Technical advice to Task Force on Northern Mechanical Ventilation Equipment Design and Testing

Final Report Submitted to:

Charles Zaloum
Program Manager, Export Products and Services,
CMHC International
C1-420, CMHC National Office
700 Montreal Road
Ottawa, ON Canada
K1A 0P7
Phone: (613) 748 5122
Fax: (613) 748 2302
Email: czaloum@cmhc-schl.gc.ca

September 16, 2010

PETER EDWARDS CO.
ENERGY SYSTEMS, ENVIRONMENT AND PRODUCT DESIGN /APPLICATION SPECIALIST
1277 Tredmore Drive • Mississauga, ON • L5J3V5 • T: 905 8226524 • F: 905 8236843 • pfedwards@sympatico.ca

1 Introduction

This interim report describes some of the activities that have been undertaken on behalf of CMHC to investigate ventilation performance issues in Northern houses.

At its January 2009 inaugural meeting, the Tri-Territorial Technical Subcommittee composed of technical and program managers from CMHC and the three Territorial Housing Corporations identified mechanical ventilation as the #1 issue of concern for northern housing. A list of specific concerns was developed at the Subcommittee's September 2009 meeting, and at a subsequent meeting held in Inuvik in March 2010. The concerns covered the gamut of ventilation issues - from equipment design and testing, to installation, maintenance, operation and training.

Two Task Forces were established at the Inuvik meeting to work with Housing Corporations, HRV manufacturers and relevant codes/standards bodies to arrive at a "northern spec" in 2011. Field tests of a prototype HRV and work on HRV installation and maintenance training are expected to result in resolution of many of the issues by 2012.

The report is organized into sections that are identified with headings that correlate with those used in the approved work statement for this project.

2 Current and foreseeable changes in codes, standards and labelling programs.

2.1 Existing test standards and protocols.

In North America, residential heat recovery ventilators (HRVs) and energy recovery ventilators (ERVs) are tested and rated using a standard test procedure that is described in the *CAN/CSA C439 - Standard laboratory methods of test for rating the performance of heat/energy-recovery ventilators*. The first edition of C439 was published in 1985 as a preliminary standard and it has been revised in 1988, 2000 and 2009. The 2009 edition introduced measurement of standby power consumption and it includes a minimum sensible heat recovery efficiency (SRE) requirement of 55%, tested with a supply air temperature of 0°C.

CSA 439 defines an HRV and an ERV as follows:
Heat-recovery ventilator (HRV) - a factory-assembled packaged unit, including fans or blowers, designed to transfer heat between two isolated airstreams.
Energy-recovery ventilator (ERV) - a heat-recovery ventilator designed to transfer heat and moisture.

The test procedures in CSA 439 may be applied to determine the ventilating capacity, the power consumption and the sensible, total and latent energy recovery performance for either HRVs or ERVs.

For heating tests, apparent effectiveness and sensible energy recovery efficiency (SRE) is calculated from the temperature rise in the supply air stream compared with the temperature difference between the entering exhaust and supply air streams. Total energy recovery efficiency (TRE) is calculated from the total energy (enthalpy) change compared with the total energy difference.

Sensible and total recovery efficiency calculations incorporate terms that account for differences in flows, leakages, heat transfer through the cabinet and other known energy inputs such as fan power, defrost etc. Apparent latent recovery effectiveness is a measure of the amount of moisture that is transferred from the exhaust air stream to the supply air stream based on measurements of the flows and humidity ratios of the air streams. C439 does not provide a formula to calculate latent recovery efficiency.

C439 identifies a standard indoor condition of 22°C with 40% relative humidity (7.8°C dew point) for all heating-mode tests. It requires tests to be performed with (outdoor) supply temperature of 0°C. For (optional) cooling-mode tests it specifies an indoor condition of 24°C with 50% RH (12.9°C dew point) and an outdoor condition of 35°C, 50% RH (23°C dew point). The standard also provides a test procedure for an optional low temperature performance/endurance test. The duration of the low temperature test is 72 h, with the performance ratings determined from measurements recorded during the final 12 h. C439 allows for the low temperature test to be performed at any temperature specified by the manufacturer. However, those manufacturers that rate their products using the low temperature test almost always specify an outdoor temperature of -25°C because that condition has been specified in some Canadian codes and program requirements. As a result, a 72 h low temperature test at -25°C has become the default test for the industry.

Rating tests are performed at the air flows specified by the submitter. As noted above, cooling tests and a low temperature performance/endurance test are optional.

The Home Ventilating Institute (HVI) provides a certification program for residential ventilating products that includes HRVs and ERVs. The HVI procedures manual references the CSA C439 standard and only recognizes test results from a single Canadian laboratory (Exova, formerly Bodycote, located in Mississauga, ON). HVI publishes a directory of certified products that is updated on a regular basis (approximately monthly). The current directory may be downloaded from the HVI website, HVI.org.

The HVI certified products directory does not provide complete performance ratings for HRVs and ERVs at all test conditions. For heating tests at 0°C and optional low temperature tests, there are no TRE ratings provided and for optional cooling tests at 35°C there are no SRE ratings provided.

In Europe, HRVs are rated using EN standard 13141-7 *"Performance testing of components/products for residential ventilation, Part 7: Performance testing of mechanical supply and exhaust ventilation units (including heat recovery) for mechanical ventilation systems intended for single family dwellings"*. Different editions of EN standards are published in different countries. For example in the UK, the standard is designated as BS EN 13141-7. That standard identifies rating conditions and it references a separate standard, EN 308, which may be used to determine the performance of a wide range of heat recovery systems. For HRVs tests are done with indoor conditions of 25°C and maximum wet bulb temperature of 14°C (maximum RH of 27%, equivalent to dew point less than 4.8°C) and outdoor dry bulb temperature of 5°C with no humidity specification. For systems that are designed for installation at locations with a design temperature below -10°C, an additional test is required as specified in EN 308. Definitive details of the additional test could not be located for this project. However, review of materials relating to EN308 that were available at the time of writing suggest that the additional test is a six hour test with indoor temperature of 15°C, 50% RH (5.3°C dew point) and outdoor temperature of -15°C.

Ratings in the EN standard are specific power consumptions, noise levels and temperature ratios and "No correction for the fan power input or that of other components to the temperature ratio shall be made". Specific fan powers (expressed as W/l/s) are reported for a range of tested flow rates which correspond to the number of wet rooms (9 l/s for a kitchen and 6 l/s for each additional wet room). Assuming balanced flows, temperature ratios would be more or less equivalent to the apparent sensible effectiveness determined from tests using C439. However the test conditions in the two standards are different so the ratings cannot be directly compared.

2.2 Appropriateness of existing standards for equipment destined for the high North.

The CSA C439 standard is considered to be suitable for use with Northern HRVs. It is already being used as the test method for a Canadian ENERGY STAR™ program for residential HRVs and ERVs that came into effect in January 2010. To qualify for ENERGY STAR, an HRV must meet minimum thermal efficiency requirements at both 0°C and -25°C and meet electrical (cfm per watt) requirements at 0°C. For products that achieve high thermal efficiencies (>75% SRE at 0°C) an exemption for the cfm per watt requirement is available until Tier 2 of the program comes into effect in July 2012.

