Benefits Offered by Passive Dehumidification Wheel Speed Control

White paper

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Benefits Offered by Passive Dehumidification Wheel Speed Control

The most significant advantage of the Pinnacle system is its ability to energy efficiently precondition outdoor air, which is dehumidified to humidity levels much lower that possible when using a cooling coil only. However, perhaps the second most important advantage is the system's ability to modulate the passive dehumidification wheel (PD) to optimize energy efficiency and to adjust the supply air conditions to match the space sensible and latent loads at any point in time.

This document outlines some of the more important benefits provided by the modulation of the PD wheel speed and, where appropriate, compares the resultant performance with that of a system operating the PD wheel at a constant, fixed speed.

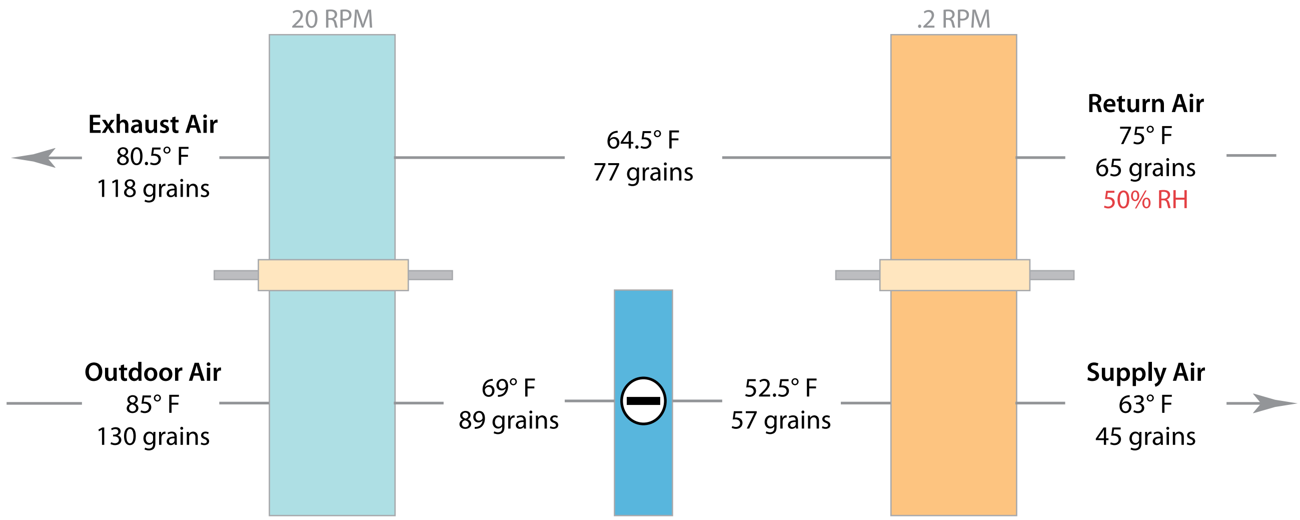
Controlling the passive dehumidification wheel

The basic Pinnacle system includes a total energy wheel, a cooling coil and the passive dehumidification wheel. More elaborate versions include heating coils, bypass dampers, recirculation damper and many other options. Both the total energy recovery wheel and the passive dehumidification wheel rotational speeds are controlled, but only the control of the PD wheel is discussed within this document.

Figure 1 shows typical performance cooling season performance for the Pinnacle system where both the maximum dehumidification and cooling capacity is required to satisfy internal space loads. Hot and humid outdoor air is cooled and dehumidified by the total energy wheel before entering the cooling coil. The air leaving the cooling coil is further dehumidified by the passive dehumidification wheel using the low relative humidity air exhausted from the space for desiccant regeneration.

Various additional operating conditions are discussed within this document, and for simplicity most diagrams omit either the total energy wheel or the cooling coil if they are not in use. Though omitted in the diagrams, all these components remain an integral part of the system.

Figure 1. Basic Pinnacle system, peak internal sensible and latent load, cooling season condition



Benefit 1: Optimize dehumidification performance

The ability to adjust the speed of the passive dehumidification wheel is needed to optimize the performance of the passive dehumidification wheel. At any given velocity, flow imbalance and moisture loading condition, there is a wheel speed that will provide the maximum dehumidification capacity while using the least amount of cooling coil energy input.

This wheel speed is selected and factory preset prior to shipment. The speed is chosen to maximize dehumidification performance while delivering a supply air temperature that best matches the estimated peak space sensible load.

