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Energy Engineering

Dr. Wayne C. Turner, Editor-in-Chief

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TWO APPROACHES TO USING ENERGY RECOVERY TO

IMPROVE OVER-ALL SYSTEM ENERGY EFFICIENCY RATING

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Abstract

Four different identical 100% Outdoor Air HVAC (Heating, Ventilation and Air Conditioning) systems with total enthalpy control where evaluated in four locations for a base system, a HRV (heat recovery) system and an ERV (enthalpy recovery) system. The locations where in New York, NY, Atlanta, GA, Omaha, NE and Sacramento, CA.

The four base systems were evaluated under design conditions for both cooling and heating. Then a HRV (heat recovery ventilation) system was added then the change in heating and cooling loads from an energy cost standpoint were tested. This was next repeated with an ERV (enthalpy system) and again the energy savings were tested and recorded.

Infrared thermal analysis was also used to explain and further evaluate and detail the thermal performance and characteristics of different HVAC components. At a national ASHRAE seminar session this presentation was well received and peer reviewed. Talking about energy savings is one thing, but actually seeing the energy savings is very interesting!

Case Studies

Real life applications in four major cities were evaluated using actual field conditions for the effects of three different systems:

1. Base 100% Outdoor Air System with No Energy Recovery.
2. Base system with 70% thermally effective (sensible only) Heat Recovery Unit.
3. Base system with 70% sensible and latent effective (sensible and latent) Energy Recovery Unit.

We can ask the question "What is Air-to-Air Energy recovery?" Typically for most standard applications for comfort for building occupants, it consists of preconditioning fresh outdoor air intake and recovering energy from the exhaust air stream(s). The exhaust air would typically have greater amounts of carbon dioxide that is normal for outside fresh air. There would also be a host of air contaminants such as by-products from office operations; the off-gasing of carpets, interior furniture and interior building elements that could off-gas a variety of complex plasticizers and the breaking down of nylon carpeting.

Air-to-Air Energy Recovery is also the component that can reduce the demand of energy for conditioning outside air that is being brought into the building. Energy recovery can save operating costs and can also reduce comfort complaint problems. It can also reduce overall energy consumption in the day to day operating costs. Properly applied, energy recovery can make the different HVAC components run with less effort making the HVAC equipment last longer.

Another advantage to Air-to-Air Energy Recovery is that it impacts the way the HVAC equipment is sized. The overall equipment with reliable and dependable air-to-air energy recovery equipment can be reduced. This energy reduction can reduce cooling and heating loads enough in many cases to increase ventilation rate without the need for expensive mechanical upgrades. The electrical demand requirements can also be greatly reduced and from practical experience, the equipment weight load points can be reduced too. There are also smaller piping requirements for hot water and chilled water and in some instances with very efficient air-to-air energy recovery the requirements for additional heating and cooling aligned with an energy recovery unit can actually be eliminated. We have proven this in many applications.

Additionally, the HVAC equipment benefits by way of higher energy efficiency and potentially less wear on the equipment. In very hot climates energy recovery equipment can reduce both the sensible and the latent loads allowing less energy to be used for dehumidification and in improving comfort.

A lot of the advantages to air-to-air energy recovery are that you are basically using the waste air streams that are being exhausted from buildings to thermally reduce the sensible loads incoming through energy recovery. It can be noted that it is not always beneficial to strip off excess moisture from the air coming in or to average the intake between the exhaust and intake air streams. In some applications, especially in the northern climates, it is beneficial to get rid of excess humidity in very tight construction. Typical in a northern climate, an HRV or heat recovery unit is generally found to be more useful and in southern climates where you always have a high humidity load, generally energy recovery units are favored. It can be noted that heat recovery units and energy recovery units are widely used all across North America. If properly engineered and sized they can be used in most applications.

Traditionally the biggest challenge with Air-to-Air Energy Recovery has been average efficiencies that require additional heating and cooling and therefore greatest cost. If you have a heat recovery or energy recovery unit that is fifty percent thermally efficient, you are going to need additional heating or cooling when it is very hot or cold outside. Running the pipe work for a coil, or whatever heating method used, can easily be much more expensive then an energy recovery or heat recovery unit itself. Therefore very efficient HRV/ERV with over 80% thermal efficiency is very beneficial.

We are now going to look at four different locations with comparative systems in New York, NY, Atlanta, GA, Omaha, NE and Sacramento, CA.

It is interesting to note that when you are working with a client in Sacramento, California, often times they will make the statement that they have very mild weather, when actually of all four cities, Sacramento has the most extreme weather. One of the things about Sacramento's climate is that it is relatively dry which improves human comfort over a wide span of temperatures and therefore the perception that the weather is relatively mild might be more based on humidity rather than temperature. Noteworthy is that the dry bulb conditions for Sacramento were the highest of among the other three cities and the wet bulb was the lowest.

Going through the different case studies we will take note of the relative tonnage requirement for cooling the three different systems, namely the base system, the sensible system which is heat recovery of thermal energy, and an enthalpy system where both latent and sensible energy recovery is taking place.

Energy recovery can take the form of a wide variety of equipment such as sensible wheels, enthalpy latent wheels, fixed plates, heat pipes, membrane plates. Different systems have different characteristics. Also, different systems can have widely different pressure drops and have a lot more power to push the air through the different systems. Some of the membrane plates or wheels can have very high pressure drops that exceed two inches of water column. Some of the fixed plates can have very low pressure drops that can be less than half an inch of water column. This contributes to the overall efficiency or lack of efficiency of the different energy recovery systems.

It is interesting to note that American Refrigeration Institute Standard for testing energy recovery equipment, ARI 1060 does not take into account the parasitic energy loss from oversized fan, pumps, wheels or belt driven motors that drive the machines. It can be noted that if you have a relatively efficient piece of energy recovery equipment, but it takes a lot of power to operate, while it will save you energy, there will also be a substantial cost to operate the equipment. The ideal situation is where very little energy is taken to drive, or use the energy recovery equipment, and the energy recovery is very efficient itself if by sensible and latent modes.

