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Heat recovery ventilators and energy recovery ventilators — Testing and calculating methods for seasonal performance factor —

Part 1: Sensible heating recovery seasonal performance factors of heat recovery ventilators (HRV)

Ventilateurs récupérateurs de chaleur et ventilateurs récupérateurs d'énergie — Méthodes d'essai et de calcul des facteurs de performances saisonnières —

Partie 1: Facteurs de performances saisonnières de la récupération de chaleur sensible des ventilateurs récupérateurs de chaleur (HRV)

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Contents

Page

Foreword

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This document was prepared by Technical Committee ISO/TC 86, *Refrigeration and air-conditioning, Subcommittee* SC 6, *Testing and rating of air-conditioners and heat pumps*.

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Heat recovery ventilators and energy recovery ventilators — Testing and calculating methods for seasonal performance factor —

Part 1: Sensible heating recovery seasonal performance factors of heat recovery ventilators (HRV)

1 Scope

This document specifies the testing and calculating methods for sensible heating recovery seasonal performance factor of heat recovery ventilators (HRV) covered by ISO 16494-1.

This document also specifies the test conditions and the corresponding test procedures for determining the sensible heating recovery seasonal performance factor of HRV and is intended for use only in marking, comparison, and certification purposes. For the purposes of this document, the rating conditions are those specified in ISO 16494-1 and in Annex B. The procedures of this document may be used for other temperature conditions.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 16494-1:2022, *Heat recovery ventilators and energy recovery ventilators — Method of test for performance — Part 1: Development of metrics for evaluation of energy related performance*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 16494-1 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
heat recovery
<sensible heating> transfer of sensible energy from exhaust air to supply air in the HRV while heating

3.2
bypass ventilation function
function for reducing power input of the fans while the heat energy recovered is less than the additional energy input due to overcoming the resistance of recovery heat exchanger during its operation time

Note 1 to entry: The bypass function makes the supply air and exhaust air go through the heat recovery exchanger bypass with energy saving control.

3.3
coefficient of energy
<sensible heating> total sensible heating energy exchanged between the air streams plus the power value of moving air, divided by the power input

Note 1 to entry: The formula for determining $C_{sh,d,t,j}$ is given in 6.2.1 and $C_{sh,u,d,t,j}$ in 6.2.2.

3.4
gross effectiveness
<sensible heating> measured effectiveness, not adjusted for leakage, motor heat gain, or heat transfer through the unit casing

Note 1 to entry: The sensible heating gross effectiveness of an HRV, at equal airflow, is described in ISO 16494-1:2022, 9.5.

3.5
bypass outdoor temperature
T_b
outdoor temperature in heating conditions, at which the electric power reduction to the HRV by operating in bypass mode is equal to the saving of electric power input to the heating system due to the heat recovered by the HRV

3.6
seasonal performance factor of sensible heating recovery
F_{sh}
ratio of seasonal amount of sensible heat recovered together with power value of moving air to the whole electricity input of HRV, under the rating conditions and seasonal outdoor temperature bins selected from this standard

3.7
building heating balance temperature
T_{BHB}
outdoor air temperature at which building internal heat gain, solar radiation, and so on, equals to heat loss through the building envelope

4 Symbols and abbreviated terms

Symbol	Description	Unit
E_{sh}	Capacity of seasonal sensible heating recovery	Wh
$C_{sh,d,t,j}$	Sensible heating coefficient of energy for ducted ventilator at outdoor air bin temperature t_j	W/W
$C_{sh,u,d,t,j}$	Sensible heating coefficient of energy for unducted ventilator at outdoor air bin temperature t_j	W/W
c_p	Specific heat of leaving supply air (SA)	kJ/kg· °C
$L_{sh,t,j}$	Reference outdoor air sensible heating load at outdoor air bin temperature t_j	W
n_j	Bin hours which the outdoor air bin temperature occurs	h
n	Number of temperature bins	-
$P_{in,t,j}$	Power input to ventilator at outdoor air bin temperature t_j	W
$P_{in,no,t,j}$	Power input to the HRV to operate the fans at outdoor air bin temperature t_j for all stages, for HRVs without bypass	W
$P_{in,by,t,j}$	Power input to the HRV at outdoor air bin temperature t_j for bin temperature in stage 1 or 2, for HRVs with bypass	W
$P_{in,h,t,j}$	Power input to a supplementary preheater at full capacity	W
$P_{in,v,t,j}$	Ventilation power input of the HRV at outdoor air bin temperature	W
$P_{vma,t,j}$	Power value of moving air at outdoor air bin temperature t_j	J/s or W

Symbol	Description	Unit
$P_{in,E}$	Electricity power input of seasonal sensible heating recovery	Wh
$Q_{m2, net}$	Net supply mass flow rate	kg/s
F_{sh}	Seasonal performance factor of sensible heating recovery	Wh/Wh
T_b	Outdoor air temperature when HRV operates under air bypass function	°C
T_F	The outdoor air bin temperature at which the frost occurs	°C
$T_{set,h}$	Temperature defined in ISO 16494-1:2022, Table 2 as T5/T6/T7	°C
ε_{sh}	Gross sensible heating effectiveness of HRV	%
$\phi_{sh,t,j}$	Sensible heat recovery capacity of the HRV at outdoor air bin temperature t_j	W

5 Tests

5.1 General requirements

The test conditions used, the accuracy and uncertainties of the instruments used shall conform with ISO 16494-1 and those in this document.

