AHRI Standard 1060 (I-P)

2018 Standard for

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

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.

Note:
This standard supersedes ANSI/AHRI Standard 1060 (I-P)-2014.
For SI ratings, see AHRI Standard 1061 (SI)-2018.

AHRI CERTIFICATION PROGRAM PROVISIONS

Scope of the Certification Program

The certification program includes performance ratings of Air-to-Air Exchangers for use in Air-to-Air Energy Recovery Ventilation Equipment (AAERVE), with supply and exhaust airflows 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, %
2. Latent Effectiveness, %
3. Supply and Exhaust Pressure Drop, in H_2O
4. Exhaust Air Transfer Ratio (EATR)
5. Outdoor Air Correction Factor (OACF)

TABLE OF CONTENTS

SECTION PAGE

Section 1. Purpose 1

Section 2. Scope 1

Section 3. Definitions 1

Section 4. Test Requirements 4

Section 5. Rating Requirements 7

Section 6. Minimum Data Requirements for Published Ratings 8

Section 7. Marking and Nameplate Data 9

Section 8. Conformance Conditions 9

TABLES

Table 1. Range of Standard Rating Conditions 4

FIGURES

Figure 1. Scheme of Airflows for Exchangers 2

Figure 2. Illustration of Range of Standard Rating Conditions 5

APPENDICES

Appendix A. References - Normative 10

Appendix B. References - Informative 10

Appendix C. Calculations - Normative 11

Appendix D. Calculations – Informative 14

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 (AAERVE): 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 (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 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 (Exchanger).* A device that transfers heat/energy between an exhaust airstream and a separated supply airstream. 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 without 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 Exhaust Airflow.* The exhaust airstream (indoor air) before passing through the Exchanger, indicated in Figure 1 as Station 3, expressed in scfm. Also referred to as return air (RA).

3.3.2 *Entering Supply Airflow*. The supply airstream (outdoor air) before passing through the Exchanger, indicated in Figure 1 as Station 1, expressed in scfm. Also referred to as outdoor air (OA).

3.3.3 *Leaving Exhaust Airflow*. The exhaust airstream (indoor air) after passing through the Exchanger, indicated in Figure 1 as Station 4, expressed in scfm. Also referred to as exhaust air (EA).

3.3.4 *Leaving Supply Airflow*. The supply airstream (outdoor air) after passing through the Exchanger, indicated in Figure 1 as Station 2, expressed in scfm. Also referred to as supply air (SA).

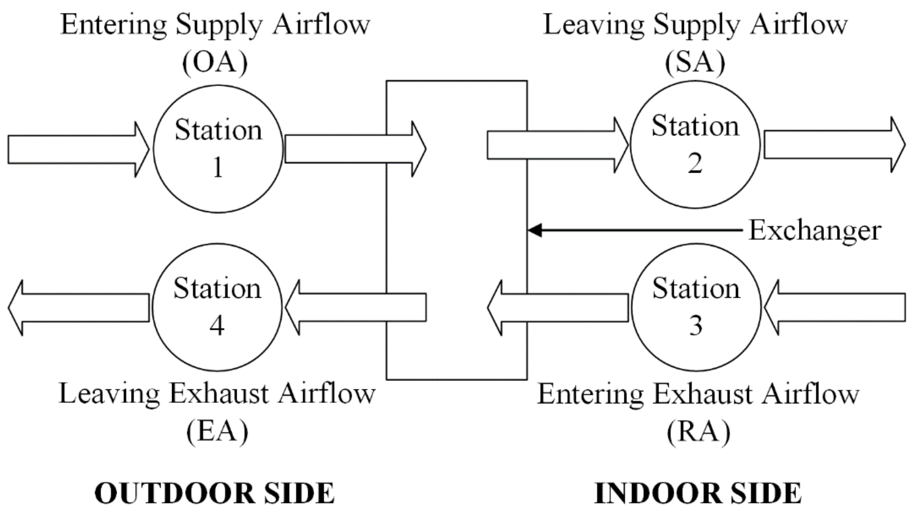

Figure 1. Scheme of Airflows for Exchangers

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.

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 *Latent Effectivene*ss. The Effectiveness determined using only measured humidity ratios, heat of vaporization values, and mass airflow rates. The equation for determining Latent Effectiveness is Equation C1 in Appendix C.

3.5.2 *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 C1 in Appendix C.

3.5.3 *Total Effectivene*ss. 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 C2 in Appendix C.

3.6 *Enthalpy Recovery Ratio*. A ratio of the change 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), with no 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 Energy Recovery Ratio is Equation C8 in Appendix C.

