

CHAPTER 3 TYPES OF DESICCANT SYSTEMS

All-Desiccant & Hybrid Systems

Desiccant systems combine a desiccant wheel with additional cooling and heating components. These may be conventional gas-driven or vapor-compression coolers, or they may be evaporative coolers combined with heat exchangers.

COMMERCIAL DESICCANT SYSTEMS

Figure 1 shows a typical example of a desiccant system designed for a commercial building. It includes a desiccant wheel for humidity control, and a conventional vapor compression cooling system for temperature control.

Such designs combine the best of both technologies, and point to one of the principal advantages of desiccant-assisted HVAC systems, namely that they can control humidity independently of temperature. The desiccant subsystem is controlled by a humidistat and the cooling coil is controlled by a thermostat. This allows humidity control regardless of what the space may or may not need for heat removal.

But fundamentally, there are two different types of desiccant systems: those which use only desiccants for all cooling and humidity control, and those like the system in figure 3, which combine desiccants with conventional components.

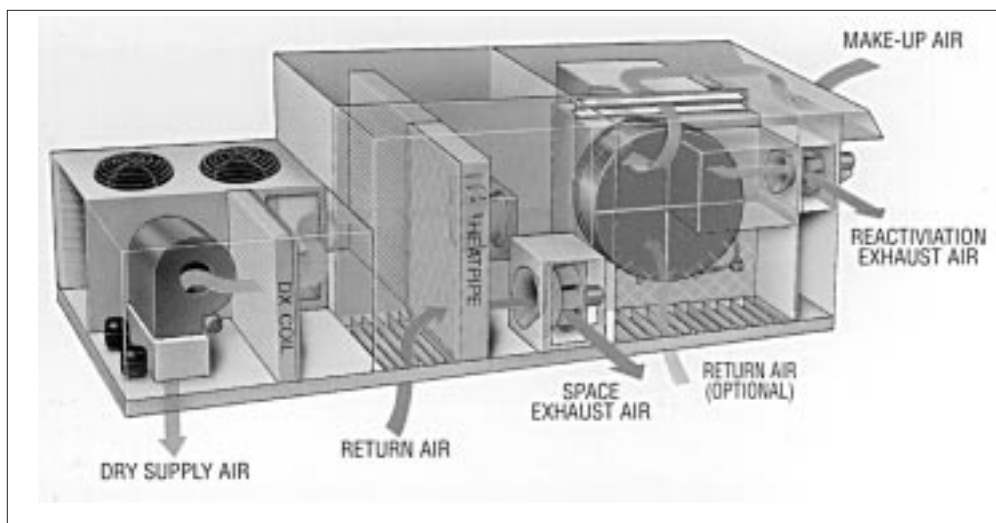


Figure 1. Hybrid desiccant system using both desiccant and vapor-compression cooling.

ALL-DESICCANT SYSTEMS

Figure 2 shows how a desiccant wheel can be combined with a rotary heat exchanger to form a complete air conditioning system. Air is dried by the desiccant wheel, and then cooled by the heat exchanger.

This configuration has useful advantages when large amounts of fresh air are needed, and when the exhaust air can be evaporatively cooled and used for post-cooling the air leaving the desiccant wheel. Under those circumstances, an all-desiccant system is the same physical size as conventional alternatives because the ventilation air required for the building defines the overall system's air flow.

The system also uses very little electrical power, so it has advantages when electrical demand charges are high. When these two circumstances combine, such as when large amounts of ventilation air must be added to an existing building in an area with high peak demand charges, the all-desiccant system will reduce both energy and first cost compared to other ways of adding the increased fresh air.

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The disadvantage of the all-desiccant system is that, at peak design temperatures, it delivers supply air at temperatures above 70°F.

