ANSI/AHRI Standard 1060 (I-P)

2014 Standard for

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

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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.

Note:
This standard supersedes AHRI Standard 1060-2013 (I-P).
For SI ratings, see ANSI/AHRI Standard 1061 (SI)-2014.

AHRI CERTIFICATION PROGRAM PROVISIONS

Scope of the Certification Program

The certification program includes Air-to-Air Exchangers for use in Air-to-Air Energy Recovery Ventilation Equipment, rated at or above 50 scfm but below or equal to 5,000 scfm at AHRI Standard Rating Conditions. In addition, Air-to-Air Exchangers for use in Air-to-Air Energy Recovery Ventilation Equipment rated above 5,000 scfm are included if the participant's basic model group(s) for those models include at least one model rated at or above 50 scfm but below or equal to 5,000 scfm.

This certification program does not include heat exchangers joined by circulated heat transfer medium (run-around loop).

Certified Ratings

The following certification program ratings are verified by test:

1. Sensible Effectiveness at 100% Summer, 75% Summer, 100% Winter, and 75% Winter, %
2. Latent Effectiveness at 100% Summer, 75% Summer, 100% Winter, and 75% Winter, %
3. Pressure Drop at 100% airflow laboratory ambient conditions, in H_2O
4. Exhaust Air Transfer Ratio (EATR) at three pressure differentials, 0.00 in H_2O and two more within the scope of the program
5. Outdoor Air Correction Factor (OACF) at three pressure differentials, 0.00 in H_2O and two more within the scope of the program

Price $10.00 (M) $20.00 (NM)
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PERFORMANCE RATING OF AIR-TO-AIR EXCHANGERS FOR ENERGY RECOVERY VENTILATION EQUIPMENT

Section 1. Purpose

1.1 *Purpose*. The purpose of this standard is to establish for Air-to-Air Exchangers intended for use in Air-to-Air Energy Recovery Ventilation Equipment: definitions; test requirements; rating requirements; minimum data requirements for Published Ratings; marking and nameplate data; and conformance conditions.

1.1.1 *Intent*. This standard is intended for the guidance of the industry, including manufacturers, designers, installers, contractors and users.

1.1.2 *Review and Amendment*. This standard is subject to review and amendment as technology advances.

Section 2. Scope

2.1 *Scope*. This standard applies to factory-made Air-to-Air Exchangers for use in Air-to-Air Energy Recovery Ventilation Equipment 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 will follow the standard industry definitions in the *ASHRAE Terminology* website (https://www.ashrae.org/resources--publications/free-resources/ashrae-terminology) unless otherwise defined in this section.

3.1 *Air-to-Air Energy Recovery Ventilation Equipment (AAERVE)*. Energy recovery components and packaged energy recovery ventilation units which 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 *Air-to-Air Exchanger (hereinafter, "Exchanger")*. A device that transfers heat/energy from an exhaust airstream to a separated supply airstream. Air-to-Air Exchangers are also referred to as energy recovery components.

3.2.1 *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 *Plate Heat Exchanger*. A device for the purpose of transferring energy (sensible or total) from one airstream to another with no moving parts. The design may incorporate parallel, cross or counter flow construction or a combination of these to achieve the energy transfer.

3.2.3 *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. It incorporates heat transfer material, a drive mechanism, a casing or frame, and includes any seals which are provided to retard the bypassing and leakage of air from one airstream to the other.

3.3 *Airflow*.

3.3.1 *Entering Supply Airflow (OA)*. The supply airstream (outdoor air) before passing through the exchanger, indicated in Figure 1 as Station 1. Sometimes referred to as the outdoor Airflow.

3.3.2 *Leaving Supply Airflow (SA)*. The supply airstream (outdoor air) after passing through the exchanger,

indicated in Figure 1 as Station 2. Sometimes referred to as the supply Airflow.

3.3.3 *Entering Exhaust Airflow (RA).* The exhaust airstream (indoor air) before passing through the exchanger, indicated in Figure 1 as Station 3. Sometimes referred to as the return Airflow.

3.3.4 *Leaving Exhaust Airflow (EA).* The exhaust airstream (indoor air) after passing through the exchanger, indicated in Figure 1 as Station 4. Sometimes referred to as the exhaust Airflow.

