CANADIAN STANDARDS ASSOCIATION

C439-09

Standard laboratory methods of test for rating the performance of heat/energy-recovery ventilators

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Update No. 1
C439-09
January 2010

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Title: *Standard laboratory methods of test for rating the performance of heat/energy-recovery ventilators* — originally published January 2009

The following revisions have been formally approved:

Revised	Outside front cover and title page
New	National Standards of Canada text
Deleted	None

CSA C439-09 originally consisted of **36 pages** (ix preliminary and 27 text), each dated **January 2009**. It now consists of the following pages:

January 2009	iii–ix and 1–27
January 2010	Cover, National Standards of Canada text, title page, and copyright page

- Update your copy by inserting these revised pages.
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CAN/CSA-C439-09
A National Standard of Canada
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Standard laboratory methods of test for rating the performance of heat/energy-recovery ventilators

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C439-09

Standard laboratory methods of test for rating the performance of heat/energy-recovery ventilators

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Preface

This is the fourth edition of CSA C439, *Standard laboratory methods of test for rating the performance of heat/energy-recovery ventilators*. It supersedes the previous editions, published in 2000, 1988, and 1985.

This Standard applies to packaged heat/energy-recovery ventilators.

CSA acknowledges that the development of this Standard was made possible, in part, by the financial support of Natural Resources Canada (NRCan), BC Hydro, Manitoba Hydro, Hydro-Québec, Ontario Ministry of Energy and Infrastructure, the Canadian Electricity Association, and the Ontario Power Authority.

This Standard is considered suitable for use for conformity assessment within the stated scope of the Standard.

This Standard was prepared by the Subcommittee on Methods of Test for Rating the Performance of Heat/Energy-Recovery Ventilators, under the jurisdiction of the Technical Committee on Heating, Ventilation, Air Conditioning, and Refrigeration and the Strategic Steering Committee on Performance, Energy Efficiency, and Renewables, and has been formally approved by the Technical Committee. It will be submitted to the Standards Council of Canada for approval as a National Standard of Canada.

January 2009

Notes:

(1) *Use of the singular does not exclude the plural (and vice versa) when the sense allows.*

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(c) be phrased where possible to permit a specific "yes" or "no" answer.

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C439-09
Standard laboratory methods of test for rating the performance of heat/energy-recovery ventilators

1 Scope

1.1

1.1.1
This Standard applies to packaged heat/energy-recovery ventilators (HRVs/ERVs) that consist of factory-assembled elements, including fans or blowers, in which heat or heat and moisture are transferred between two isolated airstreams.

1.1.2
This Standard specifies laboratory methods of test and procedures for rating the apparent effectiveness and heat-recovery efficiency of HRVs/ERVs. Procedures for determining air movement capabilities and the leakage of air from one airstream to another are also included.

1.1.3
Packaged HRVs/ERVs that use a refrigeration cycle or circulating fluid to transfer heat between two isolated airstreams may be rated using this Standard.

1.2
In CSA Standards, "shall" is used to express a requirement, i.e., a provision that the user is obliged to satisfy in order to comply with the standard; "should" is used to express a recommendation or that which is advised but not required; "may" is used to express an option or that which is permissible within the limits of the standard; and "can" is used to express possibility or capability. Notes accompanying clauses do not include requirements or alternative requirements; the purpose of a note accompanying a clause is to separate from the text explanatory or informative material. Notes to tables and figures are considered part of the table or figure and may be written as requirements. Annexes are designated normative (mandatory) or informative (non-mandatory) to define their application.

2 Reference publications
This Standard refers to the following publications, and where such reference is made, it shall be to the edition listed below, including all amendments published thereto.

CSA (Canadian Standards Association)
CAN/CSA-C62301-07
Household electrical appliances — Measurement of standby power

ANSI/AMCA (American National Standards Institute/Air Movement and Control Association International)
210-07
Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating

ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers)
ASHRAE Handbook — Fundamentals (2005)

41.1-1986 (R2006)
Standard Method for Temperature Measurement

Other publication
Wile, D.D. 1947. Air flow measurement in the laboratory. *Refrigerating engineering*: 515–521.

3 Definitions

The following definitions apply in this Standard:

Apparent effectiveness — the ratio of the actual heat transfer to the thermodynamically limited maximum heat transfer possible in a counterflow unit of infinite transfer area.
Note: *Effectiveness may be specified as total, sensible, or latent.*

Efficiency — the apparent effectiveness, adjusted to take into account fan energy, exhaust air transfer, mass and flow imbalance, frost control, and other external and internal energy gains and losses (see Clause 9.3.3).

Energy-recovery ventilator (ERV) — a heat-recovery ventilator designed to transfer heat and moisture.

Exhaust air transfer ratio — the ratio of the quantity of exhaust air found in the air supply to the total supply airflow.

Gross airflow — the measured airflow rate in the supply and exhaust streams (see Clause 8.1).

Heat-recovery ventilator (HRV) — a factory-assembled packaged unit, including fans or blowers, designed to transfer heat between two isolated airstreams.

Maximum rated airflow — the highest rated airflow specified by the manufacturer for thermal performance tests in accordance with Clause 10.3.1.

Net supply airflow — the gross supply airflow (see Clause 8.1) reduced by the exhaust air transfer (see Clause 8.2).

Psychrometric chamber — that portion of a test facility containing the wet-bulb and dry-bulb thermometers.

Standard air — air of a density of 1.20 kg/m^3.
Note: *This is approximately equivalent to dry air at a temperature of* 21 °C *and a barometric pressure of* 101 kPa.

Standard barometric pressure — a barometric pressure of 101 kPa.

4 General requirements for determining performance

4.1

HRV/ERV performance shall be determined by evaluating the following:
(a) the effectiveness of the ventilator in transferring sensible and total heat and moisture from one airstream to another;
(b) the ventilation performance under specified test conditions;
(c) the percentage of the exhaust air carried over into the supply air; and
(d) the air leakage of the casing.

4.2
Instruments other than those specified in Clauses 5 and 6 may be used to determine performance if their accuracy is within the limits specified in Clauses 5 and 6. The acceptable alternatives shall be limited to the instruments described in the chapter on measurements and instruments in the *ASHRAE Handbook — Fundamentals*.

5 Instruments for determining performance
Note: *See also Clause 6.*

5.1 General
The instruments used to determine performance shall be calibrated and traceable to a National Standard.

5.2 Temperature-measuring instruments

5.2.1
Except as specified in Clauses 5.2.2 to 5.2.6, temperature measurements and temperature-measuring instruments shall meet the requirements of ASHRAE 41.1.

5.2.2
Temperature measurements shall be made with one or more of the following instruments:
(a) mercury-in-glass thermometers;
(b) thermocouples; and
(c) electric-resistance thermometers.

5.2.3
For air wet-bulb and dry-bulb temperatures the accuracy shall be ±0.5 °C.
Note: *Wet-bulb temperatures should be read only under conditions that ensure an air velocity of* 3.5 *to* 10.0 m/s *over the wet bulb (preferably close to* 5.0 m/s*), and only after time has been allowed for evaporative equilibrium to be attained. For wet-bulb determinations at temperatures below freezing, a recommended method is to freeze a coating of ice approximately* 0.5 mm *thick directly on the bulb of the thermometer or other temperature-sensing element. Another method is to preheat an air sample before temperature measurement to raise the wet-bulb temperature above* 0 °C*. The preheat temperature should be as low as possible to minimize the wet-bulb depression. When an air sample is preheated, a dry-bulb temperature measurement should be taken upstream of the heater and the dry-bulb and wet-bulb temperatures read at the same station after preheating. Humidity may also be determined through a direct measurement of dew point using basic apparatus providing an accuracy of* ±0.4 °C*.*

5.2.4
Whenever possible, instruments for measuring the change in temperature shall be arranged so that the supply and exhaust positions can be readily interchanged to improve accuracy by using average value.

