Residential HVAC Controller Measurement Input Analysis

Final Report

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EXECUTIVE SUMMARY

The purpose of this residential HVAC controller measurement input analysis is to determine critical measured parameters with respect to the operation and energy use of single-family residences, and to make recommendations with respect to the design of a residential HVAC controller/display . The home-owner's knowledge of these parameters is key to understanding the operation of the residence and its energy use.

Sensitivity analyses were carried out (through HOT2000 simulations) to determine sensor accuracy requirements. HRV efficiency equations were used to determine HRV measurement accuracy requirements.

A survey of sensors was carried out to determine typical costs for the required accuracies. Several packages were designed to meet a variety of user needs. Approximate costs and benefits of each package were determined.

Recommendations:

Develop an HVAC controller with sufficient programming capability that it can accommodate different instrumentation packages.

Build sufficient memory capacity into the unit that pre-programmed hardware characteristics (furnaces, HRVs, water heaters, fans, etc.) can be specified at the time of commissioning. Also, allow for input of one-time measurements at the time of commissioning, such as:

- clean filter pressure drop (furnace, air handler, HRV),
- pump and fan motor energy use, under one or more sets of operation conditions, as applicable,
- flow rates (hot water circulation, air flow, etc.)

For full diagnostic capability, the HVAC controller would have control of all fans and pumps in the system, either directly or indirectly. At the very least, the HVAC controller would have to be aware of the details of operation of each element in the system (fan speed setting, control valve status, HRV defrost cycle status, etc.). If the HVAC sub-system did not allow direct outside control,. then status information should be output (the alternative is to measure the result of a change in status, which would be a duplication of effort).

Build and program a commissioning module that would allow the commissioning technician to take one-time measurements during commissioning, to ensure proper operation of the system, as well as for initialization inputs into the HVAC controller.

RÉSUMÉ

La présente analyse des données de mesure relatives aux régulateurs résidentiels de CVC vise d'abord à déterminer quels sont les paramètres essentiels évalués en ce qui concerne le fonctionnement et la consommation énergétique des maisons unifamiliales. Elle permet également de faire des recommandations au chapitre de la conception des régulateurs de CVC résidentiels, et de leurs afficheurs. La connaissance de ces paramètres demeure, pour le propriétaire, l'élément primordial afin de comprendre le fonctionnement de sa maison et sa consommation d'énergie.

Des analyses de sensibilité ont été effectuées (en ayant recours à des simulations par le logiciel HOT2000) en vue d'établir les besoins en matière de précision des détecteurs. On a fait appel à des équations relatives à l'efficacité des ventilateurs-récupérateurs de chaleur afin de cerner les besoins en matière de précision des mesures se rapportant à ces appareils.

On a procédé à une étude des détecteurs afin de déterminer ce qu'il en coûte généralement pour obtenir la précision demandée. Un grand nombre d'ensembles ont été conçus en vue de répondre aux divers besoins des utilisateurs. Les coûts et les avantages approximatifs de chaque ensemble ont été évalués.

Recommandations

Il faut concevoir un régulateur de CVC disposant de capacités de programmation suffisantes pour s'adapter à plusieurs ensembles d'appareils.

On pourrait préciser, au moment de la mise en service, la nécessité d'incorporer des capacités de mémoire suffisantes aux appareils présentant des caractéristiques matérielles particulières qui sont pré-programmées (comme les chaudières, les ventilateurs-récupérateurs de chaleur, les chauffe-eau, les ventilateurs, etc.). Il faudrait également permettre, toujours au moment de la mise en service, l'introduction en une seule fois de mesures comme :

- la perte de charge d'un filtre propre (chaudières, appareils de traitement d'air, ventilateurs-récupérateurs de chaleur);
- la consommation énergétique des pompes et des moteurs de ventilateur, dans une ou plusieurs séries de conditions selon les cas;
- le débit (circulation de l'eau chaude, débit d'air, etc.).

Pour obtenir des capacités complètes de diagnostic, il faut que les régulateurs de CVC permettent de commander l'ensemble des ventilateurs et des pompes dans le système, que ce soit directement

ou indirectement. De plus, les régulateurs de CVC doivent, en tout dernier lieu, être programmés en fonction de certains détails de fonctionnement des éléments du système (comme le réglage de la vitesse des ventilateurs, l'état des vannes de commande, le cycle de dégivrage des ventilateurs-récupérateurs de chaleur, etc.). Dans les cas où le sous-système de CVC ne permettrait pas un contrôle extérieur direct, il faudrait que la production serve d'information sur la situation (l'autre solution consisterait à mesurer les résultats d'un changement dans la situation, ce qui constituerait un dédoublement des efforts déployés).

Il faudrait construire et programmer un module de mise en service qui permettrait au technicien responsable de prendre une seule mesure à cette occasion, d'assurer le fonctionnement adéquat du système et d'initialiser les données introduites dans le régulateur de CVC.

TECHNICAL REPORT

The purpose of this residential HVAC controller measurement input analysis is to determine critical measured parameters with respect to the operation and energy use of single-family residences, and to make recommendations with respect to the design of a residential HVAC controller/display . The home-owner's knowledge of these parameters is key to understanding the operation of the residence and its energy use.

The major energy uses in a single-detached residence are:

- heating system
- cooling system (where applicable)
- ventilation system (where applicable)
- service water heating
- utilities (lighting, cooking, clothes washing & drying, etc.)

Utilities energy use is extremely lifestyle dependant and is therefore not conducive to modification through monitoring, except for information purposes. The first four items above, however, are typically single systems with energy use inversely related to the efficiency of the system. Monitoring the input and output parameters of each of these systems so as to determine its operating efficiency, and then advising the homeowner if its efficiency is outside reasonable limits, would enable the homeowner to have the system repaired before excessive energy use had taken place.

Other, more lifestyle dependant parameters (such as inside temperature, hot water use, etc.) could also be monitored and the homeowner advised of the savings in energy use (and dollars) if a change were made.

In consultation with NRCan and Horizon Technologies staff, the following list of residential HVAC systems and potential critical parameters was developed:

- outdoor temperature
- indoor temperature
  - main floor(s)
  - basement (where applicable)
- natural gas[1] space heating systems, and sub-systems -
  - natural gas use
  - status (set-points, dead-band; heating mode: on-demand or continuous fan)

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[1] Efficiency of electric resistance space and water heating is usually not a critical factor (it either works or it doesn't), however correct control of the unit can be significant.

  - forced air fan (current draw, motor temperature, air flow),
  - filtration (pressure drop, light attenuation),
  - indoor temperatures, and
- heat recovery ventilation systems, and sub-systems -
  - status (operating, flow setting, summer mode - core removed)
  - fans (current draw, motor temperature, air flow),
  - filtration (filter removed, pressure drop, light attenuation),
  - core (temperatures, efficiency)

Using these systems as a starting point, a database of Causes and Effects was created for a variety of information requirements and problems (App. A), along with supplementary databases (option lists, sensor hardware characteristics and relative costs, App. E).

An analysis was carried out to determine the sensitivity of operation to each variable, using HOT-2000, version 7.3e (Appendix D). The effect on comfort and energy use was determined for changes in several variables. Appendix B and Table 1 shows the "**Amount of change**" in each variable to produce the change in space heating requirement and total energy requirement in the next two columns. This would also be the amount of change in space heating and total energy if the **variable** were in **error** by the amount of change shown. Therefore, for a given effect on energy use, the table gives an indication of the required sensor accuracy. The houses used were typical new houses for each region.

Table 1 Space Heating Sensitivity Analysis

Location	House Type	Variable changed	Amount of change	Change: Space heat	Change: Total Energy
Vancouver	1.5 st./cs/slab/bsmt.	Tmain	1.0 C	13.60%	6.56%
		Tbsmt	1.0 C	3.89%	1.73%
		HRV efficiency	-1.0%	0.19%	0.09%
		Furnace efficiency	-1.0%	1.26%	0.61%
Calgary	1.5 storey/basement	Tmain*	1.0 C	*~13.5%*	*~6.9%*
		Tbsmt	1.0 C	9.87%	5.24%
		HRV efficiency	-1.0%	0.20%	0.11%
		Furnace efficiency	-1.0%	1.27%	0.69%
Toronto	1.5 storey/basement	Tmain	1.0 C	6.61%	3.67%
			-1.0 C	-2.82%	-1.59%
		Tbsmt	1.0 C	8.09%	4.36%
			-1.0 C	-3.52%	-2.11%
		HRV efficiency	-1.0%	0.24%	0.13%
			1.0%	-0.24%	-0.13%
			-5.0%	1.19%	0.66%
		Exhaust only		8.62%	3.44%
		Furnace efficiency	-1.0%	1.27%	0.71%
			1.0%	-1.23%	-0.69%
Montreal	1.5 st./basement	Tmain*	1.0 C	*~4.3%*	*~1.6%*
		Tbsmt	1.0 C	12.75%	5.05%
		HRV efficiency	-1.0%	0.24%	0.09%
		Furnace efficiency	-1.0%	1.02%	0.41%
Halifax	1.5 st./slab/basement	Tmain	1.0 C	4.80%	2.25%
		Tbsmt	1.0 C	10.41%	4.79%
		HRV efficiency	-1.0%	0.27%	0.13%
		Furnace efficiency	-1.0%	1.01%	0.47%

[1] *HOT2000 produced anomolous results for two cases (Calgary and Montreal) with full, heated basements (with thermostatically controlled temperature), so the Tmain results shown for those two cases are with a heated basement but without thermostatic control (basement temperature changed with changes in Tmain).

In summary, a 1C increase in either the main floor or basement temperatures increased the space heating requirement by from 4% to about 13%, depending on location and configuration of the house.

Symmetry of sensitivity was investigated for the Toronto runs. For example, an **increase** in the main floor temperatures of 1.0C resulted in an increase in space heating requirement of 6.6% (Table 1), while a **decrease** of 1.0C resulted in a decrease in space heating requirement of only 2.8%. A similar trend was shown for the basement temperature. This assymetry is due to the fact that these temperatures affect the total load curve, which approximates a "bell" or Normal distribution. Changing the inside temperature changes the amplitude of the curve, but also changes its width (length of heating season). The space heating requirement is a complex function of this total load and also the internal and solar gains (the latter are quite significant, particularly in the "tail" portions of the curve).

Changes in HRV and furnace efficiencies were approximately symmetrical, however. A change in furnace efficiency of 1% produced a change in space heating energy requirement of just over 1%.

A change in HRV efficiency of 1% produced a change in space heating energy requirement of about 0.24% (ventilation and infiltration amount to about 20% of the total load). A run with a 5% reduction in HRV efficiency confirmed linearity of extrapolation - it resulted in an increase in space heating requirement of 1.2%.

A complete failure of the supply fan motor (turning the HRV into an exhaust only system), resulted in an increase in space heating energy use, for the Toronto case, of 8.6%.

In addition, the models developed in the R-2000 and Advanced House monitoring programs were used to determine HRV efficiency with respect to measured core temperatures, flow rates and imbalanced flows (Appendix C - note that the sample is for a specific set of conditions). For the example in App. C, a reduction in the supply flow of 2 L/s (about 7% of the flow), such as could occur with a dirty intake filter, resulted in a reduction in HRV core efficiency of 5% - or, from the previous analysis, an increase in space heating energy use of 1.2%.

Based on these analyses, the following packages are recommended (either individually or in combination[2]):

1. General information

- Inside temperature
- Basement/crawlspace temperature (optional)
- Outside temperature

Package cost[3]: low to moderate
Benefits: Heating system control, occupant information (see App. A)

- output space heating requirement per Degree Day, compare with historical consumption,
- advise of potential change of about 4% to 13% in space heating energy with a 1 C change in inside temperature (key to location and house configuration - input from nomograms during commissioning).

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[2] Cost savings could be achieved with some sensing by combining more than one package. For example, a physical multiplexer would allow one sensor to measure pressure for determining filter pressure drops for both space heating and ventilation, as well as HRV supply and exhaust air flows.

[3] Package cost categories (consumer price, before taxes) based on: low - less than $150; moderate - $150 to $500; high - more than $500. Costs include sensors, installation and interface, but do **not** include commissioning or central controller cost.

2a. Gas furnace

- natural gas consumption, pulse meter or status (burner on)
- fan speed, if multispeed (from controller),
- pressure drop across filter,
- air flow rate (could be a one-time measurement during commissioning).
- supply and return air temperatures (latter could be approximated by main floor temperataure)

Package cost: moderate
Benefits: Heating system control, occupant information (see App. A)

- filter - dirty, removed (IAQ benefits)
- burner out of adjustment (reduced efficiency)

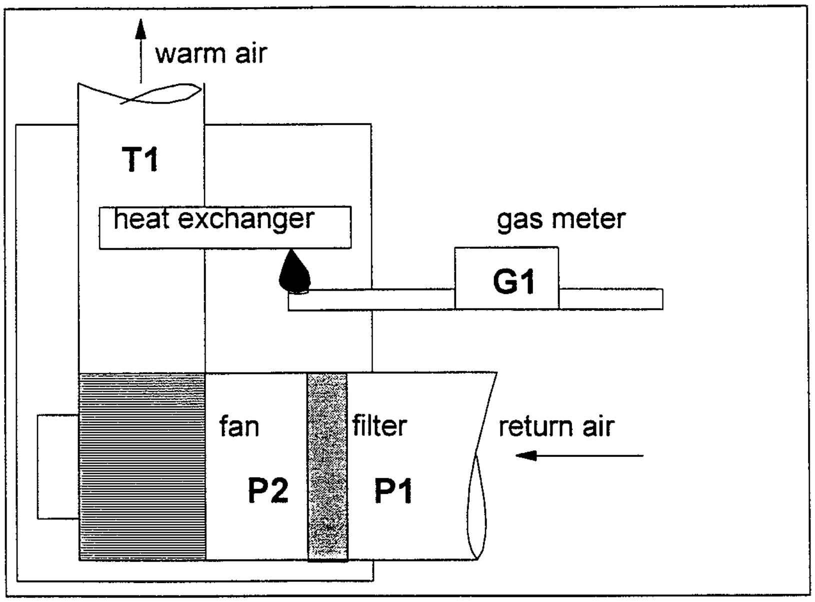

Figure 1 Natural Gas Forced Air Furnace

If the space heat air flow is fixed[4], a one-time measurement of air flow, in combination with the burner status (on/off), the warm air outlet temperature and the return air temperature (approximately equal to the main floor temperature) would yield an approximation of the space heating energy output. An adjustment to the air flow could be made with the pressure drop across the filter and the fan curve (programmed into the controller). This heat output, in combination with the gas energy input (either measured with a pulse meter, or somewhat less accurately with the burner status and a one-time gas flow measurement), would yield the furnace efficiency (calculated for a minimum time period of about one day). This efficiency could then

[4] A two speed fan could be accommodated through access to the fan speed status from the fan controller and one-time measured flow rates for both flow conditions.

be compared to a range of probable seasonal efficiencies to determine if the unit was operating within prescribed limits. A clean filter pressure drop would be programmed into the controller during commissioning.

or 2b. Gas water heater with air handler (space heat plus domestic hot water)

- natural gas consumption (G1), or burner on status (S2, from controller),
- pressure drop across filter (P1 - P2),
- water flow status to fan-coil (S1, assumed fixed flow)
- supply and return water temperatures (T1, T2)
- hot water temperature (T4)

Package cost: moderate to high
Benefits: efficiency and diagnostics of space and water heating systems (see App. A)

- filter - dirty, removed (IAQ benefits)
- burner out of adjustment (reduced efficiency)
- excessively high hot water temperature (risk of scalding), reduced efficiency

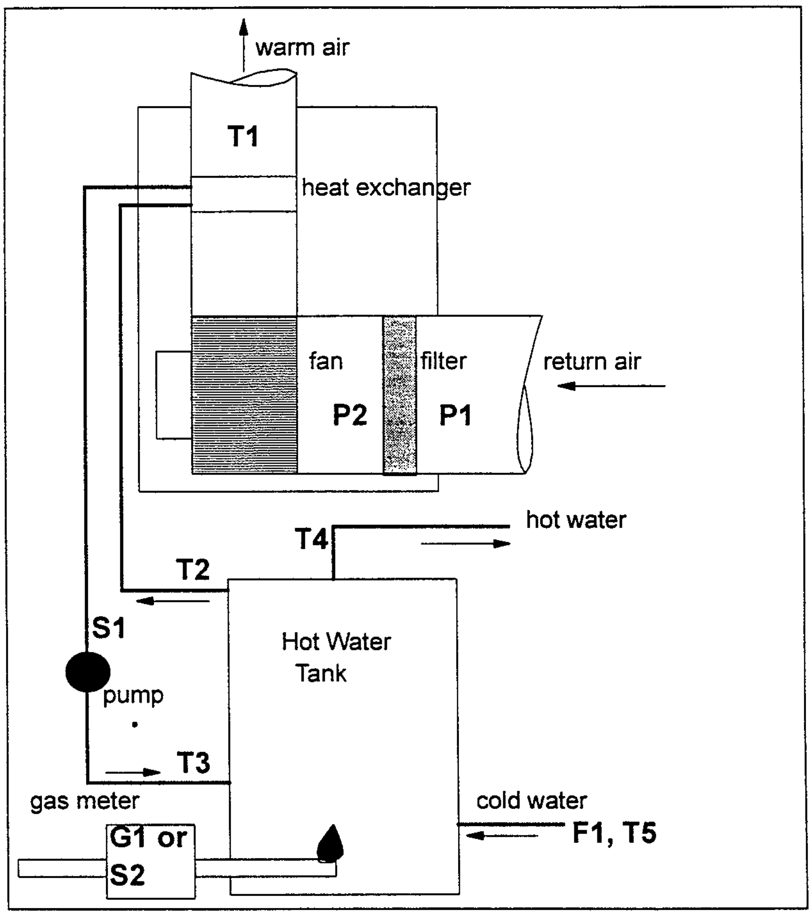

Figure 2 Natural Gas Domestic Water Heater with Space Heating Air Handler

If the space heat air flow is fixed[5], a one-time measurement of air flow, in combination with the fan status (on/off), the warm air outlet temperature and the return air temperature (approximately equal to the main floor temperature) would yield an approximation of the space heating energy output. An adjustment to the flow could be made with the pressure drop across the filter and the fan curve (programmed into the controller). A clean filter pressure drop would be programmed into the controller during commissioning.

Alternately, the circulating pump flow rate (one-time test during commissioning), in combination with the pump on/off status (S1), and the supply and return temperatures (T2, T3) would likely yield a more accurate space heating energy output.

The service water heating energy output could be determined from hot water flow (F1), in combination with the hot water temperature (T4), and cold water inlet temperature[6]. The space heat and service water heating energy output plus a calculated water tank jacket loss, in combination with the gas energy input, would yield the water heater efficiency (calculated over a minimum time period of about one week[7]). This could then be compared to a probable range of seasonal efficiencies to determine if the unit was operating within prescribed limits.

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[5] A two speed fan could be accommodated through access to the fan speed status from the fan controller and one-time measured flow rates for both flow conditions.

[6] The cold water inlet temperature could either be measured, or, with somewhat less accuracy, could be approximated by the ground temperature for the location (mean and sinusoidal seasonal variation - programmed into the controller)

[7] The longer time period is required due to the fact that the water tank has heat storage which could skew the efficiency calculation.

