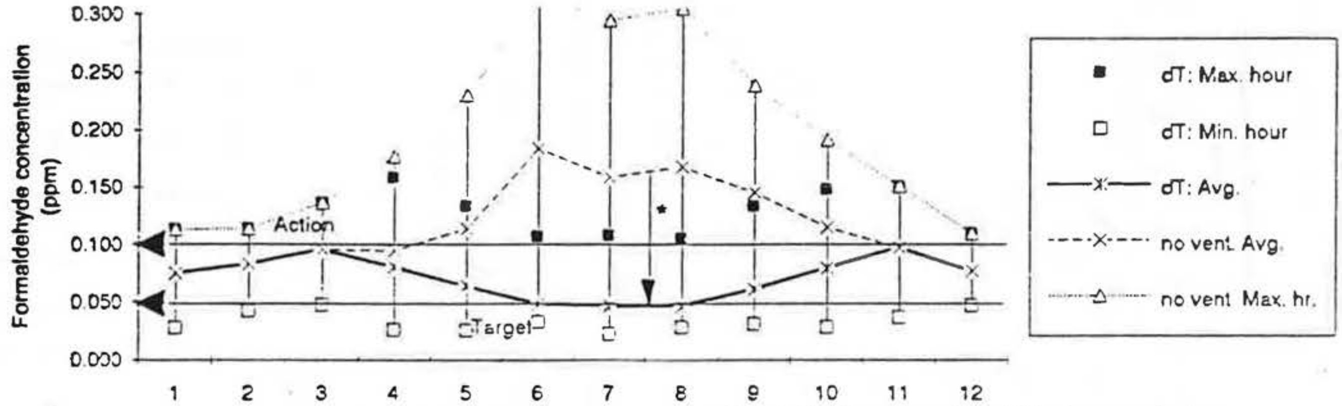
Volume 494 m^3
Bldg Ht. 4.5 m
Flue none
Foundation Bsmt
C 50 L/sPa^n
n 0.71
ELA 1,030 cm^2

	dT control	no vent.
Run ID #	36312	36331
Infil. Coeff:		
R	0.60	0.60
X	0.00	0.00
Y	0.00	0.00
Shelter:		
Building	0.90	0.90

Pollutant Source Strengths:

Whole house source strengths based on: 22 houses

	Formaldehyde	Benzene	Toluene	Xylene	Nonane (mL/hr)	Undecane	Limonene	A-pinene	Ethylbenzene	Source strengths:
House	5.500	0.985	0.856	1.162	N/A	N/A	0.521	0.805	0.385	SRC avg. meas. (whole house)



* Reduction in average formaldehyde concentration due to dT controlled ventilation

Pollutant Health Limits (ppm)

	Formaldehyde	Benzene	Toluene	Xylene	Nonane	Undecane	Limonene	a-Pinene	Ethylbenzene*	
Classes:	Aldehyde	Aromatic Hydrocarbons			Alkanes		Terpenes		Ether	Class limits are from Seifert
Limits:	0.05	0.008	0.007	0.006	0.010	0.008	0.003	0.002	0.002	Aldehyde limit is from EHD
ACGIH TLV	1.00	9	100	100	200	N/A	N/A	N/A	100	(Canada) for formaldehyde.
Predicted Pollutant Concentrations with dT controlled ventilation (ppm)										
Avg: Year	0.071	0.013	0.015	0.015	not avail.	not avail.	0.007	0.010	0.005	
Max: Oct-Apr	0.097	0.017	0.021	0.021	not avail.	not avail.	0.009	0.014	0.007	Highest monthly average for each period
May-Sep	0.097	0.017	0.021	0.021	not avail.	not avail.	0.009	0.014	0.007	
Max. hour	0.159	0.028	0.033	0.033	not avail.	not avail.	0.015	0.023	0.011	

Infiltration & Ventilation: dT control (ac/h) Month

	1	2	3	4	5	6	7	8	9	10	11	12
Max.	0.475	0.332	0.333	0.550	0.511	0.397	0.569	0.446	0.418	0.501	0.347	0.309
Min.	0.074	0.071	0.063	0.043	0.045	0.044	0.041	0.041	0.044	0.041	0.061	0.075
Avg.	0.156	0.139	0.121	0.166	0.201	0.239	0.249	0.248	0.211	0.167	0.129	0.149
Infiltration with no Ventilation (ac/h)												
Avg.	0.156	0.139	0.121	0.135	0.106	0.066	0.079	0.072	0.082	0.107	0.129	0.149

Monthly Average Temperatures (C)

Outside	-21.7	-18.0	-9.0	3.1	10.5	17.8	16.7	19.1	13.2	6.9	-5.0	-14.7
Inside	20.0	20.0	20.0	20.0	20.5	21.7	21.3	22.6	20.7	20.0	20.0	20.0

Monthly Average Winds (m/s)

AES Station	4.6	3.8	4.2	6.0	5.3	3.9	4.4	4.2	4.3	5.0	4.7	5.1
Building	3.2	2.6	2.9	4.0	3.6	2.6	3.0	2.9	2.9	3.4	3.2	3.5

18

Indoor Air Quality Profile

Description:

Region: PRAI
Age: 1981 to 1990
Percentile: 75
Ventilation Type: Exhaust
Ventilation Flow: 25 L/s
(Ventilation on if temp. difference
to outside <12C, off otherwise)

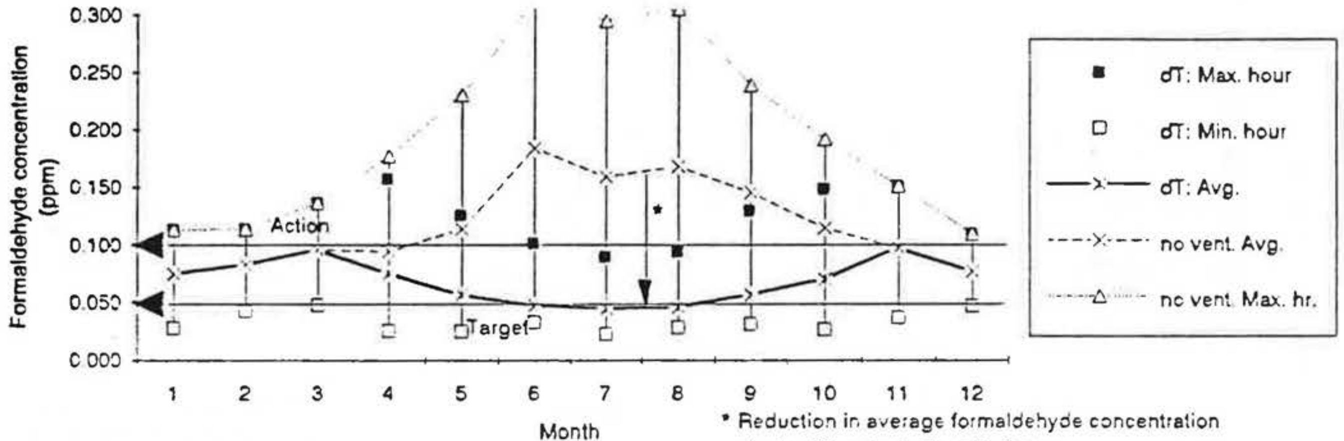
Volume 494 m^3
Bldg. Ht. 4.5 m
Flue none
Foundation Bsmt
C 50 L/sPa^n
n 0.71
ELA 1,030 cm^2

	dT control	no vent.
Run ID #	36322	36331
Infil. Coeff:		
R	0.60	0.60
X	0.00	0.00
Y	0.00	0.00
Shelter:		
Building	0.90	0.90

Pollutant Source Strengths:

Whole house source strengths based on: 22 houses

	Formalde-hyde	Benzene	Toluene	Xylene	Nonane (mL/hr)	Undecane	Limonene	A-pinene	Ethyl-benzene	Source strengths:
House	5.500	0.985	0.856	1.162	N/A	N/A	0.521	0.805	0.385	SRC avg. meas. (whole house)



* Reduction in average formaldehyde concentration due to dT controlled ventilation

Pollutant Health Limits (ppm)

	Formaldehyde	Benzene	Toluene	Xylene	Nonane	Undecane	Limonene	a-Pinene	Ethylbenzene	
Classes:	Aldehyde	Aromatic Hydrocarbons			Alkanes		Terpenes		Ether	Class limits are from Seifert
Limits:	0.05	0.008	0.007	0.006	0.010	0.006	0.003	0.002	0.002	Aldehyde limit is from EHD
ACGIH TLV	1.00	9	100	100	200	N/A	N/A	N/A	100	(Canada) for formaldehyde.
Predicted Pollutant Concentrations with dT controlled ventilation (ppm)										
Avg: Year	0.069	0.012	0.014	0.014	not avail.	not avail.	0.006	0.010	0.005	Highest monthly average for each period
Max: Oct-Apr	0.097	0.017	0.021	0.021	not avail.	not avail.	0.009	0.014	0.007	
May-Sep	0.097	0.017	0.021	0.021	not avail.	not avail.	0.009	0.014	0.007	
Max hour	0.158	0.028	0.033	0.033	not avail.	not avail.	0.015	0.023	0.011	

Infiltration & Ventilation: dT control (ac/h) Month

	1	2	3	4	5	6	7	8	9	10	11	12
Max.	0.475	0.332	0.333	0.550	0.511	0.397	0.569	0.446	0.418	0.501	0.347	0.309
Min.	0.074	0.071	0.063	0.046	0.045	0.045	0.046	0.046	0.045	0.045	0.061	0.075
Avg.	0.156	0.139	0.121	0.178	0.223	0.241	0.257	0.250	0.222	0.191	0.129	0.149
Infiltration with no Ventilation (ac/h)												
Avg.	0.156	0.139	0.121	0.135	0.106	0.066	0.079	0.072	0.062	0.107	0.129	0.149

Monthly Average Temperatures (C)

Outside	-21.7	-19.0	-9.0	3.1	10.5	17.8	16.7	19.1	13.2	6.9	-5.0	-14.7
Inside	20.0	20.0	20.0	20.0	20.5	21.7	21.3	22.6	20.7	20.0	20.0	20.0

Monthly Average Winds (m/s)

AES Station	4.6	3.8	4.2	6.0	5.3	3.9	4.4	4.2	4.3	5.0	4.7	5.1
Building	3.2	2.6	2.9	4.0	3.6	2.6	3.0	2.9	2.9	3.4	3.2	3.5

19

Indoor Air Quality Profile

Description:

Region: BC
Age: 1981 to 1990
Percentile: 75
Ventilation Type: Continuous flow, balanced
Ventilation Flow: 25 L/s

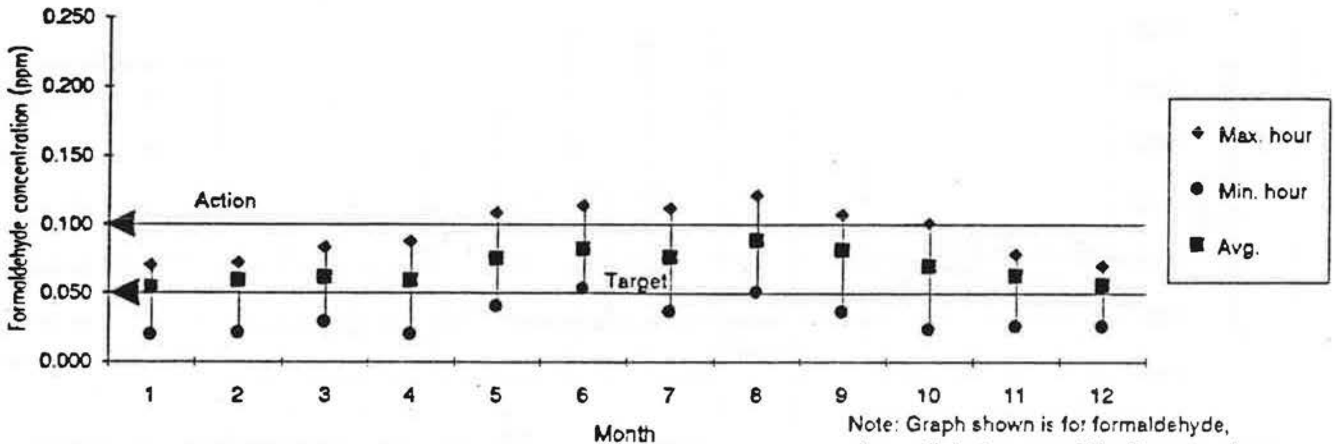
Volume 539 m^3
Bldg. Ht. 5.2 m
Flue Ht. 6.7 m
Foundation C/space
C 248 L/sPa^n
n 0.66
ELA 4,551 cm^2

	No Flue		Flue
Run ID #	1631	and	1731
Infil. Coeff:			
R	0.60		0.55
X	0.00		0.00
Y	0.00		0.09
Shelter:			
Building	0.80		0.80
Flue	0.00		0.85

Pollutant Source Strengths:

Whole house source strengths based on: 5 houses

	Formaldehyde	Benzene	Toluene	Xylene	Nonane (mL/hr)	Undecane	Limonene	A-pinene	Ethylbenzene	Source strengths:
House	17.100	0.985	0.856	1.162	N/A	N/A	0.521	0.805	0.385	SRC avg. meas. (whole house) Formaldehyde meas. (CMHC)



Note: Graph shown is for formaldehyde, other pollutant curves will be the same shape.

Pollutant Health Limits (ppm)

	Formaldehyde	Benzene	Toluene	Xylene	Nonane	Undecane	Limonene	a-Pinene	Ethylbenzene	
Classes:	Aldehyde	Aromatic Hydrocarbons			Alkanes		Terpenes		Ether	Class limits are from Seifert
Limits:	0.10	0.008	0.007	0.006	0.010	0.008	0.003	0.002	0.002	Aldehyde limit is from EHD
ACGIH TLV	1.00	9	100	100	200	N/A	N/A	N/A	100	(Canada) for formaldehyde.
Predicted Pollutant Concentrations (ppm)										
Avg: Year	0.069	0.004	0.003	0.005	not avail.	not avail.	0.002	0.003	0.002	
Max: Oct-Apr	0.070	0.004	0.003	0.005	not avail.	not avail.	0.002	0.003	0.002	Highest monthly average for each period
May-Sep	0.089	0.005	0.004	0.006	not avail.	not avail.	0.003	0.004	0.002	
Max. hour	0.121	0.007	0.006	0.008	not avail.	not avail.	0.004	0.006	0.003	

Infiltration & Ventilation (ach) Month

	1	2	3	4	5	6	7	8	9	10	11	12
Max.	1.731	1.582	1.342	1.685	0.885	0.678	0.914	0.784	0.955	1.439	1.358	1.352
Min.	0.419	0.369	0.332	0.297	0.237	0.236	0.237	0.236	0.237	0.237	0.380	0.413
Avg.	0.611	0.548	0.527	0.562	0.432	0.390	0.438	0.368	0.403	0.483	0.522	0.575
Infiltration & Ventilation (L/s)												
Avg.	92	82	79	84	65	58	66	55	60	72	78	86

Temperatures (C)

Outside	0.5	3.9	6.7	7.1	12.4	14.5	16.9	17.8	13.1	9.0	6.3	0.6
Inside	20.0	20.0	20.0	20.0	20.2	20.1	21.0	21.3	20.0	20.0	20.0	20.0

Winds (m/s)

AES Station	4.5	4.1	4.5	5.1	3.5	3.2	4.4	3.3	2.9	3.6	4.0	3.9
Building	2.9	2.6	2.9	3.2	2.3	2.1	2.8	2.2	1.9	2.3	2.6	2.5