Figure 2 shows a typical case were maximum dehumidification and minimal reheat are desired. In this case the wheel speed is at the lower end if the speed-range to minimize carry-over heat.

This condition is quite common when the indoor sensible and latent loads are high and the HVAC system can benefit from additional cooling being provided by the Pinnacle system.

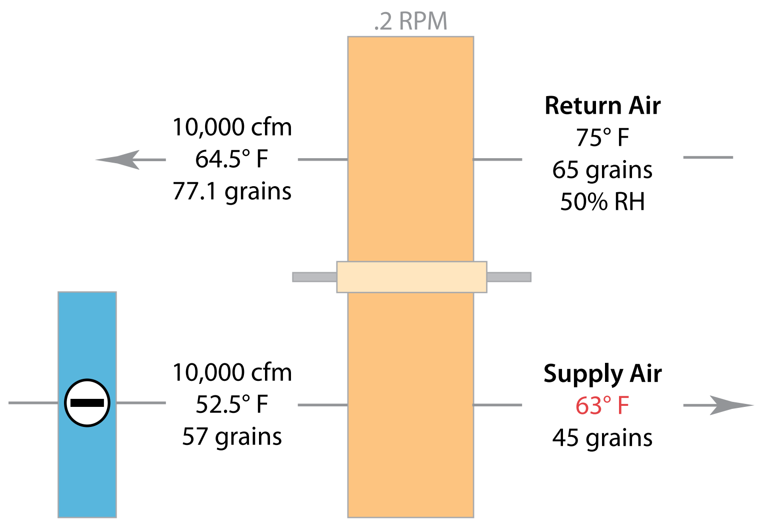


Figure 2. Sample SEMCO passive desiccant wheel - less reheat.

Benefit 2: Optimize dehumidification while providing increased reheat

It is very common that the same level of dehumidification shown above is desired, but at a somewhat warmer supply air temperature. This situation may occur whenever it is cloudy and raining outdoors for example. The solar load is removed from the building, reducing the internal sensible load, yet the internal latent load remains high. To avoid over-cooling spaces an increase in the supply air temperature is required. This is particularly true during cool, damp days when the building is also losing heat to the outdoors.

Additional reheat is especially important when designing chilled beam systems. Since all of the air introduced to the chilled beam is delivered by the dedicated outdoor air system (DOAS) spaces can be over-cooled if the primary air temperature is too low. Once again there are many hours where the outdoor air is cool and the humidity is high. To avoid beam condensation while simultaneously maintaining occupant comfort, dry air at a moderate temperature is required. Similar conditions and capabilities are often required by under-floor distribution or displacement systems.

This is accommodated by modulating the PD wheel speed. Figure 3 provides an example showing how a slight increase in the PD wheel speed used for Figure 2 can increase the supply air temperature as needed. This reduces energy consumption by eliminating the parasitic reheat that would otherwise be required.

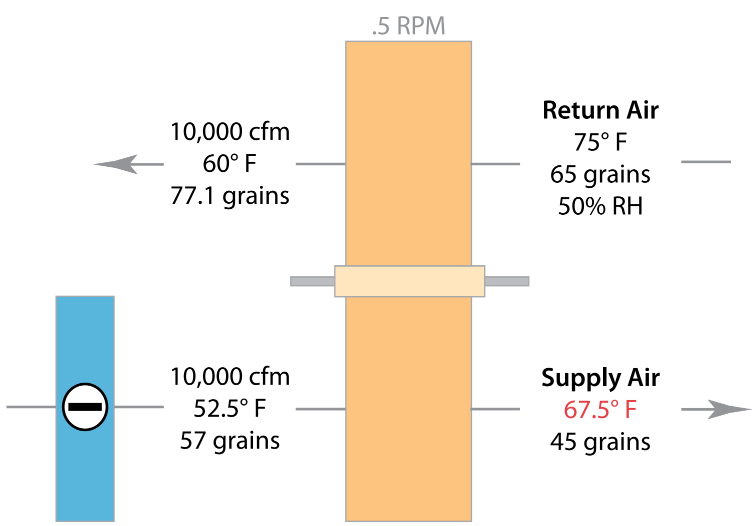


Figure 3. Sample SEMCO passive desiccant wheel - more reheat provided.