3. Gas domestic water heater

- natural gas consumption,
- status (burner on),
- hot water temperature

Package cost: moderate
Benefits: efficiency and diagnostics of domestic water heating system; occuupant information on hot water use (see App. A)

- excessively high hot water temperature (risk of scalding), reduced efficiency
- burner out of adjustment (reduced efficiency)

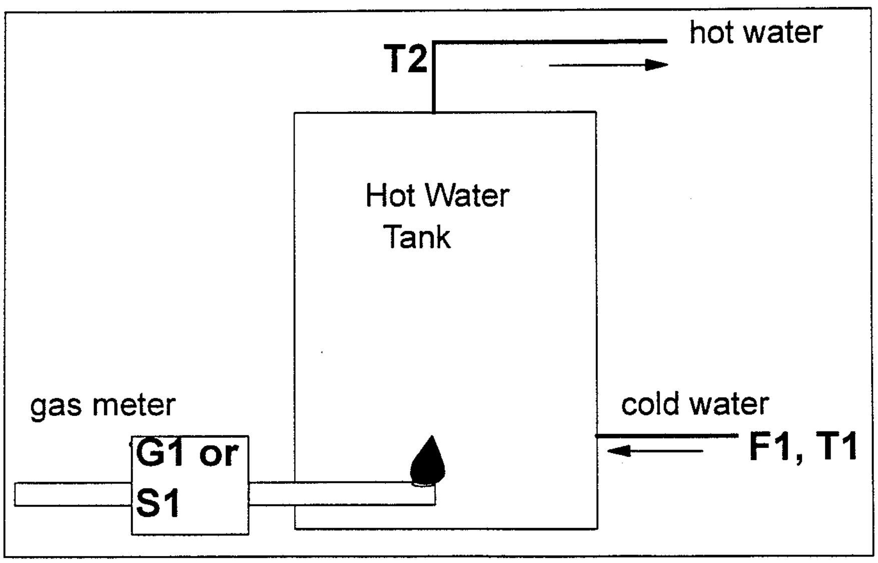

Figure 3 Natural Gas Domestic Water Heater

The service water heating energy output could be determined from hot water flow (F1), in combination with the hot water temperature (T2), and cold water inlet temperature (T1)[8]. The service water heating energy output plus a calculated water tank jacket loss, in combination with the gas energy input, would yield the water heater efficiency (calculated over a minimum time period of about one week[9]). This could then be compared to the probable seasonal efficiency to determine if the unit was operating within prescribed limits.

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[8] The cold water inlet temperature could either be measured, or, with somewhat less accuracy, could be approximated by the ground temperature for the location (mean and sinusoidal seasonal variation - programmed into the controller)

[9] The longer time period is required due to the fact that the water tank has heat storage which could skew the efficiency calculation.

4. Heat Recovery Ventilator

- supply and exhaust air flow,
- pressure drop across filter,
- supply temperatures into and out of HRV core

Package cost: moderate

Benefits: efficiency and diagnostics of heat recovery ventilating system (see App. A)

- dirty filter - effect on IAQ and flow imbalance; reduction in efficiency of about 5% for each 2 L/s change in supply flow rate (increase in space heating energy of 1.2%)
- supply side obstructions (intake, core) - reduced efficiency, as above
- exhaust obstructions (frozen core, exhaust grille plugged)
- fan controls out of adjustment (imbalanced flows) - reduced efficiency, as above
- defective fan(s)
- defective preheat/defrost sub-system and/or controls - reduced efficiency, as above

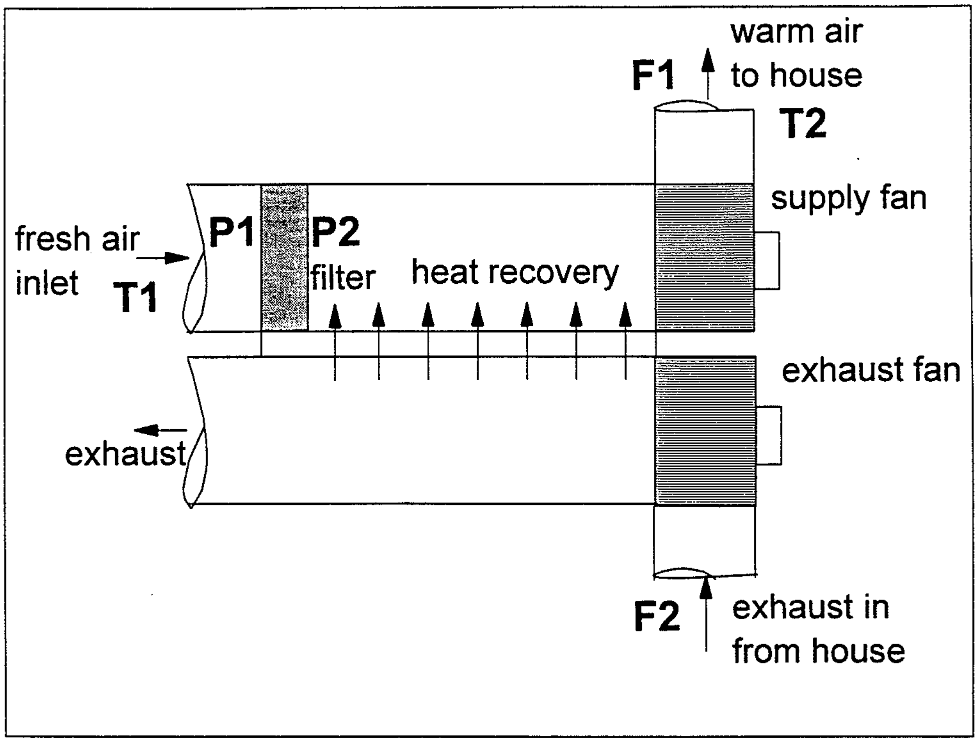


Figure 4 Heat Recovery Ventilator

With the HRV efficiency equations programmed into the controller, the core heat recovery efficiency could be determined through measurement of supply temperatures in (T1) and out (T2) of the unit in combination with supply (F1) and exhaust (F2) air flow rates[10]. In addition, energy supplied to the fan motors would be needed, but could be obtained through one-time

[10] Flow rates determined through measurement of pressure differential.

measurements during commissioning. Multi-speed fans could be accommodated through several one-time measurements and access to the fan motor controller.

With the addition of a switching multiplexer, the same pressure measuring manometer could be used for both flow rates, as well as for measuring the pressure drop across the filter.

Defrost cycle information on units with a supply-side defrost scenario could be obtained through measurement of the outside temperature and core supply in temperature (along with the supply air flow rate). Defrost cycle information on units that operate exhaust only, to defrost the core, could be obtained through monitoring of exhaust flow rate, inside and outside temperatures. In either case, the information could be compared to design probable defrost data (entered into the controller during commissioning) to determine if the unit was operating within design limits, for the outside temperature during the period[11].

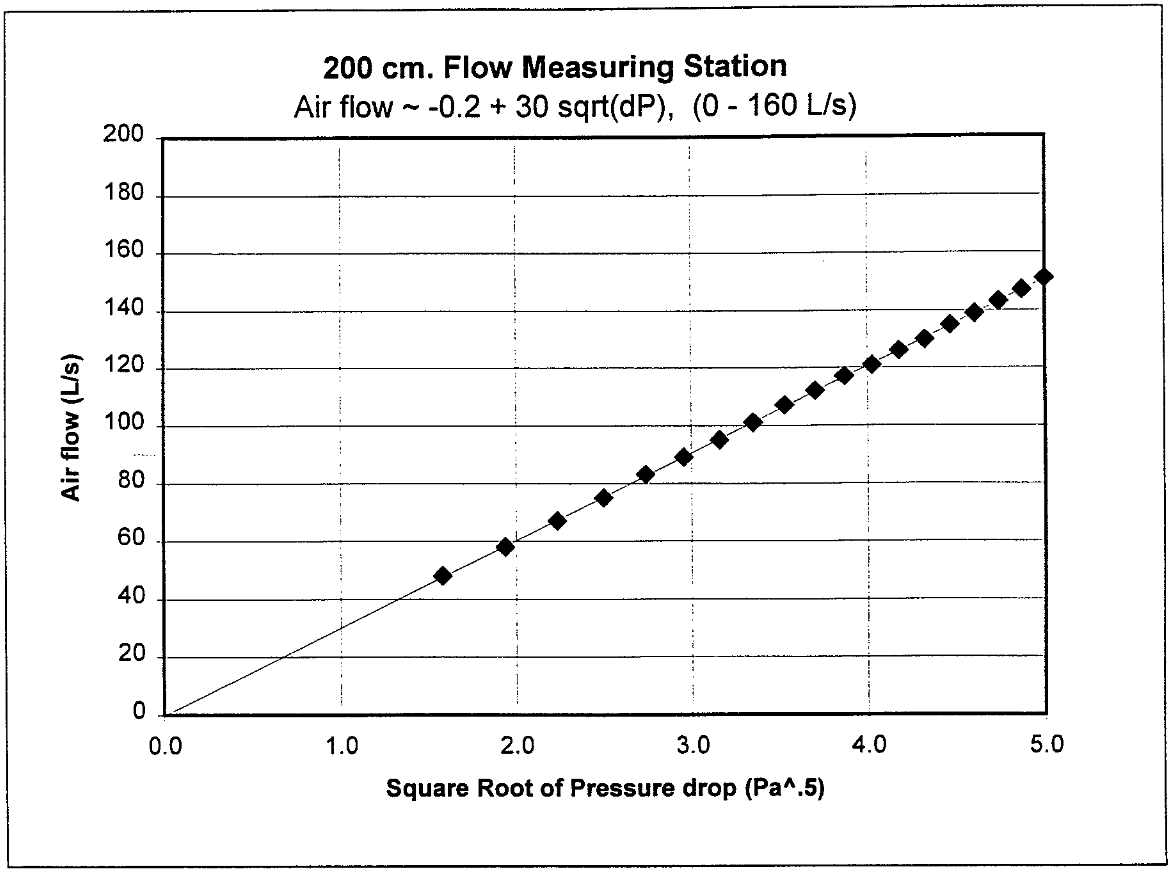


Figure 5 Sample Flow vs Pressure drop (200 cm diameter duct)

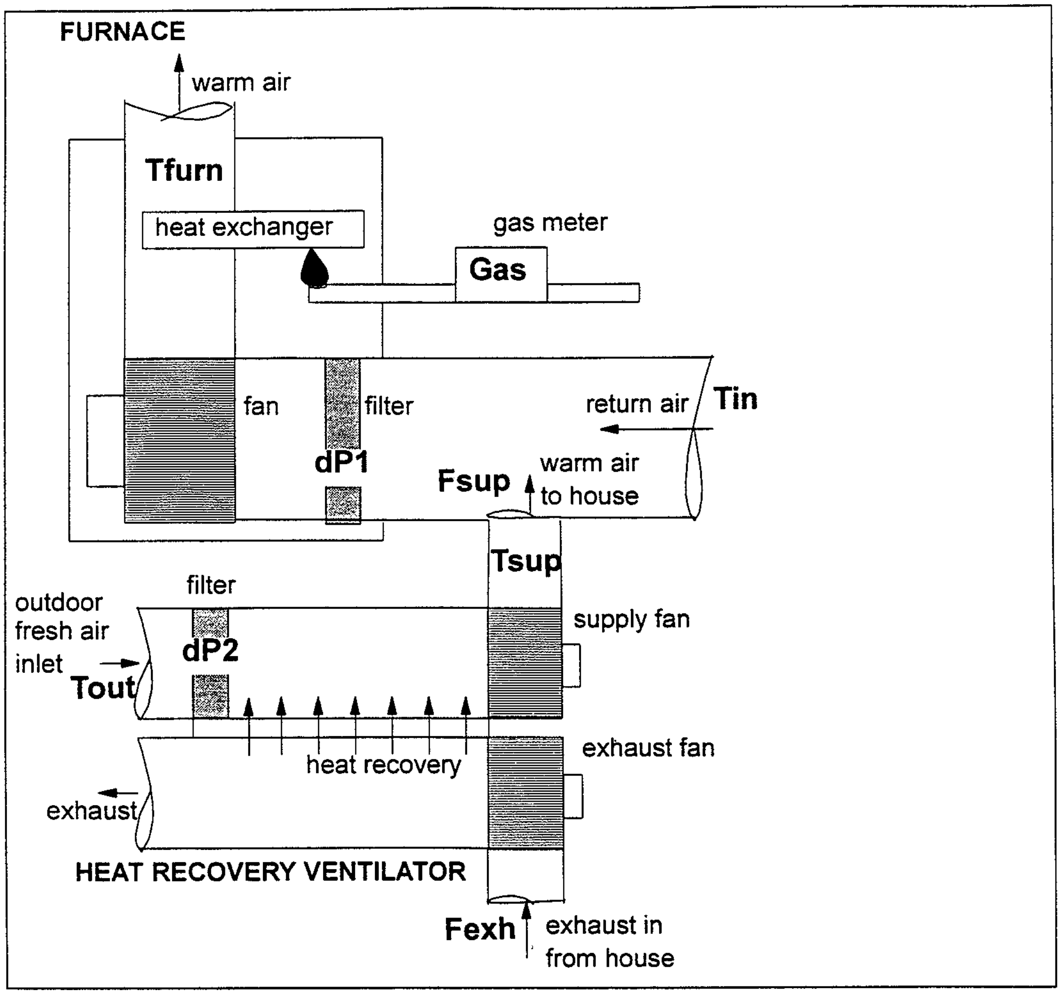
Required sensor accuracy will depend on the size of duct and normal flow range. For example, with a 200 cm. diameter duct (Figure 5), a change of pressure difference of 0.25 Pa in the 4 Pa

[11] Inside relative humidity is a significant factor in the requred frequency of defrosting, and, if measured, could reduce the range of design limits and therefore increase the accuracy of determining if the HRV defrost cycle is operating correctly.

pressure difference range (2 $Pa^{0.5}$), would result from a change in air flow of about 1.8 L/s - enough to cause a change in calculated HRV efficiency of almost 5%, and resulting change in space heating energy use of over 1%. With a 150 cm. duct, approximately a 0.45 Pa pressure difference would result from the same change in flow, so a less accurate sensor could be used.

5. Combined System: Forced Air Furnace and Heat Recovery Ventilator

Figure 6 Combined System: Forced Air Furnace and Heat Recovery Ventilator



The HRV outdoor fresh air inlet (supply) temperature could be approximated by the outdoor temperature (Tout). The furnace return air temperature could be approximated by the inside main floor temperature (Tin).

The pressure filter drop measurements, dP1 and dP2 pressure differential measurements. Clean filter pressure drops would be programmed into the controller during commissioning.

If the space heat air flow is fixed[12], a one-time measurement of air flow, in combination with the burner status (on/off), the warm air outlet temperature and the return air temperature would yield an approximation of the space heating energy output. An adjustment to the air flow could be made with the pressure drop across the filter and the fan curve (programmed into the controller). This heat output, in combination with the gas energy input (either measured with a pulse meter, or somewhat less accurately with the burner status and a one-time gas flow measurement), would yield the furnace efficiency (calculated for a minimum time period of about one day). This efficiency could then be compared to a range of probable seasonal efficiencies to determine if the unit was operating within prescribed limits.

Several packages of measurements were investigated in more detail, and their costs and benefits are outlined below. Note that retail costs (App. E) are used since a system manufacturer, who would purchase sensors, etc. at wholesale, would probably mark up the wholesale costs to retail levels for sale to the consumer. Installation costs are approximate, since they would depend on the physical location of the elements to be measured and the relative difficulty in connecting them. Controller interfacing costs are also approximate and should be determined by the HVAC controller developer/manufacturer. The cost of the HVAC controller is not included.

Package A, measuring everything shown in Figure 6 (9 sensors) would provide the following:

General information -
- Inside temperature
- Outside temperature

Furnace -
- natural gas consumption, pulse meter
- fan speed, if multispeed (from controller),
- pressure drop across filter,
- air flow rate (a one-time measurement during commissioning),
- supply and return air temperatures (latter approximated by main floor temperataure)

HRV -
- supply and exhaust air flow,
- fan speed, if multispeed (from controller),
- pressure drop across filter,
- supply temperature out of HRV core

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[12] A two speed fan could be accommodated through access to the fan speed status from the fan controller and one-time measured flow rates for both flow conditions.

Package cost: approximately $1,259[13] (plus approximately $200 commissioning costs[14])
Benefits from General measurements: Heating system control, occupant information

- output space heating requirement per Degree Day, compare with historical consumption,
- advise of potential change of about 4% to 13% in space heating energy with a 1 C change in inside temperature (key to location and house configuration - input from nomograms during commissioning).

Benefits from Furnace measurements: Heating system control, occupant information

- advise of dirty filter (IAQ benefits)
- advise if burner out of adjustment (reduced efficiency)

Benefits from HRV measurements: efficiency and diagnostics of heat recovery ventilating system (see App. A)

- advise of dirty filter - effect on IAQ and flow imbalance; reduction in efficiency of about 5% for each 2 L/s change in supply flow rate (increase in space heating energy of 1.2%),
- indication of supply side obstructions (intake, core) - reduced efficiency, as above,
- indication of exhaust obstructions (frozen core, exhaust grille plugged),
- advise if fan controls out of adjustment (imbalanced flows) - reduced efficiency, as above,
- advise if supply or exhaust fan defective,
- advise of defective preheat/defrost sub-system and/or controls - reduced efficiency, as above

This package would enable the controller to notify the occupant of most of the problems outlined in Appendix A. In some cases, the notification would of a general nature, such as "malfunction in HRV exhaust", if the exhaust flow was reduced. Closing manual dampers on either the supply or exhaust side could result in a false report of obstructions. Also, measuring flows and comparing them to the fan controller setting (in conjunction with commissioned flow rates) would enable the system to report a problem but may not be able to advise of the exact nature of the problem - for example, reduced exhaust flow could be the result of a plugged exhaust grille, motor/controller malfunction, or a closed exhaust damper.

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[13] Retail cost: approximately $731 for sensors, including pressure manometers for HRV supply and exhaust flows (some savings might be achievable if a single sensor with a multiplexer were used), $348 for installation, and $180 for HVAC controller interface costs.

[14] Approximate cost. Commissioning would include: measuring "clean filter" pressure drops (HRV and furnace); measuring furnace air flow rate(s); measuring HRV motot power use, checking temperatures; checking HRV supply and exhaust flow rates; checking HVAC controller diagnostic outputs (shut dampers, shut off fans, etc.) and input of system data/measurements into HVAC controller.

Costs could be reduced if the gas utility were to install pulse output meters for the purpose of remote reading.

This package would not sense excessive carbon monoxide due to back-drafting of furnace, fireplace, etc.

Package B, measuring everything shown in Figure 6 (9 sensors) would involve the following:

General information - as for Package A
Furnace - as for Package A, except -

- natural gas consumption from burner status (commissioning to include input to controller of consumption as a function of burner on-time)

HRV - as for Package A

Package cost: approximately $1,079[15] (plus approximately $240 commissioning costs)
Benefits from General measurements: as for Package A
Benefits from Furnace measurements: as for Package A, except -

- a less accurate determination of furnace efficiency

Benefits from HRV measurements: as for Package A

The comments for Package A would also apply to Package B, except that there would be less confidence in the reporting of furnace malfunctions.

Package C, measuring everything shown in Figure 6, except measure HRV flow differential instead of supply and exhaust flows (8 sensors):

General information - as for Package A
Furnace - as for Package A
HRV - as for Package A, except

- measure supply and exhaust air flow differential (flow imbalance),

Package cost: approximately $975[16] (plus approximately $220 commissioning costs)
Benefits from General measurements: as for Package A.
Benefits from Furnace measurements: as for Package A
Benefits from HRV measurements: as for Package A, except -

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[15] Package B retail cost: approximately $621 for sensors, $298 for installation, and $160 for HVAC controller interface costs.

[16] Package C retail cost: approximately $556 for sensors, including pressure manometers for HRV supply and exhaust flows, $289 for installation, and $130 for HVAC controller interface costs.

- indication of supply or exhaust side obstructions (intake, core.frozen core. exhaust grille plugged)[17] and/or indication of defective fan(s) - reduced efficiency

The comments for Package A would also apply to Package C, except that there would be less confidence in the reporting of HRV flow-related malfunctions. Specifically, the HVAC controller would not be able to differentiate between supply and exhaust side malfunctions. Also, HRV efficiency calculations would be less accurate, since the system would have to rely on the fan controller setting for the approximate flow rate (based on inputs at the time of commissioning).

Package D, measuring everything shown in Figure 6 except measure HRV pressure differential with a threshold activated switch, instead of supply and exhaust flows (8 sensors):

General information - as for Package A
Furnace - as for Package A
HRV - as for Package A, except

- measure supply and exhaust pressure differential (threshold activated switch),

Package cost: approximately $821[18] (plus approximately $220 commissioning costs)
Benefits from General measurements: as for Package A.
Benefits from Furnace measurements: as for Package A
Benefits from HRV measurements: as for Package A, except

- no calculation of HRV efficiency - only an indication of efficiency below a preset threshold,
- indication of supply or exhaust side obstructions (intake, core,frozen core, exhaust grille plugged)[19] and/or indication of defective fan(s) - reduced efficiency

The comments for Package A would also apply to Package D, except that there would be no calculation of HRV efficiency - only an indication of when the efficiency dropped below a preset level. Comments for Package C would also apply.

