YORK®	**AIR SYSTEMS – ENERGY SERIES** *Energy Recovery Wheels*	
APPLICATION GUIDE	Supercedes: Nothing	Form 102.20-AG6 (305)

INTRODUCTION

As fossil fuel reserves are depleted, the cost of energy continues to rise. According to the US Department of Energy, the cost of energy used in US commercial buildings increased by more than 200% between 1979 and 1995 and conservative DOE estimates predict an additional 46% increase between 2001 and 2025. Given this and the fact that, on average, HVAC systems consume 39% of the energy used in commercial buildings, energy-efficient HVAC systems represent potentially significant savings in building operating costs.

Increased ventilation rates, which are required to satisfy the ventilation standard ASHRAE 62.1-2004, mean a greater expenditure of energy to condition outside air. One way that savings can be realized in an HVAC system is through the use of exhaust air energy recovery. Exhaust air energy recovery can take many forms—rotary heat exchangers, heat-pipes, plate heat exchangers, etc., but all of the devices operate on the same principle—they use exhaust air to condition supply air through a transfer of energy. This application guide examines the rotary heat exchanger—also called an energy wheel, or energy recovery wheel—and the benefits of incorporating such a device in an air handling unit.

PRINCIPLES OF ENERGY RECOVERY

Energy recovery involves a transfer of energy between an exhaust airstream and a supply airstream. Figure 1 illustrates the heat transfer process of an energy recovery wheel where OA is outside air; SA is supply air; RA is return air from the conditioned space and EA is exhaust air.

As the two airstreams pass through the energy recovery wheel, the rotation of the wheel facilitates the transfer of energy from the higher energy airstream to the lower energy airstream. This means that the exhaust air preheats the supply air in the winter and precools the supply air in the summer. Some systems use energy recovery wheels to reheat supply air after it has been cooled—an effective means of humidity control.

Some energy recovery wheels transfer only sensible energy, while others transfer sensible and latent (i.e. total) energy.

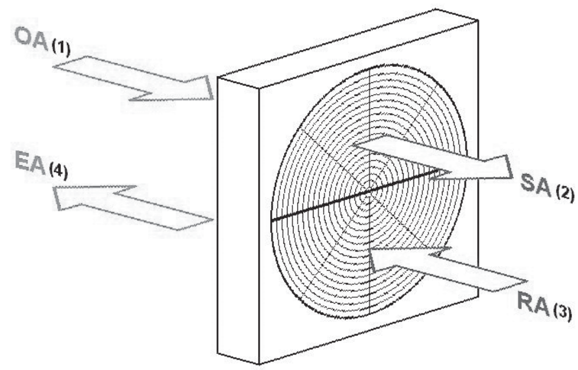

FIGURE 1. STANDARD AIRFLOW CONVENTIONS

Sensible Heat Transfer

When sensible heat is transferred, the dry-bulb temperature of the colder airstream increases and the dry-bulb temperature of the warmer airstream decreases. No moisture is transferred, so the humidity ratio of the two airstreams remains unchanged unless the dry-bulb temperature of the warmer airstream is decreased below its dew point, allowing condensation to occur.

Total Heat Transfer

This process involves the transfer of sensible and latent heat energy. Latent heat energy is dependent on the amount of water vapor in the air and therefore total heat transfer can only occur when water vapor is transferred from one airstream to the other. In an energy recovery wheel this transfer is accomplished through the use of a desiccant which absorbs/adsorbs water vapor from the higher vapor pressure airstream and releases it to the lower vapor pressure airstream. Only energy recovery wheels and certain types of fixed-plate heat exchangers with permeable membranes can transfer latent, and therefore total, energy.

Effectiveness

The ratio of the amount of energy transferred by the energy recovery device to the difference in energy levels of the two incoming airstreams is called effectiveness. The total amount of energy transferred by the wheel is a function of the effectiveness of the wheel, the airflow volumes of the two airstreams and the difference in energy levels between the two airstreams.

Equation 1 shows the calculation of effectiveness as defined by ASHRAE Standard 84-1991:

Equation 1: $\varepsilon = [V_s \cdot (x_1 - x_2)] / [V_{min} \cdot (x_1 - x_3)]$

Where:

- ε = Sensible, or total effectiveness
- x_1 = OA temp (°Fdb) or enthalpy (btu/lb.)
- x_2 = SA temp (°Fdb) or enthalpy (btu/lb.)
- x_3 = RA temp. (°Fdb) or enthalpy (btu/lb.)
- V_s = Supply (or outside) air volume (cfm)
- V_{min} = The lower of the exhaust or supply air volume (cfm)

Amount of Heat Transferred

The sensible and total energy transferred by the energy recovery wheel can be calculated using Equations 2 and 3:

Equation 2: $Q_s = \varepsilon \cdot 1.08 \cdot Vmin \cdot (t1 - t3)$

Equation 3: $Q_t = \varepsilon \cdot 4.5 \cdot Vmin \cdot (h1 - h3)$

Where:

- Q_s = Sensible heat transferred (btu/hr)
- Q_t = Total heat transferred (btu/hr)
- ε = Sensible, or total effectiveness
- V_{min} = The lower of the exhaust or supply air volumes (cfm)
- t_1 = Outside air temperature (°F)
- t_3 = Return air temperature (°F)
- h_1 = Outside air enthalpy (btu/lb.)
- h_3 = Return air enthalpy (btu/lb.)
- 1.08 = Conversion factor
- 4.5 = Conversion factor

If the effectiveness of the wheel is known, Equation 1 can be solved for x_2 to determine the supply air leaving enthalpy and/or temperature. In Example 1 the outside air and return air volumes are equal, or "balanced" ($V_s = V_{min}$). Optimal energy transfer occurs at "balanced flow" conditions, however building exfiltration and exhaust sources such as bathroom fans reduce the return air volume below the supply air volume. This unbalanced flow reduces heat transfer, even though it increases the effectiveness factor of the energy recovery wheel.

