Air Ventilation Systems for Housing in the Arctic

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NRC Artic Program

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Arctic Program Overview

Research supporting:
- Sustainable resource exploration and development
- Codes and standards development
- Marine safety technologies
- Environmental remediation
- Cold regions infrastructure
- Improved northern housing
- Improved northern shipping
- Extending the life of ice roads

OBJECTIVE
Ensure sustainable, low-impact development of the North while increasing the quality of life for Northerners
### Meeting Industry’s Challenges

#### Oil & Gas
- Lack of technology for next generation in more remote locations
- Shorter periods of operability, with lower worker productivity due to harsh environmental conditions
- Higher developmental costs

#### Marine Transportation
- New routes through more remote and ice covered waters
- IMO regulations governing emissions
- Providing a safer working environment
- New port and harbour infrastructure to support trade and development

#### Safety at Sea
- Technology in use today rarely designed for cold climates, sea ice and remoteness considerations
- Existing technology used by natural resource, academic, military, commercial parties – broad application

#### Northern Communities
- Housing sub-standard in many areas
- Current infrastructure primitive by southern standards
- Utilities expensive
- Training for maintenance unavailable
Arctic Thrusts and Themes

NRC Arctic Program

Thrust 1 Resource Development
- Theme 1 Design Ice Loads
- Theme 2 Ice Management
- Theme 3 Ice Seabed Gouging
- Theme 4 Ice Conditions
- Theme 5 Oil Spills in Ice

Thrust 2 Northern Transportation
- Theme 1 Shipping Regulations
- Theme 2 Vessel Routing
- Theme 3 Reducing Shipping Risk
- Theme 4 Winter Ice Roads

Thrust 3 Marine Safety Technologies
- Theme 1 Input into Safety Regulations
- Theme 2 Evacuation Egress Technologies
- Theme 3 Evacuation Survivability Technologies
- Theme 4 Next Generation Evacuation and Survival Systems

Thrust 4 Community Infrastructure
- Theme 1 CSA Standards
- Theme 2 Reliable Water
- Theme 3 Settling Foundations
- Theme 4 Energy Efficiency
- Theme 5 Sewage Treatment
- Theme 6 Contaminated Sites
Community infrastructure - themes

- Support Arctic infrastructure standards
- Energy efficient houses
- Indoor comfort and air quality
- Foundation systems
- Reliable water and sewage systems
- Bioremediation of contaminated sites
Minimize heat loss: **air-tightness; insulation**

Maintain healthy IAQ: **sufficient fresh air intake**

**Balanced ventilation**

**HRV cores freeze** in winter

**HRV failure** in extreme cold:
- IAQ deterioration
- Reluctance to use HRVs
Residential Ventilation Practices

- **Supply Only Ventilation**
  - Works by pressurizing a home (positive air pressure).
  - Pushes hot and/or humid air into walls and insulation; condensation can lead to mold, mildew or rot.
  - Heat escapes from inside the home as it is pushed through the walls to the exterior (increase heating cost).

- **Exhaust Only Ventilation**
  - Works by depressurizing a home (negative air pressure).
  - Infiltration of unconditioned air increases risks of mold and higher energy cost.
  - Can draw pollutants into living space (from attic, crawlspace, garages, etc.)

- **Exhaust & Supply Ventilation**
  - Equal pressure.
  - Balanced system, supply airflow is equal to stale air exhaust.
  - Heat recovery and cost-effective in cold climates.
Minimum continuous ventilation capacity requirements are calculated based on the codes and Standards (NBC and CSA).

How much air does a person need?

A person needs 7.5 CFM for breathing. $\text{CFM} = 7.5 \times N_p$

Air for people?

- Add up the number of occupants.
- Add up the number of bedrooms, then add 1.
- Whichever is greater is the number to use.
- Multiply that number times 7.5 CFM.

How much air does a house need?

