AHRI Standard 1061-2023 (SI)

2023 Standard for

# Performance Rating of Air-to-Air Exchangers for Energy Recovery Ventilation Equipment

AHRI
AIR-CONDITIONING, HEATING, & REFRIGERATION INSTITUTE
we make life better®

2311 Wilson Boulevard, Suite 400
Arlington, VA 22201, USA
www.ahrinet.org
PH 703.524.8800
FX 703.562.1942

**IMPORTANT**

**SAFETY DISCLAIMER**

AHRI does not set safety standards and does not certify or guarantee the safety of any products, components or systems designed, tested, rated, installed, or operated in accordance with this standard/guideline. It is strongly recommended that products be designed, constructed, assembled, installed, and operated in accordance with nationally recognized safety standards and code requirements appropriate for products covered by this standard/guideline.

AHRI uses its best efforts to develop standards/guidelines employing state-of-the-art and accepted industry practices. AHRI does not certify or guarantee that any tests conducted under its standards/guidelines will be non-hazardous or free from risk.

ICS Code: 23.120

Note:

This standard supersedes AHRI Standard 1061-2018 (SI).

For I-P ratings, see AHRI Standard 1060-2023 (I-P).

**AHRI CERTIFICATION PROGRAM DISCLAIMER**

AHRI Standards are developed independently of AHRI Certification activities and can have scopes that include products that are not part of the AHRI Certification Program. The scope of the applicable AHRI Certification Program can be found on the AHRI website at www.ahrinet.org.

## Intent

This standard is intended for the guidance of the industry, including manufacturers, engineers, installers, contractors, and users.

## Review and Amendment

This standard is subject to review and amendment as technology advances.

## 2023 Edition

This edition of AHRI Standard 1061 (SI), *Performance Rating of Air-to-Air Exchangers for Energy Recovery Ventilation Equipment*, was prepared by the Air-to-Air Energy Recovery Ventilation (ERV) Standards Technical Committee. The standard was approved by the Applied Standards Subcommittee on 8 November 2023.

## Origin and Development of AHRI Standard 1061 (SI)

The initial publication was AHRI Standard 1061 (SI)-2011, *Performance Rating of Air-to-Air Heat Exchangers for Energy Recovery Ventilation Equipment*.
Subsequent revisions were:

AHRI Standard 1061 (SI)-2013, *Performance Rating of Air-to-Air Heat Exchangers for Energy Recovery Ventilation Equipment*

ANSI/AHRI Standard 1061 (SI)-2014, *Performance Rating of Air-to-Air Heat Exchangers for Energy Recovery Ventilation Equipment*

AHRI Standard 1061-2018 (SI), *Performance Rating of Air-to-Air Heat Exchangers for Energy Recovery Ventilation Equipment*

## Summary of Changes

AHRI Standard 1061-2023 (SI) contains the following updates to the previous edition:

- Revised range of standard *rating conditions* for supply flow ratio and *pressure differential*.
- Updated requirements for *published ratings*.
- Pressure drop correction moved to Section 4 and clarified method to determine density and viscosity.
- Increased allowances for sensible *effectiveness* and latent *effectiveness*.
- Testing tolerances moved to Table 2 and revised.
- Added calculation of standard airflow.
- Added *sensible energy recovery ratio*.
- Corrected units in Appendix C.
- Increased maximum temperature for laboratory ambient conditions.

**Committee Personnel**

**Standards Working Group (SWG) – AHRI 1060 & 1061**

| Participant | Interest Category Classification | Voting Member Role | State or Province / Country |
|---|---|---|---|
| Matthew Friedlander<br>RenewAire, LLC | Product Manufacturer | Chair | WI, USA |
| Aaron Bentley<br>SEMCO LLC | Product Manufacturer | Primary | MO, USA |
| John Cummings<br>LG Electronics, Inc. | Product Manufacturer | Primary | GA, USA |
| Richard Lord<br>Carrier Corporation | Product Manufacturer | Primary | TN, USA |
| Alois Malik<br>Multistack LLC | Product Manufacturer | Primary | SC, USA |
| Tyler Mancl<br>Greenheck Fan Company | Product Manufacturer | Primary | WI, USA |
| Ronnie Moffitt<br>Trane U.S. Inc. | Product Manufacturer | Primary | KY, USA |
| Onieluan Tamunobere<br>Heat-Pipe Technology, Inc. | Product Manufacturer | Primary | FL, USA |
| Marc Tardif<br>Innergy Tech, Inc. | Product Manufacturer | Primary | QC, Canada |
| Kevin Teakell<br>Aaon, Inc. | Product Manufacturer | Primary | OK, USA |
| Jeremy Tidd<br>Mitsubishi Electric Cooling & Heating | Product Manufacturer | Primary | GA, USA |
| Jaime Yeh | AHRI Staff Liaison | | |

**Standards Working Group (SWG) – AHRI 1060 & 1061 Scope:**

The purpose of the SWG – AHRI 1060 & 1061 is to complete the project to revise AHRI Standard 1060-2018 (I-P) and AHRI Standard 1061-2018 (SI).

Standards Working Groups (SWGs) are temporary and are formed by and report to the Standards Technical Committee (STC). The work of the SWG shall be within the scope of the STC as defined by the Standards Subcommittee (SSC).

**Air-to-Air Energy Recovery Ventilation (ERV) Standards Technical Committee**

| Participant | Interest Category Classification | Voting Member Role | State or Province / Country |
|---|---|---|---|
| Matthew Friedlander<br>RenewAire, LLC | Product Manufacturer | Chair | WI, USA |
| Aminian Behzad<br>CORE Energy Recovery Solutions | General Interest | Primary | BC, Canada |
| John Bade<br>2050 Partners | General Interest | Primary | CA, USA |
| Aaron Bentley<br>SEMCO LLC | Product Manufacturer | Primary | MO, USA |
| John Cummings<br>LG Electronics, Inc. | Product Manufacturer | Primary | GA, USA |
| Richard Lord<br>Carrier Corporation | Product Manufacturer | Primary | TN, USA |
| Alois Malik<br>Multistack LLC | Product Manufacturer | Primary | SC, USA |
| Tyler Mancl<br>Greenheck Fan Company | Product Manufacturer | Primary | WI, USA |
| Ronnie Moffitt<br>Trane U.S. Inc. | Product Manufacturer | Primary | KY, USA |
| Kevin Peck<br>Intertek | Testing Laboratory | Primary | NY, USA |
| Aniruddh Roy<br>Energy Solutions | General Interest | Primary | CA, USA |
| Onieluan Tamunobere<br>Heat-Pipe Technology, Inc. | Product Manufacturer | Primary | FL, USA |
| Marc Tardif<br>Innergy Tech, Inc. | Product Manufacturer | Primary | QC, Canada |
| Kevin Teakell<br>Aaon, Inc. | Product Manufacturer | Primary | OK, USA |
| Jeremy Tidd<br>Mitsubishi Electric Cooling & Heating | Product Manufacturer | Primary | GA, USA |
| Sebastian Wejchert<br>Swiss Rotors Inc. | Product Manufacturer | Primary | GA, USA |
| Jeff Whitelaw<br>Daikin Comfort Technologies Manufacturing, L.P. | Product Manufacturer | Primary | GA, USA |
| Helen Davis<br>Energy Solutions | General Interest | Alternate to Aniruddh Roy | CA, USA |
| Erik Sprague<br>Mitsubishi Electric Cooling & Heating | Product Manufacturer | Alternate to Jeremy Tidd | GA, USA |
| Jaime Yeh | AHRI Staff Liaison | | |

**Air-to-Air Energy Recovery Ventilation (ERV) Standards Technical Committee Scope:**

The Air-to-Air Energy Recovery Ventilation (ERV) Standards Technical Committee is responsible for the development and maintenance of AHRI standards and guidelines pertaining to Performance Rating of *Air-to-Air Exchangers* for Energy Recovery Ventilation Equipment, Calculating the Efficiency of Energy Recovery Ventilation and its Effects on Efficiency and Size of Building HVAC Systems, and Selecting, Sizing and Specifying Packaged *air-to-air energy recovery ventilation equipment*.