5.2 Test conditions

For the purpose of ε_{sh}, E_{sh} and F_{sh}, there are three standard test conditions T5/T6/T7 corresponding to ISO 16494-1:2022, Table 2. The HRV shall be tested at one of the three test conditions, which shall be selected to most closely represent the outdoor temperature bin distribution in the region as described in Annex B and Annex D.

Outdoor temperature bin distribution and bin hours differ from region to region. If bin hours are set to a certain value for a certain region, the integrated value of heating load and electric energy consumption can be determined.

Table 1 shows the requirement of default values and the reference outdoor temperature bin distribution for test and calculation. In case of setting other outdoor temperature bin distribution, refer to the setting method as described in Annex D.

Table 1 — Conditions of performance test (heating)

	Outdoor air temperature (°C)		Indoor air temperature (°C)		Application temperature bin type for calculation
	Dry bulb	Wet bulb	Dry bulb	Wet bulb	
T5	2	1	21	14	In Annex B or D
T6	5	3	20	15	
T7	7	6	20	12	
NOTE Allowable variation of readings is given in Table F.2 in ISO 16494-1:2022.					

5.3 Test methods

5.3.1 General

For higher seasonal energy performance, HRV can be designed with airflow bypass function integrating fan speed control or airflow dampers adjust, which can change the fan power input according to different outdoor temperature condition, while keeping necessary aerodynamic performance.

5.3.2 Energy saving stage limit temperature

To assess the energy saving ability of HRV, the operation stages under the application temperature bin are shown in Annex A using a schematic diagram.

5.3.3 Sensible heating recovery performance test

5.3.3.1 Standard condition performance tests

The sensible heating recovery performance tests shall be conducted in accordance with ISO 16494-1. The sensible heating recovery performance, efficiency, as well as airflow and static pressure shall be measured corresponding to the selected standard heating performance tests conditions in Table 1.

5.3.3.2 Determination of performance at application climate

The sensible heating recovery performance under certain climate temperature bins shall also be determined by calculation using the temperature bins see Annex B and Annex D.

5.3.4 Determination of bypass outdoor temperature

The manufacturer shall specify the value of bypass outdoor temperature. The laboratory shall verify that the unit under test is functioning and what the test action temperature is. If it is not specified by the manufacturer, the laboratory shall calculate the outdoor bypass temperature and set it as the T_b in accordance with Annex E.

5.3.5 Measurement of power input of heat recovery ventilator with bypass ventilation function

5.3.5.1 The manufacturer may provide information on how to set the bypass function if requested by the testing laboratories.

NOTE 1 Due to the additional air resistance of the heat recovery exchanger, when the heat energy recovered is less than the additional energy input due to overcoming the resistance of recovery heat exchanger during its operation time, the equipment can provide the bypass ventilation function to reduce the additional energy consumption, when only ventilation is necessary.

NOTE 2 When the bypass ventilation function acts, there can be several means to reduce the additional energy consumption (e.g. with fan speed control or valve control in the fan's inlet or outlet, etc., to keep the same airflow rate and pressure as rating performance condition).

5.3.5.2 The tests shall be conducted at the required control set which allows steady state operation of the equipment at the given test conditions.

5.3.5.3 Test of unit with bypass ventilation function and fan speed control:

a) Set up the bypass ventilation function according to the manufacturer's instructions.

b) Adjust test auxiliary device to keep the average pressure value at air outlet and inlet of unit in Figure A.1 of ISO 16494-1:2022, within the 5 % of tested unit's nominal value, the airflow rate larger or equal to its nominal value.

c) According to ISO 16494-1, measure and record the data of airflow rate, the pressure and electricity power input.

d) Determine and record the outdoor temperature at which the bypass ventilation function acts, either by manufacturer's statement, or by measure. The power input value measured when bypass ventilation functions is activated is recorded as the bypass ventilation function power input, used for calculation for F_{sh} corresponding to each outdoor bin temperature in ventilation period.

5.3.5.4 Test of unit with bypass ventilation function and with electric driving air damper automatically, but without fan speed control:

a) Set up the bypass ventilation function according to the manufacturer's instructions.

b) Adjust the test auxiliary device to keep the average pressure value within the 5 % of the tested unit's nominal value, the airflow rate larger or equal to its nominal value.

c) Determine and record the outdoor temperature at which the bypass ventilation function acts, either by the manufacturer's statement, or by measurement. The power input value measured when bypass ventilation function is on shall be recorded as the bypass ventilation function power input, used for the calculation of F_{sh} corresponding to each outdoor bin temperature in the ventilation period.

