RESEARCH REPORT

Assessment of Natural Ventilation for Canadian Residential Buildings

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Assessment of Natural Ventilation for Canadian Residential Buildings

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To

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Executive Summary

The investigation reported in this document sought to use air infiltration modeling to assess the natural ventilation situation in Canadian housing, in terms of whether or not natural ventilation, via air infiltration through leaks in the exterior building envelope and through intentional openings in that envelope that are not normally sealed during typical occupancy, can satisfy ventilation requirements for dwellings in Canada. The intention was to draw on existing modeling tools, standards and building code regulations, and sources of measured data for both house characteristics and for climate conditions.

The first task was to determine a definition of adequate residential ventilation that could be used to assess the model simulations of natural ventilation in Canadian houses. This included a survey of the development of ventilation requirements for dwellings within the National Building Code of Canada, since its inception to the present day. It also included a survey of North American standards for residential ventilation that have been published by authoritative agencies such as the American National Standards Institute and the Standards Council of Canada. The overall house ventilation requirement of 0.3 ac/h was selected as this criterion, that could be applied to all house types & sizes. Room-by-room based requirements are gaining favour in the regulatory and standards writing communities, but their application would require more detailed information than is available for large datasets of house characteristics.

The next three tasks were somewhat circular or iterative: selections of (a) a suitable modeling tool, (b) suitable house characteristics and sources of that data, and (c) suitable weather data. Not all available modeling tools require the same input information, so the selection of the house characteristics information required by various available models was considered in the context of what information existed in various sources of such data for Canadian houses. The air infiltration model created by Shaw at NRC in 1987 was selected as the computational engine for the assessment calculations. It requires the minimum of input data to describe the house characteristics, and in a 1989 study was found to have equivalent prediction accuracy as other single-cell air infiltration models that required extra input data that is often difficult to provide.

Over the past four decades, Canadian federal government agencies have supported a substantial number of investigations that have examined the various characteristics of small to moderate sized groups of houses either in specific locations, such as a development of energy-efficient houses built in one city, or in several locations across Canada. Reports from most of those investigations were reviewed in this study. Each of those investigations have gathered either very detailed information of various sorts about a small set of houses, or less detailed information about larger sets of houses. However the recent federal government program EnerGuide for Houses had, by late 2004, amassed a very large database of quite detailed information about more than 125,000 houses across Canada. That detailed information was gathered during visits by skilled inspectors to audit the energy efficiency of each house, at the voluntary invitation of the homeowner, and included a “blower door” test to measure the airtightness of each house. This database was selected to be the primary source of house characteristics information for this study. Three cities were selected from the EnerGuide for Houses dataset: Ottawa – with a climate including hot summers and cold winters and a population of houses with a wide variety of energy efficiency performance, Vancouver – with a mild climate that can be very damp and a population of houses that are often much less airtight than other regions in Canada, and Saskatoon – with a very cold and dry winter, dry summers, and a population of houses that are often substantially more airtight than other regions in Canada. Hourly weather data for typical years are available for all three of these cities from various sources and in various formats – all of which have been developed based on Environment Canada’s measured weather information.

A number of characteristics of a house may influence its natural ventilation, independent of climate conditions. The subsets of data for each city were examined for influence of such factors as age, house type, and number of storeys on the measured envelope airtightness. The neutral pressure level, the height above grade where, in the absence of wind, static pressures inside and outside the house are equal, is the only input data required by the Shaw model that is difficult to measure. Several investigations have reported NPL data measured in a variety of ways under varied conditions, and these were surveyed and summarized to provide guidance on selecting representative values of NPL for the model calculations. Other than the distribution of accidental leakage openings about the exterior envelope, the existence or absence of one or more open flues in a house can be a major influence on its NPL. The type of heating system is often the dominant factor affecting the flue characteristics for each house, and thereby the NPL. The sets of measured NPL data in Canadian housing are summarized in an appendix.

The three cities' subsets of house characteristics revealed that the most common type of house was a detached, two-storey house with a conventional-efficiency, gas-fired furnace with a continuous pilot and natural draft flue, and conventional gas-fired water heater. In Saskatoon, the most common house type was single-storey rather than two-storey. In Ottawa, the number of conventional-efficiency, induced-draft mid-efficiency, and condensing high-efficiency furnaces were similar. A prototypical detached, two-storey house heated by a conventional gas-fired furnace with a natural draft furnace flue was defined for each of the three cities, with airtightness equal to the median airtightness for that grouping of houses in the respective city's subset. Examination of the yearly profile of month-by-month hourly infiltration rates calculated for these three prototypical houses indicated that the influence of stack effect predominated the air infiltration situation. In mild to warmest months, where outdoor air temperatures did not generate strong stack effect, air infiltration for the house with all doors and windows closed was typically inadequate, based on the 0.3 ac/h requirement. Only in the coldest few months in each city was air infiltration sufficient to satisfy ventilation requirements. It is likely that occupants would open windows or take other steps to increase ventilation when air infiltration into the shut-up house is insufficient to meet their IAQ & comfort needs.

The statistics of annual simulations of hourly infiltration rates for groupings of houses, by heating system type and by period of construction, were aggregated in order to identify trends for air infiltration in the three cities. Three gas-fired heating systems were examined: conventional-efficiency furnace with natural draft flue, assigned an NPL=0.7 for the model calculations; induced-draft, mid-efficiency furnace assigned an NPL=0.6; and condensing, high-efficiency furnace assigned NPL=0.5. In Ottawa, air infiltration in the three groups of houses was less than 0.3 ac/h for 50%, 46% and 57% of the hours in the year, respectively. The longest periods during which air infiltration was continuously less than 0.3 ac/h ranged from 1.5 months to almost 3 months. In Vancouver, air infiltration was less than 0.3 ac/h for 24%, 43%, and 44% of the hours in the year, respectively, with the longest duration of continuously low air infiltration ranged from one week to more than one month. In Saskatoon the number of hours in the year with inadequate air infiltration ranged from 67% to 89%, with the longest periods of continuously inadequate air infiltration ranging from 3 months to more than 6 months.

The need for mechanical ventilation to supplement naturally occurring air infiltration seems clear across Canada from regions with the most airtight house construction to those with the leakiest construction. However, based on the month-by-month examination of model predictions, it also is apparent that additional airtightening is an appropriate energy conservation measure for the leakiest of Canadian houses, many located in mild climate regions like Vancouver, as long as mechanical ventilation is also available for those substantial parts of the year where natural ventilation by air infiltration cannot be expected to meet all the ventilation needs.

Résumé

L'investigation dont il est ici question visait à se servir de la modélisation des infiltrations d'air pour juger de la ventilation naturelle des habitations au Canada et ainsi déterminer si celle suscitée par l'air s'infiltrant dans l'enveloppe extérieure du bâtiment et par les ouvertures intentionnelles qui sont généralement bloquées lors de l'occupation des lieux, permet de satisfaire aux exigences de ventilation des logements au Canada. L'intention était de tirer parti des outils de modélisation, des normes et des dispositions du code du bâtiment en vigueur, de même que des sources de données mesurées à l'égard des caractéristiques de maisons et des conditions climatiques.

La première tâche consistait à arrêter une définition de la ventilation résidentielle suffisante qui permettrait d'évaluer les simulations de la ventilation naturelle des maisons au Canada. Cela comportait une enquête sur l'élaboration des exigences de ventilation des habitations dans les limites du Code national du bâtiment du Canada, depuis ses débuts jusqu'à ce jour. Cette tâche consistait également en une étude des normes nord-américaines en matière de ventilation résidentielle, qui ont été diffusées par des organismes compétents tels l'American National Standards Institute et le Conseil canadien des normes. L'exigence d'assurer globalement dans la maison 0,3 ra/h a été le critère retenu, puisqu'elle peut s'appliquer aux maisons de tous types et de toutes tailles. Les exigences d'assurer la ventilation pièce par pièce gagnent la faveur des organismes de rédaction de normes et de réglementation, mais leur application requerra davantage d'information approfondie que ce qui est disponible pour d'importants ensembles de données touchant les caractéristiques des maisons.

Les trois tâches suivantes étaient quelque peu circulaires ou itératives : choix a) d'un outil de modélisation convenable; b) de caractéristiques convenables des maisons et sources des données pertinentes; et c) de données climatiques convenables. Les outils de modélisation disponibles ne requièrent pas tous le même apport de renseignements, si bien que la sélection des caractéristiques des maisons requise des différents modèles disponibles a été considérée dans le contexte de l'information des différentes provenances de telles données pour les maisons canadiennes. Le modèle des infiltrations d'air créé par Shaw au CNR en 1987 a été choisi à titre de moteur de computation pour les calculs d'évaluation. Il requiert le minimum de saisie de données pour décrire les caractéristiques des maisons; de plus, lors d'une étude effectuée en 1989, on a trouvé qu'il présentait des prédictions d'une exactitude équivalente à d'autres modèles d'infiltrations d'air à cellule unique qui requièrent la saisie de données supplémentaires souvent difficiles à fournir.

Au cours des quatre dernières décennies, les organismes fédéraux du gouvernement canadien ont soutenu un nombre appréciable d'investigations qui ont porté sur les différentes caractéristiques de groupes de maisons de taille petite ou moyenne dans des endroits précis, comme un aménagement de maisons éconergétiques construites dans une ville ou dans plusieurs localités du Canada. Les rapports de la plupart de ces investigations ont été passés en revue aux termes de la présente étude. Chacune de ces investigations a permis de recueillir des renseignements très détaillés de diverses sortes au sujet d'un petit ensemble de maisons, ou des renseignements moins détaillés au sujet d'un ensemble plus important de maisons. Par contre, le récent programme fédéral ÉnerGuide pour les maisons avait constitué, vers la fin de 2004, une très importante base de données plutôt détaillées à propos de plus de 125 000 maisons dans tout le pays. Ces renseignements détaillés ont été recueillis lors des visites d'inspecteurs qualifiés appelés à vérifier l'efficacité énergétique de chacune des maisons, à l'invitation du propriétaire-occupant, qui ont par la même occasion effectué un essai d'infiltrométrie pour mesurer l'étanchéité à l'air des maisons. Cette base de données a été sélectionnée pour constituer la principale source de caractéristiques des maisons pour les besoins de la présente étude. Trois villes ont été retenues à partir de la série de données du

programme ÉnerGuide pour les maisons : Ottawa, ville située dans une zone climatique se caractérisant par des étés chauds et des hivers froids et regroupant des maisons offrant une large diversité d'efficacité énergétique; Vancouver, ville située dans une zone climatique douce qui peut être très humide, regroupant des maisons bien souvent beaucoup moins étanches à l'air que celles des autres régions du Canada; et Saskatoon, ville aux prises avec un hiver très froid et sec, regroupant des maisons bien souvent beaucoup plus étanches à l'air que celles des autres régions du Canada. Les données météorologiques horaires d'années types existent pour les trois villes, de sources différentes et en différents formats, qui ont toutes été élaborées en fonction des données climatiques mesurées d'Environnement Canada.

Certaines caractéristiques d'une maison peuvent influer sur sa ventilation naturelle, quelles que soient les conditions climatiques. Les sous-ensembles de données pour chacune des villes ont été étudiés pour déterminer l'influence de facteurs tels l'âge, le type de maison, et le nombre d'étages, sur l'étanchéité à l'air de l'enveloppe. Le plan de pression neutre, qui correspond à la hauteur par rapport au niveau du sol où, en l'absence de vent, les pressions statiques à l'intérieur comme à l'extérieur de la maison sont égales, est la seule donnée que requiert le modèle de Shaw, mais difficile à mesurer. Plusieurs investigations ont signalé des plans neutres mesurés de différentes façons dans différentes conditions; ils ont d'ailleurs été relevés et résumés pour servir de guide quant au choix de valeurs représentatives du plan neutre pour les calculs du modèle. À part la répartition des ouvertures de fuite accidentelles de l'enveloppe extérieure, la présence ou l'absence d'un ou de plusieurs conduits de cheminée ouverts risque d'exercer une grande influence sur le plan neutre de la maison. Le type de système de chauffage constitue bien souvent le facteur déterminant qui agit sur les caractéristiques du tirage de la cheminée de chacune des maisons, et par conséquent le plan neutre. Les ensembles de données de plan neutre mesurées dans les maisons au Canada sont résumés dans l'annexe.

Les sous-ensembles de caractéristiques des maisons des trois villes ont révélé que le type le plus courant de maison était la maison individuelle de deux étages, équipée d'un générateur de chaleur au gaz d'efficacité classique, avec veilleuse continue et conduit de fumée à tirage naturel, et d'un chauffe-eau classique au gaz. À Saskatoon, le type de maison le plus courant était la maison de plain-pied plutôt que la maison à deux étages. À Ottawa, la répartition du nombre de générateurs de chaleur d'efficacité traditionnelle, d'appareils à tirage induit d'efficacité moyenne et d'appareils haute efficacité à condensation, était semblable. Le prototype de maison individuelle à deux étages équipée d'un générateur de chaleur classique au gaz, avec conduit de fumée à tirage naturel, a été défini pour chacune des trois villes, l'étanchéité à l'air étant égale à l'étanchéité médiane de ce groupe de maisons du sous-ensemble respectif de la ville. L'examen du profil annuel des taux d'infiltration horaires mois par mois calculés pour ces trois maisons prototypes indique que l'effet de tirage domine l'infiltration d'air. Dans les mois doux ou très chauds, alors que les températures de l'air à l'extérieur ne suscitent pas un important effet de tirage, l'infiltration d'air de la maison, toutes les portes et fenêtres fermées, était généralement insuffisante par rapport à l'exigence de 0,3 ra/h. Uniquement pendant les quelques mois très froids, l'infiltration d'air dans les maisons des trois villes suffisait pour répondre aux exigences de ventilation. Il est probable que les occupants décideraient d'ouvrir les fenêtres ou de prendre d'autres mesures pour accroître la ventilation lorsque l'infiltration d'air dans les maisons ne serait pas suffisante pour assurer la qualité de l'air intérieur et répondre aux besoins de confort.

Les statistiques des simulations annuelles des taux d'infiltration horaires pour les groupes de maisons, selon le type de système de chauffage et la période de construction, ont été réunies en vue de cerner les tendances de l'infiltration d'air dans les trois villes. Trois systèmes de chauffage au gaz ont fait l'objet d'un examen : le générateur de chaleur d'efficacité traditionnelle avec conduit de fumée à tirage naturel, avec un plan neutre de 0,7 pour les calculs du modèle;

le générateur de chaleur d’efficacité moyenne à tirage induit, avec un plan neutre de 0,6; et le générateur de chaleur haute efficacité à condensation, avec un plan neutre de 0,5. À Ottawa, l’infiltration d’air dans les trois groupes de maisons était inférieure à 0,3 ra/h pendant 50 %, 46 % et 57 % des heures au cours de l’année. Les plus longues périodes pendant lesquelles l’infiltration d’air était continuellement inférieure à 0,3 ra/h variaient entre 1,5 mois et près de 3 mois. À Vancouver, l’infiltration d’air était inférieure à 0,3 ra/h pendant 24 %, 43 % et 44 % des heures au cours de l’année, la durée la plus longue d’infiltration d’air continuellement faible variant entre une semaine et plus mois. À Saskatoon, le pourcentage d’heures pendant l’année où l’infiltration d’air était insuffisante variait entre 67 % et 89 %, les périodes les plus longues d’infiltration d’air continuellement insuffisante variant entre 3 mois et plus de 6 mois.

La nécessité de compter sur la ventilation mécanique pour suppléer aux infiltrations d’air d’origine naturelle semble manifeste dans tout le pays, que ce soit dans les régions présentant les bâtiments les plus étanches à l’air ou dans celles qui comptent les bâtiments les moins étanches à l’air. Pourtant, d’après l’examen mois par mois des prédictions du modèle, il est également manifeste que le raffermissement de l’étanchéité à l’air constitue une mesure d’économie d’énergie tout indiquée pour les maisons les moins étanches au Canada, bon nombre étant situées dans des zones climatiques douces comme Vancouver, tant qu’on peut compter sur la ventilation mécanique pour les grandes périodes de l’année où la ventilation naturelle attribuable aux infiltrations d’air ne saurait permettre de répondre à tous les besoins de ventilation.

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Assessment of Natural Ventilation for Canadian Residential Buildings

Project Description

This report describes the results of a research project whose main objective was to attempt to determine the frequency and duration of periods where natural ventilation in dwellings in Canada can be expected to be inadequate, and thereby where supplemental mechanical ventilation is needed. The project was supported by the Canada Mortgage and Housing Corporation (CMHC) and the National Research Council of Canada (NRC). The work was undertaken primarily by the Ventilation & Indoor Air Quality Group in the Indoor Environment (IE) Research Program of the Institute for Research in Construction (IRC) of NRC.

Background

This project was conducted in parallel with another research project (PERD-081, IRC-B3316) funded in part by the Panel on Energy Research & Development (PERD), within the Building & Community Energy Technology (BCET) R&D Theme Area. There are two federal government agencies participating in that project, the National Research Council of Canada and Natural Resources Canada (NRCan). That project is focused on developing energy efficient hybrid ventilation systems for residential buildings. The results of the project reported upon in this document provide one of the foundations on which that PERD-funded project and its conclusions will be based.

This document reports on the work accomplished by the Ventilation & Indoor Air Quality Group at NRC towards this project's goals: Existing NRC/IRC data sets have been reviewed and analyzed to determine the frequency and duration of periods during which the driving forces for natural ventilation in dwellings are inadequate. This involved the use of a suitable air infiltration / natural ventilation model to relate measured historical records of weather conditions and typical residential envelope characteristics to identify when natural ventilation are inadequate. The statistics of how often and for how long such periods occur have been calculated, presented and discussed. Those statistics are expected to be useful to the various Canadian agencies considering establishing and revising requirements for mechanical ventilation in dwellings.

Objectives

The objectives of the research undertaken by the NRC/IRC team were the following:

- To establish a definition for adequate ventilation for a typical Canadian dwelling,
- To establish the ranges of house characteristics, relevant to natural ventilation (including air infiltration), that will be used to represent typical Canadian dwellings,
- To select a suitable air infiltration/natural ventilation simulation model to apply in the review of existing NRC/IRC datasets in order to identify the frequency and duration of periods where the driving forces for natural ventilation were inadequate to satisfy residential ventilation requirements,
- To identify the NRC/IRC data sets of house airtightness characteristics and weather data suitable for this review / analysis,
- To conduct the analytical review of the suitable data sets for periods of inadequate natural ventilation situations for the range of house characteristics identified previously,

- To calculate and report the statistics of the frequency and duration of periods of inadequate natural ventilation in Canadian dwellings, and
- To assist CMHC in disseminating the results of the project to interested agencies in Canada.

Work Plan

Task 1 – to establish an acceptable and useful definition of adequate residential ventilation for this overview assessment of Canadian housing.

Task 2 – to review available data, from previous IRC projects and elsewhere in Canada, from which a range of house characteristics, with respect to ventilation, can be developed that can be used to represent Canadian housing.

Task 3 – to review existing models of residential ventilation, compare their input data requirements, computational complexity and output information, and identify the model(s) that can be used in this assessment.

Task 4 – to review the available datasets suitable for input to the selected model(s), including house characteristics and weather data, and identify those for analysis.

Task 5 – to apply the simulation model to the range of house characteristics and weather conditions based on the available data sets to calculate the estimates of air infiltration / natural ventilation and therefrom to determine the statistics of frequency and duration of periods of inadequate natural ventilation in Canadian dwellings. Initially this analysis was to focus on the cities of Ottawa and Vancouver, but later the city of Saskatoon was added to the analysis.

Task 6 – to prepare the final report describing the work and the conclusions and recommendations drawn from the analysis. Participate with CMHC in the technology transfer.

Task 1 – Establish Definition of Adequate Residential Ventilation

The National Building Code of Canada and the relevant National Standards of Canada were reviewed to establish a definition of what can be considered adequate ventilation in a dwelling. The relevant documents are the existing editions (1941 – 2005) of the National Building Code of Canada, the Canadian Housing Standards, the Residential Standards Canada, National Housing Code of Canada (and Illustrated Guide) – all published by the National Research Council of Canada, and the National Standard of Canada CAN/CSA-F326-M91 published by the Canadian Standards Association. Many editions of the National Building Code of Canada have made reference to ASHRAE Handbooks and Standards, HRAI Digests and Manuals, SMACNA Manuals, and other documents as sources of reference for good engineering practice, but housing construction in Canada typically follows prescriptive requirements rather than performance requirements and engineering design for every dwelling.

The first edition of the National Building Code of Canada (NBC), published in 1941, referred to the recommendations in the ASHVE Guide, Volume 17 (ASHVE 1939), as “good commercial practice” for the design, construction and installation of HVAC in Canadian buildings. In the NBC 1941, for dwelling units, every habitable room, including bathrooms and water-closet rooms, required windows to provide natural ventilation and daylighting. Those windows required an openable area of no less than 5% of the room’s floor area whose top was at least 6 ft 6 in. above the floor. Storm sashes were required to have an openable area at least 12.5% of the glass area of its openable window. If mechanical ventilation systems were installed in a dwelling unit, the following were required:

- exhaust only direct to outdoors for bathrooms and water-closet rooms,

- no more than 75% of supply air be recirculated to indoor air and only if that recirculated air were filtered/cleaned of dust, odours and toxic substances,
- system be designed for continuous operation,
- airspeeds in the occupied zone of a room or space be less than 3 ft/s for ventilation and 5 ft/s for heating air flow,
- fresh (outdoor) air supply rates be no less than **15 cfm per person** for most rooms,
- bathroom and water-closet rooms supply air flow rates at least 2 cfm per square foot of floor area.

In 1953, the second edition of the NBC added a requirement that bathrooms and water-closet rooms' windows have at least 2 sq.ft of openable area per fixture, for natural ventilation. Where mechanical ventilation was provided, its supply rate was required to comply with two curves (provided in its Figure 3.1) relating the minimum outdoor air supply rate to the volume of air per person for situations of ventilation only or ventilation combined with air-conditioning. In that figure, for ventilation only, **15 cfm per person** corresponds to 225 cu.ft per person.

From 1960 onwards the National Building Code was revised and published on a five-year cycle, except for a temporary (one cycle) decision by the Associate Committee on the National Building Code to adopt a 2-year cycle that resulted in a 1977 edition of the NBC. The 1960 NBC Building Services Part 6 ventilation requirements were unchanged from those in the 1953 NBC, but Part 9 appeared for the first time containing requirements specific for housing. This first version of NBC Housing Part 9 required that all habitable rooms in dwellings be ventilated either naturally or mechanically according to good practice as described in a companion document the Canadian Housing Standards (NRC 1960) referenced at the beginning of the Part 9. Natural ventilation openings (windows) were required to be (a) at least 3 sq.ft for habitable rooms or series of habitable spaces, (b) at least 1 sq.ft for bathrooms or water-closet rooms, and (c) allowed to be omitted from living rooms or combined living dining rooms. Mechanical ventilation systems for dwellings were required to be capable of providing at least one air change per hour (**1 ach**) for all spaces or rooms serviced and could allow natural ventilation openings to be omitted.

The most recent version (2005) of the National Building Code of Canada, which is a consensus-based model building code for Canada, has separate requirements for ventilation in residential buildings for the heating season and for the non-heating season. For the ventilation during the non-heating season, it allows natural ventilation provided by minimum openings specified in Table 9.32.2.2 (unchanged since NRC 1960, except the requirement for natural ventilation of unfinished basement space by 0.2% of relevant floor area introduced in NRC 1970). Alternatively, during the non-heating season, mechanical ventilation is required that must (a) be designed and installed according to good engineering practice, and (b) provide outdoor air supply to or exhaust air from each habitable room according to its Table 9.32.2.3, if the spaces are mechanically cooled (simply **0.5 ac/h** was required in NBC 1995). If a space or room is neither naturally ventilated nor mechanically cooled then its mechanical ventilation system must be capable of exhausting air from it or supplying outside air to it at a rate of **1 ac/h** (same as required in NBC 1995). These cited tables are reproduced here for convenience as Tables 1 and 2. Rules for interpreting and applying the mechanical ventilation rates in Table 2 are also provided in the NBC 2005 – borrowed virtually verbatim from the Canadian standard "Residential Mechanical Ventilation Requirements" (CSA 1991), which requires as a minimum whole house outdoor air change rate of **0.3 ac/h**. That standard remains the only existing consensus-based ventilation standard in Canada, although it is under review for anticipated revision at the time of writing.

Table 1. Natural Ventilation Area Requirements per NBC 2005 Table 9.32.2.2 Natural Ventilation Area, Forming Part of Sentence 9.32.2.2.(1).

Location		Minimum Unobstructed Area
Within a dwelling unit	Bathrooms or water-closet rooms	0.09 m^2
	Unfinished basement space	0.2% of the floor area
	Dining rooms, living rooms, bedrooms, kitchens, combined rooms, dens, recreation rooms and all other finished rooms	0.28 m^2 per room or combination of rooms

Table 2. Ventilation Rates for Various Habitable Room Types, per NBC 2005 Table 9.32.2.3 Air Change Rate, Forming Part of Clause 9.32.2.3.(1)(a).

Room or Space	Rate, L/s
Master bedroom	10
Other bedrooms	5
Living room	5
Dining room	5
Family room	5
Recreation room	5
Basement	10
Kitchen	5
Bathroom or water-closet room	5
Laundry room	5
Utility room	5
Other habitable rooms	5

For heating season ventilation, the 2005 NBC requires mechanical ventilation complying with either (a) good engineering practice, such as the CSA F326 standard (CSA 1991) although it does not refer directly to the year of publication of that standard – probably to allow for an anticipated revision and republication of that standard, or (b) the prescriptive requirements described in the balance of the Subsection 9.32.3 Heating-Season Mechanical Ventilation, which include a principal exhaust ventilation system, supplemental exhaust fans, and protection against depressurization. The ventilation system's principal exhaust fan is required to be able to operate at a normal operating capacity based on the number of bedrooms in the dwelling, listed in Table 3, reproduced from Table 9.32.3.3 in the 2005 NBC. The supplemental exhaust fan(s) requirements of subsection 9.32.3.7 provide for an installed total exhaust capacity for the dwelling of at least double the rates indicated in Table. This brings the heating season ventilation system capacity into approximate equivalence with or slightly greater than the total capacity determined using Table 2 rates.

Table 3. Normal Operating Exhaust Capacity of Principal Ventilation Fan, per NBC 2005 Table 9.32.3.3, Forming Part of Sentence 9.32.2.2.(2)

Number of Bedrooms in *Dwelling Unit*	Normal Operating Exhaust Capacity of Principal Ventilation Fan, L/s	
	Minimum	Maximum
1	16	24
2	18	28
3	22	32
4	26	38
5	30	45
More than 5	System must comply with CAN/CSA-F326-M	

The other major North American standard concerning residential ventilation requirements is the recently published ASHRAE Standard 62.2 (ASHRAE 2004). In one of its earliest drafts this ASHRAE standard had borrowed heavily from the Canadian CSA-F326 standard. However, by the time this consensus-based standard was published, its revisions made it look much more like the requirements now contained in the latest National Building Code of Canada (NRC 2005).

The principal objective of this project was to determine the adequacy of residential ventilation in Canadian houses. The broad overview required to achieve this objective, and the approach that involves the application of a simulation model to a representative set of house characteristics using weather data for a collection of regions across Canada to estimate the frequency and duration of periods of inadequate natural ventilation, requires a ventilation criterion that can be applied broadly without needing specific details of how many bedrooms, windows, deliberate openings or fans a house has, or whether it has air-conditioning. Therefore, a room-by-room flow-rate ventilation requirement that varies for the heating and non-heating season is not useful to this approach. An overall air change rate requirement is the sort of criterion that can be used in this assessment. Based on the discussion above, and the description of the evolution of residential ventilation requirements in codes and standards, the author recommended that an hourly air change rate of **0.3 ac/h** be used as the base ventilation requirement year-round and the criterion to be applied to the later simulations of this project.

The decision to use this recommended definition as the final and only criterion for assessing the adequacy of forecast natural ventilation in Canadian dwellings was made in consultation with CMHC in early April 2006.

Task 2 – Establish Typical Characteristics of Canadian Dwellings

The results of previous research projects and surveys of Canadian houses were reviewed to establish a range of house characteristics that are relevant to natural ventilation and air infiltration, and values of those characteristics that can represent a broad cross-section of Canadian housing. The database of the airtightness characteristics of thousands of Canadian houses assembled by the EnerGuide for Houses program at NRCan was another source of this information that was considered.

Previous Research Projects with House Leakage Distribution Data

In a previous IRC project, a contractor collected a number of Canadian datasets from other non-NRC research projects in which residential airtightness and air leakage characteristics had been measured up to 1987. Those are listed in Table 4 below, together with a description of the relevant information of interest to this assessment project. The criteria that were used to select those relevant data were based on the sets of input parameters needed by several single-zone air infiltration models. Since that project needed measured air change rates to compare with the models' calculated air change rates, it was an added selection criterion. Also included in the data sets listed in Table 4, in bold outline, are more recent studies in which were measured airtightness characteristics and sufficient other information about their subject houses to enable an air infiltration model simulation of their air change rate to be calculated.

Table 4. Non-NRC Research Projects With House Leakage Data

Project Name	**No. of Houses**	**Age Range**	**Data Types**	**Comments**
Richmond Hill Air Sealing Study (real homes)	21	1940-1970	Fan test data: C, n, ELA_{10}; geometry: Vol., Env.Area, Height.	Ont. Variety of styles & sizes
U.Alberta Home Heating Facility (research houses)	2	1981	Fan test data: C, n, ELA_{10}; geometry: Vol., Env.Area, Height	Alta. Extensive data, 1-storey
R-2000 Program SF6 Testing (R-2000 & real homes)	25		Fan test data: C, n, ELA_{10}; geometry: Vol., Env.Area, missing height data	Ont., Sask., BC questionable quality, some fan test data missing
Sheltair study of heating capacity in two townhouses	2	1985	Fan test data: C, n, ELA_{10}; geometry: Vol., Env.Area, Height	BC, 2-storey
Apple Hill Project	35-52	1984	Fan test data: C, n, ELA_{10}; NPL; geometry: Vol., Env.Area, Height, 3 tracer gas tests per house	Kanata, Ont. For CMHC
Scanada R2000 Passive Solar House	1	1983	Fan test data: C, n, ELA_{10}; geometry: Vol., Env.Area, Height	Ottawa area
Survey of Winnipeg Houses	78	1902-1980	Fan test data: C, n, ELA_{10}; geometry: Vol., Env.Area, Height	Random sample of 78 Winnipeg houses

Survey of New 1997 Conventional & R-2000 (Hamlin & Gusdorf 1997)	163 63	1990-1996 1983-1995	Fan test data: C, n, ELA_{10}; geometry: Vol., Env.Area, Height	NRCAn, CMHC, NRC, CHBA
Flair Homes Energy Demo/ CHBA Flair Mark XIV Project, Proskiw 1992	10 14	1985-1989	Fan test data: C, n, ELA_{10}; geometry: Vol., Env.Area, Height	Compare poly air barrier w/ ADA.
Ventilation & IAQ in Electrically Heated Houses in Quebec	30	----	ACH@50, Vol., IAQ and tracer gas data, vent'n system type.	Quebec, electrical heat, representative of Quebec stock.
Field Testing of House Characteristics	52	----	Fan test data: ELA_{10}, ACH@50; NPL; duct leakage; room pressuruzations	12 houses each in BC, MB, ON & NS, 4 in PQ.
Ventilation Control in Medium Air Tightness Houses	20	1921-1990	Fan test data: C, n, , ACH@50; NPL, geometry: Vol. Height. PFT tracer gas data, HOT-2000 annual htg. loads	20 houses in Saskatoon, NPL in four OTCV houses
Verification of HRAI De-pressurization Calculation (Bowser 1995)	30	1955-1995	Fan test data: C, n, ELA_{10}; geometry: Vol., Env.Area, Height	HRAI for CHBA / R-2000 program

Several research projects carried out by IRC, both with and without other partner agencies also created datasets with measured house leakage characteristics. Some of those are listed in Table 5.

Table 5. NRC Research Projects With House Leakage Data

Project Description	**No. of Houses**	**Age Range**	**Data Types**	**Comments**
Prairie Regional Station Low-energy houses (Hickling 1987)	1	1981	Fan test data: C, n, ELA_{10}; geometry: Vol., Env.Area, Height	Repeat tests on R-2000 split-level. Saskatchewan
Prairie Regional Station Survey of Saskatoon area Houses (Dumont et al 1981)	19 20 97 40	Pre 1945 1946-1960 1961-1980	Fan test data: C, n, ELA_{10}; geometry: Vol., Env.Area, Height	40 energy efficient houses and the rest conventional construction

Air Leakage and Pressure Measurements on Two Occupied Houses (Tamura & Wilson 1963)	2	1962	Fan test data: C, n, ELA_{10}; geometry: Vol., Env.Area, Height	Two 1-storey houses in Ottawa
Townhouse air leakage testing (Reardon et al 1987)	3		Fan test data: C, n, ELA_{10}; geometry: Vol., Env.Area, Height	Upper and lower 2-storey units in townhouse building in Ottawa
Air Infiltration Modelling Study (Reardon 1989)	22	1910-1979	Fan test data: C, n, ELA_{10}; NPL; geometry: Vol., Env.Area, Height	Ottawa area houses
Air Infiltration Modelling Study (Reardon 1989)	9	1922-1971	Fan test data: C, n, ELA_{10}; NPL; geometry: Vol., Env.Area, Height	Winnipeg area houses
Mark XI Energy Research Project (Scheuneman 1982)	4	1977	Fan test data: C, n, ELA_{10}; NPL; geometry: Vol., Env.Area, Height	Demonstration houses - Ottawa
Air Tightness of New Housing in Ottawa (Beach 1979)	63	1978	Fan test data: C, n, ELA_{10}; geometry: Vol., Env.Area, Height	Survey of then brand new Ottawa area houses' air tightness
Passive ventilation in Mark XI HUDAC houses (Shaw & Brown 1982, Shaw & Kim 1984)	2	1977	Fan test data: C, n, ELA_{10}; NPL; geometry: Vol., Env.Area, Height	Demonstration houses - Ottawa
Small diameter ventilation systems (Reardon 1995, Reardon & Shaw 1993)	1	1987	Fan test data: C, n, ELA_{10}; NPL; geometry: Vol., Env.Area, Height	Two-storey Ottawa research house
Cross-Canada Survey of Airtightness in New Homes (Haysom et al 1990, Hamlin et al 1990)	195	1988-1989	Fan test data: C, n, ELA_{10}; some NPL; geometry: Vol., Env.Area, Height - for three degrees of air-sealing	NRCan/CMHC/NRC joint survey in 12 Canadian cities of developer-built conventional homes

Viewed collectively, these various sets of house characteristics data provide a sample for a broad age range of houses in the provinces of Ontario and Saskatchewan, and in the City of Winnipeg; for a range of ages for electrically heated houses in the province of Quebec, and for late1980s' through mid 1990s' houses across Canada. This collection of datasets provides a rather limited basis for developing a representative range of house characteristics for Canadian dwellings. Fortunately, a relatively recent program of the Canadian federal government has assembled a large dataset that includes characteristics of houses of all ages and types across Canada, described next.

Current and Developing Sources for Additional House Leakage Distribution Data

The EnerGuide For Houses Program (EGH) operated by the Office of Energy Efficiency within the federal government department of Natural Resources Canada was a program to encourage homeowners to consider retrofitting their houses to better conserve energy. Part of that program involved accumulating the measurements and information collected during the initial EGH home inspections by qualified agents into a large and growing database. That program provided a subset of that database's records at December 2004 for assessment in this project (Roux 2004). A summary of the number of records by province contained in that dataset is contained in Table 6.

This dataset did not include the "native" airtightness characteristics for each of its house properties records, instead it lists the Air Changes per Hour @ 50 Pa, and the CGSB Equivalent Air Leakage Area @ 10 Pa values determined from analysis of the airtightness test of each house inspected by the program. However, these two "indices" of the airtightness characteristics for each record in the database can be used to calculate the "native" airtightness characteristics: the house flow coefficient and the house flow exponent, for each house.

The house interior volume and footprint area are provided, so the house height can be estimated, but the grade level is unknown. The numbers of flues, vents and the heights of the uppermost ceiling above grade and the neutral pressure level are other characteristics that would be helpful for natural ventilation / air infiltration model simulation calculations, that are not included in the EnerGuide For Houses database.

The dataset contains records for 125,837 houses in all provinces and territories (except Nunavut), with 243 cities, towns or municipal districts that have 50 or more houses – identified as "major centres" in Table 6.

