

AHRI Standard 1060-2023 (I-P)

2023 Standard for

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



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ICS Code: 23.120

Note:

This standard supersedes AHRI Standard 1060-2018 (I-P).

For SI ratings, see AHRI Standard 1061-2023 (SI).

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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 1060 (I-P), *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 1060 (I-P)

The initial publication was ARI Standard 1060-1997, *Rating Air-to-Air Energy Recover Ventilation Equipment*. Subsequent revisions were:

ARI Standard 1060-2001, *Rating of Air-to-Air Heat Exchangers for Energy Recovery Ventilation Equipment*

AHRI Standard 1060-2005, *Performance Rating of Air-to-Air Heat Exchangers for Energy Recovery Ventilation Equipment*

AHRI Standard 1060 (I-P)-2011, *Performance Rating of Air-to-Air Heat Exchangers for Energy Recovery Ventilation Equipment*

AHRI Standard 1060 (I-P)-2013, *Performance Rating of Air-to-Air Heat Exchangers for Energy Recovery Ventilation Equipment*

ANSI/AHRI Standard 1060 (I-P)-2014, *Performance Rating of Air-to-Air Heat Exchangers for Energy Recovery Ventilation Equipment*

AHRI Standard 1060-2018 (I-P), *Performance Rating of Air-to-Air Heat Exchangers for Energy Recovery Ventilation Equipment*

Summary of Changes

AHRI Standard 1060-2023 (I-P) 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.

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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).

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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.

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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, 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.

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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 in scfm. 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 scfm. 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 scfm. 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 scfm. Can be referred to as supply air (SA).

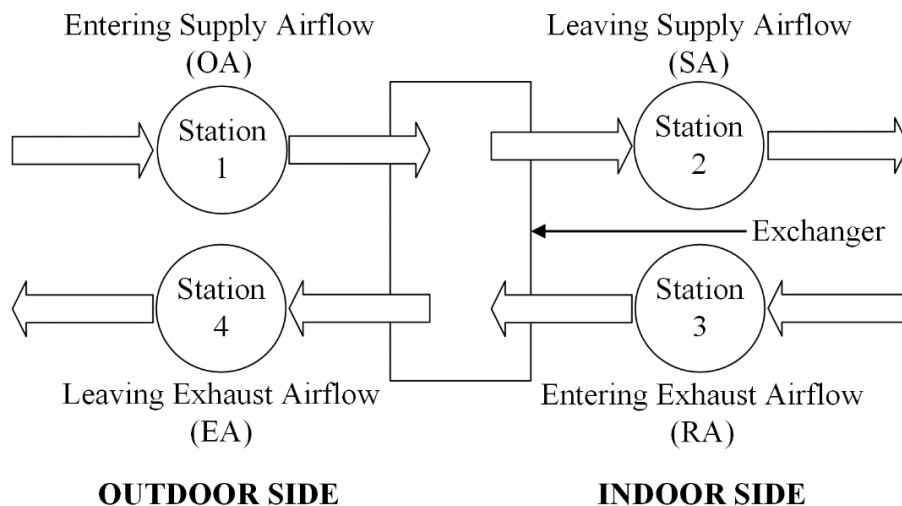


Figure 1 Scheme of Airflows for Exchangers

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 0.075 lb/ft³ with a viscosity of 1.226×10^{-5} lb_m/ft·s that approximates dry air at 70°F and at a barometric pressure of 29.92 in Hg.
- 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 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) <i>Entering supply airflow</i> or <i>entering exhaust airflow</i> conditions ¹	—
a) Dry-bulb temperature, °F	Minimum: 35 Maximum: 120
b) Wet-bulb temperature, °F	≤ 80
c) Humidity ratio ² , gr _w /lb _{da}	≥ 10.0
d) Relative humidity, %	≤ 95
2) <i>Leaving supply airflow, entering exhaust airflow</i> , scfm	Maximum and minimum declared by the manufacturer.
3) <i>Supply flow ratio</i>	Not less than 0.8 nor greater than 1.25
4) <i>Pressure differential</i> , in H ₂ O	-2.5 to 2.5
Notes: 1. See Figure 2 for psychrometric range defined in Item 1 . 2. 1 lb _w /lb _{da} = 7000 gr _w /lb _{da}	