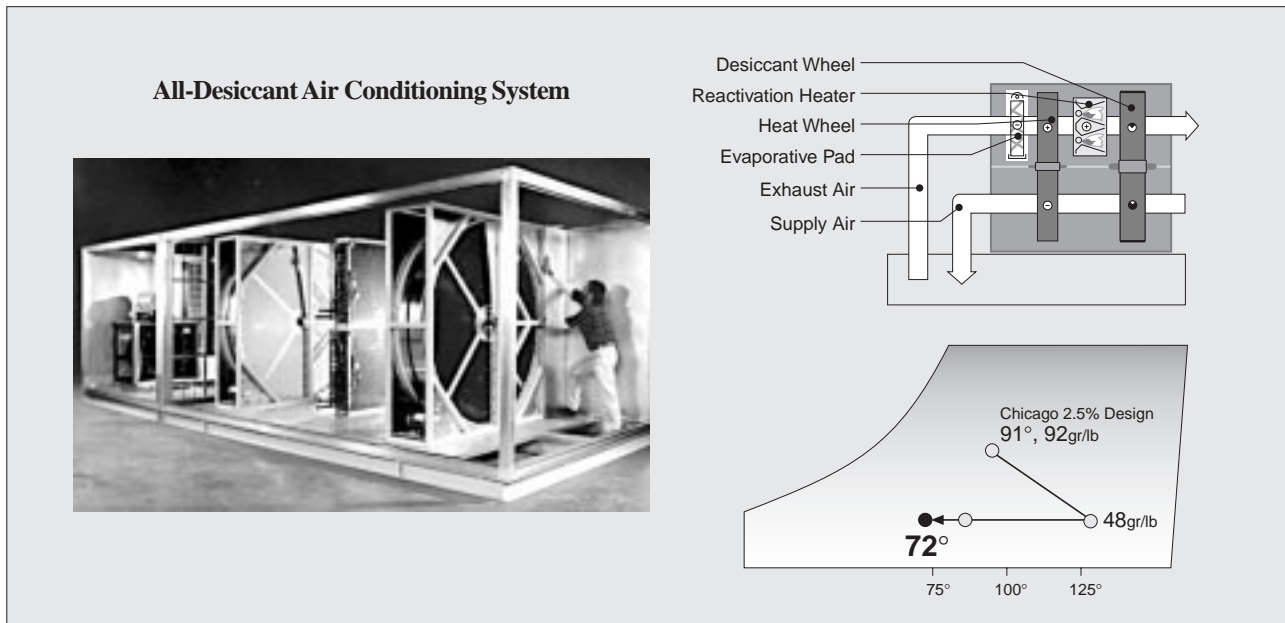


Figure 2 All-Desiccant system, including an indirect evaporative cooler.

The only exceptions are in far-north and high-altitude climates, where the ambient moisture is so low that evaporative cooling can provide lower air temperatures.

So in most climates, if the building does *not* need a large percentage of ventilation air, and when the exhaust air *cannot* be collected and brought back to the unit for post-cooling, the all-desiccant system has a disadvantage compared to a hybrid system. Since it cannot cool air below 70°F on a "design day", the all-desiccant system must use large amounts of air to remove a given heat load. Such systems are physically much larger than an equivalent conventional cooling system. The conventional system would supply 55° air, and therefore remove the same internal sensible heat load using less air.

For example, consider a small office building maintained at 75°F with an internal sensible heat load of 180,000 Btu/h (15 tons). If the supply air can be cooled to 55°F, the system will have to supply 8,333 cfm:

$$\begin{aligned} \text{Btu/h} &= \text{cfm} \times 1.08 \times \Delta t \\ \text{cfm} &= (180,000) \div (1.08 \times (75 - 55)) \\ \text{cfm required @55°F} &= 8,333 \end{aligned}$$

But if the supply air can only be cooled to 70°F, the temperature difference between supply and return is only 5°F, so the air flow needed to remove the load is much greater:

$$\begin{aligned} \text{Btu/h} &= \text{cfm} \times 1.08 \times \Delta t \\ \text{cfm required @ 70°F} &= (180,000) \div (1.08 \times (75 - 70)) \\ \text{cfm} &= 33,333 \end{aligned}$$

However, if that office building needs a great deal of outside air, the all-desiccant system could handle the ventilation load, and a separate system arranged to handle the internal heat load. In that circumstance, the all-desiccant system has advantages over a conventional system.