21a

Indoor Air Quality Profile

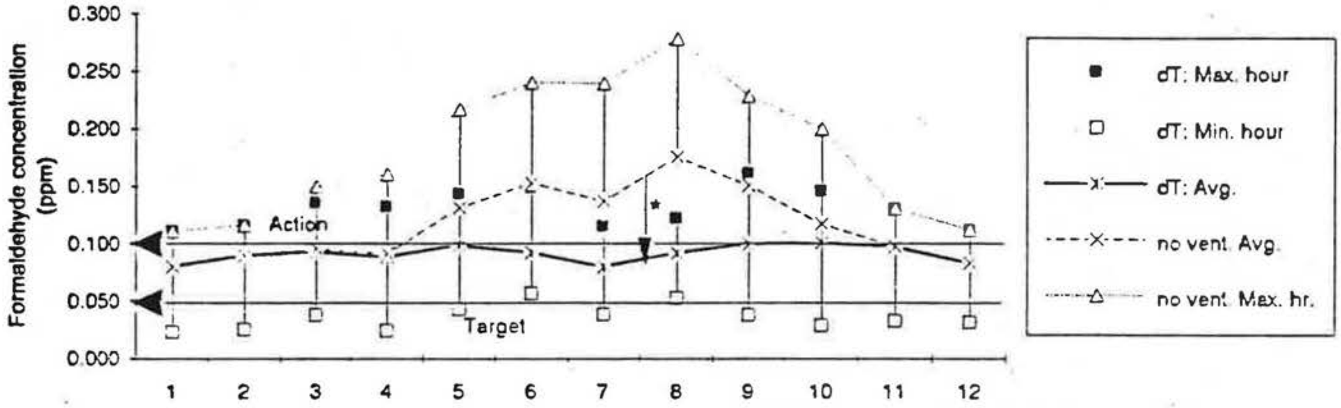
Description:

Region:	BC	Volume	539 m^3		dT control	no vent.
Age:	1981 to 1990	Bldg. Ht.	5.2 m	Run ID #	16302	16331
Percentile:	75	Flue	none	Infil. Coeff:		
Ventilation Type:	Exhaust	Foundation	C/space	R	0.60	0.60
Ventilation Flow:	25 L/s	C	248 L/sPa^n	X	0.00	0.00
(Ventilation on if temp. difference to outside <8C, off otherwise)		n	0.66	Y	0.00	0.00
		ELA	4,551 cm^2	Shelter:		
				Building	0.80	0.80

Pollutant Source Strengths:

Whole house source strengths based on: 5 houses

	Formaldehyde	Benzene	Toluene	Xylene	Nonane (mL/hr)	Undecane	Limonene	A-pinene	Ethylbenzene	Source strengths:
House	17.100	0.985	0.856	1.162	N/A	N/A	0.521	0.805	0.385	SRC avg. meas. (whole house)



* Reduction in average formaldehyde concentration due to dT controlled ventilation

Pollutant Health Limits (ppm)

	Formaldehyde	Benzene	Toluene	Xylene	Nonane	Undecane	Limonene	a-Pinene	Ethylbenzene	
Classes:	Aldehyde	Aromatic Hydrocarbons			Alkanes		Terpenes	•	Ether	Class limits are from Seifert
Limits:	0.05	0.008	0.007	0.006	0.010	0.008	0.003	0.002	0.002	Aldehyde limit is from EHD
ACGIH TLV	1.00	9	100	100	200	N/A	N/A	N/A	100	(Canada) for formaldehyde.
Predicted Pollutant Concentrations with dT controlled ventilation (ppm)										
Avg: Year	0.091	0.005	0.006	0.006	not avail.	not avail.	0.003	0.004	0.002	Highest monthly average for each period
Max: Oct-Apr	0.101	0.006	0.007	0.007	not avail.	not avail.	0.003	0.005	0.002	
May-Sep	0.101	0.006	0.007	0.007	not avail.	not avail.	0.003	0.005	0.002	
Max. hour	0.161	0.009	0.011	0.011	not avail.	not avail.	0.005	0.008	0.004	

Infiltration & Ventilation: dT control (ac/h) Month

	1	2	3	4	5	6	7	8	9	10	11	12
Max.	1.493	1.351	1.123	1.449	0.853	0.656	0.680	0.756	0.919	1.214	1.136	1.133
Min.	0.247	0.198	0.192	0.188	0.176	0.176	0.177	0.177	0.177	0.177	0.208	0.241
Avg.	0.431	0.370	0.356	0.390	0.343	0.354	0.419	0.357	0.338	0.344	0.345	0.396
Infiltration with no Ventilation (ac/h)												
Avg.	0.431	0.369	0.348	0.381	0.256	0.215	0.261	0.193	0.226	0.305	0.344	0.395

Monthly Average Temperatures (C)

Outside	0.5	3.9	6.7	7.1	12.4	14.5	16.9	17.8	13.1	9.0	6.3	0.6
Inside	20.0	20.0	20.0	20.0	20.2	20.1	21.0	21.3	20.0	20.0	20.0	20.0

Monthly Average Winds (m/s)

AES Station	4.5	4.1	4.5	5.1	3.5	3.2	4.4	3.3	2.9	3.6	4.0	3.9
Building	2.8	2.6	2.8	3.1	2.2	2.1	2.8	2.1	1.9	2.3	2.5	2.5

21b

Indoor Air Quality Profile

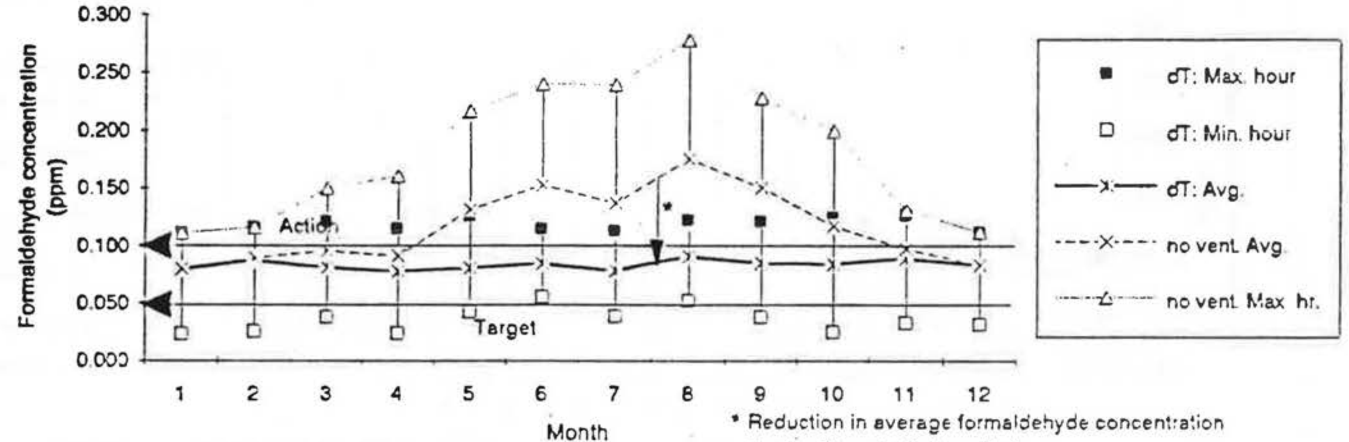
Description:

Region:	BC	Volume	539 m^3		**dT control**	**no vent.**
Age:	1981 to 1990	Bldg Ht.	5.2 m	Run ID #	16322	16331
Percentile:	75	Flue	none	Infil. Coeff:		
Ventilation Type:	Exhaust	Foundation	C/space	R	0.60	0.60
Ventilation Flow:	25 L/s	C	248 L/sPa^n	X	0.00	0.00
(Ventilation on if temp. difference to outside <12C, off otherwise)		n	0.66	Y	0.00	0.00
		ELA	4,551 cm^2	Shelter:		
				Building	0.80	0.80

Pollutant Source Strengths:

Whole house source strengths based on: 5 houses

	Formalde-hyde	Benzene	Toluene	Xylene	Nonane (mL/hr)	Undecane	Limonene	A-pinene	Ethyl-benzene	Source strengths:
House	17.100	0.985	0.856	1.162	N/A	N/A	0.521	0.805	0.385	SRC avg. meas. (whole house)



* Reduction in average formaldehyde concentration due to dT controlled ventilation

Pollutant Health Limits (ppm)

	Formaldehyde	Benzene	Toluene	Xylene	Nonane	Undecane	Limonene	a-Pinene	Ethylbenzene	
Classes:	Aldehyde	Aromatic Hydrocarbons			Alkanes		Terpenes		Ether	Class limits are from Seifert
Limits:	0.05	0.008	0.007	0.006	0.010	0.008	0.003	0.002	0.002	Aldehyde limit is from EHD
ACGIH TLV	1.00	9	100	100	200	N/A	N/A	N/A	100	(Canada) for formaldehyde.
Predicted Pollutant Concentrations with dT controlled ventilation (ppm)										
Avg: Year	0.083	0.005	0.006	0.006	not avail.	not avail.	0.003	0.004	0.002	
Max: Oct-Apr	0.089	0.005	0.006	0.006	not avail.	not avail.	0.003	0.004	0.002	Highest monthly average for each period
May-Sep	0.090	0.005	0.006	0.006	not avail.	not avail.	0.003	0.004	0.002	
Max. hour	0.127	0.007	0.009	0.009	not avail.	not avail.	0.004	0.006	0.003	

Infiltration & Ventilation: dT control (ac/h) Month

	1	2	3	4	5	6	7	8	9	10	11	12
Max.	1.493	1.351	1.123	1.449	0.853	0.656	0.880	0.756	0.919	1.381	1.138	1.133
Min.	0.247	0.234	0.234	0.234	0.230	0.234	0.236	0.234	0.230	0.230	0.230	0.241
Avg.	0.434	0.384	0.412	0.441	0.407	0.382	0.428	0.360	0.367	0.411	0.364	0.396
Infiltration with no Ventilation (ac/h)												
Avg	0.431	0.369	0.348	0.381	0.256	0.215	0.261	0.193	0.228	0.306	0.344	0.396

Monthly Average Temperatures (C)

Outside	0.5	3.9	6.7	7.1	12.4	14.5	16.9	17.8	13.1	9.0	6.3	0.6
Inside	20.0	20.0	20.0	20.0	20.2	20.1	21.0	21.3	20.0	20.0	20.0	20.0

Monthly Average Winds (m/s)

AES Station	4.5	4.1	4.5	5.1	3.5	3.2	4.4	3.3	2.9	3.6	4.0	3.9
Building	2.8	2.6	2.8	3.1	2.2	2.1	2.8	2.1	1.9	2.3	2.5	2.5

Indoor Air Quality Profile

22

Description:

Region: ONT
Age: 1981 to 1990
Percentile: 75
Ventilation Type: None
Ventilation Flow: 0 L/s

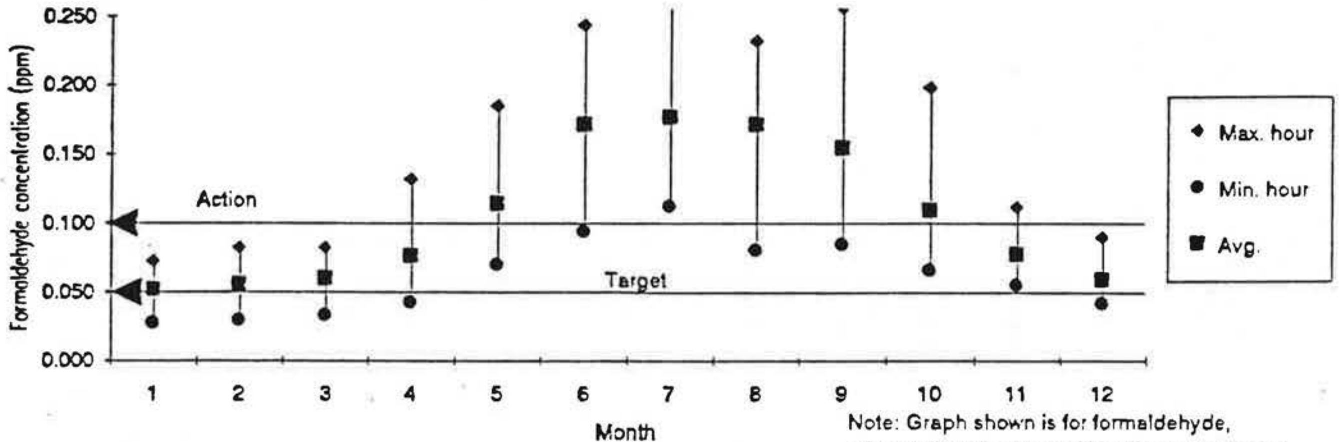
Volume 725 m^3
Bldg. Ht. 6.5 m
Flue Ht. 8.0 m
Foundation Bsmt
C 169 L/sPa^n
n 0.69
ELA 3,323 cm^2

	No Flue		Flue
Run ID #	6630	and	6730
Infil. Coeff:			
R	0.60		0.54
X	0.00		0.00
Y	0.00		0.12
Shelter:			
Building	0.80		0.80
Flue	0.00		0.85

Pollutant Source Strengths:

Whole house source strengths based on: 22 houses

	Formaldehyde	Benzene	Toluene	Xylene	Nonane (mL/hr)	Undecane	Limonene	A-pinene	Ethylbenzene	Source strengths:
Mat'ls	5.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	User input
House	5.500	0.985	0.856	1.162	N/A	N/A	0.521	0.805	0.385	SRC avg. meas. (whole house)
Total	10.500	0.985	0.856	1.162	N/A	N/A	0.521	0.805	0.385	



Note: Graph shown is for formaldehyde, other pollutant curves will be the same shape.

Pollutant Health Limits (ppm)

	Formaldehyde	Benzene	Toluene	Xylene	Nonane	Undecane	Limonene	a-Pinene	Ethylbenzene	
Classes:	Aldehyde	Aromatic Hydrocarbons			Alkanes		Terpenes		Ether	Class limits are from Seifert
Limits:	0.10	0.008	0.007	0.006	0.010	0.008	0.003	0.002	0.002	Aldehyde limit is from EHD
ACGIH TLV	1.00	9	100	100	200	N/A	N/A	N/A	100	(Canada) for formaldehyde.
Predicted Pollutant Concentrations (ppm)										
Avg: Year	0.107	0.010	0.009	0.012	not avail.	not avail.	0.005	0.008	0.004	
Max: Oct-Apr	0.110	0.010	0.009	0.012	not avail.	not avail.	0.005	0.008	0.004	Highest monthly average for each period
May-Sep	0.177	0.017	0.014	0.020	not avail.	not avail.	0.009	0.014	0.006	
Max. hour	0.265	0.025	0.022	0.029	not avail.	not avail.	0.013	0.020	0.010	

Infiltration & Ventilation (ach) — Month

	1	2	3	4	5	6	7	8	9	10	11	12
Max.	0.578	0.538	0.455	0.431	0.289	0.256	0.195	0.258	0.285	0.267	0.326	0.409
Min.	0.174	0.158	0.151	0.059	0.038	0.035	0.037	0.037	0.037	0.040	0.105	0.146
Avg.	0.286	0.268	0.245	0.196	0.132	0.087	0.064	0.088	0.102	0.142	0.190	0.250
Infiltration & Ventilation (L/s)												
Avg.	58	54	49	40	27	18	17	18	20	29	36	50

Temperatures (C)

Outside	-6.8	-4.7	-3.0	4.2	12.0	18.2	19.4	19.0	15.6	9.6	4.6	-4.8
Inside	20.0	20.0	20.0	20.0	20.5	22.2	22.6	22.6	21.1	20.1	20.0	20.0

Winds (m/s)

AES Station	5.3	5.8	4.8	4.8	4.0	3.1	3.5	3.5	3.3	3.6	4.8	4.4
Building	2.2	2.4	2.0	2.0	1.7	1.4	1.5	1.6	1.5	1.6	2.0	1.9

Indoor Air Quality Profile

31

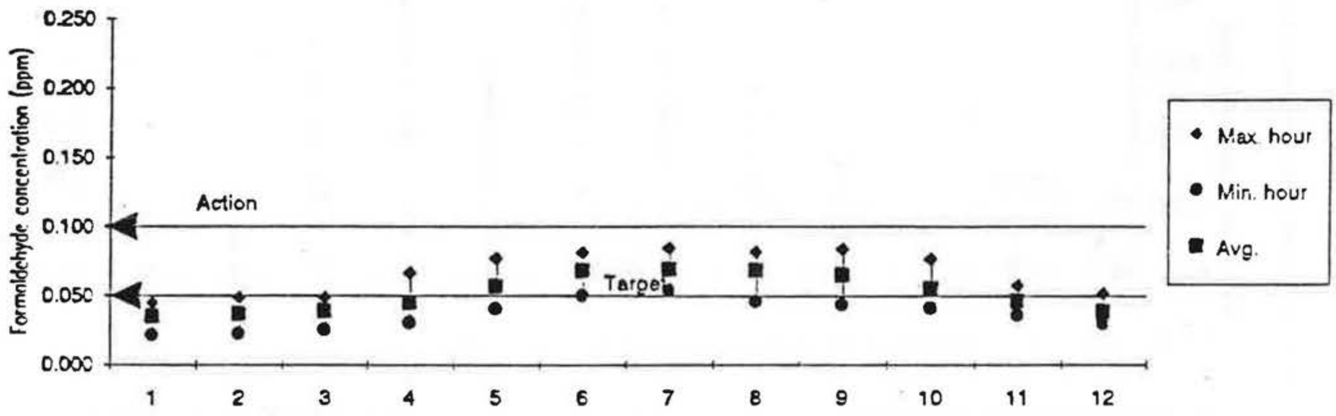
Description:

Region:	ONT	**Volume**	725 m^3		No Flue	and	Flue
Age:	1981 to 1990	**Bldg. Ht.**	6.5 m	**Run ID #**	6631	and	6731
Percentile:	75	**Flue Ht.**	8.0 m	**Infil. Coeff:**			
Ventilation Type:	Continuous flow, balanced	**Foundation**	Bsmt	**R**	0.60		0.54
Ventilation Flow:	25 L/s	**C**	169 L/sPa^n	**X**	0.00		0.00
		n	0.69	**Y**	0.00		0.12
		ELA	3,323 cm^2	**Shelter:**			
				Building	0.80		0.80
				Flue	0.00		0.85

Pollutant Source Strengths:

Whole house source strengths based on: 22 houses

	Formaldehyde	Benzene	Toluene	Xylene	Nonane (mL/hr)	Undecane	Limonene	A-pinene	Ethylbenzene	Source strengths:
Mat'ls	5.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	User Input
House	5.500	0.985	0.856	1.162	N/A	N/A	0.521	0.805	0.385	SRC avg meas. (whole house)
Total	10.500	0.985	0.856	1.162	N/A	N/A	0.521	0.805	0.385	



Note: Graph shown is for formaldehyde,
other pollutant curves will be the same shape.