Another thing that needs to be considered is the reliability of the equipment. Currently, this author having served as Past Chairman of Owning and Operating Commercial Buildings and Evaluating Life Cycle Costing and also having been Past Chairman of Air-to-Air Energy Recovery, there is a movement to make the equipment more reliable overall and to help people evaluate the reliability of different forms of energy recovery and HVAC equipment in general.

Improving overall system Energy Efficiency Ratio (EER) is only going to be looking at the cooling side of the system. For the reader's interest, we also have the heat load savings, but this does not go into the calculations for EER. We will present and evaluate a base system without any air to air energy recovery, and a sensible system which incorporates a sensible exchanger. We will look at the heat load energy savings by themselves for the reader's interest.

EER (energy efficiency ratio) is a measure of how efficiently a cooling system will operate when the outdoor temperature is at a specific level (usually 95° F). A higher EER means the system is more efficient. The term EER is most commonly used when referring to window and unitary air conditioners and heat pumps, as well as water-source and geothermal heat pumps. The formula for calculating EER is:

$$EER = \frac{\text{Btu/hr of cooling at } 95^\circ \text{ F}}{\text{watts used at } 95^\circ \text{ F}}$$

For instance, if you have a window air conditioner that draws 1500 watts of electricity to produce 12,000 Btu per hour of cooling when the outdoor temperature is 95°, it would have an EER of 8.0 (12,000 divided by 1500). A unit drawing 1200 watts to produce the same amount of cooling would have an EER of 10 and would be more energy efficient.

Using this same example, you can see how efficiency can affect a system's operating economy. First, you'll need to determine the total amount of electricity — measured in kilowatt-hours — the unit will consume over a period of time. (A kilowatt-hour is defined as 1,000 watts used for one hour. This is the measure by which your monthly utility bills are calculated.) To do this, let's assume you operate your 8 EER window air conditioner — drawing 1500 watts at any given moment — for an average of 12 hours every day during the summer. At this rate, it will use 18,000 watt-hours, or 18 kilowatt-hours (kWh) each day, leading to a total consumption of 540 kWh over the course of a 30-day month. At a summer electric rate of 6.34¢ per kWh, it would cost you $34.24 to operate that window air conditioner each month. At the same time, a 1200-watt, 10 EER system, consuming 14.4 kilowatt-hours per day and 432 kWh per month, would cost you $27.39, a 20% savings over the less efficient model.

It can be noted that a sensible exchanger could be a sensible wheel, fixed plate, heat pipe, or some form of run around loop. A latent system incorporates an enthalpy exchanger which transfers both moisture and temperature. In some applications, such as swimming pools, this might not be advantageous, but for most commercial buildings and residential applications, it is generally seen, especially in the southern regions of the United States to be advantageous. The intention is to show the overall impact that these different approaches to energy recovery can have on energy efficiency ratings.

We will be using the following guidelines to evaluate the overall improvement of system energy efficient ratings. The performance will be rated on a flat rate of 70%, as this author believes that this can be achieved by most forms of energy recovery, either by greatly oversizing the energy recovery element or simply using energy efficiency equipment.

Therefore there is an advantage to making energy recovery or heat recovery equipment that is so efficient that you are basically close enough to room temperature that you do not need to do supplemental heating and cooling. The least expensive equipment to be installed could be relatively expensive compared to other energy recovery units, but if it efficient enough that you do not need supplemental heating and cooling, it could actually provide the least expensive installed cost compared to other technologies.

We will be using the following guidelines:

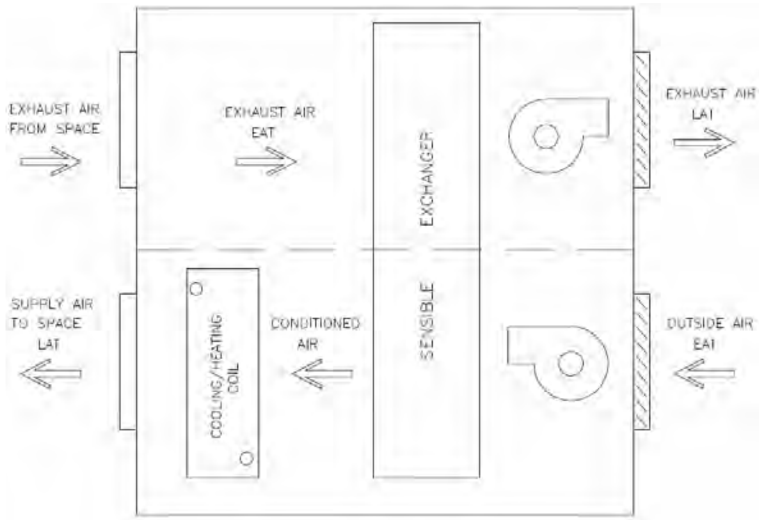
- The type of Air to Air Energy Recovery Equipment used in this discussion is non-specific.

- Performance is based on a flat efficiency rating of 70%.
  - 10,000 cfm of Supply and Exhaust air.

- Summer - Exhaust air conditions of 75º (F) db and 62.5º (F) wb.
  - Cooling coil supply LAT of 55 º (F).

- Winter - Exhaust air conditions of 70º (F) db and 52º (F) wb.
  - Heating coil supply LAT of 75 º (F).

SENSIBLE SYSTEM



We have four different cities spread all throughout the United States so we see the advantage of the impact of a latent system in relatively dry desert climates and relatively humid coastal seaside town.

COOLING CYCLE

Location	ASHRAE 0.4% Design		Base System	Sensible System	Enthalpy System
	ºF db	ºF wb	Tons Req.	Tons Req.	Tons Req.
New york,NY	92.0	74.0	53.5	43.5	-
Atlanta, GA	93.0	75.0	57.0	46.5	-
Omaha, NE	95.0	75.0	56.9	45.0	-
Sacramento CA	100.0	69.0	36.6	21.8	-
Based on 10,000 cfm, Exhaust Air of 75º db / 62.5º wb and a supply air temp of 55.0º db					

HEATING CYCLE

Location	ASHRAE 0.4% Design		Base System	Sensible System	Enthalpy System
	ºF db	ºF wb	MBH Req.	MBH Req.	MBH Req.
New york,NY	13.0	10.4	787.7	228.9	-
Atlanta, GA	18.0	14.8	727.5	212.6	-
Omaha, NE	-7.0	-8.1	1020.5	294.0	-
Sacramento CA	31.0	26.2	557.6	170.3	-
Based on 10,000 cfm, Exhaust Air of 70º db / 52º wb and a supply air temp of 75.0º db					

The base system is a typical 100% outdoor air system with exhaust air from an odiferous area of the operation such as bathrooms, kitchen or possible a process area. These subject applications were generally nursing homes.