In Europe, the EN standards are used as the test methods to determine HRV product eligibility for programs such as the UK SAP (Standard Assessment Procedure) Appendix Q and Passivhaus. A six hour low temperature test at -15°C (described in section 2.1 of this report) is considered to be an inadequate test for an HRV intended for use in the North. It is possible that the European EN standards could be adapted to make them more suitable for Northern HRVs, if an appropriate low temperature test (or tests) and corresponding low temperature performance criteria are developed and included within a performance specification. However, because the CSA C439 test standard and the HVI certification program for residential HRVs and ERVs are widely recognised throughout North America, it would be preferable to use the recognized tests wherever possible, unless specific advantages are identified with the European testing methods.

Low temperature testing is discussed further in the next section.

2.3 Evaluation of the need for cold testing (-40°C) and capability of approved labs.

When the first preliminary edition of the CSA C439 was published in 1985, it included a specification for a low temperature test using an indoor temperature of 22°C and 30% relative humidity (3.6°C dew point) and an outdoor temperature of -22°C. The test duration was not directly specified but the standard stated that the unit be tested until the performance had stabilized. Low temperature performance ratings were to be based on measured performance after the unit had stabilized. This approach led to lengthy tests in the laboratory because it was often difficult to determine if small changes in the test measurements were being caused by the effects of frost accumulation or from changes in barometric pressure, instrumentation drift or other factors. Some HRV units would gradually freeze in the laboratory over a period of five or six days, creating a huge burden on the laboratory environmental conditioning apparatus and instrumentation. At the time, anecdotal reports from the field were indicating problems with many installed HRVs during cold winter conditions.

The CSA C439 TSC revised the low temperature test procedure to simplify the test, while making it more robust. Specific changes included making the test duration a fixed period of 72 h; reporting the final 12 h; and increasing the indoor RH from 30% to 40% (7.8°C dew point), which was believed to approximate a “worst case” for evaluation of frost control for HRVs. Higher indoor humidity releases more energy from condensate formation within an HRV core, making freeze-up less likely, while lower humidity results in less water condensed within the cores which makes removal of the condensate easier.

At the same time that the C439 standard conditions were changed, a revised R2000 specification changed their low temperature test requirement by reducing the outdoor temperature to -25°C from -22°C. NRCan (then known as EMR) encouraged some additional testing of cold climate HRVs by offering to pay a portion of testing costs for products that were tested with an outdoor temperature of -40°C and that used less than a specified amount of electricity (70 W at 30 l/s). For a manufacturer to obtain partial payment of the testing cost, its product had to satisfy all performance requirements and the manufacturer was required to provide a full copy of the laboratory report. Attempts to obtain a copy of the detailed performance specification for use with this report were not successful.

The overall impact of these changes was to rapidly advance the industry’s understanding of low temperature performance and frost control for residential HRVs. Units that had previously survived for several days with the older test conditions often froze within a matter of hours with the new test at -25°C. Problem reports from the field also decreased dramatically after the revised low temperature test came into effect and units that met the specifications started to be installed.

A handful of units satisfied the -40°C requirements from the NRCan testing program, but only one of those units has ever been listed in the HVI certified products directory. It was included in June 1991in the first HVI directory that included the HRV product category. The -40°C certified performance rating for that product has subsequently been withdrawn by its manufacturer. There are currently no HRVs or ERVs with HVI certified ratings at a temperature below -25°C.

Responses to initial enquiries that were made to Exova Inc., the only test lab for HRVs recognized by HVI, indicated that their testing facility may no longer be capable of testing HRVs at -40°C because of equipment changes and refrigerant replacements that have occurred over time. After further investigation, Exova personnel now believe that their test facilities are capable of conducting limited testing at -40°C, but it is likely that adjustments to certain components of their refrigeration systems will be required to achieve and control their test chamber at that temperature. The actual time duration for which the facility will be capable of maintaining a test at -40°C is not known because no such tests have been performed for many years and the required adjustments will not be performed until they are needed to perform a test. The refrigeration load that is imposed on the test chamber (live load) during any test is affected by the selected test air flow, the efficiency of the HRV, the defrost strategy and other factors. However, based on currently available information from the testing laboratory, it appears that at least limited testing at temperatures below -25°C would be feasible, if there is a market demand for such testing.

As stated earlier, the de-facto low temperature test point that is used by the North American residential HRV industry today (and for many years) is -25°C. It should be noted that although HRVs are not actually tested at lower temperatures, many HRVs have been installed and operated in locations with winter design temperatures well below -25°C.

Most of the manufacturers that rate their products to -25°C now utilize some form of staged defrost strategies whereby their defrost cycles change as outdoor temperature changes. Colder conditions automatically produce more frequent defrost cycles and/or longer defrost cycles. This is discussed in the next section.

3 Current technology employed by the industry and suitability in an extreme cold climate

3.1 Heat exchange core technology (plastic, metal, cross-flow, counter-flow, counter-cross flow, ERV membranes)

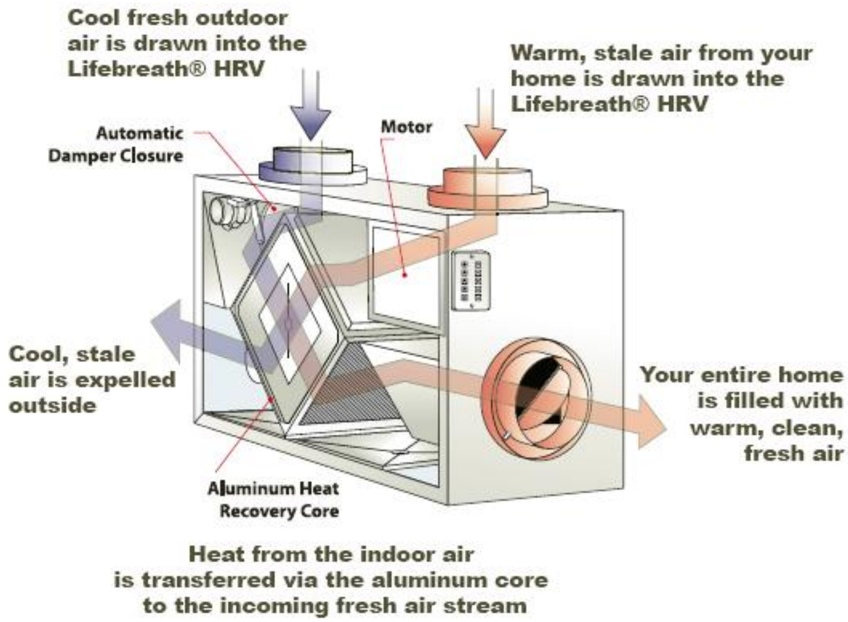
Although there are now a number of companies that produce these products, it is believed that the North American market for HRVs is currently dominated by two major players, namely Venmar Ventilation and Airia (Airia is a recent name change and the company is better known by their Nutech and Lifebreath brand names).

