Specifying Desiccant Dehumidifiers

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Desiccant dehumidifiers are used for lower-dew-point (below 50 to 55 F) applications, such as frozen-food display, plastics production, and records storage. Places they are most likely to be found include supermarkets, ice arenas, water-treatment facilities, surgical suites, and museums.

This article will discuss the specification of active, as apposed to passive, desiccant dehumidifiers. Active desiccant dehumidifiers require an external heat source for regeneration, while passive units exchange moisture and heat between fresh- and exhaust-air streams.

ACTIVE UNITS

Active desiccant units are most cost-effective when they use low-grade heat for regeneration. This is relatively inexpensive heat from sources such as microturbine exhaust and direct-expansion (DX) hot gas. A lower leaving dew point will be obtained with a higher regeneration temperature, lower process entering dry bulb, lower process entering dew point, and, to a lesser extent, lower process face velocity and entering regeneration dew point. The process leaving dry bulb will vary as these conditions change. Desiccant systems are most beneficial where thermal energy is readily available, the price of electricity is high, and the sensible-load fraction is low (sensible-heat ratio [SHR] less than 0.65).

For comfort-conditioning and process uses, the most common desiccant dehumidifiers use a rotating wheel. Desiccant units and rotors—the honeycomb-shaped, desiccant-media matrices formed into wheels—are very much project- and manufacturer-specific, so application engineering is especially critical for a cost-effective project. Performance-rating standards were not available until 1998, so the certified apples-to-apples ratings engineers take for granted with other HVAC equipment usually are not available with desiccant equipment. Nonetheless, desiccant units are becoming more standardized. In the right application, a properly applied, well-engineered system can pay for itself in reduced cooling tonnage and energy savings, while providing consistent comfort under all weather conditions.

CONFIGURATION

The heart of a solid desiccant-wheel unit is the rotor. Supply air passes through one sector of the rotor and is dehumidified and heated. The rotor turns slowly into the reactivation-air stream, which dries the desiccant and exhausts the moisture from the unit. By itself, the rotor performs no useful cooling. It merely converts latent load into high-temperature sensible heat that can be rejected with minimal energy input.

Because of latent heat and transfer from the regeneration stream, dehumidified process air leaves the rotor at a temperature much higher than that of the inlet. The temperature is 6- to 9-F hotter for each 10 grains of moisture reduction. This temperature rise mostly represents the conversion

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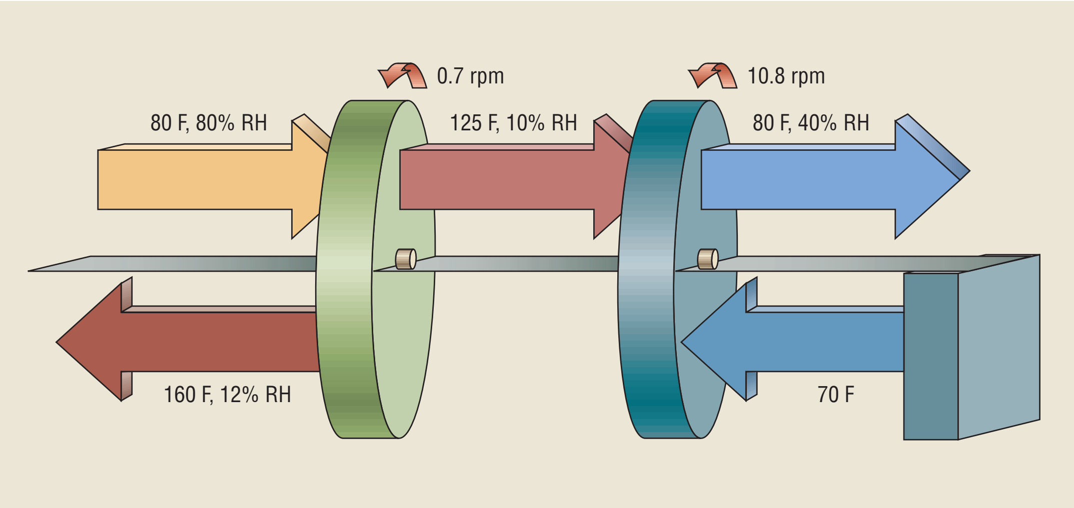

