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Method of test and characterization of performance for energy recovery components

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

ICS: 23.120; 91.120.10

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Foreword

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The committee responsible for this document is 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.

Introduction

[TBC]

Method of test and characterization of performance for energy recovery components

1 Scope

This standard prescribes the methods for testing 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. This standard prescribes methods to characterize the performance of exchangers for use in calculation of the energy performance of buildings. The types of air-to-air heat/energy exchangers covered by this standard are:

a. fixed-plate exchangers [also known as recuperators],

b. rotary exchangers, including heat wheels and total energy wheels [also known as regenerators],

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

This standard 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.

ASHRAE 84-2020*Method of Testing Air-to-Air Heat/Energy Exchangers*.

ISO 3966:2008, *Measurement of fluid flow in closed conduits — Velocity area method using Pitot static tubes*

ISO 5167-1:2003, *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/TR 9464:2008, *Guidelines for the use of ISO 5167:2003*

ISO/TR 5168:2015, *Measurements of fluid flow procedures for the evaluation of uncertainty*

ISO 5801:2017, *Fans — Performance testing using standardized airways*

ISO 13253:2017, *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 http://www.iso.org/obp

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

3.1
effectiveness
the actual energy transfer rate (sensible, latent, or total) divided by the maximum possible *energy transfer rate*.

Note 1 to entry: the equation for effectiveness is given in (5.1).

3.2
exhaust air transfer ratio (EATR)
the tracer gas concentration difference between the supply air outlet and the supply air inlet, divided by the tracer gas concentration difference between the exhaust air inlet and the supply air inlet which quantifies the air quantity transferred from the exhaust to the supply.

Note 1 to entry: the equation for exhaust EATR is given in (5.5).

Note 2 to entry: may be expressed as a percentage for rating purposes but is used as a ratio in the calculation of RER.

3.3
fixed-plate exchanger
an 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
an 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)
a factor defined as the entering supply airflow divided by the leaving supply airflow.

Note 1 to entry: the equation for OACF is given in (5.4).

3.6
recovery efficiency ratio (RER)
a 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 equation for RER is given in (5.3).

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

3.7
rotary exchanger
an 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 (SI units)
dry air with a density of 1.2043 kg/m^3, and dynamic viscosity of 1.8247 x 10^{-5} kg/(m·s).

Note 1 to entry: These conditions approximate dry air at 20°C and 101.3250 kPa absolute

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

3.10
static pressure differential
static pressure at supply outlet less the static pressure at exhaust inlet.

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

3.11
Entering Supply Air
outside air entering the Exchanger.

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

Note 2 to entry: sometimes referred to as the Outdoor Airflow (OA).

Note 3 to entry: sometimes referred to as the Supply air inlet

3.12
Leaving Supply Air
outside air after passing through the Exchanger.

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

Note 2 to entry: sometimes referred to as the Supply Airflow (SA).

Note 3 to entry: sometimes referred to as the Supply air outlet.

3.13
Entering Exhaust Air
indoor air entering the Exchanger.

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

Note 2 to entry: sometimes referred to as the Return Airflow (RA).

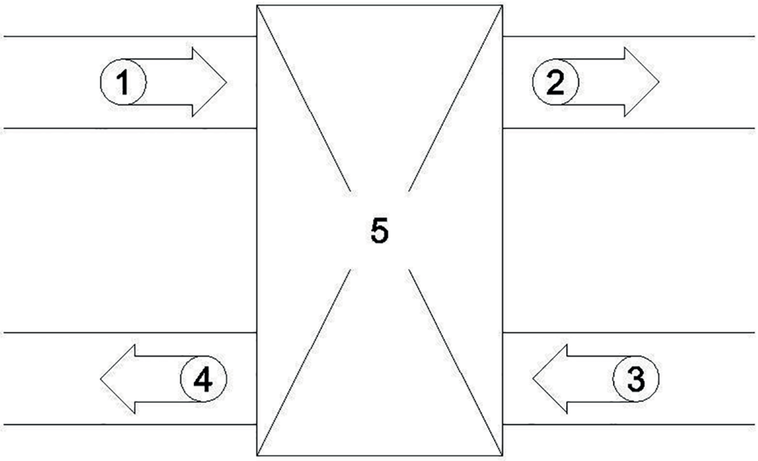
Note 3 to entry: sometimes referred to as the Exhaust air inlet.

3.14
Leaving Exhaust Air
indoor air after passing through the Exchanger.

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

Note 2 to entry: sometimes referred to as the Exhaust Airflow (EA).