The desiccant system's 70°F delivered air removes some internal load since the space is being maintained at 75°F. And the heat exchanger in the desiccant system can operate during cooler months, to recover waste heat from the building exhaust. Since the system size is governed by the required outside air quantity and not by the internal load, the all-desiccant system is the same size as a conventional alternative. So installed cost is close to the same, and the desiccant system costs much less to operate because it uses so little electrical power.

In summary, an all-desiccant system is generally attractive when:

- Large amounts of air must be exhausted from the building.
- The exhaust air can be brought back to where the make-up air enters the building.
- Electrical demand charges are high.
- Supplying outside air at 70°F is adequate for the application.

In other circumstances, the engineer may wish to consider a hybrid desiccant system.

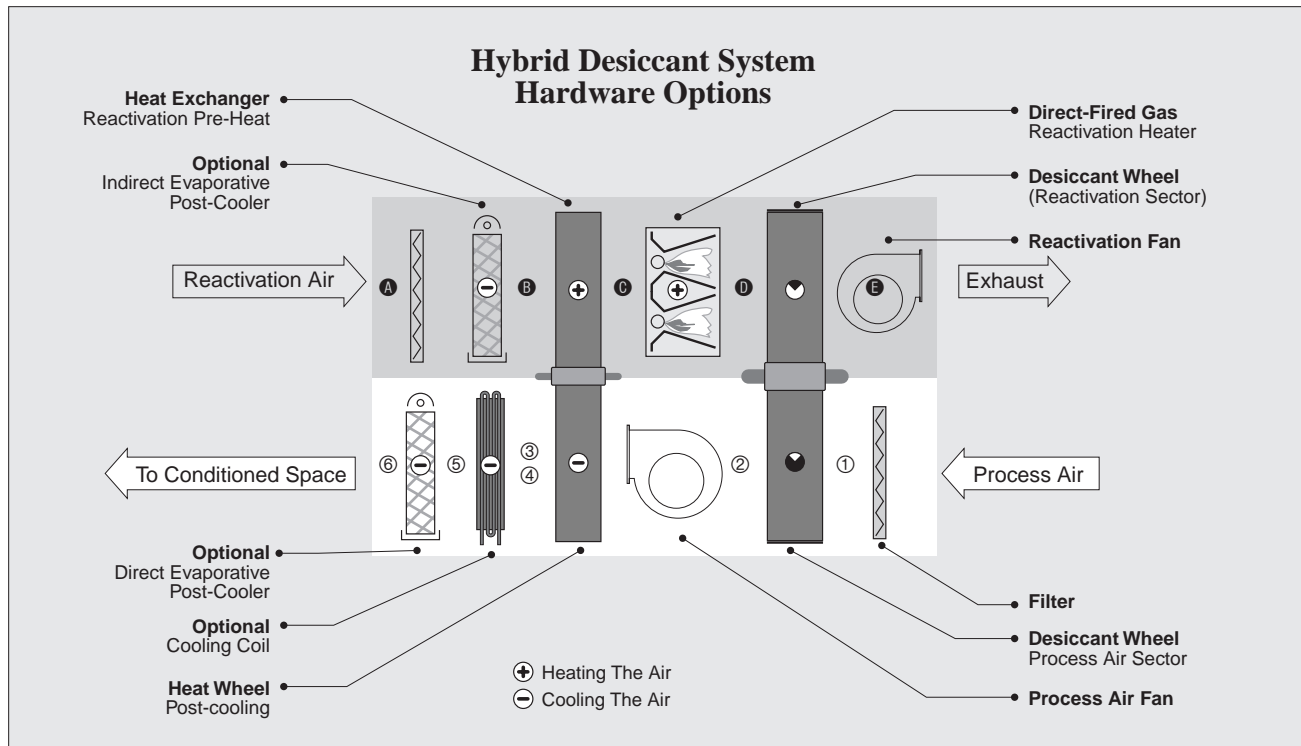


Figure 5. Hybrid desiccant system, including a variety of heating and cooling options.

