Evaluation of IAQ impact of balanced residential ventilation devices that incorporate heat recovery ventilation (HRV) and/or enthalpy recovery ventilation (ERV)

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https://doi.org/10.4224/21105051

Evaluation of IAQ Impact of Balanced Residential Ventilation Devices that Incorporate Heat Recovery Ventilation (HRV) and/or Enthalpy Recovery Ventilation (ERV)

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Prepared for: Government of Canada,
Clean Air Agenda, Indoor Air Initiative,
Evaluation of IAQ Solutions in Support of Industry Innovation

Date Issued: July 17th, 2012

Notice

This test method was developed by the National Research Council Canada (NRC) to evaluate the indoor air quality (IAQ) impact of “balanced” residential ventilation devices that incorporate heat recovery ventilation (HRV) and / or enthalpy recovery ventilation (ERV). The project was funded as part of the Government of Canada’s Clean Air Agenda, as part of NRC’s Indoor Air Initiative (IAI), and was one of three protocols for evaluating the effectiveness of “IAQ Solutions”. It was prepared by NRC researchers under the guidance of a Technical Advisory Committee (TAC) assembled for this task, whose members included participants representing Federal and Provincial Agencies, Industry Associations, Non-Governmental Organizations (NGOs), Municipal governments, and Standards Associations from Canada. The contributions of the TAC members (listed below) to this work are gratefully acknowledged.

Compliance to the test method and to the data interpretation developed in this test method is voluntary.

Members of the ***Technical Advisory Committee*** on IAQ Solutions, NRC-Construction Indoor Air Initiative:

TAC Member	Agency / Organization
Zuraimi M Sultan, *Chair*	National Research Council Canada, NRC - Construction
Prabjit Barn	British Columbia Centre for Disease Control (BCCDC)
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Test Method: IAQ Impact of "balanced" residential ventilation devices that incorporate heat recovery ventilation (HRV) and / or enthalpy recovery ventilation (ERV)

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2 PREFACE

This test method describes procedures for evaluating the IAQ impact of balanced residential ventilation devices that incorporate heat recovery ventilation (HRV) and / or enthalpy recovery ventilation (ERV). The protocol was developed by the National Research Council of Canada's Construction Portfolio under the guidance of a Technical Advisory Committee (see list in page 3) formed to develop a series of evaluation protocols for "IAQ Solutions".

A HRV system is a type of balanced system in the sense that it combines both supply and exhaust air flows in one housing unit. Typically, a pair of fans within the HRV unit drives the two air flow streams. At the heart of an HRV unit, a heat exchanger transfers heat between the outdoor (intake airstream) and indoor (exhaust airstream) air flow streams to reduce heat loss during winter season and to reduce cooling losses when air conditioning is employed during summer months. An ERV is mechanically similar, but uses a moisture-permeable system between the two flow streams so that humidity transfer (latent heat) also occurs in addition to the sensible heat transfer. In winter, an ERV could prevent excessive drying of the indoor air by re-capturing some of the moisture from the indoor air and returning it to the incoming dry outdoor air (pre-humidifying the incoming air). In summer, the opposite occurs, high humidity outdoor air transfers moisture to the outgoing exhaust air (pre-dehumidifying the incoming air), keeping the indoor humidity level somewhat lower. There are multiple ways and levels of complexity by which an HRV or ERV system can be installed in a house including installation as completely independent systems with their own dedicated supply and return ductwork systems.

A basic balanced system with heat recovery is shown in Figure 2-1.

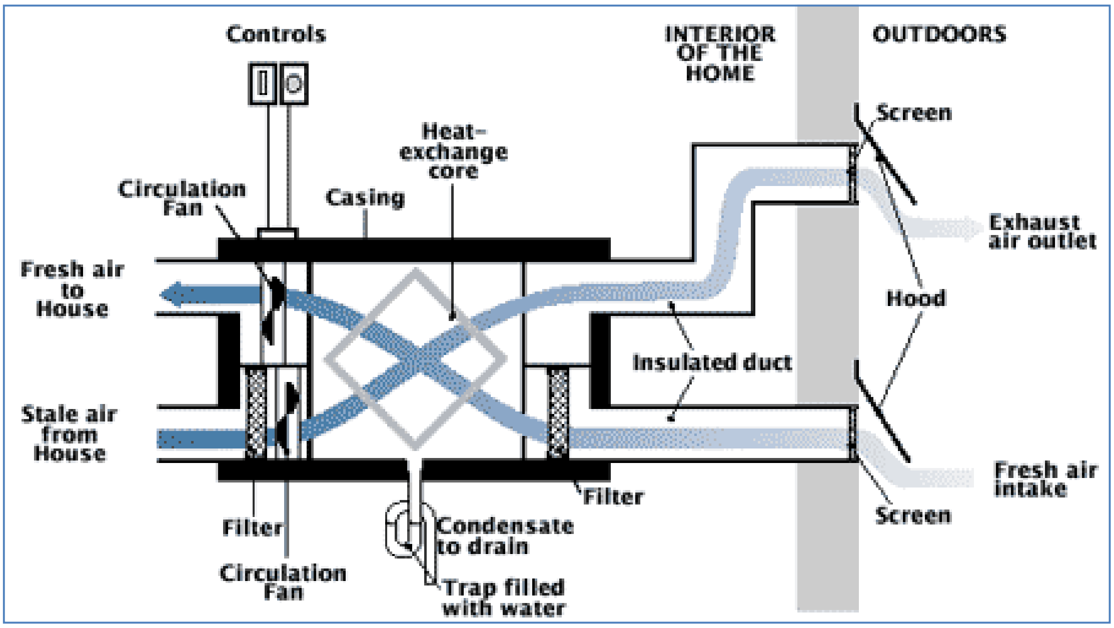

Figure 2-1: Basic HRV System

Source: http://www.oee.nrcan.gc.ca/residential/personal/new-homes/r-2000/standard/how-hrv-works.cfm

Several standards exist that evaluate the ventilation, thermal and energy efficiency of these devices as well as their mechanical and electrical safety (***CAN/CSA C-439***, ***CAN/CSA 22.2 No. 113-M***, and ***HVI 915***) (Please refer to Appendix 10.1 for additional details). Through these standards, the following performance characteristics are assessed:

- Net outdoor airflow
- Low-temperature ventilation reduction factor (LTVR)
- Exhaust air contamination (transfer) ratio (EATR)
- Apparent effectiveness (sensible, latent and total)
- Heat-recovery efficiency (sensible, latent and total)

Balanced ventilation systems utilize a wide range of components and materials assembled in a variety of configurations. While many use very basic filtration intended primarily to protect the mechanical equipment, others incorporate enhanced filtration systems intended to improve residential indoor air quality. The actual installation practices of these balanced ventilation systems within a residence depend on many factors, including whether a forced air system for heating/cooling exists, and how the HRV/ERV unit is interfaced with this system.

The high degree of variability makes design of a “standard” test configuration to evaluate IAQ impact impossible. This test method follows the approach taken by CAN-CSA C439-09 in utilizing a standard test rig for mounting the “unit under test” (UUT). By building on existing standardized methods and using or adapting their specific techniques and terminology to the extent possible, this test method will facilitate adoption by industry/standardization bodies and simplify overall testing needs.

An initial review of IAQ Solution Technologies (Zuraimi et al., 2011) identified gaps in existing standards associated with testing the HRV/ERV performance. Despite the incorporation of filtration technologies in many HRV/ERV devices, there is currently no test method that evaluates the pollutant removal performance of these technologies in the HRV/ERV units under a single pass or recirculation mode. Furthermore, test methods to determine cleanliness or emissions of HRV/ERV systems or parts are not available. This is a critical gap as the supply air may become contaminated if HRV/ERV systems or parts are made of materials that off-gas chemicals into the airstream. Existing standards have focussed only on ventilation and energy efficiency aspects, while none deal with these IAQ performance aspects (see Sections 10.1 to 10.4).

Following the above mentioned review, a stakeholder workshop comprising builders, researchers, industry partners and health professionals was held in Ottawa, Ontario in March 2010 to identify gaps and prioritize areas of the HRV/ERV test method development. Among the various IAQ performance aspects discussed, stakeholders recommended evaluation of HRV/ERV filtration, effectiveness of optional IAQ sensors for indoor humidity and HRV/ERV operations and controls (flow balancing and defrost performance) as high priority areas. They also recommended indoor VOC and particulate matter as pollutants that need to be addressed when evaluating IAQ performance of HRV/ERV. Under the guidance of the TAC, these suggestions were reduced to four priority areas based on feasibility, practicality and resource availability considerations. In particular, the TAC recommended addressing the following priorities:

1. verifying the initial (new system) performance of HRV/ERV systems in terms of the volumetric flow rates,
2. characterizing emissions and by-product release of contaminants from the HRV/ERV system into the supply air,
3. characterizing particle filtration efficiency, and
4. characterizing emissions of contaminants from single HRV/ERV components.

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3 SCOPE

This test method addressed gaps identified by key stakeholders through extending existing HRV/ERV performance standards. Specifically, it examines the following performance aspects of balanced ventilation systems with heat/enthalpy recovery:

- Volumetric flow rates: confirmation of all specified volumetric flow rates of the installed system
- Emissions of volatile organic compounds (VOCs) and carbonyl compounds [1](including formaldehyde[2]) released into the residential supply air by the complete HRV/ERV system (including all required/recommended ducting materials, connections and intakes)
- Headspace analysis[3] of emissions from individual HRV/ERV components (if deemed necessary to pinpoint contaminant sources – Figure 6.1)
- Potential ozone formation by HRV/ERV system motors and/or supplemental filtration devices[4]
- Filtration of outdoor air particulates (PM_{10} and $PM_{2.5}$ [5] mass fractions as well as number concentrations). Filtration of return air particulates from indoor sources (PM_{10} and $PM_{2.5}$ mass fractions as well as number concentrations) for systems claiming to provide recirculation filtration as a means of indoor PM control.

4 REFERENCE PUBLICATIONS

ANSI/AHRI 1060-2005 *Performance Rating of Air-to-Air Exchangers for Energy Recovery Ventilation*

ANSI/AMCA 210-2007 - ANSI**/ASHRAE Standard 51-07** *Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating*

ANSI/ASHRAE Standard 41.2-1987 (R1992) - *Standard Methods for Laboratory Airflow Measurement*

ANSI/ASHRAE Standard 52.2-2007 *Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size*

ANSI/ASHRAE Standard 62.2-2010 *Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings*

ANSI/ASHRAE Standard 84-2008 M*ethod of Testing Air-to-Air Heat Exchangers*

ASHRAE Fundamentals-2009

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[1] Carbonyl compounds are a group of chemical compounds that can be classified as volatile organic compounds. In this test method however, they are classified separately because the sampling and analytical methods used are different from those used for volatile organic compounds (see sections 6.5 and 6.6).

[2] Health Canada has developed an indoor air quality guideline for formaldehyde in residences. The guideline sets recommended maximum formaldehyde levels for two types of exposures: short term (100ppb) and long term (40ppb) exposures.

[3] This is a semi-quantitative screening method to get an overview over the relevant emitting parts of the HRV or ERV system.

[4] Health Canada advises against using devices that intentionally generate ozone. The indoor air quality guideline for ozone in residences sets a recommended maximum ozone level for long-term exposure of 20 ppb.

[5] PM_{10} : Coarse and Fine Particulate Matter (PM) airborne particulate matter with a mass median aerodynamic diameter less than 10 µm; $PM_{2.5}$: Fine PM with a mass median aerodynamic diameter less than 2.5 µm. PM_{10} is chosen for this test method because it is associated with PM that is inhalable into the human body. Health Canada has identified $PM_{2.5}$ to be relevant because of its association with adverse health outcomes.

