TRANE

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energy-conscious design ideas

Air-to-Air Energy Recovery

from the authors…
Energy consumption costs money, uses natural resources, increases air pollution, and contributes to global warming. We all share responsibility for prudent energy use.

The mechanical heating, ventilating, and air-conditioning (HVAC) system accounts for a sizable portion of a building's energy costs. Heat gains and losses from various sources must be offset to create a comfortable, healthy indoor environment. Discarded heat from one location may be useful elsewhere in the building, so it's logical (and often cost-effective) to recover energy that might otherwise be wasted … particularly in a time of rising energy costs and deregulated utility rates.

Energy-Recovery Technologies

"Air-to-air energy recovery" refers to the transfer of sensible heat, or sensible and latent heat, between air streams. The 2000 *ASHRAE Handbook—Systems and Equipment* compares the most common technologies for air-to-air energy recovery.

Sensible-energy recovery systems transfer only sensible heat. Adding sensible heat raises an air stream's dry-bulb temperature; removing sensible heat lowers the dry bulb. (Removing sensible heat may cause condensation, too, but it never prompts moisture transfer to the colder air stream.)

Common examples of sensible-energy recovery devices include coil loops, fixed-plate heat exchangers, heat pipes, and sensible-energy rotary heat exchangers (sensible-energy wheels). All of these devices perform identically on the psychrometric chart; only their effectiveness differs.

Total-energy recovery systems not only transfer sensible heat, but latent heat as well—that is, energy stored in water vapor in the air stream. Such systems raise and lower both the dry bulb and dew point of an air stream.

Common examples of total-energy recovery devices include total-energy rotary heat exchangers (also known as total-energy wheels) and fixed-membrane heat exchangers.

Worth the Risk?

Questions about reliability have historically dogged rotary energy-recovery devices. Consequently, many designers are reluctant to reduce heating-plant capacity, even though the total-energy wheel makes the extra heating capacity redundant.

A wheel differs little from a supply fan, however. If the wheel "breaks" due to a failed bearing, belt, or motor, the faulty component must be fixed to assure continued operation of the system. As wheels become more widely used and accepted, reductions in heating-plant capacity should become more common. ■

Why Recover Energy?

To help answer this question and to frame our discussion of air-to-air energy recovery, let's categorize building ventilation systems based on the source of the air supplied to occupied spaces.

Dedicated outdoor-air systems supply only first-pass outdoor air. For this discussion, a central air handler (with a mechanical cooling coil) delivers the ventilation air either:

- at low temperature, usually to local mixed-air units; or
- at space-neutral temperature, usually to a mixing plenum or directly to each space.

Mixed-air systems supply a blend of outdoor air and recirculated return air to each space. The central air handler delivers the supply air either:

- at modulated temperature and constant volume, usually to a single space; or
- at low temperature and varying volume, usually to multiple spaces.

Within the context of these ventilation systems, recovered energy can be used for two purposes: [1] to **temper (or reheat) supply air** for independent control of space latent and sensible loads, or [2] to **precondition outdoor air** as it enters the building for ventilation. Only systems that control supply-air dew point or space relative humidity are candidates for supply-air tempering. Any system may use preconditioning to reduce the outdoor-air load. Some systems benefit from both supply-air tempering *and* outdoor-air preconditioning. Table 1 summarizes these applications of air-to-air energy recovery.

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

Ventilation System		Energy-Recovery Technology	
Source	Supply-Air Temperature	Supply-Air Tempering	Outdoor-Air Preconditioning
Dedicated outdoor air	Cold	Not applicable	■ Sensible or total
	Neutral	■ Sensible (parallel or series)	■ Sensible or total
Mixed air (outdoor air *plus* recirculated return air)	Modulated (constant volume)	■ Sensible (parallel or series)	■ Sensible or total
	Cold (variable volume)	Not applicable	■ Sensible or total

Tempering supply air requires sensible-energy recovery to raise the dry-bulb temperature of the supply air without changing its dew point. Total-energy recovery would defeat the purpose of tempering during dehumidification. Supply-air tempering is only needed during mechanical cooling operation.