Venmar produces residential HRVs and ERVs that are sold directly and through a number of HVAC distributors. Their products are marketted using a variety of brand names that include Venmar, NuTone, Venmar AVS, Heil, Flair, York, vänEE, Sears, Conformax, Guardian by Broan, Carrier, Bryant, Payne, Day & Night, Rheem, Ruud, Protech, Weatherking, Nordyne, Gibson and Tappan.

Airia markets their HRVs and ERVs directly using the Lifebreath brand name and they also supply OEM branded products that are marketted under names that include Tradewinds, Honeywell, Lennox, Fresh-X-Changer, American Aldes, Raydot, Standex, Sears Authorized Indoor Clean Air Services, Nutone and Airflow.

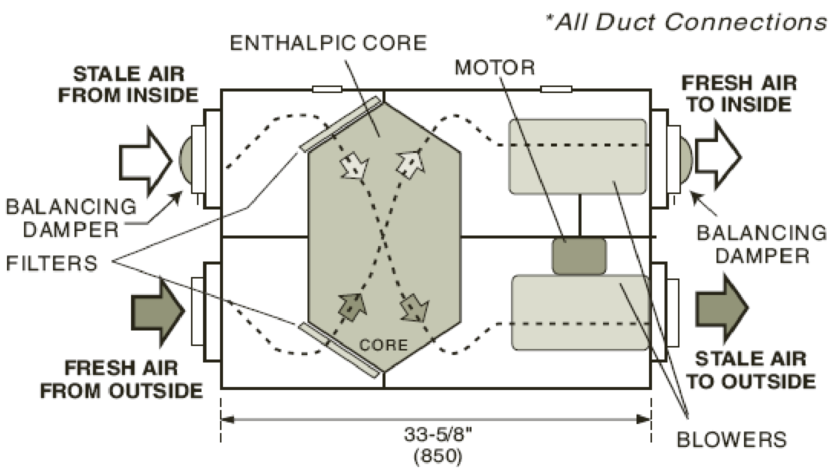
Other manufacturers of HRVs and ERVs include Air Tech Equipment, Nu-Air Ventilation, Fantech, Summeraire, Imperial Air, Air 2000, Reversomatic, and Renewaire.

The earliest developed and still the most common type of residential HRV uses a flat plate heat exchanger as shown in the illustration below

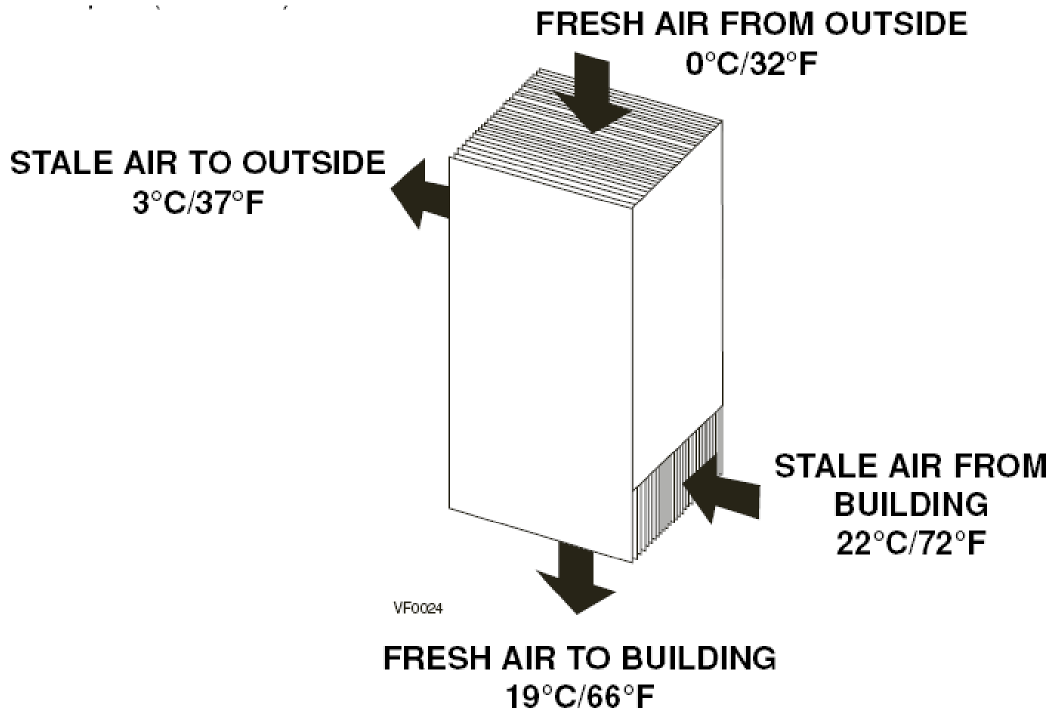


Source: www.lifebreath.com

Heat exchanger cores are commonly fabricated from polypropylene (coroplast) or aluminium for HRV applications, but other materials that include specially impregnated paper and polymeric materials that are designed to allow water vapour to transfer across the core may also used for ERV applications. Cross flow exchangers are commonly used in North American units while counter flow exchangers are common in European designs. There are a few North American units that use counter flow or cross-counter flow exchangers. A few examples are shown.

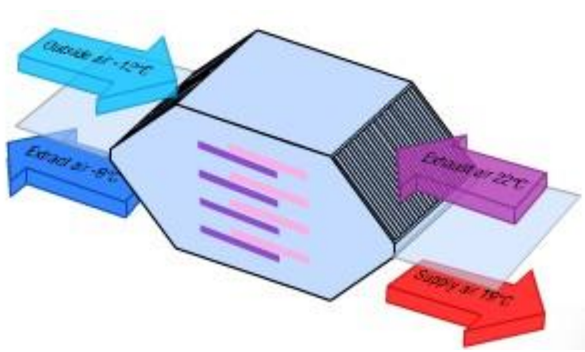


Source: Lifebreath operating manual, MAX series



Source: Venmar HE Manual

An illustration of a European counter flow exchanger is shown below.

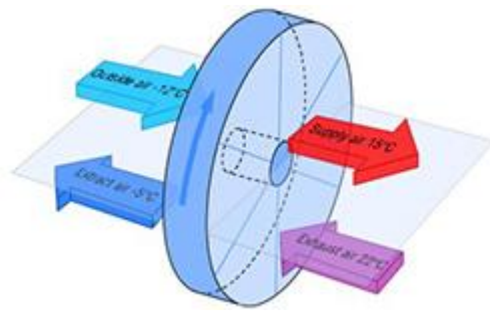


Source: www.imofa.co.uk

Rotary wheel exchangers are also available for residential ERVs. The energy recovery cores of these devices rotate through two flow paths. When warm humid air passes through the cores they heat up and absorb moisture. When the cores are rotated to a cooler drier air stream, the cores release the heat and moisture. The flow direction is usually counter flow with the exhaust flow and supply flow through the wheel in opposite directions.

The amount of energy and moisture that is transferred from the warm air stream to the colder stream may be controlled by varying the speed of rotation, the air flow rate and by changing surface hygroscopic characteristics of the rotary core itself.

