PRODUCT APPLICATION GUIDE

A technical bulletin for engineers, contractors and students in the air movement and control industry.

Frost Control for Energy Recovery Wheels

Frost control for energy recovery devices comes in various strategies – all of which are designed to do what the name suggests – control frost. This article will discuss frost control strategies as they apply to a passive, air-to-air energy recovery wheel process (also referred to as an enthalpy wheel). Often times, the option is specified without enough consideration for the best strategy or whether the option is even needed at all.

To understand how frost occurs, we must first understand the recovery process of an enthalpy wheel. Enthalpy wheels recover both sensible and latent energy (i.e. temperature and moisture). A well-designed wheel will recover each of these at nearly the same effectiveness percentage. As such, the recovery process on a psychrometric chart can be plotted as a straight line between the indoor and outdoor design points. If this process line intersects the saturation curve, moisture from the exhaust airstream will condense onto the wheel. If the conditions of the saturated moisture fall below a temperature of 32°F (0°C), the moisture will freeze and frost will form. (*See Figure 1.*) Left uncontrolled, the frost will continue to build up and decrease airflow and recovery, reducing energy savings. In some circumstances, the frost may cause damage to the energy recovery device or cause other damage as a by-product of the excess moisture.

Common frost control strategies

To prevent problems as a result of frost build-up, manufacturers offer various frost "control" strategies.

Three of the more common strategies are:

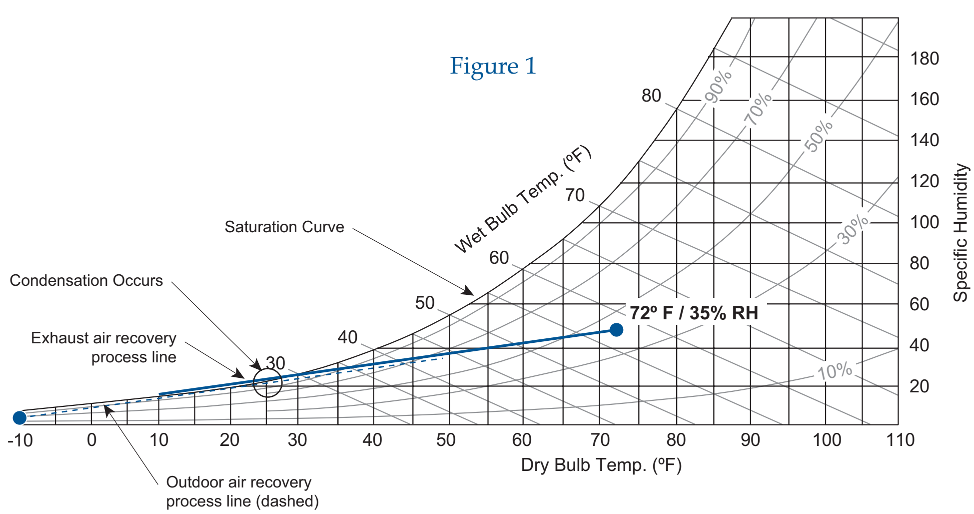
1. Timed Exhaust
2. Electric Preheat
3. Modulating Wheel.

We will discuss each of these strategies and why they exist, but the first question to answer is "Do I need frost control?" The answer to this question can be found with a simple analysis of the winter indoor and outdoor conditions plotted on a psychrometric chart.

Information required for the frost control analysis:

- Winter outdoor design temperature
- Winter indoor design (temperature and relative humidity)