Out of scope for this STC include Chillers, Variable Frequency Drives (VFD), Humidifiers, Air Distribution, Chilled Beams, Unit Ventilators, Room Fan Coils, Heat Exchange, Air Handling, Air Filters, Dehumidifiers, Air Cooling and Air Heating Coils (ACAH), Thermal Storage Equipment (TSE) and Datacom equipment (DCOM).

Product definitions are as defined within AHRI 1060 and 1061, Guideline V, and Guideline W.

**Applied Standards Subcommittee**

| Participant | Interest Category Classification | Voting Member Role | State or Province / Country |
|---|---|---|---|
| Patrick Marks<br>Johnson Controls, Inc. | Product Manufacturer | Chair | PA, USA |
| Brandon Bates<br>Energistics Laboratory | Product Manufacturer | Primary | TX, USA |
| Craig Burg<br>Desert Aire Corp. | Product Manufacturer | Primary | WI, USA |
| Jennifer Butsch<br>Copeland | Product Manufacturer | Primary | OH, USA |
| Jeff deRoos<br>Carrier Corporation | Product Manufacturer | Primary | FL, USA |
| Henry Ernst<br>Daikin Applied Americas Inc. | Product Manufacturer | Primary | MN, USA |
| Dana Fischer<br>Mitsubishi Electric Cooling & Heating | Product Manufacturer | Primary | GA, USA |
| Armin Hauer<br>ebm-papst Inc. | Product Manufacturer | Primary | CT, USA |
| Jeffrey Kellow<br>GE Appliances, a Haier Company | Product Manufacturer | Primary | KY, USA |
| Darcy Lee<br>Trane U.S. Inc. | Product Manufacturer | Primary | GA, USA |
| Tom McDermott<br>Swegon North America Inc. | Product Manufacturer | Primary | ON, Canada |
| Karl Best | AHRI Staff Liaison | | |

**Applied Standards Subcommittee Scope:**

The scope of the Applied Standards Subcommittee is standards and guidelines related to the end products that are part of the AHRI Applied Industry Sector. (The definition of and list of products associated with each sector are found on the AHRI website at www.ahrinet.org.)

These lists represent the membership at the time the Standards Working Group, Standards Technical Committee, and Standards Subcommittee were balloted on the final text of this edition. Since that time, changes in the membership may have occurred. Membership on these committees shall not in and of itself constitute an endorsement by the committee members or their employers of any document developed by the committee on which the member serves.

## TABLE OF CONTENTS

Page

### SECTIONS



### FIGURES



### TABLES



### APPENDICES

# PERFORMANCE RATING OF AIR-TO-AIR EXCHANGERS FOR ENERGY RECOVERY VENTILATION EQUIPMENT

## Section 1. Purpose

This standard establishes definitions, test requirements, rating requirements, minimum data requirements for *published ratings*. marking and nameplate data, and conformance conditions for *air-to-air exchangers* intended for use in *air-to-air energy recovery ventilation equipment* (*AAERVE*).

## Section 2. Scope

**2.1 Scope**

This standard applies to factory-made *air-to-air exchangers* for use in *AAERVE* as defined in Section 3.

**2.2 Exclusions**

This standard does not apply to the rating and testing of heat exchangers joined by circulated heat transfer medium (run-around loop). A run-around loop employs liquid-containing coils connected in a closed loop and placed in each of two or more airstreams.

## Section 3. Definitions

All terms in this document shall follow the standard industry definitions in the ASHRAE Terminology website unless otherwise defined in this section.

**3.1 Expression of Provisions**

Terms that provide clear distinctions between requirements, recommendations, permissions, options, and capabilities.

**3.1.1 "Can" or "cannot"**

Express an option or capability.

**3.1.2 "May"**

Signifies a permission expressed by the document.

**3.1.3 "Must"**

Indication of unavoidable situations and does not mean that an external constraint referred to is a requirement of the document.

**3.1.4 "Shall" or "shall not"**

Indication of mandatory requirements to strictly conform to the standard and where deviation is not permitted.

**3.1.5 "Should" or "should not"**

Indication of recommendations rather than requirements. In the negative form, a recommendation is the expression of potential choices or courses of action that is not preferred but not prohibited.

**3.2 Standard Specific Definitions**

**3.2.1 Air-to-Air Energy Recovery Ventilation Equipment (AAERVE)**

Energy recovery components and packaged energy recovery ventilation units that employ *air-to-air exchangers* to recover energy from exhaust air for the purpose of pre-conditioning outdoor air prior to supplying the conditioned air to the space, either directly or as part of an air-conditioning (to include air heating, air cooling, air circulating, air cleaning, humidifying and dehumidifying) system.

### 3.2.2 Air-to-Air Exchanger (Exchanger)

A device that transfers heat/energy between an exhaust airstream and a separated supply airstream. Can be referred to as energy recovery components.

#### 3.2.2.1 Heat Pipe Heat Exchanger

A device employing tubes charged with a fluid for the purpose of transferring sensible energy from one airstream to another. Heat transfer takes place through the vaporization of the fluid exposed to the warmer airstream and condensation of the fluid in the cooler airstream.

#### 3.2.2.2 Plate Heat Exchanger

A device that transfers energy (sensible or total) from one airstream to another without moving parts. The design can incorporate parallel, cross, or counter flow construction or a combination of these to achieve the energy transfer.

#### 3.2.2.3 Rotary Heat Exchanger

A device incorporating a rotating cylinder or wheel for the purpose of transferring energy (sensible or total) from one airstream to the other. Incorporates heat transfer material, a drive mechanism, a casing or frame, and includes any seals that are provided to impede the bypassing and leakage of air from one airstream to the other.

### 3.2.3 Airflow

#### 3.2.3.1 Entering Exhaust Airflow

The exhaust airstream (indoor air) before passing through the *exchanger*, indicated in Figure 1 as *station* 3, expressed L/s of *standard air*. Can be referred to as return air (RA).

#### 3.2.3.2 Entering Supply Airflow

The supply airstream (outdoor air) before passing through the *exchanger*, indicated in Figure 1 as *station* 1, expressed in L/s of *standard air*. Can be referred to as outdoor air (OA).

#### 3.2.3.3 Leaving Exhaust Airflow

The exhaust airstream (indoor air) after passing through the *exchanger*, indicated in Figure 1 as *station* 4, expressed in expressed L/s of *standard air*. Can be referred to as exhaust air (EA).

#### 3.2.3.4 Leaving Supply Airflow

The supply airstream (outdoor air) after passing through the *exchanger*, indicated in Figure 1 as *station* 2, expressed in expressed L/s of *standard air*. Can be referred to as supply air (SA).