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ASHRAE Handbook -2009 – *HVAC Systems and Equipment*

ASTM D3154-00(2006) *Standard Test Method for Average Velocity in a Duct (Pitot Tube Method)*

ASTM D5116-2010 - *Standard Guide for Small-Scale Environmental Chamber Determinations of Organic Emissions from Indoor Materials/Products*

ASTM D5197-2009e1 - *Standard Test Method for Determination of Formaldehyde and Other Carbonyl Compounds in Air (Active Sampler Methodology)*

ASTM D6196-03(2009) - *Standard Practice for Selection of Sorbents, Sampling, and Thermal Desorption Analysis Procedures for Volatile Organic Compounds in Air*

ASTM D6345-2010 - *Standard Guide for Selection of Methods for Active, Integrative Sampling of Volatile Organic Compounds in Air*

CAN/CSA 22.2 NO. 113-M1984 (R2004) *Fans and Ventilators*. Canadian Standards Association

CAN/CSA C439-00 (2009) *Standard Laboratory Methods of Test for Rating the Performance of Heat/Energy-Recovery Ventilators*

CAN/CSA F326-M91 (R2010) - *Residential Mechanical Ventilation Systems*

Health Canada (2006) *Residential Indoor Air Quality Guideline - Formaldehyde*

Health Canada (2010) *Residential Indoor Air Quality Guideline - Carbon Monoxide*

Health Canada (2010) *Residential Indoor Air Quality Guideline - OZONE*

HVI Publication 915 (2009) Loudness *Testing and Rating Procedure*. Revised Edition (1 March 2009). Home Ventilating Institute

National Building Code of Canada (2010)

UL 867 (1995) *Electrostatic Air Cleaners.* Underwriters Laboratories

UL 1812 (2010) *Ducted Heat Recovery Ventilators.* Underwriters Laboratories

WHO (2010) World Health Organization Guidelines for indoor air quality: Selected pollutants

Zuraimi MS, Magee R, Nilsson G. (2011). IAQ Solutions and Technologies: Review and Selection for Protocol Development, pp. 1-173, March-31-11 (NRCC-54495) http://www.nrc-cnrc.gc.ca/obj/irc/doc/pubs/nrcc54495.pdf

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5 TERMINOLOGY:

5.1 Fan performance

External Static Pressure (ESP) - the rise in static pressure across the fan as result of airflow resistance due to ductwork, fittings, dampers, grilles and any other devices located in the airstream
ESP = [OSP + ISP (abs value)]

Fan Static Pressure (FSP) – commonly used to rate fan performance, Fan Static Pressure is the calculated difference between Fan Total Pressure and Fan Outlet Velocity pressure

FSP = [FTP – OVP] = Fan Total Pressure minus Fan Outlet Velocity pressure

Fan Total Pressure (FTP) – FTP = [OTP + ITP (absolute value)] = rise across the fan of total pressure

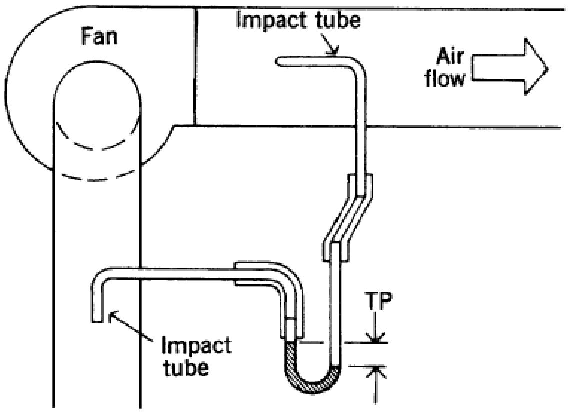

Figure 5-1: Diagram of FTP measurements (source: Kruger Fan Technical Bulletin TBN002.2/2003)

Inlet Static Pressure (ISP) - Static pressure measured *upstream* of fan

Inlet Total Pressure (ITP) - ITP = [ISP + IVP]

Inlet Velocity Pressure (IVP) - Velocity pressure measured *upstream* of fan

Outlet Static Pressure (OSP) - Static pressure measured *downstream* of fan

Outlet Total Pressure (OTP) - OTP = [OSP + OVP]

Outlet Velocity Pressure (OVP) - Velocity pressure measured *downstream* of fan

Unit Under Test (UUT) - The complete HRV/ERV system being evaluation, including recommended flex ducting and connections

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5.2 HRV / ERV Performance

Table 5-1: HRV/ERV Performance Terms and Definitions

Term	Definition	Source
Carryover	In regenerators, the amount of exhaust air that is transferred to the supply by the mechanical operation (the rotation) of the exchanger, i.e., the air trapped within the matrix pore space of the energy wheel as it rotates from the exhaust to the supply airstream	ANSI/ASHRAE 84
Exhaust Air Transfer Ratio (EATR)	The ratio of the exhaust air transfer to the supply flow rate.	ANSI/ASHRAE 84
	The tracer gas concentration difference between the Leaving Supply Airflow and the Entering Supply Airflow divided by the tracer gas concentration difference between the Entering Exhaust Airflow and the Entering Supply Airflow at 100% rated airflows, expressed as a percentage.	ANSI/AHRI 1060
Entering Exhaust Airflow (Return Air)	The exhaust airstream before passing through the heat exchanger, shown as Station 3 in ASHRAE Standard 84.	ANSI/AHRI 1060
Entering Supply Airflow	The Supply Airflow before passing through the heat exchanger, also referred to as outdoor air, and defined in ASHRAE Standard 84 as Station 1.	ANSI/AHRI 1060
Exhaust Air Transfer	The air quantity transferred from the exhaust to the supply. Exhaust air transfer is typically a measure of both carryover and leakage.	ANSI/ASHRAE 84
Exhaust Airflow	Airflow leaving the conditioned space.	
HEPA	High Efficiency Particulate Air (U.S. Department of Energy definition), also High Efficiency Particulate Arrestance, or High Efficiency Particulate Absorbing • MIL-STD-282 Method 102.9.1 o HEPA = 99.97% capture of contaminants at 0.3 um	U.S. Department of Energy MIL-STD-282 Method 102.9.1
Leaving Exhaust Airflow (Exhaust Air to Outside).	The exhaust airstream after passing through the heat exchanger, shown as Station 4 in ASHRAE Standard 84.	ANSI/AHRI 1060
Leaving Supply Airflow	The Supply Airflow after passing through the heat exchanger, and defined in ASHRAE Standard 84 as Station 2.	ANSI/AHRI 1060
Net Supply Airflow	That portion of the Leaving Supply Airflow that originated as Entering Supply Airflow. The Net Supply Airflow is determined by subtracting air transferred from the exhaust side of the heat exchanger from the gross airflow measured at the Supply Airflow leaving the heat exchanger and is given by the equation: Net Supply Airflow = Leaving Supply Airflow x (1 - EATR)	ANSI/AHRI 1060
Outdoor Air Correction Factor (OACF)	The Entering Supply Airflow divided by the measured (gross) Leaving Supply Airflow.	ANSI/AHRI 1060

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Term	Definition	Source
	The entering supply airflow divided by the leaving supply airflow (= m_1 / m_2 where m_1 and m_2 are the mass flow rates of dry air at Stations 1 – Supply Inlet and 2 – Supply Outlet).	ANSI/ASHRAE 84
Recovery Efficiency Ratio (RER)	Ratio of the energy recovered divided by the energy expended in the energy recovery process. $\text{RER} = \dfrac{\dot{m}(h_1 - h_2)}{(\Delta p_s Q_s / \eta_{fs} + \Delta p_e Q_e / \eta_{fe} + q_{aux})}$	ANSI/ASHRAE 84
Standard air	Dry air at 21°C and 101.325 kPa absolute. Under these conditions dry air has a mass density of 1.204 kg/m^3.	ANSI/ASHRAE 84
Supply Airflow.	The outdoor airflow, also referred to as rated airflow.	ANSI/AHRI 1060

5.3 Other Abbreviations

CAS#	Chemical Abstracts Service registration number
cfm	cubic feet per minute
DNPH	2,4-Dinitrophenylhydrazine
GC/MS	gas chromatograph/mass spectrometer
HPLC	high performance liquid chromatography
L	litres
L/s	litres per second
ng	nanograms
NIST	National Institute of Standards and Technology
Pa	Pascals
PM	particulate matter
ppb	parts per billion
ppm	parts per million
RT	retention time
s	seconds
TVOC	Total volatile organic compounds
UV	ultra-violet
wg	inch of water gauge
$\mu g/m^3$	microgram per cubic metre

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6 PROTOCOL

6.1 Overview of Test Methods:

The TAC recommended testing the initial (new system) performance of HRV/ERV systems in four key areas:

- **Volumetric Flow Rates:** Confirmation of specified volumetric flow rates of the installed system **(Test 1).**
- **Complete System Emissions:** By-product (ozone) and organic compounds emissions of the installed complete system **(Tests 2a and 2b).**
- **Particle Filtration:** Removal efficiency performance of the installed system **(Test 3).**
- **System Component Emissions:** Organic compound emissions of individual HRV/ERV System components (headspace chamber tests of system components if results from Test 2b indicate the presence of a contaminant source from the system) **(Test 4).**

Figure 6-1 illustrates the flow chart of the test method.

Test 1 simply verifies that the UUT is providing the specified flow rates under standard conditions (as claimed by the manufacturer and / or certified by independent test agencies). It also provides an initial flush-out or conditioning period for the UUT. **Test 1** is a Pass / Fail based on UUT age and flow performance criteria that shall be passed before IAQ performance testing (**Tests 2, 3 and 4**) is initiated**.**

Tests 1 to 3 are considered "core" IAQ performance tests that shall be completed on fully assembled operational HRV/ERV systems.

Test 4, examining component emissions, is required only if the results from **Test 2** indicate presence of strong (a "Fail" in the evaluation criteria given in this protocol) organic compound source or sources that individual component testing will help to identify for corrective action or product improvement/retesting.

For Tests 1, 2 and 3, any flexible ductwork specified by the manufacturer is included in the UUT system. A standard bench top test rig based on an existing standard - CAN/CSA-C439 has been developed for this purpose (Section 7). However, due to the wide range of specific system components, design features and operational modes available for any particular HRV / ERV system, the precise steps required for **Tests 2 and 3** may depend on the particular HRV/ERV system under test. Examples include systems that incorporate enhanced filtration systems (gas-phase or particulate) and / or flow pathways that can switch to partial or full recirculation modes depending on user-defined setpoints and / or periodic cycles that may or may not depend on outdoor air temperature, or responses from optionally humidity or sensors that crudely measure IAQ.

Tests 2 and 3 must be conducted on a new system shipped directly from the manufacturing site in order to determine initial performance and IAQ impact.

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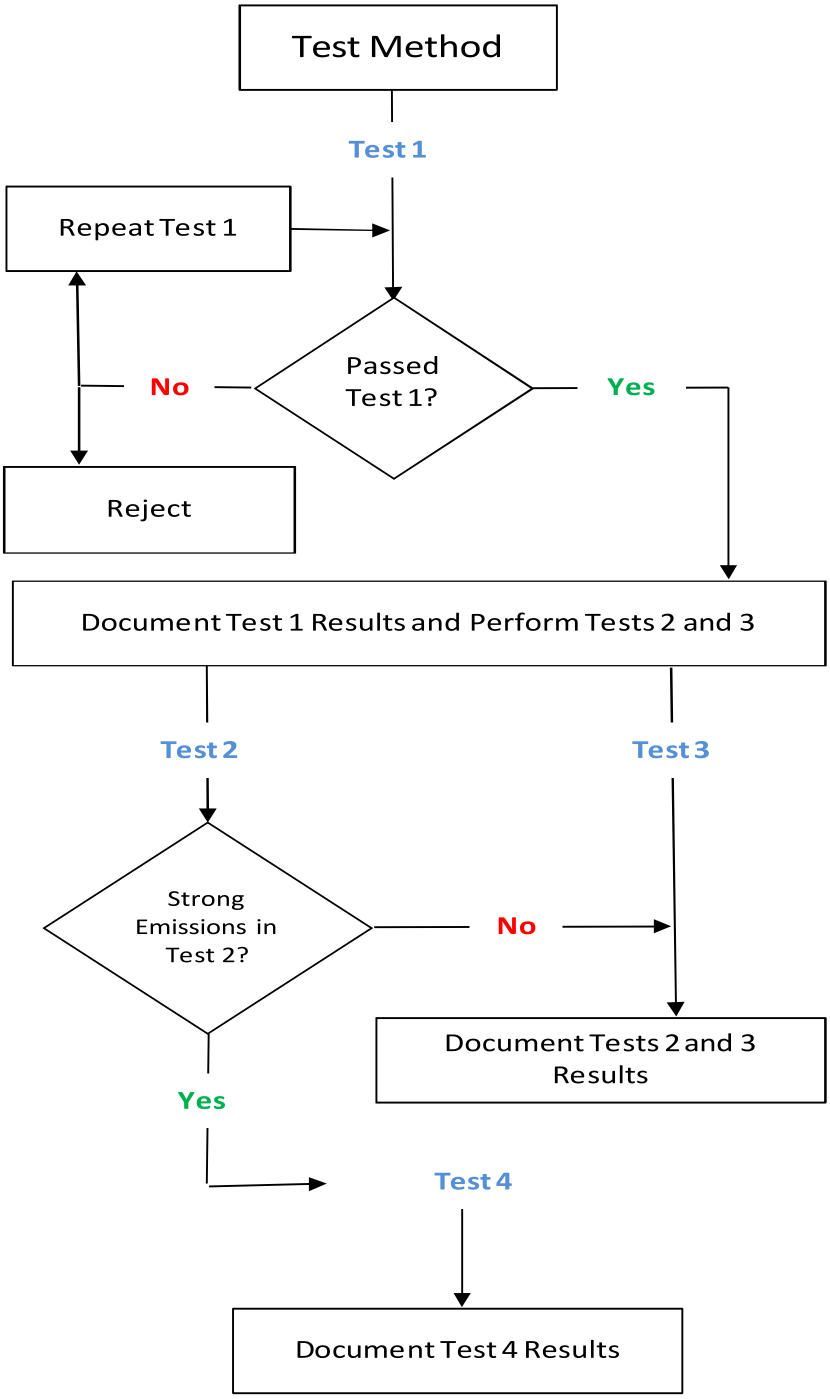

Figure 6-1: Flow chart of the test method

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7 FACILITIES AND INSTRUMENTS FOR DETERMINING PERFORMANCE

7.1 HRV System / Ductwork Test Platform

The basic test rig used for **Tests 1, 2 and 3** consists of four sets of ductwork segments to which the UUT can be connected to simulate basic operation of the installed system. It is similar to the test rig used by CAN/CSA C439 (Figure 7-1) with the following modifications:

- temperature and humidity conditioning of the inlet air streams to the UUT (to support thermal or humidity exchange efficiency monitoring) are not required, instead lab air may be used providing specified T/RH ranges are met,
- the test rig does not consist of recirculation loops, but features instead straight, single pass sections, and
- The test rig differs from the C439 apparatus in providing ports specifically designed for air sampling analysis and for injection of particulate matter challenges (used in **Tests 2** and **3**).