Another, more recent, dataset was made available by other IRC colleagues (Cornick 2006) that included detailed measurements of airtightness characteristics and other relevant information for seven houses in each of Inuvik, NWT and Prince Rupert, BC. The inclusion of this data might enable meaningful simulation calculations in these two cities, that might serve as examples of a very cold & dry location (Inuvik) and a mild & wet location (Prince Rupert).

A the beginning of April 2006, the decision was made with CMHC to use only the EnerGuide For Houses dataset for the subsequent analysis in this project, since it was the largest single dataset for houses all across Canada at that time.

Table 6. EnerGuide For Houses Dataset, Provincial Contents

Province	No. Houses	No. Major Centres[1]
AB	24043	30
BC	25357	40
MB	9002	8
NB	768	3
NL	1612	5
NS	3465	12*
NWT	2	0
ON	39475	74
PEI	296	1
PQ	9171	50
SK	11059	15
YK	1587	5
Totals	**125,837**	**243**
1. Number of cities, towns and municipal districts with 50 or more houses each.		
* Aggregating some adjacent municipalities.		

Task 3 – Select Suitable Air Infiltration/Natural Ventilation Model for Houses

Over the past four decades there has accumulated a substantial body of literature describing the development and validation testing of a broad assortment of models to simulate air infiltration and ventilation in houses and other types of buildings. A very good discussion can be found in the recent edition of the ASHRAE Handbook of Fundamentals (ASHRAE 2005), Chapter 27 "Ventilation and Infiltration". One major distinction can be made between models that treat the house as a single zone and those that simulate the multizone aspects of a house. For the purposes of this project, multizone modeling represents an unrealistic degree of detail, both in the input information required by the model (which will typically not be known for a broad range of houses of interest to this assessment) and in the detailed calculation output data produced by multizone simulation. The subsequent discussion will focus exclusively on single-zone modeling for houses.

A previous research project of IRC examined several single-zone models of air infiltration and compared their accuracies against air infiltration rates measured in a selection of houses in the Ottawa and Winnipeg areas over a complete fall/winter/spring heating season (Reardon 1989). That project concluded that any of the models examined provided good prediction accuracy when provided measured house characteristics as input data. The results of that project also included an extensive data set that can be utilized in this work.

The three air infiltration models examined in the IRC report (Reardon 1989) all use some form of quadrature for superposing the air leakage caused separately by temperature difference and by wind. The infiltration model developed by Shaw at IRC (Shaw 1981, Shaw 1987)) is somewhat simpler to use than the other two in two respects. For wind-driven infiltration, the Shaw model treats the house as either sheltered or exposed to wind effect, while the other two models: Sherman & Grimsrud (1980) and Yuill (1985) require assessment of the degree of shielding and the terrain class to transform the wind speed over flat terrain to that expected at the house top. For the component of infiltration driven by stack-effect, the Shaw model requires the overall airtightness characteristics (available from a blower door type of depressurization test) and the neutral pressure level (which if not measured, can be estimated); the other two models each require not only the effective leakage area (from a depressurization test), but a characterization of the distribution of leakage using two parameters while offering little guidance to the user for selection of those two parameters' values. Otherwise, all three of these models require similar input data – size of the house, wind speed and indoor and outdoor temperatures for the simulation period of interest.

The discussion of single-zone air infiltration models in Chapter 27 of the 2005 ASHRAE Handbook of Fundamentals (ASHRAE 2005) offers the Sherman & Grimsrud (1980) model as the basic (simple) single-zone model. A more recent, enhanced model is also offered there, known as the AIM-2 model (Walker and Wilson 1998). This enhanced model purports to improve on the basic model by using the actual power law representation of the building airtightness (an idea first incorporated in the variable flow exponent model, Yuill 1985, and evaluated in Reardon 1989), requiring as input data the flow coefficient and flow exponent from an actual blower door measurement of airtightness, and treating the flue as a separate leakage site. This distinct treatment of the airflow through the flue can be an advantage, but the required information about the flue's characteristics may not typically be available in the data sets for use in this general assessment of residential ventilation in Canada. A sample of data that is available for Canadian houses was gathered during the Canadian Residential Duct and Chimney Survey (Sheltair Scientific 1989).

The mathematical descriptions of each of these models (their equations) are listed in Appendix A. Their description in the Appendix has unified the nomenclature to facilitate understanding their actual differences, and has provided their native equations with their original input parameters, rather than applying assumptions for some of those parameters to calculate combined model coefficients as has been done in the ASHRAE Handbook of Fundamentals.

The Shaw model requires the following input data for its calculations of air infiltration rate for a house.

C	=	house flow coefficient from curve fit of the leakage test data [L/(s Pa^n)],
n	=	house flow exponent from curve fit of the leakage test data,
V	=	internal volume of the house including basement [m^3],
h	=	height above grade of the neutral pressure level [m],
H	=	height above grade of the upper ceiling of the house [m],
Tin	=	indoor air absolute temperature [K],
Tout	=	outdoor air absolute temperature [K],
U'	=	windspeed measured at standard reference height of 20 m [m/s].

The model actually only requires the ratio of neutral pressure level to house height. In the absence of measured neutral pressure values (NPL = h/H), default values of 0.64 for a house without a flue, and 0.86 for a house with a single 127 mm dia, flue, can be used. The leakage test data and parameters are those measured using the CGSB (1986) standard procedure, and the outdoor temperature and windspeed values can be obtained from weather data records.

The Sherman & Grimsrud model requires the following input data for its calculations of air infiltration rate for a house.

L	=	effective leakage area of the house @ 4 Pa [m^2],
h	=	height above grade of the neutral pressure level [m],

H	=	height above grade of the upper ceiling of the house [m],
L_c	=	effective leakage area in the upper ceiling [m^2],
L_f	=	effective leakage area in the floor [m^2],
C'	=	generalized shielding coefficient for the house,
α, γ	=	terrain parameters for the house site,
Tin	=	indoor air temperature [K],
Tout	=	outdoor air temperature [K],
U'	=	windspeed measured at a standard reference height of 10 m [m/s],
α', γ'	=	terrain parameters for the windspeed measurement site,
H'	=	height at which windspeed is measured [m].

The Sherman & Grimsrud model actually only needs the ratio of the neutral pressure height to the house height (β_o = h/H) rather than the actual neutral pressure height above grade. The model does require the house height, H. Similarly, only the relative fractions of the building's effective leakage area that are contained in the ceiling and in the floor (i.e., L_c/L and L_f/L) are used in the model calculations, not their actual dimensional values. The effective leakage area is determined from the analysis of measured data obtained by a blower door depressurization test of the house, similar to the C and n parameters needed by the Shaw model. Nevertheless, it is clear that the Sherman-Grimsrud model requires several more input parameters than does the Shaw model, information that is often missing in many datasets containing house characteristics. This additional information is lacking in all the existing measured datasets for Canadian houses.

The author recommended that the **Shaw model** be used for the calculations involved in this project's assessment, since it requires the fewest input parameters, has the most complete set of recommendations for approximating the values of those input parameters for which actual measured values are not available, and has been shown to have a similar prediction accuracy to that of the Sherman & Grimsrud model (Reardon 1989). At the beginning of April 2006, the decision was reached with CMHC to use the Shaw model for infiltration calculations for the subsequent analysis of this project.

Task 4 – Identification of Measured Data Sets Suitable for Analysis

Various research projects that have been conducted by IRC over the previous several decades have produced extensive sets of measured data regarding house air tightness characteristics in Ottawa and across Canada, detailed weather information for various sites in the Ottawa area, and air infiltration rates in houses in Ottawa and Winnipeg. Other sets of measured data have been gathered and reported by other Canadian agencies.

The data sets accumulated by IRC have been listed above. As mentioned above, the decision was made with CMHC to use only the EnerGuide For Houses dataset, since it was the largest single dataset for houses all across Canada at that time.

Weather Data

Several weather data sources were considered for the analyses in this assessment, ranging from those measured by IRC in Ottawa, to the standard one-year, hourly weather data files created by Environment Canada from weather stations across Canada, to standardized one-year, hourly weather sets publicly available for use in analyses with several widely recognized building simulation models, such as DOE2, ESP-r, EnergyPlus, etc. The weather data files for Canadian locations that are available for public download, formatted for use by the DOE2 simulation model actually originate from Environment Canada's own weather records. The weather datasets publicly available and formatted for use with the ESP-r simulation model, for several locations in Canada, including Ottawa, Saskatoon and Vancouver, also originate from Environment Canada's data records. Ultimately, the ASCII format weather files from the ESP-r website were selected for use with a computer program implementation of the Shaw infiltration model, which was written in the Microsoft Visual C++ programming language. Table 7 lists the ASCII weather data files available from the ESP-r website for Canadian cities. CWEC format weather data files for a broader selection of Canadian locations are available from Environment Canada and the DOE2 website.

Table 7. ESP-r Weather Data Files, in ASCII Format, Available for Canadian Cities

City	Filename
Calgary, AB	CAN_AB_Calgary_CWEC.a
Halifax, NS	CAN_NS_Shearwater_CWEC.a
Montreal, PQ	can_montreal.a
Ottawa, ON	can_ottawa.a
Quebec City, PQ	CAN_PQ_Quebec_CWEC.a
Saskatoon, SK	CAN_SK_Saskatoon_CWEC.a
St.John's, NL	CAN_NF_St.Johns_CWEC.a
Toronto, ON	CAN_ON_Toronto_CWEC.a
Vancouver, BC	CAN_BC_Vancouver_CWEC.a
Whitehorse, YK	CAN_YT_Whitehorse_CWEC.a
Winnipeg, MB	CAN_MB_Winnipeg_CWEC.a

The set of house characteristics selected in Task 2 were assembled into model input data set(s) and using the air infiltration model identified in Task 3, the weather data set(s) were analyzed to identify periods of inadequate natural ventilation for each of the house types. The statistics of the frequency and duration of these periods of inadequate natural ventilation were determined through suitable analysis described later in this report. Weather data for Ottawa was analyzed first to represent a wide range of weather conditions: very cold winters and hot summers. Vancouver weather data was analyzed to represent a very mild Canadian climate where natural driving forces may most frequently fail to provide adequate natural ventilation. Saskatoon weather data was added to the analysis to represent a very cold and dry winter climate.

House Characteristics

In selecting records from the Ontario subset of the EnerGuide For Houses dataset records for Ottawa, it became apparent that some records were identified as belonging to houses in Ottawa, and many more for houses in other municipal districts that are considered within the new City of Ottawa. Table 8 lists the various municipal districts that were lumped together to create an Ottawa house characteristics dataset.

Similarly, in selecting records from the British Columbia subset of the EnerGuide For Houses dataset records for Vancouver, it became apparent that some records were identified as belonging to houses in Vancouver, but many more for houses in other municipal districts that make up the greater metro Vancouver area. Table 9 lists these municipal districts that were combined to create the Vancouver house characteristics dataset.

Table 8. Municipal Districts Assembled to Create the Ottawa-Carleton Area House Characteristics Dataset & Some Features

Municipal District	No. Rec'ds	Oldest Built	Newest Built	Smallest [cu.m]	Largest [cu.m]	Tightest [ach@50]	Leakiest [ach@50]	% of Pop'n
Ottawa	2860	1837	2003	142.5	2675.7	1.58	56.67	**74.32**
Almonte	35	1800	2003	275.6	1047.7	1.21	30.33	**0.91**
Barrhaven	1	1982	1982	358.8	358.8	4.78	4.78	**0.03**
Blackburn Hamlet	8	1971	1991	189.4	726.2	2.84	11.1	**0.21**
Carleton Place	28	1857	1994	223.7	1939.7	1.97	41.1	**0.73**
Carlsbad Springs	1	1992	1992	1408.8	1408.8	4.01	4.01	**0.03**
Carp	25	1887	2003	450.8	1442.2	1.05	9.34	**0.65**
Constance Bay	3	1950	1993	662.6	1600.8	2.28	10.42	**0.08**
Cumberland	18	1894	2002	400.3	1539.5	1.95	12.82	**0.47**
Dunrobin	23	1885	2001	441.5	1939.3	1.7	24.45	**0.60**
Embrun	5	1895	1986	373.9	718.6	3.44	5.71	**0.13**
Gloucester	58	1956	2000	290.0	1255.9	1.39	9	**1.51**
Greely	12	1860	2001	279.7	921.8	2.55	17.7	**0.31**
Kanata	133	1892	2002	292.2	1766.8	2.15	10.29	**3.46**
Kars	10	1896	2002	301.7	1135.3	2.52	13.53	**0.26**
Lanark	17	1837	1995	243.8	1507.2	2.77	17.58	**0.44**
Manotick	38	1888	1999	425.0	1712.9	2.12	13.48	**0.99**
Munster Hamlet	4	1972	1976	491.3	554.8	1.99	5.61	**0.10**
Navan	11	1950	1991	352.0	899.9	2.22	4.6	**0.29**
Nepean	269	1888	2002	369.6	1310.6	1.97	16.24	**6.99**
North Gower	16	1837	1992	375.9	1169.2	2.26	11.87	**0.42**
Orleans	128	1958	2001	294.5	1193.4	1.93	21	**3.33**
Osgoode	13	1885	1991	333.9	1031.5	2.3	8.66	**0.34**
Perth	54	1800	1997	161.4	981.3	1.34	30.67	**1.40**
Rockcliffe	3	1920	1948	511.6	1053.4	6.5	9.23	**0.08**
Russell	7	1866	2000	362.0	691.2	2.47	16.6	**0.18**
Stittsville	44	1940	2002	359.3	1156.5	2.04	11.78	**1.14**
Vanier	21	1920	2001	327.0	725.8	3.9	22.32	**0.55**
Vars	3	1890	1986	347.2	521.3	5.81	20.99	**0.08**
Min/Max'ms	**3848**	**1800**	**2003**	**142.5**	**2675.7**	**1.05**	**56.67**	**100.00**
$5^{th}/95^{th}$ %iles		**1900**	**1993**	**324.6**	**954.0**	**3.09**	**15.82**	

Table 9. Municipal Districts Assembled to Create the Vancouver Area House Characteristics Dataset & Some Features

Municipal District	No. Rec'ds	Oldest Built	Newest Built	Smallest [cu.m]	Largest [cu.m]	Tightest [ach@50]	Leakiest [ach@50]	% of Pop'n
Burnaby	777	1904	2003	210.4	2046.3	1.33	24.75	6.10%
Cloverdale	24	1928	1990	248.6	882.8	5.50	27.46	0.19%
Coquitlam	1121	1925	2000	164.46	1655.3	0.64	34.35	8.80%
Delta	840	1920	1997	223.1	1727.2	1.96	28.21	6.60%
Ladner	53	1875	1987	319.4	1064.1	2.61	21.63	0.42%
Langley	1405	1900	2001	123.3	1925.3	1.35	30.21	11.03%
Maple Ridge	235	1905	2001	104.7	1586.5	2.88	40.23	1.85%
New Westminster	176	1891	1996	203.7	1113.2	2.75	41.45	1.38%
North Delta	51	1959	1988	276.6	1079	4.33	15.44	0.40%
North Vancouver	2609	1900	2003	87.7	3261	2.04	85.58	20.49%
Pitt Meadows	60	1930	1992	235.7	1711.1	3.32	20.76	0.47%
Port Coquitlam	357	1902	2000	196.86	1291.4	2.08	28.85	2.80%
Port Moody	178	1920	2003	221.49	1197.5	2.89	21.44	1.40%
Richmond	415	1935	1998	178.8	1299.6	1.37	56.61	3.26%
Surrey	2269	1900	2004	113.7	2435	1.23	45.34	17.82%
Surrey, South	35	1950	2002	212.4	1245.5	3.53	15.74	0.27%
Vancouver	1338	1899	2004	158.54	4467.5	1.61	46.78	10.51%
West Vancouver	586	1908	2002	136.6	2461.8	2.13	63.64	4.60%
White Rock	205	1915	1999	172.4	1634.1	2.95	78.62	1.61%
Min/Max'ms	**12734**	**1875**	**2004**	**87.7**	**4467.5**	**0.64**	**85.58**	**100.00%**
5th/95th %iles		**1930**	**1993**	**286.1**	**1010.4**	**4.38**	**17.25**	

The EnerGuide for Houses dataset records for the province of Saskatchewan contained records for houses in the city of Saskatoon that were distinct from the rest of the province locations. Therefore the 4162 records identified as for houses located within the city of Saskatoon were included in this part of the analysis.

Also shown in Tables 8 & 9 are the ranges of ages (indicated by year of construction), sizes (interior volumes) and airtightness (indicated by ac/h @ 50 Pa) for each municipal district as well as for the total population. Table 10 shows the similar ranges of house characteristics in the Saskatoon dataset. Since the extremes of each measure for the entire populations for the two cities do not provide any picture of the distribution of those populations, the 5th & 95th percentiles for the total population of each measure for the Ottawa and Vancouver areas, and for the city of Saskatoon are also indicated in Tables 8, 9 & 10. In comparing the three tables, it is interesting to note that the population of Ottawa area houses in the EnerGuide For Houses dataset covers a broader age range than does the population of Vancouver area houses, despite the Ottawa dataset containing just over one quarter the number of houses than the Vancouver dataset, possibly reflecting that Vancouver is a younger city than Ottawa, although it may simply indicate that the oldest houses in the Vancouver area have not been inspected by the EnerGuide For Houses program. The Saskatoon dataset is slightly larger than the Ottawa area dataset, but contains houses in the same narrower age range as for Vancouver. The Vancouver dataset covers a broader range of house sizes however, than the Ottawa dataset, and the Vancouver area houses are generally leakier than Ottawa area houses, reflecting perhaps the more diverse economy in Vancouver, and the more severe climate in Ottawa (colder winters and hotter summers). The range of house size in Saskatoon is modestly narrower than in Ottawa, and the range of envelope airtightness of Saskatoon houses is narrower and reflects generally tighter built houses in Saskatoon than in Ottawa.

Table 10. Saskatoon Dataset House Characteristics Ranges – 4162 total records.

Characteristic	Year Built	Internal Volume [cu.m]	Envelope Airtightness [ac/h @ 50 Pa]
Minimum	1901	104.9	0.68
5th percentile	1920	317.5	2.12
95th percentile	1991	798.8	8.63
Maximum	2003	1017.0	20.95

A number of factors, other than the measured airtightness of the exterior envelope, can influence the air infiltration that occurs in a house. In addition to weather conditions, the Shaw Model of air infiltration uses as direct input data the neutral pressure level (the ratio of the height of neutral pressure for calm conditions to the height of the ceiling of the uppermost heated storey in the house, both above grade). As mentioned earlier, the EnerGuide For Houses dataset does not include neutral pressure level data for its houses. However, some measured NPL data is available from other sources, and is provided in tables in Appendix B. Guidance for selection of suitable default values of NPL for the groupings of houses analyzed was drawn primarily from earlier IRC measured datasets, as will be discussed later in this report.

Separate from the specific numerical input data required by a calculation model, some of the factors include the age of the house, the number of storeys, the types of heating system and domestic hot water (DHW) system, the existence and types of flues or chimneys, other deliberate openings, type of ventilation system, exterior envelope construction, the surroundings of the house – both terrain type and shielding from the wind, etc. Some of this information is directly available in the EnerGuide For Houses dataset, some is unavailable there, and some can be inferred from other related information contained in the dataset.

The distributions of house type and number of storeys for the Ottawa, Vancouver and Saskatoon datasets, along with some measures of the statistical distributions of measured airtightness (as ac/h @ 50 Pa) for each subset of houses are provided in Tables 11, 12 & 13. Before proceeding to discuss the conclusions that might be drawn from the statistics reported in these three tables, it may be interesting to review some expectations based on theoretical considerations. As the number of storeys increases, the house height will increase, and with that the maximum stack effect pressure difference across the building envelope and the expanse of building envelope over which those stack pressures act will both increase as well. Consequently, the air change rate due to stack effect alone might be expected to increase with the number of storeys. One possible impact of a partial top storey, e.g., comparing a 1_ storey house with a single storey house, is to increase the effective height for the development of stack effect pressure differences to that of a house with the next whole number of storeys. Following the example, the “stack” height for the one-and-a-half storey house will be approximately the same as a two-storey house. Another possible impact relates to the unlikely successful airtight construction of the complex detailing where the roof assembly, forming most of the exterior envelope of the partial top storey, joins with the wall assembly into which windows are set. This might be expected to exaggerate the leakiness of the, say 1_ storey house compared to an equivalent two-storey house of otherwise identical construction. A consequence of these two factors might lead to a greater air change rate in the 1_ storey house than the one-storey house, and possibly greater than the two-storey house.

The airtightness distributions for the Ottawa houses subset, in Table 11, seem to follow the theoretical arguments described in the previous paragraph. The one-storey houses are more airtight than the two-storey houses that, in turn, are more airtight than the three-storey houses. However, the 1_ storey houses are leakier than not only the one-storey houses, but they are also leakier than the two-storey houses. Similarly, the 2_ storey houses are leakier than both the two-storey and the three storey houses. This might suggest that the envelope construction details for the partial top storey are not generally as airtight as simple vertical walls.

The airtightness distributions for the Vancouver houses subset, in Table 12, seem to tell the opposite tale, in that the three-storey houses are more airtight than the two-storey houses, which, in turn, are more airtight than the one-storey houses. The group of 1_ storey houses is more airtight than the group of one-storey houses, and the group of 2_ storey houses is more airtight than the two-storey houses, indeed than all the other groupings by number of storeys. The reason(s) for this discrepancy from both theoretical expectations and from the Ottawa houses dataset is(are) not clear.

The airtightness distributions for the Saskatoon houses subset, in Table 13, seem to follow the theoretical arguments described above for the Ottawa houses. The one-storey houses are more airtight than the two-storey houses that, in turn, are more airtight than the three-storey houses. The 1_ storey houses are leakier than not only the one-storey houses, but they are also leakier than the two-storey houses, and the 2_ storey houses are leakier than both the two-storey and the three storey houses, and leakier than the 1_ houses. This sheds no further light on the apparent discrepancies displayed by the Vancouver area subset.

The age of a house can influence how leaky it may be, due to deterioration with age and UV exposure of caulking and other air sealing measures, from drying and dimensional change of construction materials such as wood trim, structural framing, sheathing panels, and plastic foam insulation, and general wear & tear of seals such as door (bottom) sweeps, weather stripping of windows and doors, and so forth. Specifically the year of construction will also determine the version of building code regulations with which the construction and assembly methods of the house complied at the time it was built. Tables 14, 15 & 16 show similar measures of the statistical distributions of measured airtightness characteristics for the Ottawa, Vancouver and Saskatoon subsets for various eras of construction to reflect the period prior to the conclusion of the Second World War, that year 1945, and the periods that correspond to substantially different ventilation and envelope construction requirements under the evolving National Building Code of Canada. The trend to ever more and more airtight houses with newer and newer construction is consistent among all three cities’ datasets, in agreement with expectations.

Tables 11 & 14, indicate that two-storey dwellings constitute 2/3 of the Ottawa dataset, of which _ are single-family, detached houses, and the period between 1961 and 1980 has the largest number of two-storey houses in the Ottawa dataset. Similarly, Tables 12 & 15 indicate that two-

Table 11. Distribution of Measured Airtightness with Number of Stories and House Type for the Ottawa Area Subset of the EnerGuide For Houses Dataset.

No. of Storeys	No. of Records	House Type			Measured Airtightness Distribution [ach@50Pa]						Percent of Population
		Single, Detached	Semi-detached	Row House	10th Percentile	1st Quartile	Median	Mean	3rd Quartile	90th Percentile	
1	830	766	10	54	3.25	3.93	5.00	5.60	6.50	8.60	**21.57%**
1 _	42	42	0	0	5.32	6.36	7.89	9.59	9.97	15.69	**1.09%**
Split Entry	2	2	0	0							**0.05%**
Split Level	26	25	1	0	3.19	4.33	5.88	6.80	8.53	10.35	**0.68%**
2	2541	1894	125	522	3.62	4.61	6.47	7.57	8.97	12.80	**66.03%**
2 _	28	22	1	5	6.93	8.48	11.44	12.00	14.63	17.14	**0.73%**
3	379	253	25	101	6.37	8.23	10.02	10.73	12.88	15.94	**9.85%**
Dataset	**3848**	**3004**	**162**	**682**	**3.58**	**4.56**	**6.38**	**7.50**	**9.10**	**12.90**	**100.00%**
% of population		**78.07%**	**4.21%**	**17.72%**							

Table 12. Distribution of Measured Airtightness with Number of Stories and House Type for the Vancouver Area Subset of the EnerGuide For Houses Dataset.

No. of Storeys	No. of Records	House Type				Measured Airtightness Distribution [ach@50Pa]						Percent of Population
		Single, Detached	Semi-detached	Row House	Mobile Home	10th Percentile	1st Quartile	Median	Mean	3rd Quartile	90th Percentile	
1	3448	3360	12	53	23	6.52	8.33	10.00	11.14	12.53	16.66	**27.08%**
1 _	450	442	1	7	0	5.72	7.58	9.47	10.60	12.37	16.21	**3.53%**
Split Entry	34	34	0	0	0	6.58	7.98	9.41	9.72	11.20	12.43	**0.27%**
Split Level	592	587	2	3	0	6.18	7.56	9.41	9.94	11.52	13.89	**4.65%**
2	6455	5945	89	419	2	5.44	7.21	9.05	9.51	11.18	13.81	**50.69%**
2 _	326	318	1	7	0	3.76	4.95	6.73	7.55	9.20	12.40	**2.56%**
3	1429	1328	14	87	0	3.98	5.55	7.83	8.50	10.43	13.62	**11.22%**
Dataset	**12734**	**12014**	**119**	**576**	**25**	**5.36**	**7.22**	**9.22**	**9.85**	**11.48**	**14.66**	**100.00%**
% of population		**94.35%**	**0.93%**	**4.52%**	**0.20%**							

Table 13. Distribution of Measured Airtightness with Number of Stories and House Type for the Saskatoon Subset of the EnerGuide For Houses Dataset.

No. of Storeys	No. of Records	House Type			Measured Airtightness Distribution [ach@50Pa]						Percent of Population
		Single, Detached	Semi-detached	Row House	10th Percentile	1st Quartile	Median	Mean	3rd Quartile	90th Percentile	
1	3001	2928	9	64	2.5	3.05	3.71	4.049667	4.62	5.91	72.10%
1 _	70	68	0	2	3.52	5.415	6.66	7.401286	9.39	11.23	1.68%
Split Entry	3	3	0	0							0.07%
Split Level	19	18	0	1	2.94	3.29	4.06	4.382273	5.18	5.93	0.46%
2	997	925	5	67	2.34	3	3.94	4.711673	5.47	8.47	23.95%
2 _	30	29	0	1	6.32	6.99	9.37	9.498333	10.07	15.60	0.72%
3	42	41	0	1	5.26	6.26	7.54	8.306667	10.25	13.43	1.01%
Dataset	**4162**	**4012**	**14**	**136**	**2.48**	**3.06**	**3.8**	**4.348611**	**4.91**	**6.87**	**100.00%**
% of population		**96.40%**	**0.34%**	**3.27%**							

Table 14. Distribution of Measured Airtightness and Number of Stories with Construction Era for the Ottawa Area Subset of the EnerGuide For Houses Dataset.

Year Built	No. Rcds	% of Pop.	No. of Storeys						Measured Airtightness [ach@50Pa]					
			1	1.5	Split	2	2.5	3	10th %ile	1st Q'rtile	Medn.	Mean	3rd Q'rtile	90th %ile
Pre 1900	149	3.87%	0	3	0	111	0	35	7.76	8.96	12.34	13.71	16.12	21.19
1900-1944	866	22.51%	21	12	0	537	24	272	6.36	8.03	10.22	11.31	13.78	17.42
Pre 1945	1015	26.38%	21	15	0	648	24	307	6.56	8.19	10.45	11.67	14.19	18.19
1945	45	1.17%	9	3	0	31	0	2	5.75	6.92	8.47	8.90	10.30	13.67
1946-1960	832	21.62%	340	20	3	461	3	5	4.20	5.22	6.63	7.15	8.60	10.89
1961-1980	1228	31.91%	377	4	25	810	0	12	3.64	4.33	5.39	5.90	6.90	8.61
1981-1995	571	14.84%	46	0	0	484	1	40	2.86	3.46	4.23	4.85	5.57	7.76
1996-2004	157	4.08%	37	0	0	107	0	13	2.35	2.89	3.68	4.25	5.20	6.84
All	**3848**	**100%**	**830**	**42**	**28**	**2541**	**28**	**379**	**3.58**	**4.56**	**6.38**	**7.50**	**9.10**	**12.90**

Table 15. Distribution of Measured Airtightness and Number of Stories with Construction Era for the Vancouver Area Subset of the EnerGuide For Houses Dataset.

Year Built	No. Rcds	% of Pop.	No. of Storeys						Measured Airtightness [ach@50Pa]					
			1	1.5	Split	2	2.5	3	10th %ile	1st Q'rtile	Medn.	Mean	3rd Q'rtile	90th %ile
Pre 1900	3	0.02%	1	1	0	1	0	0						
1900-1944	1161	9.12%	207	163	5	419	43	324	7.27	8.89	10.86	12.22	13.94	18.39
Pre 1945	1164	9.14%	208	164	5	420	43	324	7.28	8.89	10.86	12.21	13.93	18.36
1945	97	0.76%	45	9	2	36	1	4	6.86	8.62	10.61	11.72	13.33	17.70
1946-1960	2268	17.81%	994	80	90	978	12	114	6.62	8.30	9.98	11.20	12.64	16.61
1961-1980	5910	46.41%	1724	118	394	3258	73	343	6.42	7.82	9.46	10.10	11.54	14.42
1981-1995	2980	23.40%	449	76	133	1609	180	533	4.08	5.30	7.28	7.73	9.50	11.77
1996-2004	315	2.47%	28	3	2	154	17	111	3.06	3.64	5.02	5.89	8.01	9.88
All	**12734**	**100.0%**	**3448**	**450**	**626**	**6455**	**326**	**1429**	**5.36**	**7.22**	**9.22**	**9.85**	**11.48**	**14.66**

Table 16. Distribution of Measured Airtightness and Number of Stories with Construction Era for the Saskatoon Subset of the EnerGuide For Houses Dataset.

Year Built	No. Rcds	% of Pop.	No. of Storeys						Measured Airtightness [ach@50Pa]					
			1	1.5	Split	2	2.5	3	10th %ile	1st Q'rtile	Medn.	Mean	3rd Q'rtile	90th %ile
Pre 1900	0	0.00%												
1900-1944	487	11.70%	144	42	0	233	29	39	4.69	5.75	7.14	7.80	9.35	11.68
1945	21	0.50%	14	0	0	7	0	0	4.04	5.16	6.51	6.84	8.31	10.67
1946-1960	840	20.18%	745	20	3	72	0	0	3.11	3.66	4.43	4.83	5.47	6.86
1961-1980	1872	44.98%	1505	4	16	345	0	2	2.741	3.14	3.68	3.86	4.33	5.12
1981-1995	803	19.29%	500	4	3	295	1	0	2.05	2.48	3.02	3.20	3.64	4.50
1996-2004	139	3.34%	93	0	0	45	0	1	1.44	1.65	1.93	2.14	2.42	2.72
All	**4162**	**100.0%**	**3001**	**70**	**22**	**997**	**30**	**42**	**2.48**	**3.06**	**3.80**	**4.35**	**4.91**	**6.87**

storey houses make up just over _ of the Vancouver dataset, of which over 90% are single-family, detached residences, and the period between 1961 and 1980 has almost _ the total number of two-storey houses in the Vancouver dataset. Tables 13 & 16 indicate that single storey dwellings make up almost _ of the Saskatoon dataset, of which over 96% are single-family, detached houses. Almost _ of the houses in the Saskatoon dataset were built in the period between 1961 and 1980.

This probably reflects to some degree demographics and the general trend to more and more houses built every year, and that the two newest groupings of houses, built between 1996 and 2004 and between 1981 and 1995 would have been built with modern, reasonably good, energy efficiency features and thus would be less likely to have undergone EnerGuide For Houses audits. If the population of houses contained in the EnerGuide For Houses dataset reflects in any way the distribution of existing houses in Canada, with the noted exception that the newest population of houses will probably be under represented due to the energy retrofit support principal objective of the EnerGuide For Houses program, then it could be concluded that the most prevalent house type for both the Ottawa and Vancouver areas is a two-storey, single-family, detached house, and that typical house was probably built between 1961 and 1980, and the most prevalent house type for Saskatoon is a one-storey, single-family, detached house, also probably built in that same 1961-1980 period.

Mechanical Systems Characteristics

The three principal mechanical systems in a typical Canadian dwelling that impact energy consumption are the space heating (and cooling) system, the domestic hot water system and the ventilation system. The EnerGuide For Houses dataset includes information about the furnace type, furnace fuel, DHW type and central ventilation system for each house record. In the Ottawa subset, over 91% of the house records indicate no central ventilation system, almost 5% fans without heat recovery (possibly bathroom and kitchen exhaust fans), and less than 4% heat recovery ventilators. The Vancouver subset indicates no central ventilation in over 96% of the houses, fans without heat recovery in less than 4% and heat recovery ventilators in less than 0.1% of the houses. The Saskatoon dataset indicates no central ventilation system in over 94% of the houses, fans without heat recovery in less than 3%, and heat recovery ventilators in less than 3% of the houses. There seem to be too few houses with central ventilation systems in either subset to try to analyze the influence of mechanical ventilation on the total ventilation typical in the Ottawa, Vancouver or Saskatoon house populations. The EnerGuide For Houses database that was provided to the author of this document did not contain information specifically about kitchen or bathroom fans in the houses, despite the fact that most houses built in the past three or four decades, or more, will have local exhaust fans in both their bathrooms and kitchens. This fact will figure later in this report in the discussions of infiltration model calculation results and the context in which they should be considered.

Tables 17, 18 & 19 indicate the distributions of furnace type and furnace fuel for the Ottawa, Vancouver and Saskatoon subsets, in the EnerGuide For Houses dataset. In the Ottawa subset, almost _ of the houses use natural gas as the energy source for space heating, and the three dominant types of furnaces are either conventional efficiency with continuous pilot light, induced draft medium efficiency with spark ignition, and condensing high efficiency. Another almost 20% of the Ottawa houses are heated with oil, with the dominant furnace type unspecified, and probably have barometric dampers on their otherwise natural draft flues. In the Vancouver subset, more than 95% of the houses are heated with natural gas, with over _ of those of conventional efficiency with continuous pilot lights and probably natural draft flues. Another 10% of the natural gas furnaces are of the mid-efficiency, induced draft type. Oil is used for space heating in less than 1% of the Vancouver houses. In the Saskatoon subset, over 99% of the houses are heated using natural gas furnaces, of which over 2/3 are conventional gas furnaces with a continuous pilot, another _ are mid-efficiency, induced draft furnaces, and virtually all the rest are high-efficiency, condensing gas furnaces. From all three of these subsets the predominant heating system uses a furnace burning natural gas, of conventional efficiency, likely with a continuous pilot light and a natural draft furnace flue. This suggests that the most common neutral pressure level (NPL) for the Ottawa, Vancouver and Saskatoon subsets of the EnerGuide For Houses dataset would be 0.7 or greater, drawing from information summarized in Tables 17, 18 & 19 and described in an earlier study (Reardon 1989).

Table 17. Distribution of Heating System and Energy Source for the Ottawa Area Subset of the EnerGuide For Houses Dataset.

Heating System	No. Hos	% of pop'n	Heating Energy Source					Furnace Flue*
			Electy	Naturl Gas	Oil	Propn	Wood	
Baseboard/Hydronic/Plenum(duct) htrs.	183	4.76%	183					N
Boiler	4	0.10%			4			BD
Boiler w/ continuous pilot	6	0.16%		6				YP
Boiler w/ flue vent damper	2	0.05%			2			BD
Boiler w/ spark ignit.,vent dmpr	15	0.39%		15				AD
Boiler w/ spark ignition	5	0.13%		5				Y
Condensing boiler	1	0.03%		1				N
Condensing furnace: gas	815	21.18%		797	1	17		N
Conventional stove or furnace	2	0.05%					2	Y
Direct vent, non-condensing furnace	2	0.05%			2			N
Forced air furnace	70	1.82%	70					N
Furnace	258	6.70%			258			BD
Furnace w/ continuous pilot	695	18.06%		693		2		YP
Furnace w/ flame retention head	251	6.52%			251			BD
Furnace w/ flue vent damper	176	4.57%			176			BD
Furnace w/ spark ignition & vent damper	185	4.81%		184		1		AD
Furnace w/ spark ignition	279	7.25%		279				Y
Induced draft fan boiler	3	0.08%		3				Y
Induced draft fan furnace	853	22.17%		851		2		Y
Mid-efficiency furnace (no dilution air)	38	0.99%			38			N
Radiant ceiling panels	5	0.13%	5					N
Entire Dataset (sub)totals	**3848**	**100%**	**258**	**2834**	**732**	**22**	**2**	
Percent of total population			6.70%	73.6%	19.0%	0.57%	0.05%	
* Existence and type of furnace flue inferred from furnace type and energy source (furnace fuel). Y = yes, YP = yes w/ cont. pilot, N = no, BD = barometric damper, AD = automatic damper,								

In the Ottawa dataset, the three largest groups of heating systems are 851 houses with induced draft (mid-efficiency), 797 with condensing (high-efficiency) and 693 with continuous pilot (conventional efficiency) natural gas-fired, forced-air furnaces. In the Vancouver dataset, the largest group of houses are 9774 heated by continuous pilot, conventional, natural gas-fired, forced-air furnaces. The next largest group in the Vancouver dataset are 1344 heated by induced draft, natural gas-fired, forced-air furnaces. There are also 214 houses with natural

Table 18. Distribution of Heating System and Energy Source for the Vancouver Area Subset of the EnerGuide For Houses Dataset.