5.2.5
The same measuring methods and equipment shall be used at all measurement stations. Psychrometric measuring stations shall be uniformly located downstream of the diffusers at each flow measurement station.

5.2.6
The pressures in the psychrometric chambers shall be used in the humidity calculations.

5.3 Pressure-measuring instruments

5.3.1
Pressure measurements shall be made with a liquid-column manometer or calibrated pressure transducer.

5.3.2
For pressure measurements the accuracy shall be ±1% of the reading. When this requirement necessitates a pressure measurement accuracy better than ±2.5 Pa, the required accuracy shall be ±2.5 Pa.

6 Airflow measurement

6.1 General

6.1.1
Airflow rates at the four measurement stations (see Figure 1) may be determined using one of the following methods, provided that the cumulative accuracy of the instrumentation permits measurements within 5% of the actual flow rate or 5 L/s, whichever is smaller:
(a) venturi tube;
(b) flow nozzles;
(c) averaging Pitot tubes;
(d) laminar flow element; or
(e) orifice plate.

6.1.2
The accuracy of the instrumentation shall be determined by measurements performed in accordance with ANSI/AMCA 210.

6.2 Nozzles
Note: *As shown in Figure 2, a nozzle station consists of a receiving chamber and a discharge chamber separated by a partition in which one or more nozzles (which can be of equal or unequal size) are located.*

6.2.1
Each nozzle station shall have one or more diffusers, installed as follows:
(a) in the receiving chamber, diffusers whose diameter is at least 1-1/2 times larger than the diameter of the largest nozzle throat upstream of the partition wall; and
(b) in the discharge chamber, diffusers whose diameter is at least 2-1/2 times larger than the diameter of the largest nozzle throat downstream of the partition wall.

Screen diffusers shall meet the requirements of ANSI/AMCA 210.

6.2.2
The centre-to-centre distance between nozzles shall be at least three times the throat diameter of the largest nozzle. The distance from the centre of a nozzle to the nearest discharge or receiving chamber side wall shall be at least 1-1/2 times its throat diameter.

The static pressure drop across nozzles shall be measured with one or more manometers having the accuracy specified in Clause 5.3.2. One end of the manometer shall be connected to static-pressure taps flush with the inner walls of the receiving chamber, and the other end to static-pressure taps flush with the inner walls of the discharge chamber. The taps in each chamber shall be connected to manometers in parallel or manifolded to a single manometer. Alternatively, the velocity head of the airstream leaving a nozzle may be measured using a Pitot tube as shown in Figure 2.

6.2.3
Means shall be provided to determine the air density at the nozzle throat.
Note: *If freezing conditions exist, see Section 6.22 of ASHRAE 41.1.*

6.2.4
The velocity at the nozzle throat shall be not less than 15 m/s and not more than 35 m/s.

6.2.5
When nozzles are constructed in accordance with Figure 3, and installed in accordance with Clause 6.2, they may be used without calibration. If the throat diameter is 120 mm or larger, the default coefficient of discharge shall be 0.99. For nozzles with a throat diameter smaller than 120 mm, or when a more precise coefficient is desired, the following procedure shall be used:
(a) The temperature shall be measured and the corresponding temperature factor, *f*, selected from Table 1.
(b) The Reynolds number shall be calculated as follows:

$$N_{Re} = fV_aD$$

where
N_{Re} = Reynolds number
f = temperature factor
V_a = velocity at the nozzle throat, m/s
D = nozzle throat diameter, mm
(c) The Reynolds number shall be used to select the applicable coefficient of discharge from Table 2.

6.2.6
The size of a nozzle's throat shall be determined by measuring its diameter in four places approximately 45° apart in each of two planes, one at the nozzle outlet and the other in the straight section near the radius. The diameters shall be within ±0.20% of the mean at each plane. The mean diameter at the discharge plane may be 0.20% smaller than the mean diameter at the other plane. The flow rate shall be determined using the measured discharge area.

6.2.7
The maximum variation in temperature between nozzles in a nozzle chamber shall be 0.6 °C.
Note: *It is possible that a mixing device will be required to meet this condition. See Wile (1947) and ASHRAE 41.1. An illustration of a mixing device is provided in Figure 4.*

7 Static pressure measurement

7.1 General
Static pressure shall be measured at each nozzle station and on each side of the ventilator.

7.2 Construction of static pressure taps
Pressure taps should consist of 6.25 mm diameter nipples soldered to the outer plenum surfaces and centred over 1.5 mm diameter holes through the plenum walls. The edges of these holes shall be free of burrs and other surface irregularities.

8 Test procedures

8.1 Airflow rate measurement procedure

Note: *See also Clause 6.*

8.1.1

Airflow rates for HRVs/ERVs shall be measured in accordance with ANSI/AMCA 210 using a test facility similar to that shown in Figure 1 or 5. If high-resistance flow-measuring devices are used, it is possible that additional fans will be needed for the flow-measurement facility, as shown in Figure 5.

HRVs/ERVs with one or more airstream inlets or outlets not intended for connection to a duct (i.e., non-ducted HRVs/ERVs) may also be rated using this Standard by incorporation of suitable transition plenum connectors to adapt the HRVs/ERVs to a ducted configuration. Such transitions shall be fabricated to minimize flow restriction or augmentation. Static pressure differentials across the unit shall be varied using butterfly valves or other suitable flow-control devices.

Arrangements of test equipment other than those specified in this Clause may be used if equal or better accuracy is attained and all of the procedures specified in Clause 8.2 can be performed.

8.1.2

The moisture content of the air at each station shall be determined from the temperature and pressure in the station's psychrometric chamber.

8.2 Tracer gas measurement procedure

8.2.1 Test 1

8.2.1.1

A test shall be carried out to determine the cross-leakage from exhaust to outdoor air and casing leakage from the exhaust air side (see Figure 1). An inert tracer gas shall be injected into a turbulent region before Station 3. Air samples shall then be drawn from Stations 2 to 4 to determine the carry-over or dilution and from Station 1 to confirm the absence of the tracer gas.

The sampling equipment shall consist of

(a) sampling grids extending into all stations (see Figure 6);
(b) a gas chromatograph analyzer or an alternative instrument with the accuracy required by Clause 8.2.1.2; and
(c) a means of collecting and transporting air samples to the analyzer.

8.2.1.2

An inert tracer gas shall be injected into the airstream before Fan 2 (see Figure 1). The injection rate shall be sufficient to ensure that a carry-over of 0.1% from exhaust to outdoor air, and the casing leakage, are within the measuring capacity of the device being used.

8.2.1.3

A continuous air sample shall be drawn from each sampling grid. Samples shall be drawn using a laboratory-approved procedure. Care shall be taken to ensure that dilution does not occur in the sampling system.

8.2.1.4

The test shall be conducted at a laboratory ambient temperature of 15 to 35 °C. There shall be no psychrometric changes during the test and relative humidity (RH) shall be maintained at 20 to 60%.

8.2.2 Test 2

8.2.2.1

A test shall be carried out to determine the cross-leakage from outdoor air to exhaust and casing leakage from the outdoor air side (see Figure 1). An inert tracer gas shall be injected into a turbulent region before Station 1. Air samples shall then be drawn from Stations 1, 2, and 4 to determine the carry-over or dilution and from Station 3 to confirm the absence of the tracer gas.

The sampling equipment shall consist of

(a) sampling grids extending into all stations (see Figure 6);
(b) a gas chromatograph analyzer or an alternative instrument with the accuracy required by Clause 8.2.2.2; and
(c) a means of collecting and transporting air samples to the analyzer.

8.2.2.2

An inert tracer gas shall be injected into the airstream before Fan 1 (see Figure 1). The injection rate shall be sufficient to ensure that a carry-over of 0.1% from exhaust to outdoor air, and the casing leakage, are within the measuring capacity of the device being used.