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[17] Note that closing manual dampers on either the supply or exhaust side could result in a false report of obstructions.

[18] Package D retail cost: approximately $471 for sensors, including pressure manometers for HRV supply and exhaust flows, $260 for installation, and $90 for HVAC controller interface costs.

[19] Note that closing manual dampers on either the supply or exhaust side could result in a false report of obstructions.

Package E, measuring everything shown in Figure 6 except measure HRV pressure differential with a threshold activated switch, instead of supply and exhaust flows, and do not measure HRV filter pressure drop (7 sensors):

General information - as for Package A
Furnace - as for Package A
HRV - as for Package D, except

- do not measure pressure drop across HRV intake filter,

Package cost: approximately $691[20] (plus approximately $200 commissioning costs)
Benefits from General measurements: as for Package A.
Benefits from Furnace measurements: as for Package A
Benefits from HRV measurements: as for Package A, except

- no measured indication of a dirty HRV filter,
- no calculation of HRV efficiency - only an indication of efficiency below a preset threshold,
- indication of supply or exhaust side obstructions (intake, core,frozen core, exhaust grille plugged)[21] and/or indication of defective fan(s) - reduced efficiency

The comments for Package D would also apply to Package E, except that there would be no indication of a dirty HRV filter (a recommendation could be made to change the filter, based on a timed interval - input at the time of commissioning). Commissioning would not require a "clean" filter pressure drop to be measured.

The effect of this change would be reduce indoor air quality (filter not changed frequently enough in dusty environments), or increased cost for filters (filter changed too frequently in relatively clean environments).

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[20] Package E retail cost: approximately $381 for sensors, including pressure manometers for HRV supply and exhaust flows, $230 for installation, and $80 for HVAC controller interface costs.

[21] Note that closing manual dampers on either the supply or exhaust side could result in a false report of obstructions.

Package F, measuring everything shown in Figure 6 except measure HRV pressure differential with a threshold activated switch, instead of supply and exhaust flows, and do not measure HRV or furnace filter pressure drops (6 sensors):

General information - as for Package A
Furnace - as for Package A except -

- do not measure pressure drop across furnace filter,

HRV - as for Package E

Package cost: approximately $561[22] (plus approximately $180 commissioning costs)
Benefits from General measurements: as for Package A.
Benefits from Furnace measurements: as for Package A, except -

- no measured indication of a dirty furnace filter,

Benefits from HRV measurements: as for Package A, except -

- no measured indication of a dirty HRV filter,
- no calculation of HRV efficiency - only an indication of efficiency below a preset threshold,
- indication of supply or exhaust side obstructions (intake, core,frozen core, exhaust grille plugged)[23] and/or indication of defective fan(s) - reduced efficiency

The comments for Package E would also apply to Package F, except that there would be no indication of a dirty furnace filter (a recommendation could be made to change the filter, based on a timed interval - input at the time of commissioning). Commissioning would not require a "clean" filter pressure drop to be measured.

The effect of this change would be reduce indoor air quality (filter not changed frequently enough in dusty environments), or increased cost for filters (filter changed too frequently in relatively clean environments).

Any one of these packages would provide a significant improvement in residential HVAC control and diagnosis of malfunctions in residential HVAC systems. The result would be a significant improvement in the efficiency of operation of residential heating systems.

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[22] Package F retail cost: approximately $291 for sensors, including pressure manometers for HRV supply and exhaust flows, $200 for installation, and $70 for HVAC controller interface costs.

[23] Note that closing manual dampers on either the supply or exhaust side could result in a false report of obstructions.

CONCLUSIONS AND RECOMMENDATIONS

Develop an HVAC controller with sufficient programming capability that it can accommodate different instrumentation packages.

Build sufficient memory capacity into the unit that pre-programmed hardware characteristics (furnaces, HRVs, water heaters, fans, etc.) can be specified at the time of commissioning. Also. allow for input of one-time measurements at the time of commissioning, such as:

- clean filter pressure drop (furnace, air handler, HRV),
- pump and fan motor energy use, under one or more sets of operation conditions, as applicable,
- flow rates (hot water circulation, air flow, etc.)

For full diagnostic capability, the HVAC controller would have control of all fans and pumps in the system, either directly or indirectly. At the very least, the HVAC controller would have to be aware of the details of operation of each element in the system (fan speed setting, control valve status, HRV defrost cycle status, etc.). If the HVAC sub-system did not allow direct outside control,. then status information should be output (the alternative is to measure the result of a change in status, which would be a duplication of effort).

Build and program a commissioning module that would allow the commissioning technician to take one-time measurements during commissioning, to ensure proper operation of the system, as well as for initialization inputs into the HVAC controller.

APPENDICES

Appendix A

Summary of Causes and Effects

Appendix B

Sensitivity Analysis: Residential Energy Use

Appendix C

Sensitivity Analysis: HRV Efficiency

Appendix D

Sample HOT-2000 runs

Appendix E

Sensor Characteristics

APPENDIX A

Summary of Causes and Effects

Appendix A Residential Combined Space Heat & HRV Summary

	Failure Modes	Measurement	Figure 6 Meas. Code
1	dirty HRV filter	pressure switch across HRV filter	dP2
2	removal of HRV filter	resistance (switch) filter slot	-
3	removal of core (summer mode)	resistance (switch) HRV housing	-
4	plugged HRV intake	pressure difference across intake grille	*
5	plugged HRV exhaust	pressure difference across exhaust grille	*
6	frozen HRV core	pressure difference across exhaust core	*
7	plugged HRV core	pressure difference across exhaust core	*
8	plugged HRV supply core	pressure difference across supply core	*
9	defective HRV preheat control	air temperature supply into house	Tsup
10	no power to supply air preheat	current supply preheater	-
11	no power to supply fan motor	voltage supply fan motor	-
12	supply fan motor open circuit	current supply fan motor	-
13	supply fan motor overheating	surface temperature supply fan motor or thermal breaker status	-
14	no power to exhaust fan motor	voltage exhaust fan motor	-
15	exhaust fan motor open circuit	current exhaust fan motor	-
16	exhaust fan motor overheating	surface temperature exhaust fan motor or thermal breaker status	-
17	fan flows out of adjustment	pressure difference supply and exhaust	Fdiff
17	fan flows out of adjustment	supply & exhaust flows	Fsup, Fexh
18	HRV Efficiency too low (flow imbalance, motor failure, etc.)	Flow difference, controller status, Tout, Tsup	Fdiff, Tout, Tsup
18	HRV Efficiency too low	Fsupply, Fexhaust, Tout, Tsup	Fsup, Fexh, Tout, Tsup
19	excessive house depressurization	pressure difference across house wall	-
20	dirty furnace filter	pressure switch across furnace filter	dP1
21	cracked furnace heat exchanger	carbon monoxide living space	-
22	temperature control error	air temperature living space	Tin
23	no power to fan motor	voltage circulation fan motor	-
24	fan motor open circuit	current circulation fan motor	-
25	fan motor overheating	surface temperature circulation fan motor or thermal breaker status	-
26	Furnace Efficiency too low	gas supply, Tfurnace, Tin	Gas, Tfurn, Tin
27	Furnace backdrafting	carbon monoxide near furnace	-
28		Outside temperature	Tout
*	Note: if HRV exhaust and supply flows (or their difference) are measured, the controller could advise c		

Possible Reason for - True negative	False positive	Solution(s)	Severity of Problem
decreased flow	increased flow	measure supply flow	Reduced indoor air quality, efficiency
slot contaminated	sensor failure	measure pressure drop	Reduced indoor air quality
slot contaminated	sensor failure	measure pressure drop	Reduced indoor air quality
decreased flow	increased flow	measure supply flow	Reduced indoor air quality, efficiency
decreased flow	increased flow	measure exhaust flow	Reduced efficiency
decreased flow	(1) increased flow, (2) plugged core	(1) measure exhaust flow, (2) meas. outside temp.	Reduced efficiency
decreased flow	(1) increased flow, (2) frozen core	(1) measure exhaust flow, (2) meas. outside temp.	Reduced efficiency
decreased flow	increased flow	measure supply flow	Reduced indoor air quality, efficiency
sensor failure	sensor failure	meas. Tout, preheater current	Excessive energy consumption; discomfort
sensor failure: Tsupply < Tset	Tsupply > Tset	measure supply temp.	Discomfort (cool drafts)
sensor failure (?)	power turned off	access controller status	Reduced indoor air quality
sensor failure (?)	power turned off	access controller status	Reduced indoor air quality
sensor failure	sensor failure		Reduced indoor air quality; Fire hazard
sensor failure (?)	power turned off	access controller status	Reduced indoor air quality
sensor failure (?)	power turned off	access controller status	Reduced indoor air quality
sensor failure	sensor failure		Reduced indoor air quality; Fire hazard
sensor failure	sensor failure	measure supply & exhaust flows	Reduced efficiency
sensor failure	sensor failure	access controller status	Reduced efficiency
high fan power consumption	?	measure fan power (monitor or manual)	Reduced efficiency
high fan power consumption	?	measure fan power (monitor or manual)	Reduced efficiency
stack/wind effects	stack/wind effects	manual recalibration	Potential for CO contamination
decreased flow	increased flow	measure flow	Reduced indoor air quality, efficiency
sensor failure	high VOC levels		Potential for CO contamination
sensor failure	sensor failure	manual recalibration	Discomfort
sensor failure (?)	power turned off	access controller status	Discomfort (low temperature)
sensor failure (?)	power turned off	access controller status	Discomfort (low temperature)
sensor failure	sensor failure		Reduced indoor air quality; Fire hazard
decreased flow	increased flow	measure flow and/or access controller	Excessive energy consumption
sensor failure	high VOC levels		Potential for CO contamination
f obstructions (grille, core, etc.), but not their location (would also need access to fan controller)			

APPENDIX B

Sensitivity Analysis: Residential Energy Use

App. B Sensitivity Analysis

Residential Energy Use (determined for NECH archetypes with HOT-2000, ver. 7.3)

Prov.	City	Run	Descriptive			Operation		Domestic Hot Water				Infiltration	
			Volume (m3)	Floor Area (m2)	Form	Tmain (C)	Tbsmt (C)	Water Use (L/d)	Water Temp. (C)	DHW Eff. Factor	DHW Eff.	Natural (ac/h)	Total (ac/h)
BC	Vancouver	NECH HRV Base	692.0	276.8	1.5 st./cs/slab/bsmt.	21.0	20.0	236.4	55	0.539	54.8%	0.166	0.310
		Tin +1 C	692.0	276.8	1.5 st./cs/slab/bsmt.	**22.0**	20.0	236.4	55	0.539	54.9%	0.174	0.318
		Tbsmt +1 C	692.0	276.8	1.5 st./cs/slab/bsmt.	21.0	**21.0**	236.4	55	0.539	55.1%	0.166	0.310
		HRV eff.-1%	692.0	276.8	1.5 st./cs/slab/bsmt.	21.0	20.0	236.4	55	0.539	54.8%	0.166	0.310
		HRV pwr.+1W	692.0	276.8	1.5 st./cs/slab/bsmt.	21.0	20.0	236.4	55	0.539	54.8%	0.166	0.310
		Furn eff.-1%	692.0	276.8	1.5 st./cs/slab/bsmt.	21.0	20.0	236.4	55	0.539	54.8%	0.166	0.310
		Furn pwr.+1W	692.0	276.8	1.5 st./cs/slab/bsmt.	21.0	20.0	236.4	55	0.539	54.8%	0.166	0.310
PR	Calgary	NECH HRV Base	599.0	239.6	1.5 st./bsmt.	21.0	20.0	236.4	55	0.539	56.5%	0.096	0.246
		Tin +1 C	599.0	239.6	1.5 st./bsmt.	**22.0**	20.0	236.4	55	0.539	56.5%	0.100	0.250
		Tbsmt +1 C	599.0	239.6	1.5 st./bsmt.	21.0	**21.0**	236.4	55	0.539	56.8%	0.096	0.246
		HRV eff.-1%	599.0	239.6	1.5 st./bsmt.	21.0	20.0	236.4	55	0.539	56.5%	0.096	0.246
		HRV pwr.+1W	599.0	239.6	1.5 st./bsmt.	21.0	20.0	236.4	55	0.539	56.5%	0.096	0.246
		Furn eff.-1%	599.0	239.6	1.5 st./bsmt.	21.0	20.0	236.4	55	0.539	56.5%	0.096	0.246
		Furn pwr.+1W	599.0	239.6	1.5 st./bsmt.	21.0	20.0	236.4	55	0.539	56.5%	0.096	0.246
PR	Calgary	NECH HRV Base	599.0	239.6	1.5 st./bsmt.	21.0	**~18.9**	236.4	55	0.539	56.1%	0.096	0.246
	(no basement	Tin +1 C	599.0	239.6	1.5 st./bsmt.	**22.0**	**~19.5**	236.4	55	0.539	56.3%	0.100	0.250
	thermostat)	Tin -1 C	599.0	239.6	1.5 st./bsmt.	**20.0**	**~18.2**	236.4	55	0.539	55.9%	0.093	0.243
ON	Toronto	NECH HRV Base	847.0	338.8	1.5 st./bsmt.	21.0	20.0	236.4	55	0.539	54.9%	0.115	0.265
		Tin +1 C	847.0	338.8	1.5 st./bsmt.	**22.0**	20.0	236.4	55	0.539	54.9%	0.119	0.269
		Tin -1 C	847.0	338.8	1.5 st./bsmt.	**20.0**	20.0	236.4	55	0.539	54.9%	0.110	0.260
		Tbsmt +1 C	847.0	338.8	1.5 st./bsmt.	21.0	**21.0**	236.4	55	0.539	55.2%	0.115	0.265
		Tbsmt -1 C	847.0	338.8	1.5 st./bsmt.	21.0	**19.0**	236.4	55	0.539	54.5%	0.115	0.265
		Tbsmt: no thermostat	847.0	338.8	1.5 st./bsmt.	21.0	**~19.9**	236.4	55	0.539	54.7%	0.115	0.265
		HRV eff.-1%	847.0	338.8	1.5 st./bsmt.	21.0	20.0	236.4	55	0.539	54.9%	0.115	0.265
		HRV eff.+1%	847.0	338.8	1.5 st./bsmt.	21.0	20.0	236.4	55	0.539	54.9%	0.115	0.265
		HRV eff.-5%	847.0	338.8	1.5 st./bsmt.	21.0	20.0	236.4	55	0.539	54.9%	0.115	0.265
		Exhaust only	847.0	338.8	1.5 st./bsmt.	21.0	20.0	236.4	55	0.539	54.9%	0.232	0.232
		HRV pwr.+1W	847.0	338.8	1.5 st./bsmt.	21.0	20.0	236.4	55	0.539	54.9%	0.115	0.265
		Fans: DT control	847.0	338.8	1.5 st./bsmt.	21.0	20.0	236.4	55	0.539	54.9%	0.115	0.264
		Fans: DT control	847.0	338.8	1.5 st./bsmt.	21.0	20.0	236.4	55	0.539	54.9%	0.115	0.264
		Furn eff.-1%	847.0	338.8	1.5 st./bsmt.	21.0	20.0	236.4	55	0.539	54.9%	0.115	0.265
		Furn eff.+1%	847.0	338.8	1.5 st./bsmt.	21.0	20.0	236.4	55	0.539	54.9%	0.115	0.265
		Furn pwr.+1W	847.0	338.8	1.5 st./bsmt.	21.0	20.0	236.4	55	0.539	54.9%	0.115	0.265
QU	Montreal	NECH HRV Base	471.0	188.4	1.5 st./bsmt.	21.0	20.0	236.4	55	0.824	84.8%	0.081	0.231
		Tin +1 C	471.0	188.4	1.5 st./bsmt.	**22.0**	20.0	236.4	55	0.824	84.8%	0.084	0.234
		Tbsmt +1 C	471.0	188.4	1.5 st./bsmt.	21.0	**21.0**	236.4	55	0.824	85.2%	0.081	0.231
		HRV eff.-1%	471.0	188.4	1.5 st./bsmt.	21.0	20.0	236.4	55	0.824	84.8%	0.081	0.231
		HRV pwr.+1W	471.0	188.4	1.5 st./bsmt.	21.0	20.0	236.4	55	0.824	84.8%	0.081	0.231
		Furn eff.-1%	471.0	188.4	1.5 st./bsmt.	21.0	20.0	236.4	55	0.824	84.8%	0.081	0.231
		Furn pwr.+1W	471.0	188.4	1.5 st./bsmt.	21.0	20.0	236.4	55	0.824	84.8%	0.081	0.231
QU	Montreal	NECH HRV Base	471.0	188.4	1.5 st./bsmt.	21.0	**~19.4**	236.4	55	0.824	84.5%	0.081	0.231
	(no basement	Tin +1 C	471.0	188.4	1.5 st./bsmt.	**22.0**	**~20.0**	236.4	55	0.824	84.7%	0.084	0.234
	thermostat)	Tin -1 C	471.0	188.4	1.5 st./bsmt.	**22.0**	**~18.8**	236.4	55	0.824	84.3%	0.078	0.228
MT	Halifax	NECH HRV Base	671.0	268.4	1.5 st./slab/bsmt.	21.0	20.0	236.4	55	0.824	84.2%	0.094	0.244
		Tin +1 C	671.0	268.4	1.5 st./slab/bsmt.	**22.0**	20.0	236.4	55	0.824	84.2%	0.094	0.244
		Tbsmt +1 C	671.0	268.4	1.5 st./slab/bsmt.	21.0	**21.0**	236.4	55	0.824	84.6%	0.094	0.244
		HRV eff.-1%	671.0	268.4	1.5 st./slab/bsmt.	21.0	20.0	236.4	55	0.824	84.2%	0.094	0.244
		HRV pwr.+1W	671.0	268.4	1.5 st./slab/bsmt.	21.0	20.0	236.4	55	0.824	84.2%	0.094	0.244
		Furn eff.-1%	671.0	268.4	1.5 st./slab/bsmt.	21.0	20.0	236.4	55	0.824	84.2%	0.094	0.244
		Furn pwr.+1W	671.0	268.4	1.5 st./slab/bsmt.	21.0	20.0	236.4	55	0.824	84.2%	0.094	0.244