Process airflow (top) as it is dried and heated by a desiccant rotor (green wheel) and then indirect-evaporative-cooled by a sensible-only rotor (blue wheel). The 70-F stream could be relatively dry outside air or evaporatively cooled exhaust air.

of latent heat to sensible heat. For example, for 1,000 cfm of air with a 10-grain moisture reduction at sea level:

$$Q_L = 0.69 \times cfm_p \times \Delta W_{1\text{-}2} = 0.69 \times 1{,}000 \times 10 = 6{,}900 \text{ Btuh}$$

$$\Delta T_p = Q_L \div \left(1.08 \times cfm_p\right) = 6{,}900 \div \left(1.08 \times 1{,}000\right) = 6.4 \text{ F}$$

Because active desiccant wheels increase the enthalpy of process air, reducing the temperature of air leaving a rotor is critical to system performance and efficiency. Additional temperature rise is influenced by the thermal capacity of the rotor matrix, which is a function of specific heat, mass, face velocity, and rotational speed. Generally, a lower thermal capacity, lower face velocity, and slower rotor speed result in less enthalpy increase. Post-cooling is achieved in different ways by different manufacturers, including with sensible-only rotors, heat pipes, indirect evaporative cooling, and/or DX or chilled-water coils downstream of a desiccant rotor. Methods that do not use additional electric or gas energy are preferred for most projects because the life-cycle cost will be less. Reaching very low outlet moisture levels requires the pre-cooling of inlet air to near saturation. The introduction of supply air from a desiccant unit directly into a space usually requires mechanical post-cooling.

SELECTION

Manufacturer selection charts typically show dehumidification performance as "grains of depression"—reduced absolute humidity in grains of moisture per pound of dry air. Unit size is based on airflow in cubic feet per minute. Of greater interest to most designers is supply-air dew-point temperature (in degrees Fahrenheit), latent cooling capacity (in British thermal units per hour), and energy efficiency (coefficient of performance [COP]). Often, these values must be derived from data in manufacturers' product literature. Of course, a unit with higher energy efficiency is desirable because the cost of operating it will be lower. For a fair comparison, calculate COP by dividing total capacity (sensible plus latent) by total energy input (waste heat, natural gas, plus all electric). Some ratings simply are latent capacity divided by heat input, which is misleading because sensible capacity often is negative (heating), and the electric fan power needed to provide 2- to 3-in.-wc internal static pressure is considerable. Energy-efficiency ratings consider only electric input to fans and compressors, if there are any. The COP of desiccant equipment varies greatly with entering-air conditions, so it is important to calculate COP at a range of design conditions. Even better is to use a joint-frequency bin analysis or an hourly computer simulation.

For most fresh-air-ventilation applications, a design dew-point temperature or latent cooling load must be met at various entering-air conditions. Table 1 shows standard Air-Conditioning and Refrigeration Institute (ARI) rating conditions, which some manufacturers still do not follow.

Number	Dry bulb, F	Wet bulb, F	Grains per pound	Percent relative humidity	Dew point, F
1	95	75	99.0	39.9	66.8
2	80	75	123.6	79.6	73.1
3	80	67	78.6	51.1	60.3
4	45	45	44.3	100.0	45.0

TABLE 1. Standard ARI desiccant-equipment rating conditions.