Example 1: Calculate the supply air conditions leaving a *total* heat recovery wheel with 12,000 cfm of outside air at 94°Fdb and 77°Fwb; and 12,000 cfm of return air at 75°Fdb and 50% RH, if both the sensible & latent effectiveness of the wheel is 60%. Calculate the reduction in required cooling energy.

At the conditions given above:

x_3 = the return air enthalpy = 28.15 btu/lb. = h_3

x_1 = the outside air enthalpy = 40.38 btu/lb. = h_1

From Equation 1:

$h_2 = h_1 - [\varepsilon \cdot V_{min} \cdot (h_1 - h_3)]/V_s$

$h_2 = 40.38 - [0.6 \cdot 12000 \cdot (40.38 - 28.15)] / 12000$

$\underline{h_2 = 33.04 \text{ btu/lb.}}$

Also from Equation 1:

$t_2 = t_1 - [\varepsilon \cdot V_{min} \cdot (t_1 - t_3)]/V_s$

$t_2 = 94 - [0.6 \cdot 12000 \cdot (94 - 75)] / 12000$

$\underline{t_2 = 82.6°F.}$

Therefore, the supply air leaving the heat recovery wheel will be: **82.6°Fdb / 68.9°Fwb**

From Equation 3:

$Q_t = \varepsilon \cdot 4.5 \cdot V_{min} \cdot (h_1 - h_3)$

$Q_t = 0.6 \cdot 4.5 \cdot 12000 \cdot (40.38 - 28.15)$

$\underline{\mathbf{Q_t = 396{,}252 \text{ btu/hr} = 33 \text{ tons}}}$

Figure 2 shows the effect of unbalanced airflow on effectiveness.

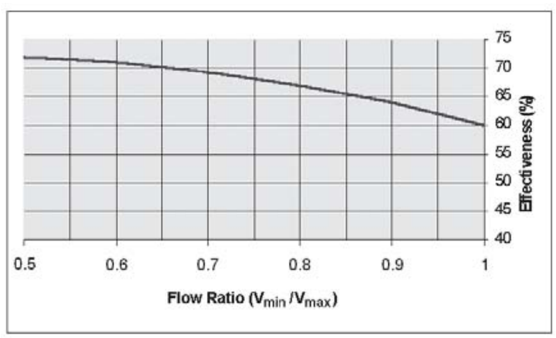

FIGURE 2– EFFECT OF UNBALANCED AIRFLOW

Example 2 indicates that despite a 7% increase in effectiveness, the overall heat transfer of the wheel decreased by 10% in relation to the balanced flow conditions of Example 1.

Example 2: Consider the unit from Example 1, but instead of balanced flow, the return airflow is only 9,600 due to exfiltration and/or exhaust air. What are the conditions of the supply air leaving the energy recovery wheel in this case? What is the new heat transfer rate? (Assume the outside air and return air conditions remain the same.)

V_{min}/V_{max} = 9,600 cfm / 12,000 cfm = 0.8.

From Figure 2: At 0.8 flow ratio, ε = 67%.

Solving Equation 1 for x_2 (h_2):

$h_2 = h_1 - [\varepsilon \bullet V_{min} \bullet (h_1 - h_3)]/V_s$

$h_2 = 40.38 - [0.67 \bullet 9600 \bullet (40.38 - 28.15)] / 12000$

$\underline{h_2 = 33.82 \text{ btu/lb.}}$

And:

$t_2 = t_1 - [\varepsilon \bullet Vmin \bullet (t_1 - t_3)]/V_s$

$t_2 = 94 - [0.67 \bullet 9600 \bullet (94 - 75)] / 12000$

$\underline{t_2 = 83.8°F.}$

Therefore, the supply air leaving the energy recovery wheel will be: **83.8°Fdb / 69.8°Fwb**

From Equation 3:

$Q_t = \varepsilon \bullet 4.5 \bullet V_{min} \bullet (h_1 - h_3)$

$Q_t = 0.67 \bullet 4.5 \bullet 9600 \bullet (40.38 - 28.15)$

$\mathbf{\underline{Q_t = 353,985 \text{ btu/hr} = 29.5 \text{ tons}}}$

If a sensible-only energy recovery device, such as a heat pipe, had been used, the energy savings in Example 1 would have been:

$Q_s = 0.6 \bullet 1.08 \bullet 12000 \bullet (94-75)$

= 147,744 btu/hr

= 12.3 tons

And for Example 2:

$Q_s = 0.67 \bullet 1.08 \bullet 9600 \bullet (94-75)$

= 131,985 btu/hr

= 11.0 tons

The additional energy savings achieved by transferring total energy illustrate one of the advantages of using energy recovery wheels over a device that only transfers sensible energy.

Transfer of Air between Airstreams

Inherent in the operation of an energy recovery wheel is a direct transfer of air between the return and supply airstreams (See Figure 3). This air transfer is due to leakage through the seals separating the airstreams as well as by the small amount of air carried over in the matrix of the wheel as it rotates from one airstream to the other.

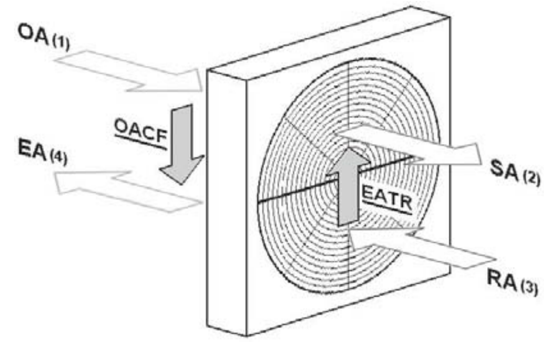

FIGURE 3 – AIR TRANSFER PATHS

The air passing from the return airstream to the supply airstream is defined as the Exhaust Air Transfer Ratio (EATR). The EATR is the percentage of supply air that originated as return air. This ratio is determined by measuring the concentrations of a tracer gas in the RA, SA and OA airstreams.