Heating System	No. Houses	% of pop'n	Heating Energy Source					Furnace Flue*
			Electrty	Natural Gas	Oil	Propane	Wood	
Baseboard/Hydronic/Plenum(duct) htrs.	440	3.46%	440					**N**
Boiler	1	0.01%			1			**BD**
Boiler w/ continuous pilot	18	0.14%		18				**YP**
Boiler w. spark ignition	1	0.01%		1				**Y**
Condensing furnace	214	1.68%		214				**N**
Condensing furnace (no chimney)	1	0.01%			1			**N**
Forced air furnace	6	0.05%	6					**N**
Furnace	82	0.64%			82			**BD**
Furnace w/ continuous pilot	9777	76.78%		9774		3		**YP**
Furnace w/ flame retention head	3	0.02%			3			**BD**
Furnace w/ flue vent damper	8	0.06%			8			**BD**
Furnace w/ spark ign, vent damper	367	2.88%		367				**AD**
Furnace w/ spark ignition	450	3.53%		450				**Y**
Induced draft fan furnace	1344	10.55%		1344				**Y**
Mid-efficiency furnace (no diln. air)	4	0.03%			4			**N**
Radiant ceiling panels	15	0.12%	15					**N**
Radiant floor panels	3	0.02%	3					**N**
Entire Dataset (sub)totals	**12734**	**100%**	**464**	**12168**	**99**	**3**	**0**	
Percent of population			3.64%	95.56%	0.78%	0.02%	0.00%	
* Existence and type of furnace flue inferred from furnace type and energy source (furnace fuel). Y = yes, YP = yes w/ cont. pilot, N = no, BD = barometric damper, AD = automatic damper,								

gas, condensing furnaces in the Vancouver dataset. In the Saskatoon dataset, the largest group of houses are 2870 with conventional, continuous pilot, gas-fired, forced-air furnaces. The next largest group in Saskatoon are 968 houses heated by induced draft, gas-fired furnaces. There are also 243 Saskatoon houses heated by high-efficiency, gas-fired, condensing furnaces. Conventional gas furnaces with continuous pilot lights will most likely have natural draft furnace flues, and their representative NPL will be 0.7. Condensing gas furnaces will not have a furnace flue, and their representative NPL may be 0.5. Induced draft, gas furnaces will likely have a furnace flue that will be open but without a continuous pilot light, their NPL may more typically be 0.6. This offers three subsets that can be compared amongst the three cities.

Tables 20, 21, and 22 show the distributions of domestic hot water heating systems in the houses in the Ottawa, Vancouver and Saskatoon subsets of the EnerGuide For Houses database. No information is provided therein about the energy source used by these systems, although the DHW system's efficiency is reported for each house. For systems whose stated efficiency is 100%, it might be assumed that they use electricity for heating the water, and have no flue. For houses that use natural gas, propane or oil as their furnace fuel, it is likely that their water heater uses the same fuel when the stated DHW efficiency is not 100%. Hence, the sub-distributions by furnace fuel are also reported in these DHW tables. In the Vancouver area houses, over 98% use a conventional water heater, and will thereby have a natural draft type

Table 19. Distribution of Heating System and Energy Source for the Saskatoon Subset of the EnerGuide For Houses Dataset.

Heating System	No. of Rec'ds	% of pop'n	Heating Energy Source					Furnace Flue*
			Electy	Natrl Gas	Oil	Propn	Wood	
Baseboard/Hydronic/Plenum(duct) htrs.	7	0.17%	7					**N**
Boiler w/ continuous pilot	14	0.34%		14				**Y**
Boiler w/ spark ignition & vent damper	1	0.02%		1				**BD**
Condensing boiler	1	0.02%		1				**N**
Condensing furnace: gas	243	5.84%		243				**N**
Forced air furnace	6	0.14%	6					**N**
Furnace	4	0.10%			4			**BD**
Furnace w/ continuous pilot	2871	68.98%		2870		1		**YP**
Furnace w/ flame retention head	1	0.02%			1			**BD**
Furnace w/ spark ignition & vent damper	4	0.10%		4				**AD**
Furnace w/ spark ignition	42	1.01%		42				**Y**
Induced draft fan furnace	968	23.26%		968				**Y**
Entire Dataset (sub)totals	**4162**	**100%**	**13**	**4143**	**5**	**1**	**0**	
Percent of total population			0.31%	99.5%	0.12%	0.02%	0.00%	

* Existence and type of furnace flue inferred from furnace type and energy source (furnace fuel).
Y = yes, YP = yes w/ cont. pilot, N = no, BD = barometric damper, AD = automatic damper,

of flue if the furnace uses a flue. In Saskatoon, over 97% of the houses have a conventional water heater, and thus will have a natural draft flue. Over 80% of the Ottawa area houses use a conventional tank water heater that uses a natural draft type of flue. Another 14% of Ottawa houses use an induced draft (power-vented) water heater, which typically vents through a sidewall, low on the house exterior. When in operation, their power venting will serve as an exhaust fan that tends to raise the house NPL, but when not in operation, their sidewall vent may serve as an opening in the lower part of the building envelope which tends to lower the house NPL. However, the majority, 80%, of these power-vent DHW systems are in houses that also have a high-efficiency condensing gas furnace, and another 10% of them are in houses with a mid-efficiency, induced draft gas furnace which will tend to have NPLs that are lower than houses with a natural draft furnace and/or DHW flue. These statistics for the three cities support the indications described above that are drawn from the statistics for the distributions of furnace type and furnace fuel in the same cities. There is no need to attempt to subdivide further the three most frequent scenarios with their characteristic NPL values described above for comparison amongst the three cities.

Table 20. Distribution of DHW System and Furnace Fuel for the Ottawa Area Subset of the EnerGuide For Houses Dataset.

Water Heater	No. of Rec'ds	% of pop'n	Heating Energy Source					DHW Flue*
			Electricity	N.Gas	Oil	Propane	Wood	
Condensing	4	0.10%		4				**N**
Conserver tank	98	2.55%	22	18	57	1		**?**
Conventional tank	2390	62.11%	212	1516	654	6	2	**Y**
Conventional tank (pilot)	709	18.43%		705	3	1		**YP**
Direct vent (sealed)	31	0.81%		29	1	1		**N**
Direct vent (sealed, pilot)	25	0.65%	2	22		1		**N**
Heat pump	2	0.05%	2					**N**
Induced draft fan	523	13.59%	13	487	13	10		**N**
Induced draft fan (pilot)	58	1.51%	5	50	2	1		**N**
Instantaneous	1	0.03%		1				**Y**
Instantaneous (pilot)	1	0.03%		1				**YP**
Solar collector system	1	0.03%		1				**N**
Tankless coil	3	0.08%			2	1		**?**
Not specified	2	0.05%	2					**N**
Entire Dataset (sub)totals	**3848**	**100.0%**	**258**	**2834**	**732**	**22**	**2**	
Percent of total population			6.70%	73.6%	19.0%	0.57%	0.05%	
* Existence and type of DHW flue inferred from DHW type and energy source (furnace fuel). Y = yes, YP = yes w/ cont. pilot, N = no, BD = barometric damper, AD = automatic damper,								

Table 21. Distribution of DHW System and Furnace Fuel for the Vancouver Area Subset of the EnerGuide For Houses Dataset.

Water Heater	No. of Rec'ds	% of pop'n	Heating Energy Source					DHW Flue*
			Electricity	N.Gas	Oil	Propane	Wood	
Condensing	17	0.13%	2	15				**N**
Conserver tank	104	0.82%	19	82	3			**?**
Conventional tank	1305	10.25%	352	866	85	2		**Y**
Conventional tank (pilot)	11195	87.91%	82	11101	11	1		**YP**
Direct vent (sealed)	10	0.08%		10				**N**
Direct vent (sealed, pilot)	21	0.16%	3	18				**N**
Heat pump	2	0.02%	2					**N**
Induced draft fan	21	0.16%		21				**N**
Induced draft fan (pilot)	15	0.12%	4	11				**N**
Instantaneous	15	0.12%		15				**Y**
Instantaneous (pilot)	21	0.16%		21				**YP**
Solar collector system	0	0.00%						**N**
Tankless coil	8	0.06%		8				**?**
Entire Dataset (sub)totals	**12734**	**100.0%**	**464**	**12168**	**99**	**3**	**0**	
Percent of total population			**3.64%**	**95.56%**	**0.78%**	**0.02%**	**0.00%**	
* Existence and type of DHW flue inferred from DHW type and energy source (furnace fuel). Y = yes, YP = yes w/ cont. pilot, N = no, BD = barometric damper, AD = automatic damper,								

Table 22. Distribution of DHW System and Furnace Fuel for the Saskatoon Subset of the EnerGuide For Houses Dataset.

Water Heater	No. of Rec'ds	% of pop'n	Heating Energy Source					DHW Flue*
			Electricity	N.Gas	Oil	Propane	Wood	
Condensing	14	0.34%		14				**N**
Conventional tank	3700	88.90%	12	3683	4	1		**Y**
Conventional tank (pilot)	367	8.82%		366	1			**YP**
Direct vent (sealed)	13	0.31%		13				**N**
Direct vent (sealed, pilot)	5	0.12%		5				**N**
Induced draft fan	49	1.18%		49				**N**
Induced draft fan (pilot)	6	0.14%		6				**N**
Instantaneous	5	0.12%		5				**Y**
Not Applicable	3	0.07%	1	2				**?**
Entire Dataset (sub)totals	**4162**	**100.0%**	**13**	**4143**	**5**	**1**	**0**	
Percent of total population			0.31%	99.54%	0.12%	0.02%	0.0%	
* Existence and type of DHW flue inferred from DHW type and energy source (furnace fuel). Y = yes, YP = yes w/ cont. pilot, N = no, BD = barometric damper, AD = automatic damper,								

Task 5 – Analytical Review of Selected Data to Determine Periods of Inadequate Natural Ventilation

As mentioned earlier, the Shaw model for simulation of air infiltration in houses was implemented in a computer program using the Microsoft Visual C++ language, to facilitate the calculation of hourly air infiltration rates for each house in the Ottawa, Vancouver and Saskatoon subsets of the EnerGuide For Houses dataset, using hourly weather data for a typical meteorological year for those three locales. The computer program was designed to also accumulate the annual statistics, for each house record, of that house's hourly infiltration rates: the average (mean), median, standard deviation, maximum and minimum, as well as the total number of hours during the year, and the number of continuous periods, when the air infiltration rate was less than 0.3 ac/h, and the longest such period.

A new, proposed "metric" of performance of natural ventilation compared to constant mechanical ventilation at the rate of 0.3 ac/h, was also calculated and output for each house (Macdonald & Reardon, 2007). This new metric, called the Under Supply, is the total integrated number of air changes less than those that would have been supplied by a constant ventilation rate at the 0.3 ac/h requirement, for all the periods where the infiltration rate was less than the required continuous rate. This metric allows no credit for excess ventilation just before or just after a period where the natural ventilation rate is less than the required continuous rate. This Under Supply metric can be expressed mathematically as shown in Equation 1 below.

$$US = \sum_i (0.3ac/h - I_i), \qquad \text{for all } i \text{ where } I_i < 0.3 \text{ ac/h} \qquad \text{(Eq.1)}$$

<u>where</u>:

US = Under Supply metric, [air changes]

I_i = natural ventilation (infiltration) rate calculated by the model for the ith hour of the year, [ac/h].

The input data files created for processing the houses in the three cities' subsets contained the house flow coefficient [L/sPa^n], the house flow exponent, the house volume [cu.m], and a neutral pressure level value for the house. The year of construction for the house was added to the front of each input record as a redundant identifier. To streamline the calculations, separate input data sets were created using one value of NPL from the range of NPL values of possible interest to this study: 0.25, 0.5, 0.6, 0.65, 0.7, 0.75, and 0.9, for each of the two cities. That range consists of two components, the first of which is a simple coverage by quarters of the theoretical range of NPL values between the extremes of 0 and 1 (neither extreme is of practical interest), i.e., 0.25, 0.5 and 0.75. The second component is drawn from previous research in which NPL values were actually measured for approximately 20 houses in Ottawa and seven in Winnipeg (Reardon 1989) where 0.6 for houses without a natural draft flue and 0.7 for houses with a natural draft flue were found to be reasonably representative of that small sample. That same study concluded that a default value of 0.65 for the NPL could be useful for model calculations where it was not known whether the house, or houses, of interest had a natural draft flue. The extreme value of 0.9, and greater, was actually observed in the set of measured NPL values in the cited study, and 0.25 is close enough to the smallest observed NPL value in that same study to serve two purposes in this range of NPL values. The 1989 Cross-Canada Survey of Airtightness in New Merchant-Built homes (Parekh & Reynolds, 1992) also produced measured NPL values in 20 Saskatchewan houses (10 in Regina and 10 in Saskatoon), which were in the range of 0.216 to 0.843, and the 10th and 90th percentile NPL values were 0.352 and 0.712. Additional sources of measured NPL data in Canadian houses are discussed in Appendix B. Some of those sources and their measured NPL data required assumptions that cannot be verified precisely in order to reference their NPL values to grade level around their respective houses. In other NPL datasets, NPL values greater than 1.0 were reported, and such values outside the theoretical range require some influence other than pure stack effect (the basis for the theoretical range) on the building's envelope pressure distribution. Some examples of such influences are: unacceptably high wind speeds, flues that are warmed by pilot lights or combustion appliances actually firing, and operation of net-exhaust or net-supply mechanical ventilation. Those extenuating circumstances are not described in sufficient detail in these other source documents to be able to exploit their NPL data in this study.

The simulation output files contained as many calculation records as houses: 3848 for Ottawa, 12734 for Vancouver, and 4162 for Saskatoon, and 10 extra fields of calculated data than entered in the input data files. The message here is that the output data are too numerous to present individually in any form other than an electronic data file. However, the simulation results for each value of NPL were appended to the original EnerGuide For Houses subset datasets, record for record, to facilitate groupings for which trends and statistics could be examined. Appendix C contains listings of the yearly statistics of hourly air infiltration rates calculated by the model computer program that have been grouped by heating system and by age (period of construction), for each NPL value and for each city considered.

What is presented here is a detailed examination of the hourly infiltration rates calculated for a prototypical but real, two-storey, detached house in Ottawa of median airtightness (6.47 ac/h @ 50 Pa, identified as a house built in 1948, with a high-efficiency, natural gas-fired, condensing furnace. With a condensing gas furnace, this house would not likely have a natural draft furnace flue, so its NPL might better be represented by a value of 0.6 (or arguably, even 0.5), and for an urban and suburban setting, it was assumed to be shielded for purposes of modeling wind-driven air infiltration. Table 23 lists the average natural ventilation by air infiltration for each month of the year calculated from the hourly infiltration rates calculated for the house, and the breakdown of the infiltration due to stack effect alone and to wind alone, and the balance between these individual components alone and the monthly average of modeled total air infiltration. The figures for the entire year of hourly infiltration rates are also included in

Table 23. From these results it can be seen that over the entire year, air infiltration provides approximately 128 excess air changes, based on a continuous requirement of 0.3 ac/h, and that during the milder and warm weather months from May through September natural infiltration into the house as if it were operated completely shut-up with all windows and doors kept closed does not meet the supply of 0.3 ac/h, as indicated by a negative value for the excess air changes for those months. This should not be surprising, since stack effect is diminished when the outside air temperature is mild to hot, and wind may not pick up the "slack" when stack effect-driven infiltration falls off as the weather warms. During the months November through March the infiltration provides more than sufficient ventilation, perhaps wasteful of space heating energy. The months of April and October have average air change rates that meet the 0.3 ac/h requirement without excess ventilation.

Also reported in Table 23 are the monthly figures for the proposed new metric Under Supply as well as the yearly value, expressed both as the actual number of air changes deficit and as a percentage of the total supply required at the continuous rate of 0.3 ac/h. According to the proposed acceptability range for the Under Supply metric (Macdonald & Reardon 2007) of 5-7% along with the average or mean air change rate being acceptable, i.e., at least 0.3 ac/h, Table 23 results indicate that the natural ventilation by air infiltration is acceptable for the months October through April, but less than acceptable for the months May through September.

Table 23. Monthly and Entire Year Average Infiltration Rates [ac/h] for a Two-Storey, Detached Ottawa Area House with Median Airtightness of 6.47 ac/h at 50 Pa, and Assumed NPL = 0.60

Month	Supplied by Stack Effect Alone	Extra Provided by Wind	Supplied by Wind Alone	Extra Provided by Stack Effect	Average Monthly Airchange Rate	Excess Air Changes for Month	Under Supply for Month [ac]	[%]
January	**0.4006**	**0.0616**	**0.2793**	**0.1829**	**0.4622**	**120.69**	**0.0489**	0.02%
February	0.3828	0.0343	0.2073	0.2098	0.4171	78.70	0.2294	0.11%
March	0.3179	0.0799	0.2749	0.1229	0.3977	72.72	0.8425	0.38%
April	0.2367	0.0930	0.2463	0.0833	0.3296	21.34	11.2052	5.19%
May	0.1619	0.1213	0.2444	0.0387	0.2831	-12.56	24.7807	11.10%
June	0.1022	0.1432	0.2256	0.0198	0.2454	-39.28	47.0147	21.77%
July	0.0842	0.1180	0.1812	0.0210	0.2023	-72.72	76.5447	34.29%
August	**0.0843**	**0.0823**	**0.1404**	**0.0262**	**0.1666**	**-99.25**	100.8296	45.17%
September	0.1380	0.0775	0.1624	0.0532	0.2156	-60.80	**145.5042**	67.36%
October	0.2182	0.0885	0.2282	0.0784	0.3067	4.97	14.9619	6.70%
November	0.2857	0.0525	0.2001	0.1381	0.3382	27.51	5.0200	2.32%
December	0.3644	0.0530	0.2473	0.1701	0.4174	87.35	1.2135	0.54%
Entire Year	**0.2306**	**0.0841**	**0.2200**	**0.0947**	**0.3147**	**128.67**	**345.7190**	**13.16%**

The changing make-up of infiltration as outdoor air temperature warms up from winter to summer is illustrated graphically in Figures 1 & 2 in which are plotted, for the months of January and August respectively the extremes in Ottawa for most and least air infiltration, the dominant component contributing to the total infiltration for that month and the complement added by the infiltration component of secondary importance, be it stack effect dominant for the cold month or wind effect for the warm month.

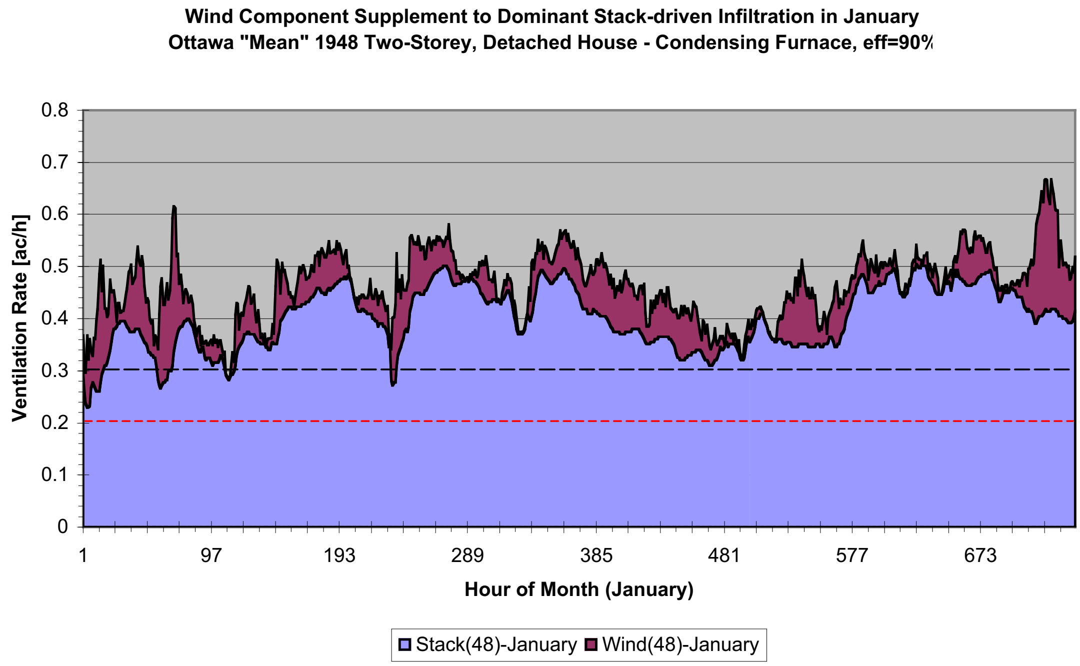

Figure 1. Dominant and Secondary Components of Air Infiltration for January in Ottawa "Average" House – Two-Storey, Detached, 6.47 ac/h@50Pa, Condensing, High-Efficiency Natural Gas Furnace, Shielded from Wind, NPL=0.6.

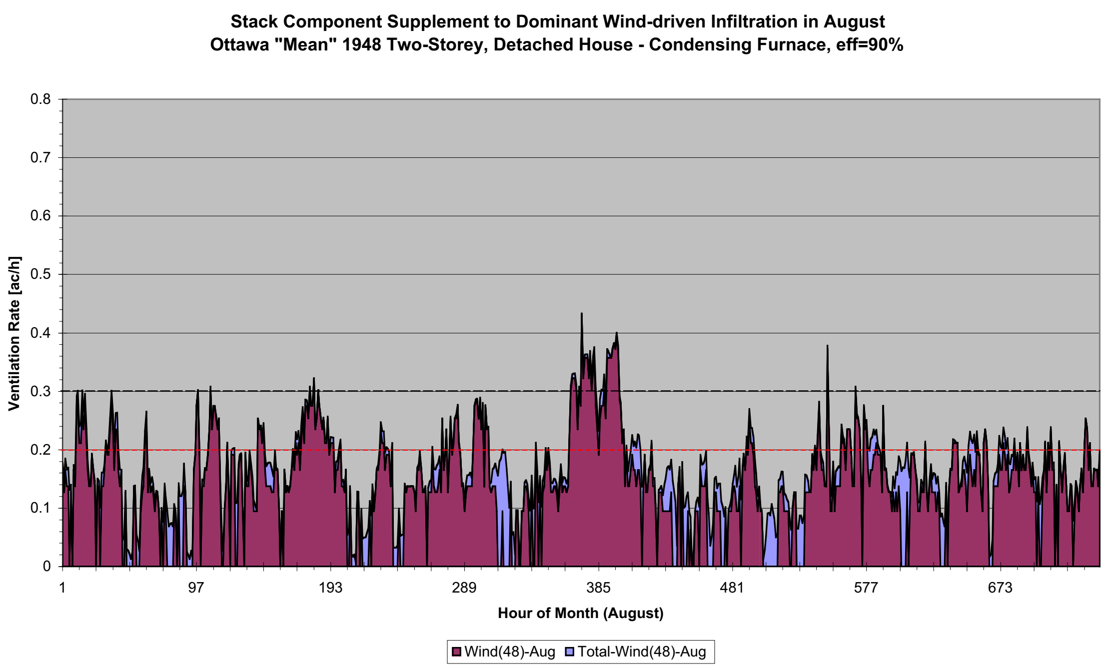

Figure 2. Dominant and Secondary Components of Air Infiltration for August in Ottawa "Average" House – Two-Storey, Detached, 6.47 ac/h@50Pa, Condensing, High-Efficiency Natural Gas Furnace, Shielded from Wind, NPL=0.6

In the coldest month, January, Figure 1 shows that stack-effect alone meets or exceeds the required ventilation rate of 0.3 ac/h, and the added influence of the wind is relatively minor. In Figure 2, for August, with the least air infiltration, the wind effect dominates very weak stack effect, and the total infiltration rate, for the house operated with all windows, doors and intentional openings closed, almost never meets the required ventilation rate of 0.3 ac/h, and is usually much less than that requirement. It is important to note that the type of building operation represented by this simple modeling approach is unrealistic. During mild and warm weather, occupants often open their windows wide when they are at home, and even weak breezes will move much more air into and out of the house through the opened windows, than the model of air infiltration indicates.

The most typical house type and number of storeys in the Vancouver subset is also a two-storey, detached house, and the median airtightness for that group of two-storey houses in Vancouver is 9.05 ac/h @ 50 Pa. The specific prototypical house was built in 1971, interior volume is 513 cu.m, and it has a conventional efficiency, natural gas furnace with a continuous pilot light and a natural draft flue. Its NPL value should be 0.7 or greater. Table 24 summarizes the hourly infiltration rates calculated by the model for each month and for the entire year, assuming its NPL is 0.7 and it is shielded from the wind, typical of urban and suburban settings. These results indicate that the month with the maximum average air infiltration rate is December in Vancouver, not January as it was in Ottawa, and the month with the lowest average infiltration rate is July, not August as in Ottawa. However, even in the month with the lowest average air infiltration rate, the requirement of 0.3 ac/h is met, with an excess of total air changes for the month. The changing make-up of natural ventilation from coldest to mildest month in Vancouver is shown in Figures 3 and 4.

Table 24. Monthly and Entire Year Average Infiltration Rates [ac/h] for a Two-Storey, Detached Vancouver Area House with Median Airtightness of 9.05 ac/h at 50 Pa, NPL = 0.70.

Month	Supplied by Stack Effect Alone	Extra Provided by Wind	Supplied by Wind Alone	Extra Provided by Stack Effect	Average Monthly Airchange Rate	Excess Air Changes for Month	Under Supply for Month	
							[ac]	[%]
January	0.4528	0.0562	0.2722	0.2367	0.5090	155.47	0.00	0.00%
February	0.4214	0.0488	0.2473	0.2229	0.4702	114.41	0.00	0.00%
March	0.4028	0.0688	0.2923	0.1793	0.4716	127.70	0.33	0.15%
April	0.3544	0.0758	0.2804	0.1498	0.4303	93.79	1.72	0.80%
May	0.2930	0.1029	0.2916	0.1043	0.3959	71.36	4.37	1.96%
June	0.2197	0.1150	0.2653	0.0693	0.3347	24.97	15.35	7.11%
July	**0.1780**	**0.1401**	**0.2695**	**0.0486**	**0.3181**	**13.46**	**19.91**	**8.92%**
August	0.1679	0.1637	0.2924	0.0392	0.3316	23.53	12.79	5.73%
September	0.2489	0.1400	0.3110	0.0778	0.3889	63.98	5.94	2.75%
October	0.3351	0.0905	0.3063	0.1193	0.4256	93.42	0.72	0.32%
November	0.4164	0.0671	0.2838	0.1997	0.4835	132.10	0.03	0.01%
December	**0.4456**	**0.0855**	**0.3477**	**0.1833**	**0.5311**	**171.92**	0.00	0.00%
Entire Year	**0.3274**	**0.0966**	**0.2887**	**0.1353**	**0.4240**	**1086.10**	**61.16**	**2.33%**

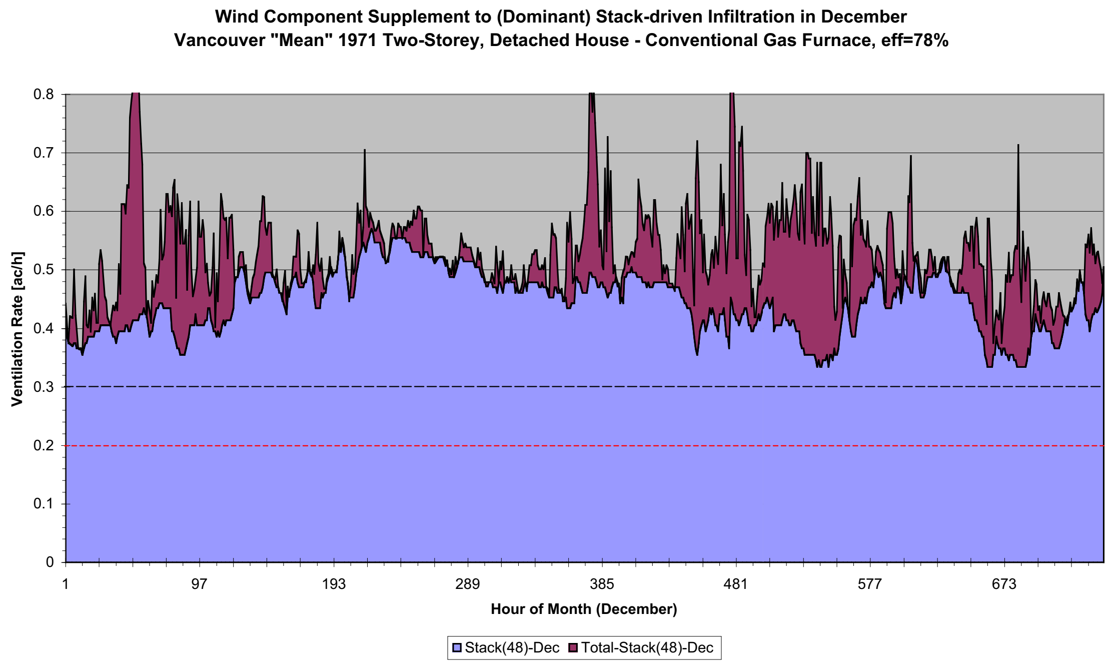

Figure 3. . Dominant and Secondary Components of Air Infiltration for December in Vancouver "Average" House – Two-Storey, Detached, 9.05 ac/h @ 50 Pa, Conventional Efficiency, Natural Gas Furnace, Shielded from Wind, NPL=0.7.

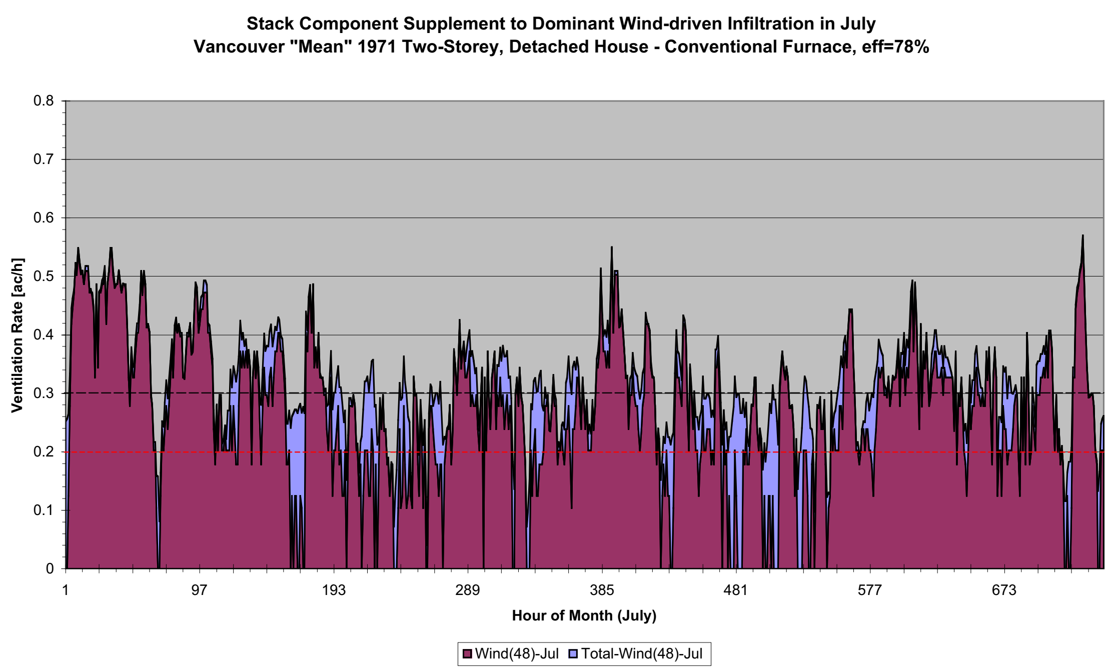

Figure 4. Dominant and Secondary Components of Air Infiltration for July in Vancouver "Average" House – Two-Storey, Detached, 9.05 ac/h @ 50 Pa, Conventional Efficiency, Natural Gas Furnace, Shielded from Wind, NPL=0.7.

This prototypical Vancouver house is leakier than the prototypical Ottawa house by almost 50%, and it is larger in volume. It also will have a higher neutral pressure level, all of which will contribute to greater overall air infiltration, even if it were located in the same climate as the Ottawa prototype. Table 24 indicates that the air infiltration exceeds the 0.3 ac/h requirement in most months of the year. Figure 3 illustrates a substantial excess ventilation during the coldest month, which will cause an unnecessary energy penalty for heating that excess ventilation air. This could be ameliorated by reducing the air leakage in this house. Figure 4 illustrates that even though the monthly average air infiltration rate reported in Table 24 is acceptable, the hour-by-hour satisfaction of the 0.3 ac/h requirement is somewhat sketchy.

The most typical house in the Saskatoon dataset is a one-storey, detached house and the median airtightness for this group of houses is 3.71 ac/h at 50 Pa. The specific, real prototype house was built in 1961, has an interior volume of 486.26 cu.m, and a conventional gas-fired furnace with a stated efficiency of 60%. It has a continuous pilot and undoubtedly a natural draft flue, so its NPL value will be assigned the value 0.7. Table 25 summarizes the averages of hourly infiltration rates calculated by the model for each month and for the entire year, assuming its NPL is 0.7 and it is shielded form the wind, typical of urban and suburban settings.

Table 25. Monthly and Entire Year Average Infiltration Rates [ac/h] for a One-Storey, Detached Saskatoon Area House with Median Airtightness of 3.71 ac/h at 50 Pa, NPL = 0.70.

Month	Supplied by Stack Effect Alone	Extra Provided by Wind	Supplied by Wind Alone	Extra Provided by Stack Effect	Average Monthly Airchange Rate	Excess Air Changes for Month	Under Supply for Month	
							[ac]	[%]
January	**0.2831**	**0.0223**	**0.1102**	**0.1953**	**0.3054**	**4.03**	**15.04**	**6.74%**
February	0.2671	0.0263	0.1171	0.1763	0.2934	-4.44	15.80	7.84%
March	0.2373	0.0290	0.1178	0.1486	0.2663	-25.06	29.02	13.00%
April	0.1592	0.0704	0.1617	0.0679	0.2297	-50.65	52.81	24.45%
May	0.1036	0.0823	0.1447	0.0411	0.1859	-84.93	85.12	38.14%
June	0.0700	0.0711	0.1130	0.0282	0.1411	-114.38	114.40	52.96%
July	**0.0602**	**0.0665**	**0.1048**	**0.0219**	**0.1267**	**-128.91**	**128.91**	**57.76%**
August	0.0670	0.0627	0.1051	0.0247	0.1297	-126.67	126.67	56.75%
September	0.1105	0.0628	0.1255	0.0478	0.1733	-91.23	91.23	42.23%
October	0.1524	0.0383	0.1103	0.0804	0.1907	-81.31	81.37	36.46%
November	0.2251	0.0271	0.1137	0.1385	0.2522	-34.41	38.28	17.72%
December	0.2727	0.0206	0.1048	0.1885	0.2933	-4.99	18.32	8.21%
Entire Year	**0.1668**	**0.0484**	**0.1190**	**0.0962**	**0.2152**	**54.02**	**796.96**	**30.33%**

These results indicate that the month with the maximum average air infiltration rate is January in Saskatoon, as it was in Ottawa, and the month with the lowest average air infiltration rate is July like Vancouver, not August as in Ottawa. The only month in which the requirement of 0.3 ac/h is met on average is January, and is the only month with an excess of total air changes for the month. This is a very airtight house and is one-storey so it does not have the height needed to generate strong stack effect pressures. It is likely that the 0.3 ac/h requirement is not satisfied on a continuous hour-by-hour basis in this house, even in the one coldest month of January, as indicated in Table 25, following the lesson learned from Figures 1 and 3 above for the other two cities of Ottawa and Vancouver.

