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Methods of test and characterization of performance for energy recovery components

Méthode d'essai et caractérisation des performances des composants récupérateurs d'énergie

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

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*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Methods of test and characterization of performance for energy recovery components

1 Scope

This document specifies methods for testing and characterizing the performance of air-to-air heat/energy exchangers when used as devices to transfer heat or heat and water vapor between two airstreams used in ventilation systems. It also specifies methods to characterize the performance of exchangers for use in calculation of the energy performance of buildings. This document is applicable to:

— fixed-plate exchangers (also known as recuperators),

— rotary exchangers, including heat wheels and total energy wheels (also known as regenerators),

— heat pipe exchangers using a heat transfer medium, excluding those using mechanical pumping.

This document does not provide a method for measuring the response of exchangers to the formation of frost.

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 3966, *Measurement of fluid flow in closed conduits — Velocity area method using Pitot static tubes*

ISO 5167-1, *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full — Part 1: General principles and requirements*

ISO 5801, *Fans — Performance testing using standardized airways*

ISO 13253, *Ducted air-conditioners and air-to-air heat pumps — Testing and rating for performance*

ISO/IEC 17025:2017, *General requirements for the competence of testing and calibration laboratories*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological 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
effectiveness
actual energy transfer rate (sensible, latent, or total) divided by the maximum possible energy transfer rate

Note 1 to entry: The formula for effectiveness is given in 5.2.

3.2
exhaust air transfer ratio
EATR
tracer gas concentration difference between the *leaving supply air* (3.12) and the *entering supply air* (3.11), divided by the tracer gas concentration difference between the *entering exhaust air* (3.13) and the entering *supply air* (3.11), which quantifies the air quantity transferred from the exhaust to the supply

Note 1 to entry: The formula for EATR is given in 5.6.

Note 2 to entry: It can be expressed as a percentage for rating purposes, but is used as a ratio in the calculation of RER (3.6).

3.3
fixed-plate exchanger
exchanger with multiple alternate airflow channels, separated by a heat or heat and water vapor transfer plate(s) and connected to supply and exhaust airstreams

3.4
heat pipe exchanger
exchanger with an array of finned and sealed tubes that are placed in side-by-side supply and exhaust airstreams, which may include an internal wick structure in each tube, and filled with a heat transfer medium

Note 1 to entry: Thermosiphon exchangers are a subset (or type) of heat pipe exchanger in which the heat transfer medium moves by gravitational forces only.

3.5
outside air correction factor
OACF
factor defined as the *entering supply air* (3.11) divided by the *leaving supply air* (3.12)

Note 1 to entry: The formula for OACF is given in 5.5.

3.6
recovery efficiency ratio
RER
ratio of the recovered energy rate divided by the sum of the calculated combined fan power and the auxiliary power

Note 1 to entry: The formula for RER is given in 5.4.

Note 2 to entry: RER can be characterized as gross, or as net in which case EATR (3.2) is accounted for.

3.7
rotary exchanger
exchanger with porous discs, fabricated from materials with heat or heat and water vapor retention capacity, that are regenerated by collocated supply and exhaust airstreams

3.8
standard air
dry air with a density of 1,204 3 kg/m^3 and a dynamic viscosity of 1,824 7 x 10^{-5} kg/(m·s)

Note 1 to entry: These conditions approximate dry air at 20 °C and 101,325 kPa absolute.

3.9
station
location in the test apparatus at which conditions such a temperature, humidity, pressure or airflows are measured

Note 1 to entry: indicated in Figure 1 as 1, 2, 3 and 4.

3.10
static pressure differential
static pressure at supply outlet minus the static pressure at exhaust inlet

Note 1 to entry: A positive pressure differential occurs when the static pressure at *station* (3.9) 2 is higher than the static pressure at station 3. A negative pressure differential occurs when the static pressure at station 2 is lower than the static pressure at station 3.

3.11
entering supply air
supply air inlet
outdoor airflow
OA
outside air entering the exchanger

Note 1 to entry: Indicated in Figure 1 as 1.