A house needs 3 CFM of fresh air per 100 ft$^2$ of living space. $\text{CFM} = 0.03 \times A_{\text{floor}}$

Total ventilation requirement (people air needs + house air needs)

$Q_{\text{tot}} = 0.03A_{\text{floor}} + 7.5(N_p)$
Heat and Energy Recovery Ventilators

- HRVs simultaneously supply and exhaust equal quantities of air to and from a house while transferring heat (by way of a heat exchanger) between the two airstreams.

- ERV functions in a similar way to an HRV, but in addition to recovering heat, it also transfers moisture between the exhaust and supply airstreams.

- This can be advantageous when there is a need to maintain indoor RH levels in the winter or to reduce the moisture incoming outdoor air in the summer (a concern in warm, humid climates)
Defrost Strategies: impact on IAQ and energy

HRV Systems operated in cold climates require devices to help prevent freezing and frost formation.

- Closing the incoming supply damper and exhausting inside air through the core
  - Transform the ventilation system temporarily into an exhaust-only ventilation strategy
  - Can draw pollutants into living space (from attic, crawlspace, etc.)

- Closing the incoming supply air and recirculates the interior air for a set period of time to melt any frost that has built in the core
  - Recirculating interior stale air reduces the amount of fresh air into the space

- Pre-heating the incoming air with an electric duct heater
  - The heater uses electricity and can make the HRV less efficient
PERD Project 2016-20 - Partners

- NRC Arctic Program
- NRCan CanmetENERGY Ottawa
- NRCan CanmetENERGY Varennes
- CMHC Ottawa
- Engage Industry
- Collaborate with Northern Stakeholders
PERD Project 2016-20 - Objectives

Develop an energy efficient and reliable air ventilation systems for Housing in the Arctic.

- Improve the understanding of arctic ventilation issues and requirements.
- Investigate means of improving the energy efficiency of providing ventilation for housing in a harsh northern climate communities.
- Develop innovative heat/energy recovery systems that are effective at managing frost built in the North while delivering effective heat recovery and required fresh air supply.
- Disseminate best-of-practice knowledge and housing design.
Ventilation and Heating Challenges in Canada’s North

- A challenging accomplishment in an environment where heat recovery ventilators are very vulnerable to freezing.
- All heat recovery ventilation systems need additional defrost provisions.
- Ventilation openings need protection from wind-driven snow.
- Improper installation and set-up in the remote northern locations.
- Lack of energy resources in remote locations – no natural gas, propane, and diesel must be transported in tanks or drums.
Current Technology

- Currently single core heat/energy recovery ventilation systems are installed in the North.
- Usually designed/developed for southern market (mild and hot climates).
- Dual-core heat/energy approach recovery system can be a new viable solution as alternative to single core units
  - Series configuration
  - Parallel configuration
The technology works by using one core as a pre-heater and a second as a booster.

Such as and enthalpy core (booster) and sensible core (pre-heater).

Designed to reduce the potential of core freeze-up

Outdoor air is brought through the pre-heat core first and the into the booster core,

Exhaust air passes through the booster core first and then through the pre-heat core.

This allows moisture in the exhaust air to condense in the booster core and be drained away reducing the likelihood of freeze-up in the pre-heat core.
Dual-core – Parallel configuration

- Dual core regenerative technology
- As one core is defrosting, the other core is being used to pre-condition ventilation air (the active core).
- As the active core becomes frosted up, a set of dampers switch the air flow to the core that was defrosting.
- The ventilation flow rate is maintained as the outdoor air directed to each core in turn.
- A dual core unit heat exchanger is installed at the Churchill Northern Studies Centre, does not require any preheat.
NRC Arctic Program

Their work will focus on a dual core heat recovery technologies;
- Propose (in collaboration with industry partners) 2-3 technologies for evaluation.
- Lab testing of the selected technologies using a climatic chamber.
- Side-by-side testing (comparison with conventional technology) using the CCHT twin houses in Ottawa.
- Deployment in the North for field monitoring.
- Performance of deployed technologies (energy, ventilation effectiveness and IAQ).