HYBRID DESICCANT SYSTEMS

Figure 5 shows the wide variety of components which can form hybrid desiccant systems, i.e.: systems which include a desiccant component along with gas cooling or conventional coils.

Figure 6 shows the psychrometric behavior of different system alternatives. Note especially the dry bulb temperature leaving the system. To a great extent, the leaving air temperature determines which applications are economically practical for each system alternative.

Some applications, such as hotel corridors and ice rinks, are not sensitive to a leaving air temperature of 78 to 85°F on a design day during the summer. So an indirect evaporative post-cooler is the best cooling option because it is quite economical to install and operate. Other applications like hospital operating rooms must have air at relative humidities below 50% rh and temperatures below 65°F. In those cases, gas cooling or conventional cooling coils will be required downstream of the desiccant wheel.

To understand each equipment alternative, we will track the process air as it moves through the system. The diagrams in figure 6 assume the system is arranged to handle 100% outdoor air on the process side, and 100% outdoor air for reactivation.

- 1 Air enters the process side of the desiccant wheel from outside the building. It is hot and humid.
- 2 Air leaves the process side of the desiccant wheel hotter, and much drier than when it entered the system. In most cases, this air is too hot to send directly to the building. It must be cooled.
- 3 Dry air leaves the first stage of post-cooling at a lower temperature. The sensible heat has been removed from the process air and transferred to the reactivation air by a heat exchanger. The schematic here shows a rotary heat wheel, but heat pipes and plate-type heat exchangers are used by many system suppliers instead of heat wheels. Regardless of the type of heat exchanger, it provides a double benefit: the process air is cooled using only the energy needed to push the air through the exchanger. So the operating cost of the cooling is very low. Secondly, the heat from process is used to pre-heat incoming reactivation air, which saves slightly on the cost of thermal energy.
- 4 Point 4 represents the additional cooling which can be accomplished by the heat exchanger if the air on the other side of the heat exchanger is