5.3.5.5 Test of equipment with bypass ventilation function and without fan speed control and without automatic adjust air damper:

a) Set up the bypass ventilation function according to manufacturer's instruction.

b) According to ISO 16494-1, do not adjust any of the test auxiliary devices during test and record the data of airflow rate, the pressure and power input.

c) Determine and record the outdoor temperature that the bypass ventilation function acts, either by the manufacturer's statement, or by test.

d) The power input value measured when bypass ventilation functions on is recorded as the bypass ventilation function power input, used for calculation for F_{sh} corresponding to each outdoor bin temperature in ventilation period.

5.3.5.6 Test of equipment with no bypass ventilation function:

For the equipment with no bypass ventilation function, the power input is the value as same as in 5.3.3.1 all stages, which shall be used for calculation for F_{sh} corresponding to each outdoor temperature in ventilation period.

5.3.6 Determination of the frosting temperature by test

5.3.6.1 The frost temperature test shall be conducted in accordance with ISO 16494-1.

The manufacturer may provide information on how to operate the equipment if requested by the testing laboratories.

5.3.6.2 The test condition shall be as follows:

a) The airflow rate and static pressure shall keep the same as 5.3.3.1.

b) The entering exhaust air (RA) temperature shall be kept at conditions T5/T6/T7 specified in Table 1 and entering supply air (OA) temperature shall be gradually reduced from 0 °C, or, in order to reduce the duration time of the test, from the $T_{F,0}$, which is described in Annex C, plus 2 K.

NOTE The calculation of $T_{F,0}$ refers to Annex C.

5.3.6.3 Confirmation of frost outdoor air temperature:

a) Turn off the supplement heat function for anti-frost.

b) Conduct the tests of gross sensible heating recovery effectiveness of HRV by changing outdoor temperature from the $T_{F,0}$ plus 2 K to lower temperature. While adjusting the outdoor air temperature, keep the reducing rate of temperature not less than 0,5 K per hour and not greater than 1,0 K per hour.

c) Record the inlet and outlet air parameters so that gross sensible heating effectiveness can be calculated every 0,5 h.

d) Calculate the gross sensible heat effectiveness in accordance with ISO 16494-1:2022, 9.5.

e) If the absolute value of the change of the gross sensible heating effectiveness between the outdoor temperature t_j and temperature t_{j-1} is greater than 5 %, the higher temperature of the outdoor temperatures is confirmed as a frost outdoor temperature.

f) Compare the tested T_F with the one in practice, if the tested T_F is lower than the one in practice, select the temperature in practice as the stage limitation temperature, otherwise, the tested T_F shall be the stage limitation temperature.

5.3.6.4 Data collection:

During the frost temperature tests, airflow rate, static pressure, barometer pressure and power input as well as air temperature shall be collected and recorded. A continuous air temperature variation curve drawing shall be necessary.

6 Calculations

6.1 Gross sensible heating recovery effectiveness (ε_{sh})

The gross sensible heating recovery effectiveness of HRV at rated test condition is described in ISO 16494-1:2022, 9.5.

6.2 Sensible heating coefficient of energy

6.2.1 Sensible heating coefficient of energy: ducted ventilators

The sensible heating coefficient of energy for a ducted ventilator ($C_{sh,d,t,j}$) shall be calculated by Formula (1):

$$C_{sh,d,t,j} = \frac{\left| Q_{m2,net} \times c_p \times (T_0 - t_j) \right| \times \varepsilon_{sh} \times 1\,000 + P_{vma,t,j}}{P_{in,t,j}} \quad (1)$$

where

$C_{sh,d,t,j}$ is the sensible heating coefficient of energy for a ducted ventilator at outdoor air bin temperature t_j (W/W);

T_0 is the dry temperature of entering exhaust air (RA) under ISO 16494-1 standard testing conditions (T5/T6/T7), (°C);

t_j is the dry temperature of outdoor air corresponding to application temperature bin j (°C);

$Q_{m2,net}$ is the net supply mass flow rate (kg/s);

c_p is the specific heat of air (kJ/kg· °C);

ε_{sh} is the gross sensible heating recovery effectiveness of HRV at rated test condition is described in ISO 16494-1:2022, 9.5 (%);

$P_{vma,t,j}$ is the power value of moving air at outdoor air bin temperature t_j (J/s);

$P_{in,t,j}$ is the input power to ventilator at outdoor air bin temperature t_j (W).