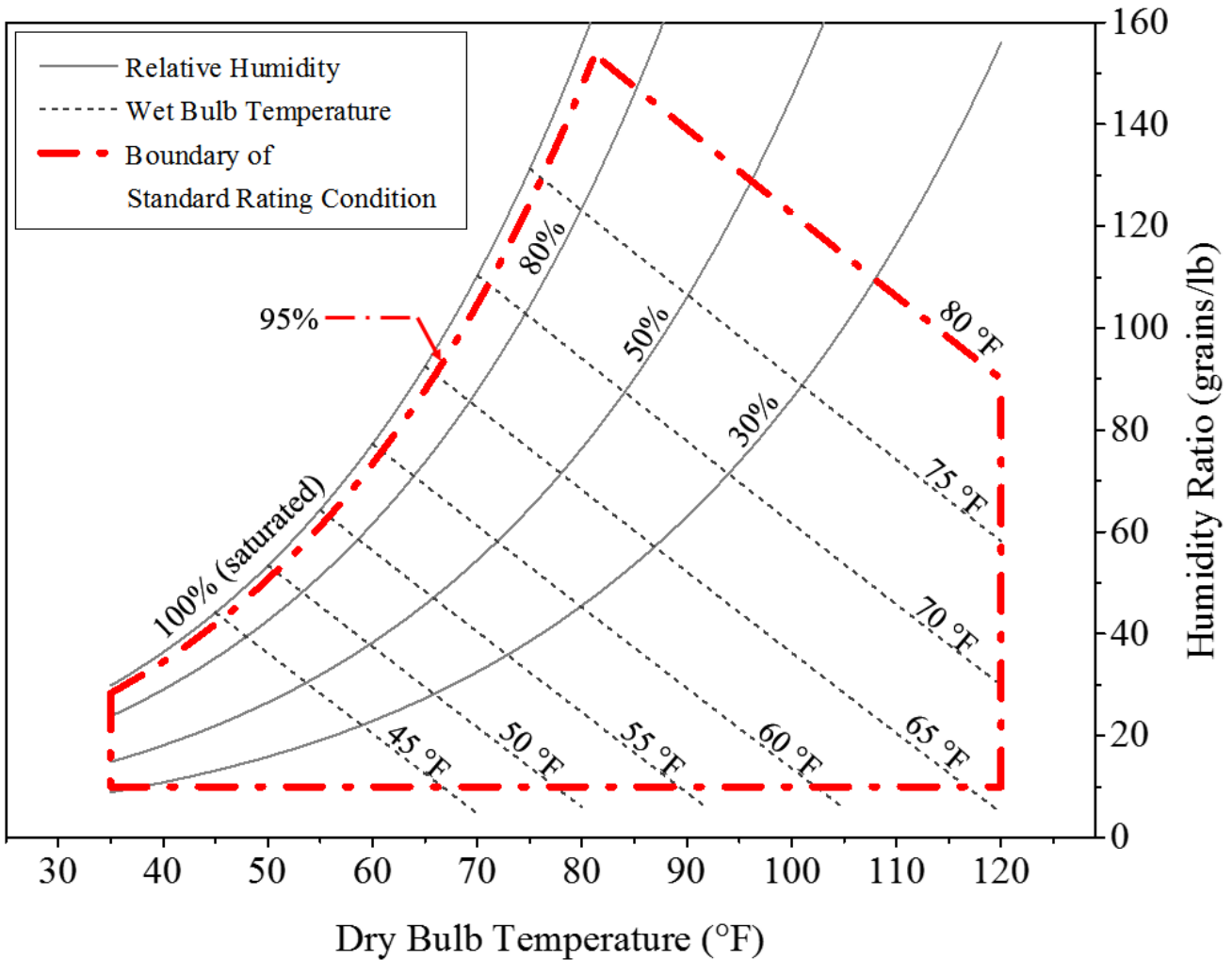


Figure 2 Illustration of Range of Standard Rating Conditions

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 $\pm 10\%$ 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 60°F and 85°F dry bulb. The room ambient temperature shall be measured within 6 ft 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) <i>Entering supply airflow</i> or <i>entering exhaust airflow</i> conditions	—	—
a) Dry-bulb temperature	1.0°F	0.5°F
b) Wet-bulb temperature	0.6°F	0.3°F
2) <i>Leaving supply airflow, entering exhaust airflow</i>	1.5% or 5 scfm, whichever is greater	1.5% or 5 scfm, whichever is greater
3) <i>Pressure differential</i>	0.1 in H ₂ O	0.050 in H ₂ O
4) For <i>rotary heat exchangers</i> : Rotational Speed, rpm	10% rated rpm	—
5) For <i>rotary heat exchangers</i> : Purge angle, degrees	1°	—
6) For <i>heat pipe heat exchangers</i> : 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 below are restatements or simplifications of the relevant subset of equations in ANSI/ASHRAE Standard 84-2020.