It can be noted that no application involved hood exhaust, greasy or excessively dirty exhaust air streams. Some of the characteristics of the base system that has no air-to-air energy recovery, it is generally inefficient and is typically oversized which lowers the ability of the base system to do dehumidification. Oversized systems have trouble wringing out moisture as they are typically not run long enough to provide good dehumidification. Of course a larger system will also have higher electrical demand and will need more costly electrical gear and systems to support them. Also, an inefficient system, as shown previously, requires the most tonnage and the most heating and cooling Btu. This begs the question: How much energy can we save with sensible energy recovery?

When we talk about typical systems, we are talking about temperature and really not addressing humidity. All we are doing is changing the temperature of the outgoing air by tempering the incoming air with the outgoing air in a heat exchanger. This basically conditions the outdoor air and reduces the energy to further heat or cool the space. For sensible air-to-air energy recovery there are several options, fixed plate, counterflow or crossflow, heat pipe in a configuration of either counterflow or parallel flow. A heat pipe is a copper tube with a refrigerant, typically R22 that boils off and takes heat from a relatively warm air stream and changes this heat to a relatively cool air stream. There are no moving parts, it is just a hollow copper tube, sometimes with fins and refrigerant.

Interestingly, the biggest application of heat pipes is used to keep the Alaska pipeline from heating up the permafrost through its metal support system. On every metal support along the Alaska pipeline there are two heat pipes that wisk away the heat energy from the pipeline and dump it out into the air which keep the metal stanchions that hold up the pipe to keep it from becoming too hot and melting the permafrost.

There is also a run around coil loop which is nothing more than two fan coils with a fluid running through, typically an ethylene glycol, and a small pump to move the thermal mass or working fluid. These systems, carefully designed, can be very effective and provide very good isolation. Typically hospitals that need to precondition air for very large air flows will use run around coil loops. They are usually not well designed and if the pump is oversized, all the energy savings can easily be given back to running the pump to circulate the fluid. For our example, any option could be used. Designing a run around coil to reach 70% efficiency can be done. It would be very challenging and would have to be done by a skilled engineer.

Advantages to Sensible Systems

Efficient – Reducing the required loads

- Reduces - Overall HVAC equipment Sizing
- Reduced demand charges.
- Better comfort control.
- Can operate with more outdoor air with same Base system.
    - Improved IAQ credits.
    - Improved operation capability
- Higher efficiency's in drier climate conditions.

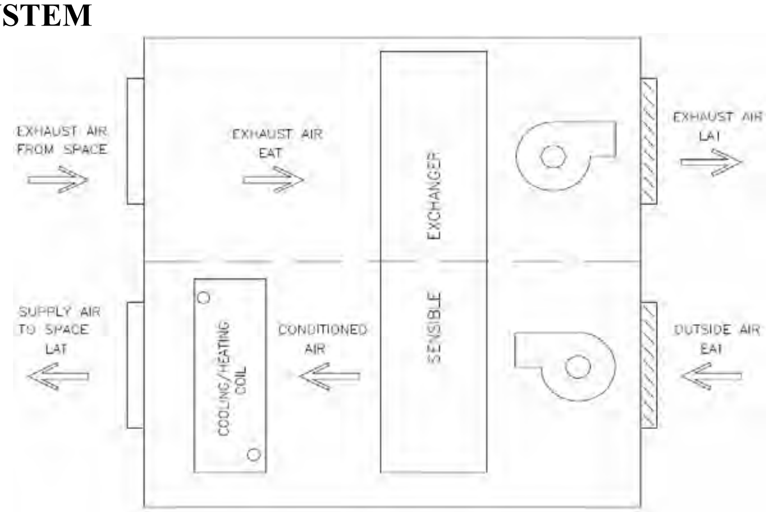
Arguably, people are more sensitive to temperature than air coming in with changing humidity. People can sense temperature more readily than humidity. There can also be improved comfort from ERVs or HRVs because a lot of equipment such as gas fired duct heaters, or even hydronic systems, take a while before they start producing heat. In the case of a gas fired duct heater, it can take up to two minutes for the firing mechanisms and the combustion safety system, to acknowledge that the pilot light is on and that it is time to deliver fuel and start heating the forced hot air exchanger. In the case of a hydronic, it takes a while for the warm water to get up to the air handler and actually start producing heat. This two minute lag can expose occupants to outdoor air temperature, which in North America during freezing weather can be extremely uncomfortable.

Thermal shock does not seem to be as much of a problem in hot weather because the HVAC system will eventually get cold and the temperature changes between outdoor and indoor are not as extreme. For a brief period of time, people can be subjected to relatively warm air and they will not be as uncomfortable as when they are being hit with twenty degree air, which most people find extremely uncomfortable. A sensible heat recovery system, if it was efficient enough, could eliminate these comfort problems and provide air that is basically tempered within five degrees of room temperature. It can also be noted that the sensible systems have higher efficiencies, dryer climate conditions and can have a greater impact.

Latent System Temperature and Moisture Air to Air Recovery

This type of system conditions the outdoor air and reduces the temperature to further heat, cool and dehumidify air coming directly into the space. For latent and sensible air to air energy recovery there are several options, membrane plate, counter and crossflow, fixed plate with an ability to take condensate and regenerate it to do evaporative cooling on the exhaust air stream and energy or desiccant wheels. For our example, any option could be used as seen in the schematic demonstrating the general location of the latent exchanger as seen in the diagram below.