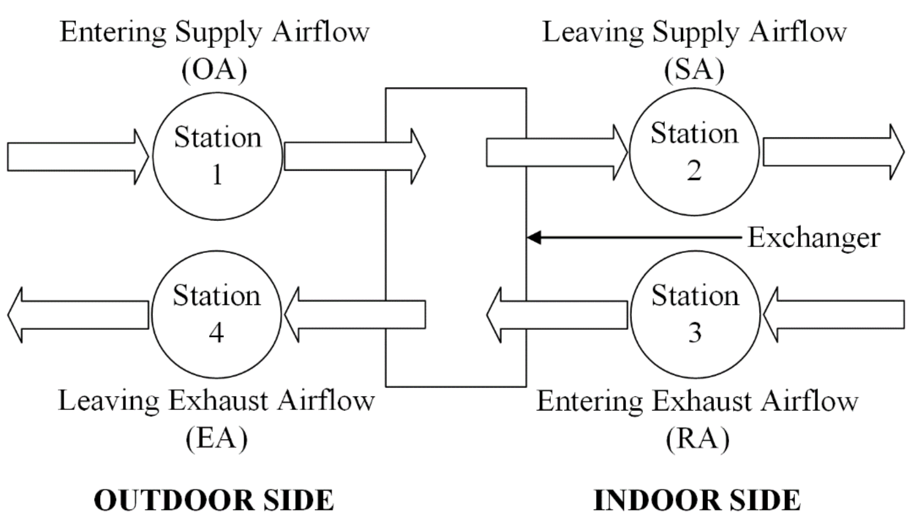


**Figure 1 Scheme of Airflows for Exchangers**

**3.2.4 Capacity Rate**

The quantity of energy an airstream at a specific mass flow rate is able to absorb or release per unit time per unit change in temperature, humidity content, or enthalpy content.

**3.2.5 Effectiveness**

A ratio of the actual energy transfer (sensible, latent, or total) to the product of the minimum energy *capacity rate* and the maximum difference in temperature, humidity ratio, or enthalpy, not adjusted to account for that portion of the psychrometric change in the *leaving supply airflow* that is the result of leakage of *entering exhaust airflow* rather than exchange of heat or moisture between the airstreams.

**3.2.5.1 Latent Effectiveness**

The *effectiveness* determined using only measured humidity ratios, heat of vaporization values, and mass airflow rates. The equation for determining *latent effectiveness* is Equation 19 in Appendix C.

**3.2.5.2 Sensible Effectiveness**

The *effectiveness* determined using only measured dry bulb temperature differences, specific heat capacities, and mass airflow rates. The equation for determining *sensible effectiveness* is Equation 19 in Appendix C.

**3.2.5.3 Total Effectiveness**

The *effectiveness* determined using only measured dry bulb temperature differences, specific heat capacities, measured humidity ratios, heat of vaporization values, and mass airflow rates. The equation for determining *total effectiveness* is Equation 20 in Appendix C.

**3.2.6 Enthalpy Recovery Ratio**

A ratio of the difference in enthalpy of the *entering supply airflow* (*station* 1) and the *leaving supply airflow* (*station* 2) to the difference in enthalpy between the *entering supply airflow* (*station* 1) and the *entering exhaust airflow* (*station* 3), without adjustment to account for that portion of the psychrometric change in the *leaving supply airflow* (*station* 2) that is the result of leakage of *entering exhaust airflow* (*station* 3) rather than exchange of heat or moisture between the airstreams. (See Figure 1 for *stations*.) The equation for determining *enthalpy recovery ratio* is Equation 26 in Appendix C.

**3.2.7 Exhaust Air Transfer Ratio (EATR)**

The tracer gas concentration difference between the *leaving supply airflow* and the *entering supply airflow* divided by the tracer gas concentration difference between the *entering exhaust airflow* and the *entering supply airflow* at the 100% rated *airflows*, expressed as a percentage. The equation for determining *EATR* is Equation 21 in Appendix C.

**3.2.8 Exhaust Pressure Drop**

The difference in static pressure of the air at the *entering exhaust airflow* inlet and the air at the *leaving exhaust airflow* outlet.

**3.2.9 Net Effectiveness**

A ratio of the actual energy transfer (sensible, latent, or total) to the product of the minimum energy *capacity rate* and the maximum difference in temperature, humidity ratio, or enthalpy, adjusted to account for that portion of the psychrometric change in the *leaving supply airflow* that is the result of leakage of *entering exhaust airflow* rather than exchange of heat or moisture between the airstreams. The derivation of *net effectiveness* is given in Appendix C.

**3.2.9.1 Net Latent Effectiveness**

The *net effectiveness* determined using only measured humidity ratios, heat of vaporization values, mass airflow rates and *EATR*. The equation for determining *net latent effectiveness* is Equation 22 in Appendix C.

#### 3.2.9.2 Net Sensible Effectiveness

The *net effectiveness* determined using measured dry bulb temperature differences, specific heat capacities, mass airflow rates and *EATR*. The equation for determining *net sensible effectiveness* is Equation 22 in Appendix C.

#### 3.2.9.3 Net Total Effectiveness

The *net effectiveness* determined using only measured dry bulb temperature differences, specific heat capacities, measured humidity ratios, heat of vaporization values, mass airflow rates and *EATR*. The equation for determining *net total effectiveness* is Equation 25 in Appendix C.

### 3.2.10 Net Supply Airflow

That portion of the *leaving supply airflow* that originated as *entering supply airflow*.

### 3.2.11 Outdoor Air Correction Factor (OACF)

The ratio of the *entering supply airflow* to the measured (gross) *leaving supply airflow*.

### 3.2.12 Pressure Differential

Static pressure at the *leaving supply airflow* outlet minus the static pressure at the *entering exhaust airflow* inlet.

### 3.2.13 Published Rating

A statement of the assigned values of those performance characteristics, under stated *rating conditions*, where a unit can be chosen to fit the application. These values apply to all units of the same nominal size and type (identification) produced by the same manufacturer. This includes the rating of all performance characteristics shown on the unit or published in specifications, advertising or other literature controlled by the manufacturer, at stated *rating conditions*.

#### 3.2.13.1 Application Rating

A *published rating* with one or more conditions outside the range of standard *rating conditions* specified in Table 1.

#### 3.2.13.2 Standard Rating

A *published rating* at conditions that are within the range of standard *rating conditions* specified in Table 1.

### 3.2.14 Rating Conditions

Any set of operating conditions where a single level of performance results and causes only that level of performance to occur.

### 3.2.15 Sensible Energy Recovery Ratio

A ratio of the difference in temperature of the *entering supply airflow* (*station* 1) and the *leaving supply airflow* (*station* 2) to the difference in temperature between the *entering supply airflow* (*station* 1) and the *entering exhaust airflow* (*station* 3), without adjustment to account for that portion of the psychrometric change in the *leaving supply airflow* (*station* 2) that is the result of leakage of *entering exhaust airflow* (*station* 3) rather than exchange of heat between the airstreams. (See Figure 1 for *stations*.) The equation for determining sensible recovery ratio is Equation 27 in Appendix C.

### 3.2.16 Standard Air

Air weighing 1,204 $kg/m^3$ with a viscosity of $1{,}824 \times 10^{-5}$ kg/m·s that approximates dry air at 20°C and at a barometric pressure of 101,325 kPa.