Figure 1



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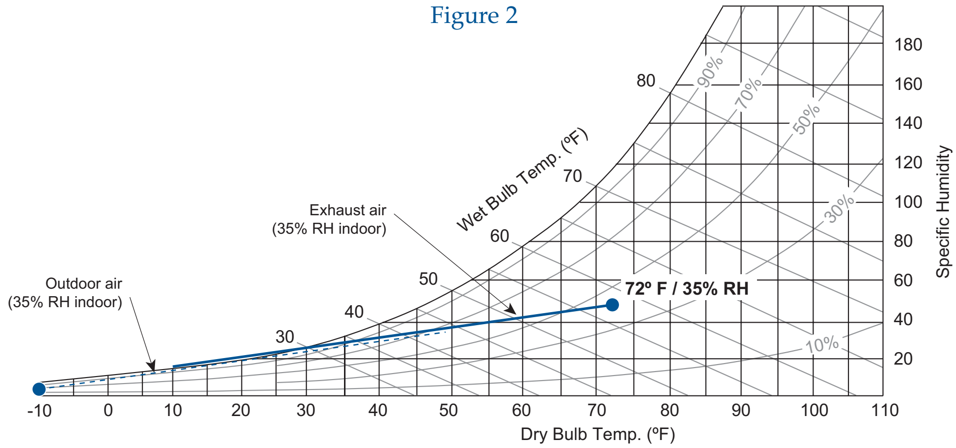
- Net energy recovery effectiveness
- "Real world" outdoor air temperature based on hours of operation
- "Real world" indoor relative humidity

Figure 2



Plotting recovery process line:

If we assume the outdoor design to be –10°F (-23.3ºC) and the indoor design to be 72°F (22.2°C)/35%RH with 75% net effectiveness, the recovery process line would be drawn 75% of the way between the two design points. (*See Figure 2.*) The exhaust air temperature and moisture are reduced by 75% each (blue line) while the outdoor air is increased by 75% each (dashed line).

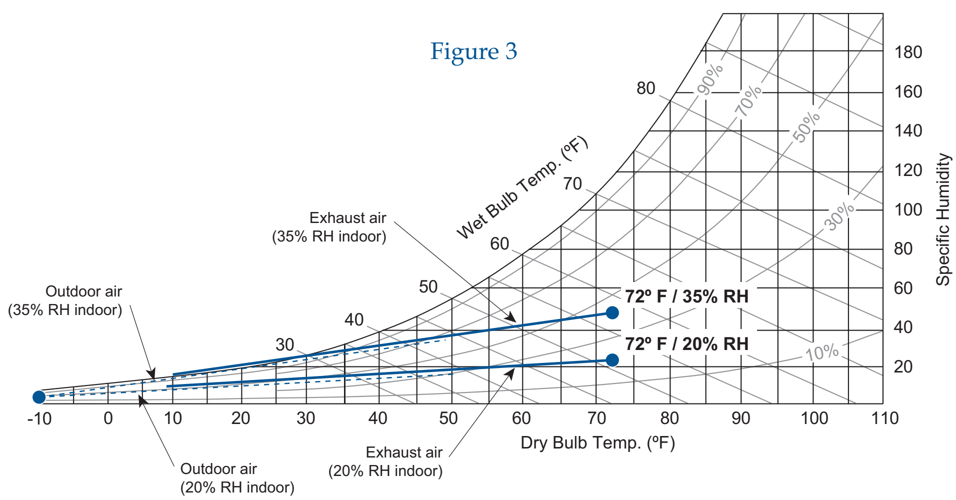
You will notice that the blue exhaust line crosses saturation at roughly 25°F (-3.9ºC). Condensation occurs at this point and since the conditions are below freezing, the frosting process begins.

It is important to realize that this analysis is based on an outdoor air design condition gleaned from ASHRAE weather bin data. In most cases, the design condition occurs less than 1% of the hours per year and very possibly, may never occur if outdoor air is only brought into the system during day time hours. Unless the indoor space is mechanically humidified, it is reasonable to assume for most applications that the relative humidity will decrease when the outdoor temperature decreases. At a –10°F (-23.3ºC) outdoor air condition, the indoor RH may drop to 15-20%. Even if we assume the wheel will be exposed to the –10°F (-23.3ºC) temperature, an indoor RH of 20% eliminates the need for frost control. Consider the new conditions on the psychrometric chart *(see Figure 3)* of:

A. Outdoor air: -10°F (-23.3ºC) (same)
B. Indoor air: 72°F/20%RH

The energy recovery process line no longer crosses saturation and frost will not occur. If real world outdoor air temperatures are considered (i.e. temperatures higher than design), the likelihood of frost decreases even further.

Figure 3



At this point it should be clear that a lot of applications exist where frost control is not necessary. In general, frost control should not be used on applications where outdoor air designs are above 5°F (-15.0ºC) and the indoor design conditions are at or below 72°F (-22.2ºC)/35%RH.

