AHRI Guideline V (I-P)

2011 Guideline for

Calculating the Efficiency of Energy Recovery Ventilation and its Effect on Efficiency and Sizing of Building HVAC Systems

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Note:

This guideline supersedes AHRI Guideline V–2003.
For the SI version, see AHRI Guideline V (SI) - 2011

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CALCULATING THE EFFICIENCY OF ENERGY RECOVERY VENTILATION AND ITS EFFECT ON EFFICIENCY AND SIZING OF BUILDING HVAC SYSTEMS

Section 1. Purpose

1.1 *Purpose.* The purpose of this guideline is to establish a method of calculating the energy efficiency of applied Energy Recovery Ventilation components and of heating, ventilating, and/or air-conditioning systems utilizing such components at selected operating conditions. It also provides guidance on proper sizing of cooling and heating equipment when such energy recovery components are applied.

1.1.1 *Intent.* This guideline is intended for the guidance of the industry, including engineers, installers, contractors and users. It provides a means for calculating the impact of applied energy recovery equipment on the energy efficiency of the heating, ventilating and air-conditioning system at a single selected operating condition. The guideline is not a rating system for Energy Recovery Ventilation (ERV) Equipment, nor does it provide a means of estimating annual energy use.

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

Section 2. Scope

2.1 *Scope.* This guideline applies to energy recovery ventilation component applications and combinations of energy recovery components with unitary heating, ventilating, and air-conditioning equipment incorporating mechanical ventilation with outside air.

2.1.1 This guideline applies only to energy recovery applications utilizing components tested and rated in accordance with AHRI Standard 1060 (I-P).

2.1.2 Because non-certified data is required for the calculations, the results should not be considered to be "certified".

Section 3. Definitions

All terms in this document 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 *Coefficient of Performance (COP).* A ratio of the cooling/heating capacity in watts to the power input values in watts at any given set of Rating Conditions expressed in watts/watts.

3.2 *Combined Efficiency (CEF).* The efficiency of a system incorporating an ERV component with a unitary packaged air conditioner, heat pump, etc. Units vary according to the application. CEF is expressed in Btu/(W·h).

3.3 *Effectiveness.* The measured energy recovery Effectiveness not adjusted to account for that portion of the psychrometric change in the leaving supply air (Figure 1, Station 2) that is the result of leakage of entering exhaust air (Figure 1, Station 3) rather than exchange of heat or moisture between the airstreams. The equation for determining Effectiveness is given in AHRI Standard 1060 (I-P), Appendix C.

3.4 *Energy Efficiency Ratio (EER*). A ratio of the cooling capacity in Btu/h to the power input values in watts at any given set of Rating Conditions expressed in Btu/(W·h).

3.5 *Energy Recovery Ventilation (ERV) Equipment.* 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

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or as part of an air-conditioning (to include air heating, air cooling, air circulating, air cleaning, humidifying and dehumidifying) system. Also referred to as the air-to-air heat exchanger (AAHX).

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

3.5.2 *Plate Heat Exchanger*. A device for the purpose of transferring energy (sensible or total) from one air stream 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.

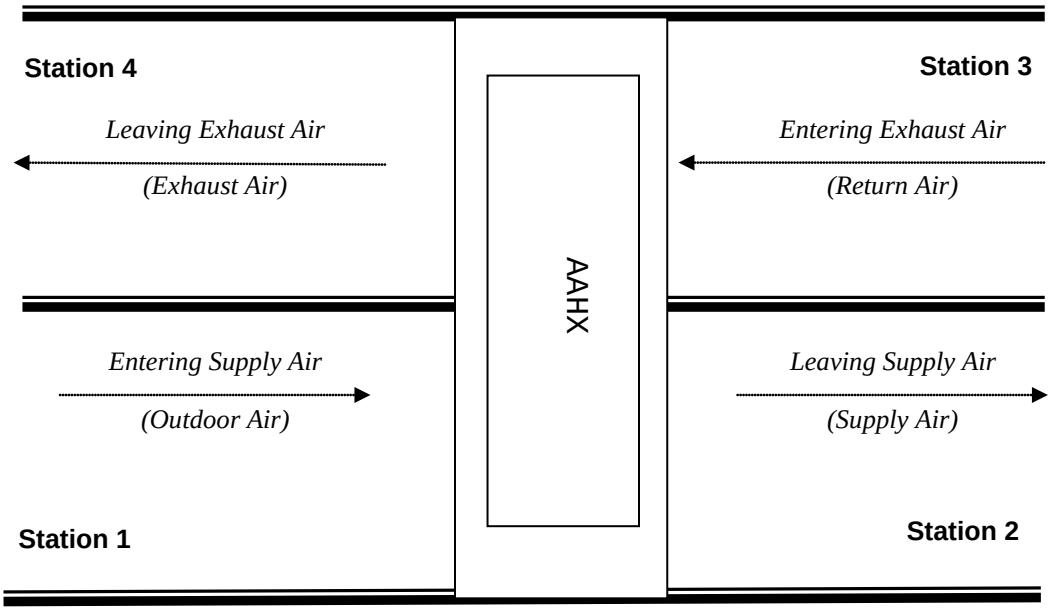


Figure 1. Generic Configuration of an Air-to-Air Heat Exchanger Used for Energy Recovery in Ventilation Applications