Pollutant Health Limits (ppm)

	Formaldehyde	Benzene	Toluene	Xylene	Nonane	Undecane	Limonene	a-Pinene	Ethylbenzene	
Classes:	Aldehyde	Aromatic Hydrocarbons			Alkanes		Terpenes		Ether	Class limits are from Seifert
Limits:	0.10	0.008	0.007	0.006	0.010	0.008	0.003	0.002	0.002	Aldehyde limit is from EHD
ACGIH TLV	1.00	9	100	100	200	N/A	N/A	N/A	100	(Canada) for formaldehyde.
Predicted Pollutant Concentrations (ppm)										
Avg: Year	0.052	0.005	0.004	0.006	not avail.	not avail.	0.003	0.004	0.002	
Max: Oct-Apr	0.055	0.005	0.004	0.006	not avail.	not avail.	0.003	0.004	0.002	Highest monthly average for
May-Sep	0.070	0.007	0.006	0.008	not avail.	not avail.	0.003	0.005	0.003	each period
Max. hour	0.085	0.008	0.007	0.009	not avail.	not avail.	0.004	0.006	0.003	

Infiltration & Ventilation (ach) Month

	1	2	3	4	5	6	7	8	9	10	11	12
Max.	0.716	0.675	0.590	0.567	0.421	0.388	0.325	0.389	0.417	0.398	0.458	0.543
Min.	0.301	0.284	0.278	0.184	0.163	0.159	0.162	0.162	0.162	0.164	0.230	0.272
Avg.	0.415	0.397	0.373	0.324	0.259	0.213	0.210	0.214	0.228	0.268	0.318	0.378
Infiltration & Ventilation (L/s)												
Avg.	83	80	75	65	52	43	42	43	46	54	64	76

Temperatures (C)

Outside	-8.8	-4.7	-3.0	4.2	12.0	18.2	19.4	19.0	15.6	9.6	4.6	-4.8
Inside	20.0	20.0	20.0	20.0	20.5	22.2	22.6	22.6	21.1	20.1	20.0	20.0

Winds (m/s)

AES Station	5.3	5.8	4.8	4.8	4.0	3.1	3.5	3.5	3.3	3.6	4.8	4.4
Building	2.2	2.4	2.0	2.0	1.7	1.4	1.5	1.6	1.5	1.6	2.0	1.9

Indoor Air Quality Profile

51

Description:

Region: BC
Age: pre 1946
Percentile: 75
Ventilation Type: None
Ventilation Flow: 0 L/s

Volume 481 m^3
Bldg. Ht. 5 m
Flue Ht. 6.9 m
Foundation C/space
C 408 L/sPa^n
n 0.61
ELA 6,673 cm^2

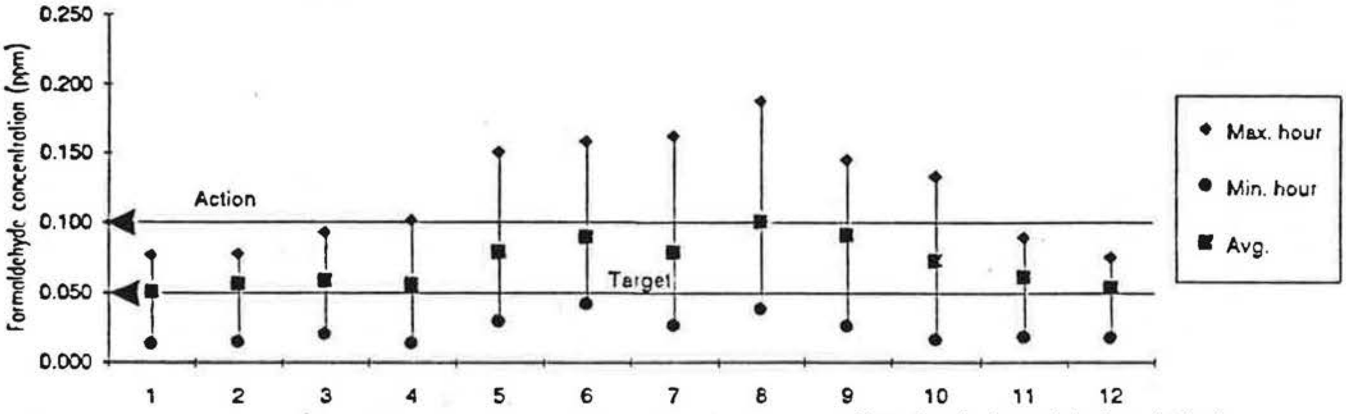
	No Flue		Flue
Run ID #	1030	and	1130
Infil. Coeff:			
R	0.40		0.38
X	0.10		0.09
Y	0.00		0.06
Shelter:			
Building	0.80		0.80
Flue	0.00		0.85

Pollutant Source Strengths:

Whole house source strengths based on: 4 houses

Max. formaldehyde source for max. monthly conc. < ACTION limit

	Formaldehyde	Benzene	Toluene	Xylene	Nonane (mL/hr)	Undecane	Limonene	A-pinene	Ethylbenzene	Source strengths:
Mat'ls	17.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	User Input
House	0.000	0.897	1.499	1.074	N/A	N/A	0.392	0.328	0.438	SRC avg. meas. (whole house)
Total	17.000	0.897	1.499	1.074	N/A	N/A	0.392	0.328	0.438	



Note: Graph shown is for formaldehyde, other pollutant curves will be the same shape.

Pollutant Health Limits (ppm)

	Formaldehyde	Benzene	Toluene	Xylene	Nonane	Undecane	Limonene	a-Pinene	Ethylbenzene	
Classes:	Aldehyde	Aromatic Hydrocarbons			Alkanes		Terpenes		Ether	
Limits:	0.05	0.008	0.007	0.006	0.010	0.008	0.003	0.002	0.002	Aldehyde limit is from EHD
ACGIH TLV	1.00	9	100	100	200	N/A	N/A	N/A	100	(Canada) for formaldehyde.
Predicted Pollutant Concentrations (ppm)										
Avg: Year	0.071	0.004	0.006	0.004	not avail.	not avail.	0.002	0.001	0.002	
Max: Oct-Apr	0.073	0.004	0.006	0.005	not avail.	not avail.	0.002	0.001	0.002	Highest monthly average for each period
May-Sep	0.101	0.005	0.009	0.006	not avail.	not avail.	0.002	0.002	0.003	
Max. hour	0.188	0.010	0.017	0.012	not avail.	not avail.	0.004	0.004	0.005	

Infiltration & Ventilation (ach) Month

	1	2	3	4	5	6	7	8	9	10	11	12
Max.	2.719	2.477	2.076	2.649	1.323	0.950	1.372	1.152	1.446	2.252	2.107	2.089
Min.	0.415	0.341	0.310	0.239	0.125	0.124	0.126	0.123	0.127	0.126	0.349	0.406
Avg.	0.756	0.656	0.635	0.700	0.481	0.414	0.516	0.385	0.427	0.556	0.619	0.689
Infiltration & Ventilation (L/s)												
Avg	101	88	85	94	64	55	69	51	57	74	83	92

Temperatures (C)

Outside	0.5	3.9	6.7	7.1	12.4	14.5	16.9	17.8	13.1	9.0	6.3	0.6
Inside	20.0	20.0	20.0	20.0	20.2	20.1	21.0	21.3	20.0	20.0	20.0	20.0

Winds (m/s)

AES Station	4.5	4.1	4.5	5.1	3.5	3.2	4.4	3.3	2.9	3.6	4.0	3.9
Building	2.9	2.6	2.8	3.2	2.3	2.1	2.8	2.1	1.9	2.3	2.5	2.5

54

Indoor Air Quality Profile

Description:

Region: BC
Age: 1946 to 1960
Percentile: 75
Ventilation Type: None
Ventilation Flow: 0 L/s

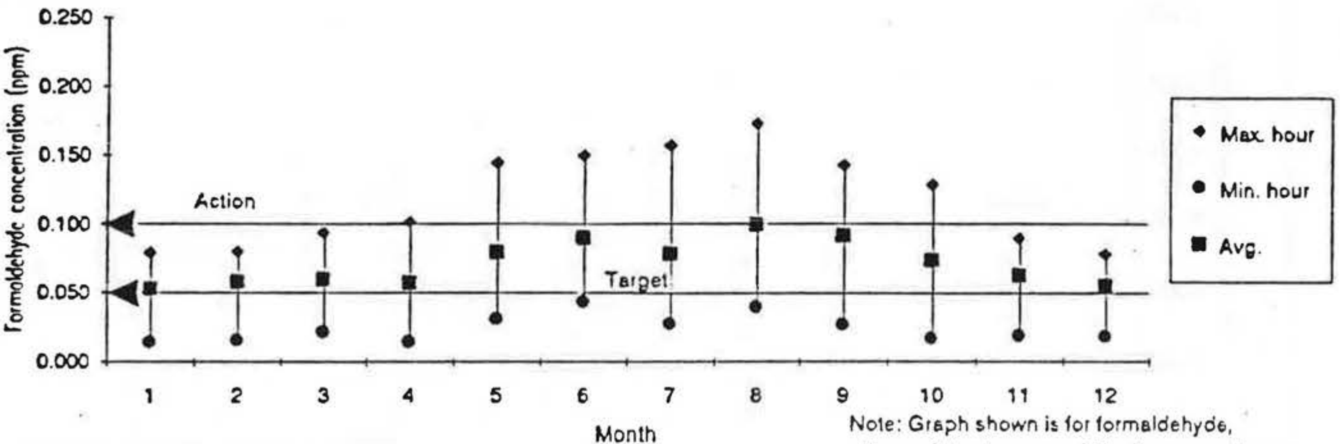
Volume 389 m^3
Bldg. Ht. 4.2 m
Flue Ht. 6.0 m
Foundation C/space
C 279 L/sPa^n
n 0.59
ELA 4,358 cm^2

	No Flue		Flue
Run ID #	1230	and	1330
Infil. Coeff:			
R	0.40		0.37
X	0.10		0.09
Y	0.00		0.09
Shelter:			
Building	0.80		0.80
Flue	0.00		0.85

Pollutant Source Strengths:

Whole house source strengths based on: 3 houses
Max. formaldehyde source for max. monthly conc. < ACTION limit

	Formaldehyde	Benzene	Toluene	Xylene	Nonane (mL/hr)	Undecane	Limonene	A-pinene	Ethylbenzene	Source strengths:
Mat'ls	11.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	User input
House	0.000	0.284	0.953	1.485	N/A	N/A	0.618 •	0.461	0.573	SRC avg. meas. (whole house
Total	11.000	0.284	0.953	1.485	N/A	N/A	0.618	0.461	0.573	



Note: Graph shown is for formaldehyde, other pollutant curves will be the same shape.

Pollutant Health Limits (ppm)

	Formaldehyde	Benzene	Toluene	Xylene	Nonane	Undecane	Limonene	a-Pinene	Ethylbenzene	
Classes:	Aldehyde	Aromatic Hydrocarbons			Alkanes		Terpenes		Ether.	
Limits:	0.05	0.008	0.007	0.006	0.010	0.008	0.003	0.002	0.002	Aldehyde limit is from EHD
ACGIH TLV	1.00	9	100	100	200	N/A	N/A	N/A	100	(Canada) for formaldehyde.
Predicted Pollutant Concentrations (ppm)										
Avg: Year	0.072	0.002	0.006	0.010	not avail.	not avail.	0.004	0.003	0.004	
Max: Oct-Apr	0.074	0.002	0.006	0.010	not avail.	not avail.	0.004	0.003	0.004	Highest monthly average for
May-Sep	0.100	0.003	0.009	0.014	not avail.	not avail.	0.006	0.004	0.005	each period
Max. hour	0.173	0.004	0.015	0.023	not avail.	not avail.	0.010	0.007	0.009	

Infiltration & Ventilation (ach) Month

	1	2	3	4	5	6	7	8	9	10	11	12
Max.	2.082	1.903	1.603	2.031	1.037	0.751	1.074	0.908	1.131	1.736	1.626	1.611
Min.	0.321	0.266	0.243	0.190	0.100	0.099	0.101	0.099	0.102	0.101	0.271	0.314
Avg.	0.586	0.511	0.498	0.549	0.380	0.330	0.411	0.309	0.338	0.436	0.484	0.534
Infiltration & Ventilation (L/s)												
Avg.	63	55	54	59	41	36	44	33	37	47	52	58

Temperatures (C)

Outside	0.5	3.9	6.7	7.1	12.4	14.5	16.9	17.8	13.1	9.0	6.3	0.6
Inside	20.0	20.0	20.0	20.0	20.2	20.1	21.0	21.3	20.0	20.0	20.0	20.0

Winds (m/s)

AES Station	4.5	4.1	4.5	5.1	3.5	3.2	4.4	3.3	2.9	3.6	4.0	3.9
Building	2.8	2.5	2.8	3.1	2.2	2.0	2.7	2.1	1.8	2.2	2.5	2.4

57

Indoor Air Quality Profile

Description:

Region: BC
Age: 1961 to 1980
Percentile: 75
Ventilation Type: None
Ventilation Flow: 0 L/s

Volume 362 m^3
Bldg. Ht. 4 m
Flue Ht. 5.7 m
Foundation C/space
C 204 L/sPa^n
n 0.65
ELA 3,658 cm^2

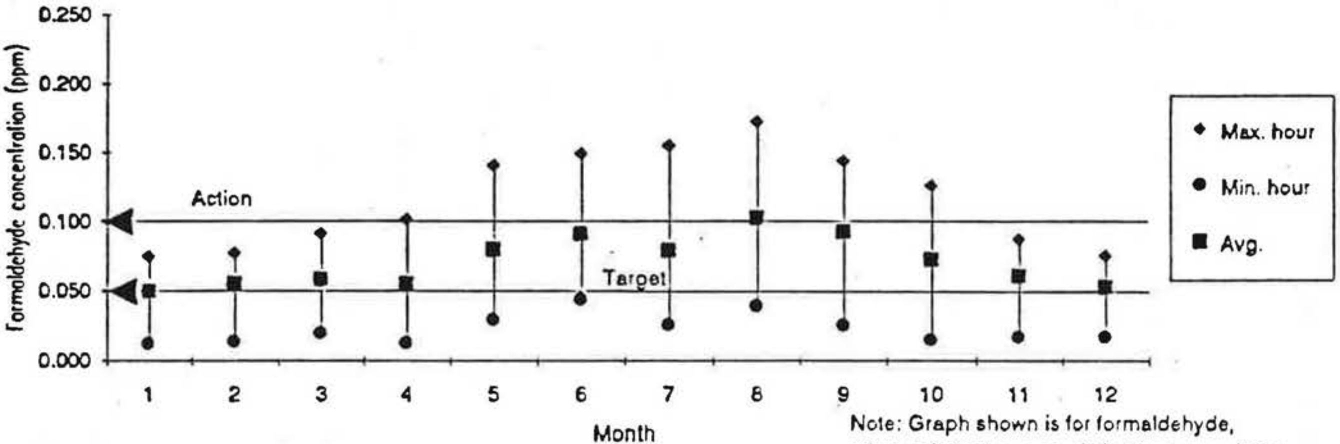
	No Flue		Flue
Run ID #	1430	and	1530
Infil. Coeff:			
R	0.50		0.45
X	0.00		0.00
Y	0.00		0.11
Shelter:			
Building	0.80		0.80
Flue	0.00		0.85

Pollutant Source Strengths:

Whole house source strengths based on: 8 houses

Max. formaldehyde source for max. monthly conc. < ACTION limit

	Formaldehyde	Benzene	Toluene	Xylene	Nonane (mL/hr)	Undecane	Limonene	A-pinene	Ethylbenzene	Source strengths:
Mat'ls	8.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	User Input
House	0.000	0.633	0.879	0.938	N/A	N/A	0.794	0.206	0.338	SRC avg. meas. (whole house)
Total	8.000	0.633	0.879	0.938	N/A	N/A	0.794	0.206	0.338	



Note: Graph shown is for formaldehyde, other pollutant curves will be the same shape.