3.12
leaving supply air
supply air outlet
supply airflow
SA
outside air after passing through the exchanger

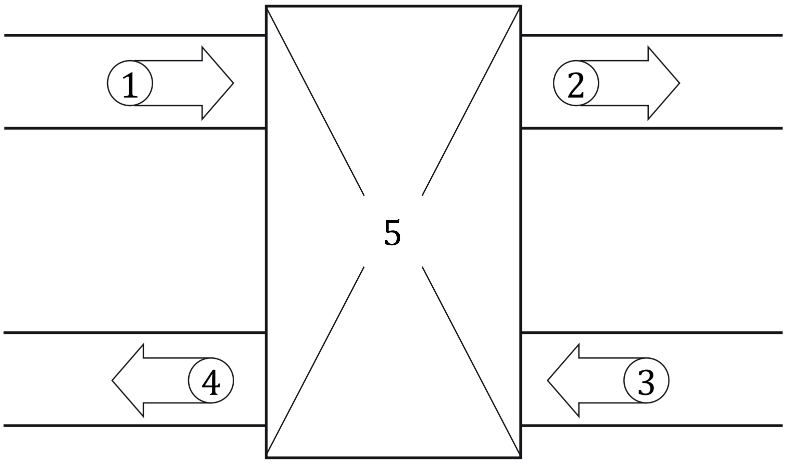
Note 1 to entry: Indicated in Figure 1 as 2.

3.13
entering exhaust air
exhaust air inlet
return airflow
RA
indoor air entering the exchanger

Note 1 to entry: Indicated in Figure 1 as 3.

3.14
leaving exhaust air
exhaust air outlet
exhaust airflow
EA
indoor air after passing through the exchanger

Note 1 to entry: Indicated in Figure 1 as 4.



Key

1 entering supply air

2 leaving supply air

3 entering exhaust air

4 leaving exhaust air

5 exchanger

Figure 1 — Schematic diagram of airflows for heat and energy recovery exchangers

4 Symbols and abbreviated terms

Symbol	Term	Units
C_i	Tracer gas concentration at station i (i = 1, 2, 3, 4)	10^{-6}
c_p	Specific heat of condensate at its measured temperature	kJ/(kg·°C)
$c_{p,i}$	Specific heat of dry air at station i (i = 1, 2, 3, 4)	J/(kg·°C)
δT_i	Maximum deviation of any temperature reading of T_i from $T_{AVE,i}$	K
δW_i	Maximum deviation of any humidity ratio reading of W_i in from $W_{AVE,i}$	kg water / kg dry air
ΔP_e	Pressure drop through the exchanger, exhaust air stream, measured	Pa
$\Delta P_{e,ref}$	Pressure drop through the exchanger, exhaust air stream, at reference conditions	Pa
ΔP_s	Pressure drop through the exchanger, supply air stream, measured	Pa
$\Delta P_{s,ref}$	Pressure drop through the exchanger, supply air stream, at reference conditions	Pa
$\Delta ps_{2,3}$	Static pressure differential	Pa
$\Delta T_{1\text{-}2}$	Temperature change in the supply airstream	°C or K
$\Delta W_{1\text{-}2}$	Humidity change in the supply airstream	kg water / kg dry air
ε	Effectiveness	%
$\varepsilon_{sensible}$	Sensible effectiveness	%
ε_{latent}	Latent effectiveness	%
ε_{total}	Total effectiveness	%
F_{oac}	Outside air correction factor (OACF)	1 [a]
h_i	Enthalpy of air at station i (i = 1, 2, 3, 4)	kJ/kg dry air

[a] Some quantities of dimension 1 are defined as ratios of two quantities of the same kind. The coherent derived unit is the number 1 (ISO 80000-1:2009, 3.8).

[b] T_e and W_e are defined and discussed in Annex E.