These devices are common in commercial applications (primarily to reduce cooling loads) but they are less common in residential HRVs.



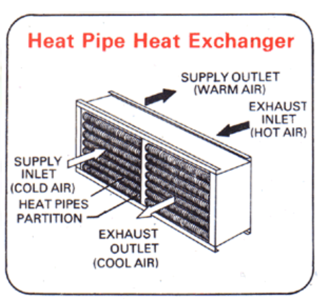
Source: www.innergytech.com and www.imofa.co.uk

Heat pipe exchanger cores are available in both commercial and residential applications. They have separate heat exchange sections that are joined by tubes that contain a heat exchange refrigerant. On the warm side the refrigerant absorbs heat from warm air, causing it to boil. The warm vapour migrates to the cold side where it releases heat to the colder air stream. The refrigerant condenses in the cold section and liquid refrigerant returns to the warm side by gravity.

The amount of heat transfer may be controlled by altering the air flow rate, number of heat pipes, finned tube design, tilt angle and through the choice of the refrigerant used.

The main advantages of heat pipe exchangers is that they can be tailored for a wide range of operating temperatures (including high temperature applications), and they can be produced with essentially no leakage between the two air streams. The absence of any leakage may be important in some ventilation applications, including hospitals. However, because there is normally no critical need to achieve absolutely zero leakage in residential ventilation systems, the high cost for an HRV with a heat pipe exchanger may be difficult to justify. Their market penetration in the residential HRV market is believed to be low.

A packaged heat pipe core is shown below



Source: www.innergytech.com and www.bryair.com

Recuperative heat exchangers are another type of heat exchanger that can be used for heat recovery ventilation. They are similar in principle to rotary heat exchangers in that they exhaust air through one medium that absorbs heat while fresh air is brought through a second identical medium. However, in recuperative exchangers, the heat transfer media do not rotate between two isolated air streams. Instead, after a period of time, the air flows reverse. Fresh air is now brought through the medium that was heated during the previous cycle while exhaust air is directed through the medium that was cooled during the previous cycle. Like rotary exchangers, recuperative exchangers are counter flow heat exchangers, but with a time offset between the flows. The time between changes in flow direction can be varied, and the system can be operated without heat recovery if desired by simply not reversing the flows. In the past a few different configurations of recuperative exchangers were marketed in North America using a variety of different materials for heat (and moisture) storage and transfer. Those materials have included metal plates and gravel “rocks”. At this time, no North American manufacturers of this type of HRV are known to exist, but it is understood that the technology is used in some European units.

Heat pump based units were briefly available in Canada in the 1980s and some are still available in Europe. Their high first cost and high electrical power requirement and associated high operating cost (compared with conventional HRVs) are problematic if they are viewed solely for their HRV functionality. If used as a key component of an integrated HVAC package where the ability to deliver higher grade heat is beneficial, it may be easier to justify their expense and electrical energy use.

HRVs are commonly recommended for application in areas subjected to cold temperatures, while ERVs are often recommended in areas dominated by cooling loads. HVI does not have any specific recommendation in this regard and they leave the choice to the consumer. They do not publish separate rating lists for HRVs and ERVs but lump both into a single rating section. Careful examination of the HVI ratings allows for identification of most HRVs and ERVs based on performance characteristics such as moisture recovery (latent transfer) compared with exhaust air transfer ratio (the performance parameter that is associated with leakage from the exhaust air stream to the supply air stream). A few models include the term “ERV” in their model designations.

Analysis of the certified HVI ratings indicate that an HRV is almost always rated at 0°C and -25°C cold temperature (and sometimes at cooling conditions) while an ERV is almost always rated at 0°C and cooling condition (and occasionally at low temperature conditions). The differences in the rating conditions chosen for certification by the manufacturers would seem to imply that an HRV would be a better choice than an ERV for a Northern climate application. A few manufacturers explicitly recommend HRVs rather than ERVs in their installation manuals for cold climate applications.

3.2 Motors: type (PSC, BLDC, other) and configuration (one or two).

Most HRVs use permanent split capacitor (PSC) motors. For a time, there was a trend towards use of a single double-shafted motor driving two fans. More recently there has been a move back to separate fans and motors for the supply and exhaust streams. Component layout, control and air balancing are all simpler with separate motors. In addition, during low temperature operation, a double-shafted single motor tends to freeze up more quickly than a unit with a separate motor for each fan. As the exhaust air side of the core starts to build ice, the exhaust flow drops and the load on the motor from the exhaust air side drops, which causes the motor speed to increase. With a double-shafted single motor the increase in motor speed will increase the air flow through the cold side of the core that, in turn, makes the exhaust side of the core freeze faster.

Brush-less direct current (BLDC) motors are available in a few North American units. They appear to be far more common in European HRV products. BLDC motors in other applications (notably furnace blowers) are often programmed to provide constant speed or constant air flow modes, where the motor can automatically compensate for differences and/or changes in system static pressures. Some European manufacturers claim to use constant air flow programs for their HRVs.

Because of their higher efficiencies, BLDC motors operate cooler than alternatives. Many also use ball bearings rather than sleeve bearings, so BLDC motors are expected to last at least as long as PSC motors. Theoretically, severe electrical power disturbances could cause some problems with the more sophisticated electronic components of BLDC motors (compared with standard PSC motors), but few, if any such problems have been reported to date in field-installed BLDC motors in either North America or Europe. Because of their design, there is a “cogging” effect with some brands of BLDC motors. This can lead to complaints about buzzing noises from the motors when they are operating at certain speeds. Some manufacturers’ models have improved isolating mounts in their motors to minimize or eliminate this problem.

3.3 Defrost strategy (types, pros/cons, issues)

Some units use a temperature sensor (often simply a click switch that closes or opens a circuit when the supply air temperature into the unit or exhaust air temperature leaving the unit is below a pre-set value) to activate a fan-shutoff defrost cycle. This works by shutting off the supply fan for a period of time but keeping the exhaust fan operating when the defrost cycle is triggered by the thermostat. A variation of this approach includes operating the exhaust fan at a higher speed during defrosts in an effort to overcome blockage in the core due to ice build up and speed up the defrost. That may result in noise complaints if the HRV is installed near the living space or bedroom area rather than a conventional basement installation. Other variations include using thermistors instead of thermostats to enable the use of different defrost cycles for different outdoor temperatures.

The main advantage for fan shut-off defrost is its simplicity. There are no dampers or linkages to stick or freeze. Disadvantages include unbalanced flow during defrost with the potential for depressurization of other equipment (including combustion appliances) and poor efficiency since there is no heat recovery during the defrost portion of the cycle. Because the defrost approach relies on passing warm air through a core that is already partially blocked by ice, the defrost duration tends to be fairly lengthy if it is to be effective.

Other units use damper-based defrost strategies. The simplest approach is to add a fifth port on the cold inlet area of the HRV. During defrost, a damper opens the fifth port to ambient air and also closes the cold air inlet port. Warm air is passed through both sides of the core. This results in faster defrosts than the simple fan shutoff defrost, but it still operates with unbalanced air flow during defrost.