LATENT SYSTEM



The next two charts show the effects of the Base System, the Sensible System and the enthalpy System. From these we see some dramatic drops in cooling tonnage. The most notable is Atlanta, Georgia going from a base system of 57.0 tons of cooling that is reduced to slightly over 30.9 tons. For Sacramento, California, there is not a lot of difference between the cooling tonnage of the Sensible or Enthalpy Systems. This is because in Sacramento, California the system is relatively dry. It can be noted that for all the systems, the cooling tonnage is basically cut in half going from 57.0 tons for Atlanta, Georgia and Omaha Nebraska down to 30.9 and 30.8 tons for both locations which is a dramatic reduction in cooling tonnage. It can be noted that often times the mechanical cooling equipment will actually be more expensive then the energy recovery equipment and the overall system can actually be less expensive to own and operate. Again, the type of equipment used and the overall reliability of the equipment become an important factor also in lifecycle cost and day to day operational considerations.

Latent System – Cooling Cycle

	ASHRAE 0.4% Design		Base System	Sensible System	Enthalpy System
Location	ºF db	ºF wb	Tons Req.	Tons Req.	Tons Req.
New york,NY	92.0	74.0	53.5	43.5	29.8
Atlanta, GA	93.0	75.0	57.0	46.5	30.9
Omaha, NE	95.0	75.0	56.9	45.0	30.8
Sacramento CA	100.0	69.0	36.6	21.8	24.8
Based on 10,000 cfm, Exhaust Air of 75º db / 62.5º wb and a supply air temp of 55.0º db					

In looking at the Heating Cycle below we see that the Sensible and Enthalpy Systems basically behave the same. This is because there is no moisture advantage in a heating cycle. In some situations where you have excessive humidity in the wintertime, you can actually find that it is a detriment. It can be noted that the drop in the heating MBH is a much greater percentage then that of the cooling because the Delta Ts, or the design temperature where there are much greater temperature drops than what we experience in the cooling cycle. Hence, for some areas like Omaha, Nebraska, a system that would be 1020.5 MBH is taken down to as little as 294 MBH, which is a dramatic reduction in heating energy used and would have a dramatic impact on the utility bills.

In the case of Omaha, Nebraska we see that heating MBH using either the Sensible or Enthalpy System show a reduction of over seventy percent. The bin hours, or run times for heating in most parts of North America are two to almost four times as great as that for cooling. The impact on overall owning and operating costs would be extremely dramatic and with high occupancy buildings could be expected to drive the cost for owning and operating the business down as much as fifty percent from an energy standpoint.

Latent System – Heating Cycle

Location	ASHRAE 0.4% Design °F db	°F wb	Base System MBH Req.	Sensible System MBH Req.	Enthalpy System MBH Req.
New york,NY	13.0	10.4	787.7	228.9	228.9
Atlanta, GA	18.0	14.8	727.5	212.6	212.6
Omaha, NE	-7.0	-8.1	1020.5	294.0	294.0
Sacramento CA	31.0	26.2	557.6	170.3	170.3
Based on 10,000 cfm, Exhaust Air of 70° db / 52° wb and a supply air temp of 75.0° db					

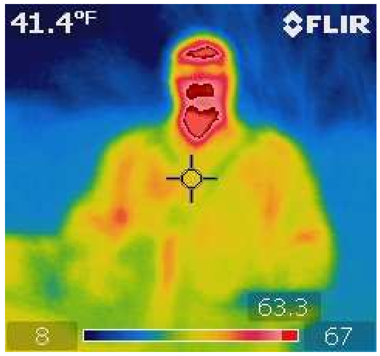
When we take a look at the different temperature and moisture readings for this latent air-to-air system, we find that it has a lot of advantages in improving latent cooling under peak conditions and can operate with more outdoor air with the same base system. Higher efficiencies in human comfort are also something that can be noted.

One of the draw backs of the latent system that the typically higher pressure drop across an enthalpy wheel which would have a tendency to reduce the overall operating efficiency, or increase fan power consumption.

Location	ASHRAE 0.4% Design ◦F db	◦F wb	Base System EER	Sensible System EER	Enthalpy System EER
New York, NY	92.0	74.0	12	14.8	21.5
Atlanta, GA	93.0	75.0	12	14.7	22.1
Omaha, NE	95.0	75.0	12	15.2	22.2
Sacramento, CA	100.0	69.0	12	20.1	17.7
Based on 10,000 cfm, Exhaust Air of 75◦F db/62.5◦F wb and a supply air temp of 55.0◦F db					
Actual EER would change for equipment based on actual tonnage used, 12 EER used for comparison					

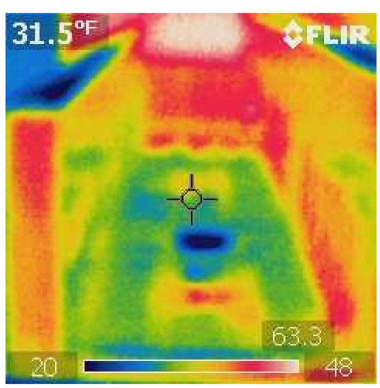
In summary, we have looked at the overall system energy efficiency ratings for the Base System, the Sensible System and the Enthalpy System and we find that given the different locations, that the energy recovery goes as high at 22.2 for an Enthalpy System and can go as high as 20.1 for a Sensible System in Sacramento, California. This is the type of efficiency that we are used to seeing from a very high efficiency closed loop, geothermal system. It can be noted that this can be done with relatively inefficient Base System with an energy recovery of only 12 in order to get the phenomenal energy performance. The question is: Why are there not more people doing it? We have asked that question in Utah at the Annual ASHRAE Meeting in a Forum that this author has chaired. We can discussion this during the question and answer period.

To help illustrate some of these thermal conditions involving comfort we have taken a thermograph of an individual in cold conditions, around 40°F to see what there body looks like. The image below is of a heat signature of the warmly dressed author, which basically shows that the greatest heat loss is in the exposed part, such as the face. The author is wearing gloves so that his hands are not thermally exposed.