3.7 *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 C3 in Appendix C.

3.8 *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.

3.9 *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.

3.9.1 *Net Latent Effectivene*ss. The Effectiveness determined using only measured humidity ratios, heat of vaporization values, mass airflow rates and Exhaust Air Transfer Ratio. The equation for determining Net Latent Effectiveness is Equation C4 in Appendix C.

3.9.2 *Net Sensible Effectiveness.* The Effectiveness determined using measured dry bulb temperature differences, specific heat capacities, mass airflow rates and Exhaust Air Transfer Ratio. The equation for determining Net Sensible Effectiveness is Equation C4 in Appendix C.

3.9.3 *Net Total Effectivene*ss. The Effectiveness determined using only measured dry bulb temperature differences, specific heat capacities, measured humidity ratios, heat of vaporization values, mass airflow rates and Exhaust Air Transfer Ratio. The equation for determining Net Total Effectiveness is Equation C7 in Appendix C.

3.10 *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 Equation 1:

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

Where:

EATR = Exhaust Air Transfer Ratio, %
SA = Leaving Supply Airflow, scfm
SA_{net} = Net Supply Airflow, scfm

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

3.12 *Pressure Differential*. Static pressure at the Leaving Supply Airflow outlet minus the static pressure at the Entering Exhaust Airflow inlet.

3.13 *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, performance rating software, advertising or other literature controlled by the manufacturer, at stated Rating Conditions.

3.13.1 *Application Rating*. A rating at conditions one or more of which are outside the range of conditions specified in Table 1.

3.13.2 *Standard Rating*. A rating at conditions that are within the range of conditions specified in Table 1.

3.14 *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.

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

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

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

3.16 *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.

3.17 *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".

3.18 *Supply Flow Ratio*. The Station 2 Airflow divided by the Station 3 Airflow, expressed as a ratio.

3.19 *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 at Standard Rating Conditions in Table 1, except where modified by this standard.

Table 1. Range of Standard Rating Conditions

Item	Conditions	Tolerances	
		All Readings During Test	Average of Readings
1. Entering Supply Airflow or Entering Exhaust Airflow conditions[1]			
1a. Dry-bulb temperature, °F	Minimum: 35 Maximum: 120	± 1.0	± 0.5
1b. Wet-bulb temperature, °F	≤ 80	± 0.6	± 0.3
1c. Humidity ratio, gr/lb	≥ 10.0	N/A	N/A
1d. Relative humidity, %	≤ 95	N/A	N/A
2. Leaving Supply Airflow, Entering Exhaust Airflow, scfm	Maximum and minimum declared by the manufacturer.	± 1.5 % or 5 scfm, whichever is greater	±1.5 % or 5 scfm, whichever is greater
3. Supply Flow Ratio	Not less than 0.5 nor greater than 2.0	N/A	
4. Pressure at Inlets, in H_2O	N/A	± 0.050	N/A
5. Pressure Differential, Leaving Supply static pressure minus Entering Exhaust (return) static pressure, for ratings of Effectiveness, EATR or OACF, and Static Pressure Drop, in H_2O	-5.0 to 5.0	See Section 4.3	

Note:
1. See Figure 2 for psychrometric range defined in Item 1.