8.2.2.3

A continuous air sample shall be drawn from each sampling grid. Samples shall be drawn using a laboratory-approved procedure. Care shall be taken to ensure that dilution does not occur in the sampling system.

8.2.2.4

The test shall be conducted at a laboratory ambient temperature of 15 to 35 °C. There shall be no psychrometric changes during the test and RH shall be maintained at 20 to 60%.

8.2.3 Test 3

8.2.3.1

A test shall be carried out to determine the cross-leakage from exhaust to outdoor air and thereby to determine the net supply airflow for the airflow performance specification sheet (see Figure 1 and Clause 11).

The test shall be conducted with the unit operating at its maximum operating speed and a pressure differential of 50 and 100 Pa applied to the supply and exhaust airstreams. (For non-ducted units the pressure shall be zero and for partially ducted units 25 and 50 pa.) If the leakage at the two test pressures differs significantly, leakage tests at additional static pressures shall be performed to further characterize the leakage rate.

An inert tracer gas shall be injected into a turbulent region before Station 3. Air samples shall then be drawn from Stations 2 to 4 to determine the carry-over or dilution and from Station 1 to confirm the absence of the tracer gas.

The sampling equipment shall consist of

(a) sampling grids extending into all stations (see Figure 6);
(b) a gas chromatograph analyzer or an alternative instrument with the accuracy required by Clause 8.2.3.2; and
(c) a means of collecting and transporting air samples to the analyzer.

8.2.3.2

An inert tracer gas shall be injected into the airstream before Fan 2 (see Figure 1). The injection rate shall be sufficient to ensure that a carry-over of 0.1% from exhaust to outdoor air, and the casing leakage, are within the measuring capacity of the device being used.

8.2.3.3
A continuous air sample shall be drawn from each sampling grid. Samples shall be drawn using a laboratory-approved procedure. Care shall be taken to ensure that dilution does not occur in the sampling system.

8.2.3.4
The test shall be conducted at a laboratory ambient temperature of 15 to 35 °C. There shall be no psychrometric changes during the test and RH shall be maintained at 20 to 60%.

9 Calculations

9.1 Airflow

9.1.1
The rate of airflow through a single nozzle shall be calculated from the following equations:

$$Q_n = 1.414 \times C \times A \times (P_V \times V_n')^{0.5} \qquad \textbf{(1)}$$

$$V_n' = \frac{V_n}{1+W} \qquad \textbf{(2)}$$

$$V_n = \frac{R_a \times T \times (1 + 1.6078 W_n)}{P} \qquad \textbf{(3)}$$

$$W_n = \frac{(2501 - 2.326t')W_s' - (t - t')}{2501 + 1.86t - 4.186t'} \qquad \textbf{(4)}$$

$$W_s' = 0.62198 \frac{P_{ws}'}{P - P_{ws}'} \qquad \textbf{(5)}$$

where

Q_n = nozzle flow rate, m^3/s

C = nozzle discharge coefficient (see Clause 6.2.5)

A = nozzle throat area, m^2

P_V = velocity pressure at the nozzle throat or static pressure differential across the nozzle, Pa

V_n' = volume of air at the nozzle, m^3/kg of air/water vapour mixture

V_n = volume of air at the nozzle, m^3/kg dry air

W = humidity ratio of air, kg water per kg dry air

R_a = gas constant for air, J/kg•K^{-1}

= 287.055

T = absolute temperature in the nozzle chamber, K

W_n = humidity ratio of air at the nozzle, kg water per kg dry air

P = absolute pressure in the psychrometric chamber, Pa

t' = wet-bulb temperature at the psychrometric station, °C

W_s' = humidity ratio, kg water per kg dry air, saturated at wet-bulb temperature

t = dry-bulb temperature at the psychrometric station, °C

P_{ws}' = saturation vapour pressure at wet-bulb temperature, Pa

9.1.2

When more than one nozzle is used, the total airflow rate shall be the sum of the flow rates of the individual nozzles calculated in accordance with Clause 9.1.1.

9.1.3

The flow rate of standard air shall be calculated as follows:

$$Q_s = \frac{Q_n}{1.20V_n'} \tag{6}$$

where

Q_s = flow rate of standard air, m^3/s

Q_n = nozzle flow rate, m^3/s

V_n' = volume of air at the nozzle, m^3/kg air/water vapour mixture

9.2 Apparent effectiveness

9.2.1

The apparent effectiveness of an HRV/ERV shall be calculated as follows:

$$\varepsilon = \frac{M_s \times (X_1 - X_2)}{M_{min} \times (X_1 - X_3)} \tag{7}$$

where

ε = apparent sensible, latent, or total heat effectiveness

M_s = mass flow rate of the supply air, kg dry air per unit of time

X = dry-bulb temperature, humidity ratio, or total enthalpy, respectively, at the locations indicated in Figure 7

M_{min} = M_s or M_e, whichever is less

where

M_e = mass flow rate of the exhaust air, kg dry air per unit of time

9.2.2

The specific enthalpy shall be calculated as follows:

$$h = 1.006t + W\,(2501 + 1.86t) \tag{8}$$

where

h = specific enthalpy, J/kg dry air

t = dry-bulb temperature, °C

W = humidity ratio of air, kg water per kg dry air

9.3 Supply air contamination

9.3.1 Exhaust air contamination ratio

Air leakage from the higher-pressure exhaust side to the lower-pressure intake side, and to the supply air through the casing, shall be determined by calculating the exhaust air contamination ratio as follows:

(a) If $\frac{B_2''}{B_1''} < 0.9$:

$$R = 1 - \frac{B_2''}{B_1''} \quad \textbf{(9)}$$

(b) If $\frac{B_2''}{B_1''} \geq 0.9$:

$$R = \frac{B_2'}{B_3'} \quad \textbf{(10)}$$

where

R = exhaust air transfer ratio

B_2'' = concentration of tracer gas at Station 2 (measured in the same units as B_1'') in the test described in Clause 8.2.1.1

B_1'' = concentration of tracer gas at Station 1 (measured in the same units as B_2'') in the test described in Clause 8.2.1.1

B_2' = concentration of tracer gas at Station 2 (measured in the same units as B_3') in the test described in Clause 8.2.1.1

B_3' = concentration of tracer gas at Station 3 (measured in the same units as B_2') in the test described in Clause 8.2.1.1

9.3.2 Ventilation reduction factor

The ventilation reduction factor due to cross-leakage and casing leakage is a measure of the degree to which the air supply is a mix of the outdoor air and recycled air that has leaked into the unit. It shall be calculated as follows:

$$V = 1 - R \quad \textbf{(11)}$$

where

V = ventilation reduction factor

R = exhaust air transfer ratio

9.3.3 Heat-recovery efficiency

9.3.3.1

The sensible heat-recovery efficiency shall be calculated as follows:

$$E_{SHR} = \frac{\left(\sum_{i=1}^{n} M_{s,i} \times C_p \times \left(t_{5,i} - t_{1,i}\right) \times \Delta\theta\right) - Q_{SF} - Q_{SH} - Q_C - Q_D - Q_L}{\left(\sum_{i=1}^{n} M_{max,i} \times C_p \times \left(t_{3,i} - t_{1,i}\right) \times \Delta\theta\right) + Q_{EF} + Q_{EH}} \quad \textbf{(12)}$$

where

E_{SHR} = sensible heat-recovery efficiency

n = total number of measurements

i = ith time that data are recorded

M_s = net mass flow rate of the supply air

= $M_2 \times (1 - R)$

where

M_2 = mass flow rate of air measured at Station 2, kg/s

R = exhaust air transfer ratio

C_p = specific heat of the air, kJ/kg•K

t_5 = net outdoor airflow temperature at Station 2, calculated in accordance with Clause 9.3.3.7, °C

t_1, t_3 = dry-bulb temperature at Stations 1 and 3, respectively, °C

$\Delta\theta$ = time between flow measurements, s

Q_{SF} = energy input into supply airstream attributed to fan(s), kJ

Q_{SH} = energy used by heater in supply airstream, kJ, and energy use attributed to compressor, kJ

