WHITE PAPER #:

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THE SMART SOLUTION FOR ENERGY EFFICIENCY

CLIMATEMASTER KNOWLEDGE SERIES: ENERGY RECOVERY WHEEL TECHNOLOGY

ClimateMaster®

WATER-SOURCE HEAT PUMP SYSTEMS

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Introduction
The need to introduce outside air into the modern building is becoming increasingly understood. Because most buildings are tightly sealed, indoor pollutants such as bacteria, viruses, radon and other gases become trapped inside and cause problems for the occupants. If these indoor pollutants become concentrated and rise above the minimum threshold limits tolerable by the individuals in the building, many health problems can arise.

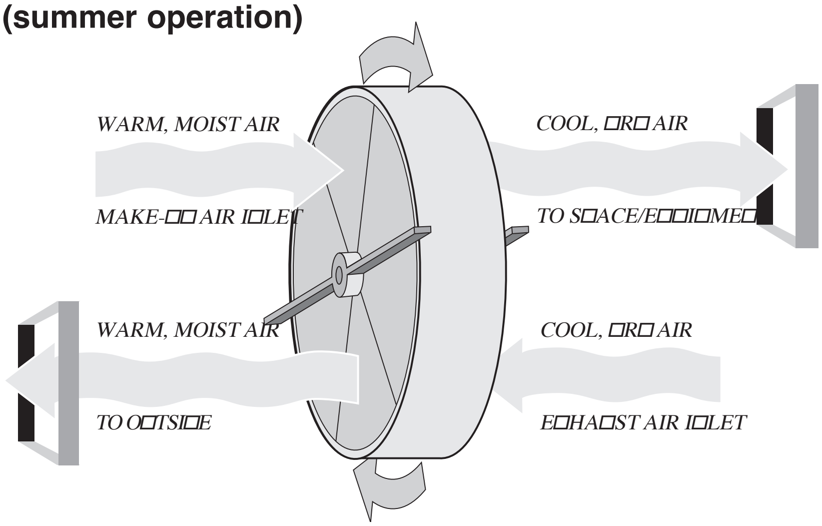
The solution is to dilute the indoor pollutants by introducing greater quantities of outdoor air. ASHRAE 62 has established a minimum level of ventilation air to achieve standard dilution. This sometimes calls for as much as 50% of an air handler's volume to be made up of outdoor air. This outdoor air load often exceeds the air handler's capacity. A dedicated 100% outdoor air system is then required to condition the air prior to introducing it to the space.

If it is possible to exhaust inside air at the same location where the 100% outdoor air unit is located, it makes sense to use a device such as a heat wheel to pre-cool the air during summertime operation or pre-heat the air during the winter months. Refer to Figures 1, 2 and 3.

Types of Wheels
There are three general types of wheels being used today. They are sensible, enthalpy and regenerative. Many times they are referred to as "desiccant" wheels, but this only confuses rather than clarifies since only two of these types have desiccant as part of their designs. The actual definitions are:

Sensible Wheel - This wheel is not coated with a desiccant and therefore transfers only sensible energy. The wheel can be constructed of almost any material (paper, metal or plastic) and transfers energy between two air streams as the mass of the material gains or loses heat to the opposite air stream. The wheel rotates at a speed of 25 to 50 revolutions per minute.

Figure 1: Typical Enthalpy Wheel Operation (summer operation)



Enthalpy Wheel - It is similar to the sensible wheel except that a desiccant media is added to the wheel's surface. As the wheel rotates, it now can transfer sensible energy and humidity. This wheel also rotates at 25 to 50 revolutions per minute.

Regeneration Wheel - This wheel is used when low dewpoint conditions (<45°F [7°C]) are required, such as industrial applications. It achieves low dewpoints by slowing the wheel to a speed of between 0.25 and 1 revolution per minute and by using an air stream heated to 250°F [121°C] or more to drive off moisture and regenerate the wheel. This heated air stream is typically focused on only 1/4 of the wheel's area thereby allowing 3/4 of the area to be available for the process side.

Desiccant Selection
By their nature, all desiccants remove water from an air stream. Each desiccant has an equilibrium capacity which determines the amount of water that it can adsorb. Kinetics defines the rate at which this equilibrium capacity is achieved. Other factors that affect water adsorption are desiccant selectivity and desiccant life.