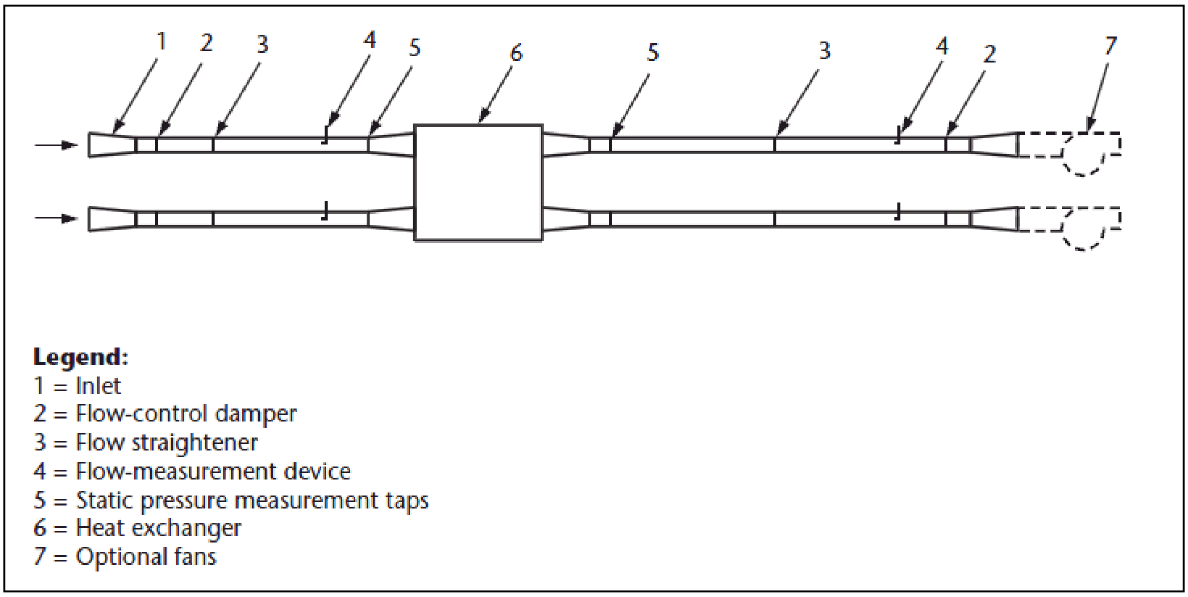

Figure 7-1: Source CSA C439

The system should be designed and constructed following the guidance provided in ASHRAE Fundamentals, including the positions of all flow and pressure sensing devices and the need for flow straighteners in the ductwork assemblies. Additional information specific for the design and location of flow sensing devices can be found in ASHRAE 41.2. Since **Test 3** involves the injection of particles in the outdoor and return air duct segments, the supply air from the HRV/ERV system should be vented outside the occupied lab space.

The schematic for the HRV/ERV system test rig required to meet the requirements for **Tests 1, 2** and **3** is shown in Figure 7-2. An example of an actual installation of the HRV/ERV system test rig is shown in Figure 7-3.

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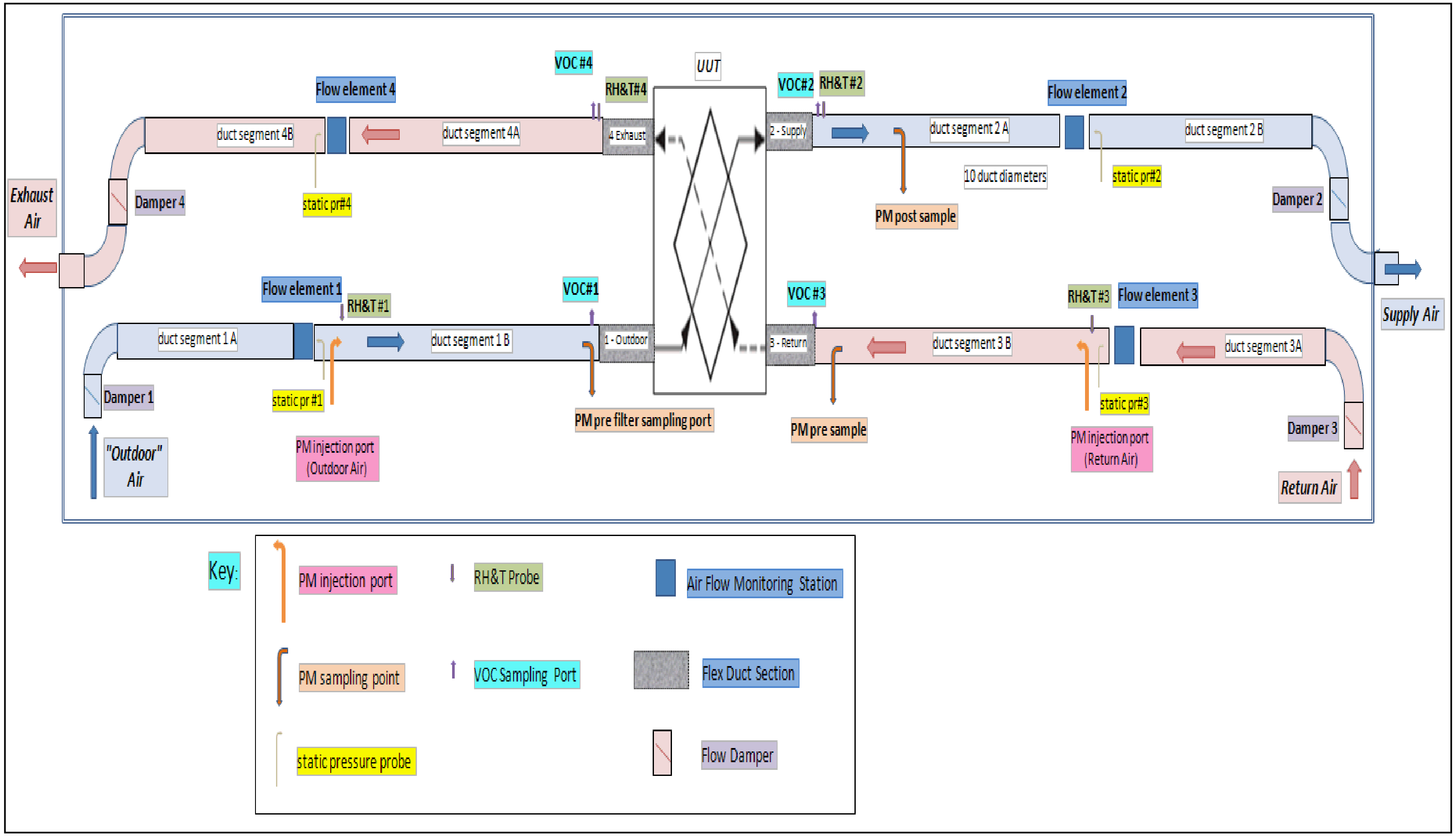

Figure 7-2: Schematic of HRV/ERV system test rig for IAQ performance testing.

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Figure 7-3: Example of an actual installation of the HRV/ERV system test rig.

As indicated in Figure 7-2, "Outdoor" air can be room (or lab) air with a temperature of 23 ± 1°C and a relative humidity of 40 ± 15%. The temperature and relative humidity conditions are established to not adversely impact the organic compound background requirements for **Test 2**. This does not mean that true outdoor air cannot be used and appropriately conditioned if preferred, provided that the temperature and humidity conditioning systems employed can provide an inlet air temperature of 23 ± 1°C and relative humidity of 40 ± 15%. The supply air from the UUT is exhausted to the outdoors since the particulate matter (PM) levels in the supply air stream may become elevated during **Test 3** which requires the generation and injection of fine particulate matter into the outdoor and return air duct segments.

The facility (as indicated by the blue outline in Figure 7-2) housing the HRV/ERV system test rig, must have sufficient air exchange to compensate for the impact of UUT's operation. In the setup shown, both the outdoor and return air flows are obtained from the lab space (as exhaust and supply air streams). Sufficient air exchange has to be supplied to avoid depressurization of the facility. During operation of the UUT, a maximum pressure difference between outdoor and indoor must not exceed 10Pa.

As an alternative arrangement, it is acceptable to install HEPA filtration in the supply air section downstream of the test sections. In this case, the setup would likely require installation of a blower unit downstream of the HEPA filter that would compensate for the HEPA's air flow resistance and enable balanced airflow delivery within the UUT.

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7.2 Requirements for Ductwork and Test Parameter Monitoring Stations

The ductwork used in the construction of the test rig shall be rigid sections with a minimum internal diameter of 15.2 mm (6 inches). Spiral duct is acceptable if the joints are well-sealed to prevent leakage. Galvanized ducting is adequate, provided it is carefully cleaned with laboratory grade detergent (for example detergent used for glass cleaning) and rinsed with clean water to remove any residual oils from the manufacturing process. Each of the four duct sections shall be fitted with air flow rate monitoring equipment, air temperature and relative humidity sensing, as well as ports for air sampling. Principles outlined in ASHRAE Fundamentals should be followed regarding the design and positioning of these air flow sensors and controls. As indicated in Figure 7-2, the termination of each duct section is fitted with a damper that can be used for flow balancing as necessary. Additionally, the dampers in the "supply" and "exhaust" sections can be fully closed when the facility is not in use to block flow of outdoor air into the test apparatus.

The design and naming convention used for identifying these duct segments shall conform to the station identification established in both ASHRAE Standard 84 – *Method of Testing Air-to-Air Heat/Energy Exchangers* and CAN/CSA-C439 *Standard Laboratory Methods of Test for Rating the Performance of Heat/Energy Recovery Ventilators*:

- Station 1 = Supply Air Inlet = Outdoor Air
- Station 2 = Supply Air Outlet = Supply Air
- Station 3 = Exhaust Air Inlet = Return Air
- Station 4 = Exhaust Air Outlet = Exhaust Air

Environmental parameters and flow conditions at each monitoring station will be identified according to this naming convention, thus the air temperature at Station 2; Supply Air should be identified as T_2. All sensors used for monitoring temperature, humidity, pressure and flow shall be calibrated at manufacturer-recommended intervals or annually (whichever is less) to traceable standards. Calibration records shall be kept on file and available for review by the manufacturer of the UUT.

Airflow rate, static pressure, temperature, and relative humidity shall be measured at each station according to the detailed guidance that follows. Air sampling and analysis requirements for organic compounds, ozone, and particulate matter will be described for the specific test methods (**Tests 2** and **3**) below.

7.3 Temperature and Relative Humidity

Temperature measurements in each measuring station shall be recorded using one of the following instruments:

a) Resistance Temperature Detectors (RTD),

b) thermistors, or

c) thermocouples.

Temperature sensors shall be calibrated and traceable to NIST Standards and have an accuracy of least ± 0.5 ^{o}C.

Humidity at each measuring station shall be recorded using either dew point or relative humidity sensors. Sensors employed shall be calibrated and traceable to NIST Standards and have a minimum accuracy to provide a humidity reading of ± 5 %RH.

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The temperature and humidity sensors shall be mounted such that measurements are taken near the midpoint of the airstream at each monitoring station. Their location and design shall be such that flow rate monitoring at the station is not affected. Note that in duct segments 1 and 3, Outdoor and Return Air, respectively, the temperature and humidity sensors shall be located upstream of the Particulate Matter injection position to prevent fouling of the temperature and humidity probes during the particle injection challenges for Test 3.

7.4 Static and Differential Pressure

Duct static pressures shall be monitored using probes following ASHRAE Standard 41.2 - *Standard Methods for Laboratory Air-Flow Measurement*. If surface mount static pressure probes are used, care must be taken to ensure that the inner duct surfaces are free of irregularities including burrs, and that probes are installed so as to accurately measure static pressure at each monitoring station. Pressure transducers used to monitor the system static and differential pressures should be selected (range and precision) to provide a minimum accuracy of ± 1% of reading.

7.5 Volumetric Air Flow Rates

Volumetric Air Flow rates (L/s) shall be measured according to the requirements of ASHRAE Standard 41.2-1987 (R1992) - *Standard Methods for Laboratory Airflow Measurement* and ANSI/AMCA 210-2007 - ANSI/ASHRAE Standard 51-07 - *Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating.* Where commercially available flow monitoring devices are used, the units must be sized appropriately according to the anticipated flow ranges of the UUT (typically between 25 and 200 L/s, or 53 to 424 cfm per National Building Code of Canada, NBC Article 6.2.1.6), and have a minimum cumulative accuracy (including error associated with any pressure sensing devices used to determine flow rates) of 5% or 5 L/s, whichever is smaller. The flow monitoring devices must be calibrated prior to use (at manufacturer-recommended intervals, or annual, whichever is less).

Acceptable flow monitoring devices include averaging or pitot tube arrays installed and tested according to guidance provided by ASTM D3154-00(2006) *Standard Test Method for Average Velocity in a Duct (Pitot Tube Method)*, flow nozzles, and venturi tubes. Laminar flow elements or orifice plates should only be used in combination with supplemental balancing fans to prevent pressurization (positive or negative) of the UUT flow pathways. Note that particle injection ports in the outdoor and return air duct sections should be located downstream of the flow monitoring stations.

7.6 Data Acquisition System (DAS)

A DAS system shall be installed to automatically record all test parameters and conditions at the levels of accuracy and precisions outlined above. Sampling frequency of the DAS shall be sufficient to provide data at 15 second increments at minimum. A point-to-point inspection must be conducted to check electrical connections to all sensors, confirm that locations are properly identified and logged, and to confirm correct sensor response must be conducted. DAS readings are to be verified using handheld monitors that are calibrated to traceable standards. Reported values are to be converted to measured parameters using calibration curves developed for individual sensors. Sensors used for the DAS (temperature, RH, volumetric flow rate, static pressure, differential pressures) shall be regularly maintained and calibrated as described in greater detail above.

