Using ERV to Improve Sensible Heat Ratio

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Building systems that do more with less are increasingly recognized not only as an ethical priority but as good business. Market demand for environmentally responsible HVAC&R engineering and systems has grown rapidly in several industry sectors. The ASHRAE GreenGuide was published in 2003 to help engineers meet this growing demand and to help the HVAC industry make its fair share contribution to efficient resource use.

The *GreenGuide* includes 29 *GreenTips* that provide summary information sufficient to initially evaluate systems approaches and technologies. *GreenTips* provide a useful survey of technologies to help building systems do more with less. The list includes three *GreenTips* on air-to-air heat recovery, or energy recovery ventilation (ERV).

Chapter 44 in the *2004 ASHRAE Handbook—HVAC Systems and Equipment* reviews several ERV technologies, including pumped runaround systems, fixed plate heat exchangers, heat pipes, rotary sensible-only wheels, active desiccant wheels, and rotary enthalpy wheels. All such technologies depend on recovering or deriving energy from one airstream, called the regeneration airstream, and transferring it to another airstream, called the process airstream.

If the process airstream passes a media that adsorbs water vapor such as an enthalpy wheel, some dehumidification benefit is possible in addition to sensible heat transfer. Rotary enthalpy wheels can improve dehumidification performance in summer while decreasing required compressor and heating capacity, along with energy consumption. Enthalpy wheel packages, including required additional blowers and filters are available as standard accessories for major manufacturers' standard rooftop packaged units. Indoor humidity control and energy performance improve when these ERV accessory add-ons are specified. Often, including a wheel accessory allows a stock rooftop unit to handle latent loads that might otherwise dictate a more costly, more complicated design response.

ERV applications include purpose-built dehumidification equipment, custom-engineered, built-up systems with ERV, and packaged units modified with stock ERV add ons. First, this article summarizes a general approach to screening ERV technologies. Many of the concepts and performance evaluation methods apply to all three application categories. These four steps outline a traditional engineering approach to evaluating ERV for a given application:

1. Screen the available technologies based on technical issues to determine those compatible with the application at hand;
2. Optimize the system design that best incorporates each applicable energy recovery ventilation technology and, if required for decision making, optimize the system design without any ERV technology;
3. Compare impacts on building space or arrangement requirements and other impacts on architectural, structural, or other aspects of design. And, compare impacts on costs: first, energy, operations and maintenance, and periodic cost; and
4. Follow project process to make decision using the previous comparisons.

Of course, another possible approach is less linear, where the entire building's performance is optimized and systems are not fit into an emerging design, but are developed in concert with the overall building design. With the right team, such an approach can result in such tight integration of systems with building design that reselecting system type is not an option. Systems resistant to value engineering are a good thing, right? However, with owners or other project team members new to environmentally responsible projects, the linear process detailed next can help demonstrate value added by the engineer or designer in optimizing system design, especially if the comparisons are well documented.

1. Screening the Technologies. Not all ERV technologies are technically appropriate for every application. Pumped runaround has low comparative efficiency and does not transfer latent heat, so it appeals only where potential contaminant transfer from process to regeneration airstreams cannot be tolerated, and the two airstreams cannot be adjacent. Fixed plate heat exchangers, rotary wheels, and heat pipes only can be applied where the two airstreams are adjacent. Heat pipes contain refrigerant and may require control valves or bypass ductwork to allow proper year-round control. For enthalpy wheels, control or bypass may be required to avoid wintertime freeze damage to the wheel. All ERV applications increase fan energy and require air filtration. Some applications require additional fans to avoid bypass leakage of regeneration air to process supply air.

As with any technology, incorporating energy recovery in a project should be considered carefully with respect to the building owner or management's maintenance programs and personnel. Is there any point including a system element of any kind if it is defeated, bypassed, or removed after building startup and hand-off?

To protect system integrity after construction, acknowledge ERV in the design intent and system narratives if you provide these to your clients. Also, include any comparative cost calculations (the operating and maintenance costs for ERV as another component of the HVAC system), check building automation system sequences for any required control such as freeze protection, scrutinize the ERV installation when performing the punchlist, and ensure contractors provide manuals to owners or operators that address both operations and maintenance procedures for ERV(s).

Except in dry climates, unimproved stock direct expansion units at, say, 25% outdoor air during occupancy essentially pump water vapor into the conditioned space under many operating conditions. Except in spaces with virtually no internal moisture loads and high equipment or lighting loads, air-conditioning systems are required to remove moisture, not add it! Take the same unit, add a 75% efficient enthalpy wheel, and now consider its cooling and dehumidification performance. At any higher outdoor intake rate, below 100% the improved system delivers drier air than the conventional unit at 25% outdoor air. Or, the rooftop unit with ERV can provide 100% outdoor air while consuming roughly the same overall energy as the same unit without ERV at 25% outdoor air.

Airflow Arrangements	Counterflow (Typical)
Airflow Range	50 cfm and up
Typical Sensible Effectiveness	50% to 85%
Typical Latent Effectiveness	50% to 85%
Face Velocity	500 to 1,000 fpm
Pressure Drop	0.4 to 1.2 in. H_2O

Table 1: Typical characteristics of enthalpy wheel., adapted from Table 2, p. 44.17, **2004 ASHRAE Handbook.**

2. Optimizing the Results. Optimizing each alternative before comparison includes matching equipment to loads as best as possible at all conditions to provide the best possible indoor conditions. Peak coincident load calculations are much improved if performed twice, once with respect to sensible loads as is customary, and again with respect to latent loads. The coincident indoor and outdoor conditions that combine

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for peak sensible loads will not necessarily occur at the same time that coincident latent loads will peak. Addressing this issue in load calculations and selection procedures is essential to predicting the suitability of equipment for a given application.