The most advanced forms of damper-based defrost utilize internal dampers that re-circulate warm air back through the supply side of the core during defrost. That avoids flow imbalance during defrost since there is no net supply or exhaust flow (and no ventilation) when the unit is defrosting. It is the most energy efficient method for defrost that is currently in use but it relies on the integrity of a mechanical damper or multiple dampers to operate. There have been reports of problems related to damper motor failures and damper linkage jamming with some units. The damper motors also use some electricity. With some manufacturers' designs, dampers are powered in only one direction with spring return while others use dampers that are powered in each direction.

Supply air pre-heaters can be used as a frost avoidance strategy. These work by raising the temperature of incoming air high enough to avoid frost formation within the core. For a typical North American HRV, that would require pre-heating the incoming supply air to a temperature of between -5°C and -10°C. Raising the temperature of incoming air reduces the temperature difference across the core and consequently it reduces the amount of heat that can be recovered by the HRV. For example, cutting the temperature difference across the HRV by half also cuts the sensible energy available for recovery by the HRV in half, while the energy use of the fans, controls and other components remains unchanged. Operation of the heater may be costly, particularly if electrical heaters are used. As a result, this type of frost control is rarely, if ever, used in currently available HRVs. Exhaust air pre-heaters work in a similar way by heating exhaust air so that the core temperature will be too high to allow freezing. As with a supply air preheat strategy, exhaust air preheat is inefficient and rarely used. Because of the dramatic reduction in efficiency that results from the use of electric heaters, HRVs with electrical heaters are ineligible for ENERGY STAR qualification in Canada. It is unlikely that an HRV with an electric defrost pre-heater would be capable of meeting the minimum SRE requirements at -25°C for ENERGY STAR even without an explicit exclusion for products with electric heaters.

3.4 Controls (types, functions, sensors, and add-ons)

The most common control for a North American HRV is a de-humidistat controller that brings the unit to a higher speed setting (or switches it on) when indoor humidity exceeds the setting. Controllers with built-in carbon dioxide (CO_2) sensors are available from some HRV manufacturers. In addition, some manufacturers offer pollutant sensors that are intended to sense a broad spectrum of indoor contaminants, including carbon monoxide (CO), CO_2 and volatile organic compounds (VOCs) to control the HRV in a manner similar to the de-humidistat control approach described above. The accuracy and calibration stability of CO_2 and broad spectrum pollution sensing controllers may be an issue.

Most HRV manufacturers offer a full range of sophisticated controls that allow their units to be operated on programmable time cycles (e.g. 20 minutes on, 20 minutes off). Some allow the units to be operated as circulation devices without heat recovery. Many provide "furnace" interlocks to operate a central air handler to distribute ventilation air. Most interlock relays are integrated into the HRV cabinets, requiring low voltage wiring to the furnace (R-G) thermostat terminals but a few units require exterior relay kits.

3.5 Balancing techniques

Balancing the supply and exhaust airflows requires measurement of each air flow and adjusting the flows to make them equal. With a unit that has a single motor driving two fans, the duct with the higher flow must be restricted to reduce the flow to match the lower flow. Most HRVs have dampers integrated into their collars to accommodate such balancing.

HRVs that use separate motors for each air stream are often equipped with some form of speed control that may be used for balancing. The damper approach can be used as a fall-back if required.

Perhaps the biggest problem with HRV balancing is obtaining accurate flow measurements. Balancing manuals commonly suggest the use of a flow grid with a Magnehelic™ gauge or similar. However, with the low continuous flow settings that are generally used for continuous ventilation (30 l/s to 55 l/s would be a typical continuous flow range), accurate measurement of the low differential pressures from a flow sensor in a six inch duct is simply not possible with a magnehelic gauge. The velocity pressure that corresponds with 30 l/s ventilation flow in a six inch duct is approximately 0.006 inches of water (1.5 Pa). If using a velocity sensor (e.g. a Flo-Cal) that is designed to amplify the velocity pressure, the differential pressure would amount to no more than 0.012 inches (3 Pa). The most precise magnehelic gauge available has a full scale range of 0.25 inches (62.5 Pa) and the smallest marked increment is 0.005 inches (1.25 Pa). The distance between the smallest marked increments is approximately the width of the indicating pointer. Accurate measurement of the low pressure produced by a flow grid requires a precision laboratory grade electronic manometer or a cumbersome incline manometer.

To deal with air flow measurement problems, some HRV manufacturers provide measurement ports on their units that are designed to permit simple measurement of air flow in the field. The short term and the long term accuracy and reliability of these integrated measurement approaches is unknown.

Some manufacturers of European HRVs with BLDC motors claim to have constant air flow programming in their motor electronics. This is commonly used in North American furnace blowers with BLDC motors, but is not presently used in any North American HRV. If constant air flow programming works as claimed, the HRV would be self balancing and the need for precise measurement of flows in the field would be reduced or perhaps avoided.

3.6 Duct connections (collars).

HRVs are typically supplied with duct collars that accommodate insulated flex duct or solid duct. In theory, the inner collars can be sealed to the inner layer of ductwork and the outer layer can be used to attach the vapour barrier layer with the insulation in between. Some units allow the collars to be detached for service without disturbing the seals. In reality, it is difficult to attach and seal standard flex duct to the collars. The collar is designed to fix the duct, but it must be taped to seal it. The poly sock over the insulation acts as the air-barrier. It is easily damaged, and any perforation of that barrier leads to air leakage and condensation within the insulation. That could result in water dripping from the flex duct and possible mould formation. Some units have longer inner collars to provide more surface area for attaching the ducts.

As stated in section 3.9 of this report, the insulation level of the cold side of the HRV cabinet may be marginal. In addition, as outlined in section 3.10, the effective insulation level for the types of flex duct that are commonly used is considered marginal at best for Northern climate zones.

3.7 Filters (types, location, pros/cons, issues)

The C439 requires that HRVs be tested with filters but the standard does not specify any performance rating for the filters. Most HRVs are tested and rated with low resistance (and low performance) filters and they are marketed with the same filters. As with many other HVAC filters, the primary purpose of the filters is to protect the heat exchangers from fouling rather than filtration for air quality considerations. Some manufacturers offer upgraded filters as an option. Inline filters are available that can be installed on the supply outlet ducts external to the units. The additional static pressure from higher performance filters or aftermarket filters may affect the flow balance and ventilation capacity of the HRV. Use of an in-line filter designed to accommodate a filter with a large surface area will minimize the extra pressure drop from the filter.

3.8 Recent innovations and their potential to succeed

Recent North American innovations include limited adoption of BLDC motors and improved fan blowers, including more widespread usage of “motorized impellors” with backward-inclined fan wheels, as commonly used in Europe. Other recent innovations include limited introduction of cross-flow cores and provision of flow measurement ports or taps on the HRVs. No significant warm or cold climate issues with these technologies have been identified, although as stated in section 3.5, the reliability of on-board flow measurement devices must still be considered as unproven.

3.9 Cabinet insulation levels

Residential HRVs are typically insulated using either fibreglass board or foam. Insulation thickness ranges from about 5/8 inch to 1 inch. That would result in an R value on the order of R-2 to R-4.