### 3.2.17 Station

For each of the *airflows* defined in Section 3.2.3 and shown in Figure 1, the *station* is the location in the test apparatus at where conditions such as temperature, humidity, pressure, or *airflow* are measured. These locations are identified as “Station 1”, “Station 2”, “Station 3” and “Station 4”.

Note: *Station* 1 can be referred to as supply side inlet, entering supply air, supply air inlet, outdoor airflow, OA, or outside air entering the *exchanger*.

*Station* 2 can be referred to as leaving supply air, supply air outlet, supply airflow, SA, or outside air after passing through the *exchanger*.

*Station* 3 can be referred to as entering exhaust air, exhaust air inlet, return airflow, RA, or indoor air entering the *exchanger*.

*Station* 4 can be referred to as leaving exhaust air, exhaust air outlet, exhaust airflow, EA, or indoor air after passing through the *exchanger*.

**3.2.18 Supply Flow Ratio**

The *station* 2 *airflow* divided by the *station* 3 *airflow*, expressed as a ratio.

**3.2.19 Supply Pressure Drop**

The difference in static pressure of the air at the *entering supply airflow* inlet and the air at the *leaving supply airflow* outlet.

## Section 4. Test Requirements

**4.1 Test Requirements**

*Standard ratings* shall be verified by tests conducted in accordance with ANSI/ASHRAE Standard 84-2020 at standard *rating conditions* in Table 1, except where modified by this standard. Figure 2 shows the psychrometric range of standard *rating conditions*.

**Table 1 Range of Standard Rating Conditions**

| Item | Conditions |
|---|---|
| 1) *Entering supply airflow* or *entering exhaust airflow* conditions[1] | — |
| a) Dry-bulb temperature, °C | Minimum: 2<br>Maximum: 49 |
| b) Wet-bulb temperature, °C | ≤ 27 |
| c) Humidity ratio, $g_w/kg_{da}$ | ≥ 1,4 |
| d) Relative humidity, % | ≤ 95 |
| 2) *Leaving supply airflow*, *entering exhaust airflow*, L/s of *standard air* | Maximum and minimum declared by the manufacturer. |
| *3) Supply flow ratio* | Not less than 0,8 nor greater than 1,25 |
| 4) *Pressure differential*, Pa | -625 to 625 |
| Note:<br>1. See Figure 2 for psychrometric range defined in Item 1). | |

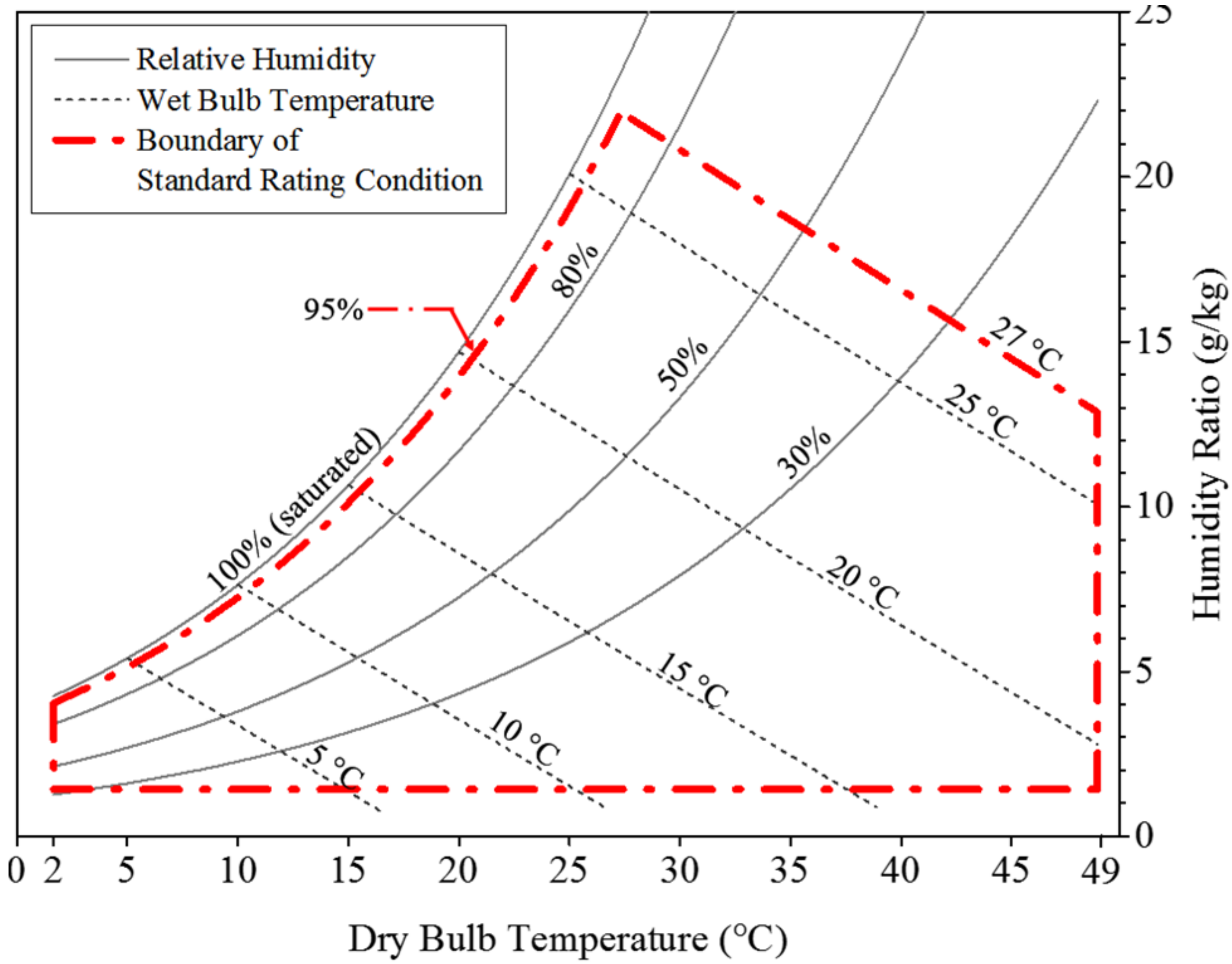


**Figure 2 Illustration of Range of Standard Rating Conditions**

## 4.2 Test Set-up

### 4.2.1 Heat Pipe Heat Exchangers

The tilt angle of *heat pipe heat exchangers* shall be as specified by the manufacturer. The tilt angle can change between heating and cooling conditions provided that an automatic mechanism to do so is provided by the manufacturer.

### 4.2.2 Plate Heat Exchangers

Confirm that the orientation of the *plate heat exchanger* is as specified by the manufacturer.

### 4.2.3 Rotary Heat Exchangers

#### 4.2.3.1 General

Drive motors used in *rotary heat exchangers* shall be placed in the airstream as specified by the manufacturer. All *standard ratings*, under both heating and cooling conditions, shall be measured with the drive motor in the same location. In addition, the *rotary heat exchanger* shall rotate within ± 10% of the speed or speed range specified by the manufacturer.

**4.2.3.2 Adjustable Purge**

If an adjustable purge is provided, it shall be set at the manufacturer's specified purge angle or setting. *Effectiveness* shall be measured using the same purge angle or setting used when measuring *EATR* and *OACF*.