App. B Sensitivity Analysis

Residential Energy Use

Prov.	City	Run	Vent. Type	Ventilation: Vent. rate (L/s)	Fan power (W)	HRV 0C rated efficiency	HRV Eff.	Space Heating: Heating System Fuel	Heating System Type	Distribution	Heating Rated Efficiency	Heating Seasonal Efficiency
BC	Vancouver	NECH HRV Base	HRV	27.6	125.0	55%	44.7%	Gas	Induced draft	Forced air	80%	78.8%
		Tin +1 C	HRV	27.6	125.0	55%	45.9%	Gas	Induced draft	Forced air	80%	78.8%
		Tbsmt +1 C	HRV	27.6	125.0	55%	43.8%	Gas	Induced draft	Forced air	80%	78.8%
		HRV eff.-1%	HRV	27.6	125.0	**54%**	43.9%	Gas	Induced draft	Forced air	80%	78.8%
		HRV pwr.+1W	HRV	27.6	**126.0**	55%	44.7%	Gas	Induced draft	Forced air	80%	78.8%
		Furn eff.-1%	HRV	27.6	125.0	55%	44.7%	Gas	Induced draft	Forced air	**79%**	77.8%
		Furn pwr.+1W	HRV	27.6	125.0	55%	44.7%	Gas	Induced draft	Forced air	80%	78.8%
PR	Calgary	NECH HRV Base	HRV	25.0	125.0	55%	45.0%	Gas	Induced draft	Forced air	80%	78.8%
		Tin +1 C	HRV	25.0	125.0	55%	46.1%	Gas	Induced draft	Forced air	80%	78.8%
		Tbsmt +1 C	HRV	25.0	125.0	55%	44.2%	Gas	Induced draft	Forced air	80%	78.8%
		HRV eff.-1%	HRV	25.0	125.0	**54%**	44.2%	Gas	Induced draft	Forced air	80%	78.8%
		HRV pwr.+1W	HRV	25.0	**126.0**	55%	45.0%	Gas	Induced draft	Forced air	80%	78.8%
		Furn eff.-1%	HRV	25.0	125.0	55%	45.0%	Gas	Induced draft	Forced air	**79%**	77.8%
		Furn pwr.+1W	HRV	25.0	125.0	55%	45.0%	Gas	Induced draft	Forced air	80%	78.8%
PR	Calgary	NECH HRV Base	HRV	25.0	125.0	55%	45.8%	Gas	Induced draft	Forced air	80%	78.8%
	(no basement	Tin +1 C	HRV	25.0	125.0	55%	46.5%	Gas	Induced draft	Forced air	80%	78.8%
	thermostat)	Tin -1 C	HRV	25.0	125.0	55%	45.2%	Gas	Induced draft	Forced air	80%	78.8%
ON	Toronto	NECH HRV Base	HRV	35.3	125.0	55%	46.1%	Gas	Induced draft	Forced air	80%	78.8%
		Tin +1 C	HRV	35.3	125.0	55%	46.1%	Gas	Induced draft	Forced air	80%	78.8%
		Tin -1 C	HRV	35.3	125.0	55%	44.5%	Gas	Induced draft	Forced air	80%	78.8%
		Tbsmt +1 C	HRV	35.3	125.0	55%	45.1%	Gas	Induced draft	Forced air	80%	78.8%
		Tbsmt -1 C	HRV	35.3	125.0	55%	46.8%	Gas	Induced draft	Forced air	80%	78.8%
		Tbsmt: no thermostat	HRV	35.3	125.0	55%	46.3%	Gas	Induced draft	Forced air	80%	78.8%
		HRV eff.-1%	HRV	35.3	125.0	**54%**	45.2%	Gas	Induced draft	Forced air	80%	78.8%
		HRV eff.+1%	HRV	35.3	125.0	**56%**	46.9%	Gas	Induced draft	Forced air	80%	78.8%
		HRV eff.-5%	HRV	35.3	125.0	**50%**	42.0%	Gas	Induced draft	Forced air	80%	78.8%
		Exhaust only	**exh.**	35.3	**62.5**	**0%**	42.0%	Gas	Induced draft	Forced air	80%	78.8%
		HRV pwr.+1W	HRV	35.3	**126.0**	55%	46.0%	Gas	Induced draft	Forced air	80%	78.8%
		Fans: DT control	bal. fans	**70.6**	**160.0**	**0%**	0.0%	Gas	Induced draft	Forced air	80%	78.8%
		Fans: DT control	bal. fans	**55.0**	**150.0**	**0%**	0.0%	Gas	Induced draft	Forced air	80%	78.8%
		Furn eff.-1%	HRV	35.3	125.0	55%	46.1%	Gas	Induced draft	Forced air	**79%**	77.8%
		Furn eff.+1%	HRV	35.3	125.0	55%	46.1%	Gas	Induced draft	Forced air	**81%**	79.7%
		Furn pwr.+1W	HRV	35.3	125.0	55%	46.1%	Gas	Induced draft	Forced air	80%	78.8%
QU	Montreal	NECH HRV Base	HRV	19.6	125.0	55%	42.3%	Electricity	Furnace	Forced air	100%	98.1%
		Tin +1 C	HRV	19.6	125.0	55%	44.0%	Electricity	Furnace	Forced air	100%	98.1%
		Tbsmt +1 C	HRV	19.6	125.0	55%	41.2%	Electricity	Furnace	Forced air	100%	98.1%
		HRV eff.-1%	HRV	19.6	125.0	**54%**	41.5%	Electricity	Furnace	Forced air	100%	98.1%
		HRV pwr.+1W	HRV	19.6	**126.0**	55%	42.3%	Electricity	Furnace	Forced air	100%	98.1%
		Furn eff.-1%	HRV	19.6	125.0	55%	44.0%	Electricity	Furnace	Forced air	**99%**	97.1%
		Furn pwr.+1W	HRV	19.6	125.0	55%	44.0%	Electricity	Furnace	Forced air	100%	98.1%
QU	Montreal	NECH HRV Base	HRV	19.6	125.0	55%	43.1%	Electricity	Furnace	Forced air	100%	98.1%
	(no basement	Tin +1 C	HRV	19.6	125.0	55%	44.2%	Electricity	Furnace	Forced air	100%	98.1%
	thermostat)	Tin -1 C	HRV	19.6	125.0	55%	42.7%	Electricity	Furnace	Forced air	100%	98.1%
MT	Halifax	NECH HRV Base	HRV	28.0	125.0	55%	45.7%	Electricity	Furnace	Forced air	100%	98.1%
		Tin +1 C	HRV	28.0	125.0	55%	45.7%	Electricity	Furnace	Forced air	100%	98.1%
		Tbsmt +1 C	HRV	28.0	125.0	55%	45.7%	Electricity	Furnace	Forced air	100%	98.1%
		HRV eff.-1%	HRV	28.0	125.0	**54%**	44.9%	Electricity	Furnace	Forced air	100%	98.1%
		HRV pwr.+1W	HRV	28.0	**126.0**	55%	45.7%	Electricity	Furnace	Forced air	100%	98.1%
		Furn eff.-1%	HRV	28.0	125.0	55%	45.7%	Electricity	Furnace	Forced air	**99%**	97.1%
		Furn pwr.+1W	HRV	28.0	125.0	55%	45.7%	Electricity	Furnace	Forced air	100%	98.1%

App. B Sensitivity Analysis

Residential Energy Use

Prov.	City	Run	Fan Power (W)	Utilities Internal Utilities (kWh/d)	Outside Utilities (kWh/d)	Energy Use Utilities (kWh/yr.)	Hot Water (kWh/yr.)	Fans (kWh/yr.)	Space Heating (kWh/yr.)	Total (kWh/yr.)	Change: Space Cond. Energy	Total Energy
BC	Vancouver	NECH HRV Base	243	14.0	2.0	5,840	8,139	3,224	16,257	33,460	0.0%	0.0%
		Tin +1 C	243	14.0	2.0	5,840	8,123	3,224	18,468	35,655	13.60%	6.56%
		Tbsmt +1 C	243	14.0	2.0	5,840	8,086	3,224	16,890	34,040	3.89%	1.73%
		HRV eff.-1%	243	14.0	2.0	5,840	8,139	3,224	16,288	33,491	0.19%	0.09%
		HRV pwr.+1W	243	14.0	2.0	5,840	8,139	3,233	16,252	33,464	-0.03%	0.01%
		Furn eff.-1%	243	14.0	2.0	5,840	8,139	3,224	16,463	33,666	1.26%	0.61%
		Furn pwr.+1W	**244**	14.0	2.0	5,840	8,139	3,232	16,251	33,462	-0.04%	0.01%
PR	Calgary	NECH HRV Base	303	14.0	2.0	5,840	8,768	3,749	21,945	40,302	0.0%	0.0%
		Tin +1 C	303	14.0	2.0	5,840	8,768	3,749	22,174	40,531	1.04%	0.57%
		Tbsmt +1 C	303	14.0	2.0	5,840	8,713	3,749	24,110	42,412	9.87%	5.24%
		HRV eff.-1%	303	14.0	2.0	5,840	8,768	3,749	21,989	40,346	0.20%	0.11%
		HRV pwr.+1W	303	14.0	2.0	5,840	8,768	3,758	21,939	40,305	-0.03%	0.01%
		Furn eff.-1%	303	14.0	2.0	5,840	8,768	3,749	22,223	40,580	1.27%	0.69%
		Furn pwr.+1W	**304**	14.0	2.0	5,840	8,768	3,758	21,937	40,303	-0.04%	0.00%
PR	Calgary	NECH HRV Base	303	14.0	2.0	5,840	8,830	3,749	19,799	38,218	0.0%	0.0%
	(no basement	Tin +1 C	303	14.0	2.0	5,840	8,796	3,749	22,476	40,861	13.52%	6.92%
	thermostat)	Tin -1 C	303	14.0	2.0	5,840	8,858	3,749	18,215	36,662	-8.00%	-4.07%
ON	Toronto	NECH HRV Base	301	14.0	2.0	5,840	8,165	3,732	22,359	40,096	0.0%	0.0%
		Tin +1 C	301	14.0	2.0	5,840	8,160	3,732	23,837	41,569	6.61%	3.67%
		Tin -1 C	301	14.0	2.0	5,840	8,160	3,732	21,728	39,460	-2.82%	-1.59%
		Tbsmt +1 C	301	14.0	2.0	5,840	8,105	3,732	24,167	41,844	8.09%	4.36%
		Tbsmt -1 C	301	14.0	2.0	5,840	8,105	3,732	21,572	39,249	-3.52%	-2.11%
		Tbsmt: no thermostat	301	14.0	2.0	5,840	8,187	3,732	21,820	39,579	-2.41%	-1.29%
		HRV eff.-1%	301	14.0	2.0	5,840	8,165	3,732	22,412	40,149	0.24%	0.13%
		HRV eff.+1%	301	14.0	2.0	5,840	8,165	3,732	22,306	40,043	-0.24%	-0.13%
		HRV eff.-5%	301	14.0	2.0	5,840	8,165	3,732	22,625	40,362	1.19%	0.66%
		Exhaust only	301	14.0	2.0	5,840	8,165	3,185	24,286	41,476	8.62%	3.44%
		HRV pwr.+1W	301	14.0	2.0	5,840	8,165	3,741	22,354	40,100	-0.02%	0.01%
		Fans: DT control	301	14.0	2.0	5,840	8,165	3,335	21,205	38,545	-5.16%	-3.87%
		Fans: DT control	301	14.0	2.0	5,840	8,165	3,478	22,281	39,764	-0.35%	-0.83%
		Furn eff.-1%	301	14.0	2.0	5,840	8,165	3,732	22,642	40,379	1.27%	0.71%
		Furn eff.+1%	301	14.0	2.0	5,840	8,165	3,732	22,083	39,820	-1.23%	-0.69%
		Furn pwr.+1W	**302**	14.0	2.0	5,840	8,165	3,741	22,352	40,098	-0.03%	0.00%
QU	Montreal	NECH HRV Base	213	14.0	2.0	5,840	5,837	2,961	9,950	24,588	0.0%	0.0%
		Tin +1 C	213	14.0	2.0	5,840	5,838	2,961	10,054	24,693	1.05%	0.43%
		Tbsmt +1 C	213	14.0	2.0	5,840	5,809	2,961	11,219	25,829	12.75%	5.05%
		HRV eff.-1%	213	14.0	2.0	5,840	5,836	2,961	9,974	24,611	0.24%	0.09%
		HRV pwr.+1W	213	14.0	2.0	5,840	5,836	2,970	9,946	24,592	-0.04%	0.02%
		Furn eff.-1%	213	14.0	2.0	5,840	5,838	2,961	10,051	24,690	1.02%	0.41%
		Furn pwr.+1W	**214**	14.0	2.0	5,840	5,838	2,970	9,945	24,593	-0.05%	0.02%
QU	Montreal	NECH HRV Base	213	14.0	2.0	5,840	5,860	2,961	9,449	24,110	0.0%	0.0%
	(no basement	Tin +1 C	213	14.0	2.0	5,840	5,846	2,961	9,855	24,502	4.30%	1.63%
	thermostat)	Tin -1 C	213	14.0	2.0	5,840	5,871	2,961	8,363	23,035	-11.49%	-4.46%
MT	Halifax	NECH HRV Base	233	14.0	2.0	5,840	5,628	3,136	12,937	27,541	0.0%	0.0%
		Tin +1 C	233	14.0	2.0	5,840	5,628	3,136	13,558	28,162	4.80%	2.25%
		Tbsmt +1 C	233	14.0	2.0	5,840	5,600	3,136	14,284	28,860	10.41%	4.79%
		HRV eff.-1%	233	14.0	2.0	5,840	5,628	3,136	12,972	27,576	0.27%	0.13%
		HRV pwr.+1W	233	14.0	2.0	5,840	5,628	3,145	12,933	27,546	-0.03%	0.02%
		Furn eff.-1%	233	14.0	2.0	5,840	5,628	3,136	13,068	27,672	1.01%	0.47%
		Furn pwr.+1W	**234**	14.0	2.0	5,840	5,628	3,145	12,931	27,544	-0.05%	0.01%

APPENDIX C

Sensitivity Analysis: HRV Efficiency

App. C Sensitivity Analysis: HRV Efficiency

Change single variable by amount shown:

Run Description		Base	meas.	meas.	meas.	meas.	comm.	meas.	meas.	meas.	meas.	meas.
hours	Change:		Tin	Tbsmt	Tout	Rhout	Phrvf	Fsup	Fexh	Tsah	Tsain	Tsaout
	Change by:		1.0	1.0	-1.0	-1%	1	-1	1	-1.0	1.0	-1.0
Efficiency:												
HRVSensE = (Msup*1.01*(Tsaout-Tsain)*Xlk-Ehrvsp-Edef)/(MAX(Mexh,Msup)*1.01*(Txain-Tsain)*Xlk+Ehrvsp))	%	**68.9%**	**69.9%**	**69.4%**	**64.0%**	**68.9%**	**68.8%**	**66.4%**	**66.8%**	**64.0%**	**62.1%**	**64.0%**
SysSensE = (Msup*1.01*(Tsaout-Tsain)*Xlk-Ehrvsp-Ereheat-Edef)/(MAX(Mexh,Msup)*1.01*(Txain-Tsah)*Xlk+Ehrvsp))	%	**62.6%**	**63.7%**	**63.1%**	**55.4%**	**62.6%**	**62.5%**	**60.3%**	**60.7%**	**55.4%**	**53.4%**	**58.0%**
HRVEnthE = (Mexh*(hexina-hexouta)-Ehrvsp-Edef)/(MAX(Mexh,Msup)*(hexina-hsupa)*Xlk+Ehrvsp))	%	**56.0%**	**57.9%**	**57.0%**	**52.0%**	**55.8%**	**56.0%**	**56.2%**	**56.4%**	**52.0%**	**47.8%**	**56.0%**
SysEnthE = (Mexh*(hexina-hexouta)*Xlk-Ehrvsp-Edef-Ereheat)/(MAX(Mexh,Msup)*(hexina-hsupha)*Xlk+Ehrvsp))	%	**52.3%**	**54.2%**	**53.2%**	**47.0%**	**52.1%**	**52.2%**	**52.4%**	**52.7%**	**47.0%**	**42.9%**	**52.3%**
dHRVSensEff	%		1.0%	0.5%	**-5.0%**	0.0%	-0.1%	**-2.5%**	**-2.1%**	-5.0%	-6.8%	-5.0%
dSystemSensEff	%		1.1%	0.5%	**-7.2%**	0.0%	-0.1%	**-2.3%**	**-1.9%**	-7.2%	-9.2%	-4.6%
dHRVEnthEff	%		1.8%	0.9%	**-4.1%**	-0.2%	-0.1%	0.2%	0.4%	-4.1%	-8.2%	0.0%
dSystemEnthEff	%		1.9%	0.9%	**-5.3%**	-0.2%	-0.1%	0.2%	0.4%	-5.3%	-9.3%	0.0%
Altitude	m	**500**	500	500	500	500	500	500	500	500	500	500
House inside average temperature: Tin	C	**21.0**	**22.0**	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0
Basement average inside temperature: Tbsmt	C	**19.0**	19.0	**20.0**	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0
Outside temperature: Tout	C	**0.0**	0.0	0.0	**-1.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Outside relative humidity: RHout	%	**55%**	55%	55%	55%	**54%**	55%	55%	55%	55%	55%	55%
HRV fan power: Phrvf	W	**100**	100	100	100	100	**101**	100	100	100	100	100
HRV supply flow rate: Fsup	L/s	**30.0**	30.0	30.0	30.0	30.0	30.0	**29.0**	30.0	30.0	30.0	30.0
HRV exhaust flow rate: Fexh	L/s	**30.0**	30.0	30.0	30.0	30.0	30.0	30.0	**31.0**	30.0	30.0	30.0
temperature into hood: Tsah = Tout	C	0.0	0.0	0.0	-1.0	0.0	0.0	0.0	0.0	**-1.0**	0.0	0.0
temperature into core: Tsain	C	**1.5**	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	**2.5**	1.5
temperature out of core: Tsaout	C	**18.3**	19.0	18.7	18.3	18.3	18.3	18.3	18.3	18.3	18.3	**17.3**
temperature into core: Txain = (2*Tin + Tbsmt)/3	C	20.3	21.0	20.7	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3
temperature out of core: Txaout	C	**3.5**	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	4.5	3.5
temperature out of hood: Txah	C	**2.5**	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
heat loss coeff. of supply duct to core: UAhrvsup	W/C	**3.14**	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14
heat loss coeff. of exhaust duct from core: UAhrvex	W/C	**2.51**	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51
RH exhaust from house: RHxa	%	**38%**	38%	38%	38%	38%	38%	38%	38%	38%	38%	38%
RH supply to house: RHsa	%	**32%**	32%	32%	32%	32%	32%	32%	32%	32%	32%	32%
percentage of HRV power to space: HRVtospace	%	**50%**	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%
exhaust<>supply cross leakage: Xleak	none	**1.00**	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Ehrv = 3.6*hrcount*Phrvf/1000	MJ/24h	8.64	8.64	8.64	8.64	8.64	8.73	8.64	8.64	8.64	8.64	8.64
Ehrvsp = 1000*HRVtosp*Ehrv/hrcount	kJ/h	180.0	180.0	180.0	180.0	180.0	181.8	180.0	180.0	180.0	180.0	180.0
Edef = Epreheat	kJ/h	199.5	198.8	199.5	330.5	199.5	199.5	192.9	199.5	330.5	330.5	199.5
Ereheat = Mexh*1.01*dThrvex))	kJ/h	42.3	42.3	44.8	42.3	42.3	42.3	42.3	42.3	42.3	42.3	42.3
Epreheat = Msup*1.01*(Tsain-Tsah)	kJ/h	199.5	198.8	199.5	330.5	199.5	199.5	192.9	199.5	330.5	330.5	199.5
Msup = densin * Qhrvsa * 3600/1000	kg/h	130	129	130	130	130	130	125	130	130	130	130
densin = 1.293/(1+0.00367*Tin))	kg/m3	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Mexh = densin * Qhrvxa * 3600/1000	kg/h	130	129	130	130	130	130	130	134	130	130	130
Xleak = One-time test of four air flows	none											
Imbalflow = Qhrvsa - Qhrvxa	L/s	0.00	0.00	0.00	0.00	0.00	0.00	-1.00	-1.00	0.00	0.00	0.00
Imbal= Imbalflow/Qhrvsa	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-3.4%	-3.3%	0.0%	0.0%	0.0%
densfurn = 1.293/(1+0.00367*Tbsmt))	kg/m3	1.21	1.21	1.20	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21
dThrvex = UAhrvex * 1.02 *(Tin - Txah)/(Mexh * 1.01)	C	0.32	0.32	0.34	0.32	0.32	0.32	0.32	0.31	0.32	0.32	0.32
TsahK = Tsah +273.16	K	273.2	273.2	273.2	272.2	273.2	273.2	273.2	273.2	272.2	273.2	273.2
TxainK = Txain + 273.16	K	293.5	294.2	293.8	293.5	293.5	293.5	293.5	293.5	293.5	293.5	293.5
TxaoutK = Txaout + 273.16	K	276.7	276.7	276.7	276.7	276.7	276.7	276.7	276.7	276.7	277.7	276.7
ToutK = Tout + 273.16	K	273.2	273.2	273.2	272.2	273.2	273.2	273.2	273.2	273.2	273.2	273.2
vpexin = EXP((-5800.2206/(TxainK))+1.3914993-(0.048640239*(TxainK))+(0.000041764768*(TxainK)^2)-(0.000000014452093*(TxainK)^3)+(6.5459673*LN(TxainK)))	Pa	2,389	2,489	2,439	2,389	2,389	2,389	2,389	2,389	2,389	2,389	2,389
vpexout as for vpexin, except using TxaoutK	Pa	787	787	787	787	787	787	787	787	787	845	787
vpsuph as for vpexin, except using TsahK	Pa	612	612	612	569	612	612	612	612	569	612	612
vpout as for vpexin, except using ToutK - not used	Pa	612	612	612	569	612	612	612	612	612	612	612
vpexina = RHxa*vpexin/100)	Pa	908	946	927	908	908	908	908	908	908	908	908
vpexouta = IF(vpexina<0.95*vpexout,vpexina,0.95*vpexout))	Pa	748	748	748	748	748	748	748	748	748	802	748
vpsupha = RHout*vpsuph/100)	Pa	336	336	336	313	330	336	336	336	313	336	336
BaroP = 101.483 * exp(-0.000122807 * Altitude)	kPa	95.4	95.4	95.4	95.4	95.4	95.4	95.4	95.4	95.4	95.4	95.4
hexina = Txain+(0.62198*vpexina/(BaroP*1000-vpexina))*(2501+1.805*Txain))	kJ/kg	35.5	36.8	36.1	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5
hexouta = Txaout+(0.62198*vpexouta/(BaroP*1000-vpexouta))*(2501+1.805*Txaout))	kJ/kg	15.8	15.8	15.8	15.8	15.8	15.8	15.8	15.8	15.8	17.8	15.8
hsupha = Tsah+(0.62198*vpsupha/(BaroP*1000-vpsupha))*(2501+1.805*Tsah))	kJ/kg	5.5	5.5	5.5	4.1	5.4	5.5	5.5	5.5	4.1	5.5	5.5
hsupa = Tsain+(0.62198*vpsupha/(BaroP*1000-vpsupha))*(2501+1.805*Tsain))	kJ/kg	7.0	7.0	7.0	6.6	6.9	7.0	7.0	7.0	6.6	8.0	7.0