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7.7 Ozone Monitors

Ozone monitors employed in this test should meet the requirements of UL867 and have a limit of detection of 2 ppb ozone at minimum and an accuracy of +/- 2% of reading. Chemiluminescence and UV-based detectors are suitable. All air sampling lines connected to the ozone detector should be made of Teflon (PTFE). Sample results should be logged internally by the device or recorded using a separate DAS at a minimum sampling interval of 15 s. Paired analyzers (identical in design and sampling flow rate) should be used in order to conduct simultaneous upstream / downstream air sampling. The use of a single ozone monitor and a valve to sample upstream and downstream air sequentially is not recommended[6].

7.8 Air sampling of VOCs in outdoor, exhaust, return and supply air

Air sampling from the test rig ductwork shall be conducted according to guidelines provided in ASTM D6196. Selection of appropriate sampling media (sorbent tubes) shall be in accordance to ASTM D6345 where multisorbent tubes are recommended.

Sample analysis techniques shall be consistent with the objective of determining the identity and concentrations of individual volatile organic compounds (VOCs) present in the collected air samples. For this purpose, GC/MS analysis is recommended. The selected sampling and analytical methods should have sufficient sensitivity and accuracy to provide a detection limit of 2 $\mu g\ m^{-3}$ for individual VOCs.

Air sampling pumps and controllers should be capable of accurately determining sampling volumes using the selected sorbent tubes within 5%.

7.9 Air sampling of carbonyl compounds in outdoor, exhaust, return and supply air

Air sampling from the test rig ductwork shall be conducted according to guidelines provided in ASTM D5197.

Sample analysis techniques shall be consistent with the objective of determining the identities and concentrations of individual carbonyl compounds (e.g. formaldehyde) present in the collected air samples. For this purpose, HPLC analysis of DNPH derivatives following the ASTM 5197 procedure is recommended. The selected sampling and analytical methods should have sufficient sensitivity and accuracy to provide a detection limit of 2 $\mu g\ m^{-3}$ for individual carbonyl compounds.

Air sampling pumps and controllers should be capable of accurately determining sampling volumes using the selected sorbent tubes within 5%.

7.10 Particle Generation System

A particle generation system capable of aerosolizing Arizona Test Dust, ISO-12103-1, A2 (Fine Test Dust) shall be used for this protocol. The PM Injection nozzles are to be installed in duct segment 1 (Outdoor Air) and segment 3 (Return Air) if UUT is equipped with recirculation mode operation capability (refer to Figure 7-5). Note, as indicated in the figure, that these nozzles must be installed downstream of the RH&T sensors to prevent fouling.

7.11 Particulate Matter Sampling and Analysis

Optical particle counters (OPC) capable of detecting discrete size classes of suspended particulates at minimum $PM_{2.5}$ and PM_{10} levels shall be used. If enhanced filtration capabilities are claimed by the UUT,

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[6] Time lag and fluctuating ozone concentrations can bias the results.

then the particle monitoring equipment must be capable of monitoring at the specified performance level. Paired OPCs are required in order to perform simultaneous upstream / downstream monitoring. The paired OPCs shall be identical in design and sampling flow rate[7].

Isokinetic sampling heads mounted in duct segments 1 and 2 (and 3 if UUT has recirculation mode) are to be used as identified in Figure 7-5. The inlet nozzles of upstream and downstream sample isokinetic probes shall be sharp edged and of appropriate entrance diameter to maintain isokinetic sampling within 10% at the test airflow rate

7.12 Small Emission Chamber

Small emissions chamber (typical internal volume ~50L), although a larger chamber (~ 1 m^3) may be required to accommodate larger HRV / ERV components such as core assemblies. The chamber should be constructed and operated according to guidelines provided in ASTM D 5116. Chamber environmental conditions shall be set at 30°C ± 1°Cand 50% RH ± 5%. An example chamber system is showed below.

Figure 7-4: Small chamber system for headspace analysis of component emissions.

[7] Particle concentrations agreement between paired OPCs can be determined by conducting side-by-side measurements. Paired OPCs are considered in agreement if plots of their concentrations revealed a regression line of slope equal to 1 (± 0.1) and a y-intercept of 0 (± 0.1).

1

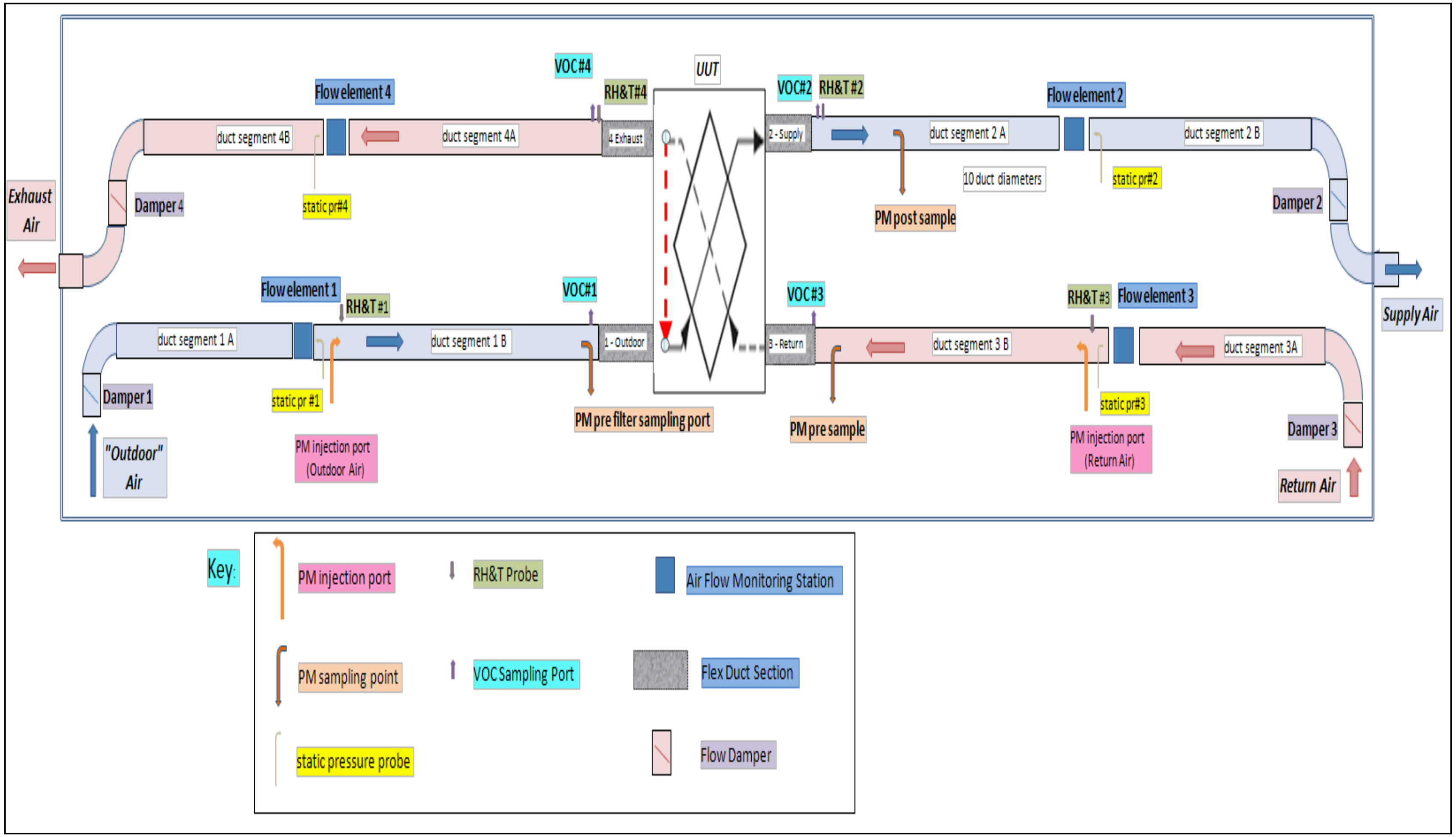

Figure 7-5: Schematic of HRV/ERV system test rig for IAQ performance testing showing UUT in optional Recirculation mode.

1

8 TEST METHODS

8.1 Descriptions of Unit Under Test (UUT) and Test Agency

The test report shall include a detailed description of the unit under test including the product description, manufacturing history (site and date), rated airflow performance, operation mode(s), IAQ related claims, certificates of performance, filter documentation (if any) and photographs of the test unit. Complete all required information using the forms provided in Section 9.1.

8.2 Test 1 – System Flow Rates

8.2.1 **Intent:**

This test is to verify, prior to IAQ impact assessment testing, that the UUT is operating per manufacturer-specified flow rates under standard conditions (and as certified by independent test agencies). Testing should be performed consistent with CAN/CSA-C439-09 Section 8.1: Airflow rate measurement procedure (which cites ANSI/AMCA 210 - ANSI/ASHRAE Standard 51-07).

Test 1 also serves to provide an opportunity to observe the UUT in operation and determine the characteristics of its various operation modes. The timing and impact of these modes on the flow paths and delivered volumetric flow rates in each airstream must be identified and noted as they may affect the successful operation of subsequent tests (an example of this being the timing or frequency of any automatic switchovers to recirculation modes and/or automated changes in fan speed operation).

Test 1 is a Pass / Fail stage that must be satisfied before IAQ performance testing (**Tests 2, 3 and 4**) should be initiated.

While **Test 1** provides an initial flush out / conditioning period for the UUT, the total operational time during **Test 1** should not exceed 48 hours. During this time period (and during **Tests 2 and 3**) it is important that background conditions (lab air if test rig configured such that lab air is used as "outdoor"air) be maintained such that UUT contamination does not occur. In practise, this requires that background TVOC and PM_{10} levels not exceed 250 µg/m^3 and 50 µg/m^3 respectively.

8.2.2 **Test Procedure – System Flow Rates**

The HRV/ERV system under test shall be connected to the test rig in accordance with the manufacturer's installation recommendations to the extent possible. This includes the use of manufacturer-supplied or recommended fittings and flexible ductwork (minimum lengths: 2m /section) for making connections to outdoor air intake, exhaust air discharge and supply and return air positions.

Once the unit is fully installed and all connections carefully sealed according to manufacturer instruction, all dampers in the duct sections shall be fully opened (Dampers 1 through 4 in Figure 7-2).

Test Conditions:

- Supply Air Flowrate (Q_2): 100% of the rated airflow of the UUT
- Return Air Flowrate (Q_3): same as Supply Air Flowrate ($Q_2 = Q_3$)
- Static Pressure of Supply Air (P_{s2}) balanced with Return Air Static Pressure (P_{s3})

1

Therefore, the pressure difference between Supply (P_{s2}) and Return (P_{s3}) should be 0 according to Section 8.2.3.

The unit under test shall then be turned on to its normal flow condition and flows shall be recorded at all four measuring stations simultaneously. As necessary, adjust dampers 1-4 in order to achieve balanced flow conditions within 90% as specified in CAN/CSA F326-M91 (R2010). Note, that some HRV/ERV systems may be supplied with balancing damper systems. In this case, install the system with the dampers in place and balance according to manufacturer's guidelines. Once the UUT has been balanced, record flow values from all four measuring stations and compare to UUT specifications provided by the manufacturer, or by an independent certification body, if applicable.

Set HRV operation to maximum air flow and observe flow readings for a minimum of 1 hour at the 4 stations. Repeat this procedure for any additional operation modes for the UUT.

With HRV set to operate in its normal mode, record flow conditions for a minimum of 1 hour at the 4 stations. Note especially the occurrence, timing and duration of any step changes in flow, e.g. resulting from default programming shifts in HRV operation. It may be necessary to override any flow shifts. If this is not possible, note the timing of their occurrence and adjust the testing procedure accordingly.

8.2.3 Data Analysis and Reporting

Record specified and observed flow rates using the tables found in Section 9.2 - Evaluation Test Reports.

Evaluation Criteria:

- CSA F326 Section 8.13.3 (d), specifies that:

  "*the supply and exhaust airflow rates of heat recovery ventilators in the normal ventilation mode shall be balanced so that the value of the lesser flow shall be at least 90% of the value of the greater flow, unless otherwise recommended by the manufacturer*".

Test 1 PASS/FAIL based on:

a) The measured flows for the UUT were within 10% of their specified values, and
b) The measured supply and exhaust flow rates were found to differ by no more than 10%.

8.3 Test 2a: Ozone Emissions of the Complete System

8.3.1 Intent:

This test is to verify that fan motors or any supplemental particulate matter air purification device (e.g. electronic filters such as ionizers or electrostatic devices) installed in the HRV/ERV system will not generate ozone in significant amounts during operation. This test requires that ozone monitoring upstream and downstream of the HRV/ERV system be conducted.

If the UUT incorporates supplemental electronic filtration device(s), then this test should be conducted in 2 stages:

1) with the filtration system turned off (to check for possible ozone production by the HRV/ERV blower motors); and
2) with any supplemental filtration system turned on to test for ozone formation as a by-product of filter operation.

8.3.2 Test Procedure

Ozone sampling:

- Turn on the two ozone monitors and position them so that both are sampling from the same room air location. Allow the monitors to warm up for the period recommended by the manufacturer, and then confirm that both units are recording the same background ozone concentration (+/- 2 ppb).
- Connect the PTFE air sampling lines from the two ozone monitors to the sampling ports at Stations 1 (Outdoor Air) and 2 (Supply Air)
- Operate the HRV/ERV system at its highest flow setting in its normal mode of operation and record ozone levels for a minimum of 10 minutes at a minimum sampling interval of 15 s.
- Plot recorded data and calculate average values and standard deviations for both upstream and downstream locations.

8.3.3 Data Analysis and Reporting

Record ozone concentrations and its net change using the tables found in Section 9.2 - Evaluation Test Reports.