QUALITY DEFINED

Examine the configuration of a desiccant unit. Look for a simple component layout and plenty of access space for inspection and cleaning. Most important for long-term energy efficiency and performance are durable, adjustable, easily replaceable, low-leakage rotor-face seals. Look for labyrinth seals and other pressure-responsive designs that minimize the rotating contact area while providing minimum leakage to at least a 6-in.-wc pressure differential. Ask about warranty coverage on the seals and the price and availability of replacement seals. Study fan location to verify that any seal leakage will be from the process side (fresh supply air) to the reactivation side. This is better for efficiency and thwarts cross-contamination. Air inlets and fan outlets that promote uniform flow across the entire rotor face also are important. A rotor air bypass and/or variable-frequency drives will save fan energy when less dehumidification is needed, as will the capability to vary regeneration heat and mix return/fresh air. For constant or cycling fans, controls that maintain space/leaving humidity or dew point can be incorporated.

Look for capacity and energy-performance ratings based on ARI Standard 940-98, *Desiccant Dehumidification Components*,[1] and ANSI/ASHRAE Standard 139-1998, *Method of Testing for Rating Desiccant Dehumidifiers Utilizing Heat for the Regeneration Process*,[2] preferably from an independent testing agency, and a five-year or longer warranty on desiccant and sensible rotors, seals, and drive components. Over the life of the unit, the rotor must be kept clean to maintain acceptable performance. Accordingly, verify that the unit cabinet accommodates 1-in. pre- or roughing filters (rated MERV-2) and at least 2-in., 30-percent-efficiency pleated final filters (rated MERV-7) for both air streams. On-site performance verification, a performance guarantee, and a nationally recognized safety listing or labeling also are important.

DESIRABLE FEATURES

Cost can vary considerably by model and manufacturer. Consider maintainability, looking for water-washable rotors that retain like-new performance. Compare construction and materials, looking for durable rotor substrate media, stainless-steel or aluminum rotor-frame/cassette parts for resistance to corrosion, and high-percent desiccant loading by total media mass. Lastly, consider service support and the length and terms of the warranty.

Sophisticated controls are important in minimizing operating costs. Variable control of regeneration temperature and wheel rotational speed is preferred over on/off control, as is modulating control of heat input (gas burner or steam/water coil). A proportional space humidistat is preferred over an on/off humidistat because it eliminates short cycling during low-load conditions. Compatibility with building-automation systems and factory-installed temperature and humidity sensors is a definite plus.

Industrial units are designed with ⅛-in. aluminum or stainless-steel cabinets, sturdier damper vanes and actuators, premium-efficiency motors, industrial-grade controls, sealed rotor drives and bearings, and desiccants that provide lower leaving-air dew-point temperature and/or higher energy efficiency. Post-cooling using heat pipes, a sensible-heat wheel, and/or indirect evaporative cooling adds to unit first cost, but significantly reduces energy cost for a lower life-cycle cost.

When comparing ratings and specifications, look for:

- Low internal static-pressure drop—less than 2.50 in. wg total.
- High reactivation-heat fuel efficiency—greater than 90 percent, which means direct-fired is preferred over indirect.
- Low electric-power kilowatts, low internal static pressure, low motor horsepower, premium-efficiency motors, no electric-resistance heat, and no DX cooling.

COMPARING UNITS

Consider rated supply-air dew-point temperature and energy efficiency at a range of design conditions. Low dew-point temperature (less than 50 F) is desirable. Very low dew-point-temperature (less than 40 to 45 F) supply air can meet a building's entire latent load; however, units capable of providing such air are more expensive. Even a 2-F difference in dew point between competing products is significant.

Desired leaving dew point depends on how much ventilation and internal latent load will be met by downstream components, such as chilled-water coils. A building's HVAC system can be designed so that a desiccant unit pre-dehumidifies ventilation air, with the cooling coil finishing the process—for example, 58-F-dew-point air leaving the desiccant unit and 50-F-dew-point air leaving the cooling coil.[3] Alternatively, the desiccant unit could provide all dehumidification, leaving the cooling coil dry—for example, 50-F-dew-point air entering and leaving the coil. In this case, the desiccant unit meets the building's entire latent load.