Outdoor-air preconditioning offers heat-recovery benefits during both mechanical cooling and heating operation. System economics determine whether preconditioning should employ sensible- or total-energy recovery. Often, the savings in first cost and operating cost make total-energy recovery the obvious best choice.

Tempering Supply Air. Dedicated outdoor-air systems designed to deliver **cold**, dry ventilation air to other (usually mixed-air) units do not require supply-air tempering, so energy recovery is not suitable for that purpose.

The opposite is true of dedicated outdoor-air systems designed to deliver **neutral**, dry ventilation air (usually directly to occupied spaces or to ceiling plenums). Sensible-energy recovery may benefit such systems because it offers a "reheat" alternative that complies with energy codes and standards. It may also decrease first cost and operating cost when compared with approaches that use new energy for tempering.

As depicted in Figure 1, sensible heat may be recovered from the exhaust air stream and transferred to the supply air. Any sensible-energy recovery technology can be used. Coil-loop systems are shown because they are usually inexpensive and can be adapted to various system designs.

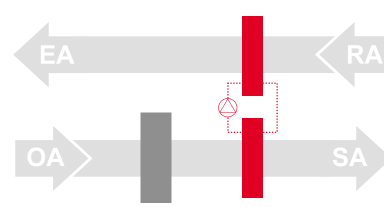
"Parallel" recovery of energy saves the cost of tempering (reheating) the supply air with new energy. It does not reduce the first cost of the cooling plant, however, when compared to supply-air tempering with new energy.

Alternatively, sensible heat may be transferred from the outdoor air upstream of the dehumidifying coil to the supply air. "Series" transfer of energy, also shown in Figure 1, reduces the need for tempering with new energy. It also permits a reduction of cooling-plant capacity when compared with other strategies for supply-air tempering.

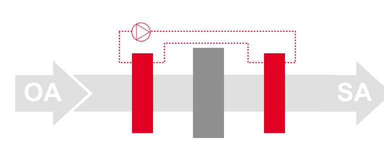
Warming the supply air to neutral temperature using series heat transfer may require capacity control to avoid overheating the supply air when it is warm outside. Also, supplemental heat may be warranted when the outdoor-air temperature is too cool to provide sufficient tempering.

Mixed-air, constant-volume systems that deliver variable-temperature supply

Figure 1. Sensible-Energy Recovery to Temper Dedicated Outdoor Air



Parallel recovery (stream to stream)



Series transfer (upstream to downstream) air also need supply-air tempering if they directly control both temperature and relative humidity in the space. Such systems can usually benefit from sensible-energy recovery or transfer.

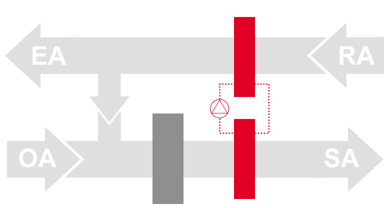
Figure 2 illustrates two arrangements. "Parallel" recovery transfers sensible energy from return air to supply air; it can eliminate the cost of tempering with new energy, but will not reduce the first costs associated with heating- and cooling-plant capacities.

The "series" arrangement transfers sensible energy from the mixed air *entering* the cooling coil to the supply air *leaving* the cooling coil. It reduces or eliminates the need for tempering with new energy; the mixed air is usually warm enough to temper during most conditions that require dehumidification.

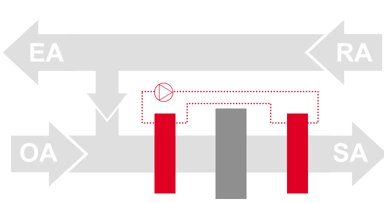
Unlike its application in dedicated outdoor-air systems, series energy transfer in mixed-air systems does *not* reduce cooling-plant capacity. That's because no energy transfer occurs at the design cooling condition.