**4.2.4 Laboratory Ambient Conditions**

Except in facilities where the *exchanger* is in one or both of the indoor and outdoor condition chambers, laboratory ambient conditions shall be maintained within the limits of 16°C and 30°C dry bulb. The room ambient temperature shall be measured within 2 m of the sample and at the height of the sample.

**4.2.5 Test Duration**

Measurements are taken for thirty minutes after a period of thirty minutes with stable input conditions based on ANSI/ASHRAE Standard 84-2020 and this Standard.

**4.3 Testing Tolerances**

For the test to be valid, it shall meet all the requirements of this section and Table 2.

**Table 2 Testing Tolerances**

| Measurement or Calculation Result | Maximum Deviation of Any Reading from Target Value | Maximum Deviation Between Average of Readings and Target Value |
|---|---|---|
| 1) *Entering supply airflow* or *entering exhaust airflow* conditions | — | — |
| a) Dry-bulb temperature | 0,6°C | 0,3°C |
| b) Wet-bulb temperature | 0,4°C | 0,2°C |
| 2) *Leaving supply airflow*, *entering exhaust airflow* | 1,5% or 2,4 L/s of *standard air*, whichever is greater | 1,5% or 2,4 L/s of *standard air*, whichever is greater |
| 3) *Pressure differential* | 25 Pa | 12,5 Pa |
| 4) For *rotary heat exchangers:* Rotational Speed, rpm | 10% rated rpm | — |
| 5) For *rotary heat exchangers:* Purge angle, degrees | 1° | — |
| 6) For *heat pipe heat exchangers:* Tilt angle, degrees | 1° | — |

**4.3.1 Stability**

Neither *sensible effectiveness* nor *latent effectiveness* shall exhibit a trend up or down for the duration of the test.

**4.3.2 Mass and Energy Inequalities**

Mass and energy inequalities shall be calculated as follows and the average shall be held within the specific limits for the duration of the test. Equation 1 through Equation 6, are restatements or simplifications of the relevant subset of equations in ANSI/ASHRAE Standard 84-2020.

$$\text{Mass flow inequality} = \frac{|\dot{m}_1 - \dot{m}_2 + \dot{m}_3 - \dot{m}_4|}{\dot{m}_{minimum(1,3)}} < 0{,}05 \quad (1)$$

$$\text{Sensible energy inequality} = \frac{|\dot{m}_1 \cdot t_1 - \dot{m}_2 \cdot t_2 + \dot{m}_3 \cdot t_3 - \dot{m}_4 \cdot t_4|}{\dot{m}_{minimum(1,3)}|t_1 - t_3|} < 0{,}20 \quad (2)$$

Note: Equation 2 differs from the comparable equation in ANSI/ASHRAE Standard 84-2020. For purposes of this standard, specific heat of dry air $c_p$ is taken as a constant 1,0 J/$kg_{da}$°C; it cancels out and is omitted here.

$$\text{Latent energy inequality} = \frac{|\dot{m}_1 W_1 - \dot{m}_2 W_2 + \dot{m}_3 W_3 - \dot{m}_4 W_4|}{\dot{m}_{minimum(1,3)}|W_1 - W_3|} < 0{,}20 \quad (3)$$

$$\text{Total energy inequality} = \frac{|\dot{m}_1 h_1 - \dot{m}_2 h_2 + \dot{m}_3 h_3 - \dot{m}_4 h_4|}{\dot{m}_{minimum(1,3)}|h_1 - h_3|} < 0{,}20 \quad (4)$$

If the rated *latent effectiveness* is 0, Equation 3 and Equation 4 are omitted for tests at winter conditions.

If the rated *latent effectiveness* is above 0, and physical condensation is visible during testing, Equation 3 and Equation 4 are replaced with Equation 5 through Equation 8.

$$\text{Latent energy inequality} = \frac{|\dot{m}_1 W_1 - \dot{m}_2 W_2 + \dot{m}_3 W_3 - \dot{m}_4 W_4 - \dot{m}_{condensate}|}{\dot{m}_{minimum(1,3)}|W_1 - W_3|} < 0{,}20 \quad (5)$$

$$\text{Total energy inequality} = \frac{|\dot{m}_1 h_1 - \dot{m}_2 h_2 + \dot{m}_3 h_3 - \dot{m}_4 h_4 - \dot{Q}_{condensate}|}{\dot{m}_{minimum(1,3)}|h_1 - h_3|} < 0{,}20 \quad (6)$$

$$\dot{Q}_{condensate} = (W_3 - W_4) \cdot [(\dot{m}_3 - \dot{m}_4)/2] \cdot 2468\ kJ/kg_{da} \quad (7)$$

$$\dot{m}_{condensate} = (W_3 - W_4) \cdot [(\dot{m}_3 - \dot{m}_4)/2] \quad (8)$$

Where

$h_n$ = Enthalpy at *station* n, kJ/kg

$\dot{m}_{min}$ = Minimum of ( $\dot{m}_2$ or $\dot{m}_3$)

$\dot{m}_n$ = Mass flow rate of dry air through *station* n, $kg_{da}$/s

n = *Station* number (see Figure 1)

$t_n$ = Temperature at *station* n, °C

$W_n$ = Humidity ratio at *station* n, $g_w/kg_{da}$

## 4.4 Tracer Gas Test

The tracer gas tests shall be performed at the rated *airflow* and *pressure differentials*. The tracer gas used shall be sulfur hexafluoride ($SF_6$). Tests shall be conducted at laboratory ambient temperature conditions without psychrometric changes. Relative humidity shall be maintained between 20% and 60% for the duration of the test.

To be valid, the tracer gas test shall meet the airflow mass inequality of Equation 1, and the tracer gas mass inequality of Equation 9, below. Equation 9 is the restatement of the relevant equation in ANSI/ASHRAE Standard 84-2020.

$$\text{Tracer gas inequality} = \frac{|\dot{m}_1 C_1 - \dot{m}_2 C_2 + \dot{m}_3 C_3 - \dot{m}_4 C_4|}{\dot{m}_{minimum(1,3)}|C_1 - C_3|} < 0{,}15 \quad (9)$$

## 4.5 Pressure Drop Test

The *supply pressure drop* and *exhaust pressure drop* shall be measured.

The pressure drop at the tested operating conditions can be corrected for air density and viscosity using Equation 10 to determine the pressure drop at *rating conditions*. To correct the pressure drop to standard conditions, Equation 10 shall be used with the density and viscosity of *standard air*.

$$\Delta P_2 = \Delta P_1 \left[\frac{\rho_1}{\rho_2}\right] \left[\frac{\mu_2}{\mu_1}\right]^m \quad \textbf{10}$$

Where:

$\Delta P_1$ = *Pressure drop* at test conditions, Pa

$\Delta P_2$ = *Pressure drop* at *rating conditions*, Pa

$\rho_1$ = Density of air at test conditions, kg/m$^3$

$\rho_2$ = Density of air at *rating conditions*, kg/m$^3$

$\mu_1$ = Viscosity of air at test conditions, kg/m·s

$\mu_2$ = Viscosity of air at *rating conditions*, kg/m·s

m = 1

For *supply pressure drop*, the density and viscosity shall be calculated as the average of the values at *station* 1 and *station* 2. For *exhaust pressure drop*, the density and viscosity shall be calculated as the average of the values at *station* 3 and *station* 4. Viscosity shall be calculated using Equation 11, restated below from ASHRAE 37.

$$\mu = (17{,}23 + 0{,}048 \times t) \times 10^{-6} \quad \textbf{11}$$

Where:

$\mu$ = Viscosity, kg/m·s

t = Dry-bulb temperature, °C

**4.6 Test Uncertainty**

All tests shall meet the uncertainty limits specified in ANSI/ASHRAE Standard 84-2020, and the test uncertainty shall be determined and reported.