Pollutant Health Limits (ppm)

	Formaldehyde	Benzene	Toluene	Xylene	Nonane	Undecane	Limonene	a-Pinene	Ethylbenzene	
Classes:	Aldehyde	Aromatic Hydrocarbons			Alkanes		Terpenes		Ether	
Limits:	0.05	0.008	0.007	0.006	0.010	0.008	0.003	0.002	0.002	Aldehyde limit is from EHD (Canada) for formaldehyde.
ACGIH TLV	1.00	9	100	100	200	N/A	N/A	N/A	100	
Predicted Pollutant Concentrations (ppm)										
Avg: Year	0.071	0.006	0.008	0.008	not avail.	not avail.	0.007	0.002	0.003	
Max: Oct-Apr	0.073	0.006	0.008	0.009	not avail.	not avail.	0.007	0.002	0.003	Highest monthly average for each period
May-Sep	0.103	0.008	0.011	0.012	not avail.	not avail.	0.010	0.003	0.004	
Max. hour	0.172	0.014	0.019	0.020	not avail.	not avail.	0.017	0.004	0.007	

Infiltration & Ventilation (ach) Month

	1	2	3	4	5	6	7	8	9	10	11	12
Max.	1.881	1.704	1.412	1.830	0.873	0.614	0.908	0.754	0.960	1.539	1.434	1.421
Min.	0.256	0.207	0.186	0.140	0.072	0.071	0.072	0.070	0.073	0.072	0.214	0.250
Avg.	0.486	0.417	0.402	0.447	0.298	0.254	0.322	0.235	0.264	0.350	0.392	0.439
Infiltration & Ventilation (L/s)												
Avg.	49	42	40	45	30	26	32	24	27	35	39	44

Temperatures (C)

Outside	0.5	3.9	6.7	7.1	12.4	14.5	16.9	17.8	13.1	9.0	6.3	0.6
Inside	20.0	20.0	20.0	20.0	20.2	20.1	21.0	21.3	20.0	20.0	20.0	20.0

Winds (m/s)

AES Station	4.5	4.1	4.5	5.1	3.5	3.2	4.4	3.3	2.9	3.6	4.0	3.9
Building	2.8	2.5	2.7	3.1	2.2	2.0	2.7	2.1	1.8	2.2	2.5	2.4

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Indoor Air Quality Profile

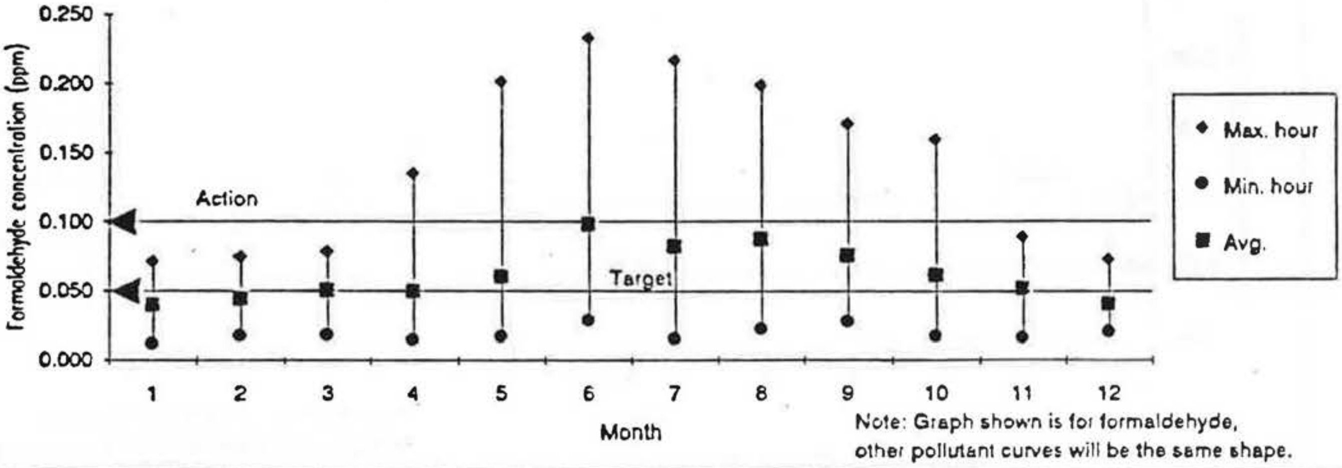
Description:

					No Flue		Flue
Region:	PRAI	Volume	315 m^3	Run ID #	3030	and	3130
Age:	pre 1946	Bldg. Ht.	4 m	Infil. Coeff:			
Percentile:	75	Flue Ht.	5.9 m	R	0.40		0.36
Ventilation Type:	None	Foundation	Bsmt	X	0.10		0.09
Ventilation Flow:	0 L/s	C	175 L/sPa^n	Y	0.00		0.12
		n	0.68	Shelter:			
		ELA	3,363 cm^2	Building	0.90		0.90
				Flue	0.00		0.95

Pollutant Source Strengths:

Whole house source strengths based on: 4 houses   Max. formaldehyde source for max. monthly conc. < ACTION limit

	Formaldehyde	Benzene	Toluene	Xylene	Nonane (mL/hr)	Undecane	Limonene	A-pinene	Ethylbenzene	Source strengths:
Mat'ls	9.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	User Input
House	0.000	0.897	1.499	1.074	N/A	N/A	0.392	0.328	0.438	SRC avg. meas. (whole house)
Total	9.000	0.897	1.499	1.074	N/A	N/A	0.392	0.328	0.438	



Note: Graph shown is for formaldehyde, other pollutant curves will be the same shape.

Pollutant Health Limits (ppm)

	Formaldehyde	Benzene	Toluene	Xylene	Nonane	Undecane	Limonene	a-Pinene	Ethylbenzene	
Classes:	Aldehyde	Aromatic Hydrocarbons			Alkanes		Terpenes		Ether	
Limits:	0.05	0.008	0.007	0.006	0.010	0.008	0.003	0.002	0.002	Aldehyde limit is from EHD
ACGIH TLV	1.00	9	100	100	200	N/A	N/A	N/A	100	(Canada) for formaldehyde.
Predicted Pollutant Concentrations (ppm)										
Avg: Year	0.062	0.006	0.010	0.007	not avail.	not avail.	0.003	0.002	0.003	
Max: Oct-Apr	0.062	0.006	0.010	0.007	not avail.	not avail.	0.003	0.002	0.003	Highest monthly average for
May-Sep	0.099	0.010	0.016	0.012	not avail.	not avail.	0.004	0.004	0.005	each period
Max. hour	0.233	0.023	0.039	0.028	not avail.	not avail.	0.010	0.009	0.011	

Infiltration & Ventilation (ach)   Month

	1	2	3	4	5	6	7	8	9	10	11	12
Max.	2.407	1.699	1.718	2.254	1.715	1.141	1.999	1.387	1.244	1.748	1.782	1.579
Min.	0.353	0.342	0.307	0.108	0.062	0.060	0.061	0.027	0.062	0.118	0.291	0.353
Avg.	0.762	0.675	0.601	0.698	0.560	0.357	0.423	0.388	0.435	0.560	0.649	0.742
Infiltration & Ventilation (L/s)												
Avg.	67	59	53	61	49	31	37	34	38	49	57	65

Temperatures (C)

Outside	-21.7	-19.0	-9.0	3.1	10.5	17.6	16.7	19.1	13.2	6.9	-5.0	-14.7
Inside	20.0	20.0	20.0	20.0	20.5	21.7	21.3	22.6	20.7	20.0	20.0	20.0

Winds (m/s)

AES Station	4.6	3.8	4.2	6.0	5.3	3.9	4.4	4.2	4.3	5.0	4.7	5.1
Building	3.2	2.6	2.9	4.1	3.6	2.7	3.0	2.9	3.0	3.4	3.3	3.5

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Indoor Air Quality Profile

Description:

Region: PRAI
Age: 1946 to 1960
Percentile: 75
Ventilation Type: None
Ventilation Flow: 0 L/s

Volume 291 m^3
Bldg. Ht. 4 m
Flue Ht. 5.8 m
Foundation Bsmt
C 102 L/sPa^n
n 0.69
ELA 2,006 cm^2

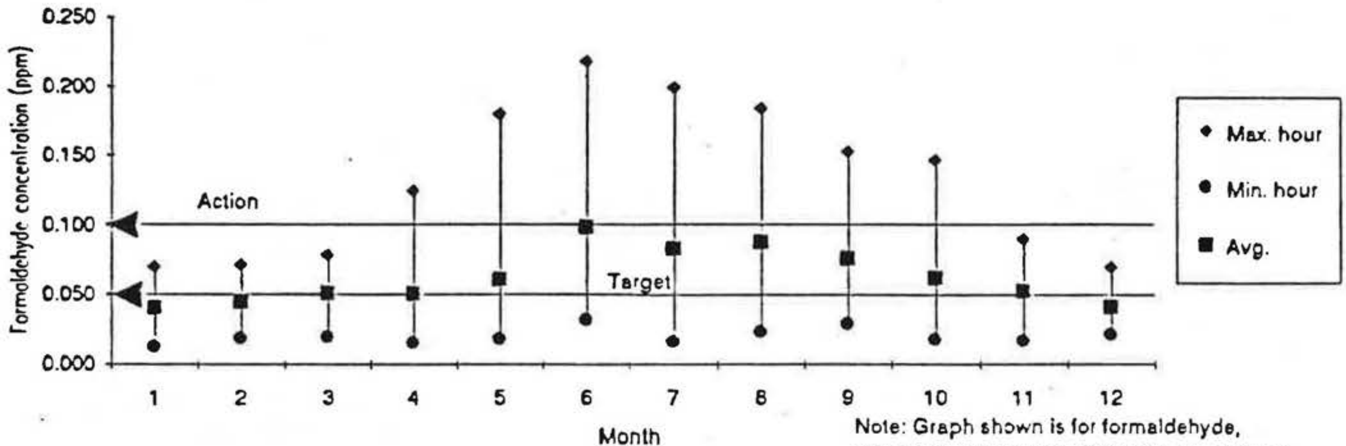
	No Flue		Flue
Run ID #	3230	and	3330
Infil. Coeff:			
R	0.40		0.33
X	0.10		0.08
Y	0.00		0.20
Shelter:			
Building	0.90		0.90
Flue	0.00		0.95

Pollutant Source Strengths:

Whole house source strengths based on: 3 houses

Max. formaldehyde source for max. monthly conc. < ACTION limit

	Formaldehyde	Benzene	Toluene	Xylene	Nonane (mL/hr)	Undecane	Limonene	A-pinene	Ethylbenzene	Source strengths:
Mat'ls	5.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	User input
House	0.000	0.284	0.953	1.485	N/A	N/A	0.618	0.461	0.573	SRC avg. meas. (whole house)
Total	5.500	0.284	0.953	1.485	N/A	N/A	0.618	0.461	0.573	



Note: Graph shown is for formaldehyde,
other pollutant curves will be the same shape.

Pollutant Health Limits (ppm)

	Formaldehyde	Benzene	Toluene	Xylene	Nonane	Undecane	Limonene	a-Pinene	Ethylbenzene	
Classes:	Aldehyde	Aromatic Hydrocarbons			Alkanes		Terpenes		Ether	
Limits:	0.05	0.008	0.007	0.006	0.010	0.008	0.003	0.002	0.002	Aldehyde limit is from EHD
ACGIH TLV	1.00	9	100	100	200	N/A	N/A	N/A	100	(Canada) for formaldehyde.
Predicted Pollutant Concentrations (ppm)										
Avg: Year	0.063	0.003	0.011	0.017	not avail.	not avail.	0.007	0.005	0.007	
Max: Oct-Apr	0.062	0.003	0.011	0.017	not avail.	not avail.	0.007	0.005	0.006	Highest monthly average for
May-Sep	0.099	0.005	0.017	0.027	not avail.	not avail.	0.011	0.008	0.010	each period
Max. hour	0.218	0.011	0.038	0.059	not avail.	not avail.	0.025	0.018	0.023	

Infiltration & Ventilation (ach) Month

	1	2	3	4	5	6	7	8	9	10	11	12
Max.	1.586	1.114	1.126	1.483	1.124	0.743	1.313	0.906	0.812	1.146	1.169	1.035
Min.	0.228	0.221	0.198	0.069	0.039	0.038	0.039	0.017	0.039	0.075	0.188	0.228
Avg.	0.497	0.440	0.391	0.453	0.362	0.229	0.272	0.250	0.281	0.363	0.422	0.483
Infiltration & Ventilation (L/s)												
Avg.	40	36	32	37	29	19	22	20	23	29	34	39

Temperatures (C)

Outside	-21.7	-19.0	-9.0	3.1	10.5	17.8	16.7	19.1	13.2	6.9	-5.0	-14.7
Inside	20.0	20.0	20.0	20.0	20.5	21.7	21.3	22.6	20.7	20.0	20.0	20.0

Winds (m/s)

AES Station	4.6	3.8	4.2	6.0	5.3	3.9	4.4	4.2	4.3	5.0	4.7	5.1
Building	3.3	2.7	3.0	4.2	3.7	2.7	3.1	3.0	3.0	3.5	3.3	3.6