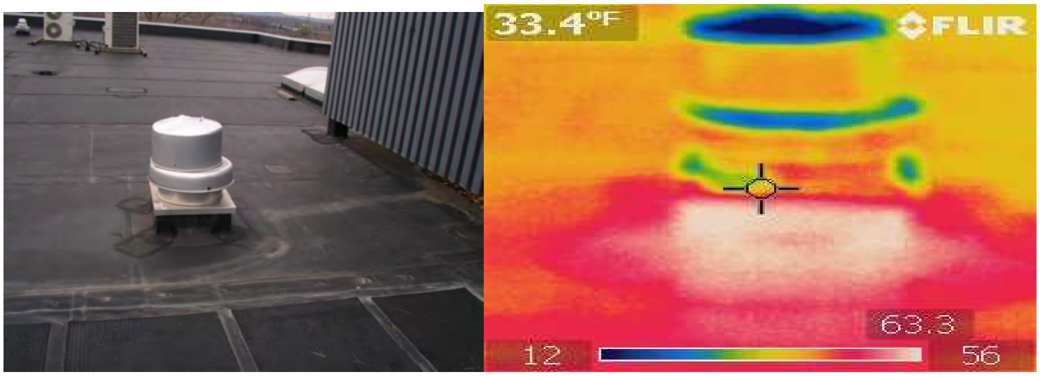


As seen in this picture, the lightest red to white coloring representing the heat loss is the area of the face, especially in the area where air is breathed in and out. This is also the same for a building where the greatest heat loss is where heat is being dumped out. If we look at the picture below of an atrium, which looks a well designed building that is very tight where we would not expect to see heat loss.

However, is looking at the following thermogram below we find that there is a lot of heat loss. The white area represent the greatest loss and in the back of the atrium, towards the center top, where we find that the ceiling plenum is not properly insulated and is actually 63.3°F in 31.5°F weather. This is a form of heat loss due to poor insulation.



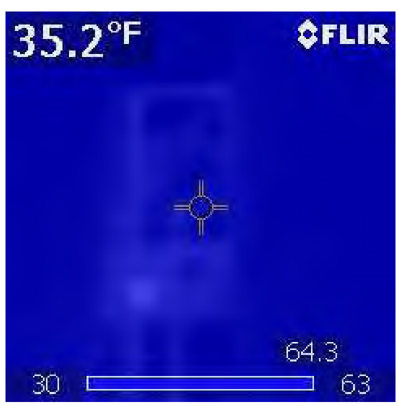
Next we take a look at a typical roof vent, where we see from the thermogram that it is venting so much warm indoor air when it is 33.3°F outside. It is actually taking the temperature of the base of the vent upwards to 63.3°F, almost to room temperature.



What we find is that if you can take this heat energy and recover it you can save a lot of money. This thermogram signature of the roof vent can also be described as thousands of dollars simply being flushed away without any recovery. If energy is recovered from this vent it would save thousands of dollars in heating and cooling on an annual basis. The easiest way to save energy is not to waste it, but rather recover it.

Overall energy savings can be found from reducing run hours of conventional Heating and Cooling Systems, and from greatly improving Energy Efficiency Ratings with less demand charges. One of the biggest benefits we have seen in actual applications is better comfort for building occupants. If energy recovery equipment is properly engineered manufactured and installed it can greatly improve the building occupant's comfort.

What Energy Recovery Can Do



From this thermogram we see what energy recovery can do. Instead of seeing a rooftop unit with massive amounts of energy being expelled, with good energy recovery this completely dark area is where the cool air is coming in at outdoor air temperature. The air that is being exhausted from this subject building is coming out at 35.3°F or basically within a couple of degrees of outdoor air temperature. This leaves the above heat signature, or lack thereof, which shows no warm areas or in a real world application does not leave any hot spots.

It can be noted that if you were trying to do something, let's say for a military application, this effective form of energy recovery would successfully hide the thermal signature from some type of ventilation system in a camp or some type of temporary set up. Of course, another challenge would be to insulate the building well enough so that the building or vehicle itself would not have a heat signature. But, with good energy recovery on the order of 90% plus, the thermal signature of a vehicle would be basically minimized.

Improved IAQ

The next thing we see is that there are advantages with energy recovery having the ability to exhaust and supply outdoor air with greatly reduced cost by retrofitting existing buildings with high efficiency energy recovery equipment for IAQ and added outdoor air intake without increasing existing traditional mechanical heating and cooling equipment.

Having worked as a consulting engineer and evaluated thousands of building over the years for energy efficient upgrades, ventilation remediation and increasing the size of HVAC equipment to be able to handle outdoor air loads, I have often found that the traditional method of increasing outdoor air capacity is to basically increase the heating and cooling plan by about fifty percent. In some instances it can be much greater. The cost is substantial because in addition to the equipment there are additional expenses for the infrastructure, the piping and the electrical power consumption needs for the equipment. In one peer reviewed presentation we found that the cost tripled for installing the increased mechanical equipment.

It can be noted that with very efficient and reliable energy recovery, this cost can be greatly minimized and typically the equipment can be installed for about thirty cents on the dollar compared to mechanical upgrades. The other advantage with highly efficient equipment is that it does not need to have additional heating and cooling in line. It has been shown that using the building itself as a thermodynamic heat and humidity bank at remote locations throughout the building, or in spot areas of high density use, an energy recovery unit can be added to mitigate ventilation and IAQ issues. Again, this needs to be done with careful consideration using an architect or engineer familiar with these types of applications.

Adding Ventilation Controls
(for use with Carbon Dioxide Sensors)

On many application demand side ventilation management in the form of a feedback control loop using a CO_2 or carbon dioxide censor has a lot of advantages and can further increase energy savings. It can be noted that an energy recovery unit with its own fan system can be an integral of demand side management and can greatly enhance the comfort operation of a building and further help to manage the latent and sensible loads of the building.

An interesting application is for offices or classrooms with occupancy sensors. The ventilation loads are generally needed while people are in the immediate area of the occupancy sensor. So, when the occupancy sensor comes on the ventilation comes on. It can be noted that the ASHRAE Standards for Ventilation concurrently only allows demand side ventilation with active CO_2 monitoring. But, with proper application it could reasonably be accepted by Code Officials as an alternative, especially where the finances for a more expensive CO_2 demand side management is not realistic or practical.