The air passing from the outside airstream to the exhaust airstream is defined as the Outside Air Correction Factor (OACF). The OACF is the OA volume at Point 1 divided by SA volume at Point 2. The OACF and EATR are determined for a given condition through testing in accordance with ARI Standard 1060-2000. Figure 4 illustrates the effect of this leakage on the airflow rates of an energy recovery wheel with a balanced, nominal flow rate of 12,000 cfm.

The EATR and OACF are typically calculated by software provided by the energy recovery wheel manufac-

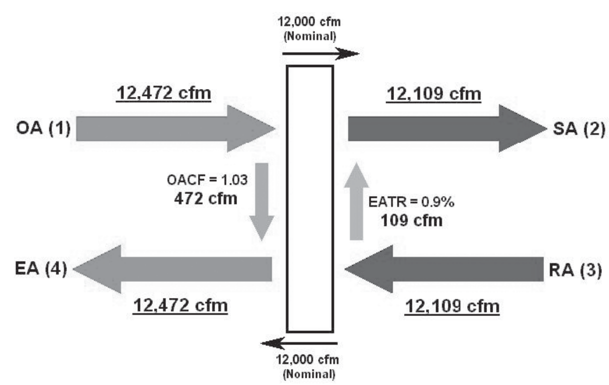

FIGURE 4 – EFFECT OF EATR AND OACF

turer, but it is important to understand how these factors affect, and are affected by, system design. The magnitude of the EATR and OACF affects fan sizing, while the positions of the supply and exhaust fans, and the air pressure drops they develop, affect the magnitude of the EATR and OACF. Figures 5 through 8 show the four possible fan arrangements along with the advantages and precautions associated with each.

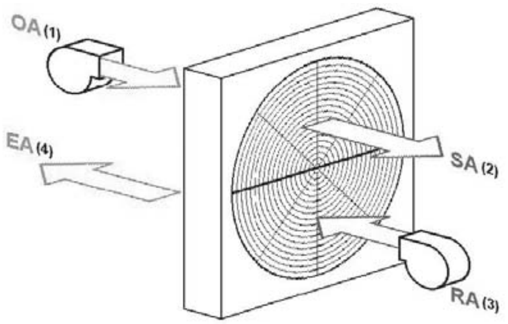

FIGURE 5 – BLOW-THRU SUPPLY/BLOW-THRU EXHAUST

Advantages

• Minimal leakage when supply and exhaust path static pressures are nearly equal.

Precautions

• Direction of leakage depends on relative static pressures.

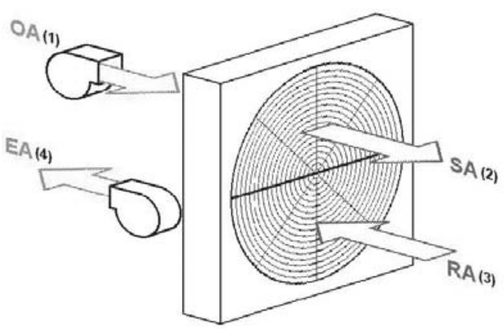

FIGURE 6 – BLOW-THRU SUPPLY/DRAW-THRU EXHAUST

Advantages

• Minimizes leakage of air from exhaust path to supply path.

Precautions

• Leakage from supply path to exhaust path can be excessive if static pressure differences are not minimized.

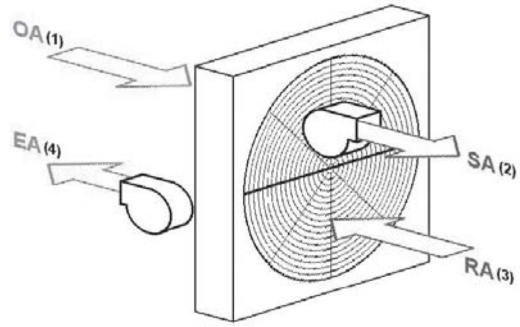

FIGURE 7 – DRAW-THRU SUPPLY/DRAW-THRU EXHAUST

Advantages

• Minimal leakage when supply and exhaust path static pressures are nearly equal.

• Good air distribution across the face of the wheel.

Precautions

• Direction of leakage depends on relative static pressure.

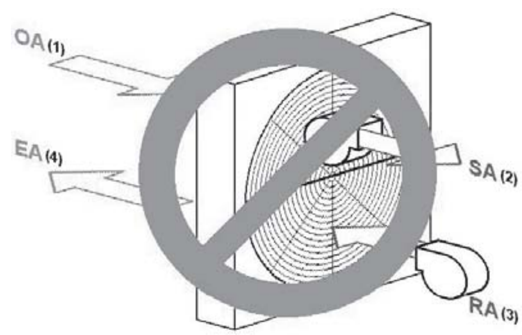

FIGURE 8 – DRAW-THRU SUPPLY/BLOW-THRU EXHAUST

Advantages

• None.

Precautions

• Significant leakage from exhaust air path to supply air path.

• **DO NOT USE**.