Evaluation Criteria:

- The net increase in ozone levels (based on the difference of the average values obtained in the Outdoor Air and Supply Air streams (Stations 1 and 2) should be below the Health Canada recommended residential IAQ guideline for ozone of 20 ppb[8].
    - Pass: net change in ozone level < 20 ppb
    - Fail: net change in ozone level ≥ 20 ppb

[8] Even though device emissions are below the guideline levels set out in this protocol, certain conditions (high outdoor ozone, other indoor sources) may cumulatively increase the concentrations above threshold guidelines when installed in residences. Under such conditions, it is recommended that appropriate mitigation measures such as indoor source removal and turning off the HRV/ERV unit during periods of high outdoor ozone levels be taken.

1

8.4 *Tests 2b and 2c: Volatile Organic Compound Emissions of the Complete System:*

8.4.1 **Intent:**

This test is to verify that HRV/ERV system (including supplied/recommended flexible ductwork and connections) does not act as a source of volatile organic or carbonyl compounds. The test is performed by conducting air sampling from the Outdoor Air upstream of the HRV /ERV system (Station 1) and immediately downstream in the Supply Air duct (Station 2). Any observed increases in contaminant levels will be attributed to the HRV/ERV system, and compared to guideline values for specific contaminants. If the HRV/ERV system provides a recirculation mode of operation, then the test should be repeated with the system set to operate in the recirculation mode, but with VOC/carbonyl sampling additionally being taken from the Return Air duct (Station 3).

8.4.2 **Test Procedures:**

*8.4.2.1 **Test 2b**: Volatile Organic Compounds*

Confirm that total operational time of UUT during **Tests 1** and **2a** has not exceeded 48 h.

If lab air is used as Outdoor Air for UUT, collect a lab air sample and confirm that VOC background levels are acceptable (TVOC < 250 $\mu g/m^3$).

To confirm that the test rig ductwork is not a source of VOC contamination, with the UUT operating under the desired test conditions, collect simultaneous 2L air samples (e.g. 20 min at 100 mL/min) from the outdoor air (or lab air depending on system configuration) and from within the Outdoor Air duct segment (Segment 1) at test location “VOC#1” identified in Figure 7-2. Compare these results. If elevation in any contaminant is observed, identify source and resolve (re-clean ductwork if necessary).

With the UUT in stable operation under “Normal” conditions (allow 30 minutes for system to stabilize, flows must be maintained +/- 10% of **Test 1** conditions), simultaneously collect air samples from points “VOC#1” (Outdoor Air) and “VOC#2” (Supply Air). Repeat so as to collect two paired sets of air samples.

Record start time and operational parameters of UUT.

For all air samples, record the following:

- Sample location (VOC#1,2,3,4,Outdoor or Lab)
- Sampling tube make/model/Serial Number
- Sampling system components (pump/controllers)
- Sampling rate (mL/min), (50 – 200 mL/min)
- Sampling start and stop time/date
- Sampling personnel name
- Discrete sample code (including Test ID and sample number)

Collect lab blank samples by briefly opening and closing clean sorbent tubes co-located with air sample tubes during UUT testing period.

If UUT possess an optional recirculation mode, repeat the above testing with simultaneous sampling at locations “VOC#2” (Supply Air) and “VOC#3” (Return Air) identified in Figure 7-5.

1

8.4.2.2 ***Test 2c***: *Carbonyl Compounds*

Coordinating with VOC sampling above, simultaneously collect 20 L air samples (e.g. 100 min at 200 mL/min) from points “VOC#1” (Outdoor Air) and “VOC#2” (Supply Air). Repeat so as to collect two paired sets of air samples.

For all air samples of carbonyl compounds, record the following:

- Sample location (VOC#1,2,3,4,Outdoor or Lab)
- Sampling tube make/model/Serial Number
- Sampling system components (pump/controllers)
- Sampling rate (mL/min), (50 – 200 mL/min)
- Sampling start and stop time/date
- Sampling personnel name
- Discrete sample code (including Test ID and sample number)

Collect lab blank samples by briefly opening and closing clean cartridges co-located with air sample tubes during UUT testing period.

If UUT possess an optional recirculation mode, repeat the above testing with simultaneous sampling at locations “VOC#2” (Supply Air) and “VOC#3” (Return Air) identified in Figure 7-5.

8.4.3 **Data Analysis and Reporting**

Describe in detail the air sampling equipment used (pumps, flow controllers, timing devices, sample collection media and its handling/preparation including cleaning).

Describe the analytical systems used for VOC and carbonyl sample analysis (including analytical instrumentation, analysis conditions, calibration, and integration parameters)

Test 2b: For VOC samples

- Reported blank - corrected values expressed as µg/m^3:

  (VOC mass on sample tube – mass in blank tube) / sample volume

- Report limit of detection, LOD, (µg/m^3: assume a 2L sample) for each VOC detected.
- Report values using the tables provided in Section 9.2.2.2 (Report VOC levels only for those compounds that exceed LOD)

Test 2c: For carbonyl compound samples:

- Reported blank - corrected values expressed as µg/m^3:

  (carbonyl compound mass on sample cartridge – mass in blank cartridge) / sample volume

- Report limit of detection, LOD, (µg/m^3: assume a 2L sample) for each compound detected.
- Report values using the tables provided in Section 9.2.2.3 (Report VOC levels only for those compounds that exceed LOD)

1

8.5 Test 3: Particle Filtration by the Complete System:

8.5.1 **Intent:**

The intent of this test is to determine the installed performance of basic and any supplemental/ enhanced particle filtration systems present in the UUT (using a single pass approach)[9]. Any by-pass leakage that may be occurring due to improperly designed/sealed flow paths within the particular UUT and/or any weaknesses in filter mounts/seals can be determined by evaluating the *in-situ* PM removal performance of the installed unit.

The test requires evaluation of both $PM_{2.5}$ and PM_{10} levels and removal performance.

The following table summarizes possible enhanced filtration capabilities in the UUT.

Table 8-1: Possible enhanced filtration capabilities in the UUT

System Component	Performance Claim	Test Requirement
Enhanced Particle Filtration	Improved removal of outdoor PM via HEPA or Electrostatic Precipitation	Dose outdoor air stream with particulates and sample supply air
Enhanced Particle Filtration: Recirculation Mode Operation	Reduce indoor particulate levels due to recirculation filtration	Dose return air stream with particulates and sample supply air

8.5.2 **Test Procedure:**

Verify that all filters, filter cartridges and frames are oriented correctly and mounted within the unit per manufacturer's instructions.

Ensure that date/time values in both DAS and OPCs are synchronized.

If lab air is used as Outdoor Air for UUT, collect a lab air sample and confirm that PM_{10} background levels are acceptable (PM_{10} < 50 µg/m^3).

Operate the UUT in normal mode and record all flowrates, temperatures and relative humidity in each test section via DAS. Allow sufficient time to confirm that all flows are stable within +/- 10% of **Test 1** conditions.

Use correct isokinetic sampling heads for sampling particulate based on UUT flowrates. Sample suspended particulate levels in Outdoor and Supply Air duct segments and record background levels.

Commence injection of PM (refer to Section 7.1) in Outdoor Air section and continue injection until stable levels of approximately 100 µg/m^3 (± 10%) have been maintained in the Outdoor Air duct for 10 to 15 minutes.

Discontinue PM dosing while continuing to sample for a further 5 to 10 minutes.

8.5.3 **Data Analysis and Reporting**

Document all filters supplied with system, including any pre-filter systems. Record all make/model information as well as any specified performance values.

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[9] The protocol assumes that the performance of the filter media itself is as specified and that it has been tested according to recognized standards.

Record system flows, temperatures and RH values for all duct sections using the DAS.

Plot observed PM levels and calculate mean levels and standard deviations before, during and after PM injection.

Use tables provided in Section 9.2.3 to record PM removal performance.

8.6 Test 4: Organic Compound Emissions of the System Components (Headspace Chambers):

8.6.1 **Intent:**

Test 4 is an optional test intended to allow the manufacturer to identify the specific cause of a failure of **Test 2b** or **2c**. It involves "headspace" emissions testing of individual HRV / ERV system components in "small" environmental chambers. General guidelines from ASTM D5116 shall be followed.

The selection of specific system component (s) to be tested will be based on evaluation of **Test 2b** and **2c** results, discussion with the HRV/ERV system manufacturer and component supplier if necessary, and may include one or more of the following:

- HRV / ERV core materials (including polypropylene / polypropylene copolymers, aluminum, stainless steel, polymer membranes).
- Flexible ducting materials and connectors (including vinyl compounds, aluminum foils, polyester laminates, metalized polyester films).
- Outdoor air intake materials.
- Motor / blower systems.
- Filtration devices (filter beds, basic Polyester air filters, pleated filters, supports, gaskets).
- Cabinet materials (metal, plastics).
- Sound deadening materials used in cabinet, including foamed plastics.
- Optional balancing dampers.

If the source of the contaminant is clearly identified by headspace test (s), then substitution by the system supplier of the component responsible for the "Fail" can precede a re-test of the complete system (Figure 8-1).

1

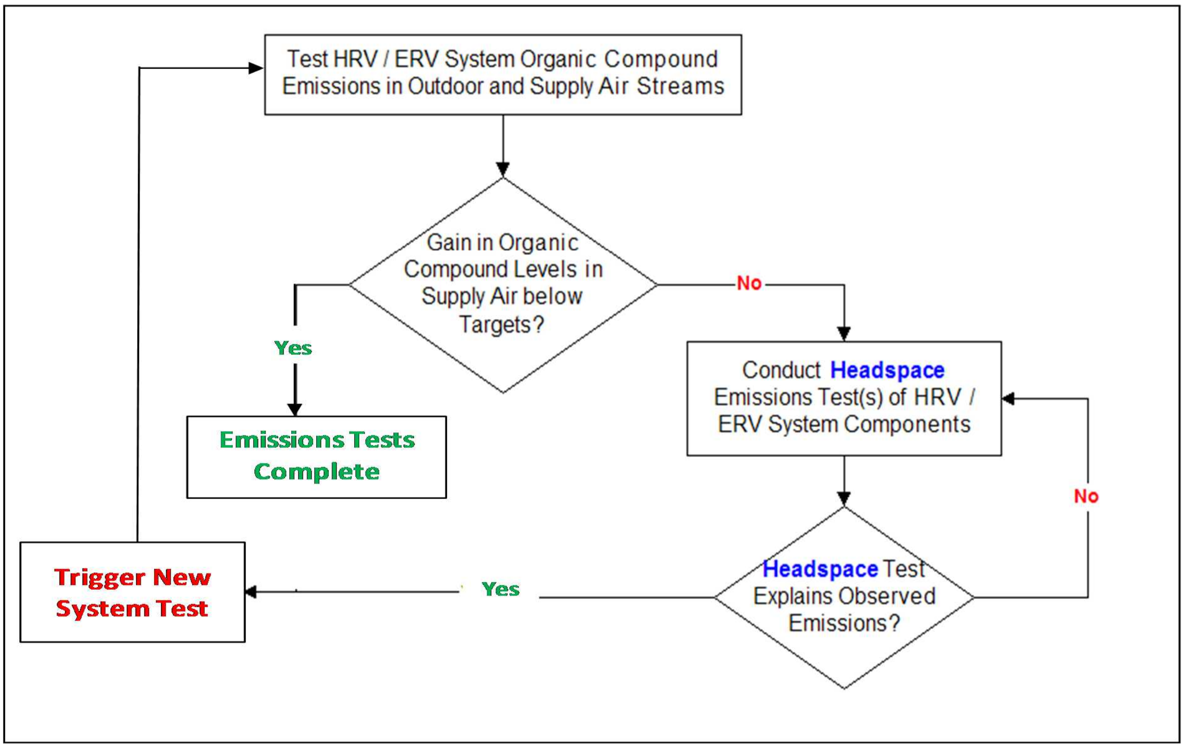

Figure 8-1: Decision process/follow-up for implementing Test 4.

8.6.2 Test Procedure

Set chamber operation conditions to 30°C via environment enclosure or lab space environmental controls.

Clean the chamber using laboratory grade glassware detergent in water. Rinse with tap water then distilled water and dry using clean cloths. Flush with clean air (50% RH) until humidity of exhaust air is stable at 50% RH +/- 5%.

Collect background air sample using techniques described in Tests 2b and2c and analyze on GC/MS and HPLC to confirm chamber background meets following criteria :

- TVOC: $\leq 10\ \mu g/m^3$
- Individual compounds, including Formaldehyde: $\leq 2\ \mu g/m^3$

If chamber background acceptable, load UUT component into chamber and reseal. Flush chamber for 3 h at 1 air change/h using 50% RH supply air. Discontinue flushing and seal chamber. Maintain chamber temperature at 30°C. After 24 h, reconnect chamber supply air and flush at 250 mL/min. Using a vented T-fitting at the chamber exhaust, immediately begin air sampling from the exhaust air at 200 mL/min. Collect VOC sample first (approx. 2L) followed by carbonyl compound sample (approx. 10L).

If background chamber is not acceptable, re-clean.

Analytical and air sampling equipments required for the headspace testing are identical to those described for Tests 2b and 2c.

8.6.3 **Data Analysis and Reporting:**

Describe and record any identification markings on tested component (s), including:

- manufacturer/make/model/serial numbers
- compositions
- specifications listed for any filter materials
- date of manufacture

Report chamber background test results.

Use tables provided in Section 9.2.4 to report headspace test results.

