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DEHUMIDIFICATION

Desiccant Based

** Definitions * Options * Technologies * Equipment * Applications*

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- **What is Dehumidification . . . . . Why Dehumidify?**
- **Applications**
  - ***Traditional*** ***– Emerging***
- **The ABC of Dehumidification**
  - ***Definitions, terminologies and psychrometrics w.r.t. Dehumidification***
  - ***Options, Technologies and Equipment***

Desiccant Dehumidification – A specialisation in it's own right

To Dehumidify or Dehumidification – literally means "pulling out or removing" the moisture/humidity from the air.

Dehumidification, unfortunately, has always been treated as a ***poor cousin*** of the airconditioning industry.

People, know what a cooling or heating system is; they understand airconditioning; they are even aware of humidification; however, when it comes to dehumidification, the awareness, even amongst engineers, is fairly low.

Since airconditioners are known to remove some amount of moisture, it is often assumed that airconditioning will lower the relative humidity in a space.

And it surprises people when the exactly opposite happens.

It is quite possible that the relative humidity actually increases when the temperature in the room is lowered, as cold air cannot retain the same amount of moisture as warm air can.

However, of late, dehumidification, has started to be recognised as the increasingly important member of the HVAC family, and as a specialisation and a science in it's own right!

The purpose of this article is to familiarise ourselves with desiccant dehumidification and it's various aspects.

Why Dehumidify?

"It isn't the Heat, it's HUMIDITY" !!!

All who have suffered the discomforts of a hot, humid summer day understand this statement and are familiar with the effects of moisture in the air. That "muggy", uncomfortable feeling results because the relative humidity of the surrounding air is high. If the relative humidity were low on that same hot summer day, our body would not feel as uncomfortable.

Applications

Dehumidifiers have been traditionally viewed as equipment for "industrial" usage.

However, in the ***recent times***, dehumidifiers are being increasingly used for treating fresh air for **Indoor Air Quality (IAQ)** needs.

Thus, in this article, we will take a look at the uses of desiccant dehumidifiers for both "*man and his machines*".

Traditional Applications of Dehumidifiers

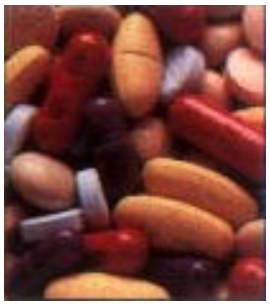
The uses of dry air are almost as limitless as the ingenuity of man. However, industrial applications can be categorised into 4 major areas …… Storage, Production & Processing, Packaging and Product Drying.

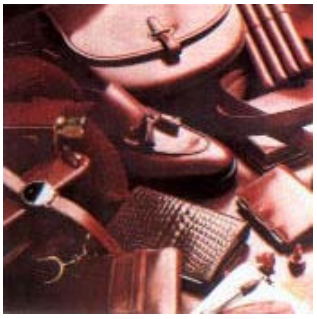
The Moisture menace

Although moisture is invisible, its damaging effect on almost everything around us is very evident.

Rusting of metals, lumping and decomposition of chemicals, increased microbial activity leading to growth of mold, mildew and fungi on organic substances, warping, decay, deterioration, etc. are some of the common problems due to high humidity encountered in our daily life.

In most cases, controlling the relative humidity to below 35% helps to keep this moisture menace under check.





The concept of dehumidification dates back to World War II when it was used by the Navy to mothball ships to maintain them in the 'as is' conditions. However, the advent of new technologies and new products has widened the scope of this field to extensive industrial applications with the result that many areas of high technology cannot function today without a controlled climate.

Emerging application of dehumidifier for treatment of fresh air

People prefer cool and dry air!

The impact of indoor humidity on people has been neglected for decades. Ventilation rates required to obtain a certain perceived air quality, have been also assumed to be independent of humidity. It has been generally accepted that pollutants from indoor air sources viz. from humans, tobacco smokes, VOCs etc, need to be diluted with outdoor air to a level perceived acceptable by the people. Thus, treating outdoor air for humidity control has not been the focus of designers. However, recent studies at various international forums have shown that perceived Indoor Air Quality (IAQ) is strongly influenced by both ***humidity*** and ***temperature*** of air we inhale! Increased awareness of IAQ and health consciousness has resulted in increased concern for methods used to treat fresh air.

Treating fresh air with rotary desiccant dehumidifiers to control humidity

Conventional treatment of air, where air is cooled, condenses the water, which tends to create health problems due to mould, mildew and bacteria formation.

Using a rotary desiccant dehumidifier to precondition air is preferred in service industry or similar areas where 100% fresh air is required to be treated.

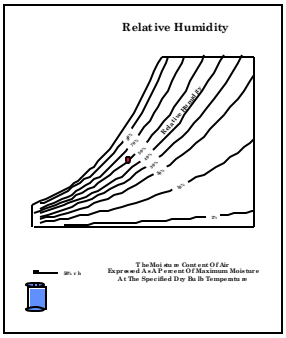
The ABC of Dehumidification

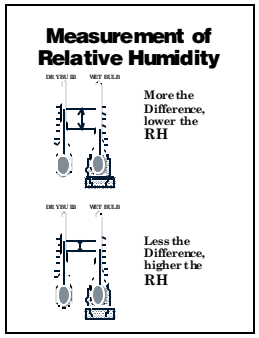
(Definitions, Terminologies and Psychrometrics)

Before we proceed further, let us familiarise ourselves with some of the often used terminologies and their definitions.

- **Relative Humidity or RH**

  Relative humidity is the actual amount of moisture