2005 STANDARD for

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

AIR-CONDITIONING & REFRIGERATION INSTITUTE

Standard 1060

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IMPORTANT

SAFETY DISCLAIMER

ARI 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.

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

ARI CERTIFICATION PROGRAM PROVISIONS

Scope of the Certification Program

The certification program includes Air-to-Air Heat 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 ARI Standard Rating Conditions. In addition, Air-to-Air Heat Exchangers for use in 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. Airflow, scfm
2. Pressure Drop, in H_2O
3. Sensible Effectiveness (at 100% and 75% rated airflow for heating and cooling conditions)
4. Latent Effectiveness (at 100% and 75% rated airflow for heating and cooling conditions)
5. Total Effectiveness (at 100% and 75% rated airflow for heating and cooling conditions)
6. Exhaust Air Transfer Ratio, Outdoor Air Correction Factor, and Purge Angle or Setting (if applicable) at 0.00 in H_2O and two or more pressure differentials
7. Tilt Angle, ^{o}, (at heating and cooling conditions, if applicable)

Note:
This standard supersedes ARI Standard 1060-2001.

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

Section 1. Purpose

1.1 *Purpose*. The purpose of this standard is to establish for Air-to-Air Heat 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 Heat 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 shall follow the standard industry definitions in the current edition of *ASHRAE Terminology of Heating, Ventilation, Air Conditioning and Refrigeration* and ASHRAE Standard 84, 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 Heat 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 Heat Exchanger.* A device that transfers heat from an exhaust airstream to a separated supply airstream. Air-to-Air Heat 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. This exchanger 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 *Effectiveness*. The measured energy recovery Effectiveness 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. The equation for determining Effectiveness is given in Appendix C.

3.4 *Exhaust Airflow*. Airflow leaving the conditioned space.

3.4.1 *Entering Exhaust Airflow (Return Air).* The exhaust airstream before passing through the heat exchanger, shown as Station 3 in ASHRAE Standard 84.

3.4.2 *Leaving Exhaust Airflow (Exhaust Air to Outside)*. The exhaust airstream after passing through the heat exchanger, shown as Station 4 in ASHRAE Standard 84.

3.5 *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 EATR is given in Appendix C.

3.6 *Net Effectiveness*. The measured energy recovery 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.

3.7 *Outdoor Air Correction Factor (OACF)*. The Entering Supply Airflow divided by the measured (gross) Leaving Supply Airflow.

3.8 *Pressure Differential* . The difference in pressure between two specific points in two separate airstreams (i.e. supply airflow static pressure verses exhaust airflow static pressure).

3.9 *Pressure Drop*. Pressure Drop through the heat exchanger shall be expressed as the difference in static pressure between the Entering Supply Airflow and the Leaving Supply Airflow.

3.10 *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 Air-to-Air Heat 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.

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

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

3.11 *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.

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

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

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

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

3.13 *Standard Air*. Air weighing 0.075 lb/ft^3 [1.2 kg/m^3] which approximates dry air at 70°F [21°C] and at a barometric pressure of 29.92 in Hg [101.3 kPa].

3.14 *Supply Airflow*. The outdoor airflow, also referred to as rated airflow.

3.14.1 *Entering Supply Airflow***.** The Supply Airflow before passing through the heat exchanger, also referred to as outdoor air, and defined in ASHRAE Standard 84 as Station 1.

3.14.2 *Leaving Supply Airflow*. The Supply Airflow after passing through the heat exchanger, and defined in ASHRAE Standard 84 as Station 2.

3.15.3 *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 heat exchanger from the gross airflow measured at the Supply Airflow leaving the heat exchanger and is given by the equation:

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

Section 4. Test Requirements

4.1 *Test Requirements*. All Standard Ratings shall be verified by tests conducted in accordance with 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 a mechanism to do so is provided by the manufacturer.

4.2.2 *Rotary Heat Exchangers*.

4.2.2.1 *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 heat exchanger shall rotate at the speed specified by the manufacturer.

Table 1. Standard Rating Conditions

Item	Conditions	
	Heating	Cooling
1. Entering supply airflow temperature a. Dry-bulb b. Wet-bulb	 35°F [1.7°C] 33°F [0.6°C]	 95°F [35°C] 78°F [26°C]
2. Entering exhaust air temperature a. Dry-bulb b. Wet-bulb	 70°F [21°C] 58°F [14°C]	 75°F [24°C] 63°F [17°C]
3. Leaving Supply Airflow, scfm [m^3/s]	100% of the rated airflow(s) 75% of the rated airflow(s)	
4. Entering Exhaust Airflow (Return Air), scfm [m^3/s]	Same rate as Leaving Supply Airflow*	
5. Pressure Differential, leaving supply airflow static pressure minus entering exhaust (return) airflow static pressure, for effectiveness tests	0.00 in H_2O [0.00 Pa]	
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	(1) 0.00 in H_2O [0.00 Pa] 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 in H_2O [-1250, -750, -250, -120, 120, 250, 750, 1250 Pa]	

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

4.2.2.2 *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).

4.3 *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 [0.002 m^3/s], 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 [2.5 Pa] and 0 in H_2O [0 Pa], and no reading shall be above 0.050 in H_2O [12.5 Pa] or below -0.050 in H_2O [-12.5 Pa]. For the purpose of rating for non-zero pressure differentials, measured pressures shall remain within a tolerance of ± 0.050 in H_2O [12.5 Pa].