Benefit 3: Avoid over-cooling the space during recirculation/unoccupied modes

A significant advantage of the Pinnacle system is that it can include both a 100% outdoor air, DOAS mode as well as a partially-occupied or unoccupied mode. The system can be modulated from 100% outdoor air down to essentially no outdoor air (minimal outdoor air required for pressurization) while still controlling building humidity.

This capability is particularly important for facilities like schools which are unoccupied a large percentage of the time as well as more advanced systems like chilled beams, where the amount of primary airflow needed to control humidity may exceed the outdoor air volume required for ventilation.

During times of low or no occupancy, the sensible load is greatly reduced, so delivering air that is too cold can often over-cool the space. This should be avoided since lowering the space temperature increases the relative humidity of the space. This can lead to problems ranging from damaged books in the media center to more serious mold problems. It is therefore most desirable to deliver the supply air during these unoccupied times that is at a low dewpoint but at a moderate temperature.

If the passive dehumidification wheel within the Pinnacle is limited to a single speed (not variable) then it would have to be set for the maximum dehumidification, maximum internal sensible load (minimum reheat) condition. During the partially occupied or unoccupied mode, parasitic reheat would have to be employed as depicted by Figure 4.

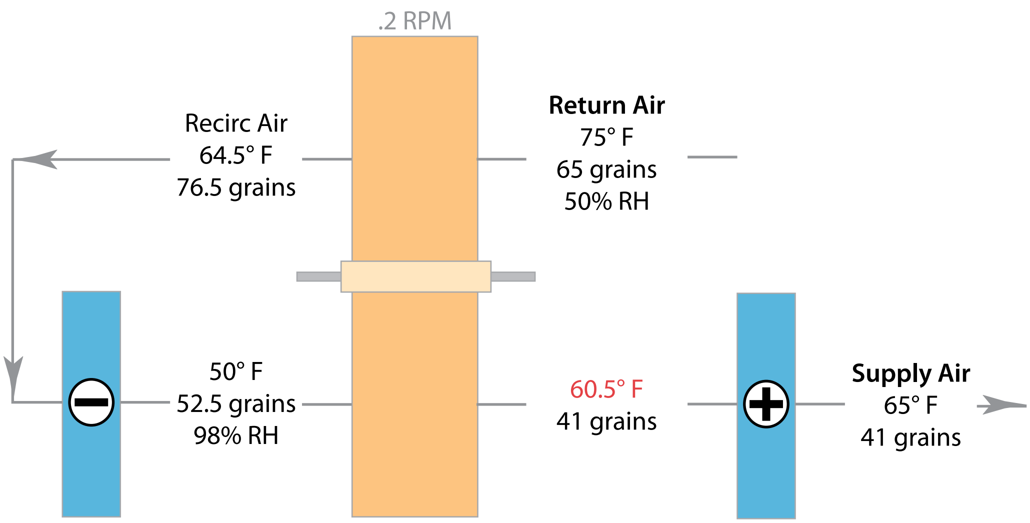


Figure 4. PD wheel not modulated - parasitic reheat energy required.

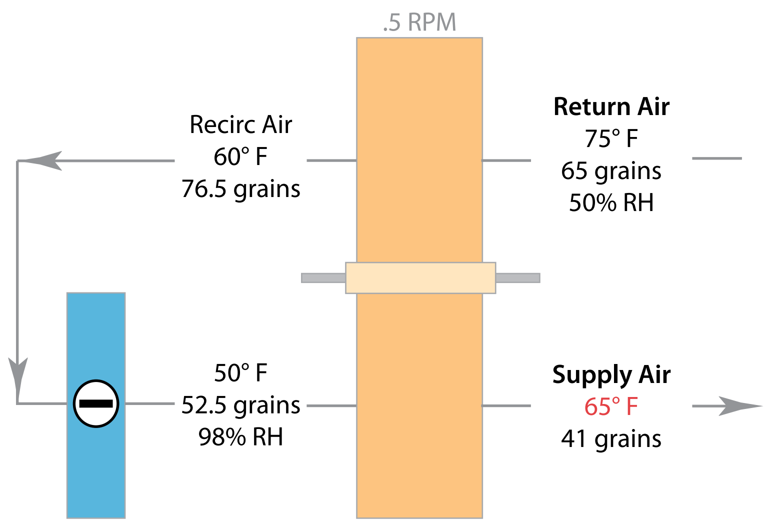
However, with the capability to modulate the PD wheel based on a response from the integral DDC controller, the supply air is reheated to the desired supply air temperature without the need for any additional parasitic energy input.