App. C Sensitivity Analysis: HRV Efficiency

Run Description		Base	meas.	meas.	meas.	comm.	comm.	meas.	meas.	comm.	Multiple variable	Multipl
hours	Change:		Txain	Txaout	Txah	UAhrvsup	UAhrvex	RHxa	RHsa	HRVtosp	changes	change
	Change by:		-1.0	1.0	-1.0	1.0	1.0	-1%	1%	1%	(bold)	(bold
Efficiency:												
HRVSensE = (Msup*1.01*(Tsaout-Tsain)*Xlk-Ehrvsp-Edef)/(MAX(Mexh,Msup)*1.01*(Txain-Tsain)*Xlk+Ehrvsp))	%	**68.9%**	**67.3%**	**68.9%**	**68.9%**	**68.9%**	**68.9%**	**68.9%**	**68.9%**	**68.7%**	**68.9%**	**40.6**
SysSensE = (Msup*1.01*(Tsaout-Tsain)*Xlk-Ehrvsp-Ereheat-Edef)/(MAX(Mexh,Msup)*1.01*(Txain-Tsah)*Xlk+Ehrvsp))	%	**62.6%**	**60.8%**	**62.6%**	**62.5%**	**62.6%**	**62.0%**	**62.6%**	**62.6%**	**62.4%**	**62.6%**	**31.1**
HRVEnthE = (Mexh*(hexina-hexouta)-Ehrvsp-Edef)/(MAX(Mexh,Msup)*(hexina-hsupa)*Xlk+Ehrvsp))	%	**56.0%**	**53.0%**	**49.6%**	**56.0%**	**56.0%**	**56.0%**	**55.4%**	**56.0%**	**55.9%**	**53.8%**	**30.2**
SysEnthE = (Mexh*(hexina-hexouta)*Xlk-Ehrvsp-Edef-Ereheat)/(MAX(Mexh,Msup)*(hexina-hsupha)*Xlk+Ehrvsp))	%	**52.3%**	**49.1%**	**46.2%**	**52.2%**	**52.3%**	**51.8%**	**51.6%**	**52.3%**	**52.1%**	**50.2%**	**24.9**
dHRVSensEff	%		-1.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.2%	0.0%	-28.4
dSystemSensEff	%		-1.8%	0.0%	-0.1%	0.0%	-0.6%	0.0%	0.0%	-0.2%	0.0%	-31.5
dHRVEnthEff	%		-3.0%	-6.4%	0.0%	0.0%	0.0%	-0.6%	0.0%	-0.1%	-2.2%	-25.9
dSystemEnthEff	%		-3.1%	-6.1%	-0.1%	0.0%	-0.4%	-0.6%	0.0%	-0.1%	-2.1%	-27.3
Altitude	m	**500**	500	500	500	500	500	500	500	500	500	5
House inside average temperature: Tin	C	**21.0**	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	**21.0**	21
Basement average inside temperature: Tbsmt	C	**19.0**	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	**19.0**	19
Outside temperature: Tout	C	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**-1**
Outside relative humidity: RHout	%	**55%**	55%	55%	55%	55%	55%	55%	55%	55%	55%	55
HRV fan power: Phrvf	W	**100**	100	100	100	100	100	100	100	100	100	1
HRV supply flow rate: Fsup	L/s	**30.0**	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	**29**
HRV exhaust flow rate: Fexh	L/s	**30.0**	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	29.0	**31**
temperature into hood: Tsah = Tout	C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**-2**
temperature into core: Tsain	C	**1.5**	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	**2**
temperature out of core: Tsaout	C	**18.3**	17.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	**16**
temperature into core: Txain = (2*Tin + Tbsmt)/3	C	20.3	**19.3**	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	**19**
temperature out of core: Txaout	C	**3.5**	3.5	**4.5**	3.5	3.5	3.5	3.5	3.5	3.5	3.5	**5**
temperature out of hood: Txah	C	**2.5**	2.5	2.5	**1.5**	2.5	2.5	2.5	2.5	2.5	**2.5**	2
heat loss coeff. of supply duct to core: UAhrvsup	W/C	**3.14**	3.14	3.14	3.14	**4.14**	3.14	3.14	3.14	3.14	3.1	3
heat loss coeff. of exhaust duct from core: UAhrvex	W/C	**2.51**	2.51	2.51	2.51	2.51	**3.51**	2.51	2.51	2.51	2.5	2
RH exhaust from house: RHxa	%	**38%**	38%	38%	38%	38%	38%	**37%**	38%	38%	**38%**	38
RH supply to house: RHsa	%	**32%**	32%	32%	32%	32%	32%	32%	**33%**	32%	**32%**	32
percentage of HRV power to space: HRVtospace	%	**50%**	50%	50%	50%	50%	50%	50%	50%	**51%**	50%	50
exhaust<>supply cross leakage: Xleak	none	**1.00**	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.(
Ehrv = 3.6*hrcount*Phrvf/1000	MJ/24h	8.64	8.64	8.64	8.64	8.64	8.64	8.64	8.64	8.64	8.64	8.(
Ehrvsp = 1000*HRVtosp*Ehrv/hrcount	kJ/h	180.0	180.0	180.0	180.0	180.0	180.0	180.0	180.0	183.6	180.0	180
Edef = Epreheat	kJ/h	199.5	199.5	199.5	199.5	199.5	199.5	199.5	199.5	199.5	199.5	572
Ereheat = Mexh*1.01*dThrvex))	kJ/h	42.3	42.3	42.3	44.8	42.3	59.1	42.3	42.3	42.3	42.3	42
Epreheat = Msup*1.01*(Tsain-Tsah)	kJ/h	199.5	199.5	199.5	199.5	199.5	199.5	199.5	199.5	199.5	199.5	572
Msup = densin * Qhrvsa * 3600/1000	kg/h	130	130	130	130	130	130	130	130	130	130	12
densin = 1.293/(1+0.00367*Tin))	kg/m3	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.2
Mexh = densin * Qhrvxa * 3600/1000	kg/h	130	130	130	130	130	130	130	130	130	125	13
Xleak = One-time test of four air flows	none											
Imbalflow = Qhrvsa - Qhrvxa	L/s	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	-2.(
Imbal= Imbalflow/Qhrvsa	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.3%	-6.9
densfurn = 1.293/(1+0.00367*Tbsmt))	kg/m3	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.2
dThrvex = UAhrvex * 1.02 *(Tin - Txah)/(Mexh * 1.01)	C	0.32	0.32	0.32	0.34	0.32	0.45	0.32	0.32	0.32	0.33	0.3
TsahK = Tsah +273.16	K	273.2	273.2	273.2	273.2	273.2	273.2	273.2	273.2	273.2	273.2	271
TxainK = Txain + 273.16	K	293.5	292.5	293.5	293.5	293.5	293.5	293.5	293.5	293.5	293.5	292
TxaoutK = Txaout + 273.16	K	276.7	276.7	277.7	276.7	276.7	276.7	276.7	276.7	276.7	276.7	278
ToutK = Tout + 273.16	K	273.2	273.2	273.2	273.2	273.2	273.2	273.2	273.2	273.2	273.2	272
vpexin = EXP((-5800.2206/(TxainK))+1.3914993-(0.048640239*(TxainK))+(0.000041764768*(TxainK)^2)-(0.000000014452093*(TxainK)^3)+(6.5459673*LN(TxainK)))	Pa	2,389	2,245	2,389	2,389	2,389	2,389	2,389	2,389	2,389	2,389	2,2
vpexout as for vpexin, except using TxaoutK	Pa	787	787	845	787	787	787	787	787	787	787	9
vpsuph as for vpexin, except using TsahK	Pa	612	612	612	612	612	612	612	612	612	612	5
vpout as for vpexin, except using ToutK - not used	Pa	612	612	612	612	612	612	612	612	612	612	5
vpexina = RHxa*vpexin/100)	Pa	908	853	908	908	908	908	884	908	908	908	8
vpexouta = IF(vpexina<0.95*vpexout,vpexina,0.95*vpexout))	Pa	748	748	802	748	748	748	748	748	748	748	8
vpsupha = RHout*vpsuph/100)	Pa	336	336	336	336	336	336	336	336	336	336	2
BaroP = 101.483 * exp(-0.000122807 * Altitude)	kPa	95.4	95.4	95.4	95.4	95.4	95.4	95.4	95.4	95.4	95.4	95
hexina = Txain+(0.62198*vpexina/(BaroP*1000-vpexina))*(2501+1.805*Txain))	kJ/kg	35.5	33.6	35.5	35.5	35.5	35.5	35.1	35.5	35.5	35.5	3
hexouta = Txaout+(0.62198*vpexouta/(BaroP*1000-vpexouta))*(2501+1.805*Txaout))	kJ/kg	15.8	15.8	17.8	15.8	15.8	15.8	15.8	15.8	15.8	15.8	1
hsupha = Tsah+(0.62198*vpsupha/(BaroP*1000-vpsupha))*(2501+1.805*Tsah))	kJ/kg	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	[illegible]
hsupa = Tsain+(0.62198*vpsupha/(BaroP*1000-vpsupha))*(2501+1.805*Tsain))	kJ/kg	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	[illegible]

APPENDIX D

Sample HOT-2000 runs

Base runs for typical houses (NECH survey of new houses) but with HRV ventilators for