<u>Relevant Questions and Answers</u>

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ASHRAE, January, 2008, Two Approaches to Using Energy Recovery to Improve Overall System EER, Coauthor; Klas C. Haglid, P.E. –CEO - Building Performance Equipment Company, Inc.™ and Haglid Engineering Incorporated®.– Coauthor; Sam Beil, Senior Applications Engineer – Berner Energy Recovery, Inc.
Greater use of air-to-air heat exchangers for energy recovery from ventilation air is of increasing importance in green and sustainable buildings where improved IAQ and energy conservation are conflicting requirements. When used with properly sized HVAC equipment, HRV's and ERV's can enable the system to achieve an effective EER that is up to 30% higher than that of the equipment alone. Matching the effective system SHR to the conditioned space latent and sensible loads also leads to improved humidity control. This seminar addresses system concepts that remain underappreciated by the sustainable design community.

Lorman Educational Services, HVAC Codes and Standards, New Jersey, January 9, 2008, Author; Klas C. Haglid, P.E. –CEO - Building Performance Equipment Company, Inc.™ and Haglid Engineering Incorporated®.
Speaking engagement on "HVAC Codes and Standards." For Attorneys, Project Managers, Construction Managers, Presidents, Vice Presidents, Owners, Engineers, Architects, Developers, Building Inspectors, Facilities Managers and House Officials.

Lorman Educational Services, Building Codes in New Jersey, January 30, 2007, Author; Klas C. Haglid, P.E. –CEO - Building Performance Equipment Company, Inc.™ and Haglid Engineering Incorporated®. Speaking engagement on "Building Codes in New Jersey." For Attorneys, Project Managers, Construction Managers, Presidents, Vice Presidents, Owners, Engineers, Architects, Developers, Building Inspectors, Facilities Managers and House Officials.

BOMA - Building Owners & Management Association, October 11, 2006, New Jersey, Klas C. Haglid, P.E. –CEO - Building Performance and Haglid Engineering
Speaking Engagement and Presentation, "Sound Building Operations,- Best Practices, Cost Savings Techniques, Technological Advancements."

ASHRAE - Summer Meeting , June 2006, Quebec City, Canada, Author; Klas C. Haglid, P.E. –CEO - Building Performance Equipment Company, Inc.™ and Haglid Engineering Incorporated®. ASHRAE-SEMINAR 26: Operational Performance Strategies for Energy

Recovery Systems. Speaking Engagement, Seminar and Presentation, "Using Fans Without Dampeners to Control Outdoor Air Intake In An Energy Recovery System: Does it Work?"

NSPE - National Society of Professional Engineers, Klas C. Haglid, P.E. – CEO - Haglid Engineering Incorporated®.
Review of article authored by Drew Peake, "Forensic Engineering of Indoor Air quality" for the National Society of Professional Engineers. June, 2006

Lorman Educational Services, Indoor Air Quality, Energy Efficiency And Code Changes Author; Klas C. Haglid, P.E. –CEO - Haglid Engineering Incorporated®.
Speaking engagement on "Indoor Air Quality, Energy Efficiency And Code Changes - How to Solve the Problems They Create". For Architects, Engineers and Legal continuing education credits.

ASTM - WK2816, Mold Sampling Collection Standard, Coauthor; Klas C. Haglid, P.E. – CEO - Building Performance Equipment Company, Inc.™ and Haglid Engineering Incorporated®. Task force leader for co-authoring and review of ASTM standard for methods and collection of Mold Samples.

Work Statement 2005 - 47 Unitary Equipment, ASHRAE Technical Committee 7.8, Author; Klas C. Haglid, P.E. –CEO - Building Performance Equipment Company, Inc.™ and Haglid Engineering Incorporated®.
Authored Work Statement for proposal to acquire funding and administration of the addition of Unitary Equipment to interactive Web-based Owning and Operating Cost Database for ASHRAE Technical Committee 7.8, Owning and Operating Costs.

ASHRAE 1984 SYSTEMS
TERMINOLOGY AND DEFINITIONS
Internal heat is the total heat generated within the conditioned space. In commercial and industrial buildings the heat is generated by lighting, occupants, equipment and the mechanical heat from the HVAC system (such as fan and heat pump gain and heat of compression). *Internal process heat* is usually derived from industrial activities and sources such as waste water, boiler flue gas, coolants, exhaust air heat and solid waste materials.
External heat is the heat from sources outside the system, i.e., gas, oil, electricity and solar. An external heat source is used to supplement *internal heat* as required to maintain the space temperature within the system.
Waste heat is the sum of the internal and external heat gains available for recovery that would be otherwise rejected from a conditioned space or process.
Stored heat is the internal or external heat sources held in reserve at the time of generation to be used as needed at a different time.
Recovered Heat is that portion of waste heat used to offset heating requirements for space heating, service water heating, air reheat in air conditioning or similar uses within the building system. Recovered heat can be used at the time of recovery or stored for use at a different time.
Utilization temperatures make up the range of temperatures at which heat can be absorbed or rejected to provide heating or cooling within the system.

Breakeven temperature(t_{be}) is the outdoor temperature at which the heat losses from the conditioned spaces and the internal heat are equal.
Balances heat recovery occurs when all the available internal heat is used before external heat is injected. Maintaining balance in the system may require raising the temperature of the reclaimed heat to a usable level (*utilization temperature*) and redistributing this energy in varying amounts to distant locations. Refer to the following section for a more detailed discussion of balanced heat recover and to Chapter 10 for the use of heat pumps in raising the utilization temperature.