$$\text{Mass flow inequality} = \frac{|\dot{m}_1 - \dot{m}_2 + \dot{m}_3 - \dot{m}_4|}{\dot{m}_{\text{minimum}(1,3)}} < 0.05 \quad 1$$

$$\text{Sensible energy inequality} = \frac{|\dot{m}_1 \cdot t_1 - \dot{m}_2 \cdot t_2 + \dot{m}_3 \cdot t_3 - \dot{m}_4 \cdot t_4|}{\dot{m}_{\text{minimum}(1,3)} |t_1 - t_3|} < 0.20 \quad 2$$

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 0.24 BTU/lb_{da}°F; it cancels out and is omitted here.

$$\text{Latent energy inequality} = \frac{|\dot{m}_1 W_1 - \dot{m}_2 W_2 + \dot{m}_3 W_3 - \dot{m}_4 W_4|}{\dot{m}_{\text{minimum}(1,3)} |W_1 - W_3|} < 0.20 \quad 3$$

$$\text{Total energy inequality} = \frac{|\dot{m}_1 h_1 - \dot{m}_2 h_2 + \dot{m}_3 h_3 - \dot{m}_4 h_4|}{\dot{m}_{\text{minimum}(1,3)} |h_1 - h_3|} < 0.20 \quad 4$$

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 below.

$$\text{Latent energy inequality} = \frac{|\dot{m}_1 W_1 - \dot{m}_2 W_2 + \dot{m}_3 W_3 - \dot{m}_4 W_4 - \dot{m}_{\text{condensate}}|}{\dot{m}_{\text{minimum}(1,3)} |W_1 - W_3|} < 0.20 \quad 5$$

$$\text{Total energy inequality} = \frac{|\dot{m}_1 h_1 - \dot{m}_2 h_2 + \dot{m}_3 h_3 - \dot{m}_4 h_4 - \dot{Q}_{\text{condensate}}|}{\dot{m}_{\text{minimum}(1,3)} |h_1 - h_3|} < 0.20 \quad 6$$

$$\dot{Q}_{\text{condensate}} = (W_3 - W_4) \cdot [(\dot{m}_3 - \dot{m}_4)/2] \cdot 1061 \text{ Btu/lb}_{da} \quad 7$$

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

Where:

- hn = Enthalpy at station n, Btu/lbda
- \dot{m}_{min} = Minimum of (\dot{m}_2 or \dot{m}_3)
- \dot{m}_n = Mass flow rate of dry air through station n, lbda/min
- n = Station number (see [Figure 1](#))
- tn = Temperature at station n, °F
- Wn = Humidity ratio at station n, lbw/lbda

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 (SF₆). 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.

$$\text{Tracer gas inequality} = \frac{|\dot{m}_1 C_1 - \dot{m}_2 C_2 + \dot{m}_3 C_3 - \dot{m}_4 C_4|}{\dot{m}_{\text{minimum}(1,3)} |C_1 - C_3|} < 0.15 \quad 9$$

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*.

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

Where:

ΔP_1	=	Pressure drop at test conditions, in H ₂ O
ΔP_2	=	Pressure drop at <i>rating conditions</i> , in H ₂ O
ρ_1	=	Density of air at test conditions, lb _{da} /ft ³
ρ_2	=	Density of air at <i>rating conditions</i> , lb _{da} /ft ³
μ_1	=	Viscosity of air at test conditions, lb _m /ft·s
μ_2	=	Viscosity of air at <i>rating conditions</i> , lb _m /ft·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.

$$\mu = (11.00 + 0.018 \times t) \times 10^{-6} \quad 11$$

Where:

μ	=	Viscosity, lb _m /ft·s
t	=	Dry-bulb temperature, °F

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:

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

Where:

$EATR$	=	Exhaust air transfer ratio, %
SA	=	Leaving supply airflow, scfm
SA_{net}	=	Net supply airflow, scfm

4.8 Calculation of the Supply Flow Ratio

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

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

Where:

Q_2	=	Station 2 airflow, scfm
Q_3	=	Station 3 airflow, scfm

4.9 Calculation of Standard Airflow

Standard airflow shall be calculated using Equation 14:

$$Q_{std} = Q_{act} \frac{\rho_{act}}{\rho_{std}} \tag{14}$$

Where:

- Q_{std} = Standard airflow, scfm
- Q_{act} = Actual airflow, cfm
- ρ_{std} = Density of *standard air*, 0.075 lb_{da}/ft³
- ρ_{act} = Actual air density, lb_{da}/ft³

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.

$$\epsilon_{s,allow} = \text{maximum} \left\{ \begin{array}{l} 0.04 \times \epsilon_{s,rated} + 2\% \\ 3\% \end{array} \right. \tag{15}$$

$$\epsilon_{s,test} \geq \epsilon_{s,rated} - \epsilon_{s,allow} \tag{16}$$

Where:

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

In this example the *sensible effectiveness* rating is 75.0%.

$$Allowance = (75.0\% \times 0.04) + 2\% = 5.0\%$$

Measured *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.

$$\epsilon_{l,allow} = \text{maximum} \left\{ \begin{array}{l} 0.06 \times \epsilon_{l,rated} + 3\% \\ 4\% \end{array} \right. \tag{17}$$

$$\epsilon_{l,test} \geq \epsilon_{l,rated} - \epsilon_{l,allow} \tag{18}$$

Where:

- $\epsilon_{l,allow}$ = Latent effectiveness allowance, %
- $\epsilon_{l,test}$ = Latent effectiveness test result, %
- $\epsilon_{l,rated}$ = Latent effectiveness published rating, %

In this example the *latent effectiveness* rating is 60.0%.

$$Allowance = (60.0\% \times 0.06) + 3\% = 6.6\%$$

Measured *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 0.050 in H₂O.

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 1 scfm.

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°F.
- 2) Air moisture properties shall be stated using one or more of the following:
 - a) Absolute humidity in multiples of 0.00001 lb_w/lb_{da} or 0.1 gr_w/lb_{da} (1 lb_w/lb_{da} = 7000 gr_w/lb_{da}).
 - b) Dew point in multiples of 0.1°F.
 - c) Wet-bulb temperature in multiples of 0.1°F and altitude in multiples of 1 ft or barometric pressure in multiples of 0.001 psi.

- d) Relative humidity in multiples of 0.1% and altitude in multiples of 1 ft or barometric pressure in multiples of 0.001 psi.

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 0.01 in H₂O. 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 1 scfm.

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 0.01 in H₂O.

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°F.
- 2) Air moisture properties shall be stated using one or more of the following:
 - a) Absolute humidity in multiples of 0.00001 lb_w/lb_{da} or 0.1 gr_w/lb_{da} (1 lb_w/lb_{da} = 7000 gr_w/lb_{da})
 - b) Dew point in multiples of 0.1°F
 - c) Wet-bulb temperature in multiples of 0.1°F and altitude in multiples of 1 ft or barometric pressure in multiples of 0.001 psi

- d) Relative humidity in multiples of 0.1% and altitude in multiples of 1 ft or barometric pressure in multiples of 0.001 psi

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 1 scfm.

6.3 Claim to Ratings

All claims to *standard ratings* within the scope of this standard shall include the statement “Standard Rating in accordance with AHRI Standard 1060 (I-P)”. All claims to *application ratings* within the scope of this standard shall include the statement “Application Rating in accordance with AHRI Standard 1060 (I-P)”.