The C439 calculations account for energy transfer through the HRV cabinet and manufacturers are careful to ensure that cabinet heat transfer is minimized during testing. However, manufacturers test their products at -25°C and they may be operated at a substantially lower temperature. The cabinet insulation level of current units is likely marginal for lower temperatures, particularly on the “cold side” of the unit where condensation may form.

3.10 Ducting materials and insulation levels

HRVs can be installed using either rigid or flexible ducts. They are usually installed using prefabricated insulated flexible duct (six inches nominal diameter is common). The claimed insulation value of commonly used flex duct is R-4. That is doubtful based on their use of low density fibreglass insulation. It is understood that improved flex duct with higher density insulation can be sourced from some of the same wholesalers who normally provide the standard flex duct.

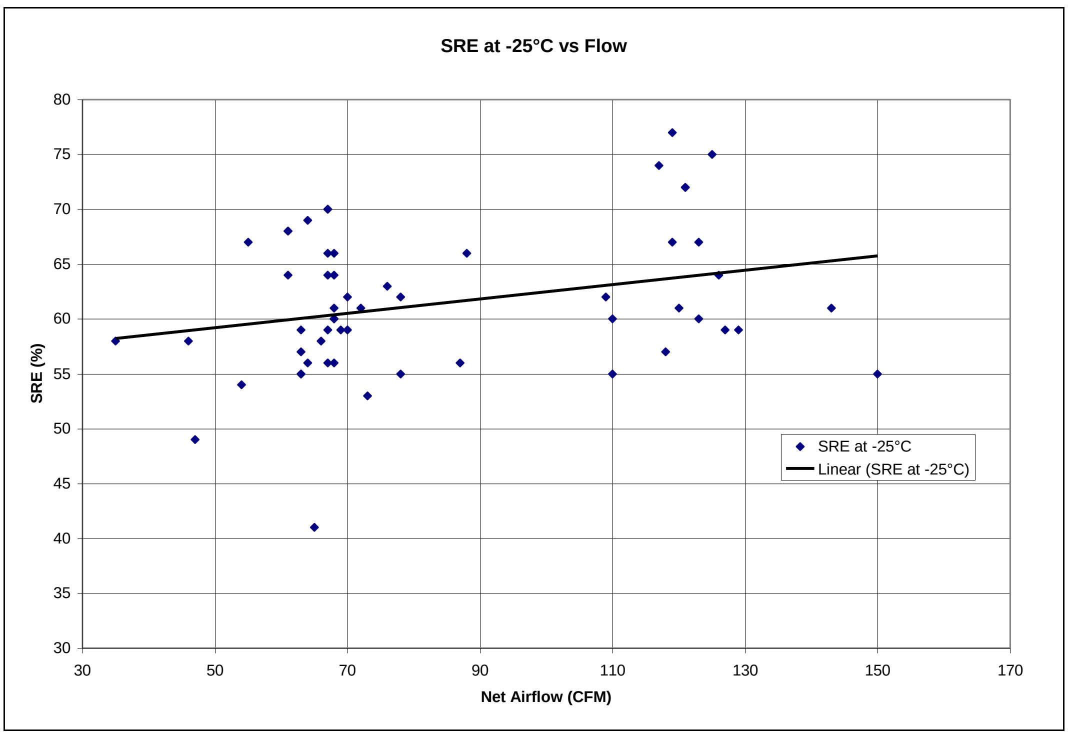
Improved cold side insulated ducts should be specified and used wherever possible. Cold side ductwork should also be as short as possible to minimize duct energy losses.

3.11 Intake and exhaust hoods, coaxial hoods

HRV manufacturers specify and supply standard inlet and outlet hoods. They generally specify a minimum horizontal separation of six feet between the inlet and outlet. Combustion codes also contain specifications for minimum separation from windows, gas meters, oil tanks, doorways etc. At least one manufacturer offers a combined vent hood as an option that would avoid the need for six feet of separation between the intake and exhaust. Details regarding procedures that were used by that manufacturer to qualify the product and demonstrate acceptability of their combined vent hood in terms of cross contamination and resistance to wind-induced effects are not provided in the installation manuals.

3.12 Heat recovery efficiency

A scatter plot of data from the September 2008 HVI directory for base HRV models shows the range of efficiencies (SRE at -25°C) for certified HRVs. The SRE ranges from about 41 % to about 77%. A few new models have been introduced to the market since 2008, but it is believed that the scatter plot would not change significantly if the newer models were added.



3.13 Pre and Post-heaters

As discussed in section 3.3, pre-heaters may be used for frost avoidance. When pre-heaters are used, it is generally for ERVs that are installed in a mild climate application where heating loads are small and the main loads are from space cooling. In such installations, a pre-heater will not operate for more than a few hours during a year, so the operating cost for the heater and the impact on energy recovery efficiency will not be significant. Pre-heaters are not commonly used for frost avoidance in cold climate applications because they would need to operate for a large number of hours during the heating season, which would have a major impact on both operating cost and energy recovery efficiency. As described in section 3.3, raising the incoming supply air temperature before it enters the HRV reduces the temperature difference across the HRV. Because the temperature difference across a heat exchanger is the thermodynamic driver for heat exchange, reducing the temperature difference reduces the amount of heat transfer, and therefore the amount of energy that can be recovered by the unit. No certified HRVs with low temperature performance ratings in the HVI directory use pre-heaters. The Canadian ENERGY STAR specification for HRVs explicitly states that HRVs with electric heaters are not eligible for ENERGY STAR.

In general HRVs are not supplied with integral post heaters. In most cases, HRVs are able to temper supply air by mixing it with air from another circulating air stream. A few HRVs have such a circulation loop included “within the box”. Their electrical use is considerably higher than for conventional HRVs, partially because they move more air but also because they usually incorporate high efficiency filtration of the circulated air stream. In Europe, the use of post heaters for tempering the supply air seems to be commonplace, particularly in Passivhaus homes that are designed to be heated using only the ventilation systems.

For context, an HRV or other ventilating device operating at a flow of 30 l/s would require a heater capacity of 365 W to raise the air temperature by 10°C. That amount of heat could be provided with an in-line electric heater or a small heating coil supplied by a glycol loop from a boiler. A heat exchanger would be required to isolate the loop from the boiler and reduce the fluid temperature to a reasonable level, as well as a circulation pump, interconnecting piping, temperature controller, insulation etc. Controls issues and likely thermal energy losses that would result from using a boiler loop to provide post heating would seem to make a boiler loop approach unattractive.

3.14 Packaged HRV/duct systems

HRVs are sold as stand alone products that are connected in the field to distribution ducts. Energy losses associated with the cold side ductwork make it important to keep the cold side ductwork as short and as well insulated as possible. A wall mounted HRV configuration with “through the wall” cold side connections could be an effective means to minimize those energy losses and it could also simplify the installation. No such HRVs are known to exist in North America.