NRCan CanmetENERGY Ottawa

Their work will focus on 1 prototype that incorporates two technologies;
- An advanced high efficiency heat exchange technology and,
- Potential defrost strategy using a solid state heat pumping from outgoing air to incoming air, that reduces the number of defrost cycles required.
NRCan CanmetENERGY Varennes

Their work will focus on a thermosyphon pre-heat;
- The approach consist of connecting a thermosyphon below the building to pre-heat coil.
- The thermosyphon unit pre-heats the outdoor air supplied to an HRV unit.
- \( \text{CO}_2 \) will be the phase change fluid used for the thermosyphon.

CMHC Ottawa

Their work will focus on a knowledge of HRV performance and techniques for improvement;
- Survey of HRV units, design/installation and common problems across the North.
- Assessment of the monitoring data from the Cambridge Bay HRV and Yukon studies.
- Support the field testing of the HRV technologies developed by project partners.
Furnace Fan Generated Air Exchanger System (winter 2013/14)
Airflow performance dependant on the available static pressure from furnace fan.

Higher sensible effectiveness and showed no sign of frost problems.

Continuous fresh air without stopping to defrost (compared to HRV unit – 64 hours defrosting over two weeks).

Small increase in heating/ventilation energy consumption, 2.5%.

Significant cooling/ventilation energy saving, 11%.
Project on the Relationship between Ventilation, IAQ and health

Will increased home ventilation decrease the number of asthmatic symptoms in children?

• Correlation of IAQ with ventilation rates in 111 homes
• Determine the effectiveness of ventilation interventions at improving IAQ and respiratory health

Partnership between;
Filed Studies: Relationship between Ventilation, IAQ and Health

Target ventilation rates met through H(E)RV’s
Relevant IAQ pollutants significantly reduced

Post-Intervention concentration reductions:

- Benzene ↓15 %
- Formaldehyde ↓30 %
- Airborne mould spores ↓38%
Project on balanced ventilation IAQ impacts

- ASHRAE Standard 62.2 - assumption that for all ventilation system cases, the entire house is a single, well-mixed zone.
- No difference between different whole-building ventilation systems in providing effective ventilation.
- Ventilation rate has to be high enough to accommodate the worst performing system, which is single point exhaust.
- A research gap is to allow credit for better performing ventilation systems, such as balanced ventilation system.
Comparing balanced ERV ventilation and exhaust-only ventilation in a side-by-side Testing

Hypothesis: Balanced ventilation system improve the IAQ compared to exhaust-only ventilation system
## Description of the side-by-side tests

<table>
<thead>
<tr>
<th>Test #</th>
<th>Test name</th>
<th>House 1</th>
<th>House 2</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Baseline</td>
<td>No ventilation</td>
<td>No ventilation</td>
<td>No central fan operation in both houses</td>
</tr>
<tr>
<td>2</td>
<td>Exhaust vs. ERV (without mixing)</td>
<td>Exhaust</td>
<td>ERV</td>
<td>Exhaust from master bathroom in House 1 ERV with supply to return plenum and exhaust from kitchen and bathrooms in House 2 No central fan operation in both houses</td>
</tr>
<tr>
<td>3</td>
<td>Exhaust vs. ERV (with mixing)</td>
<td>Exhaust</td>
<td>ERV</td>
<td>Exhaust from master bathroom in House 1 ERV with supply to return plenum and exhaust from kitchen and bathrooms in House 2 20% central fan operation (48 off / 12 on)</td>
</tr>
</tbody>
</table>
Methodology

- Air leakage characterization – fan depressurization tests
- HVAC characterization - central air distribution system airflows and ventilation systems airflows.
- Pressure in designated zones with respect to outside
- Pressure in attic and garage with respect to indoor
- Perfluorocarbon tracer gas (PFT) testing to determine zone air change rates.
- Decay tracer gas ($\text{SF}_6$) testing to determine zone air change rates
- Multi-zone sampling of volatile organic compounds (TVOC and VOCs), formaldehyde.
- Sampling of airborne particulates.
Project Progress

- Testing took place in fall 2015 and completed in December 2015.
- Data analysis is in progress.
- Project report is in progress and will be available by April 2016.
Discussion