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 Varembe, 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 <i>sensible effectiveness</i>
	=	$\dot{m}h_{fg}$ for <i>latent effectiveness</i>
C_{\min}	=	Minimum of (C_2 or C_3)
c_p	=	Specific heat of dry air, Btu/lb _{da} °F, set for purposes for rating at 0.24
h_{fg}	=	Heat of vaporization of water, Btu/lb, set for purposes for rating at 1061
\dot{m}	=	Mass flow rate of dry air, lb _{da} /min
X_n	=	Dry-bulb temperature, t , °F, or humidity ratio, W , lb _w /lb _{da} , respectively, at the <i>station</i> locations indicated in Figure 1
ε	=	<i>Sensible or latent effectiveness</i>

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, Btu/lb _{da} °F, set for purposes for rating at 0.24
h_{fg}	=	Heat of vaporization of water, Btu/lb, set for purposes for rating at 1061
\dot{m}_{\min}	=	Minimum of (\dot{m}_2 or \dot{m}_3)
\dot{m}_n	=	Mass flow rate of dry air through <i>station</i> n, lb _{da} /min
n	=	<i>Station</i> number (see Figure 1)
t_n	=	Temperature at <i>station</i> n, °F
W_n	=	Humidity ratio at <i>station</i> n, lb _w /lb _{da}
ε_{total}	=	<i>Total effectiveness</i>

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 <i>station</i> n, where n equals 1, 2, or 3
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C.4. Net Effectiveness

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

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

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 (C₂ or C₃)
- c_p = Specific heat of dry air, Btu/lb_{da}°F, set for purposes for rating at 0.24
- EATR = Exhaust air transfer ratio at the mass flow rates and *pressure differential* of the rating point
- h_{fg} = Heat of vaporization of water, Btu/lb, set for purposes for rating at 1061
- \dot{m} = Mass flow rate of dry air, lb_{da}/min
- X_n = Dry-bulb temperature, t, °F, or humidity ratio, W, lb_w/lb_{da}, respectively, at the *station* locations indicated in [Figure 1](#)
- ε_{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 X₂ 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 X₂ and X_{net}:

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

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

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

Where, for Equation 23 and Equation 24:

- n = Station number (see [Figure 1](#))
- X_n = Dry-bulb temperature, t, °F, or humidity ratio, W, lb_w/lb_{da}, respectively, at the *station* locations indicated in [Figure 1](#)

C.5. Net Total Effectiveness

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

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

Where:

- c_p = Specific heat of dry air, Btu/lb_{da}°F, set for purposes for rating at 0.24
- h_{fg} = Heat of vaporization of water, Btu/lb, set for purposes for rating at 1061
- \dot{m}_{min} = Minimum of (\dot{m}_2 or \dot{m}_3)
- \dot{m}_n = Mass flow rate of dry air through *station n*, lb_{da}/min
- n = Station number (see [Figure 1](#))
- t_n = Temperature at *station n*, °F

$$W_n = \text{Humidity ratio at station } n, \text{ lb}_w/\text{lb}_{da}$$

$$\varepsilon_{Net\ Total} = \text{Net total effectiveness}$$

C.6. Enthalpy Recovery Ratio

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

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

Where:

$$h_n = \text{Enthalpy at station } n, \text{ Btu/lb}_{da}$$

$$\mu_e = \text{Enthalpy recovery ratio}$$

C.7. Sensible Energy Recovery Ratio

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

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

Where:

$$t_n = \text{Temperature at station } n, \text{ }^\circ\text{F}$$

$$\mu_s = \text{Sensible energy recovery ratio}$$

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.

$$X_2 = X_1 - \frac{C_{min}}{c_2} \varepsilon (X_1 - X_3) \tag{28}$$

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

$$X_4 = X_3 - \frac{C_{min}}{c_4} \varepsilon (X_3 - X_1) \tag{29}$$

Where, for Equation 28 and Equation 29:

$$C = \text{Capacity rate for each airstream}$$

$$= \dot{m}c_p \text{ for sensible effectiveness}$$

$$= \dot{m}h_{fg} \text{ for latent effectiveness}$$

$$C_{min} = \text{Minimum of } (C_2 \text{ or } C_3)$$

$$c_p = \text{Specific heat of dry air, Btu/lb}_{da}\text{ }^\circ\text{F}$$

$$h_{fg} = \text{Heat of vaporization of water, Btu/lb}$$

$$\dot{m} = \text{Mass flow rate of dry air, lb}_{da}/\text{min}$$

$$X_n = \text{Dry-bulb temperature, } t, \text{ }^\circ\text{F, or humidity ratio, } W, \text{ lb}_w/\text{lb}_{da}, \text{ respectively, at the station locations indicated in Figure 1}$$

$$\varepsilon = \text{Sensible or latent effectiveness}$$

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.