To evaluate and compare energy efficiencies fairly, verify that COP is calculated the same way by each supplier. A related factor to consider is SHR, which will be negative if the supply-air dry-bulb temperature is warmer than the inlet air. A lower positive or less-negative SHR is preferred because it indicates cooler process leaving air. For example, consider a 5,000-cfm desiccant unit at 80-F/75-F-wet-bulb entering-air conditions providing a leaving dew point of 60 F at a leaving temperature of 88 F with a 250,000-Btuh-input gas burner and two 3-hp fans. The sensible and latent capacities would be:[4]

$$Q_S = 1.08 \times cfm_p \times \Delta T_{1\text{-}2} = 1.08 \times 5{,}000 \times \text{-}8 = \text{-}3.6 \text{ tons}$$

$$Q_L = 0.69 \times cfm_p \times \Delta W_{1\text{-}2} = 0.69 \times 5{,}000 \times 45 = 12.9 \text{ tons}$$

$$SHR = Q_S \div \left(Q_S + Q_L\right) = \text{-}3.6 \div 9.3 = \text{-}0.39$$

$$COP = \left(Q_S + Q_L\right) \div \left(Q_R + W\right) = 111{,}600 \div \left(250{,}000 + 14{,}620\right) = 0.42$$

PURGE SECTIONS

As media rotate out of regeneration airflow, they carry with them both heat trapped inside and hot regeneration air trapped in the rotor. A purge essentially is a misalignment of one of the seals on the face of a wheel. A purge eliminates carryover by forcing air to flush the rotor from the process inlet (fresh air) to the regeneration-air stream. This improves dehumidification, sometimes at the expense of energy efficiency. Purge commonly is used in industrial applications when very low dew points are required. This is necessary because hot desiccant does not adsorb as well. So, without a purge, the first several degrees of rotation will perform very little dehumidification, allowing untreated air into the process outlet. Purges also are used to minimize carryover of regeneration air into supply air.

Other options that may need to be specified include:[5]

- Variable regeneration-temperature control.
- Modulating heat-input control.
- Variable wheel-rotational-speed control.
- Proportional space-humidistat control.
- Digital communications interface.
- Premium efficiency (90-percent-plus), three-phase fan, and rotor-drive motors.
- 1-in. pre-filters and 2-in. pleated final filters.
- Cabinet insulation.
- External indication of faults.
- Emergency stop.

DESICCANT SELECTION

Sorbents are materials that extract and hold water vapor. They are classified into two categories: absorbents and adsorbents.

Absorbents, such as lithium chloride (LiCl) and sodium chloride, become liquid as they take in moisture—that is, they undergo a physical or chemical change. If left exposed to high-relative-humidity air without regeneration, absorbent rotors will deliquesce—that is, the desiccant will overadsorb moisture to the point damage occurs. LiCl has a very high capacity for moisture. So, if a unit is left off for an extended period, LiCl will absorb humidity until it becomes so weak it drains out of the media. The combination of water weight and soaking effect will destroy the rotor, so good controls and painstaking maintenance practices are necessary for absorbents. Also, most absorbents are salts that promote corrosion of metal parts and heat exchangers under certain conditions.

Adsorbents do not undergo a physical or chemical change. Instead, water is held on the surface and in the pores of the material. Commercial rotors use desiccants such as silica gel, molecular-sieve polymers, and activated alumina, which are formulated for specific applications, such as very low dew point, higher moisture loading, and low-temperature regeneration. Solid rotors can be sensitive to hydrothermal stress, which results from thermal expansion and contraction caused by rapid changes in temperature and desiccant moisture content. Most desiccants fall into the adsorbent category.

Within the adsorbent family, leaving moisture levels down to about 20- to 30-F dew point are best served by silica gel or titanium desiccant material. These are designed for the more saturated air streams of common HVAC applications, with good moisture capacity over a broad range of operating conditions. For lower dew points, molecular-sieve desiccants often are used, but if reactivation energy is of primary concern, then one of the higher-loading desiccants may be used.

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