To allow better comparison between Saskatoon and the other two cities, a prototypical, representative two-storey, detached house was also selected. It was built in 1983, has an interior volume of 556.14 cu.m, a conventional gas-fired furnace with continuous pilot, stated efficiency of 65%, and a natural draft furnace flue. Therefore for the analysis, its NPL was set at 0.70. The median airtightness for this group is 3.94 ac/h at 50 Pa. Table 26 summarizes the hourly infiltration rates calculated by the model for each month and for the entire year, assuming its NPL is 0.7 and it is shielded from the wind, typical of urban and suburban settings. These results indicate that the month with the maximum average air infiltration rate is January in Saskatoon, as it was in Ottawa, and the month with the lowest average air infiltration rate is July, not August as in Ottawa. The only months where the requirement of 0.3 ac/h is met, on average, are January, February, March and December. While this house is only slightly more airtight than the one-storey Saskatoon house, its yearly average infiltration rate is substantially greater, and its Under Supply metric for the year is less than one half that of the one-storey house.

Table 26. Monthly and Entire Year Average Infiltration Rates [ac/h] for a Two-Storey, Detached Saskatoon Area House with Median Airtightness of 3.94 ac/h at 50 Pa, NPL = 0.70.

Month	Supplied by Stack Effect Alone	Extra Provided by Wind	Supplied by Wind Alone	Extra Provided by Stack Effect	Average Monthly Airchange Rate	Excess Air Changes for Month	Under Supply for Month	
							[ac]	[%]
January	**0.3224**	**0.0079**	**0.2037**	**0.1266**	**0.3303**	**22.54**	**2.63**	**1.18%**
February	0.3099	0.0151	0.2098	0.1152	0.3250	16.80	2.46	1.22%
March	0.2857	0.0206	0.2105	0.0959	0.3064	4.74	9.37	4.20%
April	0.2147	0.0806	0.2668	0.0285	0.2953	-3.38	15.76	7.29%
May	0.1566	0.1042	0.2444	0.0164	0.2608	-29.17	35.75	16.02%
June	0.1186	0.0998	0.2046	0.0138	0.2184	-58.75	59.82	27.70%
July	**0.1071**	**0.0960**	**0.1945**	**0.0086**	**0.2031**	**-72.09**	**72.78**	**32.61%**
August	0.1157	0.0898	0.1955	0.0100	0.2055	-70.30	71.34	31.96%
September	0.1649	0.0804	0.2216	0.0237	0.2453	-39.42	41.08	19.02%
October	0.2091	0.0420	0.2028	0.0483	0.2511	-36.39	37.70	16.89%
November	0.2749	0.0191	0.2099	0.0841	0.2940	-4.30	12.29	5.69%
December	0.3143	0.0073	0.1955	0.1262	0.3216	16.09	4.51	2.02%
Entire Year	**0.2156**	**0.0554**	**0.2132**	**0.0579**	**0.2710**	**111.84**	**365.49**	**13.91%**

Comparing the two-storey prototype representative house for the three cities, the Ottawa house has a mean yearly air change rate of 0.3147 ac/h but an Under Supply of 13.16% for the year and has inadequate natural ventilation by air infiltration during its five warmest months. The Vancouver house has a mean yearly air change rate of 0.424 ac/h and an Under Supply of 2.33% for the year and has adequate air infiltration throughout the year. The Saskatoon two-storey house has a yearly mean air change rate of 0.2710, and an Under Supply of 13.91% for the year, and appears to have inadequate natural ventilation by air infiltration for the months April through November.

Assessments Based on Aggregated Statistics for Groups of Houses in Each City

The previous section has presented comparisons between real houses from each city's dataset that are presented as prototypes for detailed examination of their modeled hourly infiltration rates. This section presents comparisons amongst similar groupings of houses from each city. One of the potentially most useful groupings was by heating system type and fuel, since their furnace flue characteristics would be similar. The three groupings selected for detailed presentation here are all heated by natural gas, as that is the predominant fuel in all three cities. The three furnace types are (a) conventional with continuous pilot (NPL=0.70); (b) induced draft, mid-efficiency (NPL=0.60); and (c) condensing, high-efficiency (NPL=0.50). Table 27 lists the aggregated statistics for the year for all three of these heating system subsets in each of the three cities. Another useful grouping is by age, specifically by period of construction as already defined. Table 28 reports the aggregated yearly statistics for the various groupings by period of construction, for the three cities.

If the criteria for adequate or acceptable natural ventilation by air infiltration are an annual mean hourly rate at least 0.3 ac/h and percentage Under Supply less than 10%, then the results reported in Table 27 suggest that Vancouver houses overall may have acceptable ventilation by natural means, and in particular Vancouver houses with natural draft conventional gas furnaces have acceptable natural ventilation. The Vancouver houses with other types of heating systems have yearly average natural ventilation by air infiltration above 0.3 ac/h, but their Under Supply is above 10% and their longest continuous period when air infiltration is less than 0.3 ac/h each exceed 720 hrs (30 days).

If these two criteria must both be met for acceptable ventilation by natural means, then neither the Ottawa nor the Saskatoon whole sets of houses in the database, as single groups, have adequate natural ventilation. The groupings by heating system for each of Ottawa and Saskatoon also fail to meet these two criteria and therefore may be judged to have inadequate natural ventilation. However, the whole Ottawa dataset, and the three groupings by heating system all have annual average hourly infiltration rates greater than 0.3 ac/h, all but the group with condensing gas furnaces have a yearly Under Supply less than 20%. The average longest periods with air infiltration continuously less than 0.3 ac/h for Ottawa, as a whole and for the three heating system groupings, are all in excess of 1000 hours (40 days).

The Saskatoon dataset, and all three groupings by heating system fail to meet either of the two criteria. In all four cases for the Saskatoon houses, the annual average infiltration rate is less than 0.3 ac/h, and the average Under Supply metric is greater than 20%. The average longest periods with natural ventilation continuously less than 0.3 ac/h for Saskatoon, as a whole and for the three heating system groupings, are all in excess of 2400 hours (100 days).

With the exception of the Ottawa dataset, Table 27 illustrates that as the NPL increased, assuming the NPL values assigned to each heating system grouping are fairly representative, the annual average infiltration rate for the group generally increased, as might be expected from the model equations described in Appendix A. The reason why the Ottawa dataset does not follow this trend is not clear.

Table 27. Aggregated Annual Statistics for Three Cities & Three Predominant Heating System Types – EnerGuide For Houses

Heating System	No. of Houses	% of Pop'n.	NPL	Max [ac/h]	Min [ac/h]	Mean [ac/h]	StdDev [ac/h]	Median [ac/h]	No. of Hours	No. of Periods	Longest Period [h]	Under Supply [ac]	Under Supply [%]
Ottawa	**3848**	**100.00%**	**0.65**	**0.8071**	**0**	**0.3904**	**0.1386**	**0.3904**	**4073 (46%)**	**209**	**1457.7 (61d)**	**446.2**	**16.98%**
Furnace w cont. pilot	693	18.01%	0.7	0.7547	0	0.3762	0.1371	0.3755	4413 (50%)	191	1743.5 (73d)	480.8	18.30%
Induced draft fan furnace	851	22.12%	0.6	0.7910	0	0.3807	0.1323	0.3816	4076 (47%)	239	1098.6 (46d)	423.2	16.10%
Condensing furnace	815	21.18%	0.5	0.7188	0	0.3276	0.1125	0.3287	5031 (57%)	226	2144.7 (89d)	622.1	23.67%
Vancouver	**12735**	**100.00%**	**0.65**	**1.0502**	**0**	**0.4337**	**0.1173**	**0.4343**	**2609 (30%)**	**298**	**351.2 (15d)**	**224.2**	**8.53%**
Furnace w cont. pilot	9777	76.78%	0.7	1.0899	0	0.4653	0.1236	0.4683	2075 (24%)	276	213.1 (9d)	159.6	6.07%
Induced draft fan furnace	1344	10.55%	0.6	0.9431	0	0.3740	0.1048	0.3717	3745 (43%)	300	761.1 (32d)	387.0	14.73%
Condensing furnace	214	1.68%	0.5	1.0010	0	0.3721	0.1121	0.3632	3854 (44%)	374	781.1 (33d)	412.5	15.70%
Saskatoon	**4162**	**100.00%**	**0.65**	**0.4962**	**0.0064**	**0.2536**	**0.0793**	**0.2565**	**6423 (73%)**	**149**	**3056.3 (127d)**	**754.4**	**28.71%**
Furnace w cont. pilot	2871	68.98%	0.7	0.5349	0.0075	0.2804	0.0894	0.2828	5859 (67%)	163	2469.8 (103d)	630.6	24.00%
Induced draft fan furnace	968	23.26%	0.6	0.4277	0.0048	0.2114	0.0660	0.2140	7254 (83%)	112	4190.6 (175d)	969.5	36.89%
Condensing furnace	243	5.84%	0.5	0.3903	0.0037	0.1824	0.0549	0.1849	7755 (89%)	96	4852.7 (202d)	1157.5	44.04%

No. of hours is also expressed as percentage of year (8760 h/yr). Longest period, in hours, is also expressed in days (24 h/d).

Table 28. Aggregated Annual Statistics for Three Cities (NPL=0.65) & Periods of Construction – EnerGuide For Houses

Period Built	No. of Houses	% of Pop'n.	Max [ac/h]	Min [ac/h]	Mean [ac/h]	StdDev [ac/h]	Median [ac/h]	No. of Hours	% of Year	No. of Periods	Longest Period [h]	Longest Period [d]	Under Supply [ac]	Under Supply [%]
Ottawa	**3848**	**100.00%**	**0.8071**	**0**	**0.3904**	**0.1386**	**0.3904**	**4073**	**46%**	**209**	**1457.7**	**61**	**446.2**	**16.98%**
pre 1945	1015	26.38%	1.2420	0.0000	0.6140	0.2138	0.6149	1486	17%	209	145.2	6	134.9	5.13%
1945	45	1.17%	0.9465	0.0000	0.4670	0.1633	0.4678	2228	25%	253	240.5	10	201.6	7.67%
1946-1960	832	21.62%	0.7588	0.0000	0.3715	0.1323	0.3714	3716	42%	245	859.5	36	370.4	14.09%
1961-1980	1228	31.91%	0.6251	0.0000	0.3050	0.1095	0.3047	5030	57%	221	1631.9	68	533.2	20.29%
1981-1995	571	14.84%	0.5113	0.0000	0.2463	0.0911	0.2454	6473	74%	151	3514.0	146	801.2	30.49%
1996-2004	157	4.08%	0.4483	0.0000	0.2164	0.0796	0.2158	7014	80%	122	4620.2	193	958.7	36.48%
Vancouver	**12735**	**100.00%**	**1.0502**	**0**	**0.4337**	**0.1173**	**0.4343**	**2609**	**30%**	**298**	**351.2**	**15**	**224.15**	**8.53%**
pre 1945	1164	9.14%	1.3091	0.0000	0.5453	0.1456	0.5460	1413	16%	246	110.9	5	103.3	3.93%
1945	97	0.76%	1.2439	0.0000	0.5105	0.1395	0.5108	1651	19%	270	90.8	4	114.8	4.37%
1946-1960	2268	17.81%	1.2013	0.0000	0.5008	0.1336	0.5012	1730	20%	277	117.1	5	124.6	4.74%
1961-1980	5910	46.41%	1.0785	0.0000	0.4457	0.1204	0.4463	2103	24%	314	156.3	7	154.5	5.88%
1981-1995	2980	23.40%	0.8173	0.0000	0.3324	0.0919	0.3329	4394	50%	310	829.3	35	431.1	16.41%
1996-2004	315	2.47%	0.6179	0.0000	0.2481	0.0699	0.2485	6246	71%	220	2139.8	89	770.8	29.33%
Saskatoon	**4162**	**100.00%**	**0.4962**	**0.0064**	**0.2536**	**0.0793**	**0.2565**	**6423**	**73%**	**149**	**3056.3**	**127**	**754.4**	**28.71%**
pre 1945	487	11.70%	0.8930	0.0128	0.4608	0.1398	0.4667	2247	26%	237	297.6	12	182.6	6.95%
1945	21	0.50%	0.7814	0.0107	0.4024	0.1230	0.4076	3159	36%	229	589.2	25	283.5	10.79%
1946-1960	840	20.18%	0.5509	0.0071	0.2816	0.0880	0.2848	5589	64%	206	1743.7	73	565.8	21.53%
1961-1980	1872	44.98%	0.4404	0.0054	0.2242	0.0710	0.2266	7117	81%	141	3081.9	128	797.5	30.35%
1981-1995	803	19.29%	0.3645	0.0045	0.1858	0.0586	0.1878	7924	90%	74	5216.9	217	1068.7	40.66%
1996-2004	139	3.34%	0.2439	0.0031	0.1243	0.0392	0.1257	8565	98%	13	8201.5	342	1572.6	59.84%

It is perhaps instructive to compare these model forecasts of air infiltration in Tables 26, 27 & 28 with available data of measured air changes in other groups of Canadian houses. One such dataset was measured in a group of medium airtightness houses (average 2.61ac/h at 50 Pa) in Saskatoon (Dumont 1995). In that study the average of the measured hourly air change rates due to air leakage was reported as 0.20 ac/h, and ranged from 0.08 ac/h to 0.43 ac/h. None of the monthly or yearly average air changes rates reported in Table 26 are as high or low as these measured extremes in that study. However, the groups of Saskatoon houses in Tables 27 & 28 are the only groups to display non-zero minimum air change rates, and those values are typically lower than the lowest extreme value reported in the Saskatoon study. The prototype Saskatoon example house used to calculate the statistics listed in Table 25 was leakier than the average of the 20 Saskatoon houses. If a one-storey Saskatoon house with the same airtightness of 2.61 ac/h @ 50 Pa is singled out of the Saskatoon EG4H subset, only the monthly average air changes rates for December, January and February (the deep winter) are as high as the average 0.2 ac/h as measured in the 1995 study.

Another dataset with measured air change rates due to natural ventilation and measured airtightness characteristics was measured in 30 electrically heated houses in the Trois-Rivières area in Quebec (Stricker Assoc. 1994). In that dataset, the average natural ventilation rate for a one-week PFT test in each house was 0.23 ac/h, and the average airtightness in the dataset is 4.77 ac/h at 50 Pa. For the prototypical Ottawa house's model calculations reported in Table 23 (Ottawa climate and Trois-Rivières' climate may be similar), the forecast monthly average air change rates for the months of October through June are greater than the average in the 30 Quebec houses. It is important to note that this prototypical Ottawa house is 50% leakier than the average airtightness in the dataset of 30 Quebec houses. If an actual one-storey, electrically heated Ottawa house is singled out of the Ottawa EG4H subset with airtightness of 4.77 ac/h at 50 Pa, only the forecast monthly average air change rates, using NPL=0.5, for the months of December through March are greater than the average reported in (Stricker Assoc. 1994) of 0.23 ac/h.

The distributions by period of construction, for all three cities, as reported in Table 28, help to reveal another aspect of the air infiltration situation in these three cities. For all three cities, the annual average infiltration rates for the groups of houses built before the end of the Second World War are all greater than 0.3 ac/h, and their groups' average Under Supply metrics are all less than 10%, with the Saskatoon houses built during 1945 pushing the Under Supply metric just slightly. The houses built in the following decades in both Ottawa and Saskatoon all fail to satisfy the two criteria, although the Ottawa houses built in the two periods 1946-1960, and 1961-1980 have average annual infiltration rates greater than 0.3 ac/h. The most interesting story is told by the age distribution for the Vancouver set of houses. Although the discussion of Table 27 suggested that the whole set of Vancouver houses, and all its groupings by heating system, as groups, seemed to be adequately ventilated, or nearly so, by natural means, Table 28 shows that the Vancouver houses built in the periods 1981-1995, and 1996-2004, as groups, fail to meet the two criteria, and even the annual average infiltration rate of the latest-built group is less than 0.3 ac/h. It seems clear from the results shown in Table 28, that modern Canadian houses, built since the 1980 National Building Code was published, as a group, are probably not adequately ventilated by natural means, and require some form of mechanical ventilation to supplement their natural ventilation. It is possible that even the houses built in the preceding period 1961-1980 may not be adequately supplied by natural ventilation during substantial parts of the year.

Another perspective on the situation of natural ventilation in the three cities investigated herein can be achieved by considering the annual median of the modeled air change rates for the most prevalent type of home heating system across the three cities – conventional efficiency, gas-fired, natural draft, gas furnace. Figure 5 shows the distributions of the annual median air change rates calculated by the model for all the houses in each city, using NPL = 0.70. The annual median is that value amongst the year's hourly air change rates that 50% of the year's hourly rates are greater and the other 50% are less than it. In Figure 5, the dashed horizontal line corresponds to 0.3 ac/h. Only 15 % of the houses in the Vancouver subset have annual median air change rates less than 0.3 ac/h, or in other words, 15 % of Vancouver houses with conventional gas furnaces and natural draft flues experience less than 0.3 ac/h of natural ventilation for half the hours in the year or more. This is a substantially unacceptable condition in a set of houses that the discussion thus far might suggest are adequately supplied by air infiltration.

The situation is much worse in the Ottawa and Saskatoon subsets, despite colder climate conditions and stronger stack effect, probably due to the generally tighter building envelopes discussed above. In the Ottawa subset, 48% of these houses heated with conventional gas furnaces fail to be adequately ventilated by air infiltration for at least half the year. As many as 71% of Saskatoon houses heated by conventional gas furnaces are under ventilated by air infiltration for at least half the year.

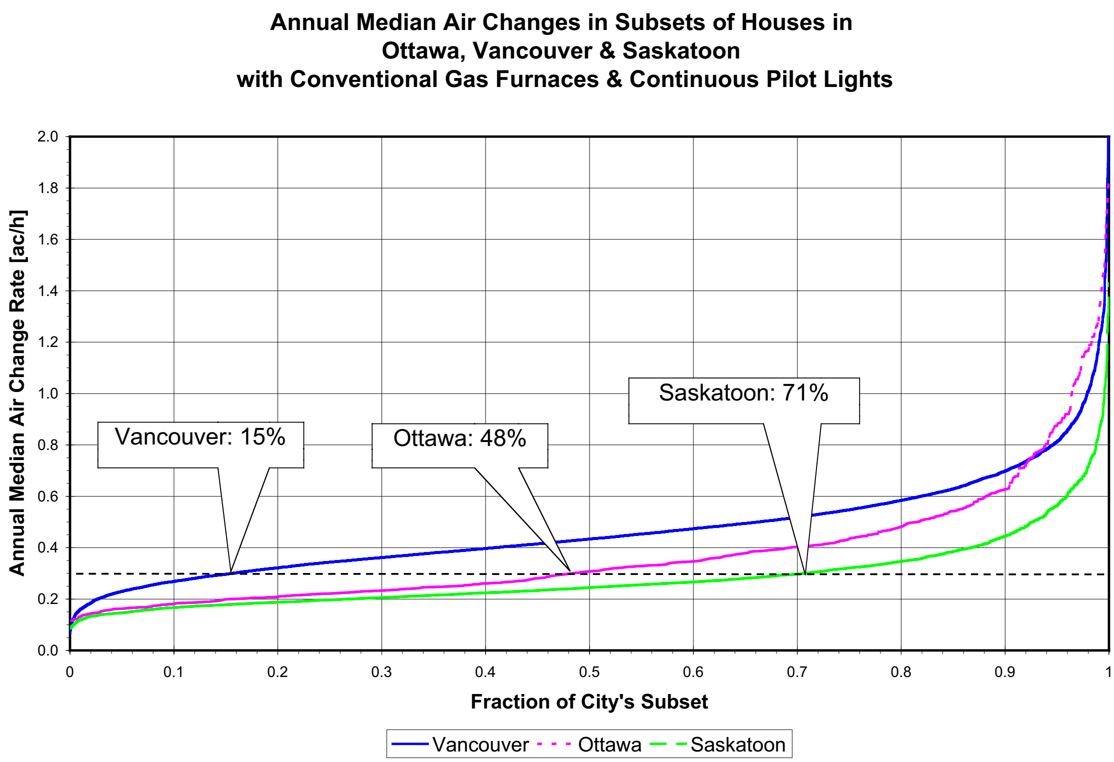

Figure 5. Distributions of Annual Median Air Change Rate in Vancouver, Ottawa & Saskatoon

Examination of the record-by-record model calculation output reveals that a full 10% of this example subset of the Saskatoon houses has fewer than 10 hours of the year where air infiltration can meet the 0.3 ac/h requirement. 14% of them have fewer than 100 hours in the year when that requirement is satisfied. It seems clear that the existing tightly constructed housing stock in Saskatoon needs mechanical ventilation to supplement natural ventilation by air infiltration. A similar examination of the Ottawa example subset reveals that almost 14% of the houses in the Ottawa subset have fewer than 30 days per year in which the 0.3 ac/h requirement is satisfied by air infiltration. Therefore, the tighter houses in Ottawa also need mechanical ventilation. A similar examination of the Vancouver example subset reveals that even 6% of those houses have fewer than 60 days per year when the 0.3 ac/h requirement is satisfied by air infiltration. The case could be argued that even these tightest of Vancouver houses might need mechanical ventilation to supplement natural air leakage.

Additional Considerations for Occupant Behaviour – Window/Door Opening & Mechanical Ventilation

It is important to note that all the results presented thus far were calculated by an air infiltration model for each house with all its doors and windows closed. Therefore, no consideration has been given to either the effects of opened windows and/or doors, nor to any mechanical ventilation in these houses. As mentioned previously, the EnerGuide For Houses database provided only indications of central ventilation systems. For each of the three cities considered here, more than 90% of the houses had no central ventilation systems. However, since the early 1960s local exhaust fans in bathrooms have been common features in many houses, as have kitchen range hood exhaust fans (although not all range hood fans are exhausted to outdoors, some simply recirculate indoor air through a filter). Mechanical exhaust became a building code requirement for houses in stages since they began to be commonplace in house construction in the sixties. The 1980 NBC required, for the first time, that mechanical exhaust-only ventilation be installed in dwellings that were not heated by fuel-fired equipment. The required total capacity of that mechanical exhaust ventilation was at least 50 L/s at a static pressure differential of 25 Pa. In other words, all-electric homes built after 1980 were required to have a total mechanical exhaust capacity of 50 L/s. By the 1990 NBC, this mechanical ventilation requirement had been broadened to be capable of achieving 0.3 ac/h averaged over any 24-hour period, and to apply to all dwellings. Consequently, most of the houses in Canada built during the later periods where infiltration has been found to be inadequate to meet total ventilation needs, as discussed above, will have some installed mechanical ventilation capacity. It might be expected that occupants would operate that mechanical ventilation when they perceive the ventilation from air leakage (infiltration) is insufficient. This expectation is however called into question by the results of a survey of owners of new houses in three Ontario cities: Toronto, Ottawa and Guelph (CMHC 2004). In that study, 30% of homeowners never operated their exhaust-only ventilation systems, almost 10% were unaware that their houses had a ventilation system, and fewer than 14% understood how to operate their ventilation system correctly in concert with their furnace fan’s circulation of indoor air.

The opening of windows and/or doors is another means by which it might be expected that occupants would intervene to improve house ventilation that they perceive to be inadequate from air infiltration alone. The month-by-month model calculations of infiltration reported in Tables 23 & 24 for Ottawa and Vancouver, indicate that natural ventilation by infiltration is insufficient to meet total ventilation needs during the milder weather months. These are the very periods when occupants might typically choose to open windows to enjoy fresh outdoor air. The opening of windows, from the perspective of its impact on calculating air exchange by natural means, serves to dramatically increase the building envelope “leakage area”, which in turn would increase the calculated air exchange rates. The impact of envelope airtightness on the calculations of air change rates by air leakage (infiltration) should be obvious from the previous discussions of results, and are explicit in the model equations in Appendix A. Figures 6 & 7 below illustrate graphically that impact, for two of the heating systems compared previously: conventional gas furnace and condensing gas furnace, for the subset of two-storey, detached houses.

It is reasonable to expect that as windows are opened in houses that are otherwise too airtight for air leakage to satisfy ventilation needs, such houses may become adequately ventilated by air leakage and air exchange through the opened windows. The main point here is that it may

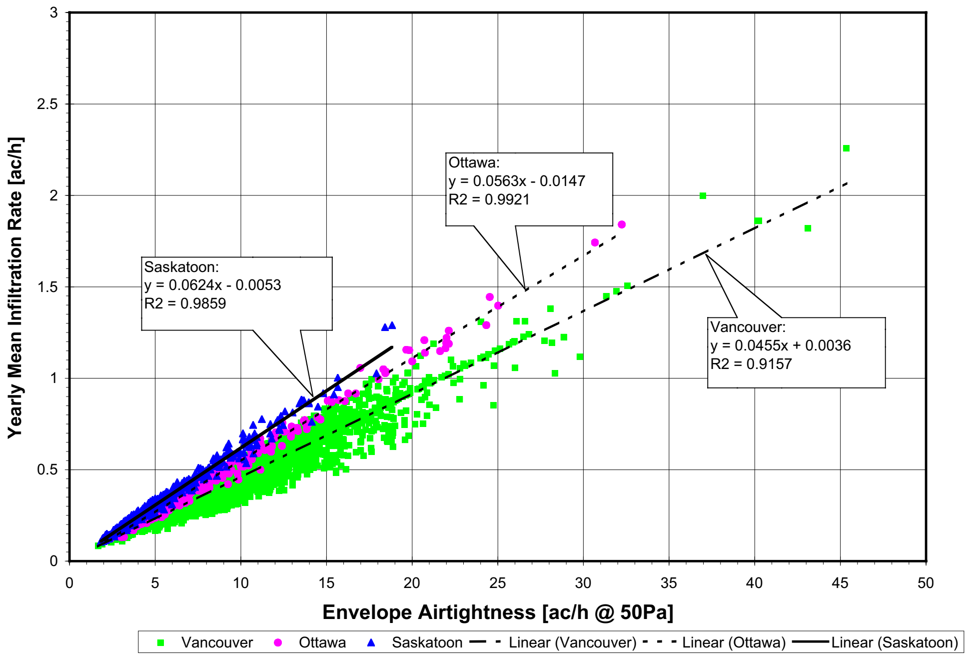

Figure 6. Air Change Rate vs. Envelope Airtightness – Two-Storey, Detached Houses with Conventional Gas Furnaces (NPL=0.7)

not be accurate to regard all the houses and groups of houses, for which the infiltration model calculations have indicated infiltration alone is insufficient to meet ventilation requirements of 0.3 ac/h, as being realistically operated normally with less than adequate ventilation. It seems reasonable to expect that most occupants will operate their houses to suit their perceived needs. In fact, the 2004 CMHC survey in new Ontario homes, cited above, found that over 90% of those occupants do open windows, even 40% do so during winter. However, almost 10% do not open their windows in mid-summer, perhaps to reduce air conditioning costs, exactly when additional ventilation is most needed in almost all but the leakiest of Canadian houses. Therefore the case can be made that mechanical ventilation may be needed in virtually all houses in Canada.

The linear fits, shown in Figures 6 & 7, to each city's subset of the data plotted on these graphs, are quite good. The increasing slopes from Vancouver to Ottawa to Saskatoon reflect the increasing severity of the cities' respective climate conditions that drive the air infiltration. In this regard it is interesting to note that Saskatoon, the most severe of the three climates used in this study, is the only one of the three cities where non-zero average minimum infiltration rates were produced by the model calculations for any grouping considered (c.f. Tables 27 & 28).

Final Considerations of Source of House Data – EnerGuide For Houses Database

Much of the discussion of model calculation results above has been equivocal or qualified, and many of the statements about the story being told by the model analysis that mechanical ventilation is needed to supplement inadequate natural ventilation might be challenged by those who believe that occupants of houses can and will take steps to improve the ventilation air

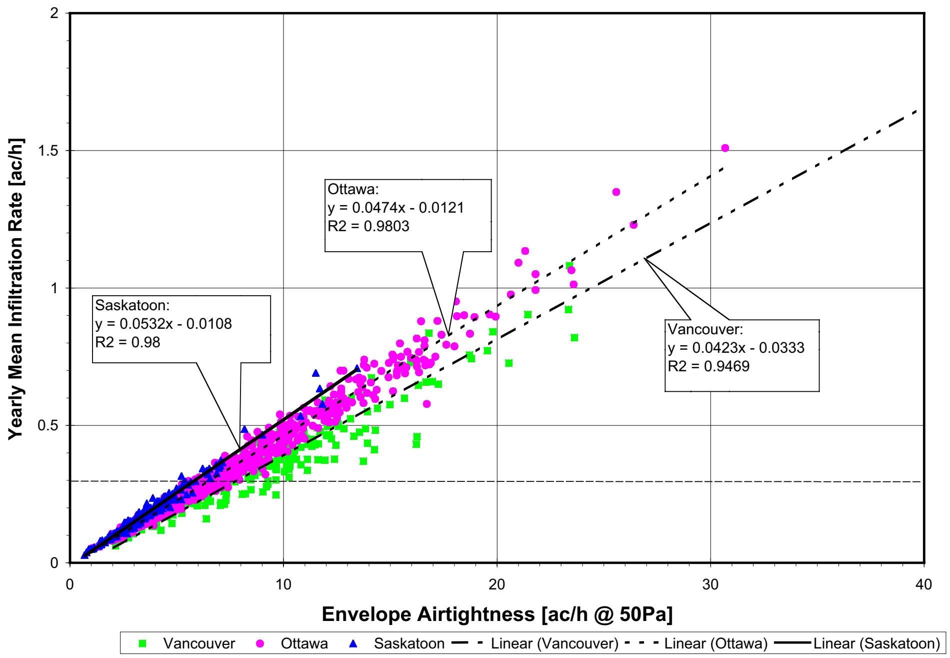

Figure 7. Air Change Rate vs. Envelope Airtightness – Two-Storey, Detached Houses with Condensing Gas Furnaces (NPL=0.5)

supply in their homes when they perceive that it is needed. However, it is important to consider from where the house characteristics data has been obtained – the EnerGuide For Houses database. The purpose of the EnerGuide For Houses program was to assist homeowners who were interested in conserving energy by improving the energy efficiency performance of their homes, in understanding how they could most effectively, from a remediation cost & effort point of view, achieve that goal, thereby furthering a major objective of the federal government to reduce energy consumption in Canada. Consequently, many of the records of measured house characteristics may already be out-of-date, since many homeowners who invited EGH inspectors to audit the energy performance of their homes will have implemented some of the recommendations made by those inspectors. A very common energy conservation measure is to seal leaks and cracks in the house exterior envelope, thereby improving airtightness and reducing air infiltration. Another common measure is to replace old windows with new ones that have improved thermal performance, such as double or triple glazing, low-e coatings, inert gas fills, and tighter sealing closures. Another popular measure is to replace older furnaces, perhaps still using natural draft flues, by newer, higher efficiency furnaces that typically do not use a natural draft flue, thereby reducing or eliminating the extra natural air change rate that takes place through a natural draft flue, especially through a flue warmed by a continuous pilot light in the furnace or DHW system. The principle here is that many of the houses described in the EGH database will have been made more airtight and now be experiencing less natural ventilation than forecast by the model calculations reported here. The assessment of natural ventilation achieved by this analysis using the EGH data can be expected to have underestimated, perhaps substantially, the state of under supply of fresh air by natural ventilation in the houses across Canada (as represented by the three cities of Ottawa, Vancouver and Saskatoon herein).

Conclusions

Several conclusions can be drawn from the analysis described in this report.

Perhaps most important, it can be argued that strictly speaking, natural ventilation, at least due to air infiltration, cannot be relied upon to provide all the ventilation needs in Canadian houses. There will always exist periods of the year when natural driving forces will be insufficient to cause enough air movement in and out through leaks in realistic building envelopes of houses to meet a continuous 0.3 ac/h ventilation requirement. Mechanical ventilation is needed in most Canadian houses to supplement natural ventilation during mild weather.

The analysis has shown, however, that during the colder periods of the year, natural ventilation due to air infiltration may in fact be sufficient to meet the 0.3 ac/h ventilation requirement. In the leakier houses, air infiltration can create excess ventilation that can increase energy consumption wastefully, and those leakier houses could be made more airtight as an effective means of conserving energy.

It is a recognized fact that Canadian houses have been built more and more airtight in the decades since the Second World War. The analysis presented in this report illustrates that fact for each of the three cities considered, and indicates that the increasing airtightness of Canadian house construction has steadily decreased natural ventilation by air infiltration.

All the houses included in the EnerGuide For Houses database were audited at the invitation of their owners seeking expert guidance for improving the energy efficiency of their houses. Consequently, many of these houses may now be more airtight, or may have newer heating systems without natural draft flues. Both of these probable improvements will have reduced the natural ventilation by air infiltration in the houses where they may have been implemented. It seems reasonable to expect therefore, that the population predictions of natural ventilation contained in this report may already be out-of-date and may overstate the amount of natural ventilation occurring by infiltration in the cities considered.

Mechanical ventilation in some form is therefore required in most Canadian houses to ensure adequate year-round ventilation air supply. While some of the leakiest houses in Canada (e.g., older homes in Vancouver) can be made more airtight to conserve energy, they will likely also require mechanical ventilation to ensure their adequate ventilation during milder parts of the year.

Future Work

One obvious topic for future work is to further develop strategies to provide energy-efficient mechanical ventilation for modern Canadian houses to supplement the natural ventilation they experience due to air infiltration, which this current study indicates is not sufficient. The latest few editions of the National Building Code of Canada have provided both prescriptive and performance approaches for that mechanical ventilation. CMHC has published guidelines that homebuilders can follow to create acceptable mechanical ventilation systems for houses.

Another suggestion for future work is that domestic mechanical ventilation systems might be further developed specifically to be able to automatically take advantage of natural ventilation when it is sufficient, as has been shown in this analysis. One such endeavour is the topic of a research project, mentioned in the introduction, that is investigating energy-efficient hybrid ventilation systems for houses.

Much of the analysis contained in this report has relied on assumed values for the neutral pressure level in houses for various types of heating systems and regional differences in house construction. While those assumptions have been based on some measured NPL data in real Canadian houses, the size of that measured NPL dataset is very small, from less than one hundred houses across Canada. It would be very helpful to future analyses of ventilation and energy use in the Canadian housing stock if more measured NPL data could be obtained. The principal impediment, other than funding, to this is the need for virtually calm wind conditions for this type of measurement.

Acknowledgements

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Appendix A – Description of the Single-Zone Air Infiltration Models Considered.

This appendix contains the detailed descriptions of the single-zone air infiltration models considered for use in this assessment of ventilation in Canadian dwellings. Any references cited are listed in the list of references in the main text of this report.

Shaw Model (Shaw 1987):

Stack-effect driven infiltration is modeled by the equation below:

$$I_S = 0.5\ (C/V)\ (h/H)\ (Tin\text{-}Tout)^n \qquad \text{(A-1)}$$

Where:

0.5 factor has the units $[m^3\ s\ Pa^n)/(L\ h\ K^n)]$,

I_S	=	infiltration air change rate due to stack effect [ac/h],
C	=	house flow coefficient from curve fit of the leakage test data $[L/(s\ Pa^n)]$,
V	=	internal volume of the house including basement $[m^3]$,
h	=	height above grade of the neutral pressure level [m],
H	=	height above grade of the upper ceiling of the house [m],
Tin	=	indoor air absolute temperature [K],
Tout	=	outdoor air absolute temperature [K],
n	=	house flow exponent from curve fit of the leakage test data.

Shaw suggests that for a house without a flue h/H = 0.64, and for a house with a single 127 mm dia, flue h/H = 0.86, based on the data set used to develop this model.