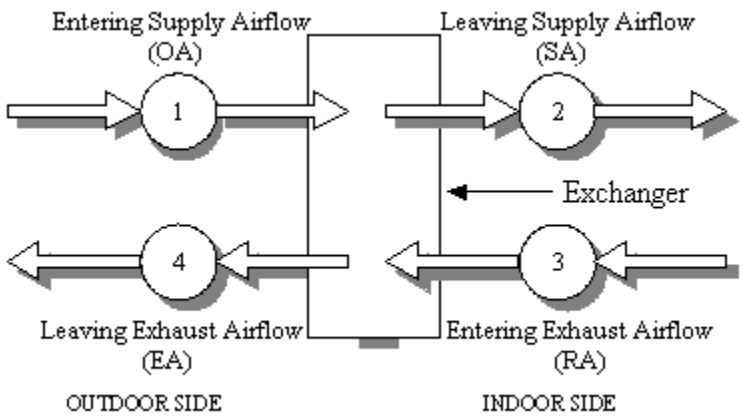

Figure 1. Scheme of Airflows for Exchangers

3.4 *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.

3.5 *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. The equation for determining Effectiveness is Equation C1 in Appendix C.

Effectiveness is 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.

3.5.1 *Sensible Effectiveness.* The Effectiveness determined in Section 3.5 using only measured dry bulb temperature differences, specific heat capacities and mass airflow rates.

3.5.2 *Latent Effectivene*ss. The Effectiveness determined in Section 3.5 using only measured humidity ratios, heat of vaporization values, and mass airflow rates.

3.5.3 *Total Effectivene*ss. The Effectiveness determined in Section 3.5 using only measured enthalpies and mass airflow rates.

3.5.4 *Net Effectiveness*. The Effectiveness 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.

3.6 *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 C2 in Appendix C.

3.7 *Net Supply Airflow*. That portion of the Leaving Supply Airflow that originated as Entering 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 the equation:

$$\text{Net Supply Airflow} = \text{Leaving Supply Airflow} \cdot (1 - \text{EATR}) \quad (1)$$

3.8 *Outdoor Air Correction Factor (OACF).* The ratio of the Entering Supply Airflow to the measured (gross) Leaving Supply Airflow.

3.9 *Pressure Differential*. The difference in static pressure between the Leaving Supply Airflow and the Entering Exhaust Airflow.

3.10 *Pressure Drop*. The difference in static pressure between the Entering Supply Airflow and the Leaving Supply Airflow.

3.11 *Published Rating*. A statement of the assigned values of those performance characteristics, under stated Rating Conditions, by which a unit may be chosen for its application. These values apply to all exchangers for use in Energy Recovery Ventilation Equipment of like size and type (identification) produced by the same manufacturer. The term Published Rating 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.

3.11.1 *Application Rating*. A rating based on tests performed at application Rating Conditions (other than Standard Rating Conditions).

3.11.2 *Standard Rating*. A rating based on tests performed at Standard Rating Conditions.

3.12 *Rating Conditions*. Any set of operating conditions under which a single level of performance results, and which cause only that level of performance to occur.

3.12.1 *Standard Rating Conditions.* Rating Conditions used as the basis of comparison for performance characteristics.

3.13 *"Shall" or "Should."* "Shall" or "should" shall be interpreted as follows:

3.13.1 *Shall*. Where "shall" or "shall not" is used for a provision specified, that provision is mandatory if compliance with the standard is claimed.

3.13.2 *Should.* "Should" is used to indicate provisions which are not mandatory but which are desirable as good practice.

3.14 *Standard Air*. Air weighing 0.075 lb/ft^3 which approximates dry air at 70°F and at a barometric pressure of 29.92 in Hg.

3.15 *Station*. For each of the Airflows defined in Section 3.3 and shown in Figure 1, the station is the location in the test apparatus at which conditions such as temperature, humidity, pressure, or Airflow are measured. These locations are identified as "Station 1", "Station 2", "Station 3" and "Station 4".

Section 4. Test Requirements

4.1 *Test Requirements*. All Standard Ratings shall be verified by tests conducted in accordance with ANSI/ASHRAE Standard 84 at the Standard Rating Conditions in Table 1, except where modified by this standard.