As shown in Figure 5, the wheel speed can be increased slightly to increase the amount of reheat delivered from the Pinnacle system without appreciably changing the dehumidification capacity delivered.

The economic benefit offered by this control option is considerable. For example, we will consider a school facility located in the mid-west requiring 10,000 cfm of supply air. Assuming the school purchases natural gas for $10/million BTUs and uses a boiler to produce hot water for reheating purposes, it will save over $2,000 annually when compared to the same system with a constant speed PD wheel. Far more if electric is used for reheating purposes.

The PD wheel can be modulated to adjust the supply air temperature based upon the return air temperature entering the Pinnacle system or sensors located within the space.

Figure 5. PD wheel modulated - increased reheat (no parasitic energy).



Benefit 4: Enhancing heating season total energy recovery & avoiding frozen chilled water coils

When the PD wheel speed is increased, its function can be changed from a dehumidification wheel into an effective total energy wheel. Due to the much greater mass associated with the increased desiccant loading, the PD wheel does not need to reach the rotational speed associated with the total energy wheel to achieve the desired performance.

Provided that the PD wheel can be modulated and that there is an effective control system in place, substantially more heating season energy recovery (and humidification) can be provided by the Pinnacle system than if the PD wheel speed is fixed. The DDC control system and algorithms are critical for two reasons.

First, the control system should determine how much reheat is desired. During moderate conditions the amount of combined energy recovery will often be much higher than required. By modulating the PD wheel and, in most cases, the total energy wheel, the supply air condition required by the building can be delivered. As the outdoor air conditions become more extreme, the total energy wheel is increased to its maximum recovery speed then the PD wheel speed is increased, as required to deliver the desired supply air condition. This is highly beneficial in cold climates since even at very low outdoor air temperatures the Pinnacle system will often be able to satisfy all of the heating season needs.

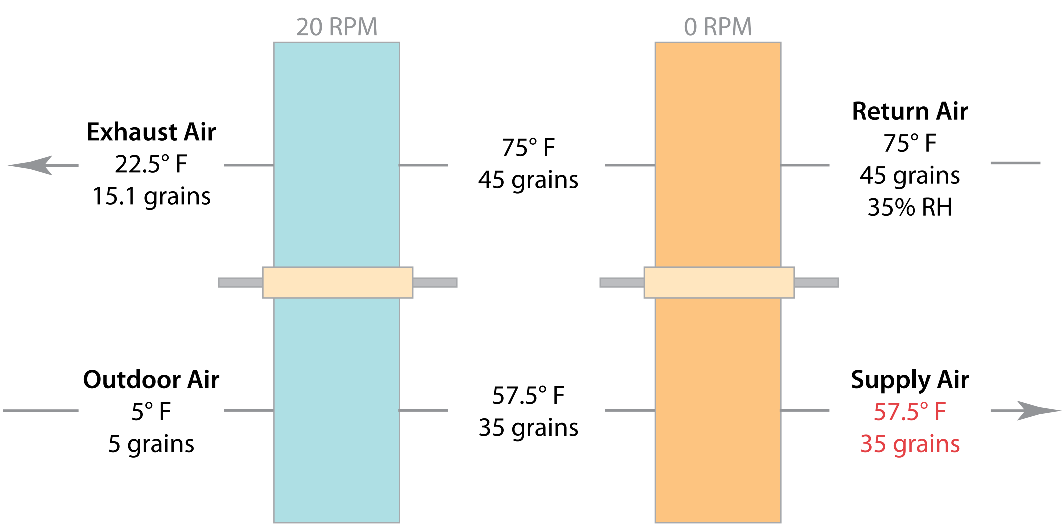


Figure 6: PD wheel off - far less recovery provided.

Figure 6 is provided to show what the recovery performance would be for a typical Pinnacle system operated without the benefit of PD wheel modulation. Figure 7 shows the increased energy efficiency possible by taking advantage of the modulated PD wheel for heating season operation. As shown, far more energy (including humidity) is recovered by this mode of operation.

The additional heating season energy savings resulting from the PD wheel modulation in this mode are considerable. Consider the same school facility located in the mid-west from our previous example. With 10,000 cfm of supply air and using the same energy costs, the heating season energy consumption would be reduced by approximately $1,510 annually.