Q_C = casing heat transfer, calculated in accordance with Clause 9.3.3.4, kJ

Q_D = energy used for defrost, calculated in accordance with Clause 9.3.3.5, kJ

Q_L = heat loss due to casing leakage, calculated in accordance with Clause 9.3.3.6, kJ

M_{max} = M_s or M_e, whichever is greater

where

M_e = net mass flow rate of the exhaust air

$$= M_4 \times \left(\frac{B_4'}{B_3'}\right)$$

where

M_4 = mass flow rate of air measured at Station 4, kg/s

B_4' = concentration of tracer gas at Station 4 (measured in the same units as B_3') in the test described in Clause 8.2.1.1

B_3' = the value specified in Clause 9.3.1

Q_{EF} = energy input into exhaust airstream attributed to fan(s), kJ

Q_{EH} = energy used by heater in exhaust airstream, kJ

For tests performed in cooling mode, the absolute values of $(t_{5,i} - t_{1,i})$ and $(t_{3,i} - t_{1,i})$ shall be used in Equation 12.

Note: *The energy input attributed to fans (Q_{SF} and Q_{EF}) is based on the location of the fan/motor(s). For systems that use a refrigeration compressor or fluid circulating pump to transfer energy between the two airstreams, all compressor and/or pump power is attributed to the supply airstream.*

9.3.3.2

Note: *See Clause 9.3.3.1 for definitions of symbols not defined in this Clause.*

The total heat-recovery efficiency shall be calculated as follows:

$$E_{THR} = \frac{\left(\sum_{i=1}^{n} M_{s,i} \times (h_{5,i} - h_{1,i}) \times \Delta\theta\right) - Q_{SF} - Q_{SH} - Q_C - Q_D - Q_L}{\left(\sum_{i=1}^{n} M_{max,i} \times (h_{3,i} - h_{1,i}) \times \Delta\theta\right) + Q_{EF} + Q_{EH}} \qquad \textbf{(13)}$$

where

E_{THR} = total heat-recovery efficiency

h_1, h_3 = enthalpy at Stations 1 and 3, respectively, kJ/kg

h_5 = enthalpy of outdoor air at Station 2, kJ/kg (see Clause 9.3.3.7)

For tests performed in cooling mode, the absolute values of $(h_{5,i} - h_{1,i})$ and $(h_{3,i} - h_{1,i})$ shall be used in Equation 13.

9.3.3.3

When a defrost system shuts off the supply air to the HRV/ERV and directs indoor air through the supply side of the HRV/ERV, the value of M_s shall be set to zero during periods of defrost for calculation of performance parameters, including E_{SHR}, E_{THR}, net outdoor airflow, maximum ventilation unbalance, and low-temperature ventilation reduction factor.

9.3.3.4

9.3.3.4.1

For determining the heat transfer from the surrounding air to the HRV/ERV, temperature sensors shall be applied to the exterior of the casing, with at least one sensor for every 0.1 m^2 of surface area, when the unit is operating at test conditions. Temperature sensors shall be applied to areas where condensation or frost is visible on the casing.

9.3.3.4.2

The casing heat transfer shall be calculated as follows:

$$Q_C = Q_{CD} + Q_{CW} \qquad \textbf{(14)}$$

where

Q_C = casing heat transfer

and Q_{CD} and Q_{CW} are as specified in Clauses 9.3.3.4.3 and 9.3.3.4.4, respectively.

9.3.3.4.3

The following calculation shall be used for surfaces that have no visible condensation or frost:

$$Q_{CD} = \left(\sum_{i=1}^{n} UA_{cd,i} \times \left(t_{case,i} - t_{air} \right) \right) \times \theta_t \qquad \textbf{(15)}$$

where

Q_{CD} = heat transfer through the dry areas of the case

n = total number of measurements

i = ith time that data are recorded

U = 7.5 $W/m^2 \bullet K^{-1}$

A_{cd} = dry area allocated to the temperature sensors, m^2

t_{case} = surface temperature of the case, °C

t_{air} = temperature of the air surrounding the case, °C

θ_t = time between measurements, s

9.3.3.4.4
The following calculation shall be used for surfaces that have visible condensation or frost:

$$Q_{CW} = \left(\sum_{i=1}^{n} U_w A_{cw,i} \times \left(h_{case,i} - h_{air} \right) \right) \times \theta_t \tag{16}$$

where

Q_{CW} = heat transfer through the areas of the case with condensation or frost

n = total number of measurements

i = ith time that data are recorded

U_w = 7.5 kg/(s•m^2)

A_{cw} = area with condensation or frost allocated to the temperature sensors, m^2

h_{case} = enthalpy of saturated air at the temperature of the casing surface, kJ/kg

h_{air} = enthalpy of the air surrounding the case, kJ/kg

θ_t = time between measurements, s

9.3.3.5
For HRVs/ERVs that circulate indoor air through the unit for defrost, the energy loss from the circulated air shall be calculated as follows:

$$Q_D = \sum_{i=1}^{n} M_{D,i} \times C_p \times \left(t_{in,i} - t_{out,i} \right) \times \theta_{D,i} \tag{17}$$

where

Q_D = energy used for defrost, kJ

n = total number of measurements

i = ith time that data are recorded

M_D = flow rate of the air circulated for defrost, kg/s

C_p = specific heat of the air, kJ/kg•K

t_{in} = temperature of the air entering the HRV/ERV, °C

t_{out} = temperature of the air leaving the HRV/ERV, °C

θ_D = total time that the defrost mode operates, s

9.3.3.6
Energy loss due to casing leakage shall be calculated in accordance with the following equations:

$$Q_L = \sum_{i=1}^{n} \left[\left(M_{3,i} - M_{4,i} \frac{B'_4}{B'_3} \right) - \left(M_{2,i} \frac{B'_2}{B'_3} \right) \right] \times C_p \times (t_{3,i} - t_{4,i}) \times \Delta\theta_i \tag{18}$$

where

If $\sum_{i=1}^{n} \left[\left(M_{3,i} - M_{4,i} \frac{B'_4}{B'_3} \right) - \left(M_{2,i} \frac{B'_2}{B'_3} \right) \right] \leq 0.1 \sum_{i=1}^{n} M_{max}$

or

If $Q_L < 0$:
then
$$Q_L = 0 \tag{19}$$

where

Q_L = energy loss due to casing leakage, kJ

n = total number of measurements

i = ith time that data are recorded

M_3 = mass flow rate of air measured at Station 3, kg/s

M_4 = mass flow rate of air measured at Station 4, kg/s

B'_4 = concentration of tracer gas at Station 4 (measured in the same units as B'_3) in the test described in Clause 8.2.1.1

B'_3 = concentration of tracer gas at Station 3 (measured in the same units as B'_4 and B'_2) in the test described in Clause 8.2.1.1

M_2 = mass flow rate of air measured at Station 2, kg/s

B'_2 = concentration of tracer gas at Station 2 (measured in the same units as B'_3) in the test described in Clause 8.2.1.1

C_p = specific heat of the air, kJ/kg•K

t_3, t_4 = dry-bulb temperature at Stations 3 and 4, respectively, °C

$\Delta\theta$ = time between flow measurements, s

M_{max} = M_s or M_e, whichever is greater

where

M_s = net mass flow rate of the supply air

M_e = net mass flow rate of the exhaust air

9.3.3.7

Conditions at Station 5 (i.e., the location where the supply air leaves the HRV/ERV without cross-leakage flow) shall be calculated from the following equations:

$$t_5 = \frac{h_2 - R \times h_3 - 2501(W_2 - R \times W_3)}{1 - R + 1.86(W_2 - R \times W_3)} \quad \textbf{(20)}$$

$$W_5 = \frac{W_2 - R \times W_3}{1 - R} \quad \textbf{(21)}$$

$$h_5 = \frac{h_2 - R \times h_3}{1 - R} \quad \textbf{(22)}$$

where

t_5 = dry-bulb temperature of supply air at Station 5, °C

h_2,h_3 = enthalpy at Stations 2 and 3, respectively, J/kg dry air

R = exhaust air transfer ratio

W_2,W_3= humidity ratio of air at Stations 2 and 3, respectively, kg water per kg dry air