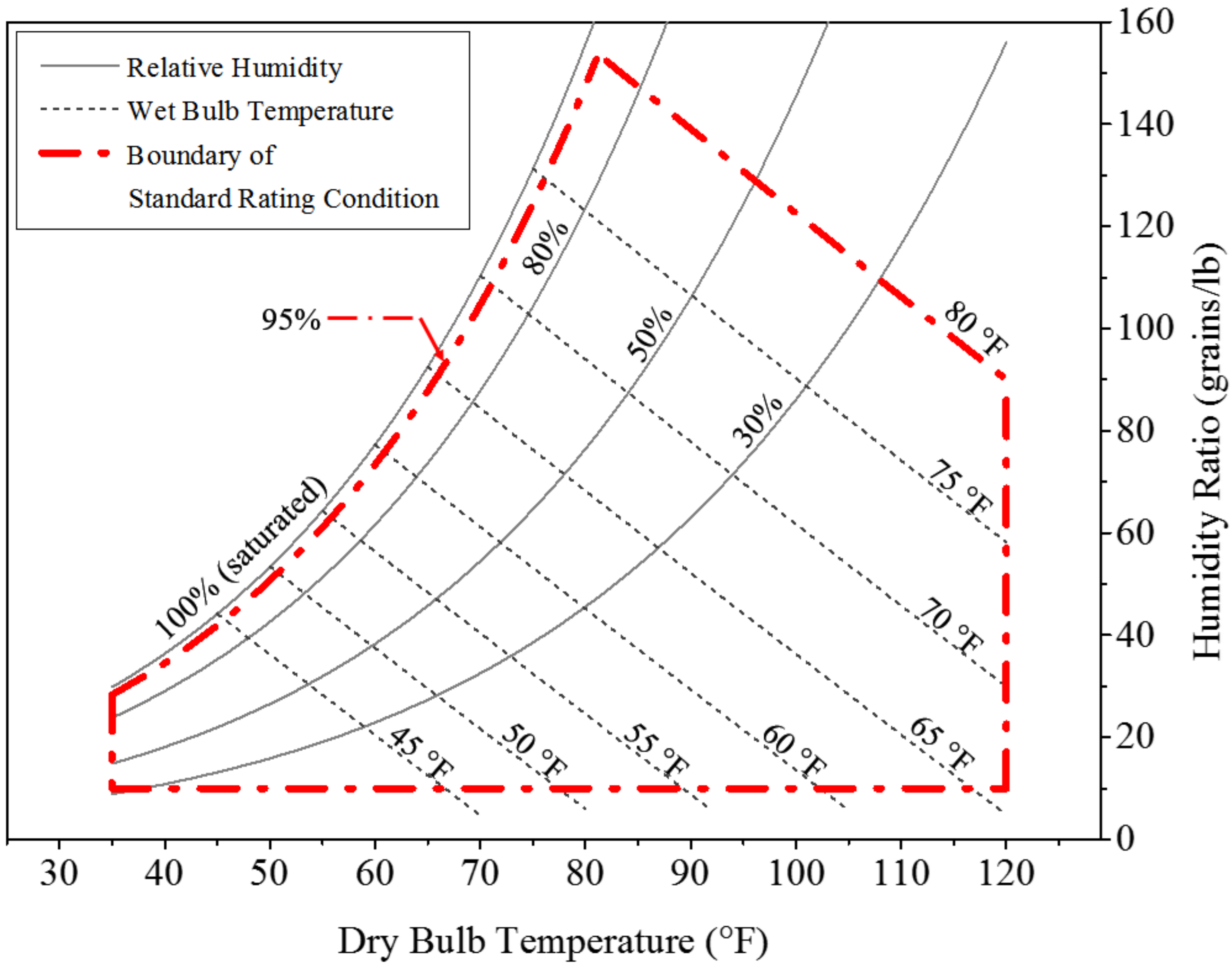

Figure 2. Illustration of Range of Standard Rating Conditions

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 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.* 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*. 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 Exhaust Air Transfer Ratio and Outdoor Air Correction Factor.

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.

4.2.5 *Test Duration*. Measurements are taken for 30 minutes after a period of 30 minutes with stable input conditions based on ANSI/ASHRAE Standard 84 and this Standard.

4.3 *Testing Tolerances*. For the test to be valid, it shall meet all the requirements of this section and Table 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 *Massflow Requirement.* Measurement at Stations 2 & 3 according to Figure 1 shall be equal to the specified massflows within ±1.5% or 5 scfm, whichever is greater.

4.3.3 *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 in ANSI/ASHRAE Standard 84.

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

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

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

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

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

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

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

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

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
$\dot{m}_{min}$ = Minimum of ($\dot{m}_2$ or $\dot{m}_3$)
$\dot{m}_n$ = 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, gr/lb

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 with no psychrometric changes. Relative humidity shall be maintained between 20% and 60% for the duration of the test.

4.4.1 *Mass Inequalities for Tracer Gas Tests.* For the tracer gas test to be valid, it shall meet the airflow mass inequality of Equation 2, and the tracer gas mass inequality of Equation 10, below. Equation 10 is the restatement of the relevant equation in ANSI/ASHRAE Standard 84.

$$\text{Tracer gas inequality} = \frac{|\dot{m}_1 C_1 - \dot{m}_2 C_2 + \dot{m}_3 C_3 - \dot{m}_4 C_4|}{\dot{m}_{minimum(1,3)}|C_1 - C_3|} < 0.15 \quad (10)$$

4.5 *Pressure Drop Test*. The pressure drop shall be measured at the rated Airflow, Pressure Differentials, and psychrometric conditions as the effectiveness tests.

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

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 Sections 5.1.1 through 5.1.5.