3.15 First cost and cost of operation

A bare-bones HRV costs a contractor less than $1000 in Southern Ontario. The installed cost to a builder is estimated to be on the order of $2500 for an extended installation (dedicated wet-room exhaust, simplified distribution), including ductwork, exterior terminals and balancing. Installed cost estimates for a simplified HRV in the North that were provided at the Inuvik meeting ranged from $5K in Whitehorse and Yellowknife to $8 K for more remote installations. The cost of a fully ducted installation in Whitehorse was estimated at $17K. (See cost section of Table 4.1).

The cost of operation depends on the system's performance. The fan efficacy of currently certified HRVs and ERVs ranges from 0.5 cfm per watt to just over 2 cfm per watt so there could be difference of a factor of four in the electricity consumption. Assuming continuous ventilation at 30 l/s (64 cfm), the electrical use for the fans could vary from 32W to 128 W. Assuming operation of the ventilation system for 7200 h/y, the electricity used to operate the HRV ranges from 230 kWh to 922 kWh per year. The cost of operation depends on the local rate for electricity. Operating at higher ventilation rates will increase the electricity required to operate the HRV and the cost.

Compared with any alternative ventilation scenario, there will be a reduction in the heating load using an HRV because of heat recovery. The reduction will be proportional to the SRE rating of the HRV. The cost savings associated with the reduced heating load depends on the local fuel price and the efficiency of the primary heating system.

3.16 Other

The potential market size needs to be established. This issue was raised during discussions with several HRV manufacturers and the testing agency while this report was being developed. Manufacturers will not develop specialized models and the testing laboratory will have difficulty justifying investing in upgraded systems without a reasonable estimate of the market potential for Northern HRVs. This requires confirmation of the required flow rates as well as development of realistic estimates of potential annual sales volumes. For a Northern specification to succeed, manufacturers must have some assurance that any additional developmental costs can be recovered through anticipated sales levels. That means that for a Northern specification program to work, the various housing agencies must commit to using products that meet program specifications.

CMHC staff provided a rough guess of the potential market size at something on the order of 2000 to 3000 units per year, with potential to increase if a successful Northern HRV specification eventually expands into other Northern climate applications (Alaska, Scandinavia, Russia), Passivhaus and similar projects in the future.

4 List of technical issues identified in Inuvik meeting.

4.1 List of issues (extracted from Inuvik meeting summary provided by CMHC)

Based on a review of the minutes from the Inuvik meeting, key issues were consolidated as follows

Category	**Proposed**	**Discussion / Comments**
Design ventilation rate	15 cfm (8 l/s)/person	Nunavut occupancy averages 6.3 people/unit
	Room count method/ F326	See comment below
Comment	Most HRVs and ERVs are tested and rated at flows close to 30 l/s and/or 55 l/s because they tend to be sized to provide the 40-60% "turned down" continuous operating requirement specified in F326. While Northern houses may be smaller, it	

	appears that they may have higher occupancies so the sizing will likely be similar (i.e. 30l/s and 55 l/s are probably still OK for system continuous ventilation ratings)	
Equipment Design	Require programmable HRV	Who will reprogram – what additional programmability is required. How to avoid subsequent tampering ?
	Defrost should be based on: (1) outside T; (2) building envelope; or (3) demand, as opposed to current timer	Most units now have staged defrost that changes the cycles as outdoor temperature drops
	Operating costs associated with prolonged defrost cycles a problem, especially in light of high electricity costs, linked to imported diesel	Prolonged defrost cycles are likely when outdoor temperatures are severe. Selecting an HRV with full recirculation defrost (rather than simple fan shut-off) helps by avoiding imbalanced flow during defrost. Electric defrost should not be used in cold climates and it is rare for current HRVs. See 3.3
	Dampers should fail in the closed position	If dampers fail defrost method fails. There may be a benefit to ensuring that when an HRV is switched off, all internal dampers move to the closed position to avoid leakage. The nature of defrost motor and damper failures would make it difficult to ensure that they would fail closed.
	Filtration of incoming air	Need effective exterior filters, but they are not normally supplied. External filters will affect static pressure and air delivery. Best approach may be to add an in-line filter (MERV 6 minimum?) at the supply outlet and ensure that the filter is serviced or replaced and cores are cleaned regularly. A washable "electrostatic filter" could probably comply with a filter performance requirement of MERV 6 to MERV 8.
	Sensors a concern	Outdoor T or triggered by indoor RH or CO_2. See 3.4
	Concerns re: excessive	May be installation / balance related

	core freezing: downtime and electrical usage issues	issue. Can reduce concern by selection of HVI certified equipment with low temperature performance ratings
	Need for pre-HRV and post-HRV heaters	Pre heaters severely degrade efficiency and amount of heat recovery. Expensive to operate as well. Post heater improves comfort but may be expensive to operate and control See 3.3 and 3.13
	Set it and forget it	Self balancing would be an advantage
	Need for ECM motors to maintain torque and variable speeds	And to reduce electrical consumption and peak demand
	Make-up air issue especially in homes with range hoods	Make-up air for range hood is not an HRV issue directly. Use of an HRV with a balanced flow defrost strategy will not compound the problem. Using an HRV as a make up air supply implies deliberately operating unbalanced with more supply air than exhaust air. That could lead to draft complaints and freeze-up of the HRV.
	1-800 sticker	Manufacturer info is provided in manuals. Leave manuals with unit. Contact information for the installer and/or service provider should be on the unit
	First cost not as important as reliability	
	Low sone fans to avoid noise	No HVI sound ratings for HRVs. Perhaps avoid high speed during defrost or develop a sound test spec. and test method. See sec. 6
	Higher insulation for cabinets and ducts	See section 3.10
	Need to maintain flow balance	See sec 3.5
	Communicate with other equipment vs. KISS	Furnace interlocks are normally provided. Additional communication/intelligent control

		benefits could be reducing speed or turning the HRV off when other exhaust devices are operating
	Motors on warm side only?	Available on some current HRVs
	Robust performance at -50°C	Tough to verify in advance. Probably would require a significant investment in testing infrastructure See sec 2.3 Field testing may help here
	NWTHC uses Clean air furnaces (CAFs) not HRVs	Note that there is no certification program for products similar to CAFs. How does a CAF defrost itself ? Have there been any problems at low temps with CAFs or similar equipment ?
Installation	High percentage of "poor" installations	Develop better procedures for inst., inspection and commissioning
	Location and access for service is critical – no basement	Behind cabinets (common in European installations as well)
	Balancing and commissioning: -inspections/certifications	YHC Checklist Sec 3.5
	Need better flex duct	Some is available – better still would be desirable. See 3.10
	Supply locations and diffusers to enhance comfort	Need to specify highly efficient systems and careful installation procedures to avoid drafts. Want to pre-mix with room air to minimize cold drafts
	Cross contamination at intakes	Codes identify minimum clearances. Basis for existing separation requirements is unclear
	HRAI training too complicated	Develop simplified training – particularly commissioning and balancing See sec 3.5
	Need longer duct collars	Easier to seal flex ducts on longer collars See sec 3.6
Testing	Need lab testing to at least -40°C	See sec 2.3, and 6
	Field testing is equally important; should be done at multiple sites	Difficult to perform and interpret field testing data (accurate and reliable measurement and data acquisition is expensive).