4.2 *Test Set-up*.

4.2.1 *Heat Pipe Heat Exchangers*. For the purpose of rating, the tilt angle of Heat Pipe Heat Exchangers shall be as specified by the manufacturer. The tilt angle may 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.* For the purpose of rating, ensure 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*. For the purpose of rating, 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 (if provided).

Table 1. Standard Rating Conditions

Item	Conditions		Tolerances	
	Heating	Cooling	All Readings During Test	Average of Readings
1. Entering Supply Airflow temperature a. Dry-bulb, °F b. Wet-bulb, °F	 35 33	 95 78	 1.0 0.6	 +/- 0.5 +/- 0.3
2. Entering Exhaust Airflow temperature a. Dry-bulb, °F b. Wet-bulb, °F	 70 58	 75 63	 1.0 0.6	 +/- 0.5 +/- 0.3
3. Leaving Supply Airflow, scfm	100% of the rated Airflow(s) 75% of the rated Airflow(s)		See Section 4.3	
4. Entering Exhaust Airflow (Return Air), scfm	Same rate as Leaving Supply Airflow[1]		See Section 4.3	
5. Pressure Differential, Leaving Supply Airflow static pressure minus Entering Exhaust (return) Airflow static pressure, for Effectiveness tests, in H_2O	0.00		See Section 4.3	
6. Pressure Differential, Leaving Supply Airflow static pressure minus Entering Exhaust (return) Airflow static pressure, for Outdoor Air Correction Factor tests and tracer gas tests of Exhaust Air Transfer Ratio, in H_2O	(1) 0.00 and (2) manufacturer's choice of two or more of the following: -5.00, -3.00, -1.00, -0.50, 0.50, 1.00, 3.00, 5.00		See Section 4.3	

Note:

1. Adjustments to balance the Airflows shall be made at the Standard Rating Conditions (i.e., temperatures), just prior to data acquisition.

4.2.3.2 *Adjustable Purge*. For the purpose of rating, if an adjustable purge is provided, it shall be set at the manufacturer's specified purge angle or setting. The purge angle or setting may vary between different tests; however, Standard Ratings of Effectiveness shall be measured using the same purge angle or setting used when measuring Standard Ratings of Exhaust Air Transfer Ratio and Outdoor Air Correction Factor at the required zero pressure differential condition (see Table 1).

4.2.4 *Laboratory Ambient Conditions.* Except in facilities in which the exchanger is located in one or both of the indoor and outdoor condition chambers, laboratory ambient conditions shall be maintained within the limits of 60°F and 80°F dry bulb. The room ambient temperature shall be measured within 6 ft of the sample and at the height of the sample.

4.3 *Testing Tolerances*. For the test to be valid, it shall meet all the requirements of this section.

4.3.1 *Airflow and Pressure.* For the purpose of rating, measured Airflow shall remain within a tolerance of ±1.5% or 5 scfm, whichever is greater, for the duration of the test. For the purpose of rating for a zero Pressure Differential, the average differential shall be between +0.010 in H_2O and 0 in H_2O, and no reading shall be above 0.050 in H_2O or below -0.050 in H_2O. For the purpose of rating for non-zero Pressure Differentials, measured pressures shall remain within a tolerance of ± 0.050 in H_2O.

4.3.2 *Stability*. Neither Sensible nor Latent Effectiveness shall exhibit a trend up or down for the duration of the test.

4.3.3 *Equal Massflow Requirement.* Measurement at Stations 2 & 3 according to Figure 1 shall be equal within ±1.5% or 5 scfm, whichever is greater.

4.3.4 *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. Equations 2 through 7, below, are the restatement of the relevant subset of Equations 11-16 in ANSI/ASHRAE 84-2013.