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 *Mass and Energy Balance.* Mass and energy balance shall be held within ±4% for the duration of the test, and shall be calculated as follows:

$$\%\text{difference}_{\text{massflow}} = 1-[(m_2+m_4)/(m_1+m_3)]$$

$$\%\text{difference}_{\text{sensible energy}} = 1-[(s_2+s_4)/(s_1+s_3)]$$

$$\%\text{difference}_{\text{latent energy}} = 1-[(l_2+l_4)/(l_1+l_3)]$$

where:

m_n = mass through station n, lbm [kg]
s_n = sensible energy through station n, BTU/h [kW/h]
l_n = latent energy through station n, BTU/h [kW/h]

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 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.

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 and Total Effectiveness.* Test results for sensible and total 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, with a minimum tolerance of 0.050 in H_2O [12.5 Pa].

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*. Test results for OACF shall not be less than 90% or more than 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:

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

where:

ΔP_s = Rated Pressure Drop, in Hg [kPa]
ΔP = Tested Pressure Drop, in Hg [kPa]
ρ = Density of air as tested, lbm/ft^3 [kg/m^3]
ρ_s = Density of standard air, lbm/ft^3 [kg/m^3]
μ_s = Viscosity of standard air, lbm/ft^h [kg/m$_s$]
μ = Viscosity of air as tested, lbm/ft^h [kg/m$_s$]
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 [m^3/s] as indicated:

Rated Airflow for Units		Multiples	
scfm	m^3/s	scfm	m^3/s
< 250	< 0.12	10	0.005
≥ 250 and < 500	≥ 0.12 and < 0.24	25	0.01
≥ 500 and < 1000	≥ 0.24 and < 0.47	50	0.02
≥ 1000	≥ 0.47	100	0.05

6.1.2 *Effectiveness*. Sensible, latent and total Effectiveness and net sensible, net latent, and total Net 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 heat exchanger shall be reported for all thermal performance tests and expressed in H_2O [Pa], in multiples of 0.050 in H_2O [12.5 Pa].

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

a. Rated rational speed, rpm [rev/s] (Rotary Heat Exchanger only)
b. Rated tilt angle, °, at heating and cooling conditions (Heat Pipe Heat Exchanger only)
c. The results of the tracer gas test as defined in Section 8.2 of ASHRAE Standard 84 and presented as *EATR*

d. Seal type and configuration, if any
e. Net airflow at the 100% rated airflow, scfm [m^3/s]
f. Net sensible, latent and total Effectiveness at the 100% rated airflow (The Net Effectiveness shall be calculated as shown in Appendix C and reported in % in multiples of 1%)
g. 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 ARI Standard 1060". All claims to ratings outside the scope of this standard shall include the statement "Outside the scope of ARI Standard 1060". 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:

a. Name or trade name of manufacturer
b. Manufacturer's model number
c. 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 ARI Standard 110. Nameplate voltages for 50 Hertz systems shall include one or more of the utilization voltages shown in Table 1 of IEC Standard Publication 60038.

Section 8. Conformance Conditions

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-ASHRAE Standard 84-1991, *Method of Testing Air-to-Air Heat Exchangers*, 1991, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle N.E., Atlanta, GA 30329, U.S.A.

A1.2 ARI Standard 110-2002, *Air-Conditioning and Refrigerating Equipment Nameplate Voltages*, 1997, Air-Conditioning and Refrigeration Institute, 4100 North Fairfax Drive, Suite 200, Arlington, VA 22203, U.S.A.

A1.3 *ASHRAE Terminology of Heating, Ventilation, Air Conditioning and Refrigeration*, Second Edition, 1991, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle N.E., Atlanta, GA 30329, U.S.A.

A1.4 IEC Standard 60038, *IEC Standard Voltages*, 2002, 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 Air-to-Air Heat Exchanger for use in Air-to-Air Energy Recovery Ventilation Equipment is described by the following equation:

$$\varepsilon = \frac{(\dot{m}_s)(X_1 - X_2)}{(\dot{m}_{min})(X_1 - X_3)} \qquad C1$$

C2 *Exhaust Air Transfer Ratio (EATR).* The *EATR* of an Air-to-Air Heat Exchanger for use in Air-to-Air Energy Recovery Ventilation Equipment is described by the following equation:

$$EATR = \frac{C_2 - C_1}{C_3 - C_1} \qquad C2$$

C3 *Net Effectiveness*. The Net Effectiveness is given by the equation:

$$\varepsilon_{net} = \frac{(\dot{m}_s)\left(X_1 - \frac{X_2 - (EATR)X_3}{(1 - EATR)}\right)}{(\dot{m}_{min})\ (X_1 - X_3)} \qquad C3$$

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* as follows:

$$X_2 = (1 - EATR)\ X_{net} + (EATR)\ X_3 \qquad C4$$

Solving for X_{net} yields:

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

C4 *Symbols and Subscripts.* The symbols and subscripts used in Equations C1 through C5 are as follows:

Symbols: align symbols and un-italic m

C = Tracer gas concentration, %
ε = Sensible, latent or total Effectiveness
$\dot{m}$ = Mass flow rate, lb/hr [kg/s]
X = Dry-bulb temperature (for sensible effectiveness), °F [°C]
or
Absolute humidity ratio (for latent effectiveness), lb H_2O/lb dry air [kg H_2O/kg dry air]
or
Total enthalpy (for total effectiveness), Btu/lb [J/kg]

Subscripts:

min = Minimum of the exhaust and supply values
s = Supply Airflow
1 = Measurement Station 1
2 = Measurement Station 2
3 = Measurement Station 3