Mixed-air, variable-air-volume (VAV) systems, which deliver constant-

Figure 2. Sensible-Energy Recovery to Temper Mixed Air



Parallel recovery (stream to stream)



Series transfer (upstream to downstream)

temperature supply air to local VAV terminals, do not require supply-air tempering at the central air handler. Although some spaces may need local supply-air tempering (reheat) at part load, local air-to-air energy recovery is not economically feasible.

Preconditioning Outdoor Air. Buildings must be ventilated with outdoor air to prevent the buildup of contaminants generated indoors. Any sensible- or total-energy recovery technology can precondition outdoor air brought into the building by any of the four ventilation systems in Table 1. In summer, total-energy recovery can precool and pre-dry outdoor air by rejecting both sensible and latent heat to the exhaust air. In winter, it can preheat and pre-humidify outdoor air by removing both sensible and latent heat from the exhaust air.

Any energy-recovery system used to precondition outdoor air is subject to frost buildup during cold weather. Sensible-energy recovery systems must include controls to prevent frost formation when the temperature outside drops below 28°F (estimated for return air at roughly 30 percent relative humidity). The frost-prevention threshold for total-energy recovery systems is much lower, about –5°F, because they remove moisture from the exhaust air stream.

Frost can be avoided either by reducing energy-recovery capacity to raise the surface temperature of the heat exchanger, or by preheating the outdoor air before it enters the heat exchanger.

For total-energy systems, preheating extends operating-cost savings by permitting continued energy recovery

Determining Effectiveness and Energy Transfer

ARI Standard 1060–2000, *Rating Air-to-Air Energy Recovery Ventilation Equipment,* provides the following equation to describe the effectiveness of an air-to-air heat exchanger used to recover energy:

$$\varepsilon = \frac{w_s \cdot (x_1 - x_2)}{w_{min} \cdot (x_1 - x_3)} = \frac{w_e \cdot (x_4 - x_3)}{w_{min} \cdot (x_1 - x_3)}$$

where:

- ε = sensible, latent, or total effectiveness
- x_1 = dry bulb (°F), humidity ratio (gr/lb), or enthalpy (Btu/lb) of entering supply air
- x_2 = dry bulb (°F), humidity ratio (gr/lb), or enthalpy (Btu/lb) of leaving supply air
- x_3 = dry bulb (°F), humidity ratio (gr/lb), or enthalpy (Btu/lb) of entering exhaust air
- x_4 = dry bulb (°F), humidity ratio (gr/lb), or enthalpy (Btu/lb) of leaving exhaust air
- w_s = mass flow rate of supply air
- w_e = mass flow rate of exhaust air
- w_{min} = the smaller mass flow rate (supply or exhaust air)

For a given heat-exchanger geometry, ε can be determined at test conditions for various flow rates. Generally, as the airflow rate decreases, ε increases but the overall energy transfer decreases.

How much heat will a total-energy recovery device transfer? The answer lies in this equation:

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

where:

- Q_t = total heat flow, Btu/h
- V_{min} = the smaller airflow (supply or exhaust), cfm
- h_1 = entering supply-air enthalpy, Btu/lb
- h_3 = entering exhaust-air enthalpy, Btu/lb

For sensible heat transfer,

$$Q_s = \varepsilon \cdot 1.085 \cdot V_{min} \cdot (t_1 - t_3)$$

where:

- Q_s= sensible heat flow, Btu/h
- t_1 = entering supply-air dry bulb, °F
- t_3 = entering exhaust-air dry bulb, °F ■

during very cold weather. On the other hand, reducing energy-recovery capacity at the heating-design condition reduces first-cost savings in the heating plant and extends the payback period for the investment in energy-recovery equipment.

Note: Although the schematics in this newsletter don't show the combined use of energy recovery for supply-air tempering and outdoor-air preconditioning, coincident application of both arrangements may be beneficial in certain cases and should be analyzed. Total-energy wheels are depicted because they recover both sensible and latent energy, which usually makes them the most cost-effective choice for preconditioning.