3.5.3 *Rotary Heat Exchanger*. A device incorporating a rotating cylinder or wheel for the purpose of transferring energy (sensible or total) from one air stream 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 air stream to the other.

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. (Note: This guideline assumes that the tracer gas concentration difference is equal to the leakage of air from the Exhaust Airflow to the Supply Airflow. EATR, a ratio of the tracer gas, is used in the guideline formulae to represent a ratio of air flow.)

3.7 *Fan/Motor Efficiency*, $\eta_{Fan/Motor}$. The product of the fan efficiency and the motor efficiency including drive losses (mechanical, electrical and/or electronic as applicable) for each airstream.

3.8 Load Ratio, Y. The percentage of the system load (heating, cooling, humidification and/or dehumidification) met by the energy recovery component is designated as Y for the purposes of the calculations in this guideline.

3.9 *Net Effectiveness*. The measured energy recovery Effectiveness adjusted to account for that portion of the psychrometric change in the leaving supply air (Figure 1, Station 2) that is the result of leakage of entering exhaust air (Figure 1, Station 3) rather than exchange of heat or moisture between the airstreams. The derivation of Net Effectiveness is given in AHRI Standard 1060 (I-P), Appendix C.

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3.10 *Net Supply Air Flow, $Q_{net\ supply}$.* That portion of the leaving supply air (Figure 1, Station 2) that originated as entering supply air (Figure 1, Station 1). The Net Supply Air Flow is determined by subtracting air transferred from the exhaust side of the AAHX from the gross air flow measured at the supply air leaving the heat exchanger and is given by the equation:

$$Q_{netsupply} = \text{Leaving supply air flow} \cdot (1 - EATR) \quad (1)$$

3.11 *Outdoor Air Correction Factor (OACF).* The entering supply air flow (Figure 1, Station 1) divided by the measured (gross) leaving supply air flow (Figure 1, Station 2).

3.12 *Pressure Drop*. The difference in static pressure between the entering air and the leaving air for a given airstream.

3.12.1 *Exhaust Pressure Drop.* The difference in static pressure between the entering exhaust air (Figure 1, Station 3) and the leaving exhaust air (Figure 1, Station 4).

3.12.2 *Supply Pressure Drop.* The difference in static pressure between the entering supply air (Figure 1, Station 1) and the leaving supply air (Figure 1, Station 2).

3.13 *Published Rating*. A statement of the assigned values of those performance characteristics at stated Rating Conditions, by which a unit may be chosen for its application. These values apply to all ERV 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.

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

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

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.

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

3.15 *Recovery Efficiency Ratio (RER).* The efficiency of the energy recovery component in recovering energy from the exhaust airstream is defined as the energy recovered divided by the energy expended in the recovery process. Units vary according to the application. For Combined Efficiency with EER, the RER is expressed in Btu/(W·h). For Combined Efficiency with COP, the RER is expressed in W/W.

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

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

3.18 *Supply Air Flow*. The measured (gross) leaving supply air flow (Figure 1, Station 2). Also referred to as the rated air flow.

Section 4. Information Requirements

4.1 *Net Effectiveness.* Ratings of Net Effectiveness at application Rating Conditions and air flow rates are required to perform calculations of efficiency. AHRI certified ratings for Net Effectiveness are available at AHRI Standard 1060 (I-P) Standard Rating Conditions.

4.2 *Blower Power.* A value for blower power input is required to perform the Combined Efficiency calculation. If manufacturer's data for blower power is not available, it may be calculated from component pressure loss and Fan/Motor Efficiency in accordance with this section and 6.1.

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4.2.1 *Pressure Drop.* Supply and Exhaust Pressure Drop values at application Rating Conditions and air flow rates are required to perform calculations of efficiency.

4.2.2 *Fan/Motor Efficiency.* Values for Fan/Motor Efficiency may be required to calculate the RER of the component as applied. Fan/Motor Efficiency is used with the pressure loss of the energy recovery component to determine the blower power consumed in the process of recovering energy.