The form of the curve fit to the leakage test data (from a fan depressurization measurement of the envelope airtightness of the house, following CGSB 1986), that is used to determine the flow coefficient and flow exponent is the power law curve:

$$Q_m = C\ (\Delta P)^n \qquad \text{(A-2)}$$

Where:

Q_m	=	measured flow rates [L/s],
ΔP	=	measured pressure difference across envelope [Pa]

Wind driven infiltration is modeled by the equation below:

$$I_W = 0.4\ (C/V)\ U'^{2n} \quad \text{Exposed} \qquad \text{(A-3)}$$

$$I_W = 0.7\ (C/V)\ U'^{n} \quad \text{Shielded} \qquad \text{(A-4)}$$

Where:

0.4 factor has units $[(m^3\ Pa^n\ s^{2n+1})/(L\ h\ m^{2n})]$,

0.7 factor has units $[m^3\ Pa^n\ s^{n+1})/(L\ h\ m^n)]$,

I_W	=	infiltration air change rate due to wind [ac/h],
U'	=	windspeed measured at height of 20m on-site [m/s]

The combined infiltration due to both stack-effect and wind is modeled by combining these two component infiltration rates using n-quadrature to effectively superpose the pressures created by these two physical phenomena, since the two component infiltration rates do not simply add, due to the non-linear relationship between driving pressure and driven flow rate. The combined model equation is:

$$I_{WS} = F\ (I_S^{1/n} + I_W^{1/n})^n \qquad \text{(A-5)}$$

Where:

I_{WS} = total combined infiltration air change rate [ac/h],
F = an empirical factor defined by the following:

$$F = 1 \text{ for } 0 \le (I_{sml}/I_{lrg}) < 0.1 \quad \text{(A-6)}$$

$$F = 0.8\,(I_{sml}/I_{lrg})^{-0.1} \text{ for } 0.1 \le (I_{sml}/I_{lrg}) \le 1.0 \quad \text{(A-7)}$$

Where:

I_{sml} = the smaller of the two components I_S and I_W,
I_{lrg} = the larger of the two components I_S and I_W.

LBL Model (Sherman & Grimsrud 1980)

Stack-effect driven infiltration is modeled using the equation below:

$$Q_S = L\, f_S^* \,(Ti - To)^{1/2} \quad \text{(A-8)}$$

or

$$Q_S = L\, f_S \,\{g\, H\, [(Ti - To)/Ti]\}^{1/2} \quad \text{(A-9)}$$

where:

Q_S = infiltration flow rate due to stack effect [m^3/s],
L = effective leakage area of the house @ 4 Pa [m^2],
g = acceleration due to gravity = 9.806 m/s^2,
H = house height (distance from grade to upper ceiling [m],
Ti = indoor temperature [K],
To = outdoor temperature [K],
f_S = dimensionless stack parameter,
f_S^* = reduced stack parameter [$(m^2/s^2/K)^{1/2}$].

The dimensionless stack parameter and the reduced stack parameter are related by the following expression:

$$f_S^* = f_S\,(g\, H/Ti)^{1/2} \quad \text{(A-10)}$$

The dimensionless stack parameter is defined by:

$$f_S = (1/3)\,(1+R/2)\,(8)^{1/2}\,\{[(\beta_o)^{1/2}\,(1 - \beta_o)^{1/2}]/[(\beta_o)^{1/2} + (1 - \beta_o)^{1/2}]\} \quad \text{(A-11)}$$

where

β_o = ratio of the neutral pressure height to house height, above grade.

Alternatively, if the neutral pressure height is not known, f_S is also defined by the “approximate” expression (Sherman 1980):

$$f_S = (1/3)\,(1+R/2)\,[1 - X^2/\,(2 - R)^2]^{(3/2)} \quad \text{(A-12)}$$

where

R = fraction of total effective leakage area located in the floor and ceiling of the house, (typically assumed to be 0.5)

X = difference between the fractions of total effective leakage area located in the ceiling and the floor (typically assumed to be zero).

These terms are defined by the following expressions:

$$\beta_o = h/H \qquad \text{(A-13)}$$

$$R = (L_c + L_f)/L \qquad \text{(A-14)}$$

$$X = (L_c - L_f)/L \qquad \text{(A-15)}$$

where

- h = height of neutral pressure level above grade [m],
- L_c = effective leakage area in the upper ceiling [m^2],
- L_f = effective leakage area in the floor [m^2].

The relationship between R, X, and β_o can be expressed by (Sherman 1980):

$$X = \{(4/3)\,(1 - R)\,[(\beta_o)^{3/2} - (1 - \beta_o)^{3/2} + R\,[(\beta_o)^{1/2} - (1 - \beta_o)^{1/2}]\} / [(\beta_o)^{1/2} + (1 - \beta_o)^{1/2})] \qquad \text{(A-16)}$$

Wind-driven infiltration is modeled using the equation below:

$$Q_W = L\, f_W^*\, U' \qquad \text{(A-17)}$$

where

- Q_W = infiltration flow rate due to wind [m^3/s],
- U' = measured windspeed [m/s],
- f_W^* = reduced wind parameter (dimensionless).

The reduced wind parameter, f_W^*, is defined as:

$$f_W^* = C'\,(1 - R)^{1/3}\, f_T \qquad \text{(A-18)}$$

and the terrain factor, f_T is defined as:

$$f_T = [\alpha\,(H/10\text{ m})^{\gamma}] / [\alpha'\,(H'/10\text{ m})^{\gamma'}] \qquad \text{(A-19)}$$

where

- C' = generalized shielding coefficient for the house,
- α, γ = terrain parameters for the house site,
- α', γ' = terrain parameters for the windspeed measurement site,
- H' = height at which windspeed is measured [m].

Combined infiltration due to stack-effect and wind is modeled using the following equation:

$$Q = (Q_S^2+Q_W^2)^{1/2} \quad \text{(A-20)}$$

where

Q = total combined infiltration flow rate for the house [m^3/s].

Enhanced ASHRAE Model (Walker & Wilson 1998)

Stack-effect driven infiltration is modeled by the equation below:

$$Q_S = (c\ C_S\ \Delta T^n) / V \quad \text{(A-21)}$$

Where:

Q_S = infiltration flow rate due to stack effect [m^3/s]
c = house flow coefficient from curve fit of the leakage test data [$m^3/(s/Pa^n)$]
C_S = stack coefficient [$(Pa/K)^n$]
ΔT = temperature difference between indoors & outdoors [K]
n = house flow exponent from curve fit of the leakage test data.

Wind driven infiltration is modeled by the equation below:

$$Q_W = c\ C_W\ (s\ U)^{2n} \quad \text{(A-22)}$$

Where:

Q_W = infiltration flow rate due to wind effect [m3/s]
c = house flow coefficient from curve fit of the leakage test data [$m^3/(s/Pa^n)$]
C_W = wind coefficient [$(Pa\ s^2/m^2)^n$]
s = shelter factor
U = building wind speed [m/s]
n = house flow exponent from curve fit of the leakage test data.

In calculating the values of C_S, C_W, and s, tabulated in Tables A-1 and A-2, the following assumptions were made:

- Each story is 2.5 m high.
- The flue is 15 cm in diameter and reaches 2 m above the upper ceiling.
- The flue is unsheltered.
- Half of the envelope leakage (not including the flue) is in the walls and one-quarter each is at the floor and ceiling, respectively.
- n = 0.67

Table A-1. Enhanced Model Stack and Wind Coefficients

	One Storey		Two Storey		Three Storey	
	No Flue	With Flue	No Flue	With Flue	No Flue	With Flue
C_S	0.054	0.069	0.078	0.089	0.098	0.107
C_W for basement / slab	0.156	0.142	0.170	0.156	0.170	0.167
C_W for crawl space	0.128	0.128	0.142	0.142	0.151	0.154

Table A-2. Enhanced Model Shelter Factor s

Shelter Class	No Flue	One Storey with Flue	Two Storey with Flue	Three Storey with Flue
1	1.00	1.10	1.07	1.06
2	0.90	1.02	0.98	0.97
3	0.70	0.86	0.81	0.79
4	0.50	0.70	0.64	0.61
5	0.30	0.54	0.47	0.43

The building wind speed is calculated from the average wind speed measured by a nearby meteorological station by the equation below:

$$U = G\ U_{met} \qquad \text{(A-23)}$$

Where:

- U = building wind speed [m/s]
- G = wind speed multiplier
- U_{met} = average wind speed measured at a meteorological station [m/s]

Using typical values for terrain factors, house height, and wind speed measurement height, the wind speed multiplier G, given in Table A-3, uses a relationship based on equations found in Chapter 16 of ASHRAE 2005.

Table A-3. Enhanced Model Wind Speed Multiplier

	House Height (No. Storeys)		
	One	**Two**	**Three**
Wind speed multiplier G	0.48	0.59	0.67

Appendix B – Listing of Measured Neutral Pressure Levels for Canadian Houses from Various Sources

Some of the earliest measurements of neutral pressure levels were carried out by a team of researchers at the Division of Building Research, National Research Council, during the Mark XI Energy Research Project. This research project involved a set of four almost identical two-storey, detached, single-family houses built in a suburb of Ottawa in the late 1970s. In a study of passive ventilation systems in one of the HUDAC Mk XI houses (Shaw and Kim, 1984), the neutral pressure level was measured for ten configurations of passive inlet vents and passive stack. Those values are reported in Table B-1.

Table B-1. Neutral Pressure Levels Measured in HUDAC Mk XI House H3 (1984)

Config	Intake Vent Area [sq.m]	Exhaust Stack Area [sq.m]	House Flow Coeff. [L/sPa^n]	House Flow Exp'nt n	NPL Value h/H	Description
0	0	0	20.95	0.71	0.593	House as is, no vents
I	0.0079	0	23.45	0.71	0.481	Vent in south basement wall
II	0.0079	0	28.69	0.66	0.389	Vent connected to FA return
IIa	0.0079	0	23.23	0.71	--	Furnace fan OFF
III	--	0.0127	23.00	0.71	0.778	Stack inlet in basement
IV	0.0079	0.0127	30.51	0.66	0.667	I and II combined
V	0.0079	0.0127	31.65	0.66	0.593	II and III combined
VII	2x0.0079	0	32.11	0.66	--	Two vents in south basement wall
IX	0.0127	0	30.06	0.66	0.778	Vent in 2nd storey window
X	0.0127	0	30.74	0.66	--	Vent in 1st storey window
Intake vents were 10 cm dia. Holes or 12.7 cm dia. ducts. Stack 12.7 cm dia.						
Two-storey, detached house: Volume = 386 cu.m; Exterior envelope area = 227.7 sq.m; Height = 5.4 m						
NPL measurements made only in calm wind conditions (wind speed less than 8 km/h).						

Another set of NPL data was measured during another NRC/IRC research project co-sponsored by the Canadian government's Department of Energy, Mines and Resources Canada "Air Infiltration Modelling Study" (Reardon 1989) for a set of 16 houses in Ottawa and 7 houses in Winnipeg. Those values are reported in Table B-2. In many of the houses, NPL values were measured for both cold and warm furnace flue states. As can be seen, not all these measurements were made with wind speeds less than 8 km/h. All seven Winnipeg houses had natural draft gas-fired furnaces, as did four Ottawa houses: O-01, O-06, O-12 & O-13. Six Ottawa houses had oil-fired furnace with a flue fitted with a barometric damper: O-02, O-04, O-05, O-18, O-19 & O-21. Two Ottawa houses had natural draft oil-fired furnaces: O-08 & O-17, three were heated by an electric forced-air furnace with no furnace flue: O-07, O-10 & O-14, and one Ottawa house had a direct vent gas-fired furnace: O-09 with no flue.

Table B-2. Neutral Pressure Levels Measured in 16 Ottawa Houses and 7 Winnipeg Houses.

House ID	Storeys	Vol [cu.m]	Area [sq.m]	Height [m]	House Flow Coeff. [L/sPa^n]	House Flow Exp'nt n	Flue State	NPL Value h/H	Wind Speed [km/h]
O-01	2	574.16	336.99	5.54	61.53	0.7204	Cold	0.5935	11
							Warm	0.5942	11
							Combined	0.594	11
O-02	2	687.86	318.12	5.47	49.1	0.6696	Warm	0.59	11
O-04	S-3	550.38	279.69	3.72	58.35	0.6528	Cold	0.8796	10
							Warm	0.8335	10
							Combined	0.855	10
O-05	1	543.98	249.79	2.96	30.01	0.6841	Cold	0.5574	6
							Warm	0.7608	6
							Combined	0.659	6
O-06	S-4	637.46	405.9	5.35	79.92	0.6442	Warm	0.527	0
O-07	1	565.06	287.58	3.32	64.49	0.6355	No Flue	0.756	5
O-08	1	497.31	233.96	2.82	65.27	0.591	Cold	0.9737	11
							Warm	1.0819	11
							Combined	1.028	11
O-09	1	477.06	226.72	3.26	39.33	0.6653	No Flue	0.196	0
O-10	S-4	628.08	304.48	5.25	43.05	0.6584	No Flue	0.609	8
O-12	2	627.42	376.46	7.08	75.61	0.6274	Cold	0.699	21
O-13	2	494.3	335.99	5.99	55.68	0.6227	Cold	0.4121	4
							Warm	0.47	4
							Combined	0.441	4
O-14	S-4	515.24	266.86	4.31	60.61	0.6831	No Flue	0.474	8
O-17	S-3	477.62	344.46	4.5	67.53	0.6701	Warm	0.643	11
O-18	1	533.15	259.41	3.51	46.83	0.6882	Warm	0.86	11
O-19	2.5	682.59	398.28	9.19	113.25	0.6108	Cold	0.5132	10
							Warm	0.5102	10
							Combined	0.512	10
O-21	1	858.01	394.71	4.83	83.92	0.622	Warm	0.522	5
W-12	1	315	284.2	3.52	51.21	0.625	Cold	1.017	13
W-17	1	483	422	3.04	23.89	0.694	Cold	0.8421	3
W-31	1	164	178.4	4.79	32.57	0.628	Cold	0.286	9
W-33	1	264.4	200.2	3.21	55.02	0.702	Cold	0.4455	9
W-54	1.5	396.6	398.1	5.89	28.19	0.752	Cold	0.8081	6
W-79	1	470.4	402.4	4.04	41.2	0.657	Cold	0.8812	6
W-80	S-4	472.6	394.9	4.43	40.6	0.64	Cold	0.6456	7

In another IRC study (Reardon & Shaw 1993), envelope pressures were monitored for approximately 12 months in the two-storey, detached research house while one basement dryer-type vent and one B-vent (12.7 cm ID) were automatically cycled through four combinations of open and closed for 10 minutes each. On-site wind speeds were also recorded, and repeat measures of the NPL values for each flue/vent-open/closed were averaged for calm winds (wind speed = 0) and for a wind speed of 5 km/h. Those values are listed in Table B-3.

Table B-3. Neutral Pressure Levels in the NRC Two-Storey Research House (1993)

Config	Flue	Vent	Wind Speed [km/h]	NPL Value h/H	House Flow Coeff. [L/sPa^n]	House Flow Exp'nt n	ELA_{10} CGSB [sq.m]
0	Closed	Closed	0	0.556	27.16	0.655	0.0492
0	Closed	Closed	5	0.538			
1	Closed	Open	0	0.495	30.89	0.639	0.0540
1	Closed	Open	5	0.480			
2	Open	Closed	0	0.749	35.70	0.629	0.0610
2	Open	Closed	5	0.737			
3	Open	Open	0	0.687	35.55	0.641	0.0625
3	Open	Open	5	0.674			
House Height = 5.956 m; Volume = 499.6 cu.m; Envelope exterior area = 292.5 sq.m							

In the study of Apple Hill Energy Efficient Homes, reported in 1984, the neutral pressure levels referenced to the top of the foundation wall, not to grade level, were measured in 24 of the 52 houses studied, during four periods of the 1982-1983 year. By making assumptions about the height of the foundation wall top above grade, these measured NPL values can be referenced to grade level. The actual reported NPL values, and the transformed NPL values referenced to grade level are listed in Table B-4. The heights of the houses listed in Table B-4 were taken from other parts of the reports on the Apple Hill Study, and the measured NPL values were taken from the low-wind summary table 4-2 in its Appendix 6. The following assumptions were made to estimate the NPL values above grade level, and to make the height of the uppermost heated ceiling agree closely with the house heights reported in the study's main report:

- Height of foundation wall top above grade (for all houses) = 0.75 m
- Depth of wood frame floor joist constructions (for all houses) = 12 in. = 0.3028 m
- Ceiling height (for all storeys above basements, for all houses) = 8 ft = 2.438 m

In the 1989 Cross-Canada Survey of Airtighness of New, Merchant Built Houses, the NPL was measured in 10 houses in Saskatoon and 10 houses in Regina, and reported in the consolidated report prepared by Parekh & Reynolds, published in 1992. Those measured data are listed in Table B-5. The protocols for that survey included fan depressurization measurements of airtightness of each house for three conditions: A, B, and C. Condition C corresponds most closely to "lived-in" conditions with no extraordinary measures taken to seal deliberate openings, other than to close any existing dampers. Multiple NPL values, corresponding to Conditions A, B & C were reported for only one house SA5002 in Saskatoon. For all other houses in all other cities in this 1989 cross-Canada survey, NPL values were not

Table B-4. Neutral Pressure Levels measured in Apple Hill Energy Efficient Homes (1984)

I.D.	NPL heights ref foundation wall top [m]					NPL heights of above grade [m]					Height	Strys	NPL Values (Dimensionless ratio h/H)				
	Phase 1	Phase 2	Phase 3	Phase 4	Mean	Phase 1	Phase 2	Phase 3	Phase 4	Mean	[m]		Phase 1	Phase 2	Phase 3	Phase 4	Mean
1				1.7	1.7				2.45	2.45	6.5	2				0.377	0.377
4			1.3	1.1	1.2			2.05	1.85	1.95	6.5	2			0.315	0.285	0.300
5			2.4	1.2	1.8			3.15	1.95	2.55	6.5	2			0.485	0.300	0.392
6	0.7		-0.6	0.05	0.08	1.45		0.15	0.8	0.83	6.5	2	0.223		0.023	0.123	0.128
7	0				0	0.75				0.75	6.5	2	0.115				0.115
11	2.1				2.1	2.85				2.85	6.5	2	0.438				0.438
12	1.1		1	1	1.03	1.85		1.75	1.75	1.78	6.5	2	0.285		0.269	0.269	0.274
13	1.5			0.6	1.05	2.25			1.35	1.8	6.5	2	0.346			0.208	0.277
14	1.5				1.5	2.25				2.25	6.5	2	0.346				0.346
16				1.2	1.2				1.95	1.95	6.5	2				0.300	0.300
17				1.4	1.4				2.15	2.15	6.5	2				0.331	0.331
18			0.3		0.3			1.05		1.05	6.5	2			0.162		0.162
20	1.5			1.1	1.3	2.25			1.85	2.05	3.5	1	0.643			0.529	0.586
21		-2		0.3	-0.8		-1.25		1.05	-0.05	3.5	1		-0.357		0.300	-0.014
22	0		0.3		0.15	0.75		1.05		0.9	3.5	1	0.214		0.300		0.257
23			-0.9		-0.9			-0.15		-0.15	3.5	1			-0.043		-0.043
24	0		-0.5		-0.25	0.75		0.25		0.5	3.5	1	0.214		0.071		0.143
25		2	0.8		1.4		2.75	1.55		2.15	3.5	1		0.786	0.443		0.614
29		-0.3			-0.3		0.45			0.45	6.5	2		0.069			0.069
31	2.2				2.2	2.95				2.95	6.5	2	0.454				0.454
35			1.6	1.8	1.7			2.35	2.55	2.45	6.5	2			0.362	0.392	0.377
37	1.2				1.2	1.95				1.95	6.5	2	0.300				0.300
39		1.4		1.5	1.45		2.15		2.25	2.2	6.5	2		0.331		0.346	0.338
51			4.1		4.1			4.85		4.85	6.5	2			0.746		0.746

Height of foundation wall top (assumed): 0.75 m above grade.

Phase 1 corresponds to NPL measurements during February to April 1982. Phase 2 corresponds to NPL measurements during June to July 1982.

Phase 3 corresponds to NPL measurements during September to October 1982.

Phase 4 corresponds to NPL measurements during December 1982 to January 1983.

Table B-5. Neutral Pressure Levels Measured in Saskatoon & Regina During 1989 Cross-Canada Survey of Airtightness in New, Merchant Built Houses

City	ID	Vent Rate Req't[1] [L/s]	House Flow Coeff[2] C [L/s Pa^n]	House Flow Exp'nt[2] n	Volume [cu.m]	Envelope. Area [sq.m]	Height [m]	NPL h/H
Regina	SA1001	70	58.157	0.6388	694.6	537.4	5.8	0.641
Regina	SA1002	60	18.8	0.664	553.2	438	3.24	0.6
Regina	SA3005	45	17.374	0.6859	411.4	351.1	4.01	0.818
Regina	SA3006	70	47.122	0.6738	698.8	493.3	5.97	0.548
Regina	SA3007	55	19.991	0.6612	500.9	403.7	3.22	0.6
Regina	SA3008	70	40.919	0.7665	698.8	493.3	6.11	0.843
Regina	SA4003	45	16.421	0.7305	372.5	324	3.65	0.712
Regina	SA4004	60	34.869	0.7111	638.6	532.6	3.04	0.6
Regina	SA6001	70	35.986	0.7116	615.4	464.7	5.75	0.216
Regina	SA6002	55	37.798	0.6827	507.7	427.6	5.23	0.6
Saskatoon	SA2001	65	48.019	0.7115	614.2	486.7	5.47	0.42
Saskatoon	SA2002	60	32.306	0.6862	494.3	413.4	3.22	0.274
Saskatoon	SA3001	70	72.24	0.6245	671.8	433	5.93	0.422
Saskatoon	SA3002	65	47.591	0.6089	595	446.7	5.81	0.361
Saskatoon	SA3003	75	27.369	0.6462	445.9	374.9	4.08	0.485
Saskatoon	SA3004	55	30.369	0.647	407.5	355.7	4.2	0.455
Saskatoon	SA4001	75	24.264	0.6863	494.3	438	4.89	0.673
Saskatoon	SA4002	60	32.653	0.633	396.8	351.3	5.03	0.376
Saskatoon	SA5001	70	26.29	0.6933	644.5	421	5.83	0.532
Saskatoon	SA5002	70	60.304	0.6802	783.9	537.2	5.86	.52/.352/.5
[1] Mechanical Ventilation Rate total of by room-by-room requirements by Std. CAN/CGSB-F326-M91.								
[2] Airtightness characteristics measured by fan depressurization test for "lived-in" Condition C.								

measured, and default values of 0.6 & 0.7 were used in the subsequent infiltration modelling using the measured airtightness characteristics.

Another set of NPL values were measured during a study in houses in several provinces across Canada: British Columbia, Manitoba, Ontario, Nova Scotia and Quebec. This study was conducted by Scanada Consultants for Canada Mortgage and Housing Corporation and was reported in an October 1993 document "Field Testing of House Characteristics". Twelve houses were tested in each of four of the provinces: BC, MB, ON & NS; and four houses in PQ. Only the NPL locations with respect to the tops, bottoms and mid-heights of the appropriate storey were recorded, so assumptions are required to transform this information into numerical data. For the purposes of this report, the same assumptions as stated above for the data listed in Table B-4 were used to calculate the data listed in Tables B-6a and B-6b.

Table B-6a. Neutral Pressure Levels in Houses in Five Provinces (Scanada 1993) – Part 1

House I.D.	NPP Location	No. of Storys	NPP Height above grade [m]	House Height above grade [m]	NPL h/H	ACH @50 [ac/h]	ELA sq.cm	NLA cm^2 $/m^2$	Ext'r Env. Area sq.m
BC01	top of 1st floor	2	3.4932	6.2364	0.560	14.4	6443.4	5.70	1130.4
BC02	half height of 1st floor	1	2.274	3.4932	0.651	9.8	1510.4	3.52	429.1
BC03	top of 1st floor	2	3.4932	6.2364	0.560	3.2	1041.5	2.12	491.3
BC04	bottom of 2nd floor	2	3.798	6.2364	0.609	9.3	3959.5	5.89	672.2
BC05	half height of 2nd floor	2	5.0172	6.2364	0.805	10.0	2210.9	5.21	424.4
BC06	half height of 1st floor	2	2.274	6.2364	0.365	6.0	1472.2	3.43	429.2
BC07	half height of 2nd floor	2	5.0172	6.2364	0.805	7.1	1305.9	3.21	406.8
BC08	half height of 2nd floor	2	5.0172	6.2364	0.805	6.1	2092.9	3.58	584.6
BC09	half height of 1st floor	1	2.274	3.4932	0.651	6.6	914.6	2.59	353.1
BC10	top of 1st floor	1	3.4932	3.4932	1.000	7.4	1363.7	3.29	414.5
BC11	top of 1st floor	2	3.4932	6.2364	0.560	11.8	3858.6	6.77	570.0
BC12	top of 1st floor	2	3.4932	6.2364	0.560	n/a	n/a	n/a	n/a
MB01	half height of 1st floor	1	2.274	3.4932	0.651	3.9	960.2	1.90	505.4
MB02	half height of 2nd floor	2	5.0172	6.2364	0.805	5.4	842.9	2.37	355.7
MB03	half height of 2nd floor	2	5.0172	6.2364	0.805	6.1	984.6	3.23	304.8
MB04	top of 1st floor	1	3.4932	3.4932	1.000	3.4	567.4	0.67	846.9
MB05	top of 1st floor	1	3.4932	3.4932	1.000	4.0	512.2	1.49	343.8
MB06	top of 1st floor	1	3.4932	3.4932	1.000	3.0	425.0	1.07	397.2
MB07	half height of 2nd floor	2	5.0172	6.2364	0.805	3.6	945.5	1.55	610.0
MB08	half height of 2nd floor	2	5.0172	6.2364	0.805	4.3	1213.0	1.44	842.4
MB09	bottom of 2nd floor	2	3.798	6.2364	0.609	4.0	1339.7	1.95	687.0
MB10	top of 1st floor	2	3.4932	6.2364	0.560	2.3	640.4	0.96	667.1
MB12	half height of 1st floor	2	2.274	6.2364	0.365	0.8	335.3	0.44	762.0
PQ01	half height of 1st floor	1	2.274	3.4932	0.651	4.9	718.3	1.96	366.5
PQ02	top of 1st floor	1	3.4932	3.4932	1.000	4.2	538.9	1.73	311.5

Table B-6b. Neutral Pressure Levels in Houses in Five Provinces (Scanada 1993) – Part 2

House I.D.	NPP Location	No. of Storys	NPP Height above grade [m]	House Height above grade [m]	NPL h/H	ACH @50 [ac/h]	ELA sq.cm	NLA sq.cm sq.m	Ext'r Env. Area sq.m
NS01	half height of 2nd floor	2	5.0172	6.2364	0.805	6.5	1121.0	3.17	353.6
NS02	top of 1st floor	1	3.4932	3.4932	1.000	6.6	1301.0	3.09	421.0
NS03	top of 2nd floor	2	6.2364	6.2364	1.000	2.5	540.0	1.37	394.2
NS04	top of 1st floor	1	3.4932	3.4932	1.000	5.4	1354.0	2.41	561.8
NS05	half height of 2nd floor	2	5.0172	6.2364	0.805	4.5	1310.0	2.52	519.8
NS06	top of 2nd floor	2	6.2364	6.2364	1.000	2.7	749.0	1.27	589.8
NS07	half height of 2nd floor	2	5.0172	6.2364	0.805	5.8	1963.0	2.84	691.2
NS08	half height of 1st floor	1	2.274	3.4932	0.651	2.7	406.0	1.23	330.1
NS09	half height of 1st floor	1	2.274	3.4932	0.651	5.5	1050.0	2.68	391.8
NS10	top of 2nd floor	2	6.2364	6.2364	1.000	10.5	2457.0	4.63	530.7
NS11	half height of 1st floor	1	2.274	3.4932	0.651	4.0	670.0	1.63	411.0
NS12	bottom of 2nd floor	2	3.798	6.2364	0.609	12.2	2076.0	4.10	506.3
ON01	half height of 2nd floor	2	5.0172	6.2364	0.805	8.0	1657.5	3.23	513.2
ON02	bottom of 2nd floor	2	3.798	6.2364	0.609	5.5	1227.3	2.46	498.9
ON03	bottom of 2nd floor	2	3.798	6.2364	0.609	4.1	787.9	1.80	437.7
ON04	half height of 2nd floor	2	5.0172	6.2364	0.805	4.5	969.8	2.15	451.1
ON05	half height of 2nd floor	3	5.0172	8.9796	0.559	10.6	2784.1	5.46	509.9
ON06	half height of 2nd floor	2	5.0172	6.2364	0.805	2.5	612.4	1.13	541.9
ON07	bottom of 1st floor	2	1.0548	6.2364	0.169	1.1	353.3	0.53	666.6
ON08	half height of 2nd floor	2	5.0172	6.2364	0.805	3.6	458.0	1.39	329.5
ON09	half height of 1st floor	2	2.274	6.2364	0.365	6.1	1260.7	2.78	453.5
ON10	top of 1st floor	2	3.4932	6.2364	0.560	11.7	1630.9	4.58	356.1
ON11	top of 2nd floor	2	6.2364	6.2364	1.000	3.4	570.9	1.41	404.9
ON12	top of 1st floor	2	3.4932	6.2364	0.560	2.5	523.6	0.99	528.9
PQ03	top of 1st floor	1	3.4932	3.4932	1.000	3.5	540.8	1.34	403.6
PQ04	top of 1st floor	1	3.4932	3.4932	1.000	4.2	689.2	1.85	372.5

The final set of measured NPL data included in this Appendix was measured in a study of 20 Saskatoon houses that were selected to be of medium airtightness (2-7 ac/h @ 50 Pa). Four of those houses were selected for trials of a prototype outdoor temperature controlled ventilation system (OTCV). The NPLs for those four houses were measured and reported in a September 1995 report by the Saskatchewan Research Council, Building Science Division to Canada Mortgage and Housing Corporation "Ventilation Control in Medium Air Tightness Houses". The measured NPL data, above grade, for these four houses are listed in Table B-7. It was discovered that the air changes at 50 Pa stated for the four Saskatoon houses in this report do not agree with the stated airtightness test parameters: house flow coefficient, C, and house flow exponent, n. Subsequent communications with the authors of that report have indicated that the stated values of ACH @ 50 Pa were measured for one set of conditions re sealing of deliberate openings in the building envelope of the subject houses, while the stated values of C & n were measured for another set of sealing conditions (Fugler and Dumont 2007).

Table B-7. Neutral Pressure Levels Measured in Four Medium Airtightness Houses in Saskatoon (1995)

House No.	NPL Height above grade [m]	House Height [m]	No. of Storeys	NPL Value h/H	House Volume [cu.m]	ACH@50 [ac/h][1]	NLA [sq.cm/ sq.m]	House Flow[1] Coeff. [L/sPa^n]	House Flow[1] Exponent n
P94-1	3.94	3.26	1	1.21	485.2	2.59	1.377	25.9	0.719
P94-3	3.69	3.19	1	1.16	467.4	2.74	1.137	18.9	0.798
P94-5	3.38	3.19	1	1.06	490.7	1.65	0.721	21.8	0.717
P94-13	3.78	4.20	SplitLevel	0.90	539.0	3.29	1.220	27.8	0.793

[1] The reported airtightness C & n parameters and the reported ACH@50 values do not agree with each other because they were measured for different conditions re sealing of deliberate openings in the building envelope of each subject house (Fugler & Dumont, 2007).

Appendix C – Listing of Calculated Annual Statistics of Hourly Air Infiltration Rates for Groups by Heating System, and Age (Period of Construction)

On the following pages in this Appendix C, are tables listing the aggregated summary statistics for air change rates calculated by the air infiltration model for various groupings of houses as discussed in the main text of this report.

Explanation of column headings in tables:

Smaller font size has been required to fit these tables onto a single page for each NPL value. The column headings have also required abbreviation, so they are explained here.

Heating System	Type or category of heating system, taken verbatim from EnerGuide For Houses database records, abbreviated slightly where necessary.
Period of Construction	The range of years during which the group of houses was constructed
avg.	Average, arithmetic mean of parameter value for the group of houses.
medn.	Median of parameter value for the group of houses.
Fuel	Energy source for the group of houses, e.g., natural gas, oil, fossil = gas and/or oil, electricity, wood.
No.	Number of houses in group, also expressed as a percentage of the entire subset of houses for that city immediately below the actual number.
Flue	Type of furnace flue, determined from the type of furnace and the furnace fuel, e.g., Y=ntural draft, BD=barometric damper, YP=natural draft flue with continuous pilot light burning in furnace, AD=automatic damper, N=no furnace flue.
Max	Maximum value of parameter for teh group of houses.
US%	"Under Supply" metric expressed as percentage of number of air changes required for the period (one year) at rate of 0.3 ac/h.
Mean	Arithmetic mean, or average, of calculated hourly air change rates for the year.
StDev	Standard deviation of calculated hourly air change rates about the mean rate, for the year.
Median	Median of hourly calculated air change rates for the year.
Hrs	Number of hours during the year that the calculated air change rate is less than 0.3 ac/h.
Prds	Number of periods during year that calculated hourly ac/h is less than 0.3 ac/h.
Lngst	Longest period of the year, in hours of duration, during which hourly calculated air chage rate is less than 0.3 ac/h.
USach	"Under Supply" metric, expressed as total number of air changes for the year, of under supply of natural ventilation, for the year, during periods when calculated air change rate is less than 0.3 ac/h, for each such hour i, Under $Supply_i$ = 0.3 – (natural air change $rate)_i$.