6.2.2 Sensible heating coefficient of energy: unducted ventilators

The sensible heating coefficient of energy for an unducted ventilator ($C_{sh,u,d,t,j}$) is described by Formula (2)

$$C_{sh,u,d,t,j} = \frac{\left| Q_{m2,net} \times c_p \times \left(T_0 - t_j \right) \right| \times \varepsilon_{sh} \times 1\,000}{P_{in,t,j}} \quad (2)$$

where

$C_{sh,u,d,t,j}$ is the sensible heating coefficient of energy for an unducted ventilator at outdoor air bin temperature t_j (W/W);

T_0 is the dry temperature of entering exhaust air (RA) under ISO 16494-1 standard testing conditions (T5/T6/T7) (°C);

t_j is the dry temperature of outdoor air corresponding to application temperature bin j (°C);

$Q_{m2,net}$ is the net supply mass flow rate (kg/s);

c_p is the specific heat of leaving supply air (kJ/kg· °C);

ε_{sh} is the gross sensible heating recovery effectiveness of HRV at rated test condition is described in ISO 16494-1:2022, 9.5;

$P_{in,t,j}$ is the input power to ventilator (W).

6.3 Calculation of seasonal performance factor of sensible heating recovery (F_{sh})

6.3.1 Reference outdoor air heating load and sensible heating recovery capacity

The reference outdoor air heating load shall be by a set of values and be assumed that they are linearly changing depending on the change of outdoor temperature, the sensible heat recovery capacity is assumed also linearly changing, see figure in Annex A. Conditions of reference heating load and recovery capacity is shown in Table 2.

Table 2 — Reference outdoor air sensible heating load and recovery capacity

	T5	T6	T7
Outdoor air Temperature (°C)	Climate bins	Climate bins	Climate bins
T_0 indoor air Temperature (°C)	21	20	20
Outdoor air heating load (W)	$L_{sh,T5,t,j}$	$L_{sh,T6,t,j}$	$L_{sh,T7,t,j}$
Recovery capacity (W)	$\Phi_{sh,T5,t,j}$	$\Phi_{sh,T6,t,j}$	$\Phi_{sh,T7,t,j}$

where T_0 is the temperature at which outdoor air heating load assumed zero.

The outdoor air sensible heating load $L_{sh,t,j}$ at outdoor temperature t_j, which is necessary to calculate the seasonal sensible heating heat recovery, shall be determined by Formula (3)

$$L_{sh,t,j} = Q_{m2,net} \times c_p \times \left| T_0 - t_j \right| \times 1\,000 \quad (3)$$

where

- $L_{sh,t,j}$ is outdoor air sensible heating load at the outdoor temperature t_j;
- $Q_{m2,net}$ is the net supply mass flow rate (kg/s);
- T_0 is the dry temperature of entering exhaust air (RA) under ISO 16494-1 standard testing conditions (T5/T6/T7) (°C);
- t_j is the dry temperature of outdoor air corresponding to application temperature bin j (°C).

6.3.2 The characteristics of sensible heating recovery capacity against outdoor temperature

Sensible heating recovery capacity $\phi_{sh,t,j}$ (W) of the HRV at outdoor temperature t_j changes depending on outdoor temperatures, as shown in Figure A.1 in Annex A, and it is determined by Formulae (4) and (5).

The stages are described in Annex A.

a) H Stage 1 ventilation with or without bypass function

For with or without bypass function, recovery capacity $\phi_{sh,t,j}$ at outdoor temperature t_j shall be zero.

b) H Stage 2 ventilation with or without bypass function at heat recovery mode

For HRV with bypass function, recovery capacity $\phi_{sh,t,j}$ at outdoor temperature t_j shall be zero.

For HRV without bypass function, recovery capacity $\phi_{sh,t,j}$ at outdoor temperature t_j shall be determined by Formula (4)

$$\phi_{sh,t,j} = L_{sh,t,j} \times \varepsilon_{sh} \quad (4)$$

where

- $\phi_{sh,t,j}$ is the sensible heat recovery capacity of the HRV at outdoor air bin temperature t_j;
- $L_{sh,t,j}$ is the outdoor air sensible heating load at the outdoor temperature t_j;
- ε_{sh} is the gross sensible heating recovery effectiveness of HRV.

c) H Stage 3 ventilation at heat recovery mode

In case of $T_F < t_j \leq T_b$, recovery capacity $\phi_{sh,t,j}$ at outdoor temperature t_j shall be determined by Formula (4).

d) H Stage 4 ventilation with supplement heat at heat recovery mode

In case of $t_j \leq T_F$, recovery capacity $\phi_{sh,t,j}$ at outdoor temperature t_j shall be determined by Formula (5)

$$\phi_{sh,t,j} = L_{sh,t,j} \times \varepsilon_{sh} - Q_{m2,net} \times c_p \times \left| T_F - t_j \right| \times 1\,000 \quad (5)$$

where

$\phi_{sh,t,j}$ is the sensible heat recovery capacity of the HRV at outdoor air bin temperature t_j;

$L_{sh,t,j}$ is the outdoor air sensible heating load at the outdoor temperature t_j;

ε_{sh} is the gross sensible heating recovery effectiveness of HRV.