Symbol	Term	Units
h_{fg}	Heat of vaporization of water	J/kg
$\dot{m}_{condensate}$	Measured condensate flow rate	kg/s
$\dot{m}_i$	Mass flow rate of dry air at station *i* (*i* = 1, 2, 3, 4)	kg/s
m_s/m_e	Ratio of supply air outlet mass flow rate to exhaust air inlet mass flow rate	1 [a]
$\eta_{fs,fe}$	Combined efficiencies of the supply and exhaust air fan and drive	1 [a]
ps_i	Static pressure at station *i* (*i* = 1, 2, 3, 4)	Pa
q_{aux}	Auxiliary power input to the exchanger (e.g. to rotate a wheel)	kW
Q_{latent}	Humidity transfer rate	kg water/(kg dry air · s)
$Q_{sensible}$	Sensible energy transfer rate	W
Q_{total}	Total energy transfer rate	W
Q_2	Leaving supply volume flow rates	m^3/s
Q_3	Entering exhaust volume flow rates	m^3/s
ρ_i	Dry air density at station *i* (*i* = 1, 2, 3, 4)	kg/m^3
R_{eat}	Exhaust air transfer ratio (EATR)	1 [a]
$R_{rer,gross}$	Gross recovery efficiency ratio (gross RER)	W/W
$R_{rer,net}$	Net recovery efficiency ratio (net RER)	W/W
Θ	Purge angle	°
$T_{AVE,i}$	Average value of temperature readings taken at station *i* (*i* = 1, 2, 3, 4) during a measurement period	°C
$T_{condensate}$	Measured temperature of the condensate	°C
T_e	Temperature efficiency	% [b]
T_i	Dry-bulb temperature at station *i* (*i* = 1, 2, 3, 4)	°C
$T_{WB,i}$	Wet-bulb temperature at station *i* (*i* = 1, 2, 3, 4)	°C
U	Expanded relative uncertainty	1 [a]
$W_{AVE,i}$	Average value of humidity readings taken at station *i* (*i* = 1, 2, 3, 4) during a measurement period	kg water/kg dry air
W_e	Humidity efficiency	% [b]
W_i	Humidity at station *i* (*i* = 1, 2, 3, 4)	kg water/kg dry air
μ_i	Dynamic viscosity at station *i* (*i* = 1, 2 3 or 4)	kg/(m·s)
μ_s	Dynamic viscosity of standard air = 1,824 7 x 10^{-5}	kg/(m·s)

[a] Some quantities of dimension 1 are defined as ratios of two quantities of the same kind. The coherent derived unit is the number 1 (ISO 80000-1:2009, 3.8).

[b] T_e and W_e are defined and discussed in Annex E.

5 Metrics

5.1 General

The performance of an air-to-air heat/energy exchanger is primarily characterized by its sensible, latent, and total effectiveness [see Formulae (1), (2) and (3)] its pressure drops [see Formulae (4), (5), (6) and (7)], its recovery efficiency ratio [see Formulae (8) and (9)], the outside air correction factor [see Formula (10)], and its exhaust air transfer ratio [see Formula (11)]. Formulae (1) to (3) reproduced with permission from ANSI/ASHRAE 84:2020. Formulae (4) through (11) are based on formulae in ANSI/ASHRAE 84-2020 with permission from ANSI/ASHRAE. Annex E provides guidance on equivalence between the metrics provided in this document and related metrics in use in certain other standards.

Derived metrics that are needed for use in calculating the performance of complete systems include sensible energy transfer rate (see Formula (12)), humidity transfer rate (see Formula (13) and enthalpy transfer rate (see Formula (14)).

See Clause 4 for the units of different quantities.

5.2 Effectiveness

The sensible, latent, and total effectiveness ($\varepsilon_{\text{sensible}}$, $\varepsilon_{\text{latent}}$ and $\varepsilon_{\text{total}}$) are defined by Formulae (1), (2) and (3):

$$\varepsilon_{\text{sensible}} = \frac{\dot{m}_2 \left(c_{p,1} T_1 - c_{p,2} T_2 \right)}{\dot{m}_{\text{min}} \left(c_{p,1} T_1 - c_{p,3} T_3 \right)} \tag{1}$$

$$\varepsilon_{\text{latent}} = \frac{\dot{m}_2 \left(h_{\text{fg},1} W_1 - h_{\text{fg},2} W_2 \right)}{\dot{m}_{\text{min}} \left(h_{\text{fg},1} W_1 - h_{\text{fg},3} W_3 \right)} \tag{2}$$

$$\varepsilon_{\text{total}} = \frac{\dot{m}_2 \left(h_1 - h_2 \right)}{\dot{m}_{\text{min}} \left(h_1 - h_3 \right)} \tag{3}$$

where

$\dot{m}_i$ is the mass flow rate at station i (i = 1, 2 or 3)

$\dot{m}_{\text{min}}$ is the lesser of $\dot{m}_2$ and $\dot{m}_3$

$c_{p,i}$ is the specific heat of dry air at station i (i = 1, 2 or 3)

$h_{\text{fg},i}$ is the heat of vaporization of water at station i (i = 1, 2 or 3)

T_i is the dry-bulb temperature at station i (i = 1, 2 or 3)

W_i is the humidity at station i (i = 1, 2 or 3)

h_i is the enthalpy at station i (i = 1, 2 or 3)

5.3 Pressure drop

5.3.1 Measured pressure drop

The air friction pressure drops (ΔP_{s} and ΔP_{e}) at specific conditions and air mass flow rate through the exchanger are defined by Formulae (4) and (5):

$$\Delta P_{\text{s}} = ps_1 - ps_2 \tag{4}$$

$$\Delta P_{\text{e}} = ps_3 - ps_4 \tag{5}$$

where ps_{i} is the static pressure at station i (i = 1, 2, 3 or 4).