Off-peak conditions often represent even larger dehumidification challenges than peak design conditions, especially to stock equipment. This can mean that apparently acceptable equipment specifications translate into unacceptable performance in application.

Moisture re-evaporation upon off-cycling of compressors in direct expansion units at low loads can return over 15% of condensate removed to the supply airstream, meaning that a nominal 80% sensible heat ratio may translate into 83% or worse except for constant run periods of peak load. Adding capacity control can help dehumidification, but will not necessarily lower energy costs. Succumbing to the temptation to oversize equipment, of course, aggravates latent capacity problems.

If chilled water is available, it is more feasible to match coils' dehumidification performance to load characteristics. But if packaged equipment is part of a project, then humidity control needs may not be met—and boosting DX latent heat removal capability with energy recovery can help.

Enthalpy wheels, available as stock accessories for commercial rooftop packaged units, help raise latent heat capacity and drop sensible heat ratio in cooling mode. Enthalpy wheels also can help raise low humidity in winter, since several available wheels transport moisture *from* regeneration air *to* process airstream for delivery to the conditioned space.

Calculating ERV's impact on heat ratio at required capacity to determine sizing is straightforward. One approach is available in ARI's *2003 Guideline for calculating the efficiency of energy recovery ventilation and its effect on efficiency and sizing of building HVAC systems, Guideline V*. Equipment manufacturers also have incorporated selection routines into their proprietary load calculation and selection software.

Energy recovery is part of the vocabulary of today's engineering work. Laboratory fume hood exhaust air is commonly used with pumped runaround to reduce energy and improve firm capacity while meeting ANSI Laboratory Ventilation Standard Z9.5-2002, which prohibits ERV applications from increasing potential transfer of contaminants from laboratory fume hood exhaust air. So an enthalpy wheel is not appropriate for such an application. However, on small commercial projects, an ERV accessory should be evaluated for rooftop unit application, since it provides a boost to humidity control and lowers energy operating costs while carrying low initial cost. Year-round, an enthalpy wheel can improve rather than confound designers' ability to improve humidity control.

3. Comparing the Alternatives. Comparing the alternatives focuses on minimizing costs. Many guides are available

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for cost calculations. While project budgets must be heeded, a thorough comparison must recognize that, given today's energy costs, the HVAC alternative with lowest first cost or quickest simple payback or highest net present value *rarely has the lowest life-cycle cost or highest internal rate of return.*

Comparing competing alternatives should fairly carry the first cost of required higher cooling capacity in any alternative without ERV, in addition to the recurring higher energy costs. While ERV technologies represent additional capital cost, by displacing raw cooling or heating capacity requirements often a reduction occurs in other capital costs in many applications. All ERV technologies typically present additional fan energy costs, but by reducing cooling or heating energy consumption a reduction occurs in other system energy costs. As with any system element, each technology requires its appropriate operations, maintenance, and periodic renewal, again with its own costs, as well as a reduction in other O&M and renewal burdens.

Different applications result in different relationships between initial, replacement, and annual costs, and the resulting payback calculations for each appropriate technology will vary with the application at hand. The cost of space for indoor equipment should be accounted for, but rooftop space is at a premium less often on smaller commercial applications where packaged units are applicable, and so need not always be penalized in cost comparisons.

Where climate permits, the base case against which the ERV-equipped rooftop packaged unit is often compared is the rooftop packaged unit with economizer. As discussed earlier, in many applications the legitimacy of this as a workable base case is questionable since stock units may not provide requisite humidity control. Particularly in wet climates or marine microclimates, economizer applications costs should carry first, annual, and replacement costs for enthalpy controls, since economizer cycles must be carefully implemented, operated, and maintained to avoid losing control of indoor humidity. While ERV must be assigned realistic life-cycle costs, it also should be credited for reduced compressor capacity required, the value of improved humidity control year-round, and reduced environmental externalities.

A matrix comparing alternatives should provide essential initial, annual and replacement costs, and also can convey the ability of some alternatives to provide improved indoor conditions and to reduce environmental externalities. Properly presented, such summaries can help an owner select a system that better protects the engineer, manufacturers, and contractors from unanticipated costs and liabilities that mount quickly when problem jobs fail to meet owner expectations.

Decision-Making and Project Process

An early design intent document that stipulates the client's preferred method of economic analysis can help reduce confusion.The further into the design process these equipment configuration choices remain open, the greater the effort required from engineers. So agreeing on early comparison of alternatives can allow the engineer to integrate the selected alternative. If integrated tightly enough into the design, attempts to revisit this choice during value engineering or "descoping" driven by budget problems is more easily thwarted. Simply deleting the ERV can be rejected based on inability to meet sensible or latent loads, while a larger stock packaged unit proposed to meet peak total load often will be more costly than a downsized packaged unit with ERV, and at any rate often can be rejected based on inability to meet latent loads and control humidity.

Conclusion

HVAC engineers are increasingly challenged to provide system designs that do more with less. ERV can play a role in meeting these challenges. Screening for appropriate technologies, optimizing system design, considering impacts on architectural, structural, or other aspects of design; and fully capturing costs of competing alternatives often helps a project team arrive at a better performing design.

On projects that include rooftop packaged units, standard accessory packages with enthalpy wheel are available, including required additional blowers and filters. Indoor humidity control and energy performance improve with these widely available ERV accessory add-ons. Including a wheel accessory can allow a stock rooftop unit to handle latent loads that could otherwise require a costlier and more complicated solution.

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