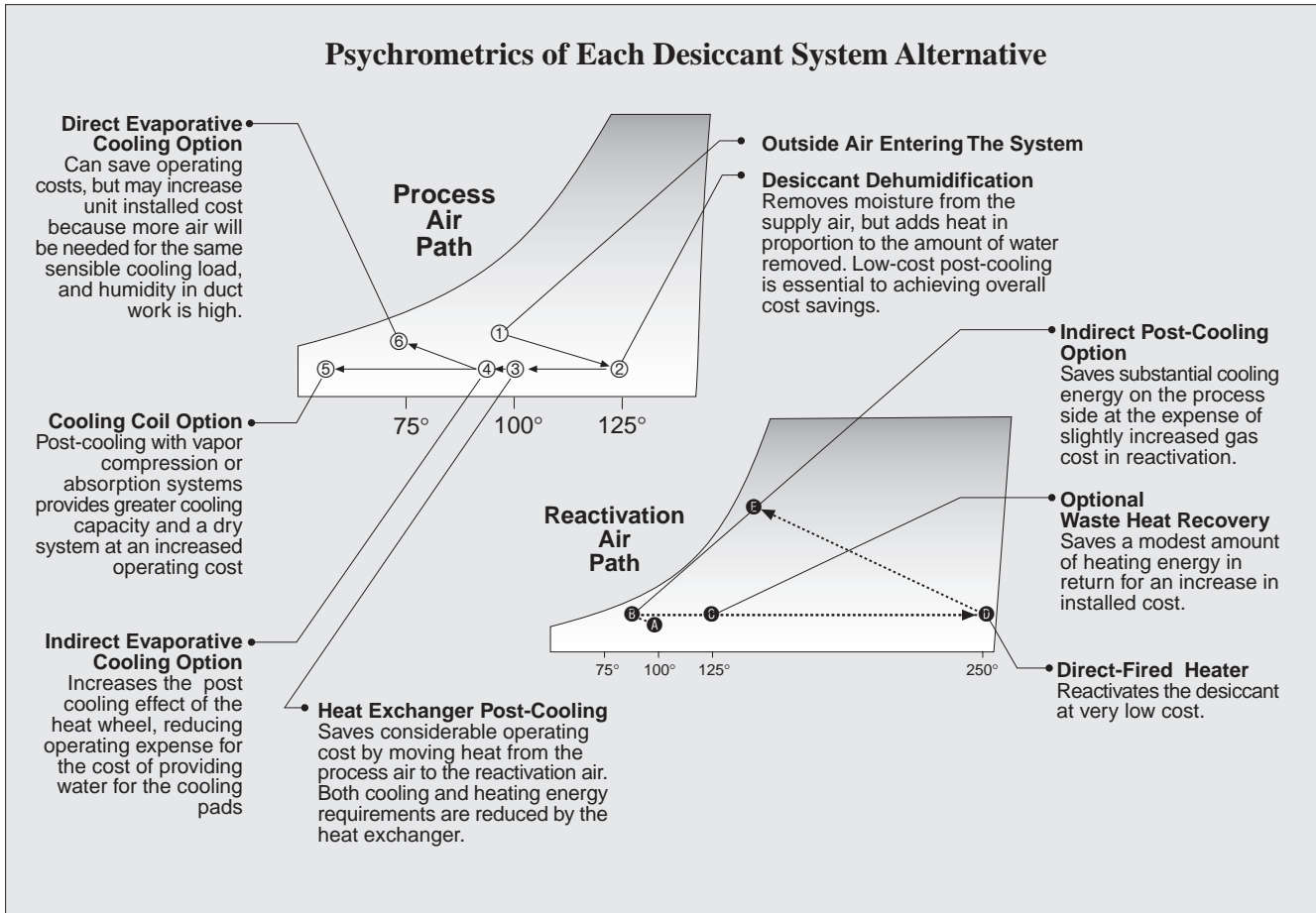


Figure 6. State points within a desiccant system.

evaporatively cooled. In this option, the incoming reactivation air is cooled by an evaporative pad before it enters the heat exchanger. Since the air on the reactivation side of the exchanger is cooler, more heat can be removed from the process side. This diagram shows roughly what happens on a design day, so the evaporative cooling effect is not very large. But when outside air temperature and moisture is lower—99% of the time during the year—the cooling effect of the evaporative pad will be substantial. This reduces the need for any subsequent post cooling.

5 Point 5 shows the temperature and moisture leaving the system when a gas cooling or conventional cooling system follows the heat exchanger. Air is sent to the building at a very cool and very dry condition. This configuration is popular because it keeps air distribution ducts and filters dry and free of microbial growth. Low temperature, dry supply air allows the system to do a great deal of cooling and dehumidification with less air than conventional cooling systems.

6 An alternative to conventional cooling coils is a second evaporative cooling pad, this time on the process air side. Direct evaporative cooling seldom chills air as deeply as a conventional coil. Also, the supply air is saturated at a comparatively high temperature (73 to 78°F on a design day). So such systems cannot be used to control humidity unless a relatively warm, highly humid environment is needed, as in a greenhouse.

The evaporative cooling option (point 6) is less expensive to install, and uses very little energy compared to conventional post-cooling alternatives. So this option has advantages when electrical power cost reduction is the principal goal of a project rather than humidity control.