To determine your frost control needs, perform the frost control analysis for your specific application. If the analysis indicates that frost control is required, the following information describes the three most common frost control options and where each should be applied.

1. Timed Exhaust Frost Control:
Simple, inexpensive method that involves turning the outdoor air fan on and off in a timed cycle (a few minutes off and up to 60 minutes on). The logic employed allows the warm exhaust air to defrost the wheel while the outdoor air fan is off. After a few minutes, the wheel will defrost and the outdoor air fan will turn back on. This strategy makes the most sense in climates where winter outdoor design conditions go down to -5°F (-20.6ºC) and frost is unlikely. The option serves more as a safeguard against an unlikely, but albeit possible, frost condition. This option should never be applied in applications where the actual indoor relative humidity will be above 35%.

Design consideration: Outdoor air shuts off creating a negative in the system for a few minutes.

2. Electric Preheater Frost Control:
The electric preheater allows the unit to continuously bring in outdoor air while eliminating frost from the wheel. The electric preheater increases the outdoor air temperature enough to avoid the recovery process line from intersecting the saturation curve. This prevents condensation and frost from further developing on the wheel and allows the warm, exhaust air to defrost the wheel (defrosting only takes a few minutes). The electric preheater option is the best method to control frost. It is the only option that does not adversely affect airflow volume or air conditions leaving the wheel.

Design consideration: Higher amp requirements.

3. Modulating Wheel Frost Control:
Like the electric preheater strategy, this method allows the unit to continuously bring in outdoor air and eliminates frost from the wheel. When this strategy is employed, a variable frequency drive reduces the rotational speed of the wheel, which in turn reduces the effectiveness. Reducing effectiveness prevents condensation from occurring and allows the warm, exhaust air to defrost the wheel (defrosting only takes a few minutes). When the frost is alleviated, the wheel will ramp back up to full speed. This option should never be applied in applications with mechanical humidification or where the actual indoor relative humidity will be above 35%.

Design consideration: Slowing the wheel speed reduces the wheel leaving air temperature. Depending on the system design, this may require one to increase the system heating capacity.

Initiating strategies

How should the frost control strategies be triggered? The best way to initiate the frost control is via a "real time" methodology. In other words, the frost control strategy should only be engaged when frost is actually occurring on the wheel. An outdoor air temperature sensor located in the outdoor air intake compartment and a pressure drop sensor mounted across the energy recovery wheel will accomplish this. The outdoor air needs to be lower than the set point on the temperature sensor (usually around 5°F (-15.0ºC) but can be field adjusted) AND the pressure drop across the wheel needs to increase (indicating frosting). Satisfying both conditions ensures that the frost control methodology is only employed under a true frosting condition.

Unfortunately, most manufacturers utilize theoretical strategies based on outdoor air temperatures only. Using a temperature only sensor to engage frost control forces the methodology to run during times when frost may not be occurring. For Timed Exhaust, this means more time when the system is running at a negative pressure. For Modulating Wheel, this means more time when the temperature leaving the wheel is reduced thus requiring more heat made up by the heating system. For Electric Preheat, this means more time when the preheater is running which equates to increased energy costs.

Summary

To properly evaluate and select frost control for air-to-air enthalpy wheels one must:

- Understand how frost occurs
- Determine "real world" indoor and outdoor air conditions for your project
- Analyze the conditions using a psychrometric chart to determine if frost control is required
- Choose the frost control strategy that best suits your climate, application, and design.

Frost Control Strategy Recommendations		
Winter Outside Air Design	Winter Indoor Design	Recommended Frost Control Strategy
≥ 10ºF *(-12.2ºC)*	≤ 50% RH	none
≥ -5ºF < 10ºF *(-20.6ºC) (-12.2ºC)*	≤ 35% RH	Timed Exhaust*
≥ 10ºF *(12.2ºC)* ≥ -5% < 10ºF *(20.6ºC) (-12.2ºC)* < -5ºF *(-20.6ºC)*	> 50% RH > 35% RH Any RH	Electric Preheat

* Modulating wheel frost control may be substituted when an energy wheel VFD is also specified for discharge temperature control purposes.

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