There are three classifications of desiccants used in dehumidification equipment within the HVAC industry:

1.) Lithium chloride
2.) Silica gel (including titanium silicate).
3.) Molecular sieves (e.g., 3Å, 4Å [0.3, 0.4nm])

Lithium chloride was widely used 20 years ago in a majority of desiccant-based equipment. It is rarely used today because it dissolves (deliquesces) as it removes moisture from the wheel. This greatly limits the life of the product.

An enthalpy wheel manufactured with silica gel is an excellent desiccant for treating saturated or near-saturated air streams. Compared to most molecular sieves on an equal weight basis, silica gel can hold more water in air streams above 50% RH. It must be noted that in the case of an enthalpy exchanger, the wheel moves between two equilibrium relationships (isotherms), that of return air and outside air. The wheel never completely dries out, but in fact remains near saturated all the time. As a result, only a very small part (less than 1%) of the isotherm curve is used. In order to accurately measure the amount of moisture that's adsorbed by the wheel in a given revolution and on an equal desiccant weight basis, you must consider the differential between the adsorption capacity at the outdoor air and return air conditions. While silica gel holds more water at RH's above 50% than do molecular sieves, it also holds more water under the return air condition. Molecular sieves and silica gel do approximately the same amount of work in an enthalpy exchange application on an equal desiccant weight basis.

The enthalpy wheel option for ClimateMaster dedicated outdoor air systems (Genesis OA & Tranquility OA Series) uses molecular sieves made of porous crystalline aluminosilicates. This type of desiccant falls under a family classification called zeolites. On an atomic level, the zeolite framework is an assemblage of silica and alumina tetrahedra joined together in various regular arrangements through shared oxygen atoms. This configuration forms an open crystal lattice of molecular-sized pores into which guest molecules can penetrate. The crystal lattice creates a micropore structure that is precisely uniform with no distribution of pore size. This single feature distinguishes zeolites from other microporous adsorbents. A 4 Angstrom [0.4nm] sieve is a sodium aluminosilicate with an effective aperture size of 3.8 Angstroms [0.38nm]. Since methane is the smallest of the organic molecules at a critical diameter of 4.2 Angstroms [0.42nm], molecular sieves effectively screen out adsorption of all organic compounds. On the other hand, water is smaller than 3.8 Angstroms [0.38nm] so it is readily adsorbed.

Figure 2: Enthalpy Wheel Performance During Summer

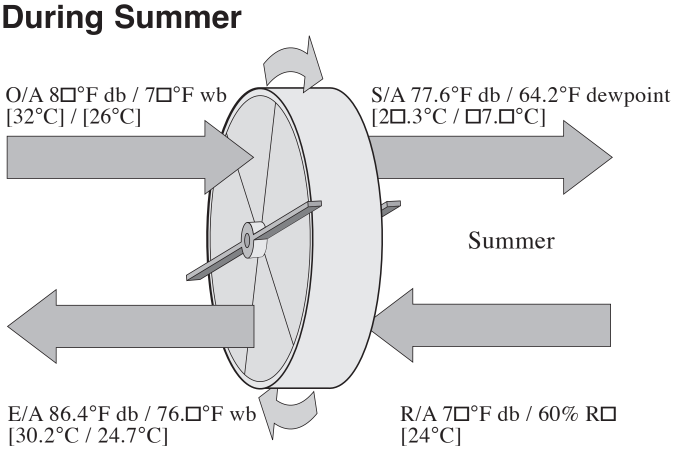
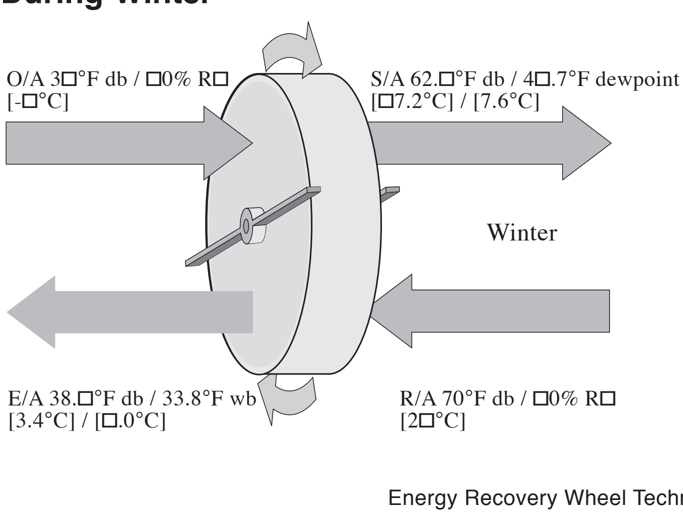