British Columbia

Alberta

Ontario

Québec

Nova Scotia

British Columbia

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*****************************************
*                                       *
*               HOT2000                 *
*            Version 7.15c              *
*               CANMET                  *
*      Natural Resources CANADA         *
*             Jul 12, 1996              *
*           Reg. # CD000131             *
*****************************************
```

File = F:\WORK\HVACCTRL\H2K\C73BC_BG.HDF

Weather Data for VANCOUVER, BRITISH COLUMBIA

Builder Code =
Data Entry by: KC   Date of entry 00/00/0000

Client name: C95: Base forced air Gas
Street address:
City: Region:
Postal code: Telephone:

*** GENERAL HOUSE CHARACTERISTICS ***

House type: Single detached
Number of storeys: One and a half
Wall construction: Platform frame, single stud wall
Year House Built: 1994
Wall colour: Default 0.40 Value .400
Plan shape: Square Front orientation: South

SOIL TYPE: Normal conductivity: dry sand, loam, clay, low water table

HOUSE THERMAL MASS LEVEL: (A) Wood frame construction, 12.5 mm (0.5 in.) gyproc walls and ceiling, wooden floor

Effective mass fraction 1.000

Occupants : 2 Adults for 50.0 % of the time
2 Children for 50.0 % of the time
0 Infants for .0 % of the time

Sensible Internal Heat Gain From Occupants = 2.40 kWh/day

*** HOUSE TEMPERATURES ***

Heating Temperatures	Main Floor	= 21.0 C
	Basement	= 20.0 C
	Crawl Space	= 12.5 C
	Calculated Crawl Space	= 19.3 C
	TEMP. Rise from 21.0 C	= 3.5 C

Basement is- Heated: Yes Cooled: Yes Separate T/S: Yes
Fraction of internal gains released in basement : .150

Indoor design temperatures for equipment sizing

Heating	= 21.0 C
Cooling	= 25.0 C

*** FOUNDATION CONSTRUCTION CHARACTERISTICS ***

Foundation Construction	Attachment Sides	Insulation Placement	Volume m3
Closed Crawl Space	1 Side	On Grade	29.6
Slab on Grade	1 Side	Edge/Exterior	
Full Basement	1 Side	Interior	81.9

*** WINDOW CHARACTERISTICS ***

Direc-tion	Seq #	Loc. Code	# of Windows	Type	Window Width m	Window Height m	OverHang Width m	Header Height m	SHGC	Curtain Factor
South	1	M1	5	200000	2.200	1.000	.60	.20	.7031	.000
East	1	M1	2	200010	2.650	1.000	.00	.00	.6977	.000
North	1	M1	4	200012	1.500	1.000	.00	.00	.5991	.000
	2	M1	2	200002	1.400	1.000	.00	.00	.6619	.000
West	1	M1	4	200010	1.680	1.000	.00	.00	.6884	.000

*** WINDOW PARAMETER CODES SCHEDULE ***

	Code	Description (Glazings, Coatings, Fill, Spacer, Type, Frame)
1	200000	Double/Double with 1 coat, Clear, 13 mm Air, Metal, Picture, Aluminum, ER* = -31.1, Eff. RSI= .27
2	200010	Double/Double with 1 coat, Clear, 13 mm Air, Metal, Hinged, Aluminum, ER* = -59.2, Eff. RSI= .21
3	200012	Double/Double with 1 coat, Clear, 13 mm Air, Metal, Hinged, Wood, ER* = -29.6, Eff. RSI= .33
4	200002	Double/Double with 1 coat, Clear, 13 mm Air, Metal, Picture, Wood, ER* = -16.9, Eff. RSI= .34

Window Standard Energy Rating estimated for assumed dimensions, and
Air tightness type: CSA - A1; Leakage rate = 2.79 m3/hr/m

*** BUILDING PARAMETER DETAILS ***

CEILING COMPONENTS

	Construction Type	Code Type	Roof Slope	Heel Ht. m	Section Area m2	R-Value RSI
C1	Cathedral	0000000000	3.00 / 12	.00	140.00	4.33

WALL COMPONENTS

	Wall Type Code	Lintel Type	Facing Dir	Number of Corners	Inter.	Height m	Perim. m	Area m2	R-Value RSI
	Main Walls								
M1	0000000000	N/A	N/A	1	1	2.15	104.5	224.90	2.07
	Basement Walls above grade								
B1	0000000000	N/A	N/A	1	1	.60	15.8	9.50	.29
	Crawl space walls								
V1	0000000000	N/A	N/A	1	1	.60	34.0	20.40	.75
	Upper Basement Walls								
1	0000000000	N/A	N/A	1	1	.60	16.2	9.70	.29
	Lower Basement Walls								
1	0000000000	N/A	N/A	1	1	1.30	15.7	20.40	.29

FLOORS

	Seq #	Construction Type	Section Area m2	R-Value RSI
Exposed or overhanging floors	1	0000000000	23.70	3.06
Crawl space floor perimeter	1	0000000000	17.90	.20
Crawl space floor Centre	1	0000000000	31.50	.20
Slab on Grade Perimeter	1	0000000000	12.00	.20
Slab on Grade Centre	1	0000000000	21.60	.20
Full Depth Floor Perimeter	1	0000000000	12.40	.20
Full Depth Floor Centre	1	0000000000	21.20	.20
Floors above Basement	1	0000000000	33.60	.50

DOORS

	Location	Type	Height m	Width m	Gross Area m2	R-value RSI
D1	M1	User specified	2.07	2.46	5.10	1.40

Roof Cavity Inputs

Sloped Roof		Total Area	.0 m2
Sheathing Material: Plywood/Part. bd 12.7 mm (1/2 in)			.11 RSI
Roofing Material: Asphalt shingles			.08 RSI
Roof colour: Medium brown 0.84		Absorptivity:	.840
Total cavity volume	.0 m3	Ventilation rate	.50 ACH/hr

WINDOWS

Orientation Location	Number	Type (Code)	Total Area(m2)	RSI Window	RSI (Shutter)
South					
M1	5	200000	11.00	.28	
East					
M1	2	200010	5.30	.26	
North					
M1	4	200012	6.00	.34	
M1	2	200002	2.80	.34	
West					
M1	4	200010	6.72	.25	

*** BUILDING PARAMETERS SUMMARY ***

Component	Area (m2) Gross	Area (m2) Net	Effective RSI	Heat Loss MJ	% Annual Heat Loss
ZONE 1 : ABOVE GRADE					
Ceiling	140.00	140.00	4.33	7462.1	4.95
Main Walls	224.90	187.98	2.07	29692.5	19.69
Doors	5.10	5.10	1.40	1294.6	.86
Exposed floors	23.70	23.70	3.06	2365.9	1.57
South windows	11.00	11.00	.28	13989.3	9.28
East windows	5.30	5.30	.26	7376.8	4.89
North windows	8.80	8.80	.34	9174.9	6.09
West windows	6.72	6.72	.25	9741.0	6.46
Slab on Grade Perimeter	12.00	12.00	.20	2493.0	1.65
Slab on Grade Centre	21.60	21.60	.20	1596.3	1.06
				=========	=======
		ZONE 1 Totals:		85186.3	56.50
INTER-ZONE Heat Transfer : Floors Above Shallow and Full Basement					
	33.60	33.60	.50	2571.3	

Component	Area (m2) Gross	Net	Effective RSI	Heat Loss MJ	% Annual Heat Loss
ZONE 2 : SHALLOW / FULL BASEMENT					
Basement Walls above grade	9.50	9.50	.29	10595.9	7.03
Upper Basement Walls	9.70	9.70	.29	5015.0	3.33
Lower Basement Walls	20.40	20.40	.29	4549.8	3.02
Full Depth Floor Perimeter	12.40	12.40	.20	1774.6	1.18
Full Depth Floor Centre	21.20	21.20	.20	1138.1	.75
		ZONE 2 Totals:		23073.3	15.30
ZONE 3 : CRAWL SPACE FOUNDATION					
Crawl space walls	20.40	20.40	.75	8486.0	5.63
Floor Perimeter	17.90	17.90	.20	2981.2	1.98
Floor Centre	31.50	31.50	.20	1915.2	1.27
		ZONE 3 Totals:		13382.5	8.88

Ventilation

House Volume	Air Change	Heat Loss MJ	% Annual Heat Loss
692.00 m3	.337 ACH	29131.7	19.32

*** AIR LEAKAGE AND VENTILATION ***

Building Envelope Surface Area = 565.2 m2
Air Leakage Test Results at 50 Pa.(0.2 in H2O) = 5.90 ACH
Equivalent Leakage Area @ 10 Pa. = 1603.0 cm2

Terrain Description		Height	m
@ Weather Station :	Open flat terrain, grass	Anemometer	10.0
@ Building site :	Suburban, forest	Bldg. Eaves	4.3

Local Shielding- Walls: Very heavy
Flue : Heavy

Leakage Fractions - Ceiling: .200 Walls: .500 Floors: .300

Normalized Leakage Area @ 10 Pa. = 2.8361 cm2/m2
Estimated Airflow to cause a 5 Pa Pressure Difference = 255 L/s
Estimated Airflow to cause a 10 Pa Pressure Difference = 399 L/s

*** F326 VENTILATION REQUIREMENTS ***

Kitchen,living,dining:	3 rooms @ 5 L/s	= 15 L/s
Utility rooms:	1 rooms @ 5 L/s	= 5 L/s
Bedrooms:	1 rooms @ 10 L/s	= 10 L/s
Bedrooms:	2 rooms @ 5 L/s	= 10 L/s
Bathrooms:	2 rooms @ 5 L/s	= 10 L/s
Other habitable rooms:	1 rooms @ 5 L/s	= 5 L/s
Basement Rooms:		0 L/s

*** OTHER EXHAUST FLOW RATES (L/s) ***

	Continuous	Intermittent
Dryer	.0	75.0
Kitchen	.0	50.0
All Bathrooms	.0	50.0
All other exhaust devices	.0	.0
Vented central vac.		.0
Largest Intermittent exhaust (other than Dryer)		50.0

Dryer is NOT vented outdoors

Total continuous exhaust flow .0 L/s
Exhaust Fan Power .0 watts

*** AIR LEAKAGE AND VENTILATION SUMMARY ***

F326 Required continuous ventilation rate = 55.0 L/s (.30 ACH)

Gross Air Leakage and Ventilation Energy Load	= 28556.0 MJ
Seasonal Heat Recovery Ventilator Efficiency	= .0 %
Estimated Ventilation Electrical Load: Heating Hours	= .0 MJ
Estimated Ventilation Electrical Load: Non-Heating Hours	= .0 MJ
Net Air Leakage and Ventilation Energy Load	= 29131.7 MJ

*** SPACE HEATING SYSTEM ***

PRIMARY Heating Fuel : Natural Gas
Equipment : Induced draft fan furnace/boiler
Manufacturer :
Model :
Output Capacity = 17.0 kW

Steady State Efficiency = 80.0 %

Fan Mode : Auto Fan Power 329. watts

*** DOMESTIC WATER HEATING SYSTEM ***

PRIMARY Water Heating Fuel : Natural Gas
Water Heating Equipment : Conventional tank (pilot)
Energy Factor : .539

Manufacturer :
Model :
Tank Capacity = 182.0 Litres Tank Blanket Insulation .0 RSI
Tank Location : Basement
Pilot Energy 17.7 MJ/day Flue Diameter 76.2 mm

*** ANNUAL SPACE HEATING SUMMARY ***

Design Heat Loss at -7.0 C = 18.30 Watts/m3 = 12661. Watts

Gross Space Heat Loss	=150774. MJ
Gross Space Heating Load	=150774. MJ
Usable Internal Gains	= 27485. MJ
Usable Internal Gains Fraction	= 18.2 %
Usable Solar Gains	= 28391. MJ
Usable Solar Gains Fraction	= 18.8 %
Auxiliary Energy Required	= 94897. MJ
Space Heating System Load	= 94897. MJ
Furnace/Boiler Seasonal efficiency	= 80.3 %
Furnace/Boiler Annual Energy Consumption	=116364. MJ

*** ANNUAL DOMESTIC WATER HEATING SUMMARY ***

Daily Hot Water Consumption	= 236.4 Litres /day
Hot Water Temperature	= 55.0 C
Estimated Domestic Water Heating Load	= 16050. MJ
PRIMARY Domestic Water Heating Energy Consumption	= 29310. MJ
PRIMARY System Seasonal Efficiency	= 54.8 %

*** BASE LOADS SUMMARY ***

	kwh/day	Annual kWh
Interior Lighting	2.1	766.5
Appliances	9.8	3577.0
Other	2.1	766.5
Exterior use	2.0	730.0
HVAC fans		
HRV/Exhaust	.0	.0
Space Heating	1.4	501.7
Space Cooling	.0	.0
Total Average Electrical Load	17.4	6341.7

*** FAN OPERATION SUMMARY (kWh) ***

Hours	HRV/Exhaust Fans	Space Heating	Space Cooling
Heating	.0	501.7	.0
Neither	.0	.0	.0
Cooling	.0	.0	.0
Total	.0	501.7	.0

*** R-2000 HOME PROGRAM ENERGY CONSUMPTION SUMMARY REPORT ***

Estimated Annual Space Heating Energy Consumption	= 118170. MJ	= 32825.0 kWh
Ventilator Electrical Consumption: Heating Hours	= 0. MJ	= .0 kWh
Estimated Annual DHW Heating Energy Consumption	= 29310. MJ	= 8141.8 kWh
ESTIMATED ANNUAL SPACE + DHW ENERGY CONSUMPTION	= 147480. MJ	= 40966.7 kWh
ANNUAL R-2000 SPACE + DHW ENERGY CONSUMPTION TARGET	= 70410. MJ	= 19558.3 kWh

*** ESTIMATED ANNUAL FUEL CONSUMPTION SUMMARY ***

Fuel	Space Heating	Space Cooling	DHW Heating	Appliances	Total
Natural Gas (m3)	3123.1	.0	786.7	.0	3909.8
Electricity (kWh)	501.7	.0	.0	5840.0	6341.7

****

Energy units: MJ = Megajoules (3.6 MJ = 1 kWh)

The calculated heat losses and energy consumptions are only estimates, based upon the data entered and assumptions within the program. Actual energy consumption and heat losses will be influenced by construction practices, localized weather, equipment characteristics and the lifestyle of the occupants.

Alberta

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*****************************************
*                                       *
*               HOT2000                 *
*            Version 7.15c              *
*               CANMET                  *
*      Natural Resources CANADA         *
*            Jul 12, 1996               *
*          Reg. # CD000131              *
*****************************************
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File = F:\WORK\HVACCTRL\H2K\C73AL_BG.HDF

Weather Data for CALGARY, ALBERTA

Builder Code =
Data Entry by: KC   Date of entry 00/00/0000

Client name: 95 Code: Base run
Street address:
City: Edmonton   Region:
Postal code: Telephone:

*** GENERAL HOUSE CHARACTERISTICS ***

House type: Single detached
Number of storeys: One and a half
Wall construction: Platform frame, single stud wall
Year House Built: 1994
Wall colour: Default   0.40   Value   .400
Plan shape: Square   Front orientation: South

SOIL TYPE: Normal conductivity: dry sand, loam, clay, low water table

HOUSE THERMAL MASS LEVEL: (A) Wood frame construction, 12.5 mm (0.5 in.)
gyproc walls and ceiling, wooden floor

Effective mass fraction   1.000

Occupants : 2 Adults   for 50.0 % of the time
2 Children for 50.0 % of the time
0 Infants for   .0 % of the time

Sensible Internal Heat Gain From Occupants   =   2.40 kWh/day

*** HOUSE TEMPERATURES ***

Heating Temperatures	Main Floor	= 21.0 C
	Basement	= 20.0 C
	TEMP. Rise from 21.0 C	= 3.5 C

Basement is- Heated: Yes   Cooled: Yes   Separate T/S: Yes
Fraction of internal gains released in basement : .150

Indoor design temperatures for equipment sizing

Heating	= 21.0 C
Cooling	= 25.0 C

*** FOUNDATION CONSTRUCTION CHARACTERISTICS ***

Foundation Construction	Attachment Sides	Insulation Placement	Volume m3
Shallow Basement	1 Side	Interior	78.5
Full Basement	1 Side	Interior	179.0

*** WINDOW CHARACTERISTICS ***

Direc-tion	Seq #	Loc. Code	# of Windows	Type	Window Width m	Window Height m	OverHang Width m	Header Height m	SHGC	Curtain Factor
South	1	M1	1	200012	2.600	1.000	.60	.20	.6239	.000
	2	M1	1	230212	1.000	1.000	.60	.20	.5319	.000
East	1	M1	2	200212	2.050	1.000	.00	.00	.6140	.000
North	1	M1	3	200012	1.200	1.000	.00	.00	.5845	.000
	2	M1	1	230202	1.000	1.000	.00	.00	.6034	.000
West	1	M1	3	200212	1.230	1.000	.00	.00	.5853	.000

*** WINDOW PARAMETER CODES SCHEDULE ***

	Code	Description (Glazings, Coatings, Fill, Spacer, Type, Frame)
1	200012	Double/Double with 1 coat, Clear, 13 mm Air, Metal, Hinged, Wood, ER* = -29.6, Eff. RSI= .33
2	230212	Double/Double with 1 coat, Low-E .20 (Hard1), 13 mm Air, Insulating, Hinged, Wood, ER* = -16.0, Eff. RSI= .44
3	200212	Double/Double with 1 coat, Clear, 13 mm Air, Insulating, Hinged, Wood, ER* = -24.9, Eff. RSI= .36
4	230202	Double/Double with 1 coat, Low-E .20 (Hard1), 13 mm Air, Insulating, Picture, Wood, ER* = -2.1, Eff. RSI= .48

Window Standard Energy Rating estimated for assumed dimensions, and
Air tightness type: CSA - A1; Leakage rate = 2.79 m3/hr/m

*** BUILDING PARAMETER DETAILS ***

CEILING COMPONENTS

	Construction Type	Code Type	Roof Slope	Heel Ht. m	Section Area m2	R-Value RSI
C1	Cathedral	0000000000	3.00 / 12	.00	107.00	5.67

WALL COMPONENTS

	Wall Type Code	Lintel Type	Facing Dir	Number of Corners	Number of Inter.	Height m	Perim. m	Area m2	R-Value RSI
	Main Walls								
M1	0000000000	N/A	N/A	1	1	2.15	72.7	156.40	2.89
	Basement Walls above grade								
B1	0000000000	N/A	N/A	1	1	.60	60.8	36.50	2.32
	Shallow Walls below grade								
1	0000000000	N/A	N/A	1	1	1.20	11.7	14.00	1.56
	Upper Basement Walls								
1	0000000000	N/A	N/A	1	1	.60	29.8	17.90	1.56
	Lower Basement Walls								
1	0000000000	N/A	N/A	1	1	1.30	30.4	39.50	1.56

FLOORS

	Seq #	Construction Type	Section Area m2	R-Value RSI
Exposed or overhanging floors	1	0000000000	6.40	4.70
Shallow Floor Perimeter	1	0000000000	12.20	.20
Shallow Floor Centre	1	0000000000	20.00	.20
Full Depth Floor Perimeter	1	0000000000	29.20	.20
Full Depth Floor Centre	1	0000000000	44.20	.20
Floors above Basement	1	0000000000	105.60	.50

DOORS

	Location	Type	Height m	Width m	Gross Area m2	R-value RSI
D1	M1	User specified	2.07	1.64	3.40	1.40

Roof Cavity Inputs

Sloped Roof   Total Area   .0 m2
Sheathing Material: Plywood/Part. bd 12.7 mm (1/2 in)   .11 RSI
Roofing Material: Asphalt shingles   .08 RSI

Roof colour: Medium brown 0.84   Absorptivity: .840
Total cavity volume   .0 m3   Ventilation rate   .50 ACH/hr

WINDOWS

Orientation Location	Number	Type (Code)	Total Area(m2)	RSI Window	(Shutter)
South					
M1	1	200012	2.60	.34	
M1	1	230212	1.00	.45	
East					
M1	2	200212	4.10	.36	
North					
M1	3	200012	3.60	.34	
M1	1	230202	1.00	.47	
West					
M1	3	200212	3.69	.36	

*** BUILDING PARAMETERS SUMMARY ***

Component	Area (m2) Gross	Net	Effective RSI	Heat Loss MJ	% Annual Heat Loss
ZONE 1 : ABOVE GRADE					
Ceiling	107.00	107.00	5.67	7665.8	6.60
Main Walls	156.40	137.01	2.89	24377.2	20.97
Doors	3.40	3.40	1.40	1340.1	1.15
Exposed floors	6.40	6.40	4.70	679.2	.58
South windows	3.60	3.60	.37	5411.1	4.66
East windows	4.10	4.10	.36	6308.7	5.43
North windows	4.60	4.60	.36	7023.5	6.04
West windows	3.69	3.69	.36	5667.2	4.88