1996 ASHRAE Systems and Equipment Handbook

System Installed Cost. Initial installed HVAC system costs are often lower when using air-to-air energy recovery devices because mechanical refrigeration and fuel-fired heating equipment can be reduced in size. Thus, a more efficient HVAC system may also have lower installed total HVAC costs. The installed costs of heat recovery systems become lower per unit of flow as the amount of outdoor air used for ventilation is increased.
Life-Cycle Cost. Air-to-air energy recovery cost benefits are best evaluated considering all the capital, installation, operating and energy-saving costs over the duration of the equipment life under its normal operating conditions in terms of a single cost relationship – the life-cycle cost. As a rule, neither the most efficient nor the least expensive energy recovery device will be most economical. The optimization of the life-cycle cost for maximum net savings may involve a large number of design variables, necessitating careful cost estimates and the use of an accurate model of the recovery system with all its design variables.
Energy Costs. The absolute cost of energy and the relative costs of various energy forms are major economic factors. High energy costs favor high levels of energy recovery. In regions where electrical costs are high relative to fuel prices, heat recovery devices with low pressure drops are preferable.
Other Conservation Options. Energy recovery should be evaluated against other cost-savings opportunities, including reducing or eliminating the primary source of waste energy through process modification.
Amount of Usable Waste Energy. Economies of scale favor large installations. Equipment is commercially available for air-to-air energy recovery applications using 50 cfm and above. Although using equipment with higher effectiveness results in more recovered energy, equipment costs and space requirements also increase with effectiveness.
Grade of Waste Energy. High-grade (i.e. high-temperature) waste energy is generally more economical to recover than low-grade energy. Large temperature differences between the waste energy source and destination are most economical.
Coincidence and Duration of Waste Heat Supply and Demand. Energy recovery is most economical when the supply is coincident with the demand and both are relatively constant throughout the year. Thermal storage may be used to store energy if supply and demand are not coincident, but this adds cost and complexity to the system.
Proximity of Supply to Demand. Applications with a large central energy source and a nearby waste energy use are more favorable than applications with several scattered waste energy sources and uses.

Operating Environment. High operating temperatures or the presence of corrosives, condensables, and particulates in either air-stream result in higher equipment and maintenance costs. Increased equipment costs result from the use of corrosion- or temperature- resistant materials, and maintenance costs are incurred by an increase in the frequency of equipment repair and washdown and additional air filtration requirements.

Effects on Pollution Control Systems. Removing process heat may reduce the cost of pollution control systems by allowing less expensive filter bags to be used, by improving the efficiency of electronic precipitators, or by condensing out contaminant vapors, thus reducing the load on downstream pollution control systems. In some applications, recovered condensables may be returned to the process for reuse.

Effects on Heating and Cooling Equipment. Heat recovery equipment may reduce the size requirements for primary utility equipment such as boilers, chillers, and burners, as well as the size of piping and electrical services to them. Larger fans and fan motors (and hence fan energy) are generally required to overcome increased static pressure losses caused by the energy recovery devices. Auxiliary heaters may be required for frost control.

Effects on Humidifying or Dehumidifying Equipment. Selecting total energy recovery equipment results in the transfer of moisture from the airstream with the greater humidity ratio to the airstream with the lesser humidity ratio. In many situations this is desirable because humidification costs are reduced in cold weather and dehumidification loads are reduced in warm weather.

TECHNICAL CONSIDERATIONS

Performance Rating

ASHRAE *Standard* 84, Method of testing Air-to-Air Heat Exchangers, establishes rating and testing procedures for commercial air-to-air heat recovery equipment. CAN/CSA-C429, Standard Methods of test for Rating the Performance of Heat-Recovery Ventilators, is used to rate small (under 400cfm) packaged ventilators with heat recovery.

The effectiveness of air-to-air heat exchangers is commonly measured in terms of

- Sensible energy transfer (dry-bulb temperature)
- Latent energy transfer (humidity ratio)
- Total energy transfer (enthalpy)

ASHRAE *Standard* 84 defines effectiveness as

$$\acute{\varepsilon} = \frac{\text{Actual transfer (of moisture or energy)}}{\text{Maximum possible transfer between airstreams}}$$

NAFE - National Academy of Forensic Engineers, July, 2005, Chicago, Illinois, Author; Klas C. Haglid, P.E. –CEO - Building Performance Equipment Company, Inc.™ and Haglid Engineering Incorporated®. Speaking Engagement and Presentation: "Forensic Evaluation of Mismanaged renovation?" Presentation demonstrated advanced computer graphic to present very complicated delay claims and project renovation issues for a million plus square foot renovation.

ASHRAE - Winter Meeting , Orlando, Florida, February 2005, Author; Klas C. Haglid, P.E. –CEO - Building Performance Equipment Company, Inc.™ and Haglid Engineering Incorporated®. Speaking Engagement, Seminar and Presentation, "Size Matters: Using Air-to-Air Energy Recovery to Meet the Humidity Control Requirements in ASHRAE Standard 62.1 Addendum X".

New York ASHRAE Chapter-High Performance Engineering, April 19, 2005, Author; Klas C. Haglid, P.E. –CEO - Building Performance Equipment Company, Inc.™ and Haglid Engineering Incorporated®. Annual Spring Symposium and Professional Development Seminar

Tuesday In Celebration of Earth Day 2005 Owego, New York

Presented "Buildings that did Not Understand ANSI/ASHRAE Std 62"

Department of Defense - Industrial Workshop, Orlando, Florida, February 2004 Author; Klas C. Haglid, P.E. –CEO - Building Performance Equipment Company, Inc.™ and Haglid Engineering Incorporated®. U.S. Army Corps of Engineers, ERDC-CERL, Speaking engagement and presentation, "Dehumidification: Using Air-to-Air Energy Recovery to meeting the Humidity Control Requirements in ASHRAE Standard 62.1 Addendum X".

NSPE - National Society of Professional Engineers - Annual Meeting 2004, Washington, DC, Author; Klas C. Haglid, P.E. –CEO - Building Performance Equipment Company, Inc.™ and Haglid Engineering Incorporated®.

Presented paper, "Forensic Engineering Analysis of Carbon Monoxide Poisoning in a Residence".

ASHRAE - Winter Meeting, Anaheim, California Author; Klas C. Haglid, P.E. –CEO - Building Performance Equipment Company, Inc.™ and Haglid Engineering Incorporated®.

Speaking Engagement, Seminar and Presentation, "Using Air-to-Air Energy Recovery to Comply with 90.1 and Score with LEED".

2004 ASHRAE Summer Convention, Nashville, Tennessee Author; Klas C. Haglid, P.E. –CEO - Building Performance Equipment Company, Inc.™ and Haglid Engineering Incorporated®.

Speaking engagement and presentation, "Avoid Mold and Get Gold - Means of Controlling Humidity. Why ***not*** to Oversize and HVAC System".

Journal of the National Academy of Forensic Engineers Author; Klas C. Haglid, P.E. –CEO - Haglid Engineering Incorporated®.
Wrote an article on Forensic Investigation of Carbon Monoxide Poisoning in a Residence, published in the Journal of the National Academy of Forensic Engineers, Vol. XXI No.1, June 2004.