Figure 3: Enthalpy Wheel Performance During Winter



In addition, an enthalpy exchanger's effectiveness is determined not only by the capacity of the desiccant it uses, but also by the quantity of desiccant it exposes to the air stream. A ClimateMaster OA Series energy recovery wheel contains over 70% by weight desiccant.

Enthalpy Wheel Design

ClimateMaster OA Series wheels are constructed of a unique corrugated synthetic fiber-based media impregnated with a non-migrating water selective molecular sieve desiccant. The wheel matrix, or its total mass, provides for sensible exchange, while the desiccant provides for moisture exchange. The fiber and desiccant are intimately bound together to form sheets with excellent heat and mass transfer properties. These sheets are then corrugated and spirally wound into wheels.

Most other media will have the desiccant coated, bonded or synthesized onto the matrix. These processes often cause the desiccant to delaminate or erode off the media. In contrast, the desiccant on ClimateMaster's media is uniformly and permanently dispersed throughout the matrix structure. Being synthetic, our wheel media is corrosion resistant. Our design offers excellent face flatness to minimize wear of inner seal surfaces and cross leakage, and maximize wheel life.

Our wheel frames are constructed of evenly spaced spokes, a galvanized steel band and an aluminum center hub. Frame component sizes and number of parts vary with wheel size.

We use a fractional horsepower AC drive motor and a durable multi-link drive belt as our standard drive system.

It is not uncommon for frost to develop on the wheel under extremely cold winter conditions. The wheel can cool down to below 32°F [0°C] and will then freeze moisture from the exhaust stream. Frost may reduce the airflow, but it will not damage the wheel. An optional electric heater is available to preheat the outdoor air and prevent the exhaust air from freezing.

Cross Contamination/Leakage

Cross contamination is a measure of the amount of unwanted compounds or impurities that are transferred from the return air stream to the supply air stream. This is usually not an issue in normal commercial heating and cooling applications although it can sometimes be important to some consulting engineers when specifying an energy recovery unit. In the effort to reduce the levels of undesirable impurities in the air, certainly heavy cross contamination can limit the effectiveness of ventilation. It is important to avoid cross contamination in conditions where there is a high volume of polluted indoor or outdoor air. It is extremely important to prevent cross contamination in medical applications. These applications include laboratories, heavily industrialized areas, paint or solvent storage areas, morgues and health care facilities.

There are three different sources of cross contamination:

I. Carryover from return to supply stream due to wheel rotation

2. Seal leakage from return to supply stream

3. Adsorption by the desiccant with later release into air stream

A purge section will minimize carryover from return air to supply air. An optional purge unit is available that adjusts from 0-15 degrees. This provides ample latitude to prevent the carryover attributed to the wheel's rotation.

The best way to prevent seal leakage is to use quality seals and to ensure that the supply wheel face has a positive pressure differential between supply and return. Our cassettes seal peripherally on the wheel band, and diametrically along the centerline of the wheel face using full-contact nylon bush seals which provide a good proximity seal. Tests have shown this proximity seal to limit air leakage to around 2% at 1 inch water column [249 Pa] of differential between the air streams.