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9 TEST REPORT

The test report shall include the following information:

9.1 Description of UUT / Test Agency:

The test report shall contain the following information:

- Make / Model / Serial Number
- Manufacturing Date and site
- 3rd party certification that UUT is representative of product
- Date received by test lab
- Rated airflow delivery rates:
- Operation Modes provided by the system
- Document any IAQ-related claims made for the UUT
- Certificates of performance – record information from any certificates attached or supplied with the UUT
- Document all filters supplied with system (or installed as optional components for the purpose of the test): include descriptions of filter sizes, types, frame/holder construction, claimed performance specifications
- Document make / model / manufacturer information of all flexible ducting supplied with or recommended for use during installation
- Photograph the test unit and all installed components

1

a) UUT Description:

Make: ________________________________

Model: ________________________________

Serial Number: ________________________________

Manufacture Site: ________________________________

Date of Manufacture: ________________________________

Specified Flows by Manufacturer:

- ____ cfm (___ L/s) @ ___in wg (___ Pa)
- ____ cfm (___ L/s) @ ___in wg (___ Pa)

Rated Air Flows (per certification label):

- Certification Source:________________________________
- Certified flows:
  - ____ cfm (___ L/s) @ ___in wg (___ Pa)
  - ____ cfm (___ L/s) @ ___in wg (___ Pa)

Modes of Operation:

- ________________________________
- ________________________________
- ________________________________
- ________________________________

Filtration Components Installed in System:

- ________________________________
- ________________________________
- ________________________________

Supplied Installation Components:

- Flexible Ducting:
  - Outdoor / Exhaust Air:
    - Make/Model: ________________________________
    - Installed Length: ________________________________
  - Supply / Return Air:
    - Make/Model: ________________________________
    - Installed Length: ________________________________

IAQ-related performance claims from Manufacturer's advertising/operational literature:

- ________________________________
- ________________________________
- ________________________________
- ________________________________

1

UUT Photos and Diagrams:

1

b) Test Lab / UUT Collection and Test Details:

Lab Name and Location: ___________________________________

Contact Name: ___________________________________

UUT collection details:

- Obtained from: ___________________________________
- Date Obtained: ___________________________________
- Condition on Receipt: ___________________________________

Internal Test Code: ___________________________________

Test Dates: ___________________________________

UUT acceptable for Testing?

- UUT age at test date: _____________ days
- Meets 2 day age criteria? (***Pass*** / ***Fail***): ________________

1

9.2 ***Evaluation Test Reports:***

9.2.1 **Test 1 Report: System air flows:**

Table 9-1: Observed UUT Flows – Normal Mode

Flow Section		Normal Mode		
	Specification (L/s)	Observed (L/s)	Date/Time	Agreement, %
Station 1: *Outdoor Air*				
Station 2: *Supply Air*				
Station 3: *Return Air*				
Station 4: *Exhaust Air*				

Table 9-2: Observed UUT Flows – Maximum Mode

Flow Section		Max Mode		
	Specification (L/s)	Observed (L/s)	Date/Time	Agreement, %
Station 1: *Outdoor Air*				
Station 2: *Supply Air*				
Station 3: *Return Air*				
Station 4: *Exhaust Air*				

Table 9-3: Observed UUT Flows – Recirculation Mode

Flow Section		Recirculation Mode (if available)		
	Specification (L/s)	Observed (L/s)	Date/Time	Agreement, %
Station 1: *Outdoor Air*				
Station 2: *Supply Air*				
Station 3: *Return Air*				
Station 4: *Exhaust Air*				

Normal mode meets CSA F326 requirement for Supply = Exhaust within 10%?:

- calculated difference: ________________ %

Conforms to flow specs and is accepted for further IAQ performance tests (***Pass*** / ***Fail***): _____________

1

9.2.2 Test 2 Report: Organic Compound Emissions from System:

*9.2.2.1 **Test 2a** - By-product **Ozone** generation:*

a) Normal mode:

Table 9-4: Ozone generation in the UUT - Normal Mode

	O_3 Level in **Outdoor Air** (Station 1), ppb	O_3 Level in **Supply Air** (Station 2), ppb	Net change in O_3 level, ppb
Test Result:			

Supply air Ozone (Normal Mode): Net change < 20 ppb: (***Pass*** / ***Fail***): _____________

b) Recirculation mode (if available):

a. Applies to this UUT? (***Yes*** / ***No***): ____________

Table 9-5: Ozone generation in the UUT - Recirculation Mode

	O_3 Level in **Return Air** (Station 3), ppb	O_3 Level in **Supply Air** (Station 2), ppb	Net change in O_3 level, ppb
Test Result:			

Supply air Ozone (Recirculation Mode): Net change < 20 ppb (***Pass*** / ***Fail*** / *Not Applicable*): ___________

c) Ozone levels during use of supplemental filtration (if available):

a. Applies to this UUT? ________ (***Yes*** / ***No***)
b. If ***yes***: Nature of supplemental filtration? _____________ (electrostatic precipitator, …)

Table 9-6: Ozone generation in the UUT during use of supplemental filtration

	O_3 Level in **Outdoor Air** (Station 1), ppb	O_3 Level in **Supply Air** (Station 2), ppb	Net change in O_3 level, ppb
Test Result:			

Supply air Ozone (with supplemental filtration) Net change < 20 ppb (***Pass*** / ***Fail*** / *Not Applicable*): _________

1

*9.2.2.2 Test 2b Report: **VOC** Emissions – Full System:*

Normal operation mode:

Report detected compounds (> LOD) using the following Table 9-7 and adapt classes and number of rows as needed.

Table 9-7: VOC emissions in the UUT – Normal Mode

VOC Class	**Organic Compound**	**RT, min**	**CAS #**	Field Blank	Normal Operation Mode			
					Corrected Concentration, $\mu g/m^3$		Net Change (Supply - Return)	
				Mass, ng	Outdoor Air	Supply Air	$\mu g/m^3$	%
Alcohol								
Aliphatic HC								
Aromatic HC								
Halogenated HC								
Ester								
Terpene								
Silyl compound								
GC / MS	SUM of Identified VOCs (as Toluene)							
	TVOC							

Evaluation Criteria:

- Pass: net level change is below all recommended guideline values listed in Table 10-3: or other criteria for acceptance
- Marginal pass: ≤ 5 guideline values are exceeded, with none by a factor of more than 2
- Fail: > 5 guideline values in Table 10-3 are exceeded by a factor of 2 or more

Test Result: ______________ (*Pass* / *Marginal Pass* / *Fail*)

Note: Emitted compounds not listed in Table 10-3, but detected at levels exceeding 100 $\mu g/m^3$, should be reviewed by a qualified toxicologist. If determined to be a health concern, then the compound must be identified as such in the evaluation report and a “Fail” assigned under organic compound emissions.

1

Recirculation operation mode (if available):

Report detected compounds (> LOD) using the following Table 9-8 and adapt classes and number of rows as needed.

Table 9-8: VOC emissions in the UUT – Recirculation Mode

VOC Class	**Organic Compound**	**RT, min**	**CAS #**	Field Blank	Recirculation Operation Mode Corrected Concentration, $\mu g/m^3$		Net Change (Supply - Return)	
				Mass, ng	Return Air	Supply Air	$\mu g/m^3$	%
Alcohol								
Aliphatic HC								
Aromatic HC								
Halogenated HC								
Ester								
Terpene								
Silyl compound								
GC / MS	SUM of Identified VOCs (as Toluene)							
	TVOC							

Evaluation Criteria:

- Pass: net level change is below all recommended guideline values listed in Table 10-3: or other criteria for acceptance
- Marginal pass: ≤ 5 guideline values are exceeded, with none by a factor of more than 2
- Fail: > 5 guideline values in Table 10-3 are exceeded by a factor of 2 or more

Test Result: _______________ (*Pass* / *Marginal Pass* / *Fail*)

Note: Emitted compounds not listed in Table 10-3, but detected at levels exceeding 100 $\mu g/m^3$, should be reviewed by a qualified toxicologist. If determined to be a health concern, then the compound must be identified as such in the evaluation report and a “Fail” assigned under organic compound emissions.

1

*9.2.2.3 Test 2c Report: By-product for carbonyl compound (including **Formaldehyde)** emission:*

a) Normal operation mode:

Report detected compounds (> LOD) using the following Table and adapt number of rows as needed.

Table 9-9: Carbonyl compounds (including formaldehyde) emissions in the UUT – Normal Mode

VOC Class	Organic Compound	RT, min	CAS #	Field Blank	Normal Operation Mode			
					Corrected Concentration, µg/m^3		Net Change (Supply - Return)	
				Mass, ng	Outdoor Air	Supply Air	µg/m^3	%
Aldehyde								
Ketone								

Supply air Formaldehyde (Normal Mode): Net change < 50 µg/m^3 (***Pass*** / ***Fail***)[10]: ______________

b) Recirculation mode (if available):

Report detected compounds (> LOD) using the following Table and adapt number of rows as needed.

Table 9-10: Carbonyl compounds (including formaldehyde) emissions in the UUT – Recirculation Mode

VOC Class	Organic Compound	RT, min	CAS #	Field Blank	Recirculation Operation Mode			
					Corrected Concentration, µg/m^3		Net Change (Supply - Return)	
				Mass, ng	Return Air	Supply Air	µg/m^3	%
Aldehyde								
Ketone								

Supply air Formaldehyde (Recirculation Mode): Net change < 50 µg/m^3 (***Pass*** / ***Fail***/ *Not Applicable*): ______

[10] Although UUT emissions can be below the guideline levels, other indoor sources of formaldehyde may cumulatively increase its concentrations above threshold guidelines when installed in residences. Under such condition, controlling organic contaminants (including formaldehyde) by removing indoor sources is recommended.

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9.2.3 Test 3 - Particulate Matter Filtration Performance:

a) Outdoor filtration performance:

Table 9-11: Outdoor filtration in the UUT – Normal Mode

	Particulate Level in **Outdoor Air** (Station 1),		Particulate Level in **Supply Air** (Station 2)	
	PM_{10} (µg/m^3)	$PM_{2.5}$ (µg/m^3)	PM_{10} (µg/m^3)	$PM_{2.5}$ (µg/m^3)
Test Result:				

Evaluation Criteria:

- **Pass**: Supply air PM_{10} below NBC Annual Acceptable Level of 70 µg/m^3 and $PM_{2.5}$ below CWS 2000 (Canada-Wide Standard released by Canadian Council of Ministers of the Environment (CCME)) guidelines for $PM_{2.5}$ of 30 µg/m^3.
- **Marginal pass**: Supply air PM_{10} exceeds NBC Annual Acceptable Level of 70 µg/m^3 but is less than the daily maximum acceptable level of 120 µg/m^3
- **Fail**: Supply air PM_{10} exceeds 120 µg/m^3

Test Result: Outdoor Filtration Meets NBC Criteria (***Pass*** / ***Marginal Pass*** / ***Fail***): ___________

b) Enhanced filtration performance (outdoor air):

a. Is enhanced filtration capability claimed for this UUT? (***Yes*** / ***No***) _________________
b. What is the nature of this filtration capability (electrostatic precipitator, HEPA, ….)? _________________
c. Claimed filtration performance: _____________________________________
d. Observed Filtration Performance: _____________________________________

Table 9-12: Enhanced filtration in the UUT for outdoor air – Normal Mode

	Particulate Level in **Outdoor Air** (Station 1),	Particulate Level in **Supply Air** (Station 2)	Net change in Particulate level, %
	Specified criteria: ___________	Specified criteria: ___________	
Test Result:			

Test Result: Observed Enhance Filtration Performance meets claim (***Pass*** / ***Fail***):___________

c) Enhanced filtration performance (recirculation air):

a. Is enhanced filtration capability claimed for this UUT? (***Yes*** / ***No***) _________________
b. What is the nature of this filtration capability (electrostatic precipitator, HEPA, ….)? _________________
c. Claimed filtration performance: _____________________________________
d. Observed Filtration Performance: _____________________________________

Table 9-13: Enhanced filtration in the UUT – Recirculation Mode

	Particulate Level in **Return Air** (Station 3),	Particulate Level in **Supply Air** (Station 2)	Net change in Particulate level, %
	Specified criteria: ___________	Specified criteria: ___________	
Test Result:			

Test Result: Observed Enhance Filtration Performance meets claim (***Pass*** / ***Fail***):___________

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9.2.4 Test 4 - VOC Emissions – UUT Component Headspace results:

UUT Component: ________________

Table 9-14a: VOC emissions in UUT component xxxxxxx: Headspace Results

VOC Class	Organic Compound	RT, min	CAS #	Field Blank Mass, ng	Corrected Headspace Concentration, µg/m^3
Alcohol					
Aliphatic HC					
Aromatic HC					
Halogenated HC					
Ester					
Terpene					
Silyl compound					
GC / MS	SUM of Identified VOCs (as Toluene)				
	TVOC				

Table 9-15a: Carbonyl emissions in UUT component xxxxxxx: Headspace Results

VOC Class	Organic Compound	RT, min	CAS #	Field Blank Mass, ng	Corrected Headspace Concentration, µg/m^3
Aldehydes					
Ketones					

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9.3 ***Evaluation Summary***

UUT Conforms to age requirements (***Pass*** / ***Fail***): __________

Test 1: ***System air flows***:

- Conforms to flow specs (***Pass*** / ***Fail***): __________
- Accepted for further IAQ performance tests (***Yes*** / ***No***): __________

Test 2: ***Organic Compound Emissions from System***:

○ **Test 2a**: ***Supply air Ozone***

- Normal Mode: Net change < 20 ppb (***Pass*** / ***Fail***): __________
- Recirculation Mode: Net change < 20 ppb (***Pass*** / ***Fail*** / ***NA***): __________
- with supplemental filtration: Net change < 20 ppb (***Pass*** / ***Fail*** / ***NA***): __________

○ **Test 2b**: ***VOC Emissions – Full System*** **(*****Pass*** / ***Marginal Pass*** / ***Fail***): __________

- Rationale for Marginal Pass or Failure: ____

Test 2b: ***VOC Emissions – Recirculation mode*** **(*****Pass*** / ***Marginal Pass*** / ***Fail***): __________

- Rationale for Marginal Pass or Failure: ____

○ **Test 2c**: ***Supply air* Formaldehyde**

- Normal Mode: Net change < 50 µg/m^3 (***Pass*** / ***Fail***): __________
- Recirculation Mode: Net change < 50 µg/m^3 (***Pass*** / ***Fail*** / ***NA***): __________

Test 3 - ***Particulate Matter Filtration Performance***:

- Outdoor Filtration **(*****Pass*** / ***Marginal Pass*** / ***Fail***):: __________
- Enhanced filtration performance (outdoor air): (***Pass*** / ***Fail***): __________
- Enhanced filtration performance (recirculation air): (***Pass*** / ***Fail***): __________

Test 4: ***VOC Emissions – UUT Components***

- Recommendations: ____

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10 APPENDICES - INFORMATIVE

10.1 Existing Standardization related to HRV performance

As ventilation devices, HRV/ERV systems are subject to Building Code regulations (National Building Code of Canada as adopted by Provincial/Territorial building Codes) and existing ventilation standards (including **CAN/CSA-F326-M91 (R2010)** - *Residential Mechanical Ventilation Systems* and **ANSI/ASHRAE 62.2-2010** *Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings*). Section 10.2 describes these requirements in greater detail.