Proper fan arrangement and control of the static pressure minimizes the air transfer caused by leakage through the gaskets and seals of the wheel, however these practices will not reduce the transfer of air caused by carryover. As Figure 9 shows, some of the air from the return/exhaust path remains in the matrix of the wheel as it rotates to the outside/supply airstream. This "carryover" air mixes with the incoming outside air and enters the supply air path. For most applications, such as comfort cooling, carryover is of little concern. However, if there were high concentrations of hazardous substances such as VOCs or carcinogens in the air, they would enter the supply airstream via the carryover air and may present a health hazard to occupants. For this reason, **energy recovery wheels should not be used in applications where high concentrations of hazardous substances may be present in the exhaust air, for example laboratories or hospital operating rooms.**

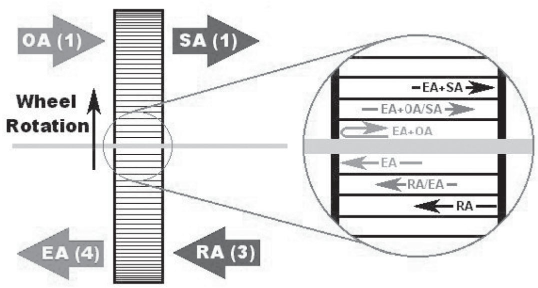

FIGURE 9 – AIR TRANSFER DUE TO CARRYOVER

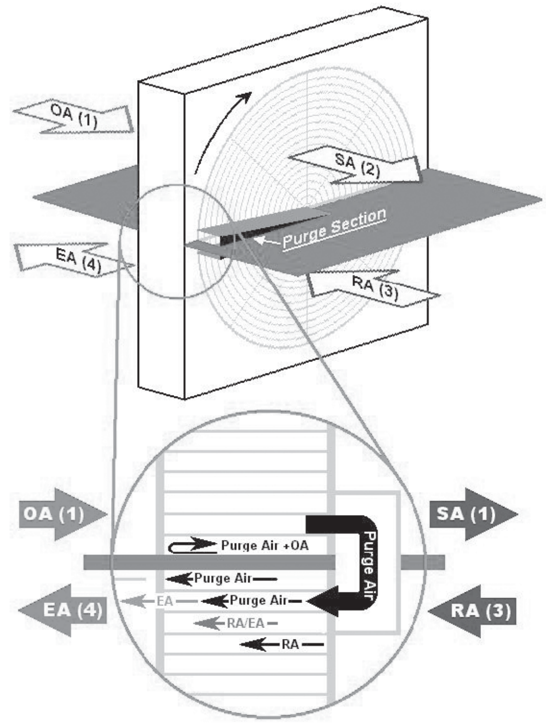

FIGURE 10 – ENERGY RECOVERY WHEEL WITH PURGE SECTION

Purge

A mechanical purge section can be used to reduce the volume of carryover air. (See Figure 10.) Mechanical purge isolates a section of the wheel on the boundary between the RA/EA path and the OA/SA path at the point where the wheel rotates from the RA/EA path into the OA/SA path.

Placing a block-off over this section of the wheel on the RA/SA side forces outside air that has traveled through the wheel to flow back into it in the opposite direction. This prevents air from the RA/EA path from entering the last few degrees of the wheel before it rotates into the OA/SA path. The return air that entered the wheel prior to the purge section has time to exit the wheel on the exhaust side. The angle of the purge section - how large a “slice” of the wheel it covers determines how effective it is. The larger the angle, the greater is the reduction in carryover. Purge should not, however, be counted on to eliminate carryover completely; therefore, **even energy recovery wheels equipped with purge sections should not be used when high concentrations of hazardous substances are likely in the exhaust airstream.**

Frost Control

Frost formation is always a concern when HVAC equipment operates in sub-freezing weather. Heat recovery equipment is no exception, but the likelihood of frost formation is greater on sensible-only heat transfer devices, including sensible-only energy wheels, than on total energy transfer devices. Consider both processes on the psychrometric chart:

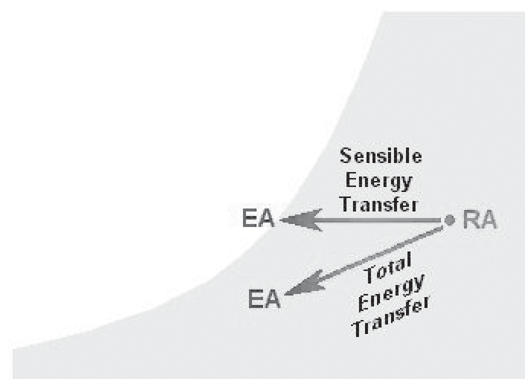

FIGURE 11 – EFFECT OF TOTAL ENERGY TRANSFER

During the heating season a total energy recovery device transfers heat and moisture from the warm, moist return air to the cold, dry outside air. This lowers the exhaust air dewpoint - the temperature at which condensation and frost formation occurs. Figure 12 compares typical frost threshold temperatures of total energy recovery wheels and sensible-only heat exchangers. Condensation and frost begin to form to the left of the respective boundary lines. The dewpoint depression achieved with total energy devices can lower the frost formation threshold well below 0°F when the indoor air relative humidity is low.

Total energy recovery wheels located in climates with extreme winter conditions, and/or where indoor air rela-

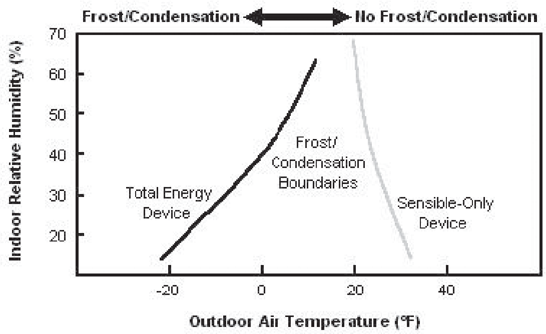

FIGURE 12 – FROST THRESHOLD TEMPERATURES

tive humidities are high may still require some means of frost prevention. There are four common methods of frost prevention - three of which are generally favored over the fourth.

On-Off control is the least expensive and least complicated method of preventing frost. When the wheel is not rotating, no energy transfer takes place and the moisture in the exhaust airstream is in no danger of condensing and freezing. The drawbacks to this method are that when the energy recovery wheel is not operating, no energy savings are realized and heating elements must be sized for design winter conditions. On-Off frost prevention control is best suited for mixed air systems with a low minimum outside air requirement and in climates where the outdoor air temperature drops below the frost threshold mainly during the unoccupied period when ventilation is not required.