Our investigations show that when preconditioning outdoor air, a total-energy wheel provides the greatest favorable impact on first cost—and usually the best payback potential. Let's look more closely at the operation of systems that use total-energy recovery to precondition outdoor air.

Preconditioning for Dedicated Outdoor Air

A system that includes a dedicated outdoor-air unit (Figure 3) can benefit from preconditioning with total-energy recovery, if properly applied and controlled. This holds true whether the dedicated air handler delivers the preconditioned outdoor air to other mixed-air units or directly to the occupied spaces.

"Subsidizing" First Cost. To demonstrate, consider the HVAC system designed for a year-round school in Jacksonville, Florida. (Figure 4 outlines the design conditions and airflows.) A total-energy wheel in the school's central air handler preconditions 10,000 cfm of outdoor air. Local bathroom exhaust and exfiltration limit central exhaust airflow to 7,000 cfm.

The total-energy wheel, operating with unbalanced airflow and an effectiveness of 82 percent, removes 270,000 Btu/h from the outdoor air at the design cooling condition, which reduces the design capacity of the cooling plant by 22.5 tons. At an incremental cost of $500 per ton, the resulting cooling-plant savings of $11,300 can be used to subsidize the cost of the wheel.

Although the total-energy wheel removes both sensible and latent energy from the exhaust air, only the sensible portion can be used to reduce heating-plant capacity during the heating season. Without the bathroom exhaust, the total-energy wheel (still with an effectiveness of 82 percent) recovers 243,000 Btu/h from the exhaust air. Wheel operation can reduce the design capacity of the heating plant as well as its first cost. Assuming an incremental cost of $20 per 1,000 Btu/h, the resulting heating-plant savings approximate $4,900.

Figure 4. Design Parameters for Example School in Jacksonville, Florida

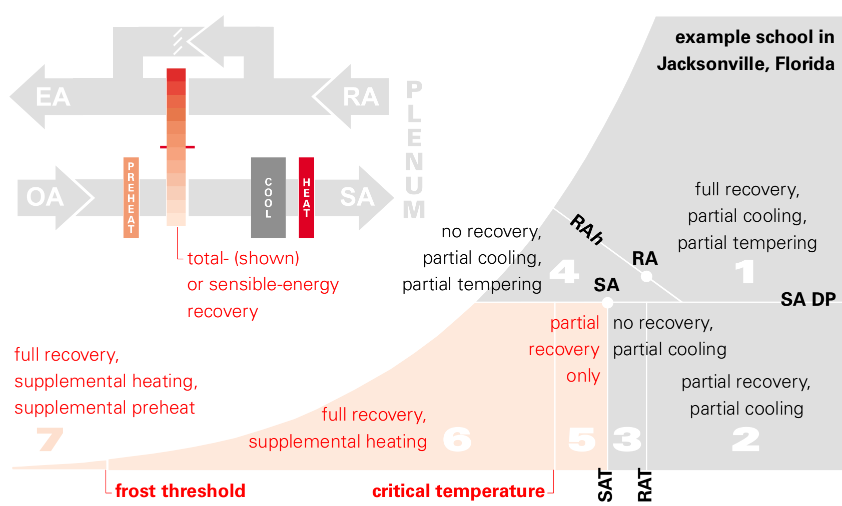
HVAC system
- 2,600 operating hours annually
- central air handler with total-energy wheel, 82% effective
- separate bathroom exhaust

Cooling design
- Outdoor air: 96°F DB, 76°F WB, 39.31 Btu/lb enthalpy
- Return air: 78°F DB, 63.5°F WB, 28.81 Btu/lb enthalpy

Heating design
- 31°F DB outdoor air
- 70°F DB return air

Design airflows
- 10,000 cfm outdoor air
- 7,000 cfm central exhaust air
- 2,500 cfm local exhaust air (bathroom)
- 500 cfm exfiltration

Figure 3. Control Modes for Preconditioned Outdoor Air and Neutral Supply Air



Note: In very cold climates, the latent energy (moisture) recovered from the exhaust air can also be used to offset the first cost and operating cost of the humidification system.