Table C-1. Aggregated Annual Statistics for Groupings by Heating System Type of Model Calculations of Natural Ventilation in Ottawa Houses with NPL = 0.25

Heating System		Fuel	No.	Flue	Max	US%	Mean	StDev	Median	Hrs	Prds	Lngst	USach
Baseboard/Hydronic/Plenum(duct) htrs	avg.	Electricity	183	N	0.819	30%	0.3097	0.1169	0.3026	5691	287	1832.3	777.7
	medn.		4.76%		0.630	27%	0.2323	0.0895	0.2274	6675	271	229.0	705.1
Boiler			4	BD									
Boiler with continuous pilot			6	YP									
Boiler with flue vent damper			2	BD									
Boiler with spark ignit.,vent damper			15	AD									
Boiler with spark ignition			5	Y									
Condensing boiler			1	N									
Condensing furnace: gas	avg.	Fossil	815	N	0.723	31%	0.2738	0.1032	0.2677	5911	292	2180.8	815.5
	medn.		21.18%		0.613	27%	0.2290	0.0874	0.2231	6839	300	234.5	715.9
Conventional stove or furnace			2	Y									
Direct vent, non-condensing furnace			2	N									
Forced air furnace	avg.	Electricity	70	N	0.626	35%	0.2354	0.0893	0.2299	6622	257	2294.3	913.2
	medn.		1.82%		0.528	36%	0.1938	0.0750	0.1896	8057	226	507.0	956.5
Furnace	avg.	Oil	258	BD	0.788	26%	0.3054	0.1127	0.2990	5446	322	1246.5	673.7
	medn.		6.70%		0.624	25%	0.2387	0.0891	0.2330	6575	348	192.0	661.2
Furnace with continuous pilot	avg.	N.Gas	693	YP	0.702	32%	0.2657	0.1001	0.2596	6254	280	2004.0	834.4
	medn.		18.01%		0.577	31%	0.2147	0.0822	0.2103	7440	256	406.0	804.0
Furnace with flame retention head	avg.	Oil	251	BD	0.785	27%	0.2998	0.1122	0.2933	5594	319	1359.9	705.3
	medn.		6.52%		0.635	26%	0.2382	0.0902	0.2314	6479	320	209.0	680.2
Furnace with flue vent damper	avg.	Oil	176	BD	0.837	24%	0.3138	0.1194	0.3066	5178	357	1064.3	627.6
	medn.		4.57%		0.717	19%	0.2751	0.1029	0.2693	5354	395	168.0	496.4
Furnace with spark ignit.,vent dmpr	avg.	N.Gas	184	AD	0.775	26%	0.2943	0.1106	0.2878	5419	355	1330.4	676.5
	medn.		4.78%		0.683	22%	0.2571	0.0972	0.2511	5898	441	168.0	567.0
Furnace with spark ignition	avg.	N.Gas	279	Y	0.832	23%	0.3170	0.1188	0.3099	4975	369	1114.9	603.6
	medn.		7.25%		0.788	16%	0.2967	0.1123	0.2895	4713	436	144.0	414.9
Induced draft fan boiler			3	Y									
Induced draft fan furnace	avg.	N.Gas	851	Y	0.771	26%	0.2938	0.1102	0.2875	5642	341	1163.9	687.5
	medn.		22.12%		0.652	25%	0.2411	0.0932	0.2356	6455	385	188.0	650.9
Mid-efficiency furnace (no dil. air)	avg.	Oil	38	Y	0.767	27%	0.2862	0.1093	0.2794	5535	355	1250.5	700.8
	medn.		0.99%		0.675	23%	0.2525	0.0959	0.2457	6130	439	188.0	595.9
Radiant ceiling panels		Electricity	5	N									
Entire Ottawa subset of houses	**avg.**		**3848**		**0.759**	**28%**	**0.2884**	**0.1084**	**0.2820**	**5718**	**317**	**1600.9**	**738.8**
	medn.		**100%**		**0.637**	**25%**	**0.2381**	**0.0908**	**0.2324**	**6562**	**343**	**192.0**	**668.2**

Table C-2. Aggregated Annual Statistics for Groupings by Heating System Type of Model Calculations of Natural Ventilation in Ottawa Houses with NPL = 0.50

Heating System		Fuel	No.	Flue	Max	US%	Mean	StDev	Median	Hrs	Prds	Lngst	USach
Baseboard/Hydronic/Plenum(duct) htrs	avg.	Electricity	183	N	0.815	22%	0.3709	0.1276	0.3722	4791	228	1845.6	586.9
	medn.		4.76%		0.632	17%	0.2845	0.1023	0.2850	4882	256	214.0	435.0
Boiler			4	BD									
Boiler with continuous pilot			6	YP									
Boiler with flue vent damper			2	BD									
Boiler with spark ignit.,vent dampr			15	AD									
Boiler with spark ignition			5	Y									
Condensing boiler			1	N									
Condensing furnace: gas	avg.	Fossil	815	N	0.719	24%	0.3276	0.1125	0.3287	5031	226	2144.7	622.1
	medn.		21.18%		0.613	18%	0.2774	0.0961	0.2775	5150	257	229.0	461.9
Conventional stove or furnace			2	Y									
Direct vent, non-condensing furnace			2	N									
Forced air furnace	avg.	Electricity	70	N	0.624	26%	0.2829	0.0982	0.2837	5724	222	2274.4	690.0
	medn.		1.82%		0.538	25%	0.2362	0.0878	0.2366	6706	252	507.0	658.9
Furnace	avg.	Oil	258	BD	0.778	19%	0.3604	0.1193	0.3623	4534	252	1232.8	489.9
	medn.		6.70%		0.621	16%	0.2818	0.0981	0.2836	5010	275	188.0	409.2
Furnace with continuous pilot	avg.	N.Gas	693	YP	0.697	24%	0.3179	0.1091	0.3190	5358	229	1975.2	624.5
	medn.		18.01%		0.576	20%	0.2593	0.0907	0.2594	5792	234	406.0	530.3
Furnace with flame retention head	avg.	Oil	251	BD	0.779	20%	0.3570	0.1211	0.3584	4616	250	1347.8	512.5
	medn.		6.52%		0.644	16%	0.2892	0.1018	0.2910	4737	277	188.0	417.7
Furnace with flue vent damper	avg.	Oil	176	BD	0.835	17%	0.3778	0.1319	0.3785	4083	270	1000.0	437.6
	medn.		4.57%		0.704	11%	0.3288	0.1154	0.3284	3528	306	168.0	286.9
Furnace with spark ignit.,vent dmpr	avg.	N.Gas	184	AD	0.769	19%	0.3515	0.1200	0.3529	4382	268	1345.6	488.5
	medn.		4.78%		0.677	13%	0.3082	0.1078	0.3095	4106	295	168.0	336.6
Furnace with spark ignition	avg.	N.Gas	279	Y	0.825	16%	0.3779	0.1284	0.3795	3940	264	1096.3	427.6
	medn.		7.25%		0.779	9%	0.3546	0.1186	0.3562	2784	297	144.0	238.1
Induced draft fan boiler			3	Y									
Induced draft fan furnace	avg.	N.Gas	851	Y	0.766	19%	0.3504	0.1193	0.3517	4575	269	1153.0	489.1
	medn.		22.12%		0.652	15%	0.2949	0.1019	0.2956	4532	302	188.0	400.2
Mid-efficiency furnace (no dil. air)	avg.	Oil	38	Y	0.766	19%	0.3456	0.1214	0.3462	4433	272	1217.8	505.8
	medn.		0.99%		0.675	14%	0.3014	0.1095	0.3018	4321	287	188.0	357.9
Radiant ceiling panels		Electricity	5	N									
Entire Ottawa subset of houses	**avg.**		**3848**		**0.754**	**21%**	**0.3444**	**0.1176**	**0.3456**	**4751**	**247**	**1580.1**	**543.7**
	medn.		**100%**		**0.636**	**16%**	**0.2875**	**0.1001**	**0.2881**	**4779**	**283**	**188.0**	**412.4**

Table C-3. Aggregated Annual Statistics for Groupings by Heating System Type of Model Calculations of Natural Ventilation in Ottawa Houses with NPL = 0.60

Heating System		Fuel	No.	Flue	Max	US%	Mean	StDev	Median	Hrs	Prds	Lngst	USach
Baseboard/Hydronic/Plenum(duct) htrs	avg.	Electricity	183	N	0.843	20%	0.4035	0.1418	0.4041	4361	203	1762.8	520.6
	medn.		4.76%		0.649	14%	0.3097	0.1156	0.3103	4037	226	211.0	365.8
Boiler			4	BD									
Boiler with continuous pilot			6	YP									
Boiler with flue vent damper			2	BD									
Boiler with spark ignit.,vent damper			15	AD									
Boiler with spark ignition			5	Y									
Condensing boiler			1	N									
Condensing furnace: gas	avg.	Fossil	815	N	0.744	21%	0.3563	0.1250	0.3569	4619	202	2062.4	552.6
	medn.		21.18%		0.632	15%	0.3028	0.1066	0.3025	4294	235	214.0	384.9
Conventional stove or furnace			2	Y									
Direct vent, non-condensing furnace			2	N									
Forced air furnace	avg.	Electricity	70	N	0.646	23%	0.3081	0.1094	0.3083	5237	203	2189.1	608.0
	medn.		1.82%		0.565	21%	0.2582	0.0977	0.2575	5775	250	507.0	554.0
Furnace	avg.	Oil	258	BD	0.800	16%	0.3905	0.1315	0.3924	4073	226	1171.0	424.8
	medn.		6.70%		0.640	13%	0.3074	0.1104	0.3073	4121	261	188.0	341.0
Furnace with continuous pilot	avg.	N.Gas	693	YP	0.721	21%	0.3457	0.1212	0.3464	4890	209	1885.9	547.5
	medn.		18.01%		0.597	17%	0.2839	0.1007	0.2819	4949	235	406.0	444.2
Furnace with flame retention head	avg.	Oil	251	BD	0.804	17%	0.3877	0.1341	0.3888	4155	223	1292.0	446.3
	medn.		6.52%		0.673	13%	0.3129	0.1131	0.3156	3882	264	188.0	352.9
Furnace with flue vent damper	avg.	Oil	176	BD	0.866	14%	0.4115	0.1470	0.4114	3615	238	954.1	378.3
	medn.		4.57%		0.732	9%	0.3579	0.1289	0.3583	2892	276	166.0	244.6
Furnace with spark ignit.,vent damper	avg.	N.Gas	184	AD	0.795	16%	0.3821	0.1332	0.3830	3926	235	1255.8	426.5
	medn.		4.78%		0.702	11%	0.3356	0.1203	0.3361	3362	268	182.0	282.7
Furnace with spark ignition	avg.	N.Gas	279	Y	0.852	14%	0.4105	0.1423	0.4117	3525	232	1021.3	371.2
	medn.		7.25%		0.795	8%	0.3881	0.1302	0.3870	2362	270	144.0	204.2
Induced draft fan boiler			3	Y									
Induced draft fan furnace	avg.	N.Gas	851	Y	0.791	16%	0.3807	0.1323	0.3816	4076	239	1098.6	423.2
	medn.		22.12%		0.672	13%	0.3221	0.1132	0.3215	3739	277	188.0	335.3
Mid-efficiency furnace (no dil. air)	avg.	Oil	38	Y	0.796	17%	0.3768	0.1356	0.3767	3953	238	1164.3	443.9
	medn.		0.99%		0.708	11%	0.3298	0.1227	0.3287	3507	264	188.0	301.8
Radiant ceiling panels		Electricity	5	N									
Entire Ottawa subset of houses	**avg.**		**3848**		**0.779**	**18%**	**0.3743**	**0.1305**	**0.3751**	**4296**	**221**	**1508.2**	**476.1**
	medn.		**100%**		**0.661**	**13%**	**0.3133**	**0.1115**	**0.3136**	**3950**	**260**	**188.0**	**346.4**

Table C-4. Aggregated Annual Statistics for Groupings by Heating System Type of Model Calculations of Natural Ventilation in Ottawa Houses with NPL = 0.65

Heating System		Fuel	No.	Flue	Max	US%	Mean	StDev	Median	Hrs	Prds	Lngst	USach
Baseboard/Hydronic/Plenum(duct) htrs	avg.	Electricity	183	N	0.862	19%	0.4210	0.1507	0.4207	4155	190	1711.6	491.0
	medn.		4.76%		0.664	13%	0.3229	0.1233	0.3239	3701	213	208.0	339.7
Boiler			4	BD									
Boiler with continuous pilot			6	YP									
Boiler with flue vent damper			2	BD									
Boiler with spark ignit.,vent damper			15	AD									
Boiler with spark ignition			5	Y									
Condensing boiler			1	N									
Condensing furnace: gas	avg.	Fossil	815	N	0.760	20%	0.3717	0.1328	0.3715	4413	192	1998.0	521.0
	medn.		21.18%		0.648	13%	0.3161	0.1134	0.3155	3914	219	208.0	354.5
Conventional stove or furnace			2	Y									
Direct vent, non-condensing furnace			2	N									
Forced air furnace	avg.	Electricity	70	N	0.661	22%	0.3216	0.1163	0.3211	4989	194	2104.5	571.1
	medn.		1.82%		0.579	19%	0.2698	0.1038	0.2690	5371	222	507.0	510.5
Furnace	avg.	Oil	258	BD	0.817	15%	0.4068	0.1393	0.4079	3843	215	1137.5	396.1
	medn.		6.70%		0.654	12%	0.3205	0.1178	0.3192	3738	243	188.0	316.8
Furnace with continuous pilot	avg.	N.Gas	693	YP	0.738	20%	0.3607	0.1287	0.3605	4650	200	1820.0	512.8
	medn.		18.01%		0.611	16%	0.2964	0.1070	0.2945	4540	221	401.0	412.9
Furnace with flame retention head	avg.	Oil	251	BD	0.822	16%	0.4043	0.1424	0.4045	3929	212	1245.3	417.2
	medn.		6.52%		0.688	13%	0.3257	0.1195	0.3271	3528	248	188.0	329.7
Furnace with flue vent damper	avg.	Oil	176	BD	0.886	13%	0.4295	0.1563	0.4286	3397	225	901.0	353.0
	medn.		4.57%		0.750	9%	0.3724	0.1371	0.3734	2698	264	166.0	228.1
Furnace with spark ignit.,vent dampr	avg.	N.Gas	184	AD	0.813	15%	0.3985	0.1414	0.3986	3712	222	1204.6	399.3
	medn.		4.78%		0.719	10%	0.3503	0.1273	0.3495	3046	257	182.0	262.7
Furnace with spark ignition	avg.	N.Gas	279	Y	0.871	13%	0.4282	0.1511	0.4284	3326	220	987.2	346.5
	medn.		7.25%		0.812	7%	0.4050	0.1375	0.4034	2219	260	91.0	190.5
Induced draft fan boiler			3	Y									
Induced draft fan furnace	avg.	N.Gas	851	Y	0.808	15%	0.3970	0.1404	0.3971	3838	225	1064.0	394.6
	medn.		22.12%		0.687	12%	0.3365	0.1200	0.3340	3438	258	188.0	311.6
Mid-efficiency furnace (no dil. air)	avg.	Oil	38	Y	0.814	16%	0.3934	0.1443	0.3925	3728	226	1137.1	417.2
	medn.		0.99%		0.725	11%	0.3449	0.1309	0.3436	3176	265	188.0	280.6
Radiant ceiling panels		Electricity	5	N									
Entire Ottawa subset of houses	**avg.**		**3848**		**0.807**	**16.98%**	**0.3904**	**0.1386**	**0.3904**	**4073**	**209**	**1457.7**	**446.2**
	medn.		**100%**		**0.676**	**12.23%**	**0.3273**	**0.1187**	**0.3264**	**3597**	**243**	**188.0**	**321.4**

Table C-5. Aggregated Annual Statistics for Groupings by Heating System Type of Model Calculations of Natural Ventilation in Ottawa Houses with NPL = 0.70

Heating System		Fuel	No.	Flue	Max	US%	Mean	StDev	Median	Hrs	Prds	Lngst	USach
Baseboard/Hydronic/Plenum(duct) htrs	avg.	Electricity	183	N	0.882	18%	0.4391	0.1605	0.4381	3960	182	1662.1	463.8
	medn.		4.76%		0.681	12%	0.3367	0.1316	0.3372	3428	197	188.0	317.8
Boiler			4	BD									
Boiler with continuous pilot			6	YP									
Boiler with flue vent damper			2	BD									
Boiler with spark ignit.,vent damper			15	AD									
Boiler with spark ignition			5	Y									
Condensing boiler			1	N									
Condensing furnace: gas	avg.	Fossil	815	N	0.778	19%	0.3877	0.1413	0.3869	4214	184	1932.7	491.7
	medn.		21.18%		0.664	12%	0.3289	0.1207	0.3280	3632	204	208.0	327.1
Conventional stove or furnace			2	Y									
Direct vent, non-condensing furnace			2	N									
Forced air furnace	avg.	Electricity	70	N	0.677	20%	0.3355	0.1239	0.3345	4745	184	1997.5	537.1
	medn.		1.82%		0.593	18%	0.2819	0.1106	0.2807	4998	213	507.0	473.7
Furnace	avg.	Oil	258	BD	0.835	14%	0.4238	0.1480	0.4244	3616	205	1085.4	370.0
	medn.		6.70%		0.669	11%	0.3347	0.1256	0.3331	3413	228	188.0	296.3
Furnace with continuous pilot	avg.	N.Gas	693	YP	0.755	18%	0.3762	0.1371	0.3755	4413	191	1743.5	480.8
	medn.		18.01%		0.625	14%	0.3085	0.1143	0.3071	4160	210	399.0	380.6
Furnace with flame retention head	avg.	Oil	251	BD	0.841	15%	0.4216	0.1515	0.4212	3711	202	1208.6	390.6
	medn.		6.52%		0.705	12%	0.3391	0.1272	0.3403	3194	236	188.0	305.7
Furnace with flue vent damper	avg.	Oil	176	BD	0.906	13%	0.4482	0.1665	0.4465	3196	212	867.1	330.2
	medn.		4.57%		0.768	8%	0.3872	0.1462	0.3887	2527	253	166.0	213.3
Furnace with spark ignit.,vent damper	avg.	N.Gas	184	AD	0.832	14%	0.4156	0.1505	0.4151	3510	209	1160.5	374.6
	medn.		4.78%		0.736	9%	0.3656	0.1348	0.3651	2818	247	182.0	245.3
Furnace with spark ignition	avg.	N.Gas	279	Y	0.891	12%	0.4465	0.1608	0.4460	3138	209	941.3	324.0
	medn.		7.25%		0.827	7%	0.4225	0.1455	0.4195	2094	249	78.0	177.8
Induced draft fan boiler			3	Y									
Induced draft fan furnace	avg.	N.Gas	851	Y	0.827	14%	0.4140	0.1494	0.4135	3613	213	1021.4	368.7
	medn.		22.12%		0.704	11%	0.3506	0.1280	0.3487	3210	249	188.0	290.8
Mid-efficiency furnace (no dil. air)	avg.	Oil	38	Y	0.833	15%	0.4107	0.1538	0.4089	3525	210	1111.1	393.2
	medn.		0.99%		0.743	10%	0.3605	0.1397	0.3588	2937	252	188.0	262.3
Radiant ceiling panels		Electricity	5	N									
Entire Ottawa subset of houses	**avg.**		**3848**		**0.815**	**16%**	**0.4072**	**0.1475**	**0.4065**	**3859**	**199**	**1402.7**	**418.8**
	medn.		**100%**		**0.692**	**11%**	**0.3410**	**0.1266**	**0.3405**	**3329**	**225**	**188.0**	**299.3**

Table C-6. Aggregated Annual Statistics for Groupings by Heating System Type of Model Calculations of Natural Ventilation in Ottawa Houses with NPL = 0.75

Heating System		Fuel	No.	Flue	Max	US%	Mean	StDev	Median	Hrs	Prds	Lngst	USach
Baseboard/Hydronic/Plenum(duct) htrs	avg.	Electricity	183	N	0.903	17%	0.4579	0.1709	0.4564	3773	173	1608.5	438.7
	medn.		4.76%		0.698	11%	0.3509	0.1404	0.3511	3213	192	188.0	298.5
Boiler			4	BD									
Boiler with continuous pilot			6	YP									
Boiler with flue vent damper			2	BD									
Boiler with spark ignit.,vent damper			15	AD									
Boiler with spark ignition			5	Y									
Condensing boiler			1	N									
Condensing furnace: gas	avg.	Fossil	815	N	0.796	18%	0.4042	0.1506	0.4030	4020	176	1875.5	464.6
	medn.		21.18%		0.679	12%	0.3427	0.1286	0.3414	3401	188	208.0	305.0
Conventional stove or furnace			2	Y									
Direct vent, non-condensing furnace			2	N									
Forced air furnace	avg.	Electricity	70	N	0.693	19%	0.3500	0.1320	0.3485	4517	179	1922.5	505.8
	medn.		1.82%		0.608	17%	0.2943	0.1178	0.2927	4627	199	507.0	441.8
Furnace	avg.	Oil	258	BD	0.855	13%	0.4414	0.1575	0.4418	3402	194	1045.8	346.5
	medn.		6.70%		0.685	11%	0.3492	0.1339	0.3476	3173	212	188.0	278.3
Furnace with continuous pilot	avg.	N.Gas	693	YP	0.773	17%	0.3923	0.1460	0.3911	4186	183	1670.7	451.5
	medn.		18.01%		0.640	14%	0.3221	0.1217	0.3211	3844	193	399.0	356.2
Furnace with flame retention head	avg.	Oil	251	BD	0.860	14%	0.4394	0.1613	0.4386	3504	192	1164.8	366.5
	medn.		6.52%		0.722	11%	0.3536	0.1357	0.3540	3002	221	188.0	285.4
Furnace with flue vent damper	avg.	Oil	176	BD	0.928	12%	0.4675	0.1774	0.4650	3010	202	831.5	309.8
	medn.		4.57%		0.788	8%	0.4026	0.1558	0.4043	2374	241	122.5	199.8
Furnace with spark ignit.,vent damper	avg.	N.Gas	184	AD	0.851	13%	0.4333	0.1603	0.4322	3322	200	1123.3	352.2
	medn.		4.78%		0.754	9%	0.3813	0.1431	0.3806	2662	227	182.0	229.8
Furnace with spark ignition	avg.	N.Gas	279	Y	0.912	12%	0.4654	0.1712	0.4645	2961	199	895.8	303.7
	medn.		7.25%		0.842	6%	0.4405	0.1550	0.4380	1977	235	78.0	166.0
Induced draft fan boiler			3	Y									
Induced draft fan furnace	avg.	N.Gas	851	Y	0.847	13%	0.4315	0.1591	0.4306	3401	203	980.9	345.5
	medn.		22.12%		0.721	10%	0.3656	0.1365	0.3640	3014	236	188.0	273.0
Mid-efficiency furnace (no dil. air)	avg.	Oil	38	Y	0.853	14%	0.4285	0.1639	0.4261	3341	198	1077.1	371.4
	medn.		0.99%		0.761	9%	0.3764	0.1491	0.3737	2760	238	185.0	246.2
Radiant ceiling panels		Electricity	5	N									
Entire Ottawa subset of houses	**avg.**		**3848**		**0.834**	**15%**	**0.4245**	**0.1571**	**0.4234**	**3655**	**190**	**1352.0**	**393.8**
	medn.		**100%**		**0.710**	**11%**	**0.3557**	**0.1349**	**0.3542**	**3111**	**215**	**188.0**	**281.0**

Table C-7. Aggregated Annual Statistics for Groupings by Heating System Type of Model Calculations of Natural Ventilation in Ottawa Houses with NPL = 0.90

Heating System		Fuel	No.	Flue	Max	US%	Mean	StDev	Median	Hrs	Prds	Lngst	USach
Baseboard/Hydronic/Plenum(duct) htrs	avg.	Electricity	183	N	0.989	14%	0.5169	0.2055	0.5113	3290	153	1416.3	374.7
	medn.		4.76%		0.783	10%	0.3983	0.1688	0.3927	2747	158	208.0	251.4
Boiler			4	BD									
Boiler with continuous pilot			6	YP									
Boiler with flue vent damper			2	BD									
Boiler with spark ignit.,vent damper			15	AD									
Boiler with spark ignition			5	Y									
Condensing boiler			1	N									
Condensing furnace: gas	avg.	Fossil	815	N	0.872	15%	0.4563	0.1810	0.4514	3496	156	1656.5	395.2
	medn.		21.18%		0.745	10%	0.3870	0.1546	0.3834	2878	163	208.0	258.8
Conventional stove or furnace			2	Y									
Direct vent, non-condensing furnace			2	N									
Forced air furnace	avg.	Electricity	70	N	0.761	16%	0.3952	0.1587	0.3906	3888	159	1625.2	426.8
	medn.		1.82%		0.677	14%	0.3331	0.1417	0.3284	3769	165	506.0	370.6
Furnace	avg.	Oil	258	BD	0.928	11%	0.4972	0.1893	0.4941	2856	169	899.7	289.1
	medn.		6.70%		0.762	9%	0.3936	0.1610	0.3896	2684	186	188.0	234.3
Furnace with continuous pilot	avg.	N.Gas	693	YP	0.846	14%	0.4427	0.1755	0.4381	3566	163	1419.7	378.4
	medn.		18.01%		0.700	11%	0.3643	0.1463	0.3605	3231	171	350.0	297.2
Furnace with flame retention head	avg.	Oil	251	BD	0.940	12%	0.4955	0.1938	0.4910	2965	170	999.2	307.1
	medn.		6.52%		0.790	9%	0.4015	0.1630	0.3962	2610	187	180.0	239.5
Furnace with flue vent damper	avg.	Oil	176	BD	1.021	10%	0.5281	0.2132	0.5213	2540	177	697.2	260.1
	medn.		4.57%		0.882	6%	0.4519	0.1874	0.4517	1975	203	78.5	165.5
Furnace with spark ignit.,vent damper	avg.	N.Gas	184	AD	0.931	11%	0.4889	0.1927	0.4841	2839	176	937.0	296.0
	medn.		4.78%		0.834	7%	0.4306	0.1719	0.4257	2283	197	101.0	190.6
Furnace with spark ignition	avg.	N.Gas	279	Y	0.996	10%	0.5249	0.2058	0.5201	2498	175	765.0	253.9
	medn.		7.25%		0.925	5%	0.4973	0.1865	0.4924	1649	196	45.0	137.1
Induced draft fan boiler			3	Y									
Induced draft fan furnace	avg.	N.Gas	851	Y	0.926	11%	0.4868	0.1912	0.4821	2862	178	825.9	288.7
	medn.		22.12%		0.792	9%	0.4117	0.1642	0.4090	2586	198	113.0	228.4
Mid-efficiency furnace (no dil. air)	avg.	Oil	38	Y	0.939	12%	0.4842	0.1970	0.4780	2871	178	908.8	317.0
	medn.		0.99%		0.848	8%	0.4263	0.1793	0.4199	2380	204	112.0	205.5
Radiant ceiling panels		Electricity	5	N									
Entire Ottawa subset of houses	**avg.**		**3848**		**0.912**	**13%**	**0.4789**	**0.1888**	**0.4742**	**3119**	**168**	**1163.5**	**331.4**
	medn.		**100%**		**0.778**	**9%**	**0.4020**	**0.1622**	**0.3971**	**2657**	**187**	**183.0**	**235.2**

Table C-8. Aggregated Annual Statistics for Groupings by Period of Construction of Model Calculations of Natural Ventilation in Ottawa Houses with NPL = 0.25

Period of Construction		No.	Max	US%	Mean	StDev	Median	Hrs	Prds	Lngst	USach
Pre 1900	avg.	149	1.415	7%	0.5510	0.2027	0.5402	1989	378	66.4	190.8
	medn.	3.87%	1.242	4%	0.4883	0.1769	0.4766	1394	374	40.0	112.6
1900-1944	avg.	866	1.153	11%	0.4415	0.1647	0.4321	2974	421	179.0	298.2
	medn.	22.51%	1.048	7%	0.4011	0.1493	0.3936	2221	463	65.0	188.1
Pre 1945	avg.	1015	1.191	11%	0.4576	0.1703	0.4480	2830	414	162.4	282.4
	medn.	26.38%	1.075	7%	0.4123	0.1530	0.4045	2092	454	65.0	173.5
1945	avg.	45	0.907	16%	0.3473	0.1295	0.3398	4126	469	286.8	414.7
	medn.	1.17%	0.828	14%	0.3150	0.1185	0.3089	4190	538	89.0	362.0
1946-1960	avg.	832	0.722	25%	0.2740	0.1031	0.2679	5713	380	976.7	668.6
	medn.	21.62%	0.661	24%	0.2470	0.0941	0.2415	6279	443	188.0	618.0
1961-1980	avg.	1228	0.594	34%	0.2240	0.0847	0.2189	6916	285	1796.2	891.5
	medn.	31.91%	0.537	34%	0.2016	0.0768	0.1970	7873	261	407.0	897.6
1981-1995	avg.	571	0.481	45%	0.1784	0.0685	0.1741	7774	159	3832.6	1188.5
	medn.	14.84%	0.419	48%	0.1549	0.0596	0.1508	8683	31	2545.0	1274.0
1996-2004	avg.	157	0.422	50%	0.1571	0.0601	0.1534	8030	130	4940.6	1324.9
	medn.	4.08%	0.365	54%	0.1384	0.0525	0.1351	8736	7	6996.0	1415.8
Entire Ottawa subset of houses	**avg.**	**3848**	**0.759**	**28%**	**0.2884**	**0.1084**	**0.2820**	**5718**	**317**	**1600.9**	**738.8**
	medn.	**100.00%**	**0.637**	**25%**	**0.2381**	**0.0908**	**0.2324**	**6562**	**343**	**192.0**	**668.2**

Table C-9. Aggregated Annual Statistics for Groupings by Period of Construction of Model Calculations of Natural Ventilation in Ottawa Houses with NPL = 0.50

Period of Construction		No.	Max	US%	Mean	StDev	Median	Hrs	Prds	Lngst	USach
Pre 1900	avg.	149	1.398	4%	0.6485	0.2138	0.6517	1222	228	60.0	109.1
	medn.	3.87%	1.246	2%	0.5752	0.1910	0.5766	735	250	22.0	58.0
1900-1944	avg.	866	1.142	7%	0.5247	0.1769	0.5270	1985	268	178.4	182.9
	medn.	22.51%	1.037	4%	0.4785	0.1590	0.4804	1308	291	41.0	103.6
Pre 1945	avg.	1015	1.180	7%	0.5428	0.1823	0.5453	1873	262	161.1	172.0
	medn.	26.38%	1.057	4%	0.4876	0.1627	0.4901	1226	288	41.0	94.7
1945	avg.	45	0.898	10%	0.4127	0.1391	0.4147	2823	321	264.1	256.8
	medn.	1.17%	0.832	8%	0.3698	0.1344	0.3724	2381	325	89.0	206.3
1946-1960	avg.	832	0.718	18%	0.3276	0.1121	0.3287	4506	297	942.6	462.9
	medn.	21.62%	0.662	14%	0.2970	0.1037	0.2975	4460	323	188.0	375.8
1961-1980	avg.	1228	0.591	25%	0.2686	0.0926	0.2695	5900	255	1783.9	656.5
	medn.	31.91%	0.535	23%	0.2431	0.0844	0.2440	6498	294	407.0	606.5
1981-1995	avg.	571	0.481	36%	0.2161	0.0764	0.2165	7144	157	3792.3	948.2
	medn.	14.84%	0.420	37%	0.1885	0.0669	0.1887	8366	116	3888.0	985.4
1996-2004	avg.	157	0.421	42%	0.1900	0.0669	0.1904	7529	126	4868.7	1102.6
	medn.	4.08%	0.366	45%	0.1662	0.0581	0.1668	8707	17	6121.0	1172.5
Entire Ottawa subset of houses	**avg.**	**3848**	**0.754**	**21%**	**0.3444**	**0.1176**	**0.3456**	**4751**	**247**	**1580.1**	**543.7**
	medn.	**100.00%**	**0.636**	**16%**	**0.2875**	**0.1001**	**0.2881**	**4779**	**283**	**188.0**	**412.4**

Table C-10. Aggregated Annual Statistics for Groupings by Period of Construction of Model Calculations of Natural Ventilation in Ottawa Houses with NPL = 0.60

Period of Construction		No.	Max	US%	Mean	StDev	Median	Hrs	Prds	Lngst	USach
Pre 1900	avg.	149	1.435	3%	0.7021	0.2351	0.7058	1031	192	57.0	91.6
	medn.	3.87%	1.284	2%	0.6161	0.2104	0.6247	604	205	21.0	47.4
1900-1944	avg.	866	1.178	6%	0.5696	0.1958	0.5714	1697	230	170.2	154.9
	medn.	22.51%	1.069	3%	0.5186	0.1767	0.5213	1108	263	40.0	85.7
Pre 1945	avg.	1015	1.216	6%	0.5890	0.2016	0.5911	1599	224	153.6	145.6
	medn.	26.38%	1.094	3%	0.5292	0.1796	0.5316	1029	258	40.0	78.6
1945	avg.	45	0.926	8%	0.4480	0.1539	0.4496	2399	270	250.8	217.4
	medn.	1.17%	0.873	7%	0.4073	0.1518	0.4031	2048	284	81.0	176.6
1946-1960	avg.	832	0.742	15%	0.3561	0.1245	0.3568	3966	261	895.5	398.0
	medn.	21.62%	0.688	12%	0.3251	0.1159	0.3238	3675	286	188.0	316.7
1961-1980	avg.	1228	0.611	22%	0.2923	0.1030	0.2927	5322	232	1694.7	571.0
	medn.	31.91%	0.554	19%	0.2640	0.0940	0.2652	5585	270	407.0	507.6
1981-1995	avg.	571	0.500	32%	0.2358	0.0855	0.2355	6716	153	3624.8	848.3
	medn.	14.84%	0.436	33%	0.2056	0.0747	0.2053	7762	138	3166.0	857.1
1996-2004	avg.	157	0.438	38%	0.2072	0.0748	0.2070	7201	122	4715.2	1005.7
	medn.	4.08%	0.380	40%	0.1812	0.0646	0.1805	8551	61	5879.0	1047.3
Entire Ottawa subset of houses	**avg.**	**3848**	**0.779**	**18%**	**0.3743**	**0.1305**	**0.3751**	**4296**	**221**	**1508.2**	**476.1**
	medn.	**100.00%**	**0.661**	**13%**	**0.3133**	**0.1115**	**0.3136**	**3950**	**260**	**188.0**	**346.4**

Table C-11. Aggregated Annual Statistics for Groupings by Period of Construction of Model Calculations of Natural Ventilation in Ottawa Houses with NPL = 0.65

Period of Construction		No.	Max	US%	Mean	StDev	Median	Hrs	Prds	Lngst	USach
Pre 1900	avg.	149	1.465	3.22%	0.7312	0.2489	0.7334	956	179	54.5	84.6
	medn.	3.87%	1.312	1.65%	0.6389	0.2226	0.6474	542	189	18.0	43.3
1900-1944	avg.	866	1.204	5.46%	0.5938	0.2077	0.5945	1577	215	160.8	143.5
	medn.	22.51%	1.091	2.99%	0.5400	0.1878	0.5420	1019	249	40.0	78.5
Pre 1945	avg.	1015	1.242	5.13%	0.6140	0.2138	0.6149	1486	209	145.2	134.9
	medn.	26.38%	1.118	2.76%	0.5524	0.1910	0.5529	934	242	40.0	72.5
1945	avg.	45	0.946	7.67%	0.4670	0.1633	0.4678	2228	253	240.5	201.6
	medn.	1.17%	0.895	6.24%	0.4271	0.1607	0.4220	1930	271	78.0	164.0
1946-1960	avg.	832	0.759	14.09%	0.3715	0.1323	0.3714	3716	245	859.5	370.4
	medn.	21.62%	0.705	11.21%	0.3391	0.1234	0.3384	3339	272	188.0	294.5
1961-1980	avg.	1228	0.625	20.29%	0.3050	0.1095	0.3047	5030	221	1631.9	533.2
	medn.	31.91%	0.567	17.85%	0.2753	0.0997	0.2759	5209	254	407.0	469.2
1981-1995	avg.	571	0.511	30.49%	0.2463	0.0911	0.2454	6473	151	3514.0	801.2
	medn.	14.84%	0.447	30.42%	0.2147	0.0796	0.2143	7364	140	3166.0	799.4
1996-2004	avg.	157	0.448	36.48%	0.2164	0.0796	0.2158	7014	122	4620.2	958.7
	medn.	4.08%	0.389	37.39%	0.1892	0.0685	0.1882	8313	88	5660.0	982.6
Entire Ottawa subset of houses	**avg.**	**3848**	**0.807**	**16.98%**	**0.3904**	**0.1386**	**0.3904**	**4073**	**209**	**1457.7**	**446.2**
	medn.	**100.00%**	**0.676**	**12.23%**	**0.3273**	**0.1187**	**0.3264**	**3597**	**243**	**188.0**	**321.4**

Table C-12. Aggregated Annual Statistics for Groupings by Period of Construction of Model Calculations of Natural Ventilation in Ottawa Houses with NPL = 0.70

Period of Construction		No.	Max	US%	Mean	StDev	Median	Hrs	Prds	Lngst	USach
Pre 1900	avg.	149	1.498	3%	0.7616	0.2644	0.7626	886	167	50.2	78.4
	medn.	3.87%	1.342	2%	0.6655	0.2364	0.6694	490	174	18.0	39.7
1900-1944	avg.	866	1.231	5%	0.6190	0.2210	0.6188	1470	201	151.8	133.5
	medn.	22.51%	1.116	3%	0.5617	0.1992	0.5641	949	236	40.0	72.3
Pre 1945	avg.	1015	1.270	5%	0.6400	0.2273	0.6399	1385	196	136.9	125.4
	medn.	26.38%	1.143	3%	0.5751	0.2032	0.5759	865	223	25.0	66.8
1945	avg.	45	0.968	7%	0.4869	0.1737	0.4868	2078	236	234.4	187.6
	medn.	1.17%	0.917	6%	0.4459	0.1704	0.4404	1826	262	76.0	152.4
1946-1960	avg.	832	0.776	13%	0.3875	0.1408	0.3867	3486	231	828.3	345.7
	medn.	21.62%	0.720	10%	0.3535	0.1313	0.3531	3102	259	188.0	274.6
1961-1980	avg.	1228	0.640	19%	0.3182	0.1166	0.3174	4746	211	1564.1	498.8
	medn.	31.91%	0.581	17%	0.2873	0.1058	0.2872	4839	241	407.0	436.3
1981-1995	avg.	571	0.524	29%	0.2571	0.0971	0.2558	6220	148	3385.4	756.8
	medn.	14.84%	0.458	28%	0.2242	0.0849	0.2235	6954	139	2662.0	743.3
1996-2004	avg.	157	0.459	35%	0.2259	0.0848	0.2250	6809	121	4492.9	913.2
	medn.	4.08%	0.397	35%	0.1973	0.0730	0.1967	7981	90	5431.0	921.7
Entire Ottawa subset of houses	**avg.**	**3848**	**0.815**	**16%**	**0.4072**	**0.1475**	**0.4065**	**3859**	**199**	**1402.7**	**418.8**
	medn.	**100.00%**	**0.692**	**11%**	**0.3410**	**0.1266**	**0.3405**	**3329**	**225**	**188.0**	**299.3**

Table C-13. Aggregated Annual Statistics for Groupings by Period of Construction of Model Calculations of Natural Ventilation in Ottawa Houses with NPL = 0.75