$Q_{m2,net}$ is the net supply mass flow rate (kg/s);

T_F is the outdoor air bin temperature at which the frost occurs (°C);

t_j is the dry temperature of outdoor air corresponding to application temperature bin j (°C).

6.3.3 Power input characteristics of sensible heating recovery against outdoor temperature

Power input $P_{in,t,j}$ (W) of the HRV at outdoor temperature t_j changes with outdoor temperatures and corresponding operation functions as shown in Figure A.1 in Annex A, and it is determined as follows:

a) H Stage 1 ventilation with or without bypass function

Power input $P_{in,t,j}$ to ventilator at outdoor temperature t_j shall be determined by the measured value $P_{in,by,t,j}$ with bypass or the measured value $P_{in,no,t,j}$ without bypass function.

b) H Stage 2 ventilation with or without bypass function at heat recovery mode

Power input $P_{in,t,j}$ to ventilator at outdoor temperature t_j shall be determined by the measured value $P_{in,by,t,j}$ with bypass or the measured value $P_{in,no,t,j}$ without bypass function.

c) H Stage 3 ventilation at heat recovery mode

Power input $P_{in,t,j}$ to ventilator at outdoor temperature t_j shall be determined by the measured value $P_{in,by,t,j}$ with bypass or the measured value $P_{in,no,t,j}$ without bypass function.

d) H Stage 4 ventilation in heat recovery mode with supplemental pre-heat

Power input $P_{in,t,j}$ at outdoor temperature t_j, shall be determined by Formula (6), with ideal proportional preheat control:

$$P_{in,t,j} = P_{in,v,t,j} + Q_{m2,net} \times c_p \times |T_F - t_j| \times 1\,000 \tag{6}$$

where

$P_{in,t,j}$ is the power input to ventilator at outdoor air bin temperature t_j (W);

$P_{in,v,t,j}$ is the ventilation power input of the HRV at outdoor air bin temperature t_j (W);

$Q_{m2,net}$ is the net supply mass flow rate (kg/s);

T_F is the outdoor air bin temperature at which the frost occurs (°C);

t_j is the dry temperature of outdoor air corresponding to application temperature bin j (°C).

Power input $P_{in,t,j}$ at outdoor temperature t_j, shall be determined by Formula (7), with simple preheat control:

$$P_{in,t,j} = P_{in,v,t,j} + P_{in,h,t,j} \tag{7}$$

where

$P_{in,t,j}$ is the power input to ventilator at outdoor air bin temperature t_j (W);

$P_{in,v,t,j}$ is the ventilation power input of the HRV at outdoor air bin temperature t_j (W);

$P_{in,h,t,j}$ is the power input to a supplementary preheater at full capacity (W).

6.3.4 Outdoor temperature bin distribution for heating

Value of outdoor temperature and bin hours differ from region to region. If bin-hours set to a certain value for a certain region, the value of heating load and electric energy consumption can be determined.

Annex B shows the reference outdoor temperature bin distribution for heating.

In case of setting other outdoor temperature bin distribution, refer to the setting method as described in Annex D.

6.3.5 Calculation of seasonal sensible heating recovery capacity (E_{sh})

Seasonal sensible heating recovery capacity (E_{sh}) shall be determine using Formula (8) from the total sum of sensible heating recovery at each outdoor temperature $t_{j.}$

$$E_{sh} = \sum_{i=1}^{n} [\phi_{sh,t,j} + P_{vma,t,j}] \times n_j \quad (8)$$

where

E_{sh} is the seasonal sensible heat recovery capacity of the HRV;

$\phi_{sh,t,j}$ is the sensible heat recovery capacity of the HRV at outdoor air bin temperature t_j;

$P_{vma,t,j}$ is the power value of moving air at outdoor air bin temperature t_j (J/s);

j is the bin number;

n_j is the hours in temperature bin.

6.3.6 Calculation of seasonal sensible heating recovery power input ($P_{in,E}$)

Seasonal sensible heating recovery power input, $P_{in,E}$, shall be determined using Formula (9) from the total sum of seasonal sensible heating power input at each outdoor temperature t_j.

$$P_{in,E} = \sum_{i=1}^{n} P_{in,t,j} \times n_j \quad (9)$$

where

$P_{in,E}$ is the seasonal sensible heating recovery power input;

$P_{in,t,j}$ is the power input to ventilator at outdoor air bin temperature t_j;

j is the bin number;

n_j is the hours in temperature bin.

6.3.7 Calculation of seasonal performance factor for sensible heating recovery (F_{sh})

Sensible heating recovery seasonal performance factor (F_{sh}) shall be determined using Formula (10):

$$F_{sh} = \frac{E_{sh}}{P_{in,E}} \quad (10)$$

where

F_{sh} is the seasonal sensible heat recovery seasonal performance factor;

E_{sh} is the seasonal sensible heat recovery capacity of the HRV;

$P_{in,E}$ is the seasonal sensible heating recovery power input.