				=========	=======
		ZONE 1 Totals:		58472.8	50.31
INTER-ZONE Heat Transfer : Floors Above Shallow and Full Basement					
	105.60	105.60	.50	7296.3	
ZONE 2 : SHALLOW / FULL BASEMENT					
Basement Walls above grade	36.50	36.50	2.32	8133.2	7.00
Shallow Walls below grade	14.00	14.00	1.56	2458.6	2.12
Shallow Floor Perimeter	12.20	12.20	.20	4375.6	3.76
Shallow Floor Centre	20.00	20.00	.20	1952.9	1.68
Upper Basement Walls	17.90	17.90	1.56	3338.9	2.87
Lower Basement Walls	39.50	39.50	1.56	4993.2	4.30
Full Depth Floor Perimeter	29.20	29.20	.20	8106.9	6.97
Full Depth Floor Centre	44.20	44.20	.20	4274.8	3.68
				=========	=======
		ZONE 2 Totals:		37634.0	32.38

Ventilation

House Volume	Air Change	Heat Loss MJ	% Annual Heat Loss
599.00 m3	.149 ACH	20125.9	17.32

*** AIR LEAKAGE AND VENTILATION ***

Building Envelope Surface Area	= 483.3 m2
Air Leakage Test Results at 50 Pa.(0.2 in H2O)	= 3.10 ACH
Equivalent Leakage Area @ 10 Pa.	= 623.0 cm2

Terrain Description		Height	m
@ Weather Station :	Open flat terrain, grass	Anemometer	10.0
@ Building site :	Suburban, forest	Bldg. Eaves	4.3

Local Shielding- Walls: Very heavy
Flue : Heavy

Leakage Fractions - Ceiling: .200 Walls: .600 Floors: .200

Normalized Leakage Area @ 10 Pa.	= 1.2890 cm2/m2
Estimated Airflow to cause a 5 Pa Pressure Difference	= 99 L/s
Estimated Airflow to cause a 10 Pa Pressure Difference	= 155 L/s

*** F326 VENTILATION REQUIREMENTS ***

Kitchen,living,dining:	3 rooms @ 5 L/s	= 15 L/s
Utility rooms:	1 rooms @ 5 L/s	= 5 L/s
Bedrooms:	1 rooms @ 10 L/s	= 10 L/s
Bedrooms:	2 rooms @ 5 L/s	= 10 L/s
Bathrooms:	2 rooms @ 5 L/s	= 10 L/s
Other habitable rooms:	1 rooms @ 5 L/s	= 5 L/s
Basement Rooms:		0 L/s

*** OTHER EXHAUST FLOW RATES (L/s) ***

	Continuous	Intermittent
Dryer	.0	75.0
Kitchen	.0	50.0
All Bathrooms	.0	50.0
All other exhaust devices	.0	.0
Vented central vac.		.0
Largest Intermittent exhaust (other than Dryer)		50.0

Dryer is NOT vented outdoors

Total continuous exhaust flow	.0 L/s
Exhaust Fan Power	.0 watts

*** AIR LEAKAGE AND VENTILATION SUMMARY ***

F326 Required continuous ventilation rate = 55.0 L/s (.33 ACH)

Gross Air Leakage and Ventilation Energy Load	= 17888.6 MJ
Seasonal Heat Recovery Ventilator Efficiency	= .0 %
Estimated Ventilation Electrical Load: Heating Hours	= .0 MJ
Estimated Ventilation Electrical Load: Non-Heating Hours	= .0 MJ
Net Air Leakage and Ventilation Energy Load	= 20125.9 MJ

*** SPACE HEATING SYSTEM ***

PRIMARY Heating Fuel : Natural Gas
Equipment : Induced draft fan furnace/boiler
Manufacturer :
Model :
Output Capacity = 20.0 kW

Steady State Efficiency = 80.0 %

Fan Mode : Auto Fan Power 388. watts

*** DOMESTIC WATER HEATING SYSTEM ***

PRIMARY Water Heating Fuel : Natural Gas
Water Heating Equipment : Conventional tank (pilot)
Energy Factor : .539

Manufacturer :
Model :
Tank Capacity = 182.0 Litres Tank Blanket Insulation .0 RSI
Tank Location : Basement
Pilot Energy 17.7 MJ/day Flue Diameter 76.2 mm

*** ANNUAL SPACE HEATING SUMMARY ***

Design Heat Loss at -31.0 C = 18.86 Watts/m3 = 11300. Watts

Gross Space Heat Loss	=116233. MJ
Gross Space Heating Load	=116233. MJ
Usable Internal Gains	= 25980. MJ
Usable Internal Gains Fraction	= 22.4 %
Usable Solar Gains	= 16001. MJ
Usable Solar Gains Fraction	= 13.8 %
Auxiliary Energy Required	= 74252. MJ
Space Heating System Load	= 74252. MJ
Furnace/Boiler Seasonal efficiency	= 80.3 %
Furnace/Boiler Annual Energy Consumption	= 91048. MJ

*** ANNUAL DOMESTIC WATER HEATING SUMMARY ***

Daily Hot Water Consumption	= 236.4 Litres /day
Hot Water Temperature	= 55.0 C
Estimated Domestic Water Heating Load	= 17823. MJ
PRIMARY Domestic Water Heating Energy Consumption	= 31568. MJ
PRIMARY System Seasonal Efficiency	= 56.5 %

*** BASE LOADS SUMMARY ***

	kwh/day	Annual kWh
Interior Lighting	2.1	766.5
Appliances	9.8	3577.0
Other	2.1	766.5
Exterior use	2.0	730.0
HVAC fans		
HRV/Exhaust	.0	.0
Space Heating	1.1	392.5
Space Cooling	.0	.0
Total Average Electrical Load	17.1	6232.5

*** FAN OPERATION SUMMARY (kWh) ***

Hours	HRV/Exhaust Fans	Space Heating	Space Cooling
Heating	.0	392.5	.0
Neither	.0	.0	.0
Cooling	.0	.0	.0
Total	.0	392.5	.0

*** R-2000 HOME PROGRAM ENERGY CONSUMPTION SUMMARY REPORT ***

Estimated Annual Space Heating Energy Consumption	= 92461. MJ	= 25683.7 kWh
Ventilator Electrical Consumption: Heating Hours	= 0. MJ	= .0 kWh
Estimated Annual DHW Heating Energy Consumption	= 31568. MJ	= 8768.8 kWh
ESTIMATED ANNUAL SPACE + DHW ENERGY CONSUMPTION	= 124029. MJ	= 34452.5 kWh
ANNUAL R-2000 SPACE + DHW ENERGY CONSUMPTION TARGET	= 97431. MJ	= 27064.2 kWh

*** ESTIMATED ANNUAL FUEL CONSUMPTION SUMMARY ***

Fuel	Space Heating	Space Cooling	DHW Heating	Appliances	Total
Natural Gas (m3)	2443.7	.0	847.2	.0	3290.9
Electricity (kWh)	392.5	.0	.0	5840.0	6232.5

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*               HOT2000                 *
*            Version 7.15c              *
*               CANMET                  *
*       Natural Resources CANADA        *
*            Jul 12, 1996               *
*          Reg. # CD000131              *
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File = F:\WORK\HVACCTRL\H2K\C730N_BG.HDF

Weather Data for TORONTO, ONTARIO

Builder Code =
Data Entry by: KC   Date of entry 00/00/0000

Client name: 95 Code: Base run
Street address:
City: Region:
Postal code: Telephone:

*** GENERAL HOUSE CHARACTERISTICS ***

House type: Single detached
Number of storeys: One and a half
Wall construction: Platform frame, single stud wall
Year House Built: 1994
Wall colour: Default   0.40   Value   .400
Plan shape: Square   Front orientation: South

SOIL TYPE: Normal conductivity: dry sand, loam, clay, low water table

HOUSE THERMAL MASS LEVEL: (A) Wood frame construction, 12.5 mm (0.5 in.)
gyproc walls and ceiling, wooden floor

Effective mass fraction   1.000

Occupants : 2 Adults   for 50.0 % of the time
2 Children for 50.0 % of the time
0 Infants   for   .0 % of the time

Sensible Internal Heat Gain From Occupants   =   2.40 kWh/day

*** HOUSE TEMPERATURES ***

Heating Temperatures	Main Floor	= 21.0 C
	Basement	= 20.0 C
	TEMP. Rise from 21.0 C	= 3.5 C

Basement is- Heated: Yes   Cooled: Yes   Separate T/S: Yes
Fraction of internal gains released in basement : .150

Indoor design temperatures for equipment sizing

	Heating	= 21.0 C
	Cooling	= 25.0 C

*** FOUNDATION CONSTRUCTION CHARACTERISTICS ***

Foundation Construction	Attachment Sides	Insulation Placement	Volume m3
Full Basement	None	Interior	271.4

*** WINDOW CHARACTERISTICS ***

Direc-tion	Seq #	Loc. Code	# of Windows	Type	Window Width m	Window Height m	OverHang Width m	Header Height m	SHGC	Curtain Factor
South	1	M1	4	200002	2.030	1.000	.60	.20	.6740	.000
East	1	M1	3	200012	1.930	1.000	.00	.00	.6121	.000
North	1	M1	3	230012	2.000	1.000	.00	.00	.5739	.000
	2	M1	1	230202	2.100	1.000	.00	.00	.6301	.000
West	1	M1	4	200012	1.200	1.000	.00	.00	.5845	.000

*** WINDOW PARAMETER CODES SCHEDULE ***

	Code	Description (Glazings, Coatings, Fill, Spacer, Type, Frame)
1	200002	Double/Double with 1 coat, Clear, 13 mm Air, Metal, Picture, Wood, ER* = -16.9, Eff. RSI= .34
2	200012	Double/Double with 1 coat, Clear, 13 mm Air, Metal, Hinged, Wood, ER* = -29.6, Eff. RSI= .33
3	230012	Double/Double with 1 coat, Low-E .20 (Hard1), 13 mm Air, Metal, Hinged, Wood, ER* = -21.4, Eff. RSI= .40
4	230202	Double/Double with 1 coat, Low-E .20 (Hard1), 13 mm Air, Insulating, Picture, Wood, ER* = -2.1, Eff. RSI= .48

Window Standard Energy Rating estimated for assumed dimensions, and
Air tightness type: CSA - A1; Leakage rate = 2.79 m3/hr/m

*** BUILDING PARAMETER DETAILS ***

CEILING COMPONENTS

	Construction Type	Code Type	Roof Slope	Heel Ht. m	Section Area m2	R-Value RSI
C1	Cathedral	0000000000	3.00 / 12	.00	120.00	5.49

WALL COMPONENTS

	Wall Type Code	Lintel Type	Facing Dir	Number of Corners	Number of Inter.	Height m	Perim. m	Area m2	R-Value RSI
Main Walls									
M1	0000000000	N/A	N/A	1	1	2.15	111.0	239.00	2.68

WALL COMPONENTS

	Wall Type Code	Lintel Type	Facing Dir	Number of Corners	Number of Inter.	Height m	Perim. m	Area m2	R-Value RSI
	Basement Walls above grade								
B1	0000000000	N/A	N/A	1	1	.60	39.3	23.60	1.33
	Upper Basement Walls								
1	0000000000	N/A	N/A	1	1	.60	44.7	26.80	2.01
	Lower Basement Walls								
1	0000000000	N/A	N/A	1	1	1.30	48.2	62.70	2.01

FLOORS

	Seq #	Construction Type	Section Area m2	R-Value RSI
Exposed or overhanging floors	1	0000000000	8.10	4.40
Full Depth Floor Perimeter	1	0000000000	41.70	.20
Full Depth Floor Centre	1	0000000000	69.60	.20
Floors above Basement	1	0000000000	111.30	.50

DOORS

	Location	Type	Height m	Width m	Gross Area m2	R-value RSI
D1	M1	User specified	2.07	2.17	4.50	1.36

Roof Cavity Inputs

Sloped Roof	Total Area	.0 m2
Sheathing Material: Plywood/Part. bd 12.7 mm (1/2 in)		.11 RSI
Roofing Material: Asphalt shingles		.08 RSI

Roof colour: Medium brown 0.84		Absorptivity:	.840
Total cavity volume	.0 m3	Ventilation rate	.50 ACH/hr

WINDOWS

Orientation Location	Number	Type (Code)	Total Area(m2)	RSI Window	RSI (Shutter)
South					
M1	4	200002	8.12	.34	
East					
M1	3	200012	5.79	.34	
North					
M1	3	230012	6.00	.43	
M1	1	230202	2.10	.48	

WINDOWS

Orientation Location	Number	Type (Code)	Total Area(m2)	RSI Window	(Shutter)
West					
M1	4	200012	4.80	.34	

*** BUILDING PARAMETERS SUMMARY ***

Component	Area (m2) Gross	Net	Effective RSI	Heat Loss MJ	% Annual Heat Loss
ZONE 1 : ABOVE GRADE					
Ceiling	120.00	120.00	5.49	6631.6	4.75
Main Walls	239.00	207.69	2.68	31436.1	22.54
Doors	4.50	4.50	1.36	1443.8	1.04
Exposed floors	8.10	8.10	4.40	721.3	.52
South windows	8.12	8.12	.34	10321.4	7.40
East windows	5.79	5.79	.34	7400.8	5.31
North windows	8.10	8.10	.44	8013.7	5.75
West windows	4.80	4.80	.34	6172.7	4.43
				=========	=======
		ZONE 1 Totals:		72141.4	51.72
INTER-ZONE Heat Transfer : Floors Above Shallow and Full Basement					
	111.30	111.30	.50	9693.9	
ZONE 2 : SHALLOW / FULL BASEMENT					
Basement Walls above grade	23.60	23.60	1.33	7191.1	5.16
Upper Basement Walls	26.80	26.80	2.01	2755.4	1.98
Lower Basement Walls	62.70	62.70	2.01	4509.9	3.23
Full Depth Floor Perimeter	41.70	41.70	.20	8199.8	5.88
Full Depth Floor Centre	69.60	69.60	.20	4522.9	3.24
				=========	=======
		ZONE 2 Totals:		27179.1	19.49

Ventilation

House Volume	Air Change	Heat Loss MJ	% Annual Heat Loss
847.00 m3	.404 ACH	40164.8	28.80

*** AIR LEAKAGE AND VENTILATION ***

Building Envelope Surface Area	=	591.5 m2
Air Leakage Test Results at 50 Pa.(0.2 in H2O)	=	3.71 ACH
Equivalent Leakage Area @ 10 Pa.	=	1153.0 cm2

Terrain Description		Height	m
@ Weather Station :	Open flat terrain, grass	Anemometer	10.0
@ Building site :	Suburban, forest	Bldg. Eaves	4.3

Local Shielding- Walls: Very heavy
Flue : Heavy

Leakage Fractions - Ceiling: .200 Walls: .600 Floors: .200

Normalized Leakage Area @ 10 Pa.	=	1.9492 cm2/m2
Estimated Airflow to cause a 5 Pa Pressure Difference	=	183 L/s
Estimated Airflow to cause a 10 Pa Pressure Difference	=	287 L/s

*** F326 VENTILATION REQUIREMENTS ***

Kitchen,living,dining:	3 rooms @ 5 L/s	= 15 L/s
Utility rooms:	1 rooms @ 5 L/s	= 5 L/s
Bedrooms:	1 rooms @ 10 L/s	= 10 L/s
Bedrooms:	2 rooms @ 5 L/s	= 10 L/s
Bathrooms:	2 rooms @ 5 L/s	= 10 L/s
Other habitable rooms:	1 rooms @ 5 L/s	= 5 L/s
Basement Rooms:		0 L/s

*** CENTRAL VENTILATION SYSTEM ***

System Type : Heat recovery ventilator (HRV)
Manufacturer:
Model Number:

Fan and Preheater Power at .0 C	=	125. Watts
Fan and Preheater Power at -25.0 C	=	125. Watts
PreHeater Capacity:	=	0. Watts
Sensible Heat Recovery Efficiency at .0 C	=	55. %
Sensible Heat Recovery Efficiency at -25.0 C	=	45. %
Total Heat Recovery Efficiency in Cooling mode	=	25. %

Low Temperature Ventilation Reduction = 0. %
Low Temperature Ventilation Reduction: Airflow Adjustment= 0 L/s (.0 %)

NO Vented combustion appliance specified

Ventilation Supply Duct

Location : Basement	Type : Flexible
Length 5.0 m	Diameter 152.4 mm
Insulation .7 RSI	Sealing Characteristics : Sealed

Ventilation Exhaust Duct

Location : Basement	Type : Flexible
Length 5.0 m	Diameter 152.4 mm
Insulation .7 RSI	Sealing Characteristics : Sealed

*** OTHER EXHAUST FLOW RATES (L/s) ***

	Continuous	Intermittent
Dryer	.0	75.0
Kitchen	.0	50.0
All Bathrooms	.0	50.0
All other exhaust devices	.0	.0
Vented central vac.		.0
Largest Intermittent exhaust (other than Dryer)		50.0

Dryer is NOT vented outdoors

Total continuous exhaust flow .0 L/s
Exhaust Fan Power .0 watts

*** AIR LEAKAGE AND VENTILATION SUMMARY ***

F326 Required continuous ventilation rate = 55.0 L/s (.23 ACH)
Central Ventilation Rate (Balanced) = 50.0 L/s (.21 ACH)
Total house ventilation is Balanced

Gross Air Leakage and Ventilation Energy Load = 54763.3 MJ
Seasonal Heat Recovery Ventilator Efficiency = 47.5 %
Estimated Ventilation Electrical Load: Heating Hours = 3565.8 MJ
Estimated Ventilation Electrical Load: Non-Heating Hours = 376.2 MJ
Net Air Leakage and Ventilation Energy Load = 41947.7 MJ

*** SPACE HEATING SYSTEM ***

PRIMARY Heating Fuel : Natural Gas
Equipment : Induced draft fan furnace/boiler
Manufacturer :
Model :
Output Capacity = 25.0 kW

Steady State Efficiency = 80.0 %

Fan Mode : Continuous Fan Power 388. watts

*** DOMESTIC WATER HEATING SYSTEM ***

PRIMARY Water Heating Fuel : Natural Gas
Water Heating Equipment : Conventional tank (pilot)
Energy Factor : .539

Manufacturer :
Model :
Tank Capacity = 182.0 Litres Tank Blanket Insulation .0 RSI
Tank Location : Basement
Pilot Energy 17.7 MJ/day Flue Diameter 76.2 mm

*** ANNUAL SPACE HEATING SUMMARY ***

Design Heat Loss at -17.2 C	= 16.87 Watts/m3	= 14290. Watts
Including credit for HRV	= 15.39 Watts/m3	= 13033. Watts
Gross Space Heat Loss		=139485. MJ
Gross Space Heating Load		=139050. MJ
Usable Internal Gains		= 33747. MJ
Usable Internal Gains Fraction		= 24.2 %
Usable Solar Gains		= 20095. MJ
Usable Solar Gains Fraction		= 14.4 %
Auxiliary Energy Required		= 85208. MJ
Space Heating System Load		= 85207. MJ
Furnace/Boiler Seasonal efficiency		= 79.0 %
Furnace/Boiler Annual Energy Consumption		=106509. MJ

*** ANNUAL DOMESTIC WATER HEATING SUMMARY ***

Daily Hot Water Consumption	= 236.4 Litres /day
Hot Water Temperature	= 55.0 C
Estimated Domestic Water Heating Load	= 16118. MJ
PRIMARY Domestic Water Heating Energy Consumption	= 29371. MJ
PRIMARY System Seasonal Efficiency	= 54.9 %

*** BASE LOADS SUMMARY ***

	kwh/day	Annual kWh
Interior Lighting	2.1	766.5
Appliances	9.8	3577.0
Other	2.1	766.5
Exterior use	2.0	730.0
HVAC fans		
HRV/Exhaust	3.0	1095.0
Space Heating	9.3	3398.9
Space Cooling	.0	.0
Total Average Electrical Load	28.3	10333.9

*** FAN OPERATION SUMMARY (kWh) ***

Hours	HRV/Exhaust Fans	Space Heating	Space Cooling
Heating	990.5	367.3	.0
Neither	104.5	3031.5	.0
Cooling	.0	.0	.0
Total	1095.0	3398.9	.0

*** R-2000 HOME PROGRAM ENERGY CONSUMPTION SUMMARY REPORT ***

Estimated Annual Space Heating Energy Consumption	= 107832. MJ	= 29953.3 kWh
Ventilator Electrical Consumption: Heating Hours	= 3566. MJ	= 990.5 kWh
Estimated Annual DHW Heating Energy Consumption	= 29371. MJ	= 8158.6 kWh
ESTIMATED ANNUAL SPACE + DHW ENERGY CONSUMPTION	= 140768. MJ	= 39102.3 kWh
ANNUAL R-2000 SPACE + DHW ENERGY CONSUMPTION TARGET	= 97011. MJ	= 26947.6 kWh

*** ESTIMATED ANNUAL FUEL CONSUMPTION SUMMARY ***

Fuel	Space Heating	Space Cooling	DHW Heating	Appliances	Total
Natural Gas (m3)	2858.6	.0	788.3	.0	3646.9
Electricity (kWh)	4389.4	.0	.0	5944.5	10333.9

****

Energy units: MJ = Megajoules (3.6 MJ = 1 kWh)

The calculated heat losses and energy consumptions are only estimates, based upon the data entered and assumptions within the program. Actual energy consumption and heat losses will be influenced by construction practices, localized weather, equipment characteristics and the lifestyle of the occupants.

Québec