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Indoor Air Quality Profile

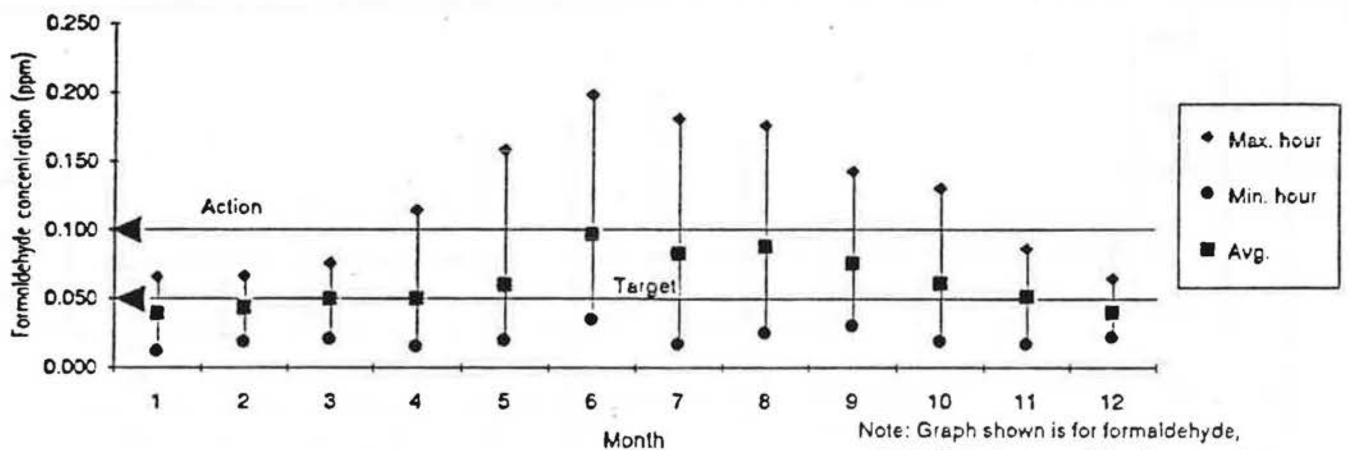
Description:					No Flue		Flue
Region:	PRAI	Volume	421 m^3	Run ID #	3430	and	3530
Age:	1961 to 1980	Bldg. Ht.	4.2 m	Infil. Coeff:			
Percentile:	75	Flue Ht.	5.9 m	R	0.50		0.41
Ventilation Type:	None	Foundation	Bsmt	X	0.00		0.00
Ventilation Flow:	0 L/s	C	97 L/sPa^n	Y	0.00		0.20
		n	0.7	Shelter:			
		ELA	1,952 cm^2	Building	0.90		0.90
				Flue	0.00		0.95

Pollutant Source Strengths:

Whole house source strengths based on: 8 houses

Max. formaldehyde source for max. monthly conc. < ACTION limit

	Formaldehyde	Benzene	Toluene	Xylene	Nonane (mL/hr)	Undecane	Limonene	A-pinene	Ethylbenzene	Source strengths:
Mat'ls	5.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	User input
House	0.000	0.633	0.879	0.938	N/A	N/A	0.794	0.206	0.338	SRC avg. meas. (whole house)
Total	5.500	0.633	0.879	0.938	N/A	N/A	0.794	0.206	0.338	



Note: Graph shown is for formaldehyde, other pollutant curves will be the same shape.

Pollutant Health Limits (ppm)

	Formaldehyde	Benzene	Toluene	Xylene	Nonane	Undecane	Limonene	a-Pinene	Ethylbenzene	
Classes:	Aldehyde	Aromatic Hydrocarbons			Alkanes		Terpenes		Ether	
Limits:	0.05	0.008	0.007	0.006	0.010	0.008	0.003	0.002	0.002	Aldehyde limit is from EHD
ACGIH TLV	1.00	9	100	100	200	N/A	N/A	N/A	100	(Canada) for formaldehyde.
Predicted Pollutant Concentrations (ppm)										
Avg: Year	0.062	0.007	0.010	0.011	not avail.	not avail.	0.009	0.002	0.004	
Max: Oct-Apr	0.061	0.007	0.010	0.010	not avail.	not avail.	0.009	0.002	0.004	Highest monthly average for
May-Sep	0.098	0.011	0.016	0.017	not avail.	not avail.	0.014	0.004	0.006	each period
Max. hour	0.199	0.023	0.032	0.034	not avail.	not avail.	0.029	0.007	0.012	

Infiltration & Ventilation (ach) Month

	1	2	3	4	5	6	7	8	9	10	11	12
Max.	1.098	0.769	0.775	1.023	0.771	0.506	0.903	0.619	0.554	0.789	0.805	0.715
Min.	0.162	0.157	0.140	0.048	0.027	0.027	0.027	0.011	0.027	0.053	0.134	0.163
Avg.	0.350	0.310	0.273	0.312	0.248	0.155	0.185	0.169	0.191	0.249	0.293	0.337
Infiltration & Ventilation (L/s)												
Avg.	41	36	32	36	29	18	22	20	22	29	34	39

Temperatures (C)

Outside	-21.7	-19.0	-9.0	3.1	10.5	17.8	16.7	19.1	13.2	6.9	-5.0	-14.7
Inside	20.0	20.0	20.0	20.0	20.5	21.7	21.3	22.6	20.7	20.0	20.0	20.0

Winds (m/s)

AES Station	4.6	3.8	4.2	6.0	5.3	3.9	4.4	4.2	4.3	5.0	4.7	5.1
Building	3.3	2.7	3.0	4.2	3.7	2.8	3.1	3.0	3.0	3.5	3.4	3.6

Indoor Air Quality Profile

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Description:

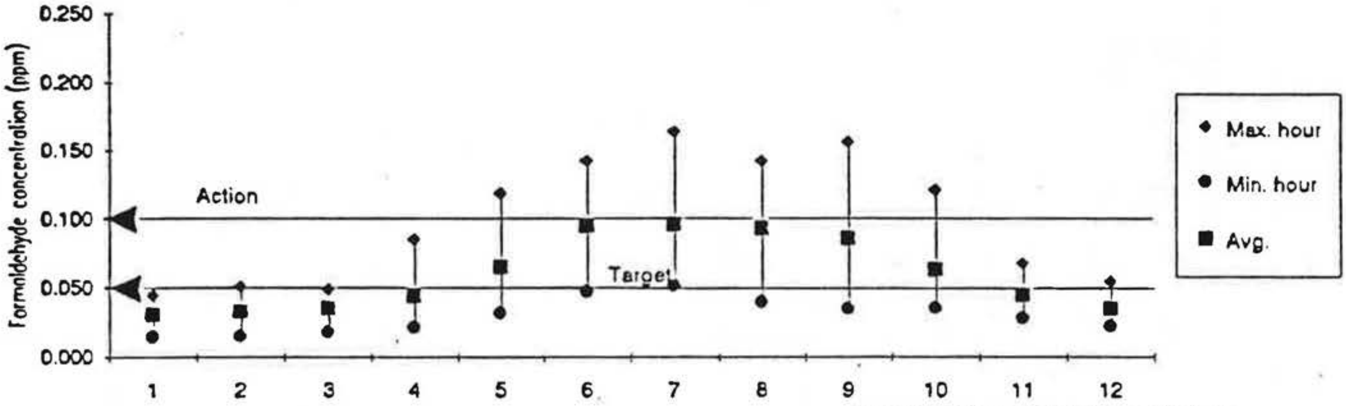
					No Flue	Flue
Region:	ONT	Volume	385 m^3	Run ID #	6030 and	6130
Age:	pre 1946	Bldg. Ht.	5.5 m	Infil. Coeff:		
Percentile:	75	Flue Ht.	7.4 m	R	0.40	0.36
Ventilation Type:	None	Foundation	Bsmt	X	0.10	0.09
Ventilation Flow:	0 L/s	C	193 L/sPa^n	Y	0.00	0.11
		n	0.67	Shelter:		
		ELA	3,624 cm^2	Building	0.80	0.80
				Flue	0.00	0.85

Pollutant Source Strengths:

Whole house source strengths based on: 4 houses

Max. formaldehyde source for max. monthly conc. < ACTION limit

	Formaldehyde	Benzene	Toluene	Xylene	Nonane (mL/hr)	Undecane	Limonene	A-pinene	Ethylbenzene	Source strengths:
Mat'ls	6.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	User Input
House	0.000	0.897	1.499	1.074	N/A	N/A	0.392	0.328	0.438	SRC avg. meas. (whole house)
Total	6.000	0.897	1.499	1.074	N/A	N/A	0.392	0.328	0.438	



Note: Graph shown is for formaldehyde, other pollutant curves will be the same shape.

Pollutant Health Limits (ppm)

	Formaldehyde	Benzene	Toluene	Xylene	Nonane	Undecane	Limonene	a-Pinene	Ethylbenzene	
Classes:	Aldehyde	Aromatic Hydrocarbons			Alkanes		Terpenes		Ether	Class limits are from Seifert
Limits:	0.05	0.008	0.007	0.006	0.010	0.005	0.003	0.002	0.002	Aldehyde limit is from EHD
ACGIH TLV	1.00	9	100	100	200	N/A	N/A	N/A	100	(Canada) for formaldehyde.
Predicted Pollutant Concentrations (ppm)										
Avg: Year	0.061	0.009	0.015	0.011	not avail.	not avail.	0.004	0.003	0.004	
Max: Oct-Apr	0.064	0.009	0.016	0.011	not avail.	not avail.	0.004	0.003	0.005	Highest monthly average for each period
May-Sep	0.097	0.014	0.024	0.017	not avail.	not avail.	0.006	0.005	0.007	
Max. hour	0.164	0.025	0.041	0.029	not avail.	not avail.	0.011	0.009	0.012	

Infiltration & Ventilation (ach)

	Month 1	2	3	4	5	6	7	8	9	10	11	12
Max.	1.127	1.054	0.892	0.876	0.607	0.540	0.412	0.531	0.599	0.529	0.649	0.805
Min.	0.320	0.280	0.287	0.112	0.070	0.066	0.069	0.069	0.069	0.075	0.190	0.262
Avg.	0.518	0.494	0.447	0.367	0.253	0.172	0.170	0.176	0.197	0.266	0.355	0.453
Infiltration & Ventilation (L/s)												
Avg.	55	53	48	39	27	18	18	19	21	28	38	48

Temperatures (C)

Outside	-8.8	-4.7	-3.0	4.2	12.0	18.2	19.4	19.0	15.6	9.6	4.6	-4.8
Inside	20.0	20.0	20.0	20.0	20.5	22.2	22.6	22.6	21.1	20.1	20.0	20.0

Winds (m/s)

AES Station	5.3	5.8	4.8	4.8	4.0	3.1	3.5	3.5	3.3	3.6	4.8	4.4
Building	2.1	2.3	1.9	1.9	1.6	1.3	1.5	1.5	1.4	1.5	1.9	1.8

Indoor Air Quality Profile

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Description:

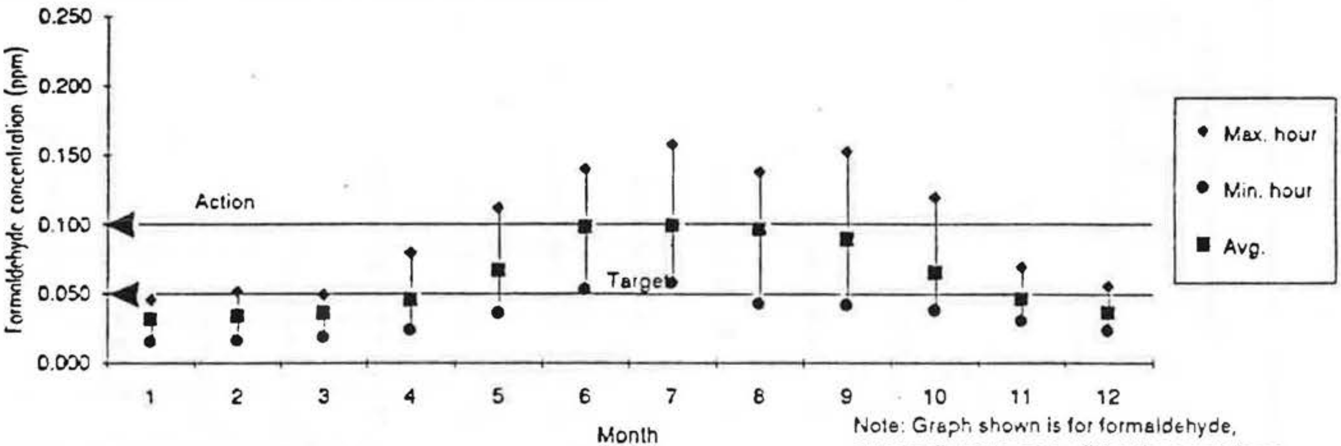
Region:	ONT	Volume	449 m^3		No Flue		Flue
Age:	1946 to 1960	Bldg. Ht.	5.5 m	Run ID #	6230	and	6330
Percentile:	75	Flue Ht.	7.3 m	Infil. Coeff:			
Ventilation Type:	None	Foundation	Bsmt	R	0.40		0.35
Ventilation Flow:	0 L/s	C	135 L/sPa^n	X	0.10		0.09
		n	0.68	Y	0.00		0.15
		ELA	2,594 cm^2	Shelter:			
				Building	0.80		0.80
				Flue	0.00		0.85

Pollutant Source Strengths:

Whole house source strengths based on: 3 houses

Max. formaldehyde source for max. monthly conc. < ACTION limit

	Formaldehyde	Benzene	Toluene	Xylene	Nonane (mL/hr)	Undecane	Limonene	A-pinene	Ethylbenzene	Source strengths:
Mat'ls	4.400	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	User input
House	0.000	0.284	0.953	1.485	N/A	N/A	0.618	0.461	0.573	SRC avg meas. (whole house
Total	4.400	0.284	0.953	1.485	N/A	N/A	0.618	0.461	0.573	



Note: Graph shown is for formaldehyde, other pollutant curves will be the same shape.

Pollutant Health Limits (ppm)

	Formaldehyde	Benzene	Toluene	Xylene	Nonane	Undecane	Limonene	a-Pinene	Ethylbenzene	
Classes:	Aldehyde	Aromatic Hydrocarbons			Alkanes		Terpenes		Ether	Class limits are from Seifert
Limits:	0.05	0.008	0.007	0.006	0.010	0.008	0.003	0.002	0.002	Aldehyde limit is from EHD
ACGIH TLV	1.00	9	100	100	200	N/A	N/A	N/A	100	(Canada) for formaldehyde.
Predicted Pollutant Concentrations (ppm)										
Avg: Year	0.063	0.004	0.014	0.021	not avail.	not avail.	0.009	0.007	0.008	
Max: Oct-Apr	0.066	0.004	0.014	0.022	not avail.	not avail.	0.009	0.007	0.009	Highest monthly average for
May-Sep	0.100	0.006	0.022	0.034	not avail.	not avail.	0.014	0.010	0.013	each period
Max. hour	0.158	0.010	0.034	0.053	not avail.	not avail.	0.022	0.017	0.021	

Infiltration & Ventilation (ach)

	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
Max.	0.696	0.650	0.549	0.539	0.371	0.330	0.251	0.324	0.366	0.323	0.398	0.495
Min.	0.194	0.170	0.174	0.067	0.041	0.039	0.041	0.041	0.041	0.044	0.114	0.159
Avg	0.317	0.302	0.273	0.223	0.153	0.103	0.102	0.106	0.119	0.161	0.216	0.276
Infiltration & Ventilation (L/s)												
Avg	40	38	34	28	19	13	13	13	15	20	27	34

Temperatures (C)

Outside	-8.8	-4.7	-3.0	4.2	12.0	18.2	19.4	19.0	15.6	9.6	4.6	-4.8
Inside	20.0	20.0	20.0	20.0	20.5	22.2	22.6	22.6	21.1	20.1	20.0	20.0

Winds (m/s)

AES Station	5.3	5.8	4.8	4.8	4.0	3.1	3.5	3.5	3.3	3.6	4.8	4.4
Building	2.1	2.3	1.9	1.9	1.7	1.3	1.5	1.5	1.4	1.5	1.9	1.8

Indoor Air Quality Profile

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Description:

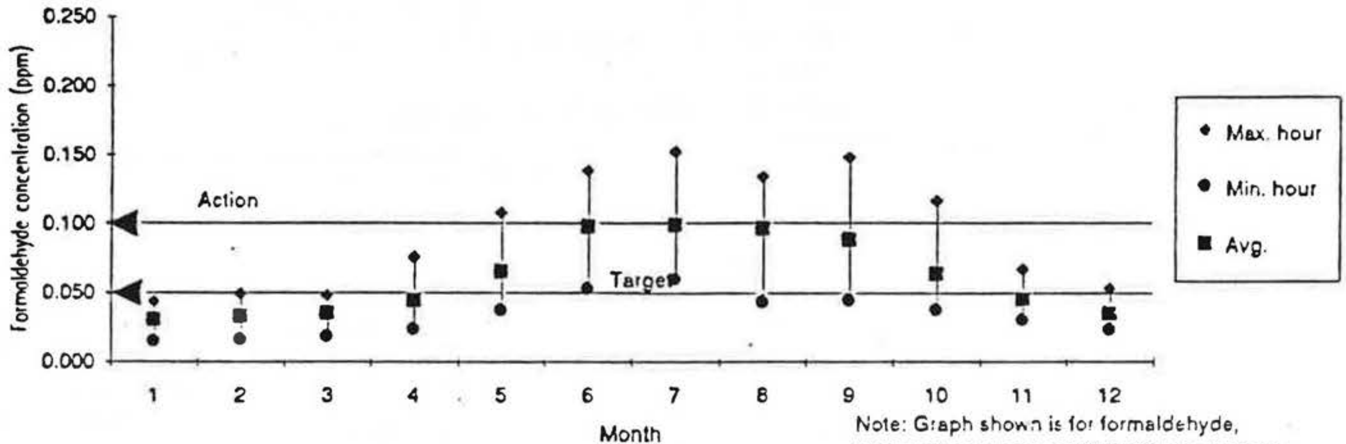
Region:	ONT		Volume	462 m^3			No Flue	Flue
Age:	1961 to 1980		Bldg. Ht.	5.5 m		Run ID #	6430 and	6530
Percentile:	75		Flue Ht.	7.2 m		Infil. Coeff:		
Ventilation Type:	None		Foundation	Bsmt		R	0.50	0.42
Ventilation Flow:	0	L/s	C	114 L/sPa^n		X	0.00	0.00
			n	0.69		Y	0.00	0.18
			ELA	2,242 cm^2		Shelter:		
						Building	0.80	0.80
						Flue	0.00	0.85

Pollutant Source Strengths:

Whole house source strengths based on: 8 houses

Max. formaldehyde source for max. monthly conc. < ACTION limit

	Formaldehyde	Benzene	Toluene	Xylene	Nonane (mL/hr)	Undecane	Limonene	A-pinene	Ethylbenzene	Source strengths:
Mat'ls	3.800	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	User input
House	0.000	0.633	0.879	0.938	N/A	N/A	0.794	0.206	0.338	SRC avg. meas. (whole house)
Total	3.800	0.633	0.879	0.938	N/A	N/A	0.794	0.206	0.338	



Note: Graph shown is for formaldehyde, other pollutant curves will be the same shape.

Pollutant Health Limits (ppm)

	Formaldehyde	Benzene	Toluene	Xylene	Nonane	Undecane	Limonene	a-Pinene	Ethylbenzene	
Classes:	Aldehyde	Aromatic Hydrocarbons			Alkanes		Terpenes		Ether	Class limits are from Seifert
Limits:	0.05	0.008	0.007	0.006	0.010	0.008	0.003	0.002	0.002	Aldehyde limit is from EHD
ACGIH TLV	1.00	9	100	100	200	N/A	N/A	N/A	100	(Canada) for formaldehyde.
Predicted Pollutant Concentrations (ppm)										
Avg: Year	0.062	0.010	0.014	0.015	not avail.	not avail.	0.013	0.003	0.005	
Max: Oct-Apr	0.064	0.011	0.015	0.016	not avail.	not avail.	0.013	0.003	0.006	Highest monthly average for
May-Sep	0.099	0.017	0.023	0.025	not avail.	not avail.	0.021	0.005	0.009	each period
Max. hour	0.152	0.025	0.035	0.038	not avail.	not avail.	0.032	0.008	0.014	

Infiltration & Ventilation (ach) Month

	1	2	3	4	5	6	7	8	9	10	11	12
Max.	0.597	0.557	0.470	0.457	0.312	0.276	0.210	0.273	0.307	0.275	0.338	0.422
Min.	0.167	0.148	0.148	0.057	0.035	0.033	0.035	0.035	0.035	0.038	0.099	0.137
Avg.	0.275	0.261	0.236	0.192	0.130	0.087	0.086	0.089	0.101	0.138	0.186	0.240
Infiltration & Ventilation (L/s)												
Avg	35	33	30	25	17	11	11	11	13	18	24	31

Temperatures (C)

Outside	-8.8	-4.7	-3.0	4.2	12.0	18.2	19.4	19.0	15.6	9.6	4.6	-4.8
Inside	20.0	20.0	20.0	20.0	20.5	22.2	22.6	22.6	21.1	20.1	20.0	20.0

Winds (m/s)

AES Station	5.3	5.8	4.8	4.8	4.0	3.1	3.5	3.5	3.3	3.6	4.8	4.4
Building	2.1	2.3	2.0	1.9	1.7	1.4	1.5	1.5	1.4	1.5	1.9	1.8

10.4.2 Hourly results

Hourly results were output for selected critical months for each region. July was assumed critical for Ontario to account for air-conditioned houses. April in the Prairies and March in the Pacific regions are critical 'shoulder season' months (corresponding months in the fall would also be critical), assuming that the houses are open during the summer. If the houses were closed during the summer for cooling or security reasons, then July or August would be critical months (see monthly profiles in section 10.4.1). The hourly results of the following runs are presented here:

Note that this is not a thermal simulation model so actual inside temperatures are not calculated. The results due to fan control by inside to outside temperature difference[27] therefore show an **indication of the potential** of this type of control, rather than its absolute potential.

Table 10.5 List of Hourly Outputs

	Region	Age	%tile	Month	Ventilation	Remarks
Critical Months:						
	Ontario	1981-90	75	July	none compared to 25L/s balanced fan with dT control	Average of surveyed levels of HCHO
	Prairies	1981-90	75	April	none compared to 25L/s balanced fan with dT control	Average of surveyed levels of HCHO
	Pacific	1981-90	75	March	none compared to 25L/s balanced fan with dT control	Average of surveyed levels of HCHO for Pacific

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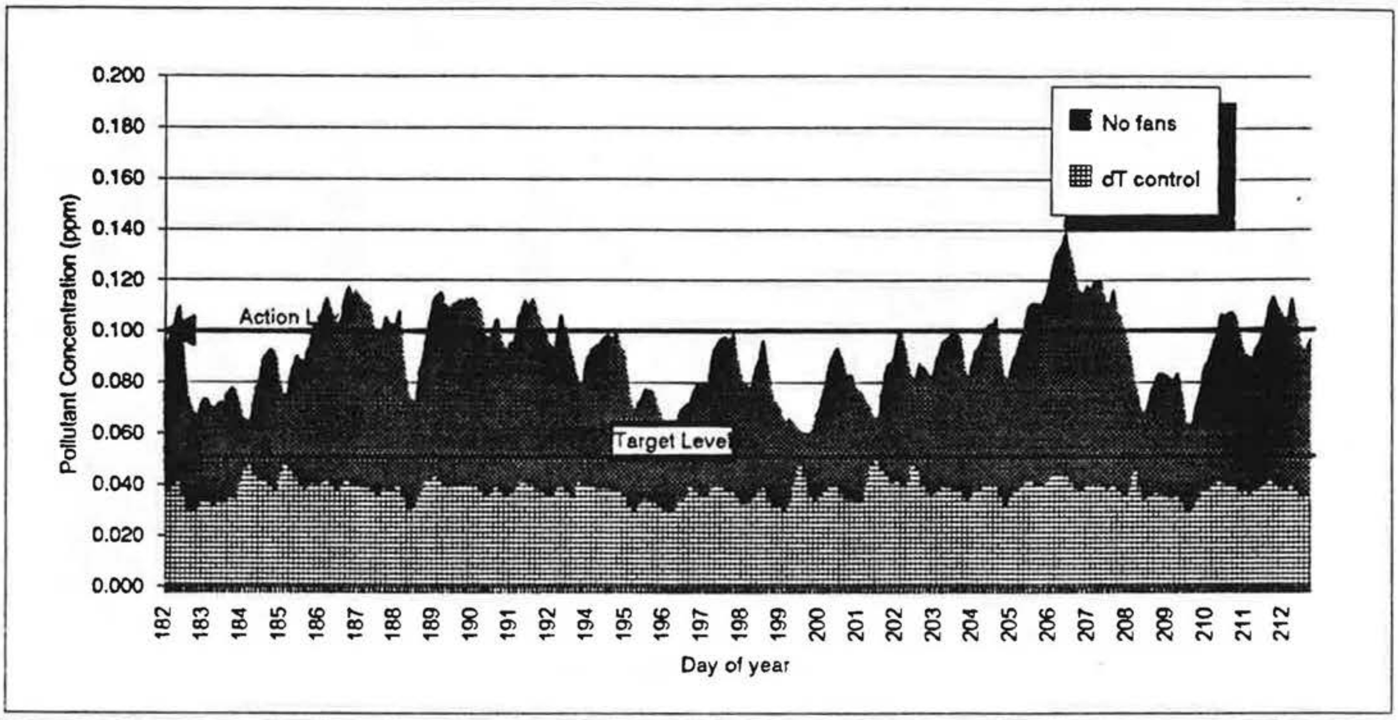
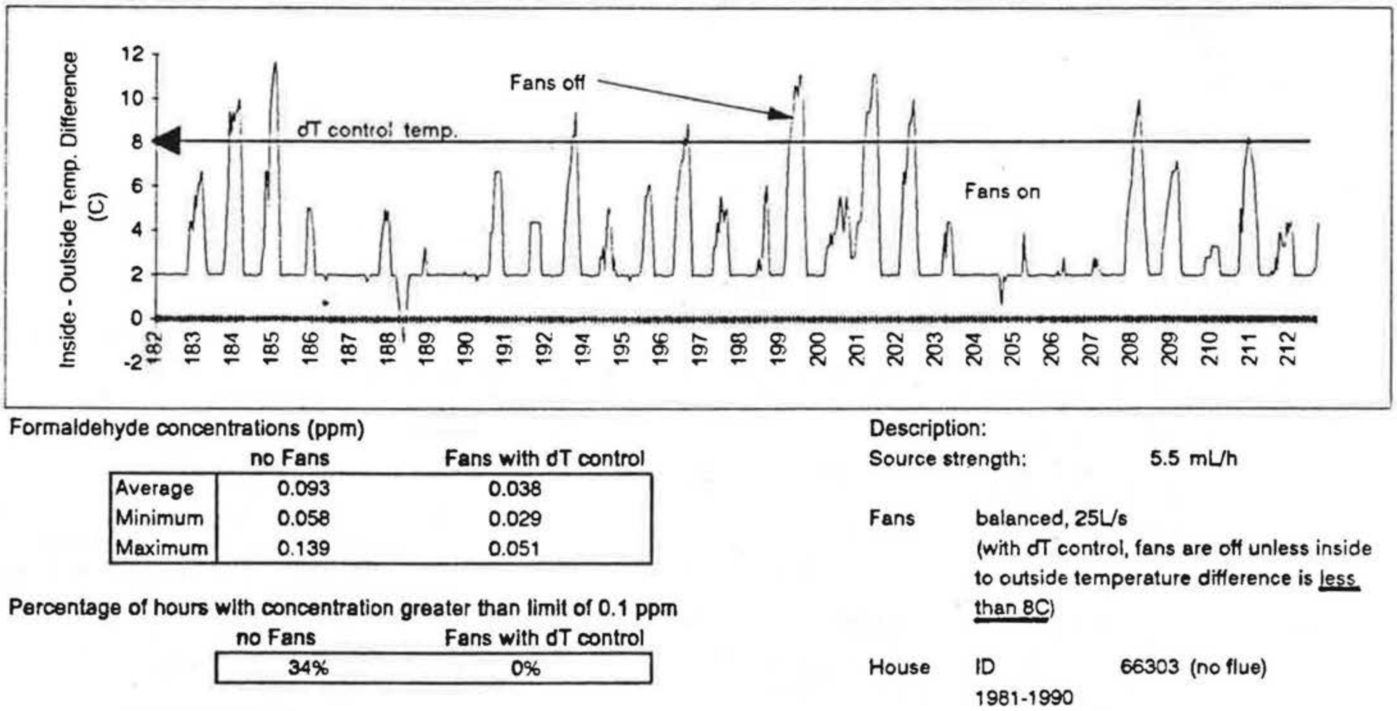
[27] dT fan control: fans on if inside to outside temperature difference less than a specified amount, otherwise fans off.

Toronto, Ontario

July





Formaldehyde concentrations (ppm)

	no Fans	Fans with dT control
Average	0.093	0.038
Minimum	0.058	0.029
Maximum	0.139	0.051

Percentage of hours with concentration greater than limit of 0.1 ppm

no Fans	Fans with dT control
34%	0%

Total infiltration and ventilation

	no Fans		Fans with dT control	
	(ach)	(L/s)	(ach)	(L/s)
Average	0.08	17	0.20	40
Minimum	0.04	7	0.10	21
Maximum	0.20	40	0.32	65

Fan operation:	0 hours	696 hours

Description:

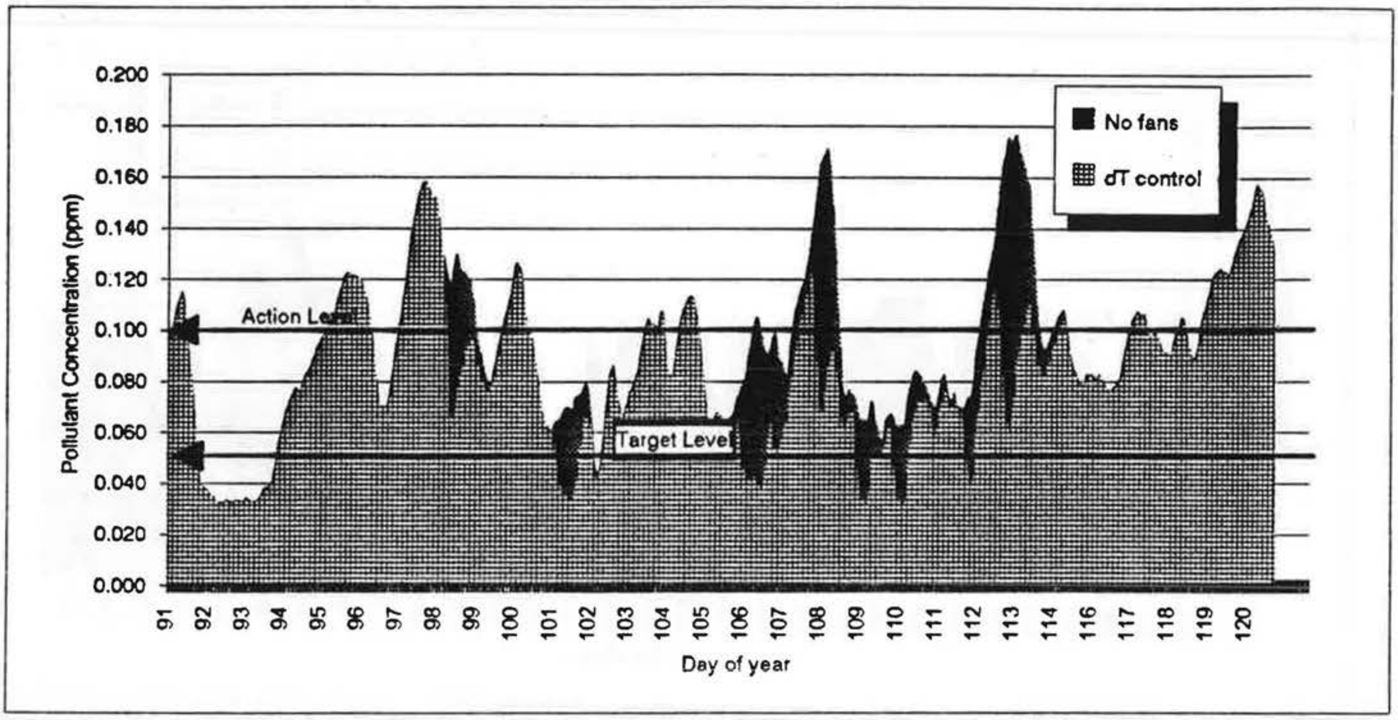
Source strength: 5.5 mL/h

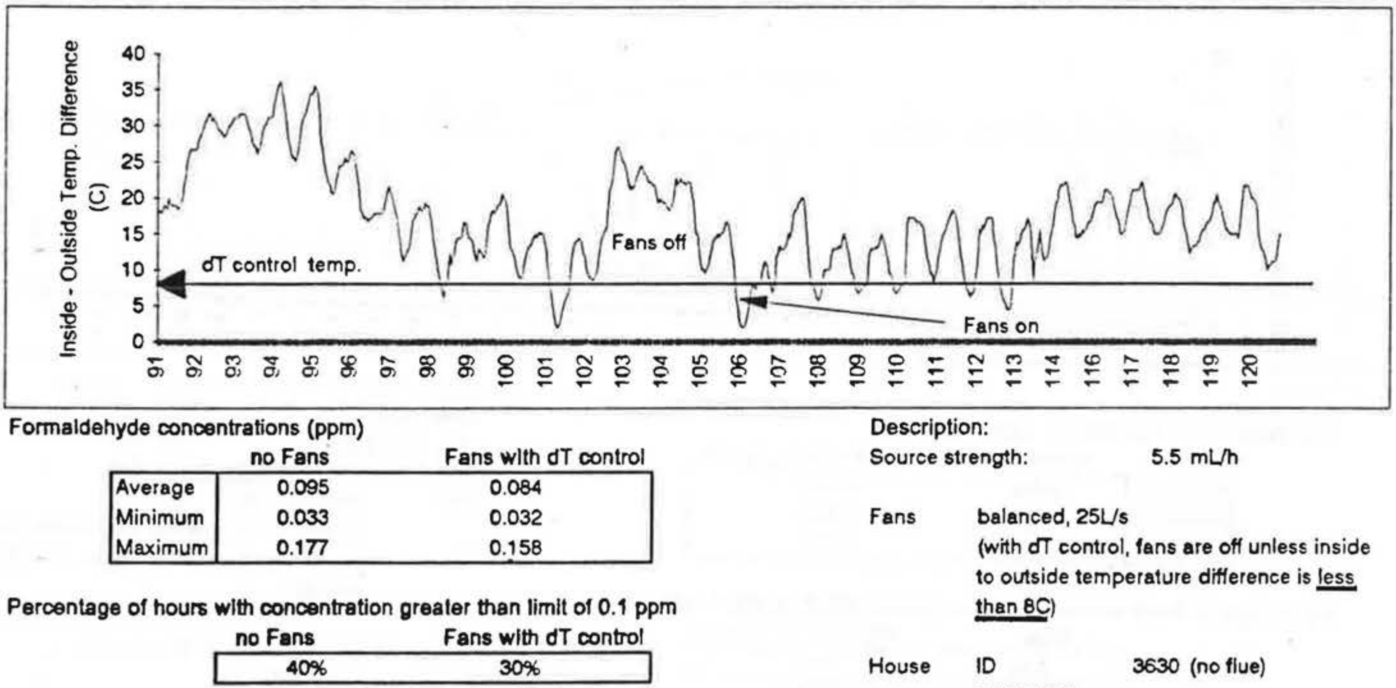
Fans balanced, 25L/s
(with dT control, fans are off unless inside to outside temperature difference is less than 8C)

House	ID	66303 (no flue)
	1981-1990	
	75th percentile	
	Volume	725 m^3
	C	169 L/sPa^n
	n	0.69
	ELA	3,323 cm^2
	Basement foundation	

Prairies

April





Formaldehyde concentrations (ppm)

	no Fans	Fans with dT control
Average	0.095	0.084
Minimum	0.033	0.032
Maximum	0.177	0.158

Percentage of hours with concentration greater than limit of 0.1 ppm

no Fans	Fans with dT control
40%	30%

Total infiltration and ventilation

	no Fans		Fans with dT control	
	(ach)	(L/s)	(ach)	(L/s)
Average	0.13	18	0.15	21
Minimum	0.02	3	0.04	5
Maximum	0.44	60	0.44	60

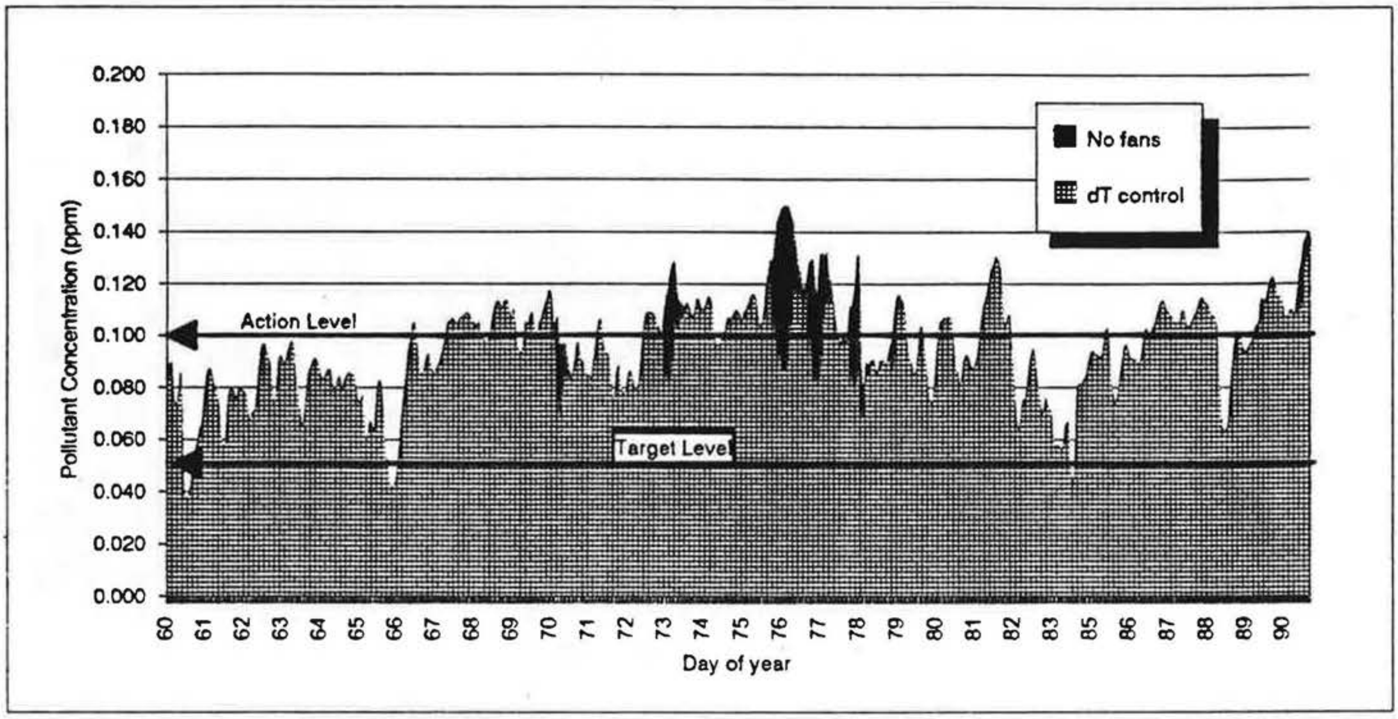
Fan operation:	0 hours	78 hours

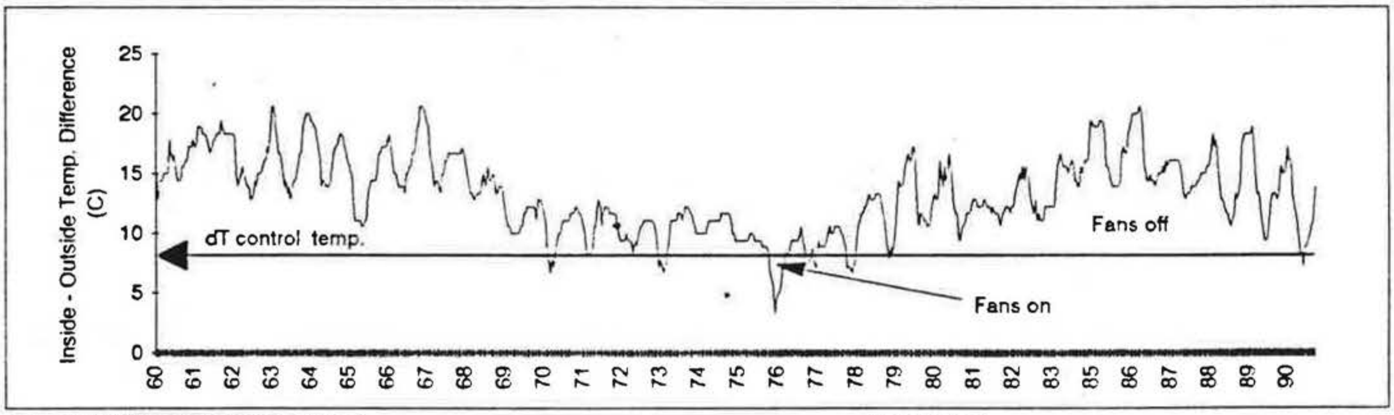
Description:

Source strength:		5.5 mL/h	
Fans	balanced, 25L/s (with dT control, fans are off unless inside to outside temperature difference is <u>less than 8C</u>)		
House	ID	3630 (no flue)	
	1981-1990		
	75th percentile		
	Volume	494 m^3	
	C	50 L/sPa^n	
	n	0.71	
	ELA	1,030 cm^2	
	Basement foundation		

Vancouver, BC

March





Formaldehyde concentrations (ppm)

	no Fans	Fans with dT control
Average	0.096	0.093
Minimum	0.038	0.038
Maximum	0.150	0.136

Percentage of hours with concentration greater than limit of 0.1 ppm

no Fans	Fans with dT control
45%	40%

Total Infiltration and ventilation

	no Fans		Fans with dT control	
	(ach)	(L/s)	(ach)	(L/s)
Average	0.35	52	0.36	53
Minimum	0.16	24	0.19	29
Maximum	1.12	168	1.12	168

Fan operation:	0 hours	34 hours

Description:

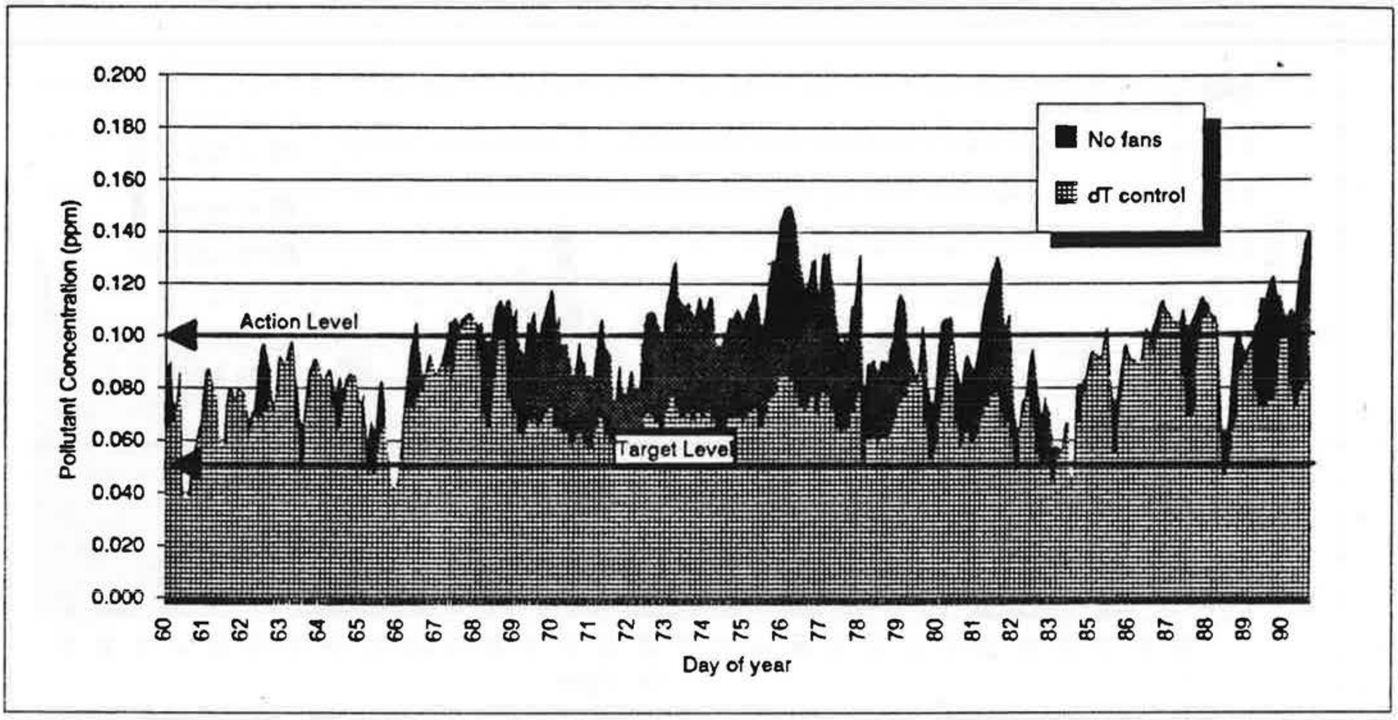
Source strength: 17.1 mL/h

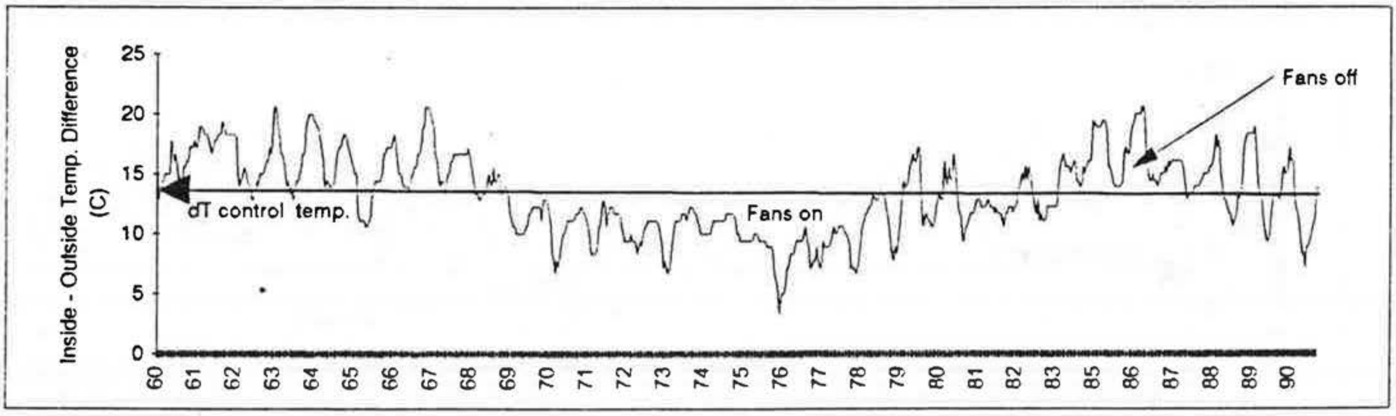
Fans balanced, 25L/s
(with dT control, fans are off unless inside to outside temperature difference is less than 8C)

House	ID	1630 (no flue)
	1981-1990	
	75th percentile	
	Volume	539 m^3
	C	248 L/sPa^n
	n	0.66
	ELA	4,551 cm^2
	Crawlspace foundation	

Vancouver, BC

March





Formaldehyde concentrations (ppm)

	no Fans	Fans with dT control
Average	0.096	0.074
Minimum	0.038	0.038
Maximum	0.150	0.111

Percentage of hours with concentration greater than limit of 0.1 ppm

no Fans	Fans with dT control
45%	6%

Total infiltration and ventilation

	no Fans		Fans with dT control	
	(ach)	(L/s)	(ach)	(L/s)
Average	0.35	52	0.45	67
Minimum	0.16	24	0.26	39
Maximum	1.12	168	1.12	168

Fan operation:	0 hours	443 hours

Description:

Source strength:		17.1 mL/h
Fans	balanced, 25L/s (with dT control, fans are off unless inside to outside temperature difference is <u>less than 14C</u>)	
House	ID	1630 (no flue)
	1981-1990	
	75th percentile	
	Volume	539 m^3
	C	248 L/sPa^n
	n	0.66
	ELA	4,551 cm^2
	Crawlspace foundation	

11 APPENDIX: B.C. AIR-TIGHTNESS TESTS

11.1 Background

The CMHC Indoor Air Quality research project required typical house air-tightness data for a range of house types and regions across Canada. Data was obtained from Scanada for Quebec, Ontario and prairie regions but was largely unavailable for both Maritime regions. It was outside the budgetary scope of the study to obtain a statistically significant data set for the Atlantic Maritime region, however it was possible to obtain data for the warmest extreme of the Pacific Maritime region - the lower mainland of B.C..