Bypassing the outside air or a portion of it is another common tactic for preventing frost formation. This method consists of mounting a bypass damper in the OA/SA path that opens to divert some of the outside air around the energy recovery wheel when outside air conditions are below the frost threshold. This reduces the heat transfer capacity of the wheel and prevents the leaving exhaust air from reaching saturation. Proper mixing is crucial to prevent stratification, which could freeze downstream coils in the air handler. The heating elements must be somewhat larger in this type of system than a system in which the wheel operates at 100% during winter design conditions, but do not necessarily have to be sized for design winter conditions. Bypass systems are best suited for climates with very few hours per year below the frost threshold and for systems that do not include humidifiers. Systems with airside economizers are required to have OA bypass to take full advantage of economizer operation.

Entering air preheat is a widely accepted method of frost control that has the additional advantage of allowing the wheel to operate at maximum air volume during design heating conditions. The approach to this frost control method is to mount a heating device on either the OA entering side of the wheel (position 1) or on the RA entering side of the wheel (position 3); see Figure 13. When the heating device is mounted in position 1, the temperature of the outside air is raised above the frost threshold temperature of the wheel, preventing the exhaust air from getting cold enough to form frost. When the heating element is placed in position 3, enough energy is added to the RA path to prevent the heat transfer to the OA/SA path from lowering the exhaust air temperature below the saturation point.

This method of frost control is well suited to climates

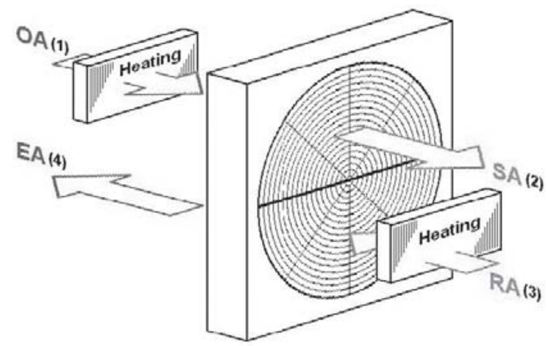

FIGURE 13 – PREHEAT FROST CONTROL

with extreme winter conditions, and for systems that include some form of mechanical humidification. If the preheat device consists of a steam or hydronic coil mounted in the outside airstream, some form of freeze protection for the coil must be included. No such precaution is necessary if a steam or hydronic coil is used to preheat the return air. Although a heating device mounted in position 3 (RA) will typically require a greater capacity than a device mounted in position 1 (OA) to provide the same degree of frost prevention, adding heat to the return air path increases the sensible heat transfer to the supply air path. When a preheat element is used in position 3, caution should be exercised so that the temperature of the entering return air does not exceed the recommended operating temperature of the energy recovery wheel.

Variable speed control can be used to reduce the rotational speed of the wheel, which reduces its ability to transfer energy. Because of all the variables involved, this method of frost control requires a sophisticated control strategy, which if not followed correctly can actually increase the likelihood of frost formation. Reducing the wheel speed can also lead to significant reductions in performance and the need for supplementary freeze protection for downstream coils. For these reasons, the previous three methods of frost prevention are generally favored over variable wheel speed control.

Capacity Control

Maximum heat transfer is not always necessary, nor desirable. The two most common methods of controlling the energy transfer rate of the wheel are variable speed control and bypass of exhaust or outside air.

Variable speed control consists of using a speed controller, such as a variable frequency drive (VFD) or silicon controlled rectifier (SCR), attached to the drive motor of the wheel. As the rotational speed of the wheel decreases, the heat transfer capacity also decreases. There are limits to this type of capacity control, however. The reduction in capacity is not proportional to the reduction in wheel speed; therefore, reducing the speed of the wheel by 50% may only result in a 10% reduction in energy transfer.

Exhaust or outside air bypass requires a bypass damper mounted in the OA/SA path or the RA/EA path and has several advantages over variable speed capacity control. Air bypass results in more linear control of the energy wheel capacity making the control strategy more reliable. Also, a greater overall reduction in capacity can be achieved by using bypass than by using variable speed control, and the pressure drop of the system is reduced as the volume of air passing through the wheel is reduced.

Placing the bypass damper in a position to divert exhaust air in lieu of outside air will minimize the possibility of stratification in 100% outside air systems. This damper could also be placed in the exhaust airstream to control the capacity of the wheel by reducing the volume of exhaust air available to transfer energy to or from. However, in an air hander with an airside economizer, when the system modulates from minimum outside air operation to 100% economizer mode, some means of diverting the outside air around the wheel must be included to prevent excessive pressure drop and unwanted preheating. In this arrangement the economizer bypass damper could be used as a capacity control damper in the minimum outside air mode, although proper mixing of treated and bypassed air would be essential to prevent freezing of hydronic coils downstream of the energy recovery wheel.

ENERGY RECOVERY APPLICATIONS

There are three application categories for air-to-air energy recovery based on the type of system the energy recovery device serves, and two subcategories based on how the device is used in the system. The application categories are process-to-process, process-to-comfort and comfort-to-comfort. Examples of these applications are given in Table 1. The subcategories are preconditioning of outside air and tempering of supply air.

Method	Typical Application
Process-to-process	Dryers
and	Ovens
Process-to-comfort	Flue stacks
	Burners
	Furnaces
	Incinerators
	Paint exhaust
	Welding
Comfort-to-comfort	Swimming pools
	Locker rooms
	Residential
	Smoking exhaust
	Operating rooms
	Nursing homes
	Animal ventilation
	Plant ventilation
	General exhaust

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Table 1. Applications for Air-to-Air Energy Recovery

Process-to-process (PTP) and process-to-comfort (PTC) applications generally only require heating. The energy recovery device transfers the heat generated by the process from the exhaust airstream back into the process supply airstream or building makeup airstream, respectively. Because excess humidity is detrimental to many process applications, PTP systems typically only require sensible heat transfer. Process-to-comfort applications may use total energy recovery devices to humidify dry outside air in the winter and to reduce the likelihood of frost formation. Comfort-to-comfort (CTC) heat recovery systems operate during both the heating and cooling seasons and may transfer sensible-only or total heat from the building exhaust sources to the makeup airstream.