7 Test report

The test report shall include:

a) the simple description of sample;

b) the International Standard used (including its year of publication);

c) the results which include at least the following: the list of mandatory test points performed, and gross sensible heating effectiveness and coefficient of sensible heating and seasonal sensible heating performance factor (F_{sh}) values and correspond rating condition; the list of optional test points performed, and gross sensible heat effectiveness and coefficient of sensible heat and seasonal sensible heating performance factor (F_{sh}) values; the default values used; the assumed default value of heating coefficient of performance of air conditioner or heating system.

d) the deviations from the procedure;

e) the unusual features observed;

f) the date of the test.

The heating seasonal performance factor (F_{sh}) shall be declared with three significant digits, with reference to the reference defined heating load and to the reference outdoor temperature bin distribution used.

NOTE Refer to Annex F for a template of the additional data to be collected and calculated results.

Annex A
(informative)

The schematic diagram of HRV heating (H) operation

For HRV with energy saving function, the operation stages under the application temperature bins are as below, which are also showed in Figure A.1 using a schematic diagram.

a) H Stage1, when the outdoor air temperature changes from a higher temperature $T_{set,h}$ equals to that defined in ISO 16494-1:2022, Table 2 as T5/T6/T7 to T_{BHB} (here 16 °C as an example), the outdoor air heating load is assumed zero due to the air conditioner off, which means heating not needed and recovery not desirable in stage 1 of Figure A.1. For ventilation, the fans will continue running and the electricity power input of fans will vary with or without ventilation bypass function in HRV.

NOTE 1 The building heating balance temperature means when the outdoor air temperature is lower than it, the room space should provide heating for comfortable indoor environment. It canbe different from country and region according energy saving code. Here and in Annex B, 16 °C is assumed as building heating balance temperature.

b) H Stage 2, when the outdoor air temperature changes from T_{BHB} to T_b, the outdoor air heating load will increase, but the electricity consumption of fans for overcoming the additional air resistance of heat recovery exchanger itself is larger than the equivalent electricity consumption calculated by using heat recovery amount to converting into. For energy saving, the supplying and exhausting airflow through heat recovery exchanger can go through with bypass function, consequently the electricity power input of fans for ventilation may be different from the units with or without ventilation bypass function.

NOTE 2 The temperature T_b for HRV with bypass function can be confirmed in laboratory when the energy saving control function is activated. For HRV without bypass function, the T_b does not exist.

c) H Stage 3, when the outdoor air temperature changing from T_b to T_F, the outdoor air heating load will continue to increase with the outdoor temperature decreasing, at this stage the bypass function of ventilation should be closed. The electricity power input of fans for ventilation is constant to HRV with or without bypass function, due to bypass function closed.

NOTE 3 The lower the T_F, the better the seasonal energy saving performance. It needs to optimize the design of HRV to keep the temperature difference between heat transfer surfaces of heat exchanger uniform, and also needs to optimize the type selection of heat exchanger, for example, when using the heat exchanger with the ability of latent transfer to sensible heating recovery purpose, the T_F can be even lower than the sensible transfer only type.

d) H Stage 4, when the outdoor air temperature changing from T_F to a lower temperature, the outdoor air heating load will increase with the outdoor temperature decrease, but the wet air frosting on the surface of heat recovery exchanger will weaken the recovery capacity. For keeping up the recovery ability, it is needed to input supplement heat to defrosting the exchanger surface. From T_F to a lower temperature, the heat recovery capacity will be the same, but the supplement electricity input will increase gradually, or a higher constant value which determined by keeping no frost in whole range of operation, correspondingly the total power input will also increase.

NOTE 4 In this document, assuming the supplement heating for F_{sh} calculation is provided all with the electricity.

NOTE 5 The methods for determine the temperature T_F see Annex C.