5.1.1 *Allowance for Sensible Effectiveness.* Test results for Sensible Effectiveness shall not be lower than the Published Rating by more than: (1) the sum of four relative percentage points and one absolute percentage point, or (2) two absolute percentage points below the Published Rating, whichever is greater.

5.1.1.1 *Example of Allowance for Sensible Effectiveness*. In this example the Sensible Effectiveness Rating is 75%.

$Allowance = (75\% \times 0.04) + 1\% = 4.0\%$
Measured Effectiveness Rating shall be greater than or equal to 71.0%

5.1.2 *Allowance for Latent Effectiveness.* Test results for Latent Effectiveness shall not be lower than the Published Rating by more than (1) the sum of six relative percentage points and one absolute percentage point, or (2) two absolute percentage points below the Published Rating, whichever is greater.

5.1.2.1 *Example of Allowance for Latent Effectiveness.* In this example the Latent Effectiveness Rating is 60%.
$Allowance = (60\% \times 0.06) + 1\% = 4.6\%$
Measured Effectiveness Rating shall be greater than or equal to 55.4%

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 H_2O.

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:

5.1.5.1 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.

5.1.5.2 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.

5.1.5.3 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.

Section 6. Minimum Data Requirements for Published Ratings

6.1 *Minimum Data Requirements for Published Ratings.* At a minimum, any Standard or Application Rating that is published, or made available through an automated rating/selection computer procedure, shall include a statement of all of the following at the specific operating condition.

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 to which the rating applies.

6.1.3 *Rated Airflow*. The Leaving Supply Airflow and Entering Exhaust Airflow at rating shall be expressed in scfm.

6.1.4 *Inlet Psychrometric conditions.* Temperature and humidity at Station 1 and Station 3 shall be indicated in °F and either relative or absolute humidity.

6.1.4.1 *Leaving Supply Airflow Psychrometric Conditions*. Temperature and humidity at Station 2 shall be reported consistent with the inlet conditions and Effectiveness as shown in Equations C9 and indicated in °F, relative humidity, or absolute humidity.

6.1.5 *Effectiveness*. Sensible Effectiveness and Latent Effectiveness (see Appendix C) shall be reported and expressed in %, in multiples of 0.1%.

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

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

6.1.8 *Pressure Drop*. Supply Pressure Drop and Exhaust Pressure Drop shall be reported and expressed in multiples of 0.01 in H_2O.

6.1.9 *Tilt angle* at heating and cooling conditions (Heat Pipe Heat Exchanger only), °

6.1.10 *Net Supply Airflow*, scfm

6.1.11 *Purge angle, or setting* (Rotary Heat Exchanger only), °

6.2 *Additional information.* The following information if reported for the Exchanger, shall meet the following requirements:

6.2.1 Total Effectiveness, Net Sensible Effectiveness, Net Latent Effectiveness, and Net Total Effectiveness (The Net Effectivenesses shall be calculated as shown in Appendix C and reported in % 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 C8 and reported in multiples of 0.1%.

6.2.3 *Leaving Exhaust Airflow Psychrometric Conditions.* Temperature and humidity at Station 4 shall be consistent with the inlet conditions and Effectiveness as shown in Equations C10 and reported in °F, relative humidity, or absolute humidity.

6.2.4 *Airflows at Stations 1 and 4.* Airflows shall be consistent with the Airflows at Stations 2 and 3 and with rated EATR and OACF.

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

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 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 AHRI Standard 1061(SI)-2018, *Performance Rating Air-to-Air Exchangers for Energy Recovery Ventilation Equipment*, 2018, Air-Conditioning, Heating, and Refrigeration Institute, 2311 Wilson Boulevard, Suite 500, Arlington, VA 22201, U.S.A.

A1.2 AHRI Standard 110-2016, *Air-Conditioning, Heating, and Refrigerating Equipment Nameplate Voltages*, 2016, Air-Conditioning, Heating, and Refrigeration Institute, 2311 Wilson Boulevard, Suite 500, Arlington, VA 22201, U.S.A.

A1.3 ANSI/ASHRAE Standard 84-2013, *Method of Testing Air-to-Air Heat/Energy Exchangers*, 2013, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle N.E., Atlanta, GA 30329, U.S.A.

A1.4 *ASHRAE Terminology*, https://www.ashrae.org/resources--publications/free-resources/ashrae-terminology, 2018, 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

B1 Listed 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

C1 *Sensible or Latent Effectiveness*. The Sensible or Latent Effectiveness of an Exchanger for use in AAERVE is described by Equation C1.