For PTP and PTC applications a plate-type heat exchanger may be more appropriate than an energy recovery wheel. This is due to the fact that in most cases cross leakage must be eliminated, also plate exchangers may be more resistant to the temperatures of the process exhaust and usually only sensible energy recovery is required. Energy recovery wheels are commonly used for CTC applications, except in cases where the possibility of cross contamination precludes their use.

Preconditioning of Outside Air

A primary use of exhaust air energy recovery is to precondition outside air. Preheating/humidifying in winter and precooling/dehumidifying in summer reduces annual operating costs and may decrease first cost as the required heating and cooling capacity is reduced. Figure 14 illustrates one possible configuration of an outside air preconditioning system.

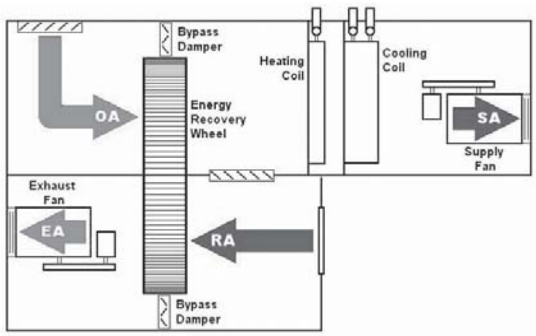


FIGURE 14 – OUTSIDE AIR PRECONDITIONING

Example 1 on page 2 illustrates a potential 33 ton (42%) equipment capacity reduction of an outside air preconditioning system in the cooling mode. Using the energy recovery wheel to preheat and humidify the outside air in the heating season can achieve similar savings and capacity reductions.

In systems with airside economizers, the energy recovery wheel should be sized for minimum outside airflow only and provisions should be included to bypass or otherwise prevent operation of the wheel during economizer mode. Operation of an energy recovery wheel during economizer mode increases energy consumption.

Tempering of Supply Air

Using an energy recovery wheel to temper supply air is an energy efficient way to control humidity. In the past, humidity control involved cooling the air below the temperature required to satisfy the sensible load and then reheating it. While this simultaneous heating and cooling provided fine temperature and humidity control, it wasted a great deal of energy. ASHRAE Standard 90.1-2004 prohibits simultaneous heating and cooling unless, among other specific exceptions, at least 75% of the reheating energy is provided from a site-recovered energy source.

Two methods of tempering the supply air are shown in Figures 15 and 16. The parallel arrangement uses the energy recovery wheel to reheat the supply air during the cooling mode by transferring energy from the return airstream to the supply airstream. During the heating mode, the wheel preheats the outside or mixed air by transferring energy to the supply airstream. This may help reduce the winter heating load, but any hydronic coils upstream of the wheel may require some of form of freeze protection, particularly in 100% outside air systems.

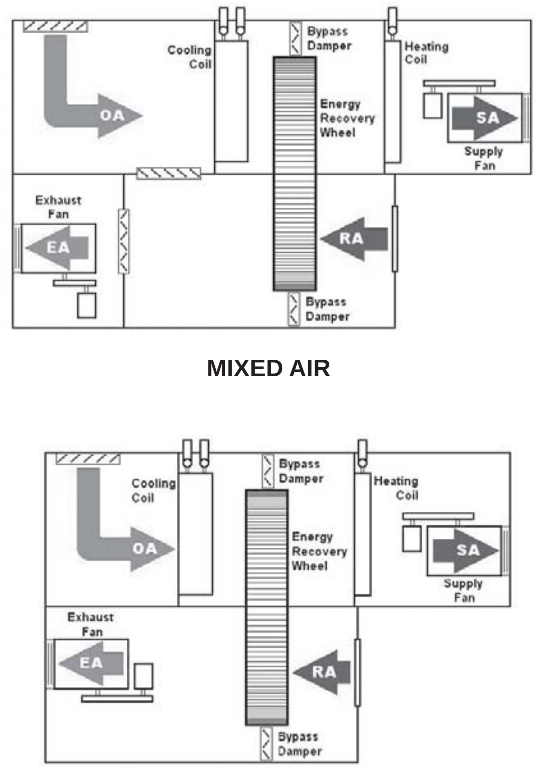


FIGURE 15 – SUPPLY AIR TEMPERATING (PARALLEL)

In the series arrangement, energy is not actually "recovered", but simply transferred from the upstream to the downstream side of the cooling coil. This transfer reheats the supply air and preconditions the outside air simultaneously. Since the goal of a series arrangement supply air tempering system is dehumidified supply air, sensible-only energy recovery devices. Series type systems as shown in Figure 16 are not used during the heating season.

In both of the supply air tempering arrangements the cooling system is designed to accommodate the peak cooling (i.e. sensible) design load, which, as Figure 17 shows, occurs at a higher dry bulb temperature than the design dehumidifying condition. The energy recovery wheel is not used during peak sensible cooling conditions because it is not desirable to add heat to the supply air when sensible cooling is the main concern. Therefore, using an energy wheel for supply air tempering will not reduce the design capacity of the cooling system.