**4.7 Calculation of Net Supply Airflow**

The *net supply airflow* is determined by subtracting air transferred from the exhaust side of the *exchanger* from the gross *airflow* measured at the *supply airflow* leaving the *exchanger* and is given by Equation 12:

$$SA_{net} = SA \cdot (1 - EATR) \quad \textbf{12}$$

Where:

*EATR* = *Exhaust air transfer ratio*, %

SA = *Leaving supply airflow*, L/s of *standard air*

$SA_{net}$ = *Net supply airflow*, L/s of *standard air*

**4.8 Calculation of the Supply Flow Ratio**

The *supply flow ratio* shall be calculated using Equation 13:

$$\textit{Supply flow ratio} = \frac{Q_2}{Q_3} \quad \textbf{13}$$

Where:

$Q_2$ = *Station* 2 *airflow*, L/s of *standard air*

$Q_3$ = *Station* 3 *airflow*, L/s of *standard air*

## 4.9 Calculation of Standard Airflow

Standard airflow shall be calculated using Equation 14:

$$Q_{std} = Q_{act}\frac{\rho_{act}}{\rho_{std}} \quad (14)$$

Where:

| | | |
|---|---|---|
| $Q_{std}$ | = | Standard airflow, L/s of *standard air* |
| $Q_{act}$ | = | Actual airflow, L/s |
| $\rho_{std}$ | = | Density of *standard air*, 1,2 kg/m$^3$ |
| $\rho_{act}$ | = | Actual air density, kg/m$^3$ |

# Section 5. Rating Requirements

## 5.1 Allowances

To comply with this standard, *published ratings* shall be based on data obtained in accordance with the provisions of this section and shall be such that any production unit, when tested, shall meet these ratings except for an allowance to cover testing and manufacturing variations as shown in Section 5.1.1 through Section 5.1.5.

### 5.1.1 Allowance for Sensible Effectiveness with Example

Test results for *sensible effectiveness* shall not be lower than the *published rating* by more than the sum of four relative percentage points and two absolute percentage points, or three absolute percentage points, whichever is greater. Relative percentage points are calculated as a percentage of the rated value. Absolute percentage points are independent of the rated value. See Equation 15 and Equation 16 below.

$$\varepsilon_{s,allow} = \text{maximum}\begin{cases}0{,}04 \times \varepsilon_{s,rated} + 2\% \\ 3\%\end{cases} \quad (15)$$

$$\varepsilon_{s,test} \geq \varepsilon_{s,rated} - \varepsilon_{s,allow} \quad (16)$$

Where:

| | | |
|---|---|---|
| $\varepsilon_{s,allow}$ | = | *Sensible effectiveness* allowance, % |
| $\varepsilon_{s,test}$ | = | *Sensible effectiveness* test result, % |
| $\varepsilon_{s,rated}$ | = | *Sensible effectiveness published rating*, % |

In this example the *sensible effectiveness* rating is 75,0%.

$$Allowance = (75{,}0\% \times 0{,}04) + 2\% = 5{,}0\%$$

Measured *sensible effectiveness* shall be greater than or equal to 70,0%.

### 5.1.2 Allowance for Latent Effectiveness with Example

Test results for *latent effectiveness* shall not be lower than the *published rating* by more than the sum of six relative percentage points and three absolute percentage points, or four absolute percentage points, whichever is greater. Relative percentage points are calculated as a percentage of the rated value. Absolute percentage points are independent of the rated value. See Equation 17 and Equation 18 below.

$$\varepsilon_{l,allow} = \text{maximum}\begin{cases}0{,}06 \times \varepsilon_{l,rated} + 3\% \\ 4\%\end{cases} \quad (17)$$

$$\varepsilon_{l,test} \geq \varepsilon_{l,rated} - \varepsilon_{l,allow} \quad (18)$$

Where:

$\varepsilon_{l,allow}$ = *Latent effectiveness* allowance, %

$\varepsilon_{l,test}$ = *Latent effectiveness* test result, %

$\varepsilon_{l,rated}$ = *Latent effectiveness published rating*, %

In this example the *latent effectiveness* rating is 60,0%.

$Allowance = (60{,}0\% \times 0{,}06) + 3\% = 6{,}6\%$

Measured *latent effectiveness* shall be greater than or equal to 53,4%.

**5.1.3 Allowance for Pressure Drop**

Test results for *pressure drop* shall not be greater than the *published rating* by the following allowances, whichever is greater: 10% of the *published rating*, or 12,5 Pa.

**5.1.4 Allowance for Exhaust Air Transfer Ratio (EATR)**

Test results for *EATR* shall not be more than one absolute percentage point greater than the *published rating*.

**5.1.5 Allowance for Outdoor Air Correction Factor (OACF)**

Test results for *OACF* shall follow the allowances below:

1) If the *OACF published rating* is less than 0,91, then the test results shall be less than or equal to 1,00 and greater than or equal to 90% of the *published rating*.
2) If the *OACF published rating* is greater than or equal to 0,91 and less than or equal to 1,11, then the test results shall be greater than or equal to 90% of the *published rating* and less than or equal to 110% of the *published rating*.
3) If the *OACF published rating* is greater than 1,11, then the test results shall be greater than or equal to 1,00 and less than or equal to 110% of the *published rating*.

## Section 6. Minimum Data Requirements for Published Ratings

**6.1 Minimum Data Requirements for Published Ratings**

As a minimum, any *standard rating* or *application rating* that is published, or provided through an automated rating/selection computer procedure, shall include a statement of all of the following at the specific *rating conditions*.

**6.1.1 Software version number**

The unique identifier for the software version generating the rating.

**6.1.2 Model Identification**

The unique identifier for the model.

**6.1.3 Rated Airflow**

The *leaving supply airflow* and *entering exhaust airflow* shall be stated in multiples of 0,5 L/s of *standard air*.

**6.1.4 Psychrometric Conditions**

Temperature and humidity at *station* 1, *station* 2, and *station* 3 shall be stated.

1) Dry-bulb temperature shall be stated in multiples of 0,1°C.
2) Air moisture properties shall be stated using one or more of the following:
   a) Absolute humidity in multiples of 0,00001 $kg_w/kg_{da}$ or 0,01 $g_w/kg_{da}$
   b) Dew point in multiples of 0,1°C
   c) Wet-bulb temperature in multiples of 0,1°C and altitude in multiples of 1 m or barometric pressure in multiples of 0,005 kPa.

d) Relative humidity in multiples of 0,1% and altitude in multiples of 1 m or barometric pressure in multiples of 0,005 kPa.

Conditions at *station* 2 shall be consistent with the inlet conditions and *effectiveness* as shown in Equation 19.

**6.1.5 Effectiveness**

*Sensible effectiveness* and *latent effectiveness* (see Appendix C) shall be stated in multiples of 0,1%.

**6.1.6 Exhaust Air Transfer Ratio (EATR)**

*EATR* shall be stated in multiples of 0,1%.