11.2 Results

The air-tightness tests were carried out by Peter Moffatt Consulting according to CGSB standards. The tests were performed in December, 1991 and early January, 1992 on a variety of houses throughout the lower mainland of B.C..

Due to budget constraints, only 36 houses could be tested. These were divided, as much as possible, according to the age divisions used by Scanada in setting up the CMHC database of houses across Canada (Table 11.1).

Table 11.1 Housing Age Categories

CMHC Database	B.C. 1992 Air-tightness Survey	Previous Studies
Pre 1920	no data	
1920 - 1945	1920 - 1945	
1946 - 1960	1946 - 1960	
1961 - 1970	1961 - 1980	
1971 - 1980	(included in above)	
1981 - 1989		1989 cross-Canada study

The data from the 1989 study of 200 new merchant houses was used to represent new housing in the simulations.

A summary of the results of this air-tightness survey of older B.C. housing stock is presented in Table 11.2, listed according to original construction date.

Table 11.2 Summary of Air-tightness Survey of B.C. Hous

No.	City	Prov.	Age	Heating Fuel	Foundatio Type	Floor Area (m ^ 2)	Volume (m ^ 3)	Envelop Area (m ^ 2)
BC9201	Vancouver	B.C.	1920	gas	bsmt.	193	449	416
BC9202	Vancouver	B.C.	1925	gas	bsmt.	457	1,154	680
BC9203	Vancouver	B.C.	1929	gas	bsmt.	334	781	569
BC9204	New West.	B.C.	1930	gas	bsmt.	183	414	475
BC9205	Deep Cove	B.C.	1930	gas	part. basm	235	481	460
BC9206	Vancouver	B.C.	1930	gas/elec	bsmt.	223	498	424
BC9207	Vancouver	B.C.	1931	gas	bsmt.	239	629	440
BC9208	Vancouver	B.C.	1932	gas	bsmt.	303	797	520
BC9209	Vancouver	B.C.	1936	gas	bsmt.	281	600	453
BC9210	N. Van	B.C.	1939	gas	bsmt.	347	844	581
BC9211	Vancouver	B.C.	1940	gas	bsmt.	262	607	444
BC9212	Vancouver	B.C.	1940	gas	bsmt.	219	547	534
BC9213	Vancouver	B.C.	1942	gas	bsmt.	174	426	359
BC9214	Vancouver	B.C.	1946	gas	bsmt.	216	540	472
BC9215	N. Van.	B.C.	1947	gas	c/space	79	185	245
BC9216	Vancouver	B.C.	1948	gas	bsmt.	166	389	366
BC9217	W. Van.	B.C.	1948	gas	bsmt.	367	745	520
BC9218	Vancouver	B.C.	1949	gas	bsmt.	233	539	404
BC9219	N. Van.	B.C.	1950	gas	bsmt.	217	504	457
BC9220	Coquitlam	B.C.	1950	gas	bsmt.	215	495	433
BC9221	Vancouver	B.C.	1952	gas	bsmt.	198	455	382
BC9222	Vancouver	B.C.	1953	gas	bsmt.	161	408	352
BC9223	N. Van.	B.C.	1953	gas	slab-c/s	217	509	426
BC9224	Vancouver	B.C.	1955	gas	bsmt.	148	384	329
BC9225	N. Van.	B.C.	1960	gas	bsmt.	202	472	417
BC9226	Coquitlam	B.C.	1962	gas	slab-c/s	267	459	465
BC9227	Langley	B.C.	1962	electric	c/space	280	614	810
BC9228	N. Van.	B.C.	1964	gas	bsmt.	251	614	528
BC9229	Coquitlam	B.C.	1965	gas	bsmt.	228	536	456
BC9230	Surrey	B.C.	1970	electric	slab	135	327	395
BC9231	Pitt Meado	B.C.	1972	gas	c/space	424	768	648
BC9232	Surrey	B.C.	1974	electric	slab	172	362	454
BC9233	Richmond	B.C.	1975	gas	slab	164	308	360
BC9234	Maple Rid	B.C.	1975	gas	bsmt-c/s	325	945	465
BC9235	Gibsons	B.C.	1978	electric	slab	202	451	480
BC9236	Surrey	B.C.	1978	gas	slab-c/s	245	490	479

r-tightness Survey of B.C. Housing

Foundatio Type	Floor Area (m^2)	Volume (m^3)	Envelope Area (m^2)	ACPH (@ 50 Pa)	ELA cm^2	NLA cm2/m2	C L/s^Pa)	n	r^2	Relative Std.Error (%)	Storeys	Ceiling height (m)	Flue height (m)	Bath Fans	Wood Appl.
bsmt.	193	449	416	14.2	2,653	6.38	152	0.634	0.9980	0.10%	1	3.9	5.2	0	1
bsmt.	457	1,154	680	8.3	4,035	7.45	238	0.620	0.9990	0.79%	1.5	6.1	7.0	2	2
bsmt.	334	781	569	7.3	2,591	4.55	166	0.582	0.9991	0.56%	2	6.1	7.1	1	1
bsmt.	183	414	475	17.5	3,021	6.35	176	0.627	0.9994	0.47%	1	6.1	9.1	1	1
part. basm	235	481	460	19.5	4,040	8.78	250	0.603	0.9991	0.72%	1	3.7	7.0	2	2
bsmt.	223	498	424	8.5	1,845	4.35	113	0.602	0.9990	0.61%	2	6.8	7.4	2	2
bsmt.	239	629	440	7.8	1,891	4.29	100	0.672	0.9917	1.89%	1.5	6.0	8.0	1	1
bsmt.	303	797	520	10.9	3,772	7.75	235	0.599	0.9959	1.59%	2	6.4	7.7	3	2
bsmt.	281	600	453	9.3	2,513	5.54	160	0.585	0.9985	0.71%	1.5	7.3	10.0	2	1
bsmt.	347	844	581	10.0	3,481	5.99	195	0.639	0.9991	0.63%	1.5	5.9	10.0	2	4
bsmt.	262	607	444	10.8	3,238	7.28	244	0.517	0.9902	5.59%	1.5	6.0	6.0	2	2
bsmt.	219	547	534	7.6	1,827	3.42	113	0.597	0.9943	1.42%	1.5	7.9	10.0	2	1
bsmt.	174	426	359	8.1	1,304	3.63	67	0.683	0.9992	0.61%	1	3.2	6.0	0	1
bsmt.	216	540	472	10.5	2,500	6.58	157	0.594	0.9993	0.49%	1.5	6.0	7.5	3	1
c/space	79	185	245	27.6	2,266	9.25	142	0.591	0.9994	0.47%	1	2.3	4.5	1	1
bsmt.	166	389	366	14.3	2,513	6.87	162	0.581	0.9995	0.43%	1	5.0	7.0	3	1
bsmt.	367	745	520	15.3	5,322	10.22	361	0.559	0.9992	0.43%	1	6.7	7.9	3	2
bsmt.	233	539	404	14.9	3,669	9.09	246	0.568	0.9987	0.63%	1.5	6.2	7.7	3	1
bsmt.	217	504	457	12.8	2,878	6.27	198	0.552	0.9979	0.79%	1	3.0	6.0	1	1
bsmt.	215	495	433	7.4	1,456	3.36	77	0.664	0.9957	1.38%	1	3.2	6.4	2	2
bsmt.	198	455	382	10.7	2,425	6.35	180	0.519	0.9960	1.05%	1	3.9	5.0	2	1
bsmt.	161	408	352	9.9	1,862	5.29	126	0.562	0.9982	0.75%	1	4.1	5.5	1	1
slab-c/s	217	509	426	9.2	2,127	4.99	140	0.572	0.9967	1.03%	2	5.0	7.0	4	1
bsmt.	148	384	329	8.0	1,148	3.49	58	0.688	0.9932	1.77%	1	4.2	5.5	3	1
bsmt.	202	472	417	5.6	1,029	2.46	54	0.671	0.9975	1.05%	1	4.4	6.0	4	1
slab-c/s	267	459	465	11.8	2,683	5.77	201	0.520	0.9909	0.54%	2	5.0	8.0	2	2
c/space	280	614	810	11.2	2,729	4.44	153	0.651	0.9966	1.37%	2	4.9	5.5	1	1
bsmt.	251	614	528	12.1	2,837	5.36	144	0.686	0.9971	1.15%	1	4.1	5.5	3	3
bsmt.	228	536	456	7.5	1,742	3.82	107	0.604	0.9983	0.77%	1	5.0	7.0	1	2
slab	135	327	395	12.6	1,742	4.40	103	0.619	0.9999	0.23%	1	2.4	4.0	1	2
c/space	424	768	648	10.8	3,799	5.86	246	0.578	0.9995	0.47%	1.5	6.7	7.1	3	1
slab	172	362	454	5.8	780	1.72	41	0.686	0.9979	0.98%	1	2.4	2.8	3	1
slab	164	308	360	11.3	1,215	3.37	53	0.750	0.9971	1.24%	1.5	5.1	6.6	4	1
bsmt-c/s	325	945	465	9.0	3,561	7.66	205	0.631	0.9989	0.74%	1	5.1	7.1	5	2
slab	202	451	480	7.3	1,170	2.44	57	0.710	0.9996	2.52%	2	4.5	7.5	3	2
slab-c/s	245	490	479	8.4	1,612	3.36	86	0.663	0.9997	0.36%	1.5	5.1	7.0	3	1

11.3 Air-tightness Testing Analysis

The analysis of the air-tightness test results that follows should be viewed with the following cautions:

- The houses were selected to be as representative as possible and to cover the range of ages, sizes and fuel types, however houses could only be tested if they were made available by their owners, so not all categories are necessarily present in the numbers desired.
- Time and budget were limited, so no attempt was made to check the statistical validity of the sample.
- The sample size is relatively small (11 to 13 houses per age category).

Figure 11.1 and Table 11.3 summarize the results according to Normalized Leakage Area (NLA), in cm^2 of leakage area per m^2 of total surface envelope[28]. There is a fairly consistent improvement from the older to newer houses, though the 1946-60 age group appears to have loosened slightly with respect to the pre 1946 houses. Post 1945, houses have steadily increased in size.

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[28] The results from the 1990 new merchant home survey are included for comparison. The results from the 1981 new home survey are not included since envelope areas in that study did include below grade areas and therefore NLAs are not comparable. Air flow data from the 1981 study will still be useful in the IAQ portion of the study, however.

Fig. 11.1 BC Air-Tightness Summary - NLA by age

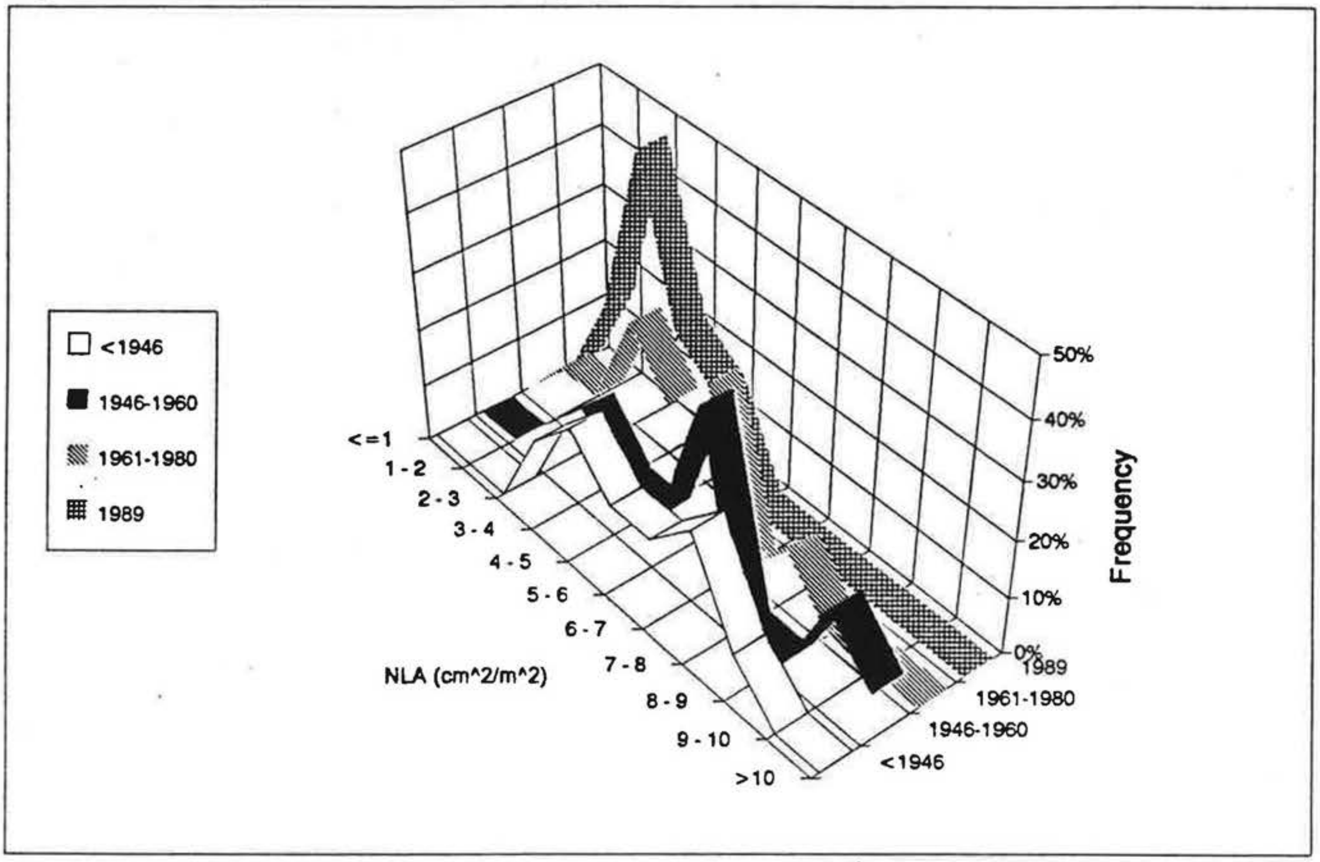

Table 11.3 B.C. NLA by age

NLA	Frequency of NLA for houses built in the years -			CMHC Merchant Home survey	
(CM^2/M^2)	<1946	1946-60	1960-1980	1989	
<=1	0%	0%	0%	0%	
1 - 2	0%	0%	9%	16%	
2 - 3	0%	8%	9%	47%	
3 - 4	15%	17%	27%	21%	
4 - 5	23%	8%	18%	16%	
5 - 6	15%	8%	27%	0%	
6 - 7	15%	33%	0%	0%	
7 - 8	23%	0%	9%	0%	
8 - 9	8%	0%	0%	0%	
9 - 10	0%	17%	0%	0%	
>10	0%	8%	0%	0%	
No. in sample	13	12	11	19	
No. Gas	13	12	7		
No. Elec.	0	0	4		
Average:					
NLA	5.8	6.2	4.4	2.8	cm^2/m^2
ELA	2,785	2,433	2,170	1,603	cm^2
ACH @ 50Pa	10.7	12.2	9.8	6.2	1/h
Volume	633	469	534	692	m^3
Sfc. Area	489	400	504	566	m^2
Sfc.Area/Vol.	0.77	0.85	0.94	0.82	1/m
C	170.0	157.8	126.8	91.3	L/sPa^n
n	0.612	0.587	0.645	0.661	