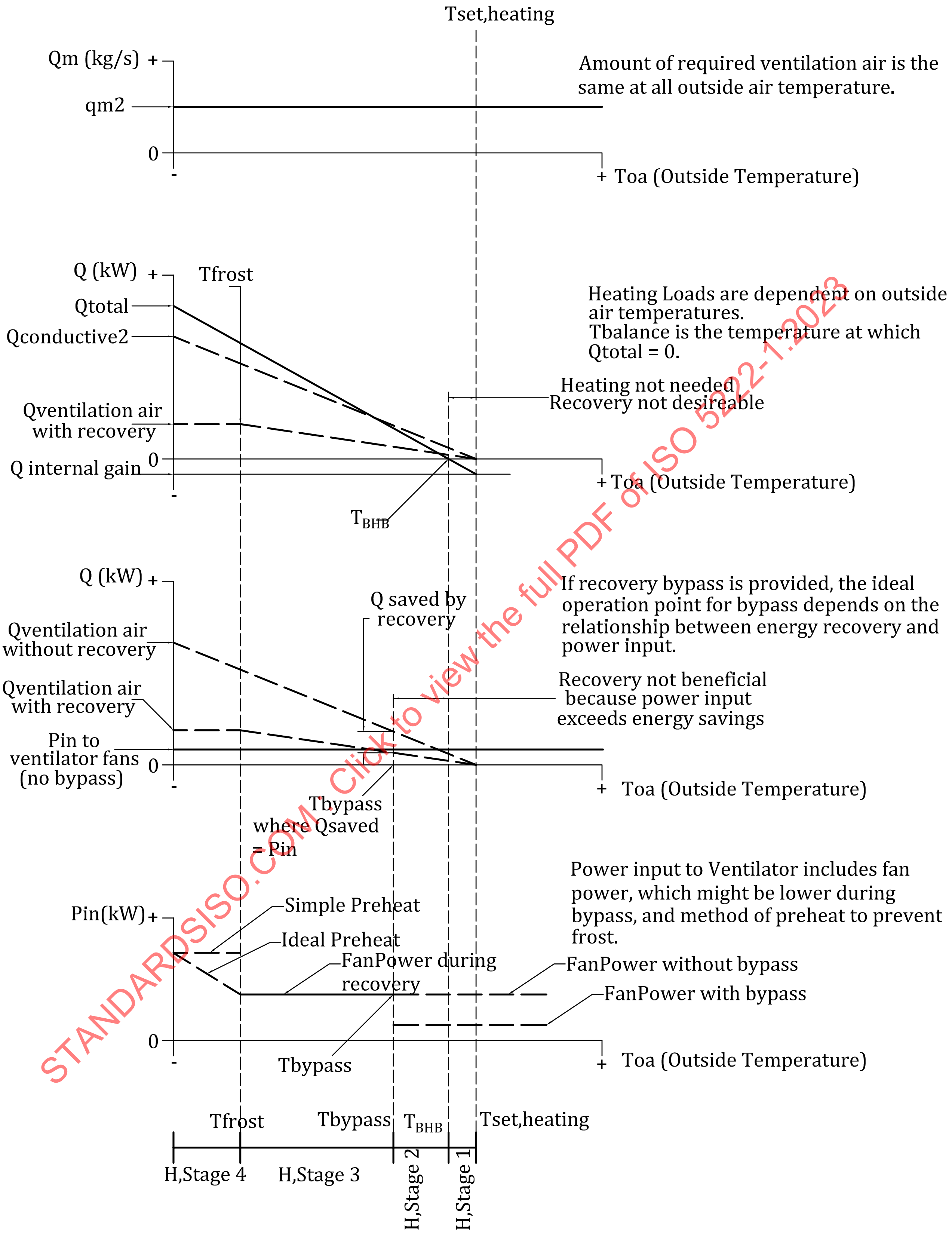

Figure A.1 — Operation stages for HRV

Annex B
(informative)

The default outdoor temperature bin distribution for heating

B.1 Sample climate bins

The bin limit temperature of T_{BHB} equals 16 °C for all types of climate when heating.

B.2 Heating

Table B.1 shows the default outdoor temperature bin distribution. Table B.2 shows the default hours for calculation of seasonal performance factor for sensible heating recovery.

NOTE The calculation of heating seasonal performance factor can also be undertaken for other temperature bin distributions as shown in Annex D.

Table B.1 — The default outdoor temperature bin distribution for heating

Bin number j	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Outdoor temperature t_j °C	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3
Fractional bin hours	0	0	0	0	0	0	0	0	0	0,001	0,005	0,012	0,024	0,042
Bin hours n_j	n_1	n_2	n_3	n_4	n_5	n_6	n_7	n_8	n_9	n_{10}	n_{11}	n_{12}	n_{13}	n_{14}
Reference bin hours (n_j) h	0	0	0	0	0	0	0	0	0	4	15	33	68	119
Bin number j	15	16	17	18	19	20	21	22	23	24	25	26	27	Total
Outdoor temperature t_j °C	4	5	6	7	8	9	10	11	12	13	14	15	16	
Fractional bin hours	0,059	0,070	0,082	0,087	0,091	0,092	0,091	0,085	0,075	0,067	0,053	0,038	0,027	
Bin hours n_j	n_{15}	n_{16}	n_{17}	n_{18}	n_{19}	n_{20}	n_{21}	n_{22}	n_{23}	n_{24}	n_{25}	n_{26}	n_{27}	
Reference bin hours (n_j) h	169	200	234	250	260	265	260	245	215	192	151	110	76	2 866

Table B.2 — Default hours for the calculation of seasonal performance factor for sensible heating recovery

HRV	AC turn on and keeping ventilation h (H stage 4 to H stage2)	AC turn off and keeping ventilation h (H stage 1)
Heating	2 866	4 077

Annex C
(normative)

Method of determination of the temperature $T_{F,0}$

The test for the determination of temperature T_F is provided in 5.3.6. The outdoor air temperature shall be gradually reduced from 0 °C, or, to save time, from a lower temperature $T_{F,0}$. This temperature is intended to be lower than 0 °C but above the actual T_F. The temperature $T_{F,0}$ shall not be used as T_F, which shall be determined by test. The temperature $T_{F,0}$ can be predicated as shown in Formula C.1:

$$T_{F,0} = T_0 - \frac{T_0}{\varepsilon_{sh}} \tag{C.1}$$

where

$T_{F,0}$ is the dry temperature of predicating frost outdoor air temperature;

ε_{sh} is the gross sensible heating recovery effectiveness of HRV at rated test condition is described in ISO 16494-1:2022, 9.5;

T_0 is the dry temperature of entering exhaust airflow temperature (RA) corresponding to ISO 16494-1 standard testing conditions (T5/T6/T7) (°C).