To date, hybrid systems have been popular, perhaps because they combine the best characteristics of each technology: desiccants for moisture removal and conventional cooling for sensible heat removal. Hybrid systems are nearly always

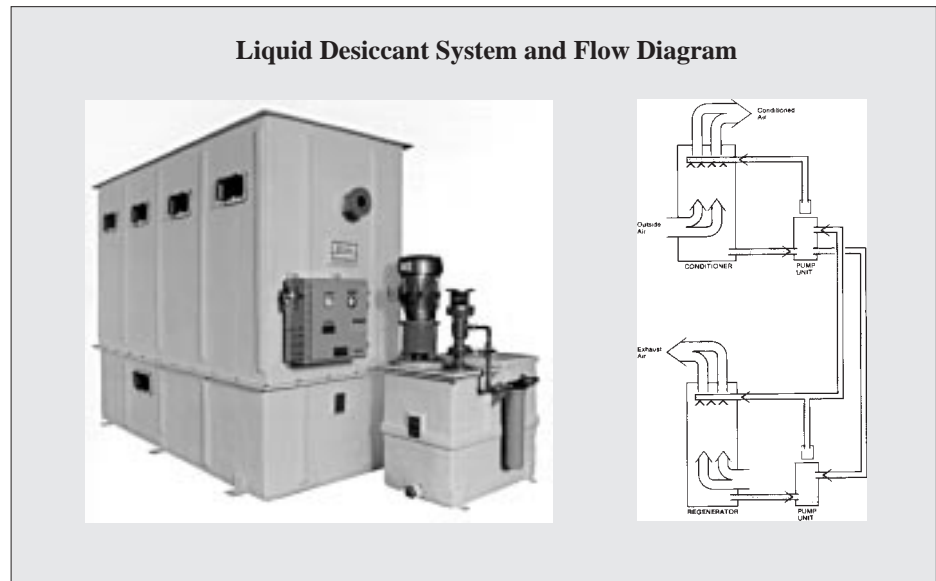


Figure 7. Liquid desiccant system

smaller than all-desiccant systems, because they can provide air at low levels of both temperature and humidity. So smaller hybrid systems can do the same work as larger all-desiccant or all-cooling units.

LIQUID DESICCANT SYSTEMS

Over the last 15 years, manufacturers of desiccant systems for commercial buildings have concentrated primarily on desiccant wheel type units, which use solid desiccants. But in industrial markets, liquid desiccant systems have been used very effectively since the 1920's. In recent years, manufacturers of liquid desiccant equipment have been expanding their activity in commercial markets.

The unique characteristics of liquid desiccant systems are effective in commercial applications, especially in larger buildings, where the advantages of liquid desiccants provide cost-effective competition to both solid desiccants and to conventional cooling systems.

How Liquid Desiccants Work

Liquid desiccants, such as lithium chloride, can absorb up to 1200 times their dry weight in water. The concentration of salt in the liquid solution determines the absorption characteristics of the liquid, which is sprayed into the process air. If the solution is concentrated, it can absorb moisture from drier air streams, and if the solution is dilute, it absorbs moisture from more humid air streams.

So by controlling the concentration of the solution, one can control the humidity of the air that passes through the liquid spray. In order to control the temperature of the process air, one simply adjusts the temperature of the liquid desiccant being sprayed into that air.

Liquid systems are very simple in concept, as described above. In hardware, they are somewhat more complex, because liquid desiccant solution can be corrosive, and because the components of the system can be located in different parts of a building with interconnecting piping. In the past, this flexibility of component arrangement has meant that in smaller sizes, liquid desiccant systems were more expensive to install than dry desiccant systems.

Unique advantages of liquid systems

In larger sizes, liquid and solid desiccant systems are closer in cost, and the advantages of liquid systems can be significant. Specifically, liquid systems:

- Kill bacteria and viruses, clearing the air of biological contamination
- Can operate effectively with very low-temperature reactivation energy (as low as 130°F)
- Can connect many process air conditioner sections with a single regenerator section, saving costs for large installations where many air inlets may be scattered widely through a building.
- Can use low-cost cooling tower water for removing sensible heat from the desiccant dehumidification process, eliminating any need for mechanical cooling equipment in many cases.

In summary, although a full discussion of liquid desiccant systems is beyond the scope of this application guide, the technology is well-proven. As manufacturers continue to reduce costs and simplify installation, liquid systems will be applied in low-rise construction as well as in the larger commercial and institutional and industrial buildings where liquids have enjoyed success in the past.