Period of Construction		No.	Max	US%	Mean	StDev	Median	Hrs	Prds	Lngst	USach
Pre 1900	avg.	149	1.532	3%	0.7931	0.2812	0.7938	827	157	46.8	73.0
	medn.	3.87%	1.372	1%	0.6939	0.2515	0.6947	454	161	18.0	36.5
1900-1944	avg.	866	1.260	5%	0.6451	0.2353	0.6444	1376	190	146.3	124.6
	medn.	22.51%	1.141	3%	0.5847	0.2116	0.5874	875	216	26.0	67.2
Pre 1945	avg.	1015	1.300	4%	0.6668	0.2420	0.6663	1295	185	131.7	117.0
	medn.	26.38%	1.169	2%	0.5991	0.2165	0.5999	801	211	25.0	62.0
1945	avg.	45	0.991	7%	0.5074	0.1849	0.5069	1945	225	208.1	175.2
	medn.	1.17%	0.940	5%	0.4641	0.1811	0.4573	1710	252	75.0	142.2
1946-1960	avg.	832	0.795	12%	0.4039	0.1500	0.4028	3276	219	792.8	323.6
	medn.	21.62%	0.738	10%	0.3691	0.1397	0.3670	2901	249	188.0	257.1
1961-1980	avg.	1228	0.655	18%	0.3318	0.1242	0.3306	4477	202	1493.9	467.8
	medn.	31.91%	0.595	16%	0.3006	0.1127	0.2988	4430	231	407.0	407.8
1981-1995	avg.	571	0.536	27%	0.2683	0.1035	0.2666	5962	146	3282.7	715.2
	medn.	14.84%	0.470	26%	0.2339	0.0906	0.2332	6525	137	2663.0	695.1
1996-2004	avg.	157	0.470	33%	0.2357	0.0904	0.2345	6593	120	4399.2	869.8
	medn.	4.08%	0.407	33%	0.2045	0.0778	0.2053	7611	111	5427.0	865.8
Entire Ottawa subset of houses	**avg.**	**3848**	**0.834**	**15%**	**0.4245**	**0.1571**	**0.4234**	**3655**	**190**	**1352.0**	**393.8**
	medn.	**100.00%**	**0.710**	**11%**	**0.3557**	**0.1349**	**0.3542**	**3111**	**215**	**188.0**	**281.0**

Table C-14. Aggregated Annual Statistics for Groupings by Period of Construction of Model Calculations of Natural Ventilation in Ottawa Houses with NPL = 0.90

Period of Construction		No.	Max	US%	Mean	StDev	Median	Hrs	Prds	Lngst	USach
Pre 1900	avg.	149	1.663	2%	0.8929	0.3378	0.8875	686	134	37.9	60.1
	medn.	3.87%	1.491	1%	0.7831	0.3022	0.7764	368	121	17.0	28.9
1900-1944	avg.	866	1.374	4%	0.7273	0.2827	0.7212	1146	164	114.5	103.1
	medn.	22.51%	1.239	2%	0.6616	0.2543	0.6558	721	182	25.0	54.7
Pre 1945	avg.	1015	1.417	4%	0.7516	0.2908	0.7456	1078	159	103.3	96.8
	medn.	26.38%	1.266	2%	0.6779	0.2600	0.6712	654	177	25.0	50.5
1945	avg.	45	1.080	6%	0.5721	0.2222	0.5675	1623	196	187.4	145.5
	medn.	1.17%	1.037	4%	0.5220	0.2176	0.5164	1439	225	42.0	117.0
1946-1960	avg.	832	0.870	10%	0.4558	0.1802	0.4511	2747	191	666.2	269.9
	medn.	21.62%	0.806	8%	0.4167	0.1680	0.4116	2481	210	112.0	213.5
1961-1980	avg.	1228	0.718	15%	0.3745	0.1493	0.3704	3779	179	1258.6	391.4
	medn.	31.91%	0.654	13%	0.3386	0.1353	0.3345	3599	197	407.0	343.2
1981-1995	avg.	571	0.591	23%	0.3034	0.1244	0.2991	5209	136	2872.9	608.0
	medn.	14.84%	0.519	22%	0.2644	0.1088	0.2611	5481	119	2064.0	574.4
1996-2004	avg.	157	0.518	29%	0.2665	0.1087	0.2629	5943	116	3972.4	753.1
	medn.	4.08%	0.447	27%	0.2303	0.0936	0.2295	6433	107	4507.0	719.1
Entire Ottawa subset of houses	**avg.**	**3848**	**0.912**	**13%**	**0.4789**	**0.1888**	**0.4742**	**3119**	**168**	**1163.5**	**331.4**
	medn.	**100.00%**	**0.778**	**9%**	**0.4020**	**0.1622**	**0.3971**	**2657**	**187**	**183.0**	**235.2**

Table C-15. Aggregated Annual Statistics for Groupings by Heating System Type of Model Calculations of Natural Ventilation in Vancouver Houses with NPL = 0.25

Heating System		Fuel	No.	Flue	Max	US%	Mean	StDev	Median	Hrs	Prds	Lngst	USach
Baseboard/Hydronic/Plenum(duct) htrs.	avg.	Electric	440	N	0.7992	35.55%	0.2490	0.1024	0.2391	6407	342	1409.6	934.26
	medn.		3.46%		0.6406	36.63%	0.1970	0.0822	0.1883	7733	271	293.0	962.56
Boiler			1	BD									
Boiler with continuous pilot			18	YP									
Boiler with spark ignition			1	Y									
Condensing furnace	avg.	N.Gas	214	N	1.0062	24.43%	0.3136	0.1289	0.3013	5154	511	794.9	642.07
	medn.		1.68%		0.9681	17.97%	0.2872	0.1216	0.2742	5238	603	98.0	472.12
Condensing furnace (no chimney)			1	N									
Forced air furnace	avg.	Electric	6	N	0.7383	34.78%	0.2371	0.0961	0.2286	6324	399	1702.7	914.03
	medn.		0.05%		0.7685	27.06%	0.2383	0.0984	0.2281	6694	487	178.5	711.12
Furnace	avg.		82	BD	1.2353	18.27%	0.3814	0.1576	0.3656	4375	535	205.2	480.05
	medn.		0.64%		1.0140	13.37%	0.3214	0.1317	0.3100	4001	601	47.5	351.36
Furnace with continuous pilot	avg.	Fossil	9777	YP	1.0701	18.70%	0.3361	0.1376	0.3233	4584	580	248.4	491.39
	medn.		76.78%		0.9934	14.82%	0.3092	0.1274	0.2963	4518	644	65.0	389.59
Furnace with flame retention head			3	BD									
Furnace with flue vent damper			8	BD									
Furnace with spark ignition & vent damper	avg.	N.Gas	367	AD	0.9031	27.77%	0.2856	0.1166	0.2751	5625	457	889.2	729.70
	medn.		2.88%		0.8447	22.16%	0.2604	0.1078	0.2479	6115	495	105.0	582.31
Furnace with spark ignition	avg.	N.Gas	450	Y	1.0028	23.02%	0.3116	0.1283	0.2990	5107	520	474.6	605.04
	medn.		3.53%		0.9482	18.52%	0.2839	0.1182	0.2707	5385	603	99.0	486.68
Induced draft fan furnace	avg.	N.Gas	1344	Y	0.9370	26.61%	0.2908	0.1197	0.2793	5472	471	775.3	699.33
	medn.		10.55%		0.8962	21.78%	0.2635	0.1117	0.2507	6052	508	105.0	572.26
Mid-efficiency furnace (no dil. air)			4	Y									
Radiant panels	avg.	Electric	18	N	0.7271	38.09%	0.2129	0.0903	0.2019	6910	345	1599.5	1000.99
	medn.		0.14%		0.6699	38.50%	0.1900	0.0809	0.1802	7857	292	342.5	1011.74
Statistics for entire Vancouver area dataset	**avg.**	**All**	**12735**		**1.0387**	**20.67%**	**0.3256**	**0.1335**	**0.3131**	**4803**	**553**	**382.3**	**543.11**
	medn.		**100.00%**		**0.9709**	**16.03%**	**0.3000**	**0.1241**	**0.2872**	**4851**	**625**	**87.0**	**421.32**

Table C-16. Aggregated Annual Statistics for Groupings by Heating System Type of Model Calculations of Natural Ventilation in Vancouver Houses with NPL = 0.50

Heating System		Fuel	No.	Flue	Max	US%	Mean	StDev	Median	Hrs	Prds	Lngst	USach
Baseboard/Hydronic/Plenum(duct) htrs.	avg.	Electric	440	N	0.7950	26.5%	0.2955	0.0890	0.2885	5638	272	1378.8	697.7
	medn.		3.46%		0.6426	24.2%	0.2366	0.0715	0.2312	7300	233	252.0	635.4
Boiler			1	BD									
Boiler with continuous pilot			18	YP									
Boiler with spark ignition			1	Y									
Condensing furnace	avg.	N.Gas	214	N	1.0010	15.7%	0.3721	0.1121	0.3632	3854	374	781.1	412.5
	medn.		1.68%		0.9651	6.8%	0.3504	0.1082	0.3420	2844	417	58.0	178.5
Condensing furnace (no chimney)			1	N									
Forced air furnace	avg.	Electric	6	N	0.7307	26.3%	0.2784	0.0818	0.2712	5293	361	1825.5	690.6
	medn.		0.05%		0.7642	14.6%	0.2837	0.0853	0.2770	5416	341	174.0	384.9
Furnace	avg.		82	BD	1.2302	10.0%	0.4543	0.1376	0.4437	3055	378	196.1	262.2
	medn.		0.64%		1.0207	4.3%	0.3813	0.1142	0.3717	1917	382	31.0	112.5
Furnace with continuous pilot	avg.	Fossil	9777	YP	1.0632	10.0%	0.3978	0.1190	0.3881	3142	418	239.1	262.3
	medn.		76.78%		0.9870	5.1%	0.3671	0.1105	0.3585	2265	442	46.0	134.9
Furnace with flame retention head			3	BD									
Furnace with flue vent damper			8	BD									
Furnace with spark ignition & vent damper	avg.	N.Gas	367	AD	0.8964	18.7%	0.3371	0.1004	0.3288	4515	362	902.4	491.9
	medn.		2.88%		0.8422	10.0%	0.3128	0.0940	0.3031	4170	391	96.0	261.8
Furnace with spark ignition	avg.	N.Gas	450	Y	0.9977	14.0%	0.3703	0.1116	0.3615	3782	389	462.7	367.8
	medn.		3.53%		0.9443	7.3%	0.3399	0.1059	0.3321	3073	415	63.0	192.6
Induced draft fan furnace	avg.	N.Gas	1344	Y	0.9328	17.5%	0.3456	0.1044	0.3373	4272	359	780.7	459.3
	medn.		10.55%		0.9023	9.5%	0.3203	0.1006	0.3126	3829	397	96.0	250.1
Mid-efficiency furnace (no dil. air)			4	Y									
Radiant panels	avg.	Electric	18	N	0.7297	28.0%	0.2587	0.0814	0.2529	5935	307	1580.8	735.4
	medn.		0.14%		0.6795	25.5%	0.2317	0.0756	0.2271	7400	356	291.0	670.4
Statistics for entire Vancouver area dataset	**avg.**	**All**	**12735**		**1.0322**	**11.9%**	**0.3856**	**0.1155**	**0.3763**	**3428**	**403**	**374.3**	**312.0**
	medn.		**100.00%**		**0.9658**	**5.8%**	**0.3580**	**0.1081**	**0.3496**	**2538**	**436**	**46.0**	**153.0**

Table C-17. Aggregated Annual Statistics for Groupings by Heating System Type of Model Calculations of Natural Ventilation in Vancouver Houses with NPL = 0.60

Heating System		Fuel	No.	Flue	Max	US%	Mean	StDev	Median	Hrs	Prds	Lngst	USach
Baseboard/Hydronic/Plenum(duct) htrs.	avg.	Electric	440	N	0.8036	23.2%	0.3197	0.0892	0.3178	5252	248	1342.5	608.6
	medn.		3.46%		0.6506	18.7%	0.2564	0.0727	0.2553	6596	221	252.0	490.2
Boiler			1	BD									
Boiler with continuous pilot			18	YP									
Boiler with spark ignition			1	Y									
Condensing furnace	avg.	N.Gas	214	N	1.0118	13.2%	0.4025	0.1123	0.3999	3336	311	758.6	347.4
	medn.		1.68%		0.9744	4.8%	0.3799	0.1083	0.3782	2039	358	44.0	126.5
Condensing furnace (no chimney)			1	N									
Forced air furnace	avg.	Electric	6	N	0.7375	23.5%	0.3004	0.0812	0.2983	4713	306	1819.2	617.6
	medn.		0.05%		0.7725	10.6%	0.3072	0.0855	0.3056	4238	310	169.0	277.4
Furnace	avg.		82	BD	1.2440	7.8%	0.4919	0.1382	0.4891	2533	310	183.3	204.4
	medn.		0.64%		1.0301	2.8%	0.4114	0.1136	0.4088	1345	368	22.0	73.5
Furnace with continuous pilot	avg.	Fossil	9777	YP	1.0743	7.7%	0.4300	0.1190	0.4273	2554	339	228.1	203.1
	medn.		76.78%		0.9977	3.4%	0.3977	0.1104	0.3954	1586	380	35.0	90.2
Furnace with flame retention head			3	BD									
Furnace with flue vent damper			8	BD									
Furnace with spark ignition & vent damper	avg.	N.Gas	367	AD	0.9055	15.9%	0.3641	0.1002	0.3618	3981	303	867.1	416.8
	medn.		2.88%		0.8510	7.1%	0.3361	0.0940	0.3348	3031	352	87.0	185.5
Furnace with spark ignition	avg.	N.Gas	450	Y	1.0086	11.4%	0.4008	0.1119	0.3984	3226	320	452.0	300.6
	medn.		3.53%		0.9508	5.0%	0.3692	0.1052	0.3663	2183	358	46.0	131.2
Induced draft fan furnace	avg.	N.Gas	1344	Y	0.9431	14.7%	0.3740	0.1048	0.3717	3745	300	761.1	387.0
	medn.		10.55%		0.9150	6.7%	0.3489	0.1023	0.3473	2801	340	87.0	174.8
Mid-efficiency furnace (no dil. air)			4	Y									
Radiant panels	avg.	Electric	18	N	0.7396	24.4%	0.2815	0.0831	0.2802	5435	284	1561.4	642.4
	medn.		0.14%		0.6908	19.8%	0.2525	0.0788	0.2510	6587	335	291.0	520.7
Statistics for entire Vancouver area dataset	**avg.**	**All**	**12735**		**1.0431**	**9.5%**	**0.4169**	**0.1156**	**0.4143**	**2858**	**329**	**360.6**	**249.6**
	medn.		**100.00%**		**0.9763**	**3.9%**	**0.3875**	**0.1082**	**0.3853**	**1784**	**369**	**36.0**	**103.7**

Table C-18. Aggregated Annual Statistics for Groupings by Heating System Type of Model Calculations of Natural Ventilation in Vancouver Houses with NPL = 0.65

Heating System		Fuel	No.	Flue	Max	US%	Mean	StDev	Median	Hrs	Prds	Lngst	USach
Baseboard/Hydronic/Plenum(duct) htrs.	avg.	Electric	440	N	0.8092	21.6%	0.3327	0.0906	0.3330	5042	238	1315.4	566.8
	medn.		3.46%		0.6556	16.3%	0.2676	0.0740	0.2679	5974	224	252.0	428.2
Boiler			1	BD									
Boiler with continuous pilot			18	YP									
Boiler with spark ignition			1	Y									
Condensing furnace	avg.	N.Gas	214	N	1.0189	12.2%	0.4188	0.1141	0.4193	3100	285	753.3	320.0
	medn.		1.68%		0.9808	4.0%	0.3955	0.1096	0.3971	1762	333	36.0	106.2
Condensing furnace (no chimney)			1	N									
Forced air furnace	avg.	Electric	6	N	0.7422	22.3%	0.3122	0.0821	0.3122	4454	271	1812.0	586.7
	medn.		0.05%		0.7779	9.0%	0.3198	0.0869	0.3202	3674	270	157.0	237.8
Furnace	avg.		82	BD	1.2528	6.9%	0.5121	0.1405	0.5132	2304	282	179.8	180.8
	medn.		0.64%		1.0366	2.3%	0.4276	0.1147	0.4286	1136	331	22.0	59.8
Furnace with continuous pilot	avg.	Fossil	9777	YP	1.0816	6.8%	0.4473	0.1207	0.4479	2301	305	220.5	179.7
	medn.		76.78%		1.0049	2.8%	0.4140	0.1119	0.4143	1375	342	22.0	74.7
Furnace with flame retention head			3	BD									
Furnace with flue vent damper			8	BD									
Furnace with spark ignition & vent damper	avg.	N.Gas	367	AD	0.9115	14.6%	0.3787	0.1015	0.3789	3741	277	851.4	384.1
	medn.		2.88%		0.8569	6.0%	0.3500	0.0956	0.3511	2602	326	87.0	157.3
Furnace with spark ignition	avg.	N.Gas	450	Y	1.0156	10.4%	0.4171	0.1137	0.4179	2980	292	444.0	272.6
	medn.		3.53%		0.9581	4.2%	0.3844	0.1074	0.3856	1891	342	43.0	111.3
Induced draft fan furnace	avg.	N.Gas	1344	Y	0.9497	13.5%	0.3892	0.1065	0.3895	3509	275	744.8	355.9
	medn.		10.55%		0.9216	5.7%	0.3633	0.1037	0.3636	2440	318	66.0	150.0
Mid-efficiency furnace (no dil. air)			4	Y									
Radiant panels	avg.	Electric	18	N	0.7456	22.8%	0.2936	0.0850	0.2943	5171	270	1552.1	600.4
	medn.		0.14%		0.6973	17.3%	0.2635	0.0814	0.2648	5912	327	267.0	455.8
Statistics for entire Vancouver area dataset	**avg.**	**All**	**12735**		**1.0502**	**8.5%**	**0.4337**	**0.1173**	**0.4343**	**2609**	**298**	**351.2**	**224.2**
	medn.		**100.00%**		**0.9831**	**3.3%**	**0.4033**	**0.1098**	**0.4037**	**1541**	**336**	**28.0**	**86.4**

Table C-19. Aggregated Annual Statistics for Groupings by Heating System Type of Model Calculations of Natural Ventilation in Vancouver Houses with NPL = 0.70

Heating System		Fuel	No.	Flue	Max	US%	Mean	StDev	Median	Hrs	Prds	Lngst	USach
Baseboard/Hydronic/Plenum(duct) htrs.	avg.	Electric	440	N	0.8155	20.1%	0.3462	0.0928	0.3485	4827	228	1296.1	527.2
	medn.		3.46%		0.6611	14.3%	0.2782	0.0756	0.2801	5308	227	252.0	375.5
Boiler			1	BD									
Boiler with continuous pilot			18	YP									
Boiler with spark ignition			1	Y									
Condensing furnace	avg.	N.Gas	214	N	1.0268	11.2%	0.4357	0.1168	0.4386	2881	260	745.7	295.5
	medn.		1.68%		0.9880	3.4%	0.4117	0.1125	0.4135	1552	298	32.0	88.8
Condensing furnace (no chimney)			1	N									
Forced air furnace	avg.	Electric	6	N	0.7476	21.2%	0.3246	0.0838	0.3267	4244	251	1802.5	558.3
	medn.		0.05%		0.7841	7.8%	0.3329	0.0891	0.3352	3213	278	134.0	205.5
Furnace	avg.		82	BD	1.2628	6.1%	0.5330	0.1441	0.5367	2091	259	173.4	160.3
	medn.		0.64%		1.0441	1.9%	0.4446	0.1176	0.4479	946	307	18.0	49.1
Furnace with continuous pilot	avg.	Fossil	9777	YP	1.0899	6.1%	0.4653	0.1236	0.4683	2075	276	213.1	159.6
	medn.		76.78%		1.0127	2.4%	0.4309	0.1144	0.4336	1167	317	22.0	62.1
Furnace with flame retention head			3	BD									
Furnace with flue vent damper			8	BD									
Furnace with spark ignition & vent damper	avg.	N.Gas	367	AD	0.9184	13.5%	0.3939	0.1038	0.3964	3520	254	830.2	354.4
	medn.		2.88%		0.8635	5.2%	0.3655	0.0986	0.3688	2265	302	63.0	135.6
Furnace with spark ignition	avg.	N.Gas	450	Y	1.0236	9.4%	0.4341	0.1165	0.4370	2752	268	435.1	247.6
	medn.		3.53%		0.9645	3.6%	0.4003	0.1104	0.4030	1686	308	33.0	94.1
Induced draft fan furnace	avg.	N.Gas	1344	Y	0.9572	12.5%	0.4050	0.1091	0.4077	3291	253	728.4	327.7
	medn.		10.55%		0.9279	5.0%	0.3788	0.1061	0.3828	2152	296	53.0	130.7
Mid-efficiency furnace (no dil. air)			4	Y									
Radiant panels	avg.	Electric	18	N	0.7521	21.4%	0.3061	0.0877	0.3087	4922	255	1531.8	561.5
	medn.		0.14%		0.7043	15.3%	0.2748	0.0845	0.2771	5310	304	252.5	401.0
Statistics for entire Vancouver area dataset	**avg.**	**All**	**12735**		**1.0583**	**7.7%**	**0.4512**	**0.1201**	**0.4542**	**2384**	**270**	**342.0**	**202.0**
	medn.		**100.00%**		**0.9907**	**2.8%**	**0.4197**	**0.1124**	**0.4225**	**1328**	**311**	**22.0**	**72.3**

Table C-20. Aggregated Annual Statistics for Groupings by Heating System Type of Model Calculations of Natural Ventilation in Vancouver Houses with NPL = 0.75

Heating System		Fuel	No.	Flue	Max	US%	Mean	StDev	Median	Hrs	Prds	Lngst	USach
Baseboard/Hydronic/Plenum(duct) htrs.	avg.	Electric	440	N	0.8225	18.6%	0.3601	0.0958	0.3643	4606	220	1248.2	489.9
	medn.		3.46%		0.6671	12.6%	0.2893	0.0782	0.2924	4724	227	252.0	330.2
Boiler			1	BD									
Boiler with continuous pilot			18	YP									
Boiler with spark ignition			1	Y									
Condensing furnace	avg.	N.Gas	214	N	1.0356	10.4%	0.4533	0.1206	0.4584	2686	236	736.6	273.8
	medn.		1.68%		0.9961	2.9%	0.4284	0.1157	0.4340	1343	259	31.0	75.6
Condensing furnace (no chimney)			1	N									
Forced air furnace	avg.	Electric	6	N	0.7536	20.2%	0.3374	0.0863	0.3411	4066	236	1798.5	531.9
	medn.		0.05%		0.7908	6.8%	0.3464	0.0920	0.3502	2852	279	124.5	178.9
Furnace	avg.		82	BD	1.2738	5.4%	0.5547	0.1489	0.5609	1887	237	165.4	142.6
	medn.		0.64%		1.0525	1.6%	0.4621	0.1210	0.4658	803	267	18.0	41.1
Furnace with continuous pilot	avg.	Fossil	9777	YP	1.0991	5.4%	0.4840	0.1274	0.4893	1873	250	205.2	142.4
	medn.		76.78%		1.0210	2.0%	0.4479	0.1182	0.4534	1012	294	20.0	52.2
Furnace with flame retention head			3	BD									
Furnace with flue vent damper			8	BD									
Furnace with spark ignition & vent damper	avg.	N.Gas	367	AD	0.9260	12.4%	0.4096	0.1070	0.4141	3311	236	805.5	327.1
	medn.		2.88%		0.8708	4.5%	0.3801	0.1023	0.3826	1994	266	53.0	117.4
Furnace with spark ignition	avg.	N.Gas	450	Y	1.0324	8.6%	0.4516	0.1203	0.4567	2544	246	428.8	225.5
	medn.		3.53%		0.9707	3.1%	0.4168	0.1140	0.4235	1461	295	31.5	80.9
Induced draft fan furnace	avg.	N.Gas	1344	Y	0.9655	11.5%	0.4213	0.1127	0.4261	3088	234	712.5	302.1
	medn.		10.55%		0.9352	4.3%	0.3950	0.1094	0.4008	1890	271	45.0	112.4
Mid-efficiency furnace (no dil. air)			4	Y									
Radiant panels	avg.	Electric	18	N	0.7593	20.0%	0.3190	0.0910	0.3228	4682	248	1526.1	525.4
	medn.		0.14%		0.7117	13.5%	0.2865	0.0883	0.2902	4758	282	252.5	354.8
Statistics for entire Vancouver area dataset	**avg.**	**All**	**12735**		**1.0672**	**6.9%**	**0.4693**	**0.1239**	**0.4746**	**2181**	**247**	**331.4**	**182.6**
	medn.		**100.00%**		**0.9992**	**2.3%**	**0.4366**	**0.1159**	**0.4417**	**1141**	**289**	**21.0**	**60.8**

Table C-21. Aggregated Annual Statistics for Groupings by Heating System Type of Model Calculations of Natural Ventilation in Vancouver Houses with NPL = 0.90

Heating System		Fuel	No.	Flue	Max	US%	Mean	StDev	Median		Hrs	Prds	Lngst	USach
Baseboard/Hydronic/Plenum(duct) htrs.	avg.	Electric	440	N	0.8466	14.9%	0.4043	0.1087	0.4131	0.30	3946	195	1146.3	392.8
	medn.		3.46%		0.6875	8.7%	0.3240	0.0890	0.3304	0.30	3343	225	209.0	229.8
Boiler			1	BD										
Boiler with continuous pilot			18	YP										
Boiler with spark ignition			1	Y										
Condensing furnace	avg.	N.Gas	214	N	1.0659	8.4%	0.5089	0.1368	0.5200	0.30	2219	186	689.0	220.5
	medn.		1.68%		1.0243	1.9%	0.4826	0.1309	0.4924	0.30	937	215	19.0	50.7
Condensing furnace (no chimney)			1	N										
Forced air furnace	avg.	Electric	6	N	0.7748	17.6%	0.3782	0.0975	0.3867	0.30	3475	207	1781.0	463.8
	medn.		0.05%		0.8140	4.7%	0.3892	0.1046	0.3981	0.30	2013	274	78.0	122.7
Furnace	avg.		82	BD	1.3115	3.9%	0.6231	0.1692	0.6370	0.30	1412	186	148.3	103.0
	medn.		0.64%		1.0820	1.0%	0.5180	0.1376	0.5307	0.30	487	207	11.0	26.6
Furnace with continuous pilot	avg.	Fossil	9777	YP	1.1309	4.0%	0.5431	0.1444	0.5552	0.30	1399	193	180.4	104.0
	medn.		76.78%		1.0497	1.3%	0.5036	0.1340	0.5147	0.30	645	219	15.0	33.1
Furnace with flame retention head			3	BD										
Furnace with flue vent damper			8	BD										
Furnace with spark ignition & vent damper	avg.	N.Gas	367	AD	0.9526	9.8%	0.4594	0.1211	0.4696	0.30	2765	194	738.1	258.4
	medn.		2.88%		0.8961	3.0%	0.4255	0.1158	0.4353	0.30	1390	228	33.0	78.7
Furnace with spark ignition	avg.	N.Gas	450	Y	1.0627	6.6%	0.5071	0.1366	0.5185	0.30	2021	196	393.2	172.9
	medn.		3.53%		0.9993	2.0%	0.4704	0.1295	0.4806	0.30	997	226	20.0	52.6
Induced draft fan furnace	avg.	N.Gas	1344	Y	0.9939	9.1%	0.4731	0.1279	0.4834	0.30	2560	192	652.1	238.2
	medn.		10.55%		0.9650	2.8%	0.4453	0.1236	0.4555	0.30	1329	224	31.0	74.6
Mid-efficiency furnace (no dil. air)			4	Y										
Radiant panels	avg.	Electric	18	N	0.7831	16.5%	0.3594	0.1041	0.3671	0.30	3982	216	1494.9	433.0
	medn.		0.14%		0.7359	9.7%	0.3230	0.1017	0.3302	0.30	3476	277	207.0	254.5
Statistics for entire Vancouver area dataset	**avg.**	**All**	**12735**		**1.0982**	**5.2%**	**0.5267**	**0.1404**	**0.5384**	**0.30**	**1691**	**193**	**298.3**	**137.7**
	medn.		**100.00%**		**1.0284**	**1.5%**	**0.4906**	**0.1316**	**0.5014**	**0.30**	**752**	**220**	**16.0**	**38.9**

Table C-22. Aggregated Annual Statistics for Groupings by Period of Construction of Model Calculations of Natural Ventilation in Vancouver Houses with NPL = 0.25

Period of Construction		No.	Max	US%	Mean	StDev	Median	Hrs	Prds	Lngst	USach
Pre 1900	avg.	3									
	medn.	0.02%									
1900-1944	avg.	1161	1.2988	13.1%	0.4122	0.1679	0.3974	3478	598	135.7	343.1
	medn.	9.12%	1.1484	9.2%	0.3694	0.1489	0.3586	3051	666	28.0	242.8
Pre 1945	avg.	1164	1.2981	13.1%	0.4119	0.1678	0.3972	3482	598	135.5	343.3
	medn.	9.14%	1.1482	9.2%	0.3693	0.1489	0.3586	3052	667	28.0	242.9
1945	avg.	97	1.2277	14.5%	0.3827	0.1571	0.3683	3824	605	113.0	379.9
	medn.	0.76%	1.0993	11.1%	0.3423	0.1456	0.3312	3508	664	38.0	291.9
1946-1960	avg.	2268	1.1915	15.1%	0.3788	0.1542	0.3653	3928	600	143.9	396.3
	medn.	17.81%	1.0659	11.7%	0.3417	0.1389	0.3282	3505	671	38.0	306.5
1961-1980	avg.	5910	1.0669	17.7%	0.3346	0.1372	0.3217	4508	607	184.7	466.1
	medn.	46.41%	1.0003	14.5%	0.3128	0.1284	0.2994	4399	671	58.0	380.0
1981-1995	avg.	2980	0.8046	31.4%	0.2469	0.1023	0.2365	6315	422	869.1	824.3
	medn.	23.40%	0.7565	28.7%	0.2294	0.0958	0.2182	6888	446	223.0	754.7
1996-2004	avg.	315	0.6060	44.6%	0.1828	0.0763	0.1746	7502	250	2196.0	1172.2
	medn.	2.47%	0.5307	46.7%	0.1614	0.0664	0.1543	8481	92	984.0	1227.7
Entire Ottawa subset of houses	**avg.**	**12735**	**1.0387**	**20.7%**	**0.3256**	**0.1335**	**0.3131**	**4803**	**553**	**382.3**	**543.1**
	medn.	**100.00%**	**0.9709**	**16.0%**	**0.3000**	**0.1241**	**0.2872**	**4851**	**625**	**87.0**	**421.3**

Table C-23. Aggregated Annual Statistics for Groupings by Period of Construction of Model Calculations of Natural Ventilation in Vancouver Houses with NPL = 0.50

Period of Construction		No.	Max	US%	Mean	StDev	Median	Hrs	Prds	Lngst	USach
Pre 1900	avg.	3									
	medn.	0.02%									
1900-1944	avg.	1161	1.2883	6.0%	0.4859	0.1443	0.4739	2045	359	123.5	157.8
	medn.	9.12%	1.1399	2.4%	0.4329	0.1278	0.4213	1153	372	22.0	62.5
Pre 1945	avg.	1164	1.2877	6.0%	0.4856	0.1443	0.4737	2047	360	123.3	157.8
	medn.	9.14%	1.1394	2.4%	0.4328	0.1278	0.4209	1154	373	22.0	62.6
1945	avg.	97	1.2220	6.8%	0.4538	0.1370	0.4429	2342	385	100.9	178.4
	medn.	0.76%	1.0826	3.5%	0.4186	0.1229	0.4071	1536	379	22.0	92.2
1946-1960	avg.	2268	1.1817	7.3%	0.4461	0.1324	0.4351	2476	394	131.2	190.7
	medn.	17.81%	1.0565	3.4%	0.4031	0.1183	0.3922	1537	415	22.0	90.3
1961-1980	avg.	5910	1.0601	8.9%	0.3962	0.1186	0.3867	2978	439	172.2	233.6
	medn.	46.41%	0.9958	4.9%	0.3708	0.1114	0.3619	2177	461	37.0	128.6
1981-1995	avg.	2980	0.8022	21.3%	0.2947	0.0897	0.2878	5256	372	870.4	560.4
	medn.	23.40%	0.7538	15.7%	0.2758	0.0844	0.2690	5824	404	141.0	412.9
1996-2004	avg.	315	0.6058	34.9%	0.2195	0.0677	0.2144	6859	249	2236.6	918.2
	medn.	2.47%	0.5287	36.5%	0.1924	0.0590	0.1869	8382	141	1744.0	958.4
Entire Ottawa subset of houses	**avg.**	**12735**	**1.0322**	**11.9%**	**0.3856**	**0.1155**	**0.3763**	**3428**	**403**	**374.3**	**312.0**
	medn.	**100.00%**	**0.9658**	**5.8%**	**0.3580**	**0.1081**	**0.3496**	**2538**	**436**	**46.0**	**153.0**

Table C-24. Aggregated Annual Statistics for Groupings by Period of Construction of Model Calculations of Natural Ventilation in Vancouver Houses with NPL = 0.60

Period of Construction		No.	Max	US%	Mean	StDev	Median	Hrs	Prds	Lngst	USach
Pre 1900	avg.	3									
	medn.	0.02%									
1900-1944	avg.	1161	1.3012	4.5%	0.5247	0.1438	0.5211	1594	276	114.4	118.3
	medn.	9.12%	1.1498	1.4%	0.4648	0.1277	0.4623	752	279	13.0	37.9
Pre 1945	avg.	1164	1.3005	4.5%	0.5244	0.1438	0.5208	1595	277	114.3	118.3
	medn.	9.14%	1.1495	1.5%	0.4647	0.1277	0.4622	753	281	13.0	38.2
1945	avg.	97	1.2353	5.0%	0.4907	0.1374	0.4874	1858	301	94.8	132.6
	medn.	0.76%	1.0890	2.2%	0.4543	0.1218	0.4507	1048	346	22.0	57.2
1946-1960	avg.	2268	1.1934	5.4%	0.4817	0.1319	0.4784	1950	311	123.2	142.9
	medn.	17.81%	1.0684	2.2%	0.4339	0.1181	0.4314	1071	337	22.0	58.7
1961-1980	avg.	5910	1.0712	6.7%	0.4284	0.1187	0.4258	2362	351	162.8	176.5
	medn.	46.41%	1.0050	3.3%	0.4010	0.1112	0.3987	1526	390	24.0	86.0
1981-1995	avg.	2980	0.8114	17.9%	0.3193	0.0903	0.3175	4679	331	847.0	470.7
	medn.	23.40%	0.7625	11.3%	0.2989	0.0852	0.2972	4503	382	126.0	298.2
1996-2004	avg.	315	0.6132	31.1%	0.2382	0.0686	0.2369	6453	230	2173.7	818.2
	medn.	2.47%	0.5375	31.6%	0.2076	0.0596	0.2058	8272	152	1744.0	830.2
Entire Ottawa subset of houses	**avg.**	**12735**	**1.0431**	**9.5%**	**0.4169**	**0.1156**	**0.4143**	**2858**	**329**	**360.6**	**249.6**
	medn.	**100.00%**	**0.9763**	**3.9%**	**0.3875**	**0.1082**	**0.3853**	**1784**	**369**	**36.0**	**103.7**

Table C-25. Aggregated Annual Statistics for Groupings by Period of Construction of Model Calculations of Natural Ventilation in Vancouver Houses with NPL = 0.65

Period of Construction		No.	Max	US%	Mean	StDev	Median	Hrs	Prds	Lngst	USach
Pre 1900	avg.	3									
	medn.	0.02%									
1900-1944	avg.	1161	1.3098	3.9%	0.5456	0.1457	0.5463	1413	245	111.1	103.3
	medn.	9.12%	1.1566	1.2%	0.4839	0.1295	0.4840	593	253	13.0	30.5
Pre 1945	avg.	1164	1.3091	3.9%	0.5453	0.1456	0.5460	1413	246	110.9	103.3
	medn.	9.14%	1.1565	1.2%	0.4838	0.1295	0.4839	593	253	13.0	30.5
1945	avg.	97	1.2439	4.4%	0.5105	0.1395	0.5108	1651	270	90.8	114.8
	medn.	0.76%	1.0954	1.7%	0.4719	0.1266	0.4687	891	295	18.0	45.4
1946-1960	avg.	2268	1.2013	4.7%	0.5008	0.1336	0.5012	1730	277	117.1	124.6
	medn.	17.81%	1.0764	1.8%	0.4512	0.1195	0.4503	885	301	18.0	47.0
1961-1980	avg.	5910	1.0785	5.9%	0.4457	0.1204	0.4463	2103	314	156.3	154.5
	medn.	46.41%	1.0116	2.7%	0.4173	0.1128	0.4184	1307	351	22.0	71.1
1981-1995	avg.	2980	0.8173	16.4%	0.3324	0.0919	0.3329	4394	310	829.3	431.1
	medn.	23.40%	0.7685	9.8%	0.3112	0.0864	0.3110	3917	369	125.0	257.8
1996-2004	avg.	315	0.6179	29.3%	0.2481	0.0699	0.2485	6246	220	2139.8	770.8
	medn.	2.47%	0.5404	28.8%	0.2154	0.0600	0.2166	8156	161	1744.0	757.7
Entire Ottawa subset of houses	**avg.**	**12735**	**1.0502**	**8.5%**	**0.4337**	**0.1173**	**0.4343**	**2609**	**298**	**351.2**	**224.2**
	medn.	**100.00%**	**0.9831**	**3.3%**	**0.4033**	**0.1098**	**0.4037**	**1541**	**336**	**28.0**	**86.4**