Supply air tempering is used at the peak dehumidifying (i.e. latent) design load when the sensible load in the space is lower and the latent load is higher than the

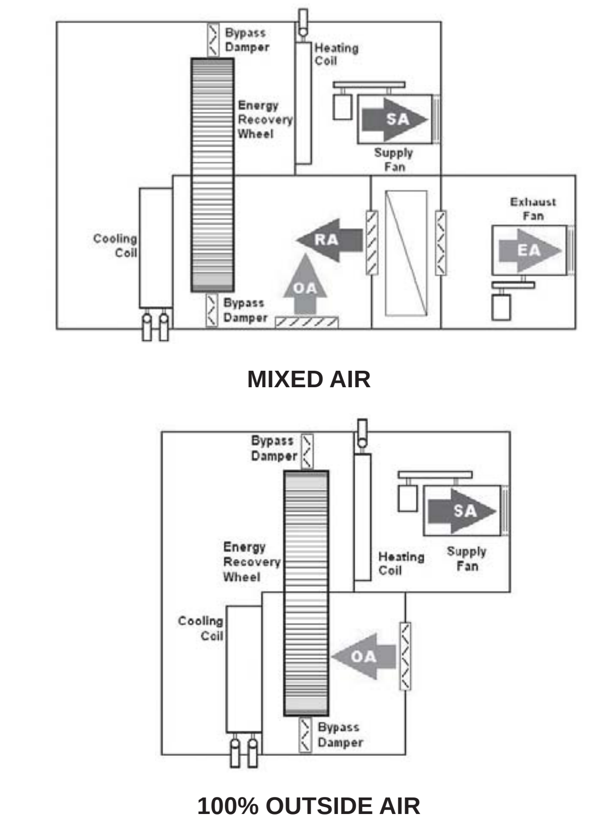
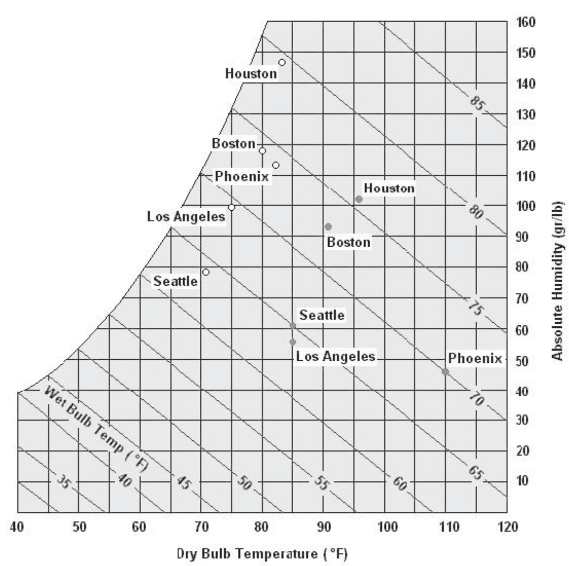


FIGURE 16 – SUPPLY AIR TEMPERATING (SERIES)



	Design (0.4%) Cooling Conditions			Design (0.4%) Dehumidifying Conditions		
Location	DB	WB	DP	DB	WB	DP
Phoenix, AZ	110	70	46.1	82	74.1	71
Los Angeles, CA	85	64	51	75	69.5	67
Boston, MA	91	73	65.2	80	74.2	72
Houston, TX	96	77	69.7	83	79.2	78
Seattle, WA	85	65	53.2	71	63.9	60

● Design Cooling (Sensible) Conditions

○ Design Dehumidifying (Latent) Conditions

FIGURE 17 – COOLING AND DEHUMIDIFYING DESIGN CONDITIONS

cooling design condition. Typically when the sensible cooling load decreases, the supply air temperature increases (in a constant volume system) or the supply air volume decreases (in a VAV system). However, due to the high latent load in the space, a temperature increase or airflow decrease results in unacceptable humidity levels in the space. To maintain acceptable humidity and temperature levels the supply air is "overcooled" to dehumidify it, then reheated to the temperature required to satisfy the sensible load. Supply air tempering accomplishes this process while reducing or eliminating the need for mechanical reheat, which satisfies the requirements of ASHRAE Standard 90.1-2004.

MAINTENANCE

Energy recovery wheels generally require little maintenance. The maintenance staff should conduct regular inspection of the drive system, checking for proper belt tensioning and motor operation, and adjusting or replacing loose or worn belts when needed. Personnel should consult product IOM manuals for the procedures and frequency of drive system maintenance recommended by the manufacturer.

Cleaning

Dry particle build-up in the heat exchange matrix is rare. Due to the laminar flow characteristics of the wheel, small particles that enter the matrix typically pass through while larger particles that lodge on the surface of the wheel are blown free when they pass into the counter-flow airstream. Build-up of oil or tar-based aerosols on the surface of the energy wheel or within the matrix presents a greater concern. These contaminants can adhere to the surface of the wheel and reduce airflow by obstructing the air or, in the case of total-energy wheels, reducing the latent effectiveness of the wheel by clogging the water adsorbing pores on the surface of the desiccant.

The wheel should periodically (no less than once per year) be inspected for contamination. In environments such as cooking facilities, bars and restaurants with high smoking rates and industrial welding applications where oil or tar-based contamination is more likely, inspections should be conducted more frequently. Inspection and cleaning may be required as frequently as every three months in industrial applications.

Regardless of the application, the wheel should be cleaned whenever contamination is detected. Dry particles can generally be removed by vacuuming, however personnel should consult IOM manuals for instructions on the removal of oil or tar-based films. Different manufacturers use different desiccants and materials of construction, and what works well for one wheel may damage or destroy another. Many manufacturers construct their wheels of multiple, independently removable segments to facilitate the cleaning process.

Care should be taken in the design of the system to allow sufficient access space for the inspection and cleaning processes.

INDUSTRY STANDARDS

The HVAC industry has published several documents that deal with the testing, rating and use of exhaust air energy recovery devices.

ASHRAE Standard 84-1991

ASHRAE Standard 84-1991, The Method of Testing Air-to-Air Heat Exchangers is an ANSI approved standard that was published in 1992. The purpose of this standard is to establish a uniform method of testing air-to-air heat exchangers. The standard specifies the test set-ups and test equipment required. It also specifies the data that must be collected, the calculations that can be used and the acceptable procedures for reporting test results.