**6.1.7 Outdoor Air Correction Factor (OACF)**

*OACF* shall be stated in multiples of 0,01.

**6.1.8 Pressure Drop**

*Supply pressure drop* and *exhaust pressure drop* shall be stated in multiples of 2,5 Pa. The *published ratings* shall indicate whether the values are calculated at standard or actual conditions.

**6.1.9 Tilt Angle**

For *heat pipe heat exchangers*, tilt angle shall be stated in multiples of 1°.

**6.1.10 Net Supply Airflow**

*Net supply airflow* shall be stated in multiples of 0,5 L/s of *standard air*.

**6.1.11 Purge Angle or Setting**

For *rotary heat exchangers*, purge angle or setting shall be stated in multiples of 1°.

**6.1.12 Rotational Speed**

For *rotary heat exchangers*, rotational speed shall be stated in multiples of 1 rpm.

**6.1.13 Pressure Differential**

*Pressure differential* shall be stated in multiples of 2,5 Pa.

**6.2 Additional information**

The following information, if stated for the *exchanger*, shall meet the following requirements:

**6.2.1 Total Effectiveness and Net Effectiveness**

*Total effectiveness*, *net sensible effectiveness*, *net latent effectiveness*, and *net total effectiveness* shall be calculated as shown in Appendix C and stated in multiples of 0,1%.

**6.2.2 Enthalpy Recovery Ratio**

*Enthalpy recovery ratio* shall be consistent with the inlet conditions and *effectiveness* as shown in Equation 26 and stated in multiples of 0,1%.

**6.2.3 Sensible Energy Recovery Ratio**

*Sensible energy recovery ratio* shall be consistent with the inlet conditions and *effectiveness* as shown in Equation 27 and stated in multiples of 0,1%.

**6.2.4 Leaving Exhaust Airflow Psychrometric Conditions**

Temperature and humidity at *station* 4 shall be consistent with the inlet conditions and *effectiveness* as shown in Equation 29.

1) Dry-bulb temperature shall be stated in multiples of 0,1°C.
2) Air moisture properties shall be stated using one or more of the following:
    a) Absolute humidity in multiples of 0,00001 $kg_w/kg_{da}$ or 0,01 $g_w/kg_{da}$
    b) Dew point in multiples of 0,1°C

c) Wet-bulb temperature in multiples of 0,1°C and altitude in multiples of 1 m or barometric pressure in multiples of 0,005 kPa

d) Relative humidity in multiples of 0,1% and altitude in multiples of 1 m or barometric pressure in multiples of 0,005 kPa

**6.2.5 Airflows at Stations 1 and 4**

*Airflows* shall be consistent with the *airflows* at *station* 2 and *station* 3 and with rated *EATR* and *OACF* and shall be stated in multiples of 0,5 L/s of *standard air*.

**6.2.6 Claim to Ratings**

All claims to *standard rating* within the scope of this standard shall include the statement "*Standard rating* in accordance with AHRI Standard 1061 (SI)". All claims to *application ratings* within the scope of this standard shall include the statement "*Application rating* in accordance with AHRI Standard 1061 (SI)".

## Section 7. Marking and Nameplate Data

As a minimum, the following information shall be shown in a conspicuous place on the equipment:

1) Name or trade name of manufacturer
2) Manufacturer's model number
3) Heat transfer fluid (for *heat pipe heat exchangers*)

Nameplate voltages for 60 Hertz systems shall include one or more of the equipment nameplate voltage ratings shown in Table 1 of AHRI 110. Nameplate voltages for 50 Hertz systems shall include one or more of the utilization voltages shown in Table 1 of IEC 60038.

## Section 8. Conformance Conditions

While conformance with this standard is voluntary, conformance shall not be claimed or implied for products or equipment within the standard's Purpose (Section 1) and Scope (Section 2) unless such product claims meet all of the requirements of the standard and all of the testing and rating requirements are measured and reported in complete compliance with the standard. Any product that has not met all the requirements of the standard shall not reference, state, or acknowledge the standard in any written, oral, or electronic communication.

# APPENDIX A. REFERENCES – NORMATIVE

Listed here are all standards, handbooks, and other publications essential to the formation and implementation of the standard. All references in this appendix are considered as part of the standard.

**A.1.** AHRI Standard 110-2016, *Air-Conditioning, Heating, and Refrigerating Equipment Nameplate Voltages*, 2016, Air-Conditioning, Heating, and Refrigeration Institute, 2311 Wilson Blvd., Suite 400, Arlington, VA 22201, USA.

**A.2.** ANSI/ASHRAE Standard 37-2009 (R2019), *Methods of Testing For Rating Electrically Driven Unitary Air-Conditioning And Heat-Pump Equipment*, 2009 (R2019), ASHRAE, 180 Technology Parkway NW, Peachtree Corners, GA 30092, USA.

**A.3.** ANSI/ASHRAE Standard 84-2020, *Method of Testing Air-to-Air Heat/Energy Exchangers*, 2020, ASHRAE, 180 Technology Parkway NW, Peachtree Corners, GA 30092, USA.

**A.4.** ASHRAE Terminology. ASHRAE. Accessed June 24, 2022. https://www.ashrae.org/technical-resources/authoring-tools/terminology

**A.5.** IEC 60038, *IEC Standard Voltages*, 2009, International Electrotechnical Commission, 3 rue de Varembé, P.O. Box 131, CH-1211 Geneva 20, Switzerland.

# APPENDIX B. REFERENCES – INFORMATIVE

Listed here are standards, handbooks and other publications which may provide useful information and background but are not considered essential. References in this appendix are not considered part of the standard.

None

# APPENDIX C. CALCULATIONS – NORMATIVE

## C.1. Sensible or Latent Effectiveness

The *sensible* or *latent effectiveness* of an *exchanger* for use in *AAERVE* is described by Equation 19.

$$\varepsilon = \frac{C_2(X_1 - X_2)}{C_{min}(X_1 - X_3)} \quad (19)$$

Where:

| | | |
|---|---|---|
| C | = | *Capacity rate* for each airstream |
| | = | $\dot{m}c_p$ for *sensible effectiveness* |
| | = | $\dot{m}h_{fg}$ for *latent effectiveness* |
| $C_{min}$ | = | Minimum of ($C_2$ or $C_3$) |
| $c_p$ | = | Specific heat of dry air, J/$kg_{da}$°C, set for purposes for rating at 1,00 |
| $h_{fg}$ | = | Heat of vaporization of water, J/kg, set for purposes for rating at 2468 kJ/kg |
| $\dot{m}$ | = | Mass flow rate of dry air, $kg_{da}$/s |
| $X_n$ | = | Dry-bulb temperature, t, °C, or humidity ratio, W, $kg_w$/$kg_{da}$, respectively, at the *station* locations indicated in Figure 1 |
| ε | = | *Sensible* or *latent effectiveness* |

## C.2. Total Effectiveness

For purposes of rating the *total effectiveness* of an *exchanger* for use in *AAERVE* is described by Equation 20.

$$\varepsilon_{total} = \frac{\dot{m}_2 c_p |t_1 - t_2| + \dot{m}_2 h_{fg} |W_1 - W_2|}{\dot{m}_{min} c_p |t_1 - t_3| + \dot{m}_{min} h_{fg} |W_1 - W_3|} \quad (20)$$