Mass flow inequality = $$\frac{|\dot{m}_1-\dot{m}_2+\dot{m}_3-\dot{m}_4|}{\dot{m}_{minimum(1,3)}} < 0.05 \quad (2)$$

Sensible energy inequality = $$\frac{|\dot{m}_1 C_{p,1} t_1-\dot{m}_2 C_{p,2} t_2+\dot{m}_3 C_{p,3} t_3-\dot{m}_4 C_{p,4} t_4|}{\dot{m}_{minimum(1,3)} C_p |t_1-t_3|} < 0.20 \quad (3)$$

Latent energy inequality = $$\frac{|\dot{m}_1 W_1-\dot{m}_2 W_2+\dot{m}_3 W_3-\dot{m}_4 W_4|}{\dot{m}_{minimum(1,3)} |W_1-W_3|} < 0.20 \quad (4)$$

Total energy inequality = $$\frac{|\dot{m}_1 h_1-\dot{m}_2 h_2+\dot{m}_3 h_3-\dot{m}_4 h_4|}{\dot{m}_{minimum(1,3)} |h_1-h_3|} < 0.20 \quad (5)$$

If the rated Latent Effectiveness is 0, Equations 4 and 5 are omitted for tests at winter conditions.

If the rated Latent Effectiveness is above 0, and physical condensation is visible during testing, Equations 4 and 5 are replaced with Equations 6 through 9 below.

Latent energy inequality = $$\frac{|\dot{m}_1 W_1-\dot{m}_2 W_2+\dot{m}_3 W_3-\dot{m}_4 W_4-\dot{m}_{condensate}|}{\dot{m}_{minimum(1,3)} |W_1-W_3|} < 0.20 \quad (6)$$

Total energy inequality = $$\frac{|\dot{m}_1 h_1-\dot{m}_2 h_2+\dot{m}_3 h_3-\dot{m}_4 h_4-\dot{Q}_{condensate}|}{\dot{m}_{minimum(1,3)} |h_1-h_3|} < 0.20 \quad (7)$$

$$\dot{Q}_{condensate} = (W_3 - W_4) \cdot [(\dot{m}_3 \cdot \dot{m}_4)/2] \cdot (1061 \text{ Btu/lb}) \quad (8)$$

$$\dot{m}_{condensate} = (W_3 - W_4) \cdot [(\dot{m}_3 \cdot \dot{m}_4)/2] \quad (9)$$

Where:

$c_{p,n}$ = Specific heat of dry air at Station n, Btu/lb$_m$°F
h_n = Enthalpy at Station n, Btu/lb$_m$
$\dot{m}_n$ = Mass flow rate of dry air through Station n, lb/min
n = Station number (see Figure 1)
t_n = Temperature at Station n, °F
W_n = Humidity ratio at Station n, lb/lb

4.4 *Tracer Gas Test*. The tracer gas tests shall be performed at the 100% rated Airflow listed in Table 1 and at the Pressure Differentials listed in Table 1. The tracer gas used shall be sulfur hexafluoride (SF_6). Tests shall be conducted at Laboratory Ambient temperature conditions with no psychrometric changes. Relative humidity shall be maintained between 20% and 60% for the duration of the test.

4.5 *Pressure Drop Test*. The pressure drop test shall be performed at laboratory ambient conditions with no psychrometric changes. The mass flow inequality of Equation 2 shall be calculated and held within the specific limit for the duration of the test.

4.5.1 Pressure drop through the exchanger shall also be recorded for all thermal performance tests, in H_2O.

4.6 *Test Uncertainty*. All tests shall meet the uncertainty limits specified in Section 7 of ASHRAE Standard 84, and the test uncertainty shall be determined and reported.

Section 5. Rating Requirements

5.1 *Standard Ratings*. Standard Ratings shall be determined at the Standard Rating Conditions specified in Table 1. All Standard Ratings shall be verified by tests conducted in accordance with Section 4.

5.2 *Tolerances*. 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.

5.2.1 *Allowance for Sensible Effectiveness.* Test results for Sensible Effectiveness shall not be less than 95% of the Published Rating, or more than two absolute percentage points below the Published Rating, whichever tolerance is greater.

5.2.2 *Allowance for Latent Effectiveness.* Test results for Latent Effectiveness shall not be less than 93% of the Published Rating, or more than two absolute percentage points below the Published Rating, whichever tolerance is greater.

5.2.3 *Allowance for Pressure Drop.* Test results for Pressure Drop shall not be more than 110% of the Published Rating, or 0.050 in H_2O, whichever tolerance is greater.