4.2.3 *Determining Fan/Motor Efficiency.*

4.2.3.1 When motor power is known:

$$\eta_{Fan/Motor} = \frac{Pwr_{Fan}}{Pwr_{Motor}} = \frac{P_{Fan} \cdot Q \cdot K_1}{K_2 \cdot \rho_A / \rho_S \cdot Pwr_{Motor}} \quad (2)$$

Where:

$\rho_{A/}\rho_S$ = Air density ratio (ratio of the air density to the density of Standard Air)
$\eta_{Fan/Motor}$ = Fan/Motor Efficiency
K_1 = 746 W/HP
K_2 = 6356 in $H_2O \cdot ft^3/HP \cdot min$
P_{Fan} = Total static pressure across the fan, in H_2O
Pwr_{Fan} = Fan Power, W
Pwr_{Motor} = Motor Power, W
Q = Air flow rate, cfm

4.2.3.2 When the fan curve is available:

$$\eta_{Fan/Motor} = \left(\frac{P_{Fan} \cdot Q \cdot K_1}{K_2 \cdot \rho_A / \rho_S \cdot Pwr_{Fan}} \right) \cdot \eta_d \cdot \eta_m \quad (3)$$

Where:

η_d = Drive efficiency
η_m = Motor efficiency
Pwr_{Fan} = Fan Power, HP

4.2.3.3 When fan, motor and drive efficiencies are known:

$$\eta_{Fan/Motor} = \eta_f \cdot \eta_d \cdot \eta_m \quad (4)$$

Where:

η_f = Fan efficiency

4.3 *Unitary Equipment Efficiency.* The EER of the unitary equipment is required to perform calculations of CEF.

Calculations at Standard Rating Conditions may be used to provide an indication of comparative performance. To characterize actual performance, application Rating Conditions should be used.

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System selection, fan configuration, energy recovery Effectiveness and outdoor air conditions can impact the applied EER of the unitary equipment. Changes in air flow rate, fan operating point or coil entering condition of the unitary equipment should be taken into account in calculating applied EER prior to completing the Combined Efficiency calculation.

Standard Ratings – EER at Standard Rating Conditions should be used when conditions (e.g. coil entering conditions and air flow rate) for the system match Standard Rating Conditions for the unitary equipment.

Application Ratings – EER at application Rating Conditions should be used if conditions (e.g. coil entering conditions and/or air flow rate) vary from Standard Rating Conditions for the unitary equipment.

Section 5. General Principles

5.1 *General Principle*. The general principle of all efficiency calculations is to determine the energy input or cost for a given useful energy output. In the case of ERV equipment, this is the recovered space conditioning energy divided by the power used to recover that energy. This can be expressed as a Recovery Efficiency Ratio (RER):

$$RER = \frac{Net\ conditioning\ energy\ recovered}{Total\ electric\ power\ consumed} \quad (6)$$

Where the net space conditioning energy can be either heating, humidification, cooling, dehumidification or a combination thereof and the total electric power consumed includes the power required to move air through both sides of the AAHX as well as any additional power, such as the wheel drive motor in a Rotary Heat Exchanger.

The power required to move air through the AAHX is a function of the Supply and Exhaust Pressure Drop values through the AAHX, as well as the Fan/Motor Efficiency of the air-moving device. The power required to rotate a Rotary Heat Exchanger can be measured directly.

Section 6. Calculating the Recovery Efficiency Ratio for the Energy Recovery Ventilation Component

6.1 *Calculating the RER for the Energy Recovery Device.* Consult manufacturer's data for information on fan power consumption or pressure loss for the component. The RER is calculated in Equations 7, 8 and/or 9:

$$RER_{Total} = \frac{AAHX_{net\ total\ capacity}}{Pwr_{blwr} + Pwr_{comp}} = \frac{\varepsilon_{net\ total}\,\dot{m}_{min}\,(h_1 - h_3)}{Pwr_{blwr} + Pwr_{comp}} \quad (7)$$

$$RER_{Sensible} = \frac{AAHX_{net\ sensible\ capacity}}{Pwr_{blwr} + Pwr_{comp}} = \frac{\varepsilon_{net\ sensible}\,\dot{m}_{min}\,c_p(t_1 - t_3)}{Pwr_{blwr} + Pwr_{comp}} \quad (8)$$

$$RER_{Latent} = \frac{AAHX_{net\ latent\ capacity}}{Pwr_{blwr} + Pwr_{comp}} = \frac{\varepsilon_{net\ latent}\,\dot{m}_{min}\,h_{fg}(\omega_1 - \omega_3)}{Pwr_{blwr} + Pwr_{comp}} \quad (9)$$

Where:

c_p = Specific heat of air, Btu/lb·°F

h_1 = Total enthalpy of the entering supply air, Btu/lb (Figure 1, Station 1)

h_{fg} = Heat of condensation of water, Btu/lb

h_3 = Total enthalpy of the entering exhaust air, Btu/lb (Figure 1, Station 3)

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