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

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, Btu/lb°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_m/min
X_n = Dry-bulb temperature, T, or humidity ratio, W, respectively, at the station locations indicated in Figure 1
ε = Sensible or Latent Effectiveness

C2 *Total Effectiveness.* For purposes of rating the Total Effectiveness of an Exchanger for use in AAERVE is described by Equation C2.

$$\varepsilon_{total} = \frac{\dot{m}_2 c_p |t_1 - t_2| + \dot{m}_2 h_{fg} |W_1 - W_2|}{\dot{m}_{min} c_p |t_1 - t_3| + \dot{m}_{min} h_{fg} |W_1 - W_3|} \quad \text{C2}$$

Where:

c_p = Specific heat of dry air, Btu/lb°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/min
n = Station number (see Figure 1)
t_n = Temperature at Station n, °F
W_n = Humidity ratio at Station n, gr/lb
ε_{total} = Total Effectiveness

C3 *Exhaust Air Transfer Ratio (EATR).* The *EATR* of an Exchanger for use in AAERVE is described by Equation C3.

$$EATR = \frac{c_{TG,2} - c_{TG,1}}{c_{TG,3} - c_{TG,1}} \quad \text{C3}$$

Where:

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

C4 *Net Effectiveness*. The Net Sensible or Latent Effectiveness is given by Equation C4.

$$\varepsilon_{net} = \frac{C_2\left(X_1 - \frac{X_2 - EATR \cdot X_3}{(1 - EATR)}\right)}{C_{min}(X_1 - X_3)} \quad \text{C4}$$

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, Btu/lb°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_m/min
X_n = Dry-bulb temperature, T, or humidity ratio, W, respectively, at the station locations indicated in Figure 1
ε_{net} = Net Sensible or Latent Effectiveness

C4.1 *Informative Note: 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.

$$X_2 = (1 - EATR)\, X_{net} + (EATR)\, X_3 \qquad C5$$

Solving for X_{net} yields:

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

Where: for Equations C5 and C6

n = Station number (see Figure 1)
X_n = Dry-bulb temperature, T, or humidity ratio, W, respectively, at the station locations indicated in Figure 1

C5 *Net Total Effectiveness.* The Net Total Effectiveness is given by Equation C7.

$$\varepsilon_{Net\ Total} = \frac{\dot{m}_2 c_p \left| t_1 - \frac{t_2 - (EATR)t_3}{(1-EATR)} \right| + \dot{m}_2 h_{fg} \left| W_1 - \frac{W_2 - (EATR)W_3}{(1-EATR)} \right|}{\dot{m}_{min} c_p |t_1 - t_3| + \dot{m}_{min} h_{fg} |W_1 - W_3|} \qquad C7$$

Where:

c_p = Specific heat of dry air, Btu/lb°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/min
n = Station number (see Figure 1)
t_n = Temperature at Station n, °F
W_n = Humidity ratio at Station n, gr/lb
$\varepsilon_{Net\ Total}$=Net Total Effectiveness

C6 *Enthalpy Recovery Ratio.* The Enthalpy Recovery Ratio is described by Equation C8.

$$\mu_e = \frac{h_1 - h_2}{h_1 - h_3} \qquad C8$$

Where:

h_n = Enthalpy at station n, Btu/lb
μ_e= Enthalpy Recovery Ratio

C7 *Outlet Psychrometric Conditions.* The Outlet Conditions shall be calculated as shown below.

C7.1 For conditions at the Leaving Supply Outlet (Station 2) Equation C9 applies.

$$X_2 = X_1 - \frac{c_{min}}{c_2}\varepsilon(X_1 - X_3) \qquad C9$$

C7.2 For conditions at the Leaving Exhaust Outlet (Station 4) Equation C10 applies.

$$X_4 = X_3 - \frac{c_{min}}{c_4} \varepsilon (X_3 - X_1) \quad \text{C10}$$

Where, for Equations C9 and C10:

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, Btu/lb°F
h_{fg} = Heat of vaporization of water, Btu/lb
$\dot{m}$ = Mass flow rate of dry air, lb_m/min
X_n = Dry-bulb temperature, T, or humidity ratio, W, 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 Equations C9 and C10, respectively.

APPENDIX D. CALCULATIONS – INFORMATIVE

D1 *Calculation of Pressure Drop at Standard Rating Conditions.* Pressure Drop at rated conditions may be corrected for air density and viscosity using Equation D1.

$$\Delta P_s = \Delta P \left[\frac{\rho}{\rho_s}\right]\left[\frac{\mu_s}{\mu}\right]^m \qquad \text{D1}$$

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