5.2.4 *Allowance for Exhaust Air Transfer Ratio.* Test results for EATR shall not be more than one absolute percentage point greater than the Published Rating.

5.2.5 *Allowance for Outdoor Air Correction Factor (OACF).* Test results for OACF shall follow the requirements below:

5.2.5.1 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.

5.2.5.2 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.

5.2.5.3 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.

5.3 *Calculation of Pressure Drop at Standard Rating Conditions.* The rated Pressure Drop shall be corrected for air density and viscosity using the following equation:

$$\Delta P_s = \Delta P \left[\frac{\rho}{\rho_s} \right] \left[\frac{\mu_s}{\mu} \right]^m \qquad 10$$

Where:

ΔP = Tested Pressure Drop, in Hg
ΔP_s = Rated Pressure Drop, in Hg
ρ = Density of air as tested, lb_m/ft^3
ρ_s = Density of Standard Air, lb_m/ft^3
μ = Viscosity of air as tested, $lb_m/ft \cdot s$
μ_s = Viscosity of Standard Air, $lb_m/ft \cdot s$
m = 1

Section 6. Minimum Data Requirements for Published Ratings

6.1 *Values of Standard Ratings*.

6.1.1 *Rated Airflow*. The rated Airflow shall be specified by the manufacturer and shall be expressed in scfm as indicated in Table 2.

Table 2. Multiples for Rated Airflow

Rated Airflow for Units, scfm	Multiples, scfm
< 250	10
≥ 250 and < 500	25
≥ 500 and < 1000	50
≥ 1000	100

6.1.2 *Effectiveness*. Sensible and Latent Effectiveness (see Appendix C) shall be reported and expressed in %, in multiples of 1%.

6.1.3 *Exhaust Air Transfer Ratio*. EATR shall be reported and expressed in %, in multiples of 0.1%.

6.1.4 *Outdoor Air Correction Factor*. OACF shall be reported and expressed in multiples of 0.01.

6.1.5 *Pressure Drop*. Pressure Drop through the exchanger shall be corrected for standard air and reported and expressed in multiples of 0.05 in H_2O.

6.2 *Additional Information*. In addition, the following information shall be reported for the exchanger unless otherwise noted:

6.2.1 Rated tilt angle at heating and cooling conditions (Heat Pipe Heat Exchanger only), °

6.2.2 The results of the tracer gas test as defined in Section 9.5 of ASHRAE Standard 84 and presented as EATR

6.2.3 Seal type and configuration, if any

6.2.4 Net Supply Airflow at the 100% rated Airflow, scfm

6.2.5 Total, net Sensible, net Latent, and net Total Effectiveness at the 100% and 75% rated Airflow (The Net Effectiveness shall be calculated as shown in Appendix C and reported in % in multiples of 1%)

6.2.6 Purge angle, or setting (Rotary Heat Exchanger only) listed for all tests, °

6.3 *Application Ratings*. Ratings at conditions other than as shown in Table 1 may be published as Application Ratings and shall be based on data determined by the methods described in Section 4.

6.4 *Minimum Data Requirements for Published Ratings.* As a minimum, Published Ratings shall include all Standard Ratings. All claims to ratings within the scope of this standard shall include the statement "Rated in accordance with ANSI/AHRI Standard 1060 (I-P)". All claims to ratings outside the scope of this standard shall include the statement "Outside the scope of ANSI/AHRI Standard 1060 (I-P)". Wherever Application Ratings are published or printed, they shall include a statement of the conditions at which the ratings apply.

Section 7. Marking and Nameplate Data

7.1 *Marking and Nameplate Data*. As a minimum, the following information shall be shown in a conspicuous place on the equipment:

7.1.1 Name or trade name of manufacturer

7.1.2 Manufacturer's model number

7.1.3 Heat transfer fluid (where appropriate)

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

Section 8. Conformance Conditions

8.1 *Conformance*. 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

A1 Listed here are all standards, handbooks, and other publications essential to the formation and implementation of this standard. All references in this appendix are considered as part of this standard.