Where:

| | | |
|---|---|---|
| $c_p$ | = | Specific heat of dry air, J/$kg_{da}$°C, set for purposes for rating at 1,00 |
| $h_{fg}$ | = | Heat of vaporization of water, J/kg, set for purposes for rating at 2468 kJ/kg |
| $\dot{m}_{min}$ | = | Minimum of ( $\dot{m}_2$ or $\dot{m}_3$) |
| $\dot{m}_n$ | = | Mass flow rate of dry air through *station* n, $kg_{da}$/s |
| n | = | *Station* number (see Figure 1) |
| $t_n$ | = | Temperature at *station* n, °C |
| $W_n$ | = | Humidity ratio at *station* n, $kg_w$/$kg_{da}$ |
| $\varepsilon_{total}$ | = | *Total effectiveness* |

## C.3. Exhaust Air Transfer Ratio (EATR)

The *EATR* of an *exchanger* for use in *AAERVE* is described by Equation 21.

$$EATR = \frac{c_{TG,2} - c_{TG,1}}{c_{TG,3} - c_{TG,1}} \quad (21)$$

Where:

| | | |
|---|---|---|
| $c_{TG,n}$ | = | Tracer gas concentration at *station* n, where n equals 1, 2, or 3 |

## C.4. Net Effectiveness

The *net sensible* or *latent effectiveness* is given by Equation 22.

$$\varepsilon_{net} = \frac{C_2\left(X_1 - \frac{X_2 - EATR \cdot X_3}{(1 - EATR)}\right)}{C_{min}(X_1 - X_3)} \quad \textbf{22}$$

Where:

| | | |
|---|---|---|
| C | = | *Capacity rate* for each airstream |
| | = | $\dot{m}c_p$ for *sensible effectiveness* |
| | = | $\dot{m}h_{fg}$ for *latent effectiveness* |
| $C_{min}$ | = | Minimum of ($C_2$ or $C_3$) |
| $c_p$ | = | Specific heat of dry air, J/kg$_{da}$°C, set for purposes for rating at 1,00 |
| *EATR* | = | *Exhaust air transfer ratio* at the mass flow rates and *pressure differential* of the rating point |
| $h_{fg}$ | = | Heat of vaporization of water, J/kg, set for purposes for rating at 2468 kJ/kg |
| $\dot{m}$ | = | Mass flow rate of dry air, kg$_{da}$/s |
| $X_n$ | = | Dry-bulb temperature, t, °C, or humidity ratio, W, kg$_w$/kg$_{da}$, respectively, at the *station* locations indicated in Figure 1 |
| $\varepsilon_{net}$ | = | *Net sensible* or *latent effectiveness* |

Note: Derivation of *net effectiveness*: The formula for *effectiveness* is given in Equation 19. The formula for *net effectiveness* is the same except that $X_{net}$ is substituted for $X_2$ where $X_{net}$ is derived from the mixed air condition at *station* 2 and the *EATR* is given in Equation 21.

Equation 23 shows the relationship between $X_2$ and $X_{net}$:

$$X_2 = (1 - EATR) \cdot X_{net} + EATR \cdot X_3 \quad \textbf{23}$$

As shown in Equation 24, solving for $X_{net}$ yields:

$$X_{net} = \frac{X_2 - (EATR)X_3}{(1 - EATR)} \quad \textbf{24}$$

Where, for Equation 23 and Equation 24

| | | |
|---|---|---|
| n | = | *Station* number (see Figure 1) |
| $X_n$ | = | Dry-bulb temperature, t, °C, or humidity ratio, W, kg$_w$/kg$_{da}$, respectively, at the *station* locations indicated in Figure 1 |

## C.5. Net Total Effectiveness

The *net total effectiveness* is given by Equation 25.

$$\varepsilon_{Net\ Total} = \frac{\dot{m}_2 c_p \left|t_1 - \frac{t_2 - (EATR)t_3}{(1 - EATR)}\right| + \dot{m}_2 h_{fg}\left|W_1 - \frac{W_2 - (EATR)W_3}{(1 - EATR)}\right|}{\dot{m}_{min} c_p |t_1 - t_3| + \dot{m}_{min} h_{fg} |W_1 - W_3|} \quad \textbf{25}$$

Where:

| | | |
|---|---|---|
| $c_p$ | = | Specific heat of dry air, J/kg$_{da}$°C, set for purposes for rating at 1,00 |
| $h_{fg}$ | = | Heat of vaporization of water, J/kg, set for purposes for rating at 2468 kJ/kg |
| $\dot{m}_{min}$ | = | Minimum of ( $\dot{m}_2$ or $\dot{m}_3$) |
| $\dot{m}_n$ | = | Mass flow rate of dry air through *station* n, kg$_{da}$/s |
| n | = | *Station* number (see Figure 1) |
| $t_n$ | = | Temperature at *station* n, °C |

| | | |
|---|---|---|
| $W_n$ | = | Humidity ratio at *station* n, $kg_w/kg_{da}$ |
| $\varepsilon_{Net\ Total}$ | = | *Net total effectiveness* |

### C.6. Enthalpy Recovery Ratio

The *enthalpy recovery ratio* is described by Equation 26.

$$\mu_e = \frac{h_1 - h_2}{h_1 - h_3} \qquad 26$$

Where:

| | | |
|---|---|---|
| $h_n$ | = | Enthalpy at *station* n, J/kg |
| $\mu_e$ | = | *Enthalpy recovery ratio* |

### C.7. Sensible Energy Recovery Ratio

The *sensible energy recovery ratio* is described by Equation 27.

$$\mu_s = \frac{t_1 - t_2}{t_1 - t_3} \qquad 27$$

Where:

| | | |
|---|---|---|
| $t_n$ | = | Temperature at *station* n, °C |
| $\mu_s$ | = | *Sensible energy recovery ratio* |

### C.8. Outlet Psychrometric Conditions

The outlet conditions shall be calculated as shown in Equation 28 and Equation 29.

1) For conditions at the *leaving supply* outlet (*station* 2) Equation 28 applies.

$$X_2 = X_1 - \frac{C_{min}}{C_2}\varepsilon(X_1 - X_3) \qquad 28$$

2) For conditions at the *leaving exhaust* outlet (*station* 4) Equation 29 applies.

$$X_4 = X_3 - \frac{C_{min}}{C_4}\varepsilon(X_3 - X_1) \qquad 29$$

Where, for Equation 28 and Equation 29:

| | | |
|---|---|---|
| C | = | *Capacity rate* for each airstream |
| | = | $\dot{m}c_p$ for *sensible effectiveness* |
| | = | $\dot{m}h_{fg}$ for *latent effectiveness* |
| $C_{min}$ | = | Minimum of ($C_2$ or $C_3$) |
| $c_p$ | = | Specific heat of dry air, J/$kg_{da}$°C, set for purposes for rating at 1,00 |
| $h_{fg}$ | = | Heat of vaporization of water, kJ/kg, set for purposes for rating at 2468 kJ/kg |
| $\dot{m}$ | = | Mass flow rate of dry air, $kg_{da}$/s |
| $X_n$ | = | Dry-bulb temperature, t, °C, or humidity ratio, W, $kg_w/kg_{da}$, respectively, at the *station* locations indicated in Figure 1 |
| ε | = | *Sensible* or *latent effectiveness* |

Enthalpy at the *leaving supply* outlet or the *leaving exhaust* outlet shall be calculated from the temperature and humidity conditions determined in Equation 28 and Equation 29, respectively.