```
******************************************
*                                        *
*               HOT2000                  *
*            Version 7.15c               *
*               CANMET                   *
*       Natural Resources CANADA         *
*            Jul 12, 1996                *
*          Reg. # CD000131               *
******************************************
```

File = F:\WORK\HVACCTRL\H2K\C73QU_BE.HDF

Weather Data for MONTREAL, QUEBEC

Builder Code =
Data Entry by: KC   Date of entry 00/00/0000

Client name: 95 Code: Base run
Street address:
City: Region:
Postal code: Telephone:

*** GENERAL HOUSE CHARACTERISTICS ***

House type: Single detached
Number of storeys: One and a half
Wall construction: Platform frame, single stud wall
Year House Built: 1994
Wall colour: Default   0.40   Value   .400
Plan shape: Square   Front orientation: South

SOIL TYPE: Normal conductivity: dry sand, loam, clay, low water table

HOUSE THERMAL MASS LEVEL: (A) Wood frame construction, 12.5 mm (0.5 in.)
                              gyproc walls and ceiling, wooden floor

Effective mass fraction   1.000

Occupants : 2 Adults   for 50.0 % of the time
             2 Children for 50.0 % of the time
             0 Infants   for   .0 % of the time

Sensible Internal Heat Gain From Occupants   =   2.40 kWh/day

*** HOUSE TEMPERATURES ***

Heating Temperatures	Main Floor	= 21.0 C
	Basement	= 20.0 C
	TEMP. Rise from 21.0 C	= 3.5 C

Basement is- Heated: Yes   Cooled: Yes   Separate T/S: Yes
Fraction of internal gains released in basement : .150

Indoor design temperatures for equipment sizing
Heating = 21.0 C
Cooling = 25.0 C

*** FOUNDATION CONSTRUCTION CHARACTERISTICS ***

Foundation Construction	Attachment Sides	Insulation Placement	Volume m3
Full Basement	None	Interior	193.3

*** WINDOW CHARACTERISTICS ***

Direc- tion	Seq #	Loc. Code	# of Windows	Type	Window Width m	Window Height m	OverHang Width m	Header Height m	SHGC	Curtain Factor
South	1	M1	3	200002	2.030	1.000	.60	.20	.6740	.000
East	1	M1	2	200012	1.450	1.000	.00	.00	.5971	.000
North	1	M1	3	230202	1.500	1.000	.00	.00	.6204	.000
	2	M1	2	200012	1.050	1.000	.00	.00	.5740	.000
West	1	M1	3	200012	1.000	1.000	.00	.00	.5698	.000

*** WINDOW PARAMETER CODES SCHEDULE ***

	Code	Description (Glazings, Coatings, Fill, Spacer, Type, Frame)
1	200002	Double/Double with 1 coat, Clear, 13 mm Air, Metal, Picture, Wood, ER* = -16.9, Eff. RSI= .34
2	200012	Double/Double with 1 coat, Clear, 13 mm Air, Metal, Hinged, Wood, ER* = -29.6, Eff. RSI= .33
3	230202	Double/Double with 1 coat, Low-E .20 (Hard1), 13 mm Air, Insulating, Picture, Wood, ER* = -2.1, Eff. RSI= .48

Window Standard Energy Rating estimated for assumed dimensions, and
Air tightness type: CSA - A1; Leakage rate = 2.79 m3/hr/m

*** BUILDING PARAMETER DETAILS ***

CEILING COMPONENTS

	Construction Type	Code Type	Roof Slope	Heel Ht. m	Section Area m2	R-Value RSI
C1	Cathedral	0000000000	3.00 / 12	.00	85.00	5.33

WALL COMPONENTS

	Wall Type Code	Lintel Type	Facing Dir	Number of Corners	Number of Inter.	Height m	Perim. m	Area m2	R-Value RSI
Main Walls									
M1	0000000000	N/A	N/A	1	1	2.15	63.6	137.00	2.84

Basement Walls above grade

WALL COMPONENTS

	Wall Type Code	Lintel Type	Facing Dir	Number of Corners	Inter.	Height m	Perim. m	Area m2	R-Value RSI
	Upper Basement Walls								
1	0000000000	N/A	N/A	1	1	.60	37.3	22.40	1.76
	Lower Basement Walls								
1	0000000000	N/A	N/A	1	1	1.30	26.2	34.00	1.76

FLOORS

	Seq #	Construction Type	Section Area m2	R-Value RSI
Exposed or overhanging floors	1	0000000000	3.40	4.19
Full Depth Floor Perimeter	1	0000000000	30.40	.20
Full Depth Floor Centre	1	0000000000	48.90	.20
Floors above Basement	1	0000000000	79.30	.50

DOORS

Location		Type	Height m	Width m	Gross Area m2	R-value RSI
D1	M1	User specified	2.07	1.16	2.40	1.40

Roof Cavity Inputs

Sloped Roof Total Area .0 m2
Sheathing Material: Plywood/Part. bd 12.7 mm (1/2 in) .11 RSI
Roofing Material: Asphalt shingles .08 RSI

Roof colour: Medium brown 0.84 Absorptivity: .840
Total cavity volume .0 m3 Ventilation rate .50 ACH/hr

WINDOWS

Orientation Location	Number	Type (Code)	Total Area(m2)	RSI Window	(Shutter)
South					
M1	3	200002	6.09	.34	
East					
M1	2	200012	2.90	.34	
North					
M1	3	230202	4.50	.48	
M1	2	200012	2.10	.34	
West					
M1	3	200012	3.00	.34	

*** BUILDING PARAMETERS SUMMARY ***

Component	Area (m2) Gross	Net	Effective RSI	Heat Loss MJ	% Annual Heat Loss
ZONE 1 : ABOVE GRADE					
Ceiling	85.00	85.00	5.33	5342.5	5.83
Main Walls	137.00	116.01	2.84	17874.0	19.52
Doors	2.40	2.40	1.40	804.8	.88
Exposed floors	3.40	3.40	4.19	340.4	.37
South windows	6.09	6.09	.34	8329.3	9.09
East windows	2.90	2.90	.34	4001.7	4.37
North windows	6.60	6.60	.42	7353.1	8.03
West windows	3.00	3.00	.34	4164.3	4.55
				=========	=======
		ZONE 1 Totals:		48210.1	52.64
INTER-ZONE Heat Transfer : Floors Above Shallow and Full Basement	79.30	79.30	.50	5871.3	
ZONE 2 : SHALLOW / FULL BASEMENT					
Basement Walls above grade	30.90	30.90	1.75	7671.6	8.38
Upper Basement Walls	22.40	22.40	1.76	3827.7	4.18
Lower Basement Walls	34.00	34.00	1.76	4139.7	4.52
Full Depth Floor Perimeter	30.40	30.40	.20	9311.3	10.17
Full Depth Floor Centre	48.90	48.90	.20	4753.1	5.19
				=========	=======
		ZONE 2 Totals:		29703.4	32.43

Ventilation

House Volume	Air Change	Heat Loss MJ	% Annual Heat Loss
471.00 m3	.139 ACH	13667.7	14.92

*** AIR LEAKAGE AND VENTILATION ***

Building Envelope Surface Area = 392.0 m2
Air Leakage Test Results at 50 Pa.(0.2 in H2O) = 2.96 ACH
Equivalent Leakage Area @ 10 Pa. = 482.0 cm2

Terrain Description		Height	m
@ Weather Station :	Open flat terrain, grass	Anemometer	10.0
@ Building site :	Suburban, forest	Bldg. Eaves	4.3

Local Shielding- Walls: Very heavy
Flue : Heavy

Leakage Fractions - Ceiling: .200 Walls: .600 Floors: .200

Normalized Leakage Area @ 10 Pa. = 1.2296 cm2/m2

Estimated Airflow to cause a 5 Pa Pressure Difference = 77 L/s
Estimated Airflow to cause a 10 Pa Pressure Difference = 120 L/s

*** F326 VENTILATION REQUIREMENTS ***

Kitchen, living, dining:	3 rooms @ 5 L/s	= 15 L/s
Utility rooms:	1 rooms @ 5 L/s	= 5 L/s
Bedrooms:	1 rooms @ 10 L/s	= 10 L/s
Bedrooms:	2 rooms @ 5 L/s	= 10 L/s
Bathrooms:	2 rooms @ 5 L/s	= 10 L/s
Other habitable rooms:	1 rooms @ 5 L/s	= 5 L/s
Basement Rooms:		0 L/s

*** OTHER EXHAUST FLOW RATES (L/s) ***

	Continuous	Intermittent
Dryer	.0	75.0
Kitchen	.0	50.0
All Bathrooms	.0	50.0
All other exhaust devices	.0	.0
Vented central vac.		.0
Largest Intermittent exhaust (other than Dryer)		50.0

Dryer is NOT vented outdoors

Total continuous exhaust flow .0 L/s
Exhaust Fan Power .0 watts

*** AIR LEAKAGE AND VENTILATION SUMMARY ***

F326 Required continuous ventilation rate = 55.0 L/s (.42 ACH)

Gross Air Leakage and Ventilation Energy Load	= 12195.1 MJ
Seasonal Heat Recovery Ventilator Efficiency	= .0 %
Estimated Ventilation Electrical Load: Heating Hours	= .0 MJ
Estimated Ventilation Electrical Load: Non-Heating Hours	= .0 MJ
Net Air Leakage and Ventilation Energy Load	= 13667.7 MJ

*** SPACE HEATING SYSTEM ***

PRIMARY Heating Fuel : Electricity
Equipment : Forced air furnace
Manufacturer :
Model :
Output Capacity = 15.0 kW

Steady State Efficiency = 100.0 %

Fan Mode : Auto Fan Power 291. watts

*** DOMESTIC WATER HEATING SYSTEM ***

PRIMARY Water Heating Fuel : Electricity
Water Heating Equipment : Conventional tank
Energy Factor : .824

Manufacturer :
Model :
Tank Capacity = 182.0 Litres Tank Blanket Insulation .0 RSI
Tank Location : Basement

*** ANNUAL SPACE HEATING SUMMARY ***

Design Heat Loss at -23.0 C = 18.48 Watts/m3 = 8705. Watts

Gross Space Heat Loss = 91581. MJ

Gross Space Heating Load = 91564. MJ
Usable Internal Gains = 20117. MJ
Usable Internal Gains Fraction = 22.0 %
Usable Solar Gains = 13575. MJ
Usable Solar Gains Fraction = 14.8 %
Auxiliary Energy Required = 57872. MJ

Space Heating System Load = 57872. MJ
Furnace/Boiler Seasonal efficiency = 100.0 %
Furnace/Boiler Annual Energy Consumption = 56770. MJ

*** ANNUAL DOMESTIC WATER HEATING SUMMARY ***

Daily Hot Water Consumption = 236.4 Litres /day
Hot Water Temperature = 55.0 C
Estimated Domestic Water Heating Load = 17821. MJ

PRIMARY Domestic Water Heating Energy Consumption = 21014. MJ
PRIMARY System Seasonal Efficiency = 84.8 %

*** BASE LOADS SUMMARY ***

	kwh/day	Annual kWh
Interior Lighting	2.1	766.5
Appliances	9.8	3577.0
Other	2.1	766.5
Exterior use	2.0	730.0
HVAC fans		
HRV/Exhaust	.0	.0
Space Heating	.8	305.9
Space Cooling	.0	.0
Total Average Electrical Load	16.8	6145.9

*** FAN OPERATION SUMMARY (kWh) ***

Hours	HRV/Exhaust Fans	Space Heating	Space Cooling
Heating	.0	305.9	.0
Neither	.0	.0	.0
Cooling	.0	.0	.0
Total	.0	305.9	.0

*** R-2000 HOME PROGRAM ENERGY CONSUMPTION SUMMARY REPORT ***

Estimated Annual Space Heating Energy Consumption = 57872. MJ = 16075.5 kWh
Ventilator Electrical Consumption: Heating Hours = 0. MJ = .0 kWh
Estimated Annual DHW Heating Energy Consumption = 21014. MJ = 5837.2 kWh

ESTIMATED ANNUAL SPACE + DHW ENERGY CONSUMPTION = 78886. MJ = 21912.7 kWh
ANNUAL R-2000 SPACE + DHW ENERGY CONSUMPTION TARGET = 55572. MJ = 15436.6 kWh

*** ESTIMATED ANNUAL FUEL CONSUMPTION SUMMARY ***

Fuel	Space Heating	Space Cooling	DHW Heating	Appliances	Total
Electricity (kWh)	16075.5	.0	5837.2	5840.0	27752.7

****

Energy units: MJ = Megajoules (3.6 MJ = 1 kWh)

The calculated heat losses and energy consumptions are only estimates, based upon the data entered and assumptions within the program. Actual energy consumption and heat losses will be influenced by construction practices, localized weather, equipment characteristics and the lifestyle of the occupants.

Nova Scotia

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*****************************************
*                                       *
*               HOT2000                 *
*            Version 7.15c              *
*               CANMET                  *
*       Natural Resources CANADA        *
*            Jul 12, 1996               *
*          Reg. # CD000131              *
*****************************************
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File = F:\WORK\HVACCTRL\H2K\C73MT_BE.HDF

Weather Data for HALIFAX, NOVA SCOTIA

Builder Code =
Data Entry by: KC   Date of entry 00/00/0000

Client name: 95 Code: Base run
Street address:
City: Region:
Postal code: Telephone:

*** GENERAL HOUSE CHARACTERISTICS ***

House type: Single detached
Number of storeys: One and a half
Wall construction: Platform frame, single stud wall
Year House Built: 1994
Wall colour: Default   0.40   Value   .400
Plan shape: Square   Front orientation: South

SOIL TYPE: Normal conductivity: dry sand, loam, clay, low water table

HOUSE THERMAL MASS LEVEL: (A) Wood frame construction, 12.5 mm (0.5 in.)
gyproc walls and ceiling, wooden floor

Effective mass fraction   1.000

Occupants : 2 Adults   for 50.0 % of the time
             2 Children for 50.0 % of the time
             0 Infants for   .0 % of the time

Sensible Internal Heat Gain From Occupants   = 2.40 kWh/day

*** HOUSE TEMPERATURES ***

Heating Temperatures	Main Floor	= 21.0 C
	Basement	= 20.0 C
	TEMP. Rise from 21.0 C	= 3.5 C

Basement is- Heated: Yes   Cooled: Yes   Separate T/S: Yes
Fraction of internal gains released in basement : .150

Indoor design temperatures for equipment sizing

	Heating	= 21.0 C
	Cooling	= 25.0 C

*** FOUNDATION CONSTRUCTION CHARACTERISTICS ***

Foundation Construction	Attachment Sides	Insulation Placement	Volume m3
Slab on Grade	1 Side	Edge/Exterior	
Full Basement	1 Side	Interior	221.4

*** WINDOW CHARACTERISTICS ***

Direc-tion	Seq #	Loc. Code	# of Windows	Type	Window Width m	Window Height m	OverHang Width m	Header Height m	SHGC	Curtain Factor
South	1	M1	3	200002	1.500	1.000	.60	.20	.6645	.000
East	1	M1	3	200012	2.030	1.000	.00	.00	.6144	.000
North	1	M1	2	200012	1.500	1.000	.00	.00	.5991	.000
	2	M1	1	200002	1.500	1.000	.00	.00	.6645	.000
West	1	M1	3	200012	1.500	1.000	.00	.00	.5991	.000
	2	M1	2	200002	1.500	1.000	.00	.00	.6645	.000

*** WINDOW PARAMETER CODES SCHEDULE ***

	Code	Description (Glazings, Coatings, Fill, Spacer, Type, Frame)
1	200002	Double/Double with 1 coat, Clear, 13 mm Air, Metal, Picture, Wood, ER* = -16.9, Eff. RSI= .34
2	200012	Double/Double with 1 coat, Clear, 13 mm Air, Metal, Hinged, Wood, ER* = -29.6, Eff. RSI= .33

Window Standard Energy Rating estimated for assumed dimensions, and
Air tightness type: CSA - A1; Leakage rate = 2.79 m3/hr/m

*** BUILDING PARAMETER DETAILS ***

CEILING COMPONENTS

	Construction Type	Code Type	Roof Slope	Heel Ht. m	Section Area m2	R-Value RSI
C1	Cathedral	0000000000	3.00 / 12	.00	115.00	5.49

WALL COMPONENTS

	Wall Type Code	Lintel Type	Facing Dir	Number of Corners	Number of Inter.	Height m	Perim. m	Area m2	R-Value RSI
Main Walls									
M1	0000000000	N/A	N/A	1	1	2.15	96.2	207.00	3.12

WALL COMPONENTS

	Wall Type Code	Lintel Type	Facing Dir	Number of Corners	Inter.	Height m	Perim. m	Area m2	R-Value RSI
	Basement Walls above grade								
B1	0000000000	N/A	N/A	1	1	.60	48.3	29.00	2.10
	Upper Basement Walls								
1	0000000000	N/A	N/A	1	1	.60	39.7	23.80	1.19
	Lower Basement Walls								
1	0000000000	N/A	N/A	1	1	1.30	37.6	48.90	1.19

FLOORS

	Seq #	Construction Type	Section Area m2	R-Value RSI
Exposed or overhanging floors	1	0000000000	14.70	4.60
Slab on Grade Perimeter	1	0000000000	2.20	1.58
Slab on Grade Centre	1	0000000000	3.90	1.58
Full Depth Floor Perimeter	1	0000000000	33.70	.38
Full Depth Floor Centre	1	0000000000	57.10	.38
Floors above Basement	1	0000000000	90.80	.50

DOORS

	Location	Type	Height m	Width m	Gross Area m2	R-value RSI
D1	M1	User specified	2.07	2.46	5.10	1.38

Roof Cavity Inputs

Sloped Roof	Total Area	.0 m2
Sheathing Material: Plywood/Part. bd 12.7 mm (1/2 in)		.11 RSI
Roofing Material: Asphalt shingles		.08 RSI

Roof colour: Medium brown 0.84		Absorptivity:	.840
Total cavity volume	.0 m3	Ventilation rate	.50 ACH/hr

WINDOWS

Orientation Location	Number	Type (Code)	Total Area(m2)	RSI Window	(Shutter)
South					
M1	3	200002	4.50	.34	
East					
M1	3	200012	6.09	.34	

WINDOWS

Orientation Location	Number	Type (Code)	Total Area(m2)	RSI Window	(Shutter)
North					
M1	2	200012	3.00	.34	
M1	1	200002	1.50	.34	
West					
M1	3	200012	4.50	.34	
M1	2	200002	3.00	.34	

*** BUILDING PARAMETERS SUMMARY ***

Component	Area (m2) Gross	Net	Effective RSI	Heat Loss MJ	% Annual Heat Loss
ZONE 1 : ABOVE GRADE					
Ceiling	115.00	115.00	5.49	7210.7	6.14
Main Walls	207.00	179.31	3.12	25552.6	21.77
Doors	5.10	5.10	1.38	1756.5	1.50
Exposed floors	14.70	14.70	4.60	1369.9	1.17
South windows	4.50	4.50	.34	6250.7	5.33
East windows	6.09	6.09	.34	8474.8	7.22
North windows	4.50	4.50	.34	6272.4	5.34
West windows	7.50	7.50	.34	10450.3	8.90
Slab on Grade Perimeter	2.20	2.20	1.58	386.2	.33
Slab on Grade Centre	3.90	3.90	1.58	308.6	.26
				=========	=======
		ZONE 1 Totals:		68032.8	57.97
INTER-ZONE Heat Transfer : Floors Above Shallow and Full Basement					
	90.80	90.80	.50	6191.6	
ZONE 2 : SHALLOW / FULL BASEMENT					
Basement Walls above grade	29.00	29.00	2.10	6115.8	5.21
Upper Basement Walls	23.80	23.80	1.19	4554.9	3.88
Lower Basement Walls	48.90	48.90	1.19	6131.0	5.22
Full Depth Floor Perimeter	33.70	33.70	.38	7751.5	6.60
Full Depth Floor Centre	57.10	57.10	.38	4666.4	3.98
				=========	=======
		ZONE 2 Totals:		29219.6	24.90

Ventilation

House Volume	Air Change	Heat Loss MJ	% Annual Heat Loss
671.00 m3	.160 ACH	20110.0	17.13

*** AIR LEAKAGE AND VENTILATION ***

Building Envelope Surface Area	= 535.3 m2
Air Leakage Test Results at 50 Pa.(0.2 in H2O)	= 3.41 ACH
Equivalent Leakage Area @ 10 Pa.	= 773.0 cm2

Terrain Description		Height	m
@ Weather Station :	Open flat terrain, grass	Anemometer	10.0
@ Building site :	Suburban, forest	Bldg. Eaves	4.3

Local Shielding- Walls: Very heavy
Flue : Heavy

Leakage Fractions - Ceiling: .200 Walls: .600 Floors: .200

Normalized Leakage Area @ 10 Pa.	= 1.4440 cm2/m2
Estimated Airflow to cause a 5 Pa Pressure Difference	= 123 L/s
Estimated Airflow to cause a 10 Pa Pressure Difference	= 193 L/s

*** F326 VENTILATION REQUIREMENTS ***

Kitchen,living,dining:	3 rooms @ 5 L/s	= 15 L/s
Utility rooms:	1 rooms @ 5 L/s	= 5 L/s
Bedrooms:	1 rooms @ 10 L/s	= 10 L/s
Bedrooms:	2 rooms @ 5 L/s	= 10 L/s
Bathrooms:	2 rooms @ 5 L/s	= 10 L/s
Other habitable rooms:	1 rooms @ 5 L/s	= 5 L/s
Basement Rooms:		0 L/s

*** OTHER EXHAUST FLOW RATES (L/s) ***

	Continuous	Intermittent
Dryer	.0	75.0
Kitchen	.0	50.0
All Bathrooms	.0	50.0
All other exhaust devices	.0	.0
Vented central vac.		.0
Largest Intermittent exhaust (other than Dryer)		50.0

Dryer is NOT vented outdoors

Total continuous exhaust flow .0 L/s
Exhaust Fan Power .0 watts

*** AIR LEAKAGE AND VENTILATION SUMMARY ***

F326 Required continuous ventilation rate = 55.0 L/s (.30 ACH)

Gross Air Leakage and Ventilation Energy Load	= 18664.7 MJ
Seasonal Heat Recovery Ventilator Efficiency	= .0 %
Estimated Ventilation Electrical Load: Heating Hours	= .0 MJ
Estimated Ventilation Electrical Load: Non-Heating Hours	= .0 MJ
Net Air Leakage and Ventilation Energy Load	= 20110.0 MJ

*** SPACE HEATING SYSTEM ***

PRIMARY Heating Fuel : Electricity
Equipment : Forced air furnace
Manufacturer :
Model :
Output Capacity = 15.0 kW

Steady State Efficiency = 100.0 %

Fan Mode : Auto Fan Power 291. watts

*** DOMESTIC WATER HEATING SYSTEM ***

PRIMARY Water Heating Fuel : Electricity
Water Heating Equipment : Conventional tank
Energy Factor : .824

Manufacturer :
Model :
Tank Capacity = 182.0 Litres Tank Blanket Insulation .0 RSI
Tank Location : Basement

*** ANNUAL SPACE HEATING SUMMARY ***

Design Heat Loss at -16.0 C = 14.34 Watts/m3 = 9622. Watts

Gross Space Heat Loss	=117362. MJ
Gross Space Heating Load	=117362. MJ
Usable Internal Gains	= 22307. MJ
Usable Internal Gains Fraction	= 19.0 %
Usable Solar Gains	= 19515. MJ
Usable Solar Gains Fraction	= 16.6 %
Auxiliary Energy Required	= 75541. MJ
Space Heating System Load	= 75541. MJ
Furnace/Boiler Seasonal efficiency	= 100.0 %
Furnace/Boiler Annual Energy Consumption	= 74103. MJ

*** ANNUAL DOMESTIC WATER HEATING SUMMARY ***

Daily Hot Water Consumption	= 236.4 Litres /day
Hot Water Temperature	= 55.0 C
Estimated Domestic Water Heating Load	= 17062. MJ
PRIMARY Domestic Water Heating Energy Consumption	= 20263. MJ
PRIMARY System Seasonal Efficiency	= 84.2 %

*** BASE LOADS SUMMARY ***

	kwh/day	Annual kWh
Interior Lighting	2.1	766.5
Appliances	9.8	3577.0
Other	2.1	766.5
Exterior use	2.0	730.0
HVAC fans		
HRV/Exhaust	.0	.0
Space Heating	1.1	399.3
Space Cooling	.0	.0
Total Average Electrical Load	17.1	6239.3

*** FAN OPERATION SUMMARY (kWh) ***

Hours	HRV/Exhaust Fans	Space Heating	Space Cooling
Heating	.0	399.3	.0
Neither	.0	.0	.0
Cooling	.0	.0	.0
Total	.0	399.3	.0

*** R-2000 HOME PROGRAM ENERGY CONSUMPTION SUMMARY REPORT ***

Estimated Annual Space Heating Energy Consumption	= 75541. MJ	= 20983.6 kWh
Ventilator Electrical Consumption: Heating Hours	= 0. MJ	= .0 kWh
Estimated Annual DHW Heating Energy Consumption	= 20263. MJ	= 5628.6 kWh
ESTIMATED ANNUAL SPACE + DHW ENERGY CONSUMPTION	= 95804. MJ	= 26612.2 kWh
ANNUAL R-2000 SPACE + DHW ENERGY CONSUMPTION TARGET	= 63800. MJ	= 17722.2 kWh

*** ESTIMATED ANNUAL FUEL CONSUMPTION SUMMARY ***

Fuel	Space Heating	Space Cooling	DHW Heating	Appliances	Total
Ele@tricity (kWh)	20983.6	.0	5628.6	5840.0	32452.2

APPENDIX E

Sensor Characteristics

App. E Sensor Characteristics

Sensor ID	Measurement	Sensor type	Mfr.	Model	Sensor accuracy	Min.	Max.	Units
G01	gas	pulse output meter						
P01	pressure difference	manometer			0.1	0	13	Pa
P03	pressure difference	switch	Dwyer	1910-00		18	38	Pa
T02	air temperature	thermistor	Dale	TE200A7: 10 K	0.2	-50	150	C
T12	air temperature	thermistor	Dale	TE200A7: 10 K	0.2	-50	150	C
T22	air temperature	thermistor	Dale	TE200E6: 10 K	0.2	-50	150	C

Sensor ID	Sensor Output	Behaviour	Sensor Sensitivity	Sensor Units	Unit Sensor cost	Installation cost	Interface cost	Remarks
G01	none	linear		ohms	$120.00	$70.00	$20.00	magnetic switch
P01	current	linear	1.50	ma/Pa	$175.00	$59.00	$50.00	15 cm flow grid
P03	none				$90.28	$30.00	$10.00	incl. air filter kit
T02	none	non-linear	-2.50	C/kohm	$10.00	$20.00	$10.00	no shielding
T12	none	non-linear	-2.50	C/kohm	$16.75	$30.00	$10.00	incl. interior shield
T22	none	non-linear	-2.50	C/kohm	$43.50	$30.00	$10.00	incl. exterior shield