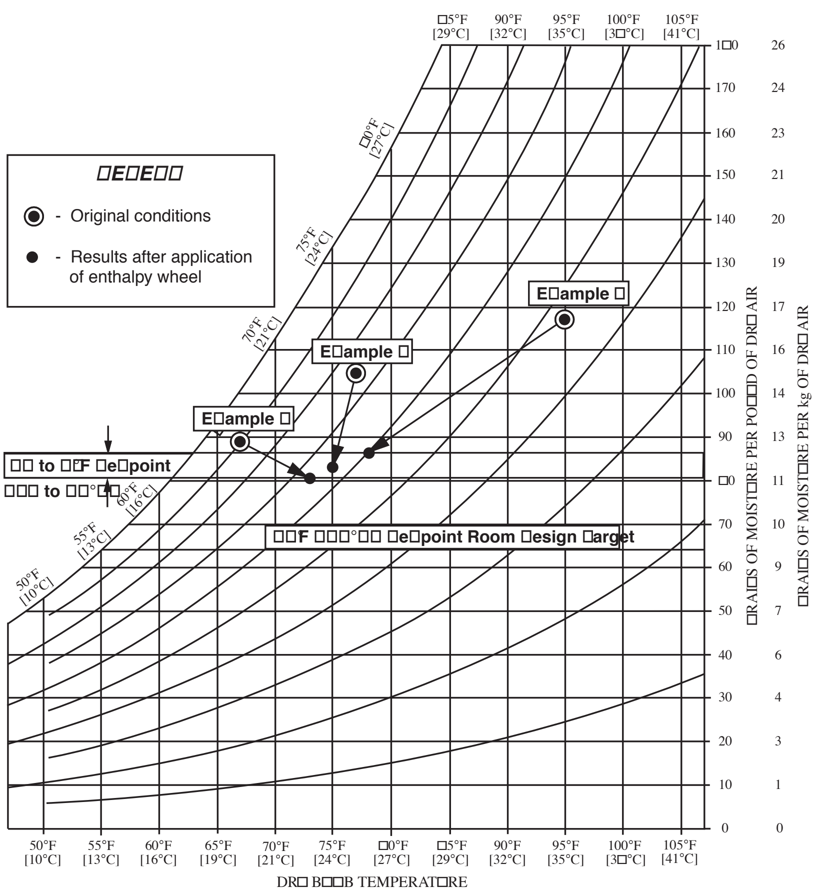
In addition to the molecular selectivity feature of molecular sieves (as explained under Desiccant Selection), it is also important to know that co-adsorption of commonly found impurities is limited. This is due to the fact that molecular adsorption rates are largely dependent on partial pressures. Since the partial pressure of water (i.e. moisture) is over 100 times greater than any of the commonly found impurities in a return air stream, adsorption of an impurity by the molecular sieve is highly unlikely. Also, molecular sieves have a natural affinity for polar molecules. Because water has the highest molecular polarity, it is readily absorbed by a molecular sieve.

System Efficiency
An enthalpy wheel's efficiency is a function of its size (diameter and depth) relative to the air volume, and the energy differential between the two air streams. In general terms, most enthalpy wheels can achieve a minimum recovery of 75% of sensible and latent energies. This high rate of energy recovery significantly decreases operating costs.

However, this is not the critical design issue according to the ASHRAE 62 ventilation code. The critical issue is whether you are supplying dry enough air to the space. An enthalpy wheel by itself will only dehumidify outside air to 61-63°F [16-17°C] dewpoint. Most engineers require a design of 52-56°F [11-13°C] dewpoint. Figure 4 demonstrates this point.

A refrigeration-based evaporator can be added to the system to lower the dewpoint and meet the required design. Figure 5 shows a complete solution to the IAQ design issue.