NSPE - National Society of Professional Engineers - Boston Massachusetts Author; Klas C. Haglid, P.E. –CEO - Building Performance Equipment Company, Inc.TM and Haglid Engineering Incorporated®.
Forensic Engineering of Indoor Air Quality - Peer review of National Journal Publications.

Department of Defense - Industrial Workshop, February, 2004, Gettysburg, Pennsylvania, Using Air-to -Air Energy Recovery for Industrial Process and Energy Optimization to Comply with 90.1 and Score with LEED, Author; Klas C. Haglid, P.E. –CEO - Building Performance Equipment Company, Inc.TM and Haglid Engineering Incorporated®.
U.S. Army Corps of Engineers ERDC-CERL
Speaking engagement and presentation, "Using Air-to -Air Energy Recovery for Industrial Process and Energy Optimization to Comply with 90.1 and Score with LEED".

ASHRAE Summer 2003 Convention, Kansas City, Kansas, Using Air-to -Air Energy Recovery for Industrial Process and Energy Optimization to Comply with 90.1 and Score with LEED, Author; Klas C. Haglid, P.E. –CEO - Building Performance Equipment Company, Inc.TM and Haglid Engineering Incorporated®.
Speaking engagement and presentation, "The Building That Did Not Understand ASHRAE Standard 62-1999". A technical analysis of building failure and solutions to indoor air quality issues.

ASHRAE Manuscript Review, By Klas C. Haglid, P.E. –CEO - Building Performance Equipment Company, Inc.TM and Haglid Engineering Incorporated®
Reviewed Manuscript Title: "Uncertainty-Based Quantitative Model for Assessing Risks in Existing Buildings, date of review - May 21, 2003.

NSPE - Nationals Society of Professional Engineers - Annual Meeting 2003, Washington, DC, Forensic Investigation of Carbon Monoxide Poisoning, Author; Klas C. Haglid, P.E. –CEO - Building Performance Equipment Company, Inc.TM and Haglid Engineering Incorporated®.
Presented an article on Forensic Investigation of Carbon Monoxide Poisoning in a Residence

Journal of the National Academy of Forensic Engineers, Author; Klas C. Haglid, P.E. –CEO Haglid Engineering Incorporated®.
Authored an article "Forensic Engineering Analysis of a Clean Room Failure", published in the Journal of the National Academy of Forensic Engineers, Vol. XIX No. 2 December 2002.

ASHRAE Winter Convention - 2002, Atlantic City, New Jersey, Author; Klas C. Haglid, P.E. –CEO - Building Performance Equipment Company, Inc.™ and Haglid Engineering Incorporated®.
Speaking engagement and open forum discussion with expert ASHRAE membership to discuss simulated versus real date for Owning and Operating Costs for Commercial Buildings.

1984 ASHRAE Handbook, HVAC Systems Volume, Chapter 7 – heat Recovery Systems. Published by ASHRAE – American Society of heating, Refrigerating and Air-Conditioning Engineers, Inc. 1791 Tullie Circle, N.E., Atlanta, GA 30329.

1996 ASHRAE Handbook, HVAC Systems and Equipment, Chapter 42 – Air to Air Energy Recovery. Published by ASHRAE – American Society of heating, Refrigerating and Air-Conditioning Engineers, Inc. 1791 Tullie Circle, N.E., Atlanta, GA 30329

2000 ASHRAE Handbook, HVAC Systems and Equipment, Chapter 44 – Air to Air Energy Recovery. Published by ASHRAE – American Society of heating, Refrigerating and Air-Conditioning Engineers, Inc. 1791 Tullie Circle, N.E., Atlanta, GA 30329

2004 ASHRAE Handbook, HVAC Systems and Equipment, Chapter 44 – Air to Air Energy Recovery. Published by ASHRAE – American Society of heating, Refrigerating and Air-Conditioning Engineers, Inc. 1791 Tullie Circle, N.E., Atlanta, GA 30329.

2004 ASHRAE Handbook, HVAC Systems and Equipment, Chapter 25 – Air to Air Energy Recovery and Chapter 47 – Heat Exchangers. Published by ASHRAE – American Society of heating, Refrigerating and Air-Conditioning Engineers, Inc. 1791 Tullie Circle, N.E., Atlanta, GA 30329

Author's Bio

Klas Haglid, P.E.
Short Resume

Klas Haglid, P.E. is CEO and President of both Building Performance Equipment Company, Inc.™ a firm that manufactures very high efficiency air to air energy recovery equipment and Haglid Engineering Incorporated®., a firm providing HVAC, Mechanical and Structural services for commercial and industrial properties. Klas is past Chairman of ASHRAE Technical Committee 5.5 *Air to Air Energy Recovery* and past Chairman of ASHRAE Technical Committee 7.8 *Owning and Operating Costs*. As an active member of ASHRAE he has moderated forums, seminars and presented at several ASHRAE Annual Meetings and published extensively on issues surrounding energy recovery and building related HVAC issues. Having worked in Central Research for DuPont, Staff Consultant for Atlantic Electric and The United States Depart of Energy for Ecolinks Projects providing energy efficient retrofits and solving many different HVAC challenges has provided practical experience to solve challenges. Klas also holds a number of patents for systems combining energy recovery devices with innovative controls to make building work more efficiently and reduce owning and operating costs.

Haglid Engineering and Building Performance are both companies that enjoy improving people's lives through excellence in engineering and creative thinking that allow buildings to work more efficiently while improving indoor air quality and peoples' comfort. By using sustainable, renewable and recovering energy we can use less of our scarce resources today and save them for tomorrow's use by our children and the generations to follow.

Current Professional Engineering License Numbers are as follows:
Connecticut License Number: PEN.23339
Delaware License Number: 8842
Hawaii License Number: 8166
Maryland License Number: 25562
Massachusetts License Number: 42776
New Jersey License Number: GE 40184
New York License Number: 080150
Oregon License Number: 17732PE
Pennsylvania License Number: PE-049727-E
Vermont License Number: 8140
Virginia 0402 042994
Current National NCEES Record