Despite reducing the effectiveness of the wheel to 72 percent, ducting the bathroom exhaust to the central air handler would improve airflow balance. It would also increase overall energy recovery—cutting 26.9 tons ($13,500) from the cooling plant and 290,000 Btu/h ($5,800) from the heating plant. Plant savings grow from $16,200 to $19,300. Clearly, adding the bathroom exhaust to the central air stream makes better use of the additional investment in energy recovery … and not just in Jacksonville.

The analysis for an identical school in Minneapolis indicates that the total-energy wheel provides additional plant first-cost savings: $19,600 to $22,600 ($8,300 to $9,800 in the cooling plant, $11,300 to $12,800 in the heating plant).

In either location, the savings in plant capacities can at least partially fund the investment in the wheel and associated ductwork, as well as the incremental increase in fan horsepower.

Proper Operation. A dedicated, neutral ventilation system configured for preconditioning outdoor air, as shown in Figure 3, can be operated in seven distinct, psychrometrically defined modes (Table 2). Proper operation within each mode and proper transition between modes maximizes energy savings and minimizes the payback period.

Note: Other unit configurations and control schemes may require the definition of additional and/or different modes of operation.

Region 1: Full recovery, partial cooling, partial tempering. All energy recovered at these outdoor conditions lessens the mechanical cooling load. To recover as much cooling energy as possible, run the total-energy wheel and modulate the cooling coil and supplemental heat to maintain the supply-air dry bulb.

Region 2: Partial recovery, partial cooling. The outdoor conditions that this region represents are found mostly in hot, dry climates. Using the exhaust-air bypass damper, modulate the capacity of the total-energy wheel to recover as much energy as possible while maintaining the supply-air dew point at or below the target. Modulate the capacity of the cooling coil to maintain the supply-air dry bulb.

Note: Varying the wheel's rotational speed is often used to modulate the capacity of the wheel rather than varying the position of the exhaust-air bypass damper. We prefer the bypass damper because it is less expensive to install and operate, is easier to control, and operates stably over a wider range of conditions.

Region 3: No recovery, partial cooling. Operating the wheel at these psychrometric conditions would increase the cooling load rather than decrease it. To avoid recovering unwanted heat, turn off the total-energy wheel. Open the bypass damper to divert the exhaust air stream around the inactive wheel, thereby reducing fan horsepower. Modulate the cooling coil to maintain the supply-air dry-bulb temperature.

Region 4: No recovery, partial cooling, partial tempering. As in Region 3, operating the wheel would actually increase the mechanical cooling load. To avoid unnecessarily adding heat and moisture, turn off the total-energy wheel, open the bypass damper, and modulate the cooling coil and supplemental heat to maintain the supply-air dry bulb.

Table 2. Control Modes for Preconditioned Outdoor Air and Neutral Supply Air

Control Mode (see Figure 3)	Psychrometric Conditions[a]	Annual Operation, hr (%)[b] Jacksonville, Fla.	Minneapolis, Minn.
1 Full recovery, partial cooling, partial tempering	OA enthalpy > RA enthalpy OA DP > SA DP target	1,584 hr (61%)	468 hr (18%)
2 Partial recovery, partial cooling	OA DB > RA DB OA DP < SA DP target	15 hr (<1%)	20 hr (<1%)
3 No recovery, partial cooling	SA DB < OA DB < RA DB OA DP < SA DP target	42 hr (<2%)	34 hr (<2%)
4 No recovery, partial cooling, partial tempering	OA enthalpy < RA enthalpy OA DP > SA DP target	414 hr (16%)	333 hr (13%)
5 Partial recovery only	OA DB < SA DB OA DP < SA DP target	76 hr (3%) [151 hr (6%)]	61 hr (2%) [165 hr (6%)]
6 Full recovery, supplemental heating	OA DB < critical temperature	469 hr (18%) [394 hr (15%)]	1,640 hr (63%) [1,536 hr (59%)]
7 Full recovery, supplemental heating, supplemental preheat	OA DB ≤ frost threshold	0 hr (0%)	44 hr (<2%)

[a] OA = outdoor air, RA = return air, SA = supply air, DB = dry bulb, DP = dew point

[b] Annual operation is based on 10,000 cfm of outdoor air and 7,000 cfm of exhaust air. Values enclosed in brackets [] represent annual operation based on 9,500 cfm of exhaust air (i.e., the addition of the bathroom exhaust).