Another critical function provided by the modulation of the PD wheel is to avoid freezing the chilled water cooling coil and/or frosting of the total energy wheel. At extreme outdoor heating conditions, especially when the return airflow is a fraction of the supply air volume (a common scenario) the temperature entering the chilled water coil can drop to 32 degrees or lower.

Figure 7: PD wheel modulated - far more recovery provided.

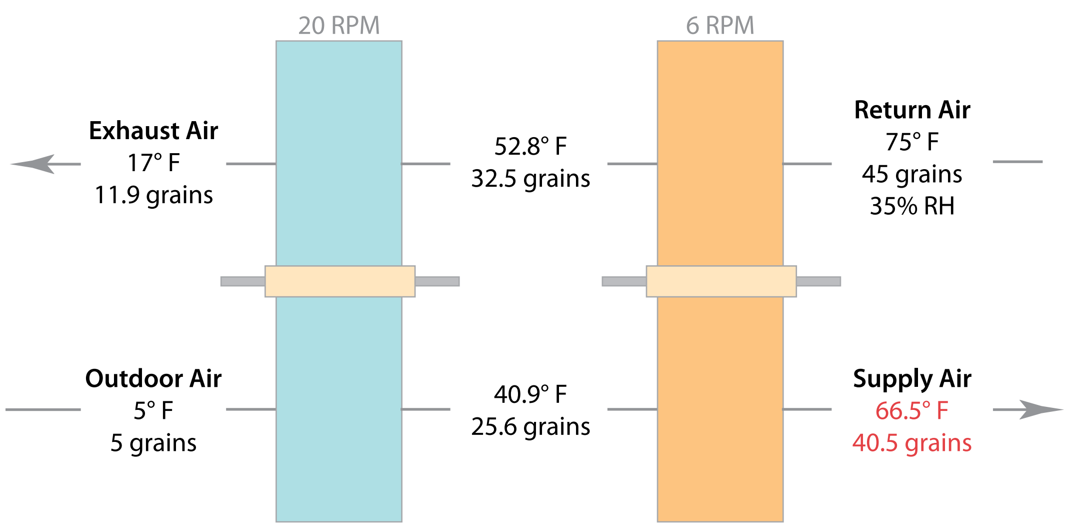
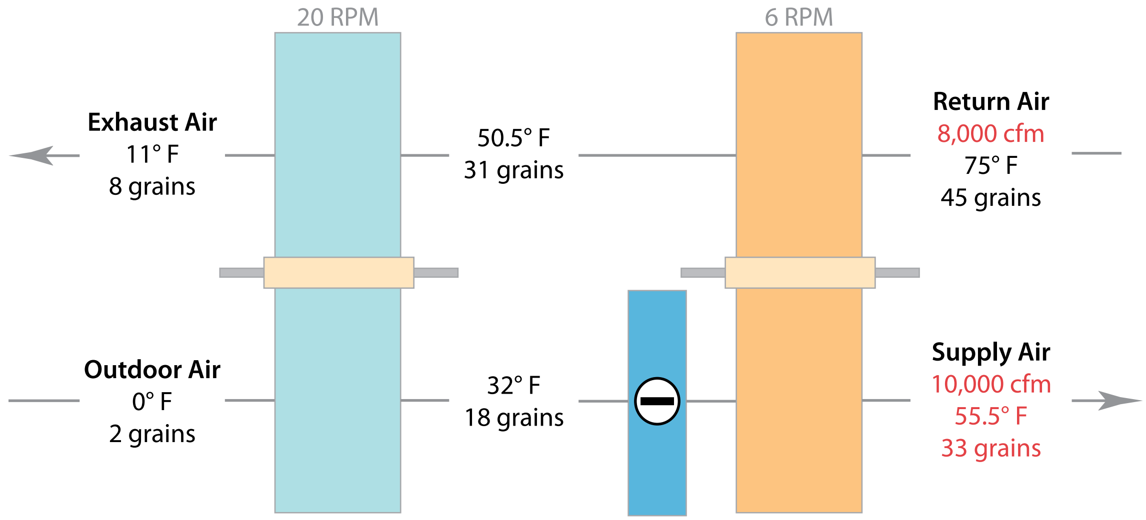


Figure 8 has been prepared to show a condition that will exist if the PD wheel is allowed to operate at an increased speed to provided maximum heat recovery during extreme outdoor heating conditions. As shown the temperature between the two wheels on the supply air side reaches a temperature that would freeze a chilled water cooling coil. The condition must obviously be avoided.