Table C-26. Aggregated Annual Statistics for Groupings by Period of Construction of Model Calculations of Natural Ventilation in Vancouver Houses with NPL = 0.70

Period of Construction		No.	Max	US%	Mean	StDev	Median	Hrs	Prds	Lngst	USach
Pre 1900	avg.	3									
	medn.	0.02%									
1900-1944	avg.	1161	1.3196	3.5%	0.5674	0.1489	0.5709	1254	219	107.0	90.9
	medn.	9.12%	1.1651	0.9%	0.5033	0.1321	0.5056	477	216	11.0	24.9
Pre 1945	avg.	1164	1.3189	3.5%	0.5670	0.1489	0.5706	1254	220	106.9	90.8
	medn.	9.14%	1.1650	0.9%	0.5031	0.1321	0.5056	478	216	11.0	24.9
1945	avg.	97	1.2536	3.8%	0.5312	0.1429	0.5348	1465	246	87.2	99.8
	medn.	0.76%	1.1030	1.4%	0.4882	0.1293	0.4903	724	278	14.0	38.0
1946-1960	avg.	2268	1.2103	4.2%	0.5208	0.1366	0.5240	1538	248	112.6	109.2
	medn.	17.81%	1.0841	1.5%	0.4682	0.1215	0.4710	733	267	17.0	38.2
1961-1980	avg.	5910	1.0868	5.2%	0.4637	0.1232	0.4667	1877	282	149.4	135.9
	medn.	46.41%	1.0188	2.3%	0.4345	0.1155	0.4374	1111	320	22.0	59.2
1981-1995	avg.	2980	0.8239	15.0%	0.3461	0.0943	0.3485	4117	291	813.1	395.0
	medn.	23.40%	0.7748	8.5%	0.3235	0.0888	0.3257	3455	344	125.0	224.3
1996-2004	avg.	315	0.6231	27.6%	0.2584	0.0719	0.2603	6043	211	2097.3	725.3
	medn.	2.47%	0.5439	26.3%	0.2248	0.0612	0.2267	7889	182	1744.0	690.1
Entire Ottawa subset of houses	**avg.**	**12735**	**1.0583**	**7.7%**	**0.4512**	**0.1201**	**0.4542**	**2384**	**270**	**342.0**	**202.0**
	medn.	**100.00%**	**0.9907**	**2.8%**	**0.4197**	**0.1124**	**0.4225**	**1328**	**311**	**22.0**	**72.3**

Table C-27. Aggregated Annual Statistics for Groupings by Period of Construction of Model Calculations of Natural Ventilation in Vancouver Houses with NPL = 0.75

Period of Construction		No.	Max	US%	Mean	StDev	Median	Hrs	Prds	Lngst	USach
Pre 1900	avg.	3									
	medn.	0.02%									
1900-1944	avg.	1161	1.3305	3.1%	0.5899	0.1534	0.5962	1115	197	103.8	80.4
	medn.	9.12%	1.1747	0.8%	0.5223	0.1368	0.5275	411	187	11.0	20.7
Pre 1945	avg.	1164	1.3298	3.1%	0.5896	0.1534	0.5959	1116	197	103.6	80.4
	medn.	9.14%	1.1746	0.8%	0.5223	0.1368	0.5272	413	187	11.0	20.7
1945	avg.	97	1.2644	3.3%	0.5525	0.1474	0.5588	1297	225	76.5	87.2
	medn.	0.76%	1.1132	1.2%	0.5054	0.1350	0.5130	619	245	13.0	32.0
1946-1960	avg.	2268	1.2203	3.7%	0.5415	0.1407	0.5473	1371	223	108.0	96.3
	medn.	17.81%	1.0929	1.2%	0.4869	0.1252	0.4914	600	229	13.0	31.9
1961-1980	avg.	5910	1.0960	4.6%	0.4823	0.1271	0.4877	1679	255	142.8	120.2
	medn.	46.41%	1.0276	1.9%	0.4520	0.1191	0.4573	956	298	18.0	49.6
1981-1995	avg.	2980	0.8312	13.8%	0.3601	0.0975	0.3644	3852	273	791.2	362.3
	medn.	23.40%	0.7819	7.5%	0.3369	0.0918	0.3410	3028	326	107.0	196.0
1996-2004	avg.	315	0.6287	25.9%	0.2691	0.0744	0.2722	5841	203	2050.7	681.6
	medn.	2.47%	0.5479	23.6%	0.2350	0.0632	0.2379	7507	216	1744.0	619.5
Entire Ottawa subset of houses	**avg.**	**12735**	**1.0672**	**6.9%**	**0.4693**	**0.1239**	**0.4746**	**2181**	**247**	**331.4**	**182.6**
	medn.	**100.00%**	**0.9992**	**2.3%**	**0.4366**	**0.1159**	**0.4417**	**1141**	**289**	**21.0**	**60.8**

Table C-28. Aggregated Annual Statistics for Groupings by Period of Construction of Model Calculations of Natural Ventilation in Vancouver Houses with NPL = 0.90

Period of Construction		No.	Max	US%	Mean	StDev	Median	Hrs	Prds	Lngst	USach
Pre 1900	avg.	3									
	medn.	0.02%									
1900-1944	avg.	1161	1.3685	2.2%	0.6616	0.1736	0.6765	810	147	89.0	58.0
	medn.	9.12%	1.2094	0.5%	0.5839	0.1539	0.5967	248	125	10.0	13.2
Pre 1945	avg.	1164	1.3678	2.2%	0.6612	0.1735	0.6761	810	147	88.9	58.0
	medn.	9.14%	1.2090	0.5%	0.5837	0.1539	0.5965	248	126	10.0	13.3
1945	avg.	97	1.3014	2.3%	0.6201	0.1671	0.6333	914	167	60.0	60.9
	medn.	0.76%	1.1476	0.8%	0.5705	0.1514	0.5820	369	170	11.0	19.8
1946-1960	avg.	2268	1.2551	2.6%	0.6072	0.1591	0.6206	992	168	91.3	68.5
	medn.	17.81%	1.1236	0.8%	0.5451	0.1416	0.5576	366	166	11.0	20.0
1961-1980	avg.	5910	1.1278	3.3%	0.5413	0.1441	0.5534	1227	194	123.0	86.1
	medn.	46.41%	1.0577	1.2%	0.5073	0.1352	0.5189	623	219	14.0	31.6
1981-1995	avg.	2980	0.8560	10.7%	0.4047	0.1109	0.4135	3137	228	723.4	281.7
	medn.	23.40%	0.8058	5.1%	0.3795	0.1042	0.3873	2180	273	62.0	135.0
1996-2004	avg.	315	0.6478	21.4%	0.3026	0.0848	0.3091	5223	186	1903.0	562.4
	medn.	2.47%	0.5638	16.7%	0.2642	0.0716	0.2702	5771	235	984.0	439.5
Entire Ottawa subset of houses	**avg.**	**12735**	**1.0982**	**5.2%**	**0.5267**	**0.1404**	**0.5384**	**1691**	**193**	**298.3**	**137.7**
	medn.	**100.00%**	**1.0284**	**1.5%**	**0.4906**	**0.1316**	**0.5014**	**752**	**220**	**16.0**	**38.9**

Table C-29. Aggregated Annual Statistics for Groupings by Heating System Type and by Period of Construction of Model Calculations of Natural Ventilation in Saskatoon Houses with NPL = 0.25

Heating System		Fuel	No.	Flue	Max	Min	Mean	StDev	Median	US%	Hrs	Prds	Lngst	USach
Baseboard/Hydronic/Plenum(duct)	avg.	Electric	7	N	0.3990	0.0016	0.1557	0.0541	0.1525	55.5%	7671	72	6377.4	1458.4
htrs.	medn.		0.17%		0.2875	0.0008	0.1067	0.0382	0.1044	64.4%	8760	1	8760.0	1693.5
Boiler with continuous pilot			14	Y										
Boiler with spark ignit.,vent dmpr			1	N										
Condensing boiler			1	N										
Condensing furnace	avg.	N.Gas	243	N	0.3659	0.0019	0.1472	0.0502	0.1441	53.7%	8177	93	5147.7	1411.9
	medn.		5.84%		0.3234	0.0013	0.1279	0.0441	0.1254	57.4%	8758	3	5463.0	1507.8
Forced air furnace			6	N										
Furnace			4	BD										
Furnace with continuous pilot	avg.	N.Gas	2871	Y	0.4677	0.0027	0.1920	0.0647	0.1877	41.9%	7616	167	3059.2	1101.2
	medn.		68.98%		0.4044	0.0020	0.1646	0.0558	0.1609	45.2%	8631	52	1525.0	1188.9
Furnace with flame retention head			1	BD										
Furnace with spark ignit.,vent dmpr			4	BD										
Furnace with spark ignition	avg.	N.Gas	42	?	0.3957	0.0021	0.1613	0.0546	0.1578	49.9%	7820	131	4918.2	1312.0
	medn.		1.01%		0.3106	0.0014	0.1275	0.0433	0.1249	57.5%	8759	3	6014.5	1510.9
Induced draft fan furnace	avg.	N.Gas	968	?	0.3867	0.0020	0.1560	0.0531	0.1527	50.9%	8084	108	4644.7	1337.8
	medn.		23.26%		0.3435	0.0015	0.1362	0.0470	0.1335	54.6%	8748	11	4566.0	1434.7
Construction Period														
1900-1944	avg.		487		0.8015	0.0049	0.3327	0.1114	0.3252	16.5%	4446	444	361.1	432.8
	medn.		11.70%		0.7310	0.0042	0.3061	0.1024	0.2987	12.4%	4440	489	90.0	324.7
1945	avg.		21		0.7004	0.0041	0.2892	0.0971	0.2829	22.7%	5367	375	816.2	596.0
	medn.		0.50%		0.6673	0.0031	0.2532	0.0894	0.2496	21.4%	6336	404	137.0	563.2
1946-1960	avg.		840		0.4911	0.0027	0.2006	0.0678	0.1963	38.2%	7514	211	2158.1	1003.8
	medn.		20.18%		0.4447	0.0022	0.1814	0.0612	0.1775	39.9%	8428	122	633.0	1048.0
1961-1980	avg.		1872		0.3914	0.0021	0.1589	0.0539	0.1555	48.3%	8340	96	3747.2	1268.7
	medn.		44.98%		0.3689	0.0017	0.1492	0.0509	0.1460	50.3%	8719	25	2752.0	1321.4
1981-1995	avg.		803		0.3242	0.0017	0.1318	0.0447	0.1289	56.7%	8550	48	5848.3	1489.8
	medn.		19.29%		0.3049	0.0015	0.1230	0.0418	0.1204	59.0%	8759	2	6566.0	1550.7
1996-2004	avg.		139		0.2170	0.0012	0.0884	0.0299	0.0864	71.0%	8661	14	8320.8	1866.4
	medn.		3.34%		0.1961	0.0010	0.0801	0.0271	0.0781	73.3%	8760	1	8760.0	1926.0
Statistics for entire Saskatoon	**avg.**		**4162**		**0.4423**	**0.0025**	**0.1807**	**0.0611**	**0.1768**	**44.8%**	**7754**	**149**	**3573.6**	**1176.6**
dataset.	**medn.**		**100.00%**		**0.3862**	**0.0019**	**0.1551**	**0.0529**	**0.1519**	**48.4%**	**8681**	**39**	**2636.0**	**1270.9**

Table C-30. Aggregated Annual Statistics for Groupings by Heating System Type and by Period of Construction of Model Calculations of Natural Ventilation in Saskatoon Houses with NPL = 0.50

Heating System		Fuel	No.	Flue	Max	Min	Mean	StDev	Median	US%	Hrs	Prds	Lngst	USach
Baseboard/Hydronic/Plenum(duct)	avg.	Electric	7	N	0.4298	0.0033	0.1966	0.0621	0.1990	47.0%	7491	61	6089.3	1235.9
htrs.	medn.		0.17%		0.2985	0.0016	0.1391	0.0472	0.1408	53.6%	8760	1	8760.0	1409.3
Boiler with continuous pilot			14	YP										
Boiler with spark ignit.,vent dmpr			1	N										
Condensing boiler			1	N										
Condensing furnace	avg.	N.Gas	243	N	0.3903	0.0037	0.1824	0.0549	0.1849	44.0%	7755	96	4852.7	1157.5
	medn.		5.84%		0.3464	0.0026	0.1601	0.0489	0.1616	46.6%	8752	6	5463.0	1225.9
Forced air furnace			6	N										
Furnace			4	BD										
Furnace with continuous pilot	avg.	N.Gas	2871	YP	0.4955	0.0053	0.2349	0.0684	0.2382	31.6%	6920	166	2830.1	831.7
	medn.		68.98%		0.4297	0.0041	0.2026	0.0595	0.2055	32.8%	8357	106	1315.0	863.3
Furnace with flame retention head			1	BD										
Furnace with spark ignit.,vent dmpr			4	BD										
Furnace with spark ignition	avg.	N.Gas	42	Y	0.4202	0.0043	0.1982	0.0584	0.2011	40.7%	7372	111	4725.3	1070.4
	medn.		1.01%		0.3334	0.0027	0.1571	0.0479	0.1593	47.6%	8755	4	6560.0	1251.5
Induced draft fan furnace	avg.	N.Gas	968	Y	0.4121	0.0040	0.1929	0.0579	0.1955	41.0%	7613	110	4388.3	1078.1
	medn.		23.26%		0.3670	0.0030	0.1707	0.0522	0.1729	43.1%	8729	17	4566.0	1133.9
Construction Period														
1900-1944	avg.		487		0.8461	0.0098	0.4042	0.1159	0.4098	9.4%	2933	301	333.1	246.4
	medn.		11.70%		0.7694	0.0084	0.3715	0.1073	0.3768	5.7%	2173	308	67.0	148.5
1945	avg.		21		0.7405	0.0082	0.3526	0.1016	0.3576	14.2%	3955	288	772.0	372.0
	medn.		0.50%		0.7167	0.0063	0.3256	0.0963	0.3297	10.7%	3453	322	101.0	281.0
1946-1960	avg.		840		0.5211	0.0055	0.2462	0.0723	0.2496	27.3%	6558	219	1953.7	716.2
	medn.		20.18%		0.4772	0.0044	0.2224	0.0664	0.2253	26.9%	7650	192	633.0	707.2
1961-1980	avg.		1872		0.4162	0.0042	0.1958	0.0581	0.1985	37.2%	7887	123	3446.0	977.7
	medn.		44.98%		0.3933	0.0035	0.1849	0.0554	0.1875	38.5%	8644	41	2636.0	1010.9
1981-1995	avg.		803		0.3446	0.0035	0.1622	0.0480	0.1645	47.2%	8326	61	5551.0	1239.8
	medn.		19.29%		0.3239	0.0030	0.1521	0.0452	0.1542	49.3%	8759	2	6566.0	1295.7
1996-2004	avg.		139		0.2305	0.0024	0.1086	0.0321	0.1101	64.6%	8614	13	8314.0	1699.0
	medn.		3.34%		0.2081	0.0019	0.0987	0.0290	0.1002	67.1%	8760	1	8760.0	1763.1
Statistics for entire Saskatoon	**avg.**		**4162**		**0.4693**	**0.0049**	**0.2218**	**0.0651**	**0.2248**	**34.7%**	**7128**	**148**	**3335.8**	**911.0**
dataset.	**medn.**		**100.00%**		**0.4092**	**0.0037**	**0.1920**	**0.0572**	**0.1948**	**36.1%**	**8545**	**66**	**1525.0**	**948.9**

Table C-31. Aggregated Annual Statistics for Groupings by Heating System Type and by Period of Construction of Model Calculations of Natural Ventilation in Saskatoon Houses with NPL = 0.60

Heating System		Fuel	No.	Flue	Max	Min	Mean	StDev	Median	US%	Hrs	Prds	Lngst	USach
Baseboard/Hydronic/Plenum(duct) htrs.	avg.	Electric	7	N	0.4472	0.0039	0.2165	0.0717	0.2186	43.3%	7334	61	5461.6	1136.9
	medn.		0.17%		0.3077	0.0019	0.1542	0.0559	0.1547	48.6%	8759	2	6566.0	1277.1
Boiler with continuous pilot			14	YP										
Boiler with spark ignit.,vent dmpr			1	N										
Condensing boiler			1	N										
Condensing furnace	avg.	N.Gas	243	N	0.4052	0.0044	0.2000	0.0627	0.2025	40.0%	7445	99	4632.4	1050.0
	medn.		5.84%		0.3595	0.0032	0.1757	0.0563	0.1781	41.5%	8682	22	5463.0	1090.2
Forced air furnace			6	N										
Furnace			4	BD										
Furnace with continuous pilot	avg.	N.Gas	2871	YP	0.5134	0.0064	0.2568	0.0775	0.2604	27.6%	6423	165	2673.6	725.1
	medn.		68.98%		0.4454	0.0049	0.2218	0.0677	0.2252	27.4%	7618	143	1005.0	720.9
Furnace with flame retention head			1	BD										
Furnace with spark ignit.,vent dmpr			4	BD										
Furnace with spark ignition	avg.	N.Gas	42	Y	0.4357	0.0052	0.2169	0.0662	0.2199	36.8%	7070	111	4617.2	967.5
	medn.		1.01%		0.3469	0.0033	0.1713	0.0558	0.1739	42.9%	8731	17	6559.5	1127.6
Induced draft fan furnace	avg.	N.Gas	968	Y	0.4277	0.0048	0.2114	0.0660	0.2140	36.9%	7254	112	4190.6	969.5
	medn.		23.26%		0.3812	0.0036	0.1871	0.0601	0.1890	38.0%	8528	43	3040.0	998.0
Construction Period														
1900-1944	avg.		487		0.8760	0.0118	0.4411	0.1305	0.4476	7.6%	2448	254	301.8	200.9
	medn.		11.70%		0.7989	0.0100	0.4051	0.1205	0.4105	4.4%	1741	273	67.0	115.2
1945	avg.		21		0.7669	0.0099	0.3851	0.1147	0.3909	11.8%	3394	245	594.0	309.5
	medn.		0.50%		0.7426	0.0075	0.3600	0.1018	0.3628	8.8%	2858	260	124.0	231.7
1946-1960	avg.		840		0.5403	0.0065	0.2694	0.0820	0.2731	23.3%	5920	211	1831.1	611.8
	medn.		20.18%		0.4951	0.0052	0.2432	0.0754	0.2469	21.9%	6714	221	633.0	575.5
1961-1980	avg.		1872		0.4317	0.0050	0.2144	0.0660	0.2172	32.5%	7409	136	3225.5	854.8
	medn.		44.98%		0.4088	0.0041	0.2022	0.0631	0.2051	33.0%	8202	86	2635.0	868.1
1981-1995	avg.		803		0.3574	0.0042	0.1776	0.0546	0.1800	42.8%	8086	69	5352.5	1125.2
	medn.		19.29%		0.3370	0.0036	0.1670	0.0510	0.1689	44.4%	8750	6	6560.0	1167.4
1996-2004	avg.		139		0.2391	0.0029	0.1189	0.0365	0.1205	61.5%	8584	13	8233.7	1616.0
	medn.		3.34%		0.2158	0.0023	0.1081	0.0328	0.1100	64.0%	8760	1	8760.0	1681.3
Statistics for entire Saskatoon dataset.	**avg.**		**4162**		**0.4865**	**0.0059**	**0.2426**	**0.0738**	**0.2459**	**30.6%**	**6678**	**148**	**3166.3**	**804.1**
	medn.		**100.00%**		**0.4247**	**0.0045**	**0.2104**	**0.0651**	**0.2133**	**30.7%**	**7955**	**112**	**1317.0**	**807.9**

Table C-32. Aggregated Annual Statistics for Groupings by Heating System Type and by Period of Construction of Model Calculations of Natural Ventilation in Saskatoon Houses with NPL = 0.65

Heating System		Fuel	No.	Flue	Max	Min	Mean	StDev	Median	US%	Hrs	Prds	Lngst	USach
Baseboard/Hydronic/Plenum(duct) htrs.	avg.	Electric	7	N	0.4572	0.0042	0.2269	0.0773	0.2283	41.4%	7230	63	5390.6	1087.5
	medn.		0.17%		0.3136	0.0021	0.1621	0.0605	0.1621	46.0%	8729	9	6566.0	1209.3
Boiler with continuous pilot			14	YP										
Boiler with spark ignit.,vent dmpr			1	N										
Condensing boiler			1	N										
Condensing furnace	avg.	N.Gas	243	N	0.4134	0.0048	0.2092	0.0674	0.2113	38.0%	7257	101	4495.8	998.4
	medn.		5.84%		0.3678	0.0034	0.1841	0.0602	0.1856	38.8%	8526	40	4462.0	1019.9
Forced air furnace			6	N										
Furnace			4	BD										
Furnace with continuous pilot	avg.	N.Gas	2871	YP	0.5235	0.0069	0.2684	0.0831	0.2716	25.7%	6146	165	2567.9	676.1
	medn.		68.98%		0.4540	0.0053	0.2318	0.0727	0.2349	25.0%	7190	154	1004.0	657.1
Furnace with flame retention head			1	BD										
Furnace with spark ignit.,vent dmpr			4	BD										
Furnace with spark ignition	avg.	N.Gas	42	Y	0.4442	0.0056	0.2268	0.0712	0.2294	34.9%	6891	109	4523.4	917.9
	medn.		1.01%		0.3541	0.0036	0.1789	0.0598	0.1814	40.4%	8608	24	6046.5	1062.3
Induced draft fan furnace	avg.	N.Gas	968	Y	0.4365	0.0052	0.2212	0.0710	0.2233	34.9%	7043	115	4070.3	917.8
	medn.		23.26%		0.3886	0.0039	0.1957	0.0645	0.1973	35.3%	8265	60	3040.0	928.4
Construction Period														
1900-1944	avg.		487		0.8930	0.0128	0.4608	0.1398	0.4667	6.9%	2247	237	297.6	182.6
	medn.		11.70%		0.8165	0.0109	0.4228	0.1295	0.4284	3.9%	1605	253	60.0	102.6
1945	avg.		21		0.7814	0.0107	0.4024	0.1230	0.4076	10.8%	3159	229	589.2	283.5
	medn.		0.50%		0.7568	0.0082	0.3779	0.1087	0.3793	8.1%	2645	243	122.0	212.6
1946-1960	avg.		840		0.5509	0.0071	0.2816	0.0880	0.2848	21.5%	5589	206	1743.7	565.8
	medn.		20.18%		0.5044	0.0057	0.2548	0.0808	0.2571	19.8%	6201	223	633.0	520.6
1961-1980	avg.		1872		0.4404	0.0054	0.2242	0.0710	0.2266	30.3%	7117	141	3081.9	797.5
	medn.		44.98%		0.4174	0.0045	0.2116	0.0677	0.2139	30.5%	7844	104	2635.0	800.8
1981-1995	avg.		803		0.3645	0.0045	0.1858	0.0586	0.1878	40.7%	7924	74	5216.9	1068.7
	medn.		19.29%		0.3434	0.0039	0.1747	0.0548	0.1763	41.8%	8703	15	6204.0	1099.0
1996-2004	avg.		139		0.2439	0.0031	0.1243	0.0392	0.1257	59.8%	8565	13	8201.5	1572.6
	medn.		3.34%		0.2204	0.0025	0.1127	0.0354	0.1146	62.4%	8760	1	8760.0	1640.9
Statistics for entire Saskatoon dataset.	**avg.**		**4162**		**0.4962**	**0.0064**	**0.2536**	**0.0793**	**0.2565**	**28.7%**	**6423**	**149**	**3056.3**	**754.4**
	medn.		**100.00%**		**0.4339**	**0.0049**	**0.2200**	**0.0699**	**0.2225**	**28.2%**	**7581**	**126**	**1317.0**	**742.2**

Table C-33. Aggregated Annual Statistics for Groupings by Heating System Type and by Period of Construction of Model Calculations of Natural Ventilation in Saskatoon Houses with NPL = 0.70

Heating System		Fuel	No.	Flue	Max	Min	Mean	StDev	Median	US%	Hrs	Prds	Lngst	USach
Baseboard/Hydronic/Plenum(duct)	avg.	Electric	7	N	0.4693	0.0046	0.2376	0.0834	0.2381	39.5%	7110	69	5245.7	1039.0
htrs.	medn.		0.17%		0.3347	0.0022	0.1700	0.0653	0.1689	43.5%	8633	17	6066.0	1142.9
Boiler with continuous pilot			14	YP										
Boiler with spark ignit.,vent dmpr			1	N										
Condensing boiler			1	N										
Condensing furnace	avg.	N.Gas	243	N	0.4232	0.0052	0.2188	0.0726	0.2201	36.1%	7047	104	4299.6	948.9
	medn.		5.84%		0.3755	0.0037	0.1928	0.0649	0.1936	36.3%	8231	49	4458.0	953.3
Forced air furnace			6	N										
Furnace			4	BD										
Furnace with continuous pilot	avg.	N.Gas	2871	YP	0.5349	0.0075	0.2804	0.0894	0.2828	24.0%	5859	163	2469.8	630.6
	medn.		68.98%		0.4641	0.0057	0.2422	0.0782	0.2444	22.9%	6707	165	1004.0	601.3
Furnace with flame retention head			1	BD										
Furnace with spark ignit.,vent dmpr			4	BD										
Furnace with spark ignition	avg.	N.Gas	42	Y	0.4535	0.0060	0.2370	0.0766	0.2389	33.1%	6706	111	4450.3	869.9
	medn.		1.01%		0.3616	0.0038	0.1867	0.0646	0.1889	37.9%	8353	48	5534.5	996.7
Induced draft fan furnace	avg.	N.Gas	968	Y	0.4471	0.0056	0.2312	0.0764	0.2326	33.1%	6813	116	3921.8	868.6
	medn.		23.26%		0.3997	0.0042	0.2049	0.0694	0.2057	32.8%	7941	75	3039.0	863.0
Construction Period														
1900-1944	avg.		487		0.9123	0.0138	0.4810	0.1502	0.4857	6.3%	2068	221	290.0	166.8
	medn.		11.70%		0.8360	0.0117	0.4406	0.1391	0.4464	3.5%	1456	242	58.0	91.9
1945	avg.		21		0.7972	0.0115	0.4203	0.1323	0.4243	9.9%	2933	215	555.0	260.6
	medn.		0.50%		0.7717	0.0088	0.3961	0.1172	0.3948	7.4%	2465	227	93.0	195.7
1946-1960	avg.		840		0.5631	0.0076	0.2942	0.0947	0.2966	19.9%	5261	201	1669.4	524.1
	medn.		20.18%		0.5146	0.0061	0.2664	0.0870	0.2681	18.0%	5708	230	633.0	474.1
1961-1980	avg.		1872		0.4505	0.0059	0.2343	0.0764	0.2360	28.3%	6801	144	2944.8	744.0
	medn.		44.98%		0.4273	0.0048	0.2210	0.0728	0.2227	28.1%	7471	121	2635.0	738.0
1981-1995	avg.		803		0.3727	0.0049	0.1941	0.0631	0.1956	38.6%	7736	78	5039.2	1013.6
	medn.		19.29%		0.3512	0.0042	0.1825	0.0589	0.1835	39.3%	8548	32	5558.0	1033.6
1996-2004	avg.		139		0.2495	0.0033	0.1299	0.0421	0.1309	58.2%	8544	13	8110.4	1528.2
	medn.		3.34%		0.2263	0.0027	0.1176	0.0382	0.1192	60.8%	8760	1	8760.0	1598.0
Statistics for entire Saskatoon	**avg.**		**4162**		**0.5073**	**0.0069**	**0.2650**	**0.0853**	**0.2671**	**26.9%**	**6156**	**148**	**2941.3**	**707.8**
dataset.	**medn.**		**100.00%**		**0.4432**	**0.0052**	**0.2301**	**0.0751**	**0.2317**	**25.9%**	**7170**	**136**	**1317.0**	**681.5**

Table C-34. Aggregated Annual Statistics for Groupings by Heating System Type and by Period of Construction of Model Calculations of Natural Ventilation in Saskatoon Houses with NPL = 0.75

Heating System		Fuel	No.	Flue	Max	Min	Mean	StDev	Median	US%	Hrs	Prds	Lngst	USach
Baseboard/Hydronic/Plenum(duct) htrs.	avg.	Electric	7	N	0.4897	0.0049	0.2485	0.0898	0.2478	37.7%	6965	74	5170.6	991.7
	medn.		0.17%		0.3586	0.0024	0.1782	0.0704	0.1763	41.1%	8422	41	5564.0	1080.0
Boiler with continuous pilot			14	YP										
Boiler with spark ignit.,vent dmpr			1	N										
Condensing boiler			1	N										
Condensing furnace	avg.	N.Gas	243	N	0.4383	0.0056	0.2286	0.0781	0.2289	34.3%	6824	106	4145.0	901.9
	medn.		5.84%		0.3874	0.0040	0.2017	0.0699	0.2014	33.9%	7924	62	3937.0	890.5
Forced air furnace			6	N										
Furnace			4	BD										
Furnace with continuous pilot	avg.	N.Gas	2871	YP	0.5511	0.0080	0.2927	0.0961	0.2940	22.4%	5570	162	2354.9	588.6
	medn.		68.98%		0.4780	0.0061	0.2531	0.0841	0.2540	21.0%	6249	164	1004.0	552.3
Furnace with flame retention head			1	BD										
Furnace with spark ignit.,vent dmpr			4	BD										
Furnace with spark ignition	avg.	N.Gas	42	Y	0.4685	0.0064	0.2475	0.0824	0.2484	31.4%	6507	110	4203.6	824.0
	medn.		1.01%		0.3777	0.0041	0.1947	0.0696	0.1962	35.5%	8116	50	5526.5	932.5
Induced draft fan furnace	avg.	N.Gas	968	Y	0.4630	0.0060	0.2415	0.0822	0.2419	31.3%	6575	117	3789.0	822.2
	medn.		23.26%		0.4136	0.0045	0.2140	0.0747	0.2141	30.5%	7598	90	3039.0	802.4
Construction Period														
1900-1944	avg.		487		0.9382	0.0147	0.5019	0.1615	0.5048	5.8%	1909	208	275.8	153.0
	medn.		11.70%		0.8634	0.0126	0.4586	0.1496	0.4644	3.2%	1333	227	58.0	83.5
1945	avg.		21		0.8206	0.0123	0.4386	0.1422	0.4410	9.1%	2740	203	537.2	240.3
	medn.		0.50%		0.7872	0.0094	0.4147	0.1262	0.4125	6.9%	2327	214	93.0	180.6
1946-1960	avg.		840		0.5811	0.0082	0.3072	0.1019	0.3084	18.5%	4946	195	1593.0	486.6
	medn.		20.18%		0.5313	0.0065	0.2785	0.0935	0.2787	16.4%	5204	227	633.0	432.3
1961-1980	avg.		1872		0.4654	0.0063	0.2447	0.0821	0.2454	26.4%	6475	147	2798.4	694.5
	medn.		44.98%		0.4430	0.0052	0.2309	0.0783	0.2317	25.8%	7049	133	2751.0	679.3
1981-1995	avg.		803		0.3847	0.0052	0.2027	0.0678	0.2034	36.5%	7523	83	4851.3	960.5
	medn.		19.29%		0.3621	0.0045	0.1907	0.0634	0.1908	37.0%	8279	41	5534.0	971.1
1996-2004	avg.		139		0.2577	0.0036	0.1356	0.0453	0.1361	56.4%	8516	14	7995.1	1483.1
	medn.		3.34%		0.2314	0.0029	0.1228	0.0411	0.1238	59.1%	8760	1	8760.0	1552.4
Statistics for entire Saskatoon dataset.	**avg.**		**4162**		**0.5234**	**0.0074**	**0.2766**	**0.0917**	**0.2777**	**25.3%**	**5884**	**147**	**2818.1**	**664.5**
	medn.		**100.00%**		**0.4583**	**0.0056**	**0.2404**	**0.0808**	**0.2408**	**23.9%**	**6703**	**142**	**1317.0**	**627.1**

Table C-35. Aggregated Annual Statistics for Groupings by Heating System Type and by Period of Construction of Model Calculations of Natural Ventilation in Saskatoon Houses with NPL = 0.90

Heating System		Fuel	No.	Flue	Max	Min	Mean	StDev	Median	US%	Hrs	Prds	Lngst	USach
Baseboard/Hydronic/Plenum(duct)	avg.	Electric	7	N	0.5841	0.0059	0.2823	0.1104	0.2784	32.8%	6452	75	4590.9	860.8
htrs.	medn.		0.17%		0.4313	0.0029	0.2032	0.0861	0.1986	34.6%	7865	53	5524.0	910.5
Boiler with continuous pilot			14	YP										
Boiler with spark ignit.,vent dmpr			1	N										
Condensing boiler			1	N										
Condensing furnace	avg.	N.Gas	243	N	0.5188	0.0067	0.2590	0.0961	0.2565	29.6%	6134	108	3819.8	777.1
	medn.		5.84%		0.4612	0.0048	0.2291	0.0858	0.2263	27.7%	6897	90	3932.0	728.5
Forced air furnace			6	N										
Furnace			4	BD										
Furnace with continuous pilot	avg.	N.Gas	2871	YP	0.6486	0.0096	0.3311	0.1184	0.3290	18.4%	4744	154	2056.8	483.0
	medn.		68.98%		0.5636	0.0074	0.2864	0.1037	0.2843	16.7%	4871	179	1004.0	439.7
Furnace with flame retention head			1	BD										
Furnace with spark ignit.,vent dmpr			4	BD										
Furnace with spark ignition	avg.	N.Gas	42	Y	0.5522	0.0077	0.2802	0.1014	0.2782	26.6%	5868	111	3545.3	699.9
	medn.		1.01%		0.4496	0.0049	0.2199	0.0856	0.2194	28.9%	7134	84	3937.0	758.7
Induced draft fan furnace	avg.	N.Gas	968	Y	0.5469	0.0072	0.2736	0.1011	0.2711	26.6%	5851	119	3411.3	699.8
	medn.		23.26%		0.4888	0.0054	0.2429	0.0920	0.2400	24.5%	6441	111	3038.0	643.2
Construction Period														
1900-1944	avg.		487		1.0984	0.0177	0.5673	0.1989	0.5646	4.6%	1532	177	229.4	120.5
	medn.		11.70%		1.0211	0.0151	0.5181	0.1845	0.5180	2.4%	1020	197	57.0	62.0
1945	avg.		21		0.9636	0.0148	0.4960	0.1752	0.4935	7.3%	2239	181	507.4	191.7
	medn.		0.50%		0.9027	0.0113	0.4722	0.1555	0.4633	5.4%	1944	192	59.0	142.9
1946-1960	avg.		840		0.6845	0.0098	0.3477	0.1254	0.3453	15.0%	4109	178	1412.9	395.3
	medn.		20.18%		0.6284	0.0078	0.3151	0.1154	0.3129	13.1%	4032	196	631.0	344.9
1961-1980	avg.		1872		0.5496	0.0075	0.2771	0.1011	0.2749	21.7%	5518	147	2453.1	570.1
	medn.		44.98%		0.5229	0.0062	0.2614	0.0963	0.2593	20.6%	5846	162	1638.0	541.8
1981-1995	avg.		803		0.4545	0.0063	0.2296	0.0835	0.2278	31.1%	6806	94	4291.1	816.8
	medn.		19.29%		0.4266	0.0053	0.2155	0.0782	0.2143	30.4%	7377	79	4997.0	797.9
1996-2004	avg.		139		0.3037	0.0043	0.1536	0.0558	0.1524	51.2%	8355	20	7483.2	1346.3
	medn.		3.34%		0.2748	0.0035	0.1390	0.0506	0.1382	53.7%	8760	1	8760.0	1410.0
Statistics for entire Saskatoon	**avg.**		**4162**		**0.6166**	**0.0089**	**0.3131**	**0.1129**	**0.3109**	**21.1%**	**5094**	**143**	**2495.8**	**553.8**
dataset.	**medn.**		**100.00%**		**0.5407**	**0.0067**	**0.2730**	**0.0996**	**0.2699**	**18.9%**	**5390**	**163**	**1005.0**	**497.8**

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