A1.1 ANSI/AHRI Standard 110-2012, *Air-Conditioning, Heating, and Refrigerating Equipment Nameplate Voltages*, 2012, Air-Conditioning, Heating, and Refrigeration Institute, 2111 Wilson Boulevard, Suite 500, Arlington, VA 22203, U.S.A.

A1.2 ANSI/ASHRAE Standard 84-2013, *Method of Testing Air-to-Air Heat Exchangers*, 2013, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle N.E., Atlanta, GA 30329, U.S.A.

A1.3 ANSI/AHRI Standard 1061 (SI)-2014, *Performance Rating Air-to-Air Exchangers for Energy Recovery Ventilation Equipment*, 2013, Air-Conditioning, Heating, and Refrigeration Institute, 2111 Wilson Boulevard, Suite 500, Arlington, VA 22201, U.S.A.

A.1.4 *ASHRAE Terminology*, https://www.ashrae.org/resources--publications/free-resources/ashrae-terminology, 2014, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, N.E., Atlanta, GA 30329, U.S.A.

A1.5 IEC Standard 60038, *IEC Standard Voltages*, 2009, International Electrotechnical Commission, 3, rue de Varembe, P.O. Box 131, 1211 Geneva 20, Switzerland.

APPENDIX B. REFERENCES - INFORMATIVE

None.

APPENDIX C. CALCULATION OF EFFECTIVENESS – NORMATIVE

C1 *Effectiveness.* The Sensible, Latent or Total Effectiveness of an exchanger for use in Air-to-Air Energy Recovery Ventilation Equipment is described by Equation C1.

$$\varepsilon = \frac{C_2(X_1 - X_2)}{C_{min}(X_1 - X_3)} \qquad \text{C1}$$

Where:

C = Capacity Rate for each airstream
= $\dot{m}c_p$ for Sensible Effectiveness
= $\dot{m}h_{fg}$ for Latent Effectiveness
= $\dot{m}$ for Total Effectiveness
C_{min} = Minimum (C_2 or C_3)
c_p = Specific heat of dry air, Btu/lb°F
h_{fg} = Heat of vaporization of water, Btu/lb
$\dot{m}$ = Mass flow rate of dry air, lb_m/min
X = Dry-bulb temperature, T, humidity ratio, W, or total enthalpy, h, respectively, at the station locations indicated in Figure 1
ε = Sensible, Latent, or Total Effectiveness

At standard rating conditions specified in Table 1, Equations C2 and C3 provide values for Total Effectiveness. At any other condition the Total Effectiveness values must be calculated using equation C1, with X denoting total enthalpy h:

$$\varepsilon_{TW} = [8.5\varepsilon_S + 4.4\varepsilon_L] / 12.9 \qquad \text{C2}$$

$$\varepsilon_{TS} = [4.9\varepsilon_S + 8.0\varepsilon_L] / 12.9 \qquad \text{C3}$$

Where:

ε_L = Latent Effectiveness
ε_S = Sensible Effectiveness
ε_{TS} = Total Effectiveness for summer
ε_{TW} = Total Effectiveness for winter

C2 *Exhaust Air Transfer Ratio (EATR).* The *EATR* of an exchanger for use in Air-to-Air Energy Recovery Ventilation Equipment is described by Equation C2.

$$EATR = \frac{c_{TG,2} - c_{TG,1}}{c_{TG,3} - c_{TG,1}} \qquad \text{C4}$$

Where:

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

C3 *Net Effectiveness.* The Net Effectiveness is given by Equation C5.

$$\varepsilon_{net} = \frac{(\dot{m}_s)\left(X_1 - \frac{X_2 - (EATR)X_3}{(1 - EATR)}\right)}{(\dot{m}_{min})\ (X_1 - X_3)} \qquad \text{C5}$$

Where:

$\dot{m}_s$ = Mass flow rate of dry air for Leaving Supply Airflow, lb_m/min

C3.1 *Derivation of Net Effectiveness*. The formula for Effectiveness is given in Equation C1. 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 C6.

$$X_2 = (1 - EATR)\, X_{net} + (EATR)\, X_3 \qquad \text{C6}$$

Solving for X_{net} yields:

$$X_{net} = \frac{X_2 - (EATR) X_3}{(1 - EATR)} \qquad \text{C7}$$