ARI Standard 1060-2000

Published by the Air-Conditioning and Refrigeration Institute in 2000, ARI 1060 is the Standard for Rating Air-to-Air Energy Recovery Ventilation Equipment. The purpose of this standard is similar to that of ASHRAE 84-1991 in that it establishes “definitions; test requirements; rating requirements; requirements for marking and nameplate data; and conformance requirements.” The test procedures referenced in ARI-1060 are the ones that are specified in ASHRAE 84-1991.

There are a few differences between the standards however. For example, ASHRAE 84-1991 includes run-around loop heat exchangers - that is a closed loop system consisting of two or more heat transfer coils mounted in different airstreams. ARI 1060 excludes this type of heat exchanger and instead applies only to heat pipes, plate heat exchangers and rotary heat exchangers. Also, the ratings outlined in ARI 1060 only apply to the performance of the energy recovery device, as it is used to precondition outside air, not as it is used to recondition, or temper supply air.

The most important difference between the two standards is that ARI administers a certification program in conjunction with Standard 1060; ASHRAE has no such certification program. This means that any energy recovery equipment manufacturer can apply for listing in ARI’s Air-to-Air Energy Recovery Ventilation Equipment Certified Product Directory. Manufacturers who are listed in the ARI directory have certified that their equipment has been tested using the procedures stipulated in Standard 1060 and that the published ratings of the equipment conform to the requirements of the standard.

To verify the ratings of a certified manufacturer, ARI randomly selects samples of the rated equipment on a regular basis and has the samples tested in accordance with Standard 1060 at an independent laboratory that is under contract to ARI. Manufacturers whose equipment passes these tests are permitted to use the ARI 1060 certification seal shown in Figure 18 on their certified models, specification sheets and other literature and advertising that pertains to equipment ratings.

FIGURE 18 – ARI 1060 CERTIFICATION SEAL

Specifying ARI 1060 certified energy recovery equipment has several advantages. It facilitates the comparison of certified products from various manufacturers by standardizing the ratings methods used by those manufacturers. It also adds credibility to published performance data by ensuring that it is based on standardized test procedures rather than estimates and calculations, as may have been the case in the past. Purchasing non-certified energy recovery equipment exposes the customer to the possibility of receiving equipment that will not perform as specified.

ASHRAE Standard 90.1-2004

Unlike the previous two standards, ASHRAE 90.1-2004, Energy Standard for Buildings Except Low-Rise Residential Buildings does not regulate the performance of energy recovery equipment, but rather when it should be used. The purpose of this standard is to provide minimum requirements for the energy efficient design of buildings. As previously mentioned, exhaust air energy recovery provides the opportunity to conserve energy in the HVAC system.

Section 6.5.6.1 of Standard 90.1-2004 requires exhaust air energy recovery in “Individual fan systems that have both a design supply air capacity of 5000 cfm or greater and have a minimum outdoor air supply of 70% or greater of the design supply air quantity...” Most comfort cooling applications only require 15-25% minimum outside air. However, even if energy recovery is not required by 90.1, it’s still a good idea because the energy it saves means it has a very short payback time.

Section 6.5.6.1 also requires a 50% or greater effectiveness in either the heating or cooling mode based on Equation 1. When the system includes an air economizer, the standard requires that provisions be made to prevent the energy recovery device from increasing energy usage during economizer mode. Several exceptions to the energy recovery requirement exist, and for more information on those exceptions, please refer to the Standard.

Energy recovery is also referenced in Section 6.5.2 - Simultaneous Heating and Cooling. This section allows simultaneous heating and cooling for temperature or humidity control if site-recovered energy (including exhaust air energy recovery) or solar energy provides at least 75% of the heat energy used to reheat the air.

ARI Guideline V

This guideline, titled, Calculating the Efficiency of Energy Recovery Ventilation and its Effect on Efficiency and Sizing of Building HVAC Systems was published in 2003. It establishes an industry-approved method of determining the efficiency of an HVAC system that includes energy recovery equipment. It also provides guidance on how to size heating and cooling components in an energy recovery system.

Like ARI Standard 1060, Guideline V applies only to heat pipes, fixed plate exchangers and rotary heat exchangers; it excludes run-around loop heat exchangers. Unlike ARI 1060, this guideline includes performance calculations for supply air tempering systems. Since such systems are not certified under Standard 1060, ARI advises that results obtained using Guideline V should not be considered "certified."

Guideline V introduces the concepts of Recovery Efficiency Ratio and Combined Efficiency to assist in analyzing the performance of the HVAC system. Recovery Efficiency Ratio (RER), which is 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." The recovered energy can be related to humidification, dehumidification heating or cooling. The energy expended includes the added fan power required to move the air through the heat exchanger and, in the case of an energy wheel, the wheel drive motor power consumption.

The Combined Efficiency (CEF) is a means of determining the overall efficiency of an HVAC system incorporating an energy recovery component and a unitary device such as a packaged air conditioner or heat pump. Depending on the conditioning device, the CEF can be expressed in either Btu/(W•h) or W/W. An example in Appendix C of the guideline shows that a total energy recovery device with an effectiveness of 70% can improve the cooling efficiency of an HVAC system from an EER of 10 Btu/(W•h) to a CEF of 13.46 Btu/(W•h).

LEED

The Leadership in Energy and Environmental Design (LEED(tm)) rating system is the U.S. Green Building Council's effort to provide a national standard for "green buildings." Optimizing building energy usage is a key step in achieving certification and energy recovery wheels are a key component in reducing HVAC system energy consumption. For building owners, economic incentives of LEED certification include higher rental rates than comparable buildings and possible tax breaks for operating a green building.

SUMMARY

Exhaust air energy recovery technology provides a valuable opportunity for engineers to reduce the first costs and operating costs of buildings. Owners benefit not only in these initial and annual savings, but may also receive incentives for operating a "green" building in some areas. Finally, the use of energy recovery reduces the use of non-renewable resources and promotes a cleaner environment. Therefore, whether mandated by state or local building codes, or not, proper application of energy recovery wheels and heat recovery in general is a win-win proposition.

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