5.3.2 Standardized pressure drop

Air friction pressure drops at reference conditions ($\Delta P_{s,ref}$ and $\Delta P_{e,ref}$)can be determined by Formulae (6 and (7):

$$\Delta P_{s,ref} = \left| ps_1 \left(\frac{\rho_1}{\rho_s}\right)\left(\frac{\mu_s}{\mu_1}\right) - ps_2 \left(\frac{\rho_2}{\rho_s}\right)\left(\frac{\mu_s}{\mu_2}\right) \right| \quad (6)$$

$$\Delta P_{e,ref} = \left| ps_3 \left(\frac{\rho_3}{\rho_s}\right)\left(\frac{\mu_s}{\mu_3}\right) - ps_4 \left(\frac{\rho_4}{\rho_s}\right)\left(\frac{\mu_s}{\mu_4}\right) \right| \quad (7)$$

where

ρ_i is the density at station i (i = 1, 2, 3 or 4) kg/m^3

ρ_s is the standard density of air = 1,2043 kg/m^3

μ_i is the dynamic viscosity at station i (i = 1, 2 3 or 4) kg/(m·s)

μ_s is the dynamic viscosity of standard air = 1,8247 x 10^{-5} kg/(m·s)

5.4 Recovery efficiency ratio

a) The gross recovery efficiency ratio ($R_{rer,gross}$) of a heat/energy exchanger is defined by Formula (8):

$$R_{rer,gross} = \frac{\dot{m}_2 \left| h_1 - h_2 \right|}{\dfrac{\Delta P_s Q_2}{1000 \cdot \eta_{fan,s}} + \dfrac{\Delta P_e Q_3}{1000 \cdot \eta_{fan,e}} + q_{aux}} \quad (8)$$

b) The net recovery efficiency ratio ($R_{rer,net}$) of a heat/energy exchanger is defined by Formula (9):

$$R_{rer,net} = \frac{\dot{m}_2 \left| h_1 - \dfrac{h_2 - (R_{eat}) h_3}{(1 - R_{eat})} \right|}{\dfrac{\Delta P_s Q_2}{1000 \cdot \eta_{fan,s}} + \dfrac{\Delta P_e Q_3}{1000 \cdot \eta_{fan,e}} + q_{aux}} \quad (9)$$

where

ΔP_s and ΔP_e are the measured pressure drops across the supply and exhaust sides of the exchanger, respectively

Q_2 and Q_3 are the leaving supply and entering exhaust volume flow rates

η_{fs} and η_{fe} is the supply and exhaust air fan and drive combined efficiencies

$q_{aux.}$ is the total auxiliary power input to the exchanger (e.g. to rotate a regenerative wheel, a pump, and to operate controls)

R_{eat} is the exhaust air transfer ratio (EATR) expressed as a ratio

In laboratory testing of heat/energy exchangers it is not usually possible to measure the power required to move air through the exchanger directly, as the blowers in the test system also are required to overcome friction pressure of the conditioning equipment, flow measurement equipment, etc. Therefore, the power required to move air through the exchanger shall be calculated, based on a reference fan and drive total efficiency which is selected for the purposes of comparison of one exchanger to another. For example, a performance rating agency could elect to use a reference fan and drive total efficiency of 0,50 in the calculation of RER for all the exchangers for which it provides ratings.

5.5 Outside air correction factor

The outside air correction factor (F_{oac}) of a heat/energy exchanger at a specific operating condition is defined by Formula (10):

$$F_{oac} = \frac{\dot{m}_1}{\dot{m}_2} \tag{10}$$

where $\dot{m}_{1,2}$ are the mass flow rates at stations 1 and 2

5.6 Exhaust air transfer ratio

The exhaust air transfer ratio (R_{eat}) of a heat/energy exchanger at a specific operating condition is defined by Formula (11):

$$R_{eat} = \frac{C_2 - C_1}{C_3 - C_1} \tag{11}$$

where C_i are the concentration of tracer gas at stations i (i = 1, 2, 3 or 4) during the test described in 9.3.