Note 3 to entry: sometimes referred to as the Exhaust air outlet



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
e	Effectiveness	%
$\dot{m}_{1,2,3,4}$	mass flow rate of dry air at Station 1, 2, 3 or 4	kg/s
EATR	Exhaust air transfer ratio	1 NOTE 1
RER	Recovery efficiency ratio	W/W
OACF	Outside air correction factor	1NOTE
$T_{1,2,3,4}$	Dry bulb temperature at Station1, 2, 3 or 4	°C
$T_{WB,1,2,3,4}$	Wet bulb temperature at Station1, 2, 3 or 4	°C
T_{AVE}	The average value of temperature readings at a measurement station for purposes of determining effectiveness.	°C
$W_{1,2,3,4}$	Humidity at Station 1, 2, 3 or 4	kg water/kg dry air
W_{AVE}	The average value of humidity readings at a measurement station for purposes of determining effectiveness.	kg water/kg dry air
h_{fg}	heat of vaporization of water,	J/kg
Q_2	Leaving supply volume flow rates	m^3/s
Q_3	Entering exhaust volume flow rates	m^3/s
$Q_{sensible}$	Sensible Energy Transfer Rate	W
Q_{latent}	Humidity Transfer Rate	kg water/(kg dry air · s)
Q_{total}	Total Energy Transfer Rate	W
$Ps_{1,2,3,4}$	Static pressure at station 1, 2, 3 or 4	Pa
DP_e	Pressure Drop through the exchanger, exhaust air stream, measured	Pa

NOTE 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).

Symbol	Term	Units
DP_s	Pressure Drop through the exchanger, supply air stream, measured	Pa
$DP_{e,ref}$	Pressure Drop through the exchanger, exhaust air stream, at reference conditions	Pa
$DP_{s,ref}$	Pressure Drop through the exchanger, supply air stream, at reference conditions	Pa
$\rho_{1,2,3,4}$	dry air density at station 1, 2, 3 or 4	kg/m^3
q_{aux}	Auxiliary power input to the exchanger (e.g. to rotate a wheel)	W
$\eta_{fs,fe}$	Combined efficiencies of the supply and exhaust air fan and drive	1[NOTE]
$DT_{1\text{-}2}$	Temperature change in the supply airstream	°C or K
$DW_{1\text{-}2}$	Humidity change in the supply airstream	kg water / kg dry air
$c_{p,1,2,3,4}$	specific heat of dry air at station 1, 2, 3 or 4	J/(kg·K)
$H_{1,2,3,4}$	Enthalpy of air at station 1, 2, 3 or 4	kJ/kg dry air
$C_{1,2,3,4}$	Tracer gas concentration at station 1, 2, 3 or 4	10^6
NOTE 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).		

Subscript	Description
sensible	Indicates parameter refers to sensible energy
latent	Indicates parameter refers to latent energy
total	Indicates parameter refers to total (enthalpic) energy
1, 2, 3, 4	Refers to stations 1, 2, 3 or 4
fs, fe	Supply fan, exhaust fan
1-2	Process or change in the outside airstream between entering and leaving
3-4	Process or change in the exhaust airstream between entering and leaving
s, e	Supply, exhaust
m_{min}	the lesser of $\dot{m}_2$ and $\dot{m}_3$

5 Metrics

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]).

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]).

5.1 Effectiveness

$$\varepsilon_{sensible} = \frac{\dot{m}_2 \left(C_{p,1} T_1 - C_{p,2} T_2 \right)}{\dot{m}_{min} \left(C_{p,1} T_1 - C_{p,3} T_3 \right)} \quad [1]$$

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

$$\varepsilon_{total} = \frac{\dot{m}_2 (h_1 - h_2)}{\dot{m}_{min} (h_1 - h_3)} \quad [3]$$

where

$\dot{m}_{1,2,3}$ mass flow rate at station 1, 2 or 3

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

$C_{p,1,2,3}$ specific heat of dry air at station 1, 2 or 3

$h_{fg,\,1,2,3}$ heat of vaporization of water at station 1, 2 or 3

$T_{1,2,3}$ dry bulb temperature at station 1, 2 or 3

$W_{1,2,3}$ humidity at station 1, 2 or 3

$h_{1,2,3}$ enthalpy at station 1, 2 or 3

5.2 Pressure drop

5.2.1 Measured pressure drop

The air friction pressure drops (DP_s and DP_e) at specific conditions and air mass flow rate through the exchanger are defined by:

$$\Delta P_s = ps_1 - ps_2 \quad [4]$$

$$\Delta P_e = ps_3 - ps_4 \quad [5]$$

where

$ps_{1,2,3,4}$ static pressure at station 1, 2, 3 or 4

5.2.2 Standardized pressure drop

Air friction pressure drops at reference conditions may be determined by:

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

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

where

$\rho_{1,2,3,4}$ density at station 1, 2, 3 or 4

ρ_s standard density of air = 1.2043 kg/m^3

$\mu_{1,2,3,4}$ dynamic viscosity at station 1, 2, 3 or 4

μ_s dynamic viscosity of standard air = 1.8247 x 10^{-5} kg/(m·s)