Annex D
(informative)

Calculating method for seasonal performance factor when setting a specific application heating load

D.1 General

Under application condition, outdoor air heating load widely varies from region and region on the globe depending on the climate conditions, the operation strategy of air conditioners and heat pumps as well as HRV.

In order to evaluate and compare the seasonal performance factor among HRVs, it is desirable to establish the method used in application condition and different operation strategy.

For this purpose, this annex provides steps and method.

D.2 Application outdoor air temperature BIN

Refer to the reference climate data of application location using the HRV, statistics and classification work shall be done and the table of outdoor climate bin hours shall be finished like used in Annex B.

D.3 Set of specific application condition of HRV

D.3.1 The temperature at which air conditioners and heat pumps are put into active mode shall be specified.

D.3.2 The indoor thermal comfortable temperature shall be set as the initial temperature for existing outdoor air heating load.

D.3.3 Test of the gross sensible heating recovery effectiveness under the indoor air temperature as D.3.2 while the outdoor air temperature shall be the same as in Table 1.

D.4 Calculation of the sensible heating performance factor of HRV

Under the redefined conditions provided above, the calculation of seasonal performance factor for sensible heating recovery (F_{sh}) is made in accordance with the provisions specified in the main standard body.

Table D.1 shows the sample template for outdoor temperature bin distribution. Table D.2 shows the sample template for the calculation of seasonal performance factor for sensible heating recovery.

Table D.1 — Sample template of outdoor temperature bin distribution for heating

Bin number j	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Outdoor temperature t_j °C	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3
Fractional bin hours														
Bin hours n_j	n_1	n_2	n_3	n_4	n_5	n_6	n_7	n_8	n_9	n_{10}	n_{11}	n_{12}	n_{13}	n_{14}
Reference bin hours (n_j) h														
Bin number j	15	16	17	18	19	20	21	22	23	24	25	26	27	Total
Outdoor temperature t_j °C	4	5	6	7	8	9	10	11	12	13	14	15	16	
Fractional bin hours														
Bin hours n_j	n_{15}	n_{16}	n_{17}	n_{18}	n_{19}	n_{20}	n_{21}	n_{22}	n_{23}	n_{24}	n_{25}	n_{26}	n_{27}	
Reference bin hours (n_j) h														

Table D.2 — Sample template of default hours for the calculation of seasonal performance factor for sensible heating recovery

HRV	AC turn on and keeping ventilation h (H stage 4 to H stage 2)	AC turn off and keeping ventilation h (H stage 1)
Heating		

Annex E
(normative)

Calculation of the bypass outdoor temperature

The outdoor temperature T_b influences the F_{sh} rating of unit. Higher values of T_b results in improved seasonal energy saving performance.

NOTE Manufacturers can optimize the selections and design of HRV by enhancing the efficiency of fans and motors as well as the effectiveness of heat recovery exchangers, also decreasing resistance of the airflow channels and selecting better speed control device of fans.

For HRV without bypass function, there is no $T_{b.}$

For HRV with bypass function, the T_b shall be calculated using Formula (E.1):

$$T_b = T_0 - \frac{\left(P_{in,no,t,j} - P_{in,by,t,j}\right) \times K}{\varepsilon_{sh} \times Q_{m2} \times c_p \times 1\,000} \quad \text{(E.1)}$$

where

T_b	is the bypass temperature of unit (°C);
T_0	is the dry temperature of entering exhaust airflow temperature (RA) corresponding to ISO 16494-1 standard testing conditions (T5/T6/T7) (°C);
ε_{sh}	is the gross sensible heating recovery effectiveness of HRV at rated test condition;
$P_{in,no,t,j}$	is the power input to the HRV to operate the fans at outdoor air temperature T_b for HRVs without bypass, (W);
$P_{in,by,t,j}$	is the power input to the HRV to operate the fans at outdoor air temperature T_b for HRVs with bypass, (W);
K	is the coefficient of performance of air conditioner operating at heating, assumes a default as 2,6 at T5, 2,8 at T6 and 3,0 at T7 or the manufacturer's data;
Q_{m2}	is the supply mass flow rate (kg/s);
c_p	is the specific heat of leaving supply air, (kJ/kg· °C).