W_5 = humidity ratio of air at Station 5, kg water per kg dry air

h_5 = enthalpy at Station 5, J/kg dry air

Note: *Station 5 is a hypothetical location and therefore does not appear in Figure 1.*

9.3.4 Net outdoor airflow

The net outdoor airflow is the value that should be used in determining the amount of outdoor air provided by a unit. It shall be calculated as follows:

$$M_{OA} = M_{maxOA} - M_{sup} \times R \qquad \textbf{(23)}$$

where

M_{OA} = net outdoor airflow provided by the unit, kg dry air per unit of time

M_{maxOA} = M_{sup} or M_{exh}, whichever is greater

where

M_{sup} = mass flow rate of the supply air at Station 2, kg dry air per unit of time

M_{exh} = mass flow rate of the exhaust air at Station 3, kg dry air per unit of time

R = exhaust air transfer ratio

10 Test preparation and performance

10.1 Test ducts

10.1.1

Before installation of the equipment to be tested, the ducts across the test section shall be connected and operated under the maximum negative pressure and flow rate expected under test conditions. Flow rates shall be determined at the four measurement stations (see Figure 1). A difference between flow rates greater than 3% from the four-station average shall be considered unacceptable. In the event of unacceptable performance, appropriate modifications shall be made to the test facility until acceptable performance is obtained.

10.1.2

Ambient conditions shall be maintained at 22 ± 3 °C and 40 ± 5% RH for the tests specified in Clauses 10.4 and 10.6.

10.2 Equipment installation

The equipment to be tested shall be installed in the test section in accordance with the manufacturer's standard installation instructions, using procedures and accessories recommended by the manufacturer.

10.3 Test procedure

10.3.1

The maximum rated airflow shall be tested under the following conditions (see Figure 1):

(a) The HRV/ERV shall be operated at the manufacturer's maximum rated airflow.

(b) The maximum rated airflow shall be achieved by selecting the specified speed setting and adjusting the airflow resistance of the test facility.

(c) The mass flow rates of the supply and exhaust airstreams shall be adjusted as closely as possible to the supply/exhaust flow ratio specified by the submitter. If the test operator is unable to adjust the airstreams to within ±5% of the specified ratio, the test shall not be performed.

(d) If no ratio is specified, the air mass flow ratio shall be balanced so that the supply/exhaust flow ratio is 1:1.

(e) The airflow resistance of the test facility shall be adjusted so that the absolute value of the static pressure at

  (i) Station 1 is approximately equal to the value at Station 2; and

(ii) Station 3 is approximately equal to the value at Station 4.

(f) If the absolute values of static pressure measured at Stations 1 to 4 are less than the values specified in the following Table, the test need not be performed or may be performed using a revised maximum rated airflow provided by the manufacturer.

	Static pressure, Pa	
Station	Rated flow up to 100 L/s	Rated flow 100 L/s and over
1	–25	–50
2	+25	+50
3	–25	–50
4	+25	+50

(g) For non-ducted and partially ducted HRVs/ERVs, the minimum static pressure for each station that is not intended for connection to a duct shall be zero.

(h) The electrical demand in watts of the test unit, including controls, dampers, etc., shall be measured and reported.

10.3.2

Additional tests may be performed at airflows other than the maximum rated airflow. These additional tests may be used to characterize the thermal effectiveness and heat-recovery efficiency for a range of available airflows.

10.3.3

HRVs/ERVs shall be tested at 60 Hz and 120 V ac ±1% (or at another supply voltage specified by the manufacturer).

10.4 Thermal effectiveness and heat-recovery efficiency

10.4.1

The test duct, measuring equipment, and equipment under test shall be operated until equilibrium conditions are attained, but for not less than 1 h. After 1 h of operation, data shall be recorded at maximum intervals of 10 min until equilibrium is indicated.

10.4.2

Apparent thermal effectiveness values shall be determined in accordance with Equation 7. The heat-recovery efficiency shall be determined in accordance with Equations 12 and 13.

10.4.3

The mass flow rates used in the equations specified in Clause 10.4.2 shall be those at Stations 2 and 3.

10.4.4

Thermal effectiveness and heat-recovery efficiency shall be tested under the conditions specified in Clause 10.3.1. Additional tests may be performed as specified in Clause 10.3.2.

10.4.5

The electrical demand of the test unit (in watts and including controls, dampers, etc.,), the thermal effectiveness, and the heat-recovery efficiency shall be determined and reported for the heating mode, and if requested by the manufacturer, for the cooling mode. For the heating mode, the tests shall be performed with an exhaust air temperature (Station 3) of 22 °C and a humidity ratio of 0.0065 kg/kg dry air (40% RH). The supply air (Station 1) shall be at a temperature of 0 °C and a humidity ratio of 0.0028 kg/kg dry air (75% RH). For the cooling mode, the tests shall be performed with an exhaust air temperature (Station 3) of 24 °C and a humidity ratio of 0.0092 kg/kg dry air (50% RH). The supply air (Station 1) shall be at a temperature of 35 °C and a humidity ratio of 0.0178 kg/kg dry air (50% RH).

10.4.6

The time-average temperature shall be held within ±0.5 °C and the time-average humidity ratio shall be held within ±0.0005 kg/kg dry air.

10.4.7

The instantaneous values of the supply and exhaust temperatures (Stations 1 and 3) shall be held within ±1.5 °C and a humidity ratio of ±0.001 kg/kg dry air.

10.5 Exhaust air transfer

10.5.1

The exhaust air transfer test shall be performed and reported at the test conditions specified in Clause 10.3.1.

10.5.2

The tracer gas tests shall be performed in accordance with Clause 8.2.

10.5.3

If the results at Station 1 in Test 1, Station 3 in Test 2, or Station 1 in Test 3 (see Clauses 8.2.1.1, 8.2.2.1, and 8.2.3.1 and Figure 1) indicate contamination of the fresh air by the tracer gas, the test shall be considered invalid and repeated.

10.6 Low-temperature ventilation performance

10.6.1

Low-temperature ventilation performance shall be determined by operating the unit continuously for 72 h. The air temperature at Station 1 shall be specified by the manufacturer. The humidity ratio of air at Station 1 shall be maintained at a time-average value corresponding to nominally 75% RH at the temperature specified by the manufacturer. The temperature of the air at Station 3 shall be maintained at a time-average temperature of 22 °C and a humidity ratio of 0.0065 kg/kg dry air (40% RH). The temperature and humidity ratio tolerances specified in Clauses 10.4.6 and 10.4.7 shall be maintained.

The low-temperature ventilation performance test shall be carried out with the airflow and fan speed adjusted to the manufacturer's specifications at the start of the test. In the absence of manufacturer's specifications, the test shall be undertaken at the maximum rated airflow as determined from Clause 10.3.1 at the start of the test. The minimum pressures specified in Items (f) and (g) of Clause 10.3.1 shall be maintained.

10.6.2

The set-up for the test specified in Clause 10.6.1 shall meet the requirements of Clauses 10.1 to 10.3. The operation of the test set-up shall not influence the pressure at the unit or the airflow through the unit.

10.6.3

The mass flow rate in both airstreams shall be recorded at the time that the mass flow rates are initially adjusted with Stations 1 and 3 at 22 °C dry-bulb temperature. The flow rates shall be taken as the average of a minimum of five consecutive readings taken at 1 min intervals. During the 72 h test period, the mass flow rate in both airstreams shall be measured every 1 min and recorded.