Figure 4: Enthalpy Wheel Performance Without Refrigeration

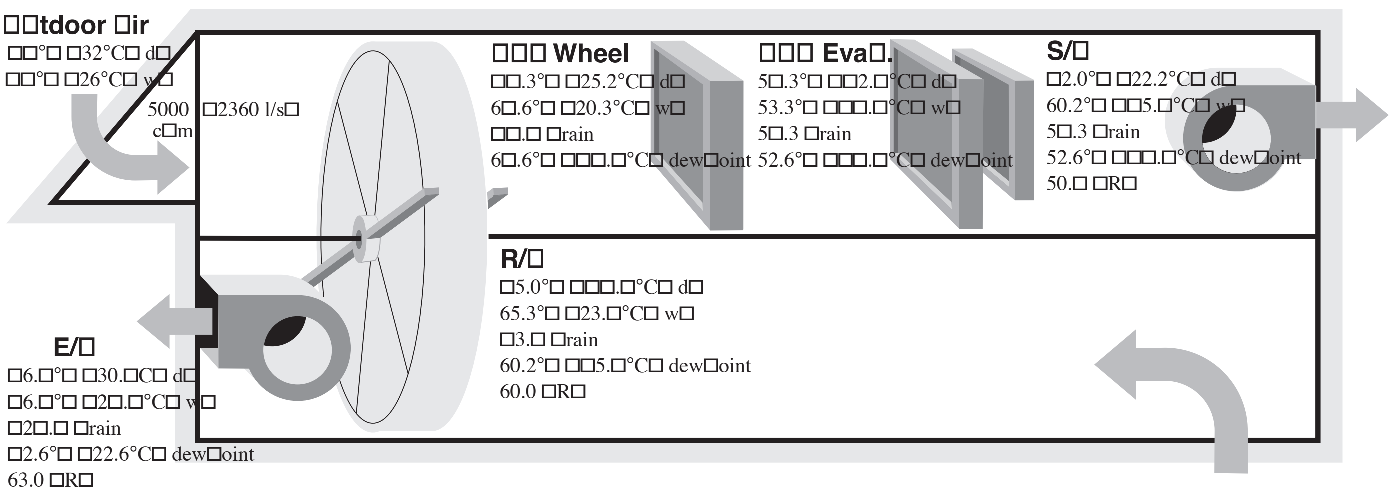


Conclusion

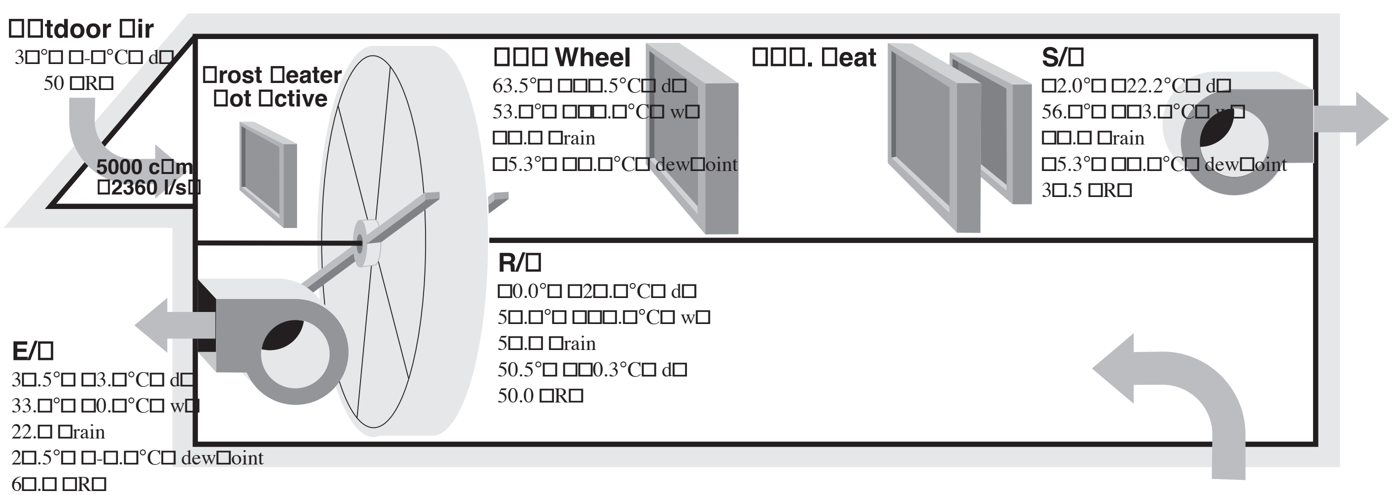
By themselves, enthalpy wheels will not achieve the desired IAQ design results. However, they can be packaged with a dehumidifier to provide the most energy efficient solution available. The wheel removes the load peaks in both winter and summer modes so that only a small refrigeration plant is required to produce the desired dewpoint air.

Figure 5: Seasonal System Performance

S□mmer Mode



Winter Mode



Revision Log:

Date	Page #	Description
02/22/06	All	First Published

7300 S.W. 44th Street
Oklahoma City, OK 73179
Phone: 405-745-6000
Fax: 405-745-6058
www.climatemaster.com

C US 155499

ENERGY STAR PARTNER