Region 5: Partial recovery only. Increased hours in this mode equate to fewer hours of heating-plant operation. Modulate the heating capacity of the total-energy wheel by controlling bypass airflow to maintain the supply-air temperature. (This strategy avoids overheating the supply air.) Only fan energy is required in this mode. The total-energy wheel is not at full heating capacity, so the recovered energy eliminates the heating-plant load.

A quick review of Table 2 reveals that centralizing the bathroom exhaust doubles the hours of Region 5 operation in both Jacksonville and Minneapolis.

Note: Don't make the mistake of continuously operating the wheel at full capacity. Recooling overheated outdoor air will increase energy consumption at the cooling plant.

Region 6: Full recovery, supplemental heating. To recover as much heat as possible from the exhaust air when it's cold outside, turn on the total-energy wheel (with bypass damper closed), and modulate the heating coil to control the supply-air dry bulb. Implement this mode when the outdoor air is colder than the "critical temperature."

Note: The "critical temperature" is a threshold defined by the supply-air dry bulb, return-air dry bulb, and the effectiveness of the wheel at full capacity. It marks the condition at which the wheel, operating at full heating capacity, can no longer maintain the target supply-air dry bulb.

Decreased hours at Region 6 conditions mean decreased hours of heating-plant operation.

Region 7: Full recovery, supplemental heating, supplemental preheat. To protect against frost formation on the exhaust side of the wheel, the wheel surface temperature must be maintained above the exhaust-air threshold temperature for frost. Modulated, supply-side preheat accomplishes this task while maximizing energy-recovery capacity.

Note: All energy-recovery devices, both sensible and total, require frost protection. As noted earlier, avoid frost-protection methods that reduce heat-recovery capacity (for example, slowing the wheel speed).

Preconditioning for Mixed Air

In mixed-air systems (Figure 5), a central air handler delivers a blend of outdoor air and recirculated return air to one or more occupied spaces. If properly applied and controlled, such systems can benefit from preconditioning with total-energy recovery. Although the benefit exists for constant- and variable-volume air distribution, our discussion considers only VAV (variable-air-volume) systems.

"Subsidizing" First Cost. For the same quantity of outdoor air, the total-energy wheel provides the same cooling- and heating-plant savings, regardless of how the supply air is distributed.

Remember the cost savings described for the school in Jacksonville? Adding a total-energy wheel to the dedicated outdoor-air handler permitted downsizing of the cooling and heating plants … *and* yielded a first-cost "subsidy" of $16,200 to $19,300. If the same school is instead served by a constant- or variable-volume mixed-air system—and the minimum ventilation requirement is unchanged (10,000 cfm of outdoor air)—the first-cost "subsidy" of adding a total-energy wheel remains $16,200 to $19,300.

Proper Operation. Figure 5 illustrates six distinct operating modes for a mixed-air system. These control modes are summarized in Table 3; a brief description of each mode follows.