10.6.4
The net outdoor airflow rate determined for each 1 min interval using Equation 23 shall be averaged over the last 12 h of the 72 h test. The 12 h period shall be extended as necessary to allow for analysis of an integral number of complete operating/defrost cycles, e.g., if the HRV/ERV is in a defrost at the end of the 72 h test.

10.6.5
The low-temperature ventilation reduction factor for net outdoor airflow shall be calculated as follows:

$$LTVR = \frac{m_{end}}{m_{start}} \tag{24}$$

where

$LTVR$ = low-temperature ventilation reduction factor

m_{end} = average net outdoor air mass flow over last 12 h

m_{start} = net outdoor air mass flow rate at start of test (see Clause 10.6.3)

Note: *Ventilation reduction factors may also be calculated independently for the supply and exhaust airstreams.*

10.6.6
The maximum unbalanced airflow measured during the 72 h test shall be recorded and reported.

10.7 Low-temperature thermal performance
The thermal performance of the HRV/ERV during low-temperature operation shall be determined and reported using the equations specified in Clauses 9.3.3.1 and 9.3.3.2 for sensible heat-recovery efficiency and total heat-recovery efficiency, respectively, using the values recorded over the last 12 h of testing. The 12 h period shall be extended as necessary to allow for analysis of an integral number of complete operating/defrost cycles.

10.8 Airflow performance of fan-type units

10.8.1
Flow rate measurements shall be taken (at ambient temperatures) from free-rated airflow to shut-off. Tests shall be performed with the static pressure differential across the unit at multiples of 25 Pa so as to characterize the curve.

10.8.2
The static pressure differential for the supply airstream, i.e., the difference in static pressure between Stations 1 and 2 (see Figure 1), shall be adjusted so that the upstream and downstream static pressure values are approximately equal, unless the HRV/ERV is designed for non-ducted operation, in which case the pressure at the non-ducted port shall be as close to zero as possible. The airflow rate shall be measured at Station 2.

10.8.3
The static pressure differential for the exhaust air, i.e., the difference in static pressure between Stations 3 and 4, shall be adjusted so that the upstream and downstream static pressure values are approximately equal, unless the HRV/ERV is designed for non-ducted operation, in which case the pressure at the non-ducted port shall be as close to zero as possible. The airflow rate shall be measured at Station 3.

10.8.4
Test results shall be presented as curves of flow rate in litres per second of standard air versus static pressure differentials in pascals. Separate curves shall be presented for the supply and exhaust streams.

10.9 Determination of airflow range for multispeed units

10.9.1
For units equipped with controls to allow operation at more than one speed, the test specified in Clause 10.9.2 shall also be performed.

10.9.2
With the unit set up for the measurement of airflow as specified in Clause 10.3.1, airflows and static pressures shall be obtained as follows:
(a) for units with fixed speeds, at each fixed speed; or
(b) for units with adjustable speeds, at the upper and lower limits of adjustment.

External balancing fans shall not be used.

10.10 Standby power
The standby power in watts shall be measured in accordance with CAN/CSA-C62301.

The manufacturer shall supply a ventilation system controller, which shall be connected in accordance with the manufacturer's instructions. If the ventilation system controller allows automatic intermittent operation, it shall be set to prevent operation of the HRV/ERV. If automatic intermittent operation is not possible, the standby power measurement shall be taken with the controller set to off.

The model number of the ventilation system controller used for the standby power test shall be reported.

11 Reporting of results
Test results shall be reported on a specification sheet similar to that shown in Figure 8. Supply temperatures shall be recorded as follows:
(a) for tests with 0 °C supply air temperature (Clause 10.4.5): the average of the supply air temperature recorded over the equilibrium test period; and
(b) for the low-temperature ventilation performance test (Clause 10.6.1) and low-temperature thermal performance test (Clause 10.7): the average of the supply air temperature recorded over the last 12 h of the 72 h test.

12 Minimum sensible heat-recovery efficiency
When an HRV/ERV is tested in heating mode in accordance with Clause 10.4.5, its minimum sensible heat-recovery efficiency (see Clause 9.3.3.1) shall be 55%.

Note: *It is anticipated that minimum efficiency ratings for designating an HRV/ERV as a high-efficiency unit will be provided in the next edition of this Standard.*

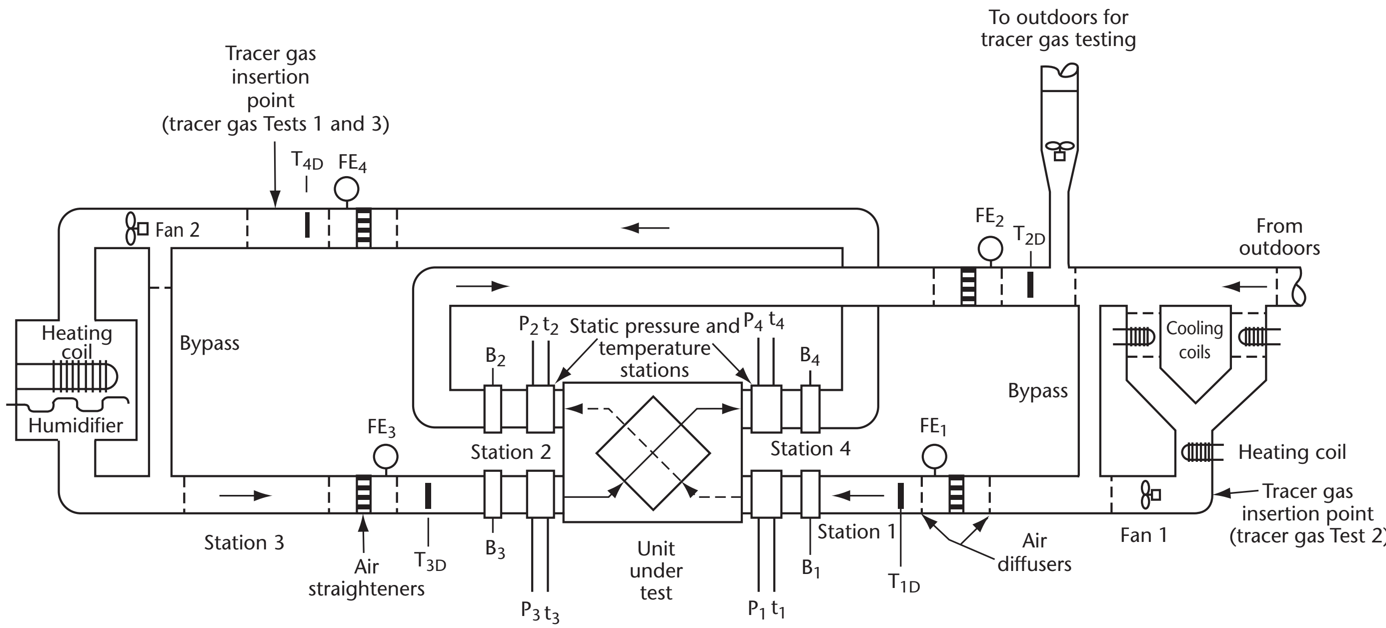
Table 1
Temperature factor, *f*
(See Clause 6.2.5.)

Temperature, °C	Temperature factor, *f*
–6.7	78.2
4.4	72.0
15.6	67.4
26.7	62.8
37.8	58.1
48.9	55.0
60.0	51.9
71.1	48.8

Note: *Interpolation may be used for temperatures not specified in this Table.*

Table 2
Coefficient of discharge
(See Clause 6.2.5.)