This is easily done by reducing the speed of the PD wheel from its maximum value down to a speed at which the possibility of coil freezing is eliminated. In this way, additional energy can be recovery while maintaining a temperature to the cooling coil that is well above the predetermined safety margin necessary to avoid the possibility of a "freeze-stat" trip.

The DDC controls and algorithms needed to modulate the PD wheel speed to maximize heating season recovery while limiting the risk of "freeze-stat" trips and total energy wheel frosting are standard options routinely supplied as part of the factory tested Pinnacle system.

Figure 8: PD wheel must be modulated to avoid freezing chilled water coils.



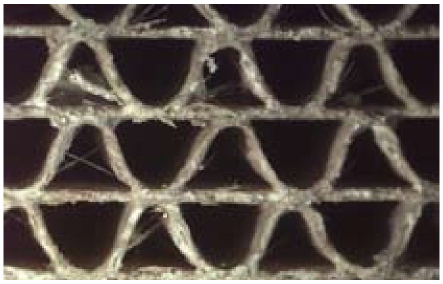
Benefit 5: Avoiding the buildup of particulate on the wheel surface

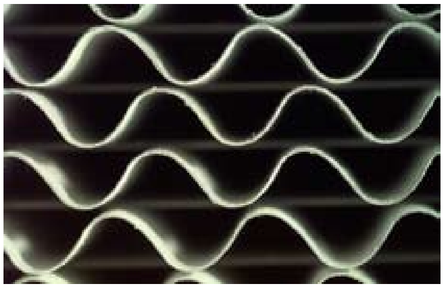
At times when no dehumidification or reheat is desired (high internal sensible load or economizer operation) it is desirable to reduce the wheel speed to its minimum speed setting. This essentially eliminates dehumidification and reheat while allowing the wheel to maintain its "self cleaning" mode, providing a constant reversal of airflow through the wheel matrix.

Stopping the wheel is not advised. Dust particulate can collect on the face of a static wheel over time, increasing pressure loss and, in the case of "paper" dehumidification wheels, degrading performance. Figure 9 shows the difference in media surface properties between the coated aluminum PD wheel developed by SEMCO and the paper based wheels used by the competition.

The paper wheel has a fibrous surface which can collect particulate and swell over time when in contact with the saturated air leaving the cooling coil in Pinnacle style systems. As a result, it is more difficult to maintain consistent performance over time with dehumidification wheels made from paper substrates.

Figure 9: Typical paper wheel surface (left) compared to SEMCO PD wheel surface (right).





Paper based wheels have a higher pressure loss than the SEMCO coated aluminum PD wheel when new. If particulate is allowed to build, this pressure increases significantly. Some DOAS systems employ an arrangement which passes the supply airflow through the PD wheel two times (wrap around concept). This approach results in high supply side static pressures on the fan. Should the pressure loss associated with a paper wheel configured in this manner increase due to particulate buildup or media "swelling" the supply fan static pressure will increase significantly. This type of wheel must be modulated to avoid these problems.

The SEMCO PD wheel has several important advantages over the paper based dehumidification wheels. First, the coated aluminum surface does not have fibers to collect particulate nor can it "swell". Secondly, the SEMCO PD wheel surface is coated with an effective anti-stick agent proven to significantly reduce the buildup of particulate over time (please see the technical report "Impact of the SEMCO Anti-stick Face Coating"). Finally, the SEMCO wheel is modulated to its minimum wheel speed any time it is not required for dehumidification or reheat to ensure a constant reversal of airflow to keep the wheel clean.

What is the point?

Proper speed modulation of passive dehumidification wheels employed within dedicated outdoor air systems coupled with total energy recovery wheels is critical. It has a significant impact on the energy savings delivered by the system, it can eliminate the need for a supplementary reheat coil, minimize the risk of frozen cooling coils and helps keep the wheel matrix from collecting particulate.

During the typical cooling mode, modulation allows for more or less reheat to be provided to better mach the internal sensible loads. During unoccupied hours, the modulation provides increased reheat to help avoid over-cooling spaces. In the heating mode, higher supply air temperatures and humidity can be delivered by optimizing the PD wheel speed. During economizer operation, the wheel remains operational at its minimum speed limit to provide a "self cleaning' mode while minimizing any carry-over heat.

The SEMCO Pinnacle system contains a factory installed and tested DDC system which includes time tested control logic and algorithms to optimize the wheel speed used by the passive dehumidification wheel. This has been proved to optimize overall system performance and energy savings.

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