Table 3. Control Modes for Preconditioned Mixed Air and Cold Supply Air (VAV)

Control Mode (see Figure 5)	Psychrometric Conditions[a]	Annual Operation, hr (%)[b] Jacksonville, Fla.	Annual Operation, hr (%)[b] Minneapolis, Minn.
1 Full recovery, partial cooling	OA enthalpy > RA enthalpy	1,585 hr (61%)	468 hr (18%)
2 No recovery, economizer, supplemental cooling	OA DB > SA DB OA enthalpy < RA enthalpy	672 hr (26%)	701 hr (27%)
3 No recovery, economizer only	OA DB < SA DB OA airflow > minimum set point	281 hr (11%)	410 hr (16%)
4 Partial recovery only	OA airflow = minimum set point OA DB > critical temperature	62 hr (2%) [62 hr (2%)]	496 hr (19%) [853 hr (32%)]
5 Full recovery, supplemental heating	OA DB < critical temperature	0 hr (0%)	481 hr (18%) [124 hr (5%)]
6 Full recovery, supplemental heating, supplemental preheat	OA DB ≤ frost threshold	0 hr (0%)	44 hr (<2%)

[a] OA = outdoor air, RA = return air, SA = supply air, DB = dry bulb, DP = dew point

[b] Annual operation is based on 10,000 cfm of outdoor air and 7,000 cfm of exhaust air. Values enclosed in brackets [] represent annual operation based on 9,500 cfm of exhaust air (i.e., the addition of the bathroom exhaust).

Region 1: Full recovery, partial cooling. All energy recovered at these conditions reduces the mechanical cooling load. To maximize the recovery of cooling energy, run the total-energy wheel and modulate the cooling coil to maintain the supply-air dry bulb.

Implement this mode when outdoor-air enthalpy exceeds return-air enthalpy. Basing operation on temperature rather than enthalpy not only misses many hours of energy recovery, but also yields many hours of wheel operation that add to the cooling-plant load.

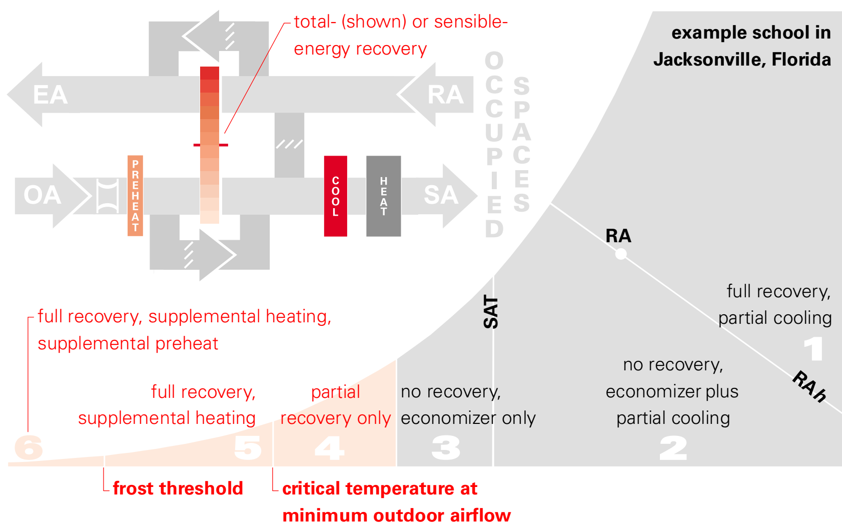
Region 2: No recovery, economizer plus partial cooling. This is the familiar "economizer-plus-mechanical cooling" mode. No energy is available for recovery, so wheel operation would increase the mechanical cooling load and operating cost. To avoid recovering unnecessary heat and moisture, turn off the total-energy wheel, open both bypass dampers, and modulate the cooling coil to maintain the supply-air dry bulb. Diverting airflow around the wheel when it's off saves fan energy. It also allows the wheel to be sized for ventilation airflow only, not economizer airflow.

What about Operating Costs?

Typically, the "real" money in air-to-air energy recovery accrues from the first-cost "subsidy" (plant-capacity savings applied to the cost of the wheel) rather than lower operating costs. Still, if first-cost savings do not entirely offset the initial investment in the wheel, operating-cost savings may quickly make up the difference.