Reynolds number, N_{Re}	Coefficient of discharge
50 000	0.970
100 000	0.978
150 000	0.981
200 000	0.984
250 000	0.985
300 000	0.986
400 000	0.988
500 000	0.989



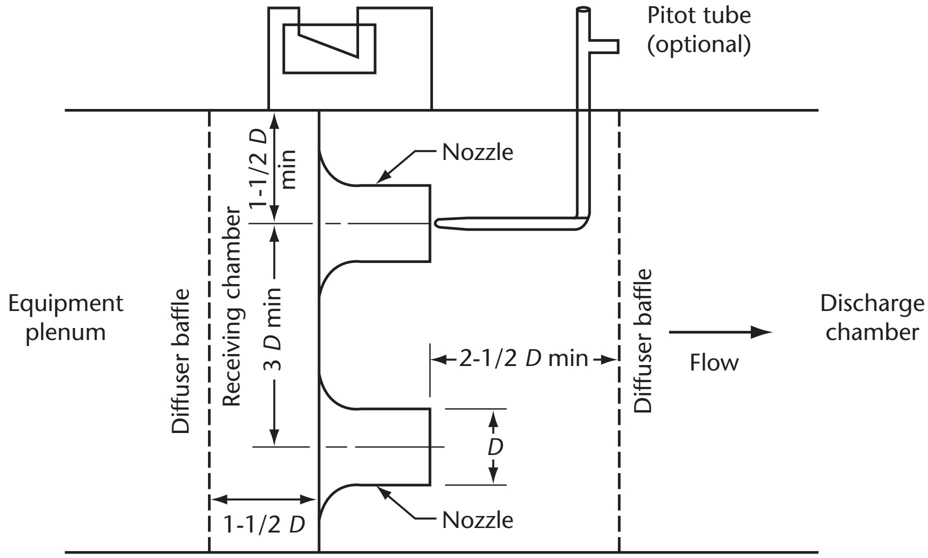
Legend			
FE_1	Flow element — supply inlet	T_{1D}	Dew point temperature Station 1
FE_2	Flow element — supply outlet	T_{2D}	Dew point temperature Station 2
FE_3	Flow element — exhaust inlet	T_{3D}	Dew point temperature Station 3
FE_4	Flow element — exhaust outlet	T_{4D}	Dew point temperature Station 4
P_1	Pressure — supply inlet	t_1	Supply inlet temperature
P_2	Pressure — supply outlet	t_2	Supply outlet temperature
P_3	Pressure — exhaust inlet	t_3	Exhaust inlet temperature
P_4	Pressure — exhaust outlet	t_4	Exhaust outlet temperature

Station	Description
1	Supply inlet
2	Supply outlet
3	Exhaust inlet
4	Exhaust outlet
B_1	Tracer gas concentration — Station 1
B_2	Tracer gas concentration — Station 2
B_3	Tracer gas concentration — Station 3
B_4	Tracer gas concentration — Station 4

Station	Section
1	FE_1 P_1 T_{1D} t_1
2	FE_2 P_2 T_{2D} t_2
3	FE_3 P_3 T_{3D} t_3
4	FE_4 P_4 T_{4D} t_4

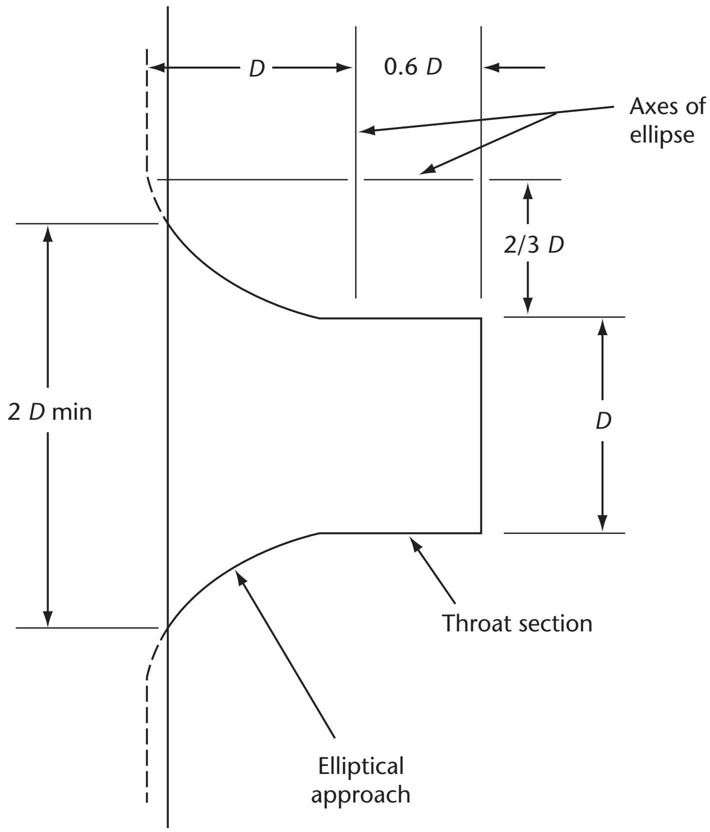
Note: *Ambient temperature = test unit ambient temperature.*

Figure 1
Schematic of test facility for HRVs/ERVs
(See Clauses 6.1.1, 8.1.1, 8.2.1.1, 8.2.1.2, 8.2.2.1, 8.2.2.2, 8.2.3.1, 8.2.3.2, 9.3.3.7, 10.1.1, 10.3.1, 10.5.3, and 10.8.2.)



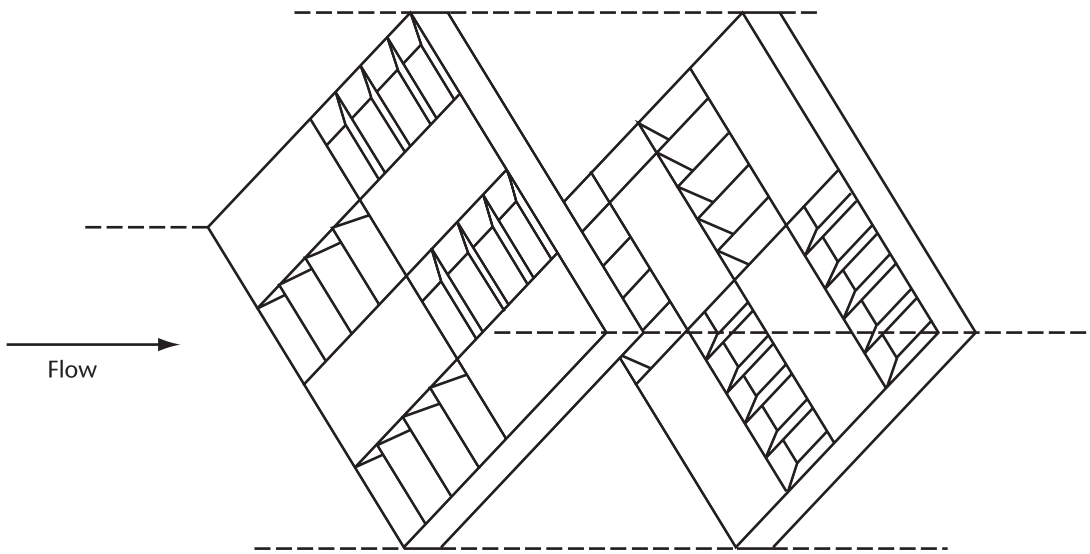
Note: *D = diameter.*

Figure 2
Airflow-measuring apparatus
(See Clauses 6.2 and 6.2.2.)



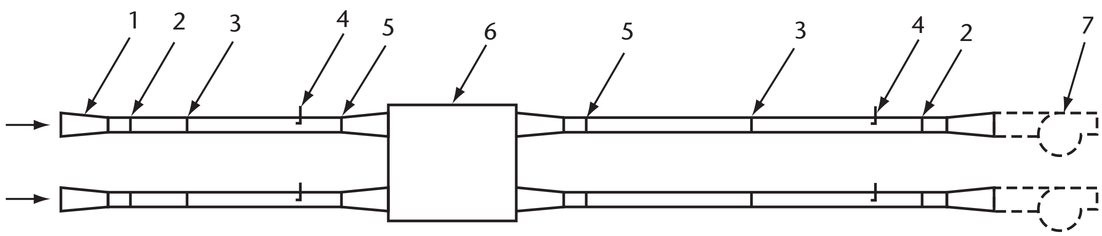
Note: *D = diameter.*

Figure 3
Nozzle
(See Clause 6.2.5.)