Specific aspects of HRV/ERV installation, operation and performance are addressed by various standards from several North American agencies. These include the following:

- **ANSI/AHRI 1060-2005**: *Rating Air-To-Air Energy Recovery Ventilation Heat Exchangers*
- **ANSI/ASHRAE 84-2008:** *Method of Testing Air-to-Air Heat Exchangers*
- **CAN/CSA 22.2 NO. 113-M1984 (R2004):** *Fans and Ventilators*
- **CAN/CSA-F326-M91 (R2010):** *Residential Mechanical Ventilation Systems* (supersedes withdrawn CAN/CSA Standard C444-M87 – *Installation Requirements for Heat Recovery Ventilators)*
- **CAN/CSA C439-00 (2009):** *Standard Laboratory Methods of Test for Rating the Performance of Heat/Energy-Recovery Ventilators*
- **HVI 915 (1 March 2009):** *Loudness Testing and Rating Procedure*
- **UL 1812:** *Ducted Heat Recovery Ventilators*

A summary of the main HRV/ERV performance aspects covered by these standards is given in Table 10 1. It confirms that as mentioned previously, these standards cover major engineering aspects as:

- Ventilation performance (expressed as Net outdoor airflow)
- Seasonal ventilation performance in cold climate (expressed as low-temperature ventilation reduction factor, LTVR)
- Leakage performance (as exhaust air transfer ratio, EATR)
- Apparent effectiveness (sensible, latent and total)
- Heat-recovery efficiency (sensible, latent and total)

In Canada, CAN/CSA C439 is the primary standard guiding the evaluation of HRV/ERV performance. It is referenced by both the National Building Code of Canada and by CAN/CSA-F326. Figure 10-1 shows the format recommended by this standard for reporting performance test results.

Thus, while these standards address important ventilation performance and energy efficiency aspects, none deal with specific IAQ performance aspects such as:

- particulate filtration performance,
- emission of organic contaminants by HRV / ERV components,
- by-product ozone formation by HRV/ERV motors and/or supplemental filtration systems.

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Table 10-1: Overview of Existing HRV/ERV Performance Standards

Existing Standard	***Performance Aspect***				
	Mechanical Performance	***Heat Transfer Efficiency***	***Cross Contamination***	***Ventilation Performance***	***Noise Level***
ANSI/AHRI 1060-2005 *Performance Rating of Air-To-Air Heat Exchangers for Energy Recovery Ventilation Heat Equipment*			• Exhaust air transfer ratio (EATR)		
ANSI/ASHRAE 84-2008 *Method of Testing Air-to-Air Heat Exchangers*		• Heat/energy transfer effectiveness • Recovery efficiency ratio	• Exhaust air transfer ratio (EATR) $= (C_{SA}-C_{OA})/(C_{RA}-C_{OA})$ where $C = [SF_6]$ • Outdoor Air Correction Factor (OACF) $= m_{OA}/m_{SA}$ where m = mass flow rate of dry air	• Pressure drop & mass flow characteristics	
CAN/CSA 22.2 NO. 113-M1984 (R2004) *Fans and Ventilators*	• Safety aspects				
CAN/CSA C439-00 (2009) *Standard Laboratory Methods of Test for Rating the Performance of Heat/Energy-Recovery Ventilators*		• Heat/moisture transfer effectiveness	• Tracer gas testing of cross leakage • Exhaust air carry-over • Casing leakage	• Gross Airflow vs External Static Pressure	
UL 1812 *Ducted Heat Recovery Ventilators*	• Mechanical requirements / materials • Wiring • Water resistivity				
HVI 915 (1 March 2009) *Loudness Testing and Rating Procedure*					• loudness rating in sones

Notes: ANSI = *American National Standards Institute*; AHRI = *Air-Conditioning, Heating and Refrigeration Institute*; ASHRAE = *American Society of Heating, Refrigerating and Air-Conditioning Engineers*; CSA = *Canadian Standards Association*; UL = *Underwriters Laboratories Inc*.; HVI = *Home Ventilating Institute*

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HRV/ERV SPECIFICATION SHEET

Testing agency: ____________________
Date tested: ____________________
Manufacturer: ____________________
Address: ____________________
____
Telephone: ____________________

Model: ____________________
Serial number: ____________________
Options installed: ____________________
____

Electrical requirements: ______ Volts ______ Amps

VENTILATION PERFORMANCE

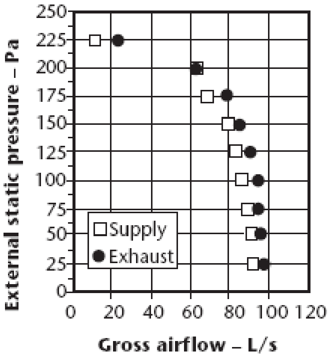
Maximum continuous rated airflows:
________ L/s @ 0 °C
________ L/s @ –25 °C

Maximum continuous rated airflows: ______ °C
Low-temperature ventilation reduction during test at –25 °C: ______ %
Maximum unbalanced airflow during test at –25 °C: ______ L/s

Airflow range for multispeed units:
High speed ______ L/s Low speed ______ L/s

Exhaust air transfer ratio: ______

External static pressure		Net supply airflow		Gross airflow				Power
				Supply		Exhaust		
Pa	in. WC	L/s	cfm	L/s	cfm	L/s	cfm	W
25	0.1							
50	0.2							
75	0.3							
100	0.4							
125	0.5							
150	0.6							
175	0.7							
200	0.8							
225	0.9							



NOTE: FAN CURVE PERFORMED ON HIGH SPEED

ENERGY PERFORMANCE

		Supply temperature		Net airflow		Supply/exhaust flow ratio	Average power, W	Sensible recovery efficiency	Apparent sensible effectiveness	Net moisture transfer
		°C	°F	L/s	cfm					
Heating	I	0	32							
	II	0	32							
	III	0	32							
	IV									
	V	– 25	– 13							
Cooling	VI	35	95					*	Comments from test agency:	
	VII									

*Indicates total recovery efficiency, not sensible recovery efficiency
250 Pa = 1 in of water; 0.47 L/s = 1 cfm

Reference report:
Sample no:

Testing was performed in general accordance with CSA C439, Standard laboratory methods of test for rating the performance of heat/energy-recovery ventilators, *in accordance with accepted professional standards.*

Figure 10-1: Reporting of HRV/ERV System performance test results (Source: CAN/CSA C439-09)

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10.2 Residential Ventilation and Outdoor Air Quality

As “ventilators”, as well as energy saving devices, HRV/ERV systems are subject to energy and building code requirements outlined in the National Model Construction Codes of Canada (NMCC) as adopted by individual Providences and Territories. Key requirements from these documents and the Standards referenced by them are briefly summarized below.

10.2.1 **National Model Construction Codes**

Six separate Model Codes are developed by the Canadian Commission on Building and Fire Codes (CCBFC) with advice from the Provincial/Territorial Policy Advisory Committee on Codes (PTPACC). Two of these, the *National Energy Code for Buildings* (NECB) and the *National Building Code of Canada* (NBCC) provide guidance related to the installation and operation of HRV/ERV systems in Canadian homes.

10.2.1.1 National Energy Code for Buildings (NECB)

The NECB (1997 version, until the 2011 is released) includes requirements related to heat recovery for ventilation air as follows:

5.3.4.3. Heat Recovery in Dwelling Units

1) Where a self-contained mechanical ventilation system is used to serve a single *dwelling unit* and where required in Table A -5.3.4.3. of Appendix A for the administrative region considered and for the *principal heating source* for the *building* or part of the *building* ventilated by the equipment, the principal exhaust component of such a ventilation system shall be equipped with heat-recovery capability (see Appendix E).

2) Heat-recovery ventilators used to meet the requirements of Sentence (1) shall have a sensible heat recovery efficiency, obtained in conformity with the low temperature thermal and ventilation test method described in CAN/ CSA-C439, “ Standard Methods of Test for Rating the Performance of Heat-Recovery Ventilators,”

a) of at least 65% at an outside air (Station 1) test temperature of 0°C, and

b) of not less than that required in Table 5.3.4.3. for the 2.5% January design temperature for the *building* location, as listed in Appendix C, Climatic Information for Building Design in Canada, of the National Building Code of Canada (see Appendix E) .

Table 5.3.4.3.
Performance of Heat-recovery Ventilators
Forming Part of Sentence 5.3.4.3.(2)

2.5% January Design Temperature at *Building* Location	Outside Air Test Temperature at Station 1, °C	Sensible Heat-recovery Efficiency
≥ −10	0	65
< −10 and > −30	−25	55
≤ −30	−40	45

3) The tests described in Sentence (2) shall be performed at the rated air flow for continuous operation of the equipment, which meets the principal exhaust component of the ventilating system referred to in Sentence (1).

4) Where a form of heat recovery other than a heat-recovery ventilator is used to meet the requirements of Sentence (1), the alternate system shall have a heat-recovery performance equivalent to that required in Sentence (2) for heat-recovery ventilators.

Appendix Note

E-5.3.4.3.(1) Heat Recovery in Dwelling Units. The National Building Code of Canada (NBC) 1995 includes detailed requirements for the mechanical ventilation of dwelling units. However, as the NBC is concerned only with health and safety issues, those requirements address only the effectiveness of ventilation systems, not their efficiency, which is left to this Code. Therefore, the requirements of this Code should be read in conjunction with those of the NBC. For example, the requirements in NBC 1995, Subsection 9.32.3., Mechanical Ventilation, can be satisfied using a heat-recovery ventilator but can also be satisfied with other types of ventilation equipment. In cases where this Code requires heat recovery from the exhaust component of the ventilation system, a heat-recovery ventilator would probably become the system of choice.

The principal exhaust component of a mechanical ventilation system is described in Article 9.32.3.4. of the NBC 1995 and represents 50% of the total ventilation capacity required by Article 9.32.3.3. of that Code.

E-5.3.4.3.(2) Heat Recovery Ventilators. The referenced CSA Standard, CAN/ CSA-C439, describes a laboratory test that determines the energy performance of a heat-recovery ventilator. The results of a test made for a manufacturer on a given model is listed in the Certified Home Ventilating Products Directory of the Home Ventilating Institute, Division of Air Movement and Control Association, 30 West University Drive, Arlington Heights, Illinois 60004-1893 U.S.A. and usually appears on a label on the equipment itself or in the manufacturer's published literature.

10.2.1.2 National Building Code of Canada (NBCC)

Sections of the NBCC that impact the installation and operation of HRV / ERV Systems are found in *Division B - Acceptable Solutions: Part 9* (Housing and Small Buildings) and *Part 6* (Heating, Ventilating and Air-conditioning).

Article 6.2.1.6. (*Heat Recovery Ventilators*) covers installation requirements for HRV systems, and states that Heat recovery ventilators with rated capacities of not less than 25 L/s and not more than 200 L/s shall be installed in accordance with Subsection 9.32.3.

Article 9.32.3.10. (Fans) sets limits on the low-temperature ventilation reduction factor of HRV systems.

Article 6.2.1.7 (Outdoor Design Conditions) specifies acceptable air quality levels for outdoor air used for building ventilation as follows.

Table 10-2: Maximum Acceptable Level of Some Outdoor Air Contaminant

Outdoor Air Contaminant	Maximum Acceptable Level
particulate matter that is 10 µm or less in diameter (PM_{10})	70 µg/m^3 annually, and 120 µg/m^3 daily
ground-level ozone (O_3)	15 ppb annually, 25 ppb daily, and 82 ppb hourly
carbon monoxide (CO)	13 ppm (15 mg/m^3) in eight hours, and 30 ppm (35 mg/m^3) hourly

When these levels are exceeded,

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NBC **Article 6.2.2.4 (*Cleaning Devices*)** requires that the ventilation systems shall "include devices that reduce particles and gases to the maximum acceptable levels described in Sentence 6.2.1.7.(2) prior to the introduction of outdoor air to indoor occupied spaces".

At present, **Article 6.2.1.7** is not specifically adopted in Part 9 (*Housing and Small Buildings*), so the air cleaning device requirements are not currently enforced for residential buildings that are less than 3 storeys and smaller than 600m² (approx. 6500 ft^2) building area. They do however serve as useful guidance for the evaluation of IAQ performance of HRV / ERV systems and should be considered carefully (as opposed to the simple assumption that outdoor air is "Fresh" air, as indicated, for example, in **Figure** 2-1).