The interaction between wheel control modes and economizer operation justifies a detailed economic analysis using a tool such as TRACE™ or DOE-2. Such an analysis can predict the length of the payback period based on building location, building type, HVAC system type, HVAC system control, and local utility rates. ■

Figure 5. Control Modes for Preconditioned Mixed Air and Cold Supply Air (VAV)



Region 3: No recovery, economizer only. Again, no energy is available for recovery at Region 3 conditions. To avoid recovering unnecessary heat, turn off the total-energy wheel, open both bypass dampers, and modulate outdoor airflow to maintain the supply-air dry bulb.

Note: "Free cooling" (Region 2 and Region 3) with outdoor air accounts for 37 percent of the school's operating hours in Jacksonville compared to 43 percent in Minneapolis … not much difference despite the disparity of climates.

Region 4: Partial recovery only. Increased hours in this mode mean fewer hours of heating-plant operation.To maintain the supply-air dry bulb without overheating, modulate the capacity of the total-energy wheel by controlling bypassed exhaust airflow with the supply-side bypass damper closed. Only fan energy is required in this mode because the wheel is not at full capacity. Recovered energy satisfies the entire heating-plant load.

Although centralizing the bathroom exhaust would not extend operation in Jacksonville, Region 4 conditions would increase from 540 hours (21percent) to 897 hours (34 percent) in Minneapolis.

Note: Don't operate the total-energy wheel continuously at full capacity when outdoor conditions correspond to Region 2, Region 3, or Region 4. Recooling overheated outdoor air increases energy consumption at the cooling plant.

Region 5: Full recovery, supplemental heating. When it's cold outside, turn on the total-energy wheel (with bypass dampers closed) to recover as much heat as possible from the exhaust air. Modulate the heating coil to control the supply-air dry bulb. Decreased hours at Region 5 conditions mean that the heating plant operates less.

Region 6: Full recovery, supplemental heating, supplemental preheat. Modulated, supply-side preheat protects against frost formation while maximizing energy-recovery capacity. Implement this mode when the exhaust-air temperature equals or is less than the frost-threshold temperature.

Note: Many designers reduce heat-recovery capacity to keep the surface of the wheel warm, thereby avoiding frost. This practice limits first-cost savings for the heating plant. Preheat keeps wheel capacity high when you need it and can substantially reduce the first cost of the heating plant.

What about Controls?

Our necessarily high-level description of energy-recovery operation didn't provide control details. Suffice it to say that an air handler with total-energy-wheel preconditioning poses a control challenge in both dedicated-outdoor-air and mixed-air systems.

Factory-installed controls with preprogrammed control sequences can minimize controls engineering in the field and assure a system that delivers optimum performance.

When bypass dampers control wheel capacity, air pressure in the mixing box fluctuates; therefore, outdoor airflow must be measured and the intake damper must be modulated to maintain the minimum outdoor airflow. Building pressure must be controlled as well.

Note that the return-air pressure also changes with wheel capacity when the central mixed-air unit includes bathroom exhaust. In these applications, bathroom-exhaust airflow must be sensed and maintained at constant flow.

Consider these important control alternatives the next time you design an HVAC system that preconditions outdoor air using total-energy recovery:

- Control wheel capacity using bypass dampers to minimize fan energy and increase control stability.
- Use preheat for freeze protection to minimize the first cost of the heating plant.

Sage Advice

Prudent energy use is important for any HVAC system, but it is particularly relevant for applications such as schools, which require large amounts of outdoor air for proper ventilation. Through our discussion of energy-recovery technologies for various ventilation systems, we identified ways to increase the heating and cooling benefits derived from energy consumed by an HVAC system:

- For systems that use a cold coil to control the latent load, apply energy recovery to reduce the operating cost of tempering.
- In *any* air distribution system, use total-energy recovery for outdoor-air preconditioning to reduce the first costs of the heating and cooling plants.
- Implement a thoughtful control strategy to lower operating costs and shorten the payback period.

Efficient HVAC systems demonstrate good stewardship by the people who design and operate them. Don't throw away reusable energy unnecessarily. ■

By Dennis Stanke, staff applications engineer; John Murphy, senior applications engineer; and Brenda Bradley, information designer, The Trane Company.

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