Note: *Dashed lines represent duct walls.*

Figure 4
Mixing device
(See Clause 6.2.7.)



Legend:
1 = Inlet
2 = Flow-control damper
3 = Flow straightener
4 = Flow-measurement device
5 = Static pressure measurement taps
6 = Heat exchanger
7 = Optional fans

Figure 5
Fan-performance test facility (complies with ANSI/AMCA 210)
(See Clause 8.1.1.)

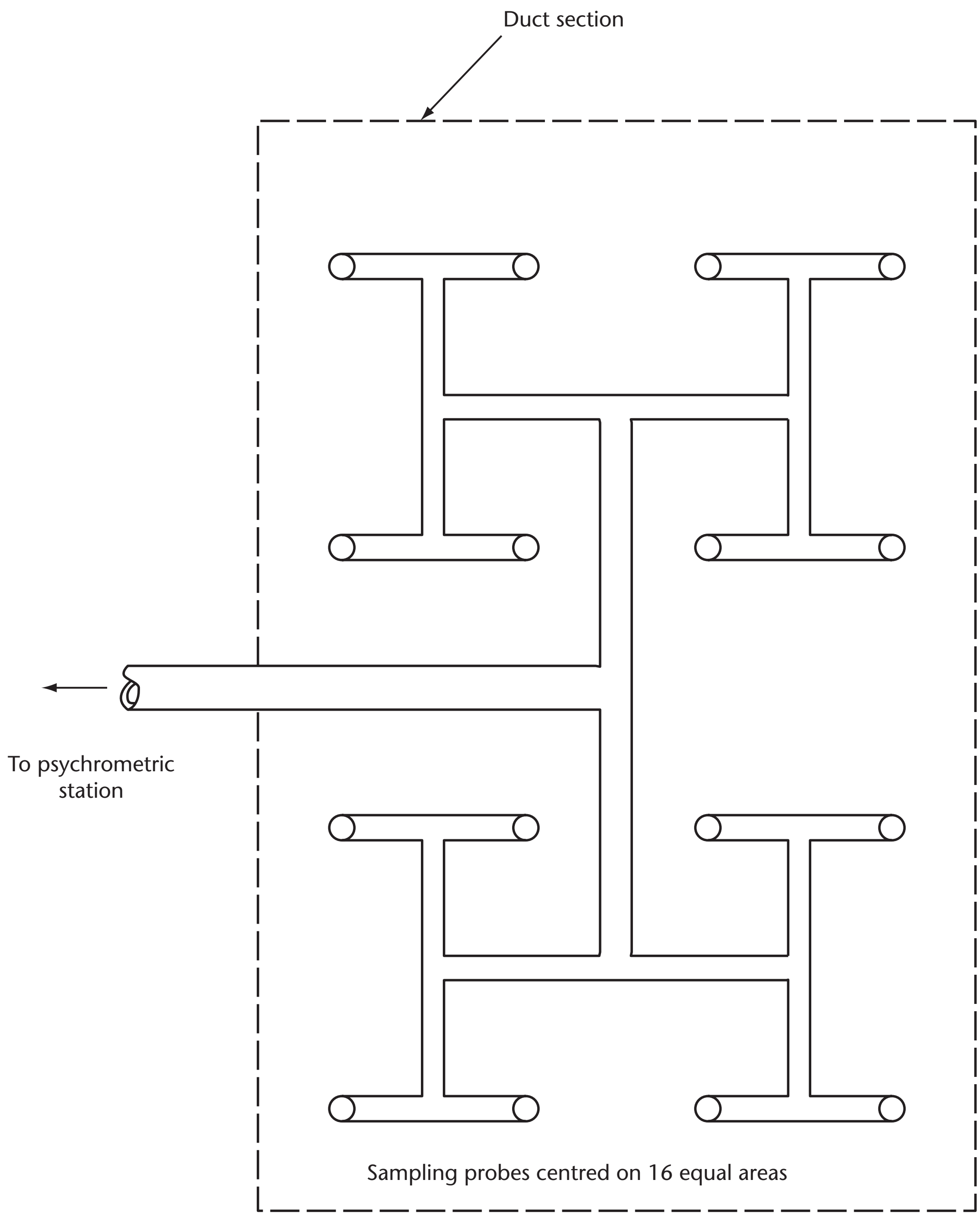


Figure 6
Typical psychrometric and tracer gas air-sampling device
(See Clauses 8.2.1.1, 8.2.2.1, and 8.2.3.1.)

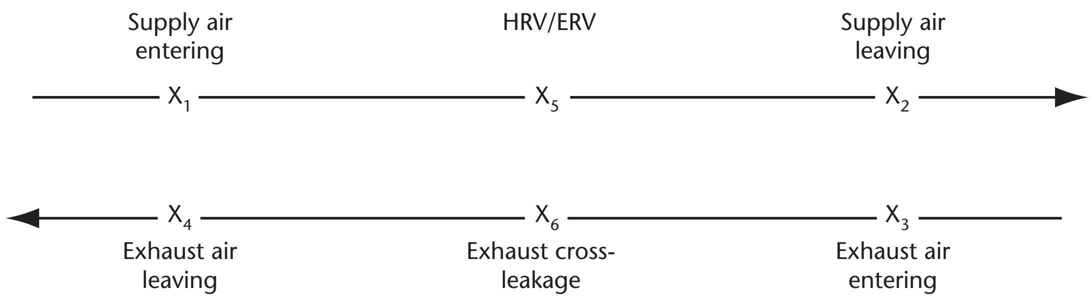


Figure 7
Schematic of an HRV/ERV
(See Clause 9.2.1.)

HRV/ERV SPECIFICATION SHEET

Testing agency: ____________________ Model: ____________________
Date tested: ____________________ Serial number: ____________________
Manufacturer: ____________________ Options installed: ____________________
Address: ____________________ ____________________
____
Telephone: ____________________ 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: ______ %

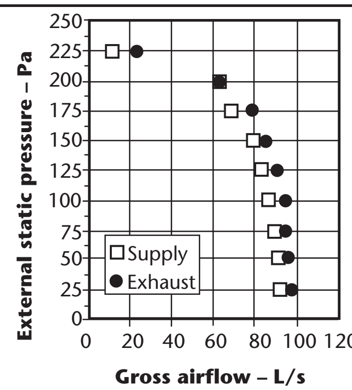
Maximum unbalanced airflow during test at –25 °C: ______ L/s

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					*		
	VII									

Comments from test agency:

Reference report:
Sample no:

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

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 8
HRV/ERV specification sheet
(See Clause 11.)

Proposition de modification

N'hésitez pas à nous faire part de vos suggestions et de vos commentaires. Au moment de soumettre des propositions de modification aux normes CSA et autres publications CSA prière de fournir les renseignements demandés ci-dessous et de formuler les propositions sur une feuille volante. Il est recommandé d'inclure

- le numéro de la norme/publication
- le numéro de l'article, du tableau ou de la figure visé
- la formulation proposée
- la raison de cette modification.

Proposal for change

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- relevant Clause, Table, and/or Figure number(s)
- wording of the proposed change
- rationale for the change.

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Affiliation: ______________________________

Adresse/Address: ______________________________

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État/Province/State: ______________________________

Pays/Country: ______________ **Code postal/Postal/Zip code:** ______________

Téléphone/Telephone: ______________ **Télécopieur/Fax:** ______________

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