NOTE: the values provided in Table 10-2 are currently under review and it is expected that guidance in future will be based on $PM_{2.5}$ levels not PM_{10}.

10.2.1.3 CAN/CSA-F326-M91 (R2010) - Residential Mechanical Ventilation Systems

CAN/CSA F326 defines the requirements for performance, installation and application, and performance verification of mechanical ventilation systems, and applies to systems that are capable of providing minimum controlled rates of ventilation air to the habitable spaces of those single-family dwellings that:

(a) fall within the Scope of Part 9 of the National Building Code of Canada; and

(b) are self-contained with respect to heating, ventilation, and air conditioning.

It applies to the installation requirements for self-contained ducted heat recovery ventilators intended for operation in dwelling units that have a maximum rated capacity of not less than 25 L/s and not more than 200 L/s. It also establishes dwelling unit pressure design requirements, and considers the house as a "system" that has ventilation subsystems which move air into and out while taking into account the leakage characteristics of the envelope, climatic conditions, the operation of exhaust devices not part of the ventilation system, and the venting characteristics of vented combustion appliances, including fireplaces. In Section 8.13.3 (d) F326 requires that "*the supply and exhaust airflow rates of heat recovery ventilators in the normal ventilation mode shall be balanced so that the value of the lesser flow shall be at least 90% of the value of the greater flow, unless otherwise recommended by the manufacturer*".

10.3 Filter Performance

In 2009, ASHRAE's Standard 52.1 *Gravimetric and Dust-Spot Procedures for Testing Air-Cleaning Devices Used in General Ventilation* was withdrawn. As a result, the older method of reporting particle filter performance in terms of "***arrestance***" and "***atmospheric dust spot efficiency***" have now been replaced by "***MERV***" values (*Minimum Efficiency Reporting Value*) as determined by ASHRAE 52.2 (2007) *Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size*.

MERV values from 1 to 16 characterize minimum filter performance for removal of particulate matter ranging from 0.3 to 10 microns (µm), with higher values indicating greater filtration efficiency. As indicated in Figure 10-2, filters with MERV rating below 8 have little effect on fine particulate matter ($PM_{2.5}$) while a MERV 14 filter will remove approximately 75% of 0.35 µm particles.

Since removal efficiency depends on the air flow rate through the filter, ASHRAE 52.2 requires that MERV values must be stated together with the air velocity at which the filter was tested.

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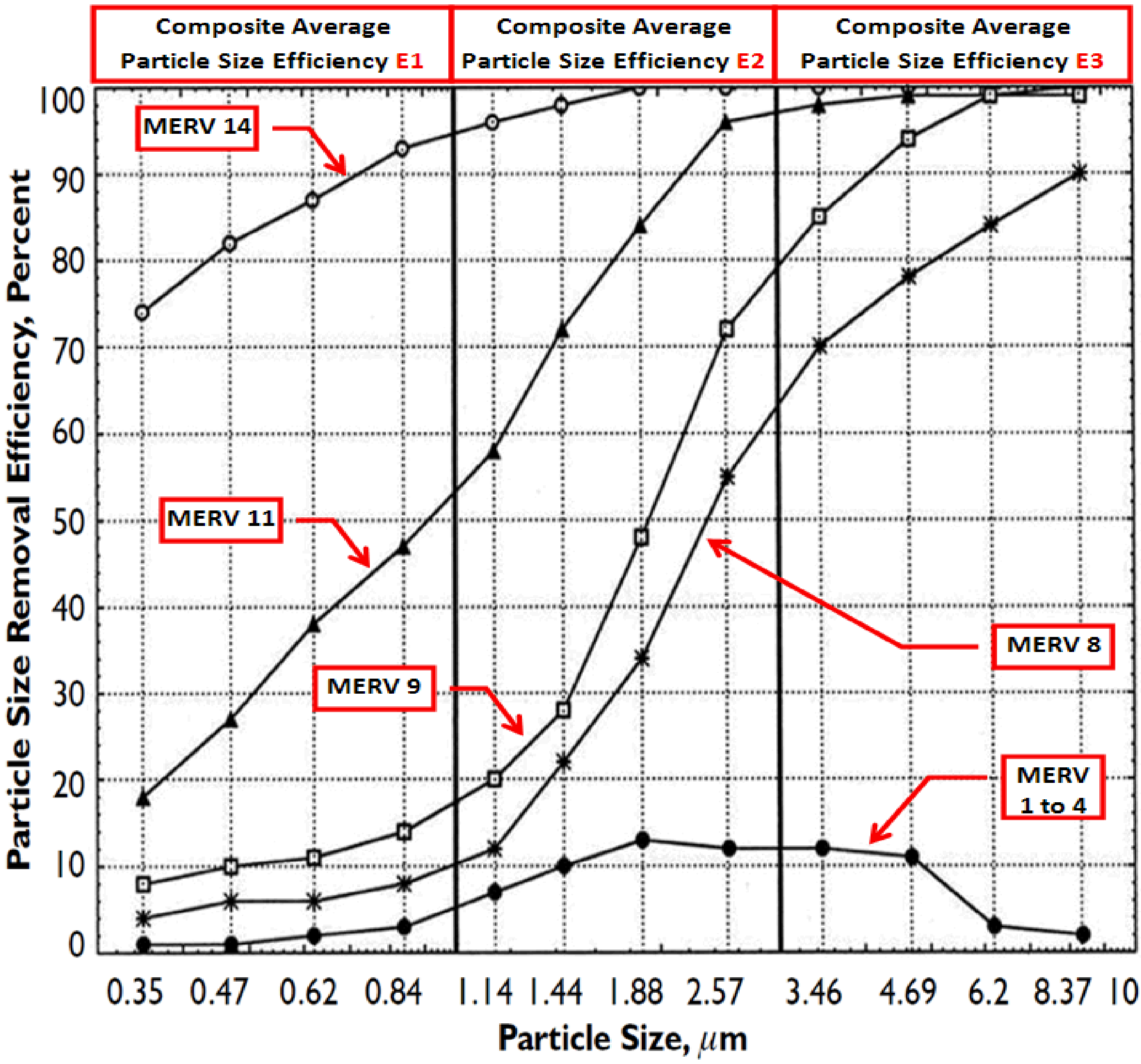

Figure 10-2: Typical minimum efficiency curves (Source: adapted from ASHRAE 52.2)

Some HRV/ERV systems claim "HEPA" performance in removing particulate matter. This acronym is generally accepted to mean "*High Efficient Particulate Air*" (although "Arrestance" is sometimes used). According to Institute of Environmental Sciences and Technology, IEST-RP-CC001.3 and the Department of Defense Test Method Standard MIL-STD-282 Method 102.9.1 (*DOP-Smoke Penetration and Air Resistance of Filters)*, HEPA filters remove 99.97% of 0.3 micron particles. Because filter performance is typically weakest at approximately 0.3 µm, this means that a HEPA filter's removal of particles smaller or larger than 0.3 µm will exceed 99.97%.

Actual filtration performance depends on a number of factors, including airflow pathways in the system in which the filter is installed and the effectiveness of air seals for the filter/frame/holder assembly to prevent by-pass. Certification of a filter at a certain level of performance (e.g. HEPA) does not necessarily guarantee the expected-level performance for the air delivered by the HRV/ERV unit.

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10.4 Guideline values for individual organic compounds, formaldehyde and ozone

Ozone Guideline:

Health Canada (2010) Residential Maximum Exposure Limit for Ozone (8h exposure): **20 ppb**

Formaldehyde Guideline:

Health Canada (2006) Residential Indoor Air Quality Guideline – Formaldehyde: **40 ppb** (50 µg/m^3)

Toluene Guideline:

Health Canada (2011) Residential Indoor Air Quality Guideline – Toluene: **600 ppb** (2300 µg/m^3)

Polycyclic Aromatic Hydrocarbons (PAHs):

Health Canada (1989) Residential IAQ Guideline: Exposure to polycyclic aromatic hydrocarbons indoors should be kept to a minimum (including Benzo(a)pyrene, acenaphthene, acenaphthylene, anthracene, benzo[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[g,h,i]perylene, benzo[k]fluoranthene, chrysene, dibenz[a,h]anthracene, fluoranthene, fluorene, indeno[1,2,3-c,d]pyrene, naphthalene, phenanthrene, pyrene

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Table 10-3: IAQ Guideline levels for selected organic compounds

VOC Class, Compound and CAS Number			IAQ Guideline Values, µg/m^3				
Class	Compound	CAS	WHO (averaging time)	Calif 01350 (OEHHA, Calif.)	ATSDR MRL (chronic)	AFSSET (France)	Health Canada Guidelines
Aldehyde	Acetaldehyde	75-07-0	50 (1 yr)	70		200	9000
	Acrolein	107-02-8	50 (30 min)	0.35			50
	Formaldehyde	50-00-0	100 (30 min)	16.5	10	10	50
Alcohols, Glycols, GlycoEthers	1,2-Ethanediol	107-21-1		200		400	
	1-Methoxy-2-propanol	107-98-2		3500		2000	
	2-Butoxyethanol	111-76-2	13,100 (1 wk)		966	982	
	2-Ethoxyethanol	110-80-5		35		170	
	2-Methoxyethanol	109-86-4				20	
	2-Propanol	67-63-0		3500			
	Phenol	108-95-2		100		200	
Esters	2-Ethoxyethyl acetate	111-15-9		150		300	
	Butyl acetate	123-86-4				4800	
Halo Carbons	1,4-Dichlorobenzene	106-46-7	1,000 (1 yr)	400	60		
	Methylene chloride	75-09-2		200	1,040		
	Tetrachloroethylene (PCE)	127-18-4	250 (1 yr)	17.5	272	250	
	Trichloroethylene (TCE)	79-01-6	23	300			
Aliphatic Hydrocarbons	Heptane	142-82-5				20800	
	Hexane	110-54-3		3500		700	
	Nonane	111-84-2				21000	
	Octane	111-65-9				14500	
Aromatic Hydrocarbons	Benzene	71-43-2	1.7	30	10		In process
	1,2-Dimethylbenzene (o-Xylene)	95-47-6	870 (1 yr)	350	217	200	
	1,3,5-Trimethylbenzene	108-67-8				1000	
	1,3-Dimethylbenzene (m-Xylene)	108-38-3	870 (1 yr)	350	217	200	
	1,4-Dimethylbenzene (p-Xylene)	106-42-3	870 (1 yr)	350	217	200	
	Ethylbenzene	100-41-4	2,2000 (1 yr)	1000	1,300	1000	
	Naphthalene	91-20-3	10 (1yr)	4.5	4	10	In process
	Styrene	100-42-5	260 (1 wk)	450	851	250	
	Toluene	108-88-3	260 (1 wk)	150	302	300	2300
PAH	Benzo[a]pyrene	50-32-8	0.12				
Terpenes	alpha-Pinene	80-56-8				450	

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Notes:

- ATSDR = Agency for Toxic Substances & Disease Registry
- OEHHA = Office of Environmental Health Hazard Assessment, California EPA
- MRL = Minimum Risk Levels (exposure ≥ 365 days)
- AFSSET = L'Agence française de sécurité sanitaire de l'environnement et du travail (France)
- PAH = Polycyclic Aromatic Hydrocarbons
- WHO - WHO guidelines for indoor air quality: Selected pollutants (WHO 2010)
- Calif 01350 = *Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources using Environmental Chambers*. Version 1.1 (2010) (Emission testing method for California Specification 01350), California Department of Public Health.
    - o The 01350 value for formaldehyde drops to 9 µg/m3 after Jan.01, 2012
- IAQ Guideline values for *benzene* and *naphthalene* are currently under review and expected to be released soon.

Note: IAQ Guideline values for *benzene* and *naphthalene* are currently under review and expected to be released soon.

10.5 Outlook for future developments of test methods related to HRV/ERV

This test method deals with emissions of VOCs and carbonyl compounds from HRV/ERV systems and components, ozone formation and filtration of particulate matter from the outdoor and return air. In future, this test method may be extended to cover additional aspects of HRV / ERV system performance, including:

- *IAQ Sensor operation*: To evaluate the sensitivity, precision / accuracy, calibration and maintenance of any "IAQ Sensors" promoted for use with HRV / ERV systems.

- *Humidity control sensor operation*: To evaluate the precision / accuracy, calibration and maintenance of RH sensors installed as options to system (as means for controlling indoor RH).

Gas-phase filtration system performance: To evaluate the removal efficiency, maintenance associated with any filtration systems associated with HRV / ERVs targeting specific outdoor contaminants including ozone and carbon monoxide (consistent with any new National Building Code of Canada requirements for quality of ventilation air – see Section 10.2). This may include using activated charcoal filters in HRV/ERV systems where testing could include under "worst case" scenarios such as high temperature and humidity outdoor air. Also, the effectiveness of any ozone filtration systems installed as part of the HRV/ERV may be evaluated by providing ozone challenges within the outdoor air duct and monitoring corresponding outdoor air and supply air levels.

- *Radon Control effectiveness - Flow and pressure balancing*: To evaluate system maintenance and ease of adjustment to support claims of balanced HRV/ERV system operation in reducing Radon concentration.

- *Outdoor / exhaust air short-circuiting*: To determine potential for exhaust air re- entrainment to occur under summer and winter conditions. This test should consider re-entrainment not only by HRV/ERV intake/exhaust but also by local contaminant sources in immediate neighbourhood.

- *ERV core cross-contamination potential*: To determine transfer rate of chemical compounds (including polar compounds such as formaldehyde) across ERV cores (i.e. Compound-specific "EATRs").
- *Long term performance:* To evaluate the performance of HRV/ERV systems after a simulated long term operation.