		Installation differences and occupant behaviour can strongly influence the findings from field trials. Require detailed testing protocols to be in place before installation and careful site selection and qualification. Field testing at severe cold climate sites could be useful to investigate the performance of defrost systems and correlate with lab tests.
Operations and Maintenance	Cold air/ drafts lead to turning HRVs off	Need to spec high efficient systems and careful installation to avoid drafts. Don't install HRVs with simple fan shut-off defrost method.
	Need to "sell" occupants on ventilation	
	Accessibility to tenants – could lead to problems if too accessible	
	Spare parts should be supplied with units	Could be purchased and stocked by the territorial housing corporations – would require trained and licensed personnel to install parts and re-commission the HRV
	Location of control is important	Installation issue. F326 requires an accessible control, centrally located
	Need regular maintenance schedule	True. Manufacturers usually provide maintenance schedule
Other	Power quality issue – surge suppressors	Most surge suppressors are of limited benefit. May be a need for more stringent CSA testing / certification of electrical components and assemblies.
	Is F 326 appropriate	F 326 is on extended Hiatus but still probably OK for sizing.
	Debate re merits of heat recovery	
	NWTHC use exhaust-only systems	This creates potential for depressurization spillage and related problems. No heat recovery. Properly qualified HRV should reduce operating costs. See 5 and 6
	Need clear bid specs	Not an HRV issue
Costs	YHC estimate $5k for an HRV in Whitehorse	

	(simplified installation) and $17 k for fully ducted system	
	NWTHC estimate $5K for a simplified Yellowknife HRV installation - additional $3K for more remote sites	
	NHC estimate $7K for simplified HRV installation in Iqaluit	

4.2 Analysis of whether the issues are legitimate concerns or a result of other factors (i.e. bad installation).

See comments in 4.1

4.3 Analysis of whether solutions to those issues exist

See comments in 4.1

5 The Ideal Northern HRV

The ideal Northern HRV would be electrically efficient as well as efficient in terms of energy recovery. The efficiency would be high enough that tempering of the supply air would not be needed. That would require a supply air temperature on the order of 15°C and provision for tempering by blending the supply air with room air before delivery from the ventilation duct.

It would be compact, quiet, use self balancing fans and be equipped with a high performance filter for the fresh air stream. It would be equipped with a durable, non depressurizing defrost mechanism that has been performance validated through independent laboratory testing at the design temperature (or colder) for the location where it will be installed. The unit would minimize the length of cold side ductwork and possibly be provided with an optional through the wall mounting configuration to avoid cold side ductwork. The cabinet would have an enhanced insulation package to prevent condensation from occurring. It would automatically sense the need for ventilation and operate when required using appropriate control sensors (occupancy, humidity, CO_2 or pollutant sensing as appropriate). Remotely located controls would enable occupants to over-ride automatic control functions. The unit would have self-diagnostics and provide an indicator (or indicators) to automatically signal when service (both routine and repair) is required to either the unit or its controls.

At this time, no known HRVs match that description.

6 Northern HRV Specification

A proposed Northern HRV specification is provided here. It relies on the recently implemented Canadian ENERGY STAR specification for HRVs and ERVs, with an additional performance test at a temperature lower than -25°C.

The existing ENERGY STAR specification requires that the unit provides a minimum fan efficacy and meet a minimum efficiency at -25°C. Those requirements will become more stringent when Tier 2 takes effect in 2012. When the requirements were finalized in December 2009, only 28 % of the then-available HVI-certified base HRV models complied with Tier 1 requirements and only 12 % would comply with Tier 2 requirements that will take effect less than two years from now. Clearly, using the ENERGY STAR criteria as a base requirement for a Northern housing specification immediately provides an effective and unbiased screen to select the top performers. It also minimizes redundancies in performance requirements.

The Tier 1 and Tier 2 requirements are shown below.

Tier 1 Canadian ENERGY STAR HRV SRE and Fan Efficacy Minimum Requirements (effective January 1, 2010)

Climate Zone	Zone Definition	Minimum SRE at 32°F (0°C)	Minimum SRE at -13°F (-25°C)	Minimum Fan Efficacy with 32°F (0°C) supply temperature	
Heating	Canada	60%	55%	SRE < 75%	1 cfm/W (0.47 L/s/W)
				SRE ≥ 75%	any cfm/W (L/s/W)

Tier 2 Canadian ENERGY STAR HRV SRE and Fan Efficacy Minimum Requirements (effective July 1, 2012)

Climate Zone	Zone Definition	Minimum SRE at 32°F (0°C)	Minimum SRE at -13°F (-25°C)	Minimum Fan Efficacy with 32°F (0°C) supply temperature	
Heating	Canada	65%	60%	SRE < 75%	1.2 cfm/W (0.57 L/s/W)
				SRE ≥ 75%	0.8 cfm/W (0.38 L/s/W)

In addition to the above requirements, a minimum (SRE) during a low temperature test at -40° is recommended for a Northern housing specification. Ideally the -40°C test would be performed in compliance with CSA C439 for a time period of 72 h at the same flow used for the other ratings. However, because of test facility limitations, that may not be possible. As a first step, an abbreviated test of at least 24 h duration immediately following a test at -25°C could be used to qualify products at -40°C, calculating the performance rating from the last 4 or 6 h of the test. A test of shorter duration would not be adequate to identify performance deficiencies at extreme temperatures because it takes some time to "cold-soak" the test sample. The minimum performance requirement might be set at a minimum of 50% SRE at -40°C. Both the test duration and minimum performance requirement could be revised if necessary as more is learned about the extreme low temperature testing capability of the laboratory, the performance of the products and the market demand for qualified units.

A filter performance specification could be included in the specification (or in a separate installation specification) if enough stakeholders feel that such a specification is warranted. Including a minimum filter performance specification may force manufacturers to use more powerful fans and motors which will increase the electrical energy use and probably require more frequent replacement of the filter. When the CSA P.10 standard was developed for integrated mechanicals, a minimum MERV of 10 was initially specified for the ventilation and air circulation systems. The pressure drop produced by MERV 10 filters proved to be problematic in early testing of prototype integrated equipment and the draft standard was revised to remove a filter performance requirement. The P.10 standard now requires only reporting of the rated MERV value for the filters that were installed during testing. No such requirement exists in CSA C439 for HRVs.

Sound ratings for HRVs, ERVs and in-line ventilating fans are not normally provided in North America because it has generally been assumed that properly ducted installations do not produce or transmit excessive sound levels. Documented complaints for some of the Northern installations that were raised during the Inuvik meeting suggest that that assumption may be questionable. The sound complaints indicate that consideration should be given to inclusion of some sound testing in the specification. CSA C439 does not currently include any procedure for sound testing of HRVs, but CSA C260 does contain sound testing procedures that could be called up if desired. However, the C260 standard test setups do not match the types of installation setups that are causing complaints, so different setups would be required. It is suggested that sound testing be assigned a lower priority than thermal and electrical performance requirements and deferred until later versions of the Northern specification.