NOTE To express exhaust air transfer ratio as a percentage, multiply by 100.

5.7 Sensible energy transfer rate for the supply airstream

Sensible energy transfer rate ($Q_{sensible}$) into or out of the supply airstream for an exchanger at a specific operating condition is defined by Formula (12):

$$Q_{sensible} = \dot{m}_2 \cdot \left(T_1 c_{p,1} - T_2 c_{p,2} \right) \tag{12}$$

where

$T_{1\text{-}2}$ are the temperatures at stations 1 and 2

$c_{p1,2}$ are the specific heats of dry air at stations 1 and 2

5.8 Humidity transfer rate for the supply airstream

Humidity transfer rate (Q_{latent}) into or out of the supply airstream for an exchanger at a specific operating condition is defined by Formula (13):

$$Q_{latent} = \dot{m}_2 \cdot \Delta W_{1-2} \tag{13}$$

where $\Delta W_{1\text{-}2}$ is the humidity change for the supply airstream.

5.9 Total energy transfer rate for the supply airstream

Total energy transfer rate (Q_{total}) into or out of the supply airstream for an exchanger at a specific operating condition is defined by Formula (14):

$$Q_{total} = \dot{m}_2 \cdot \Delta h_{1-2} \tag{14}$$

where $\Delta h_{1\text{-}2}$ is the enthalpy change for the supply airstream.

6 General test requirements

6.1 Test apparatus

The test apparatus shall consist of four measurement stations. Measurements shall be taken at each station of temperature, humidity, dry air mass flow rate, tracer gas concentration, and static pressure.

6.2 Installation

The equipment to be tested shall be installed in accordance with the manufacturer's instructions. See Figures 2 and 3.

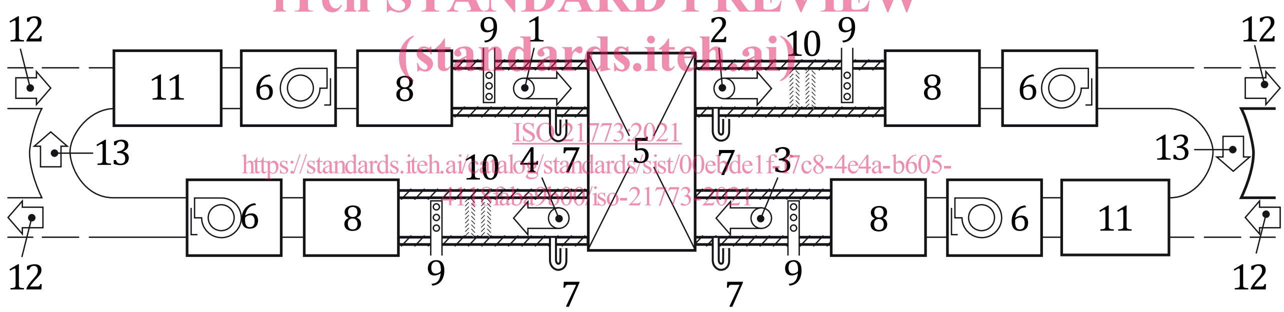
NOTE See Annex B for best practices of connecting an exchanger to test system.

6.3 Static pressures

Static pressures shall be measured according to ISO 3966, ISO 5167-1, ISO 5801 or ISO 13253.

6.4 Instrument calibration

All measurement instruments shall be calibrated using sensors, transfer standards, and primary instruments that are traceable. Calibration shall be consistent with ISO/IEC 17025:2017, 6.4 and 7.4, in order to minimize the bias of the instrument. The calibration curves associated with each instrument shall be available as a permanent record.



Key

1 entering supply air
2 leaving supply air
3 entering exhaust air
4 leaving exhaust air
5 exchanger
6 static pressure control apparatus
7 static pressure measuring apparatus
8 airflow measuring apparatus
9 temperature, humidity and tracer gas measuring instruments
10 air mixer
11 air conditioning apparatus
12 relief inlet/outlet
13 optional recycling duct

NOTE Refer to ISO 13253:2017, Annex C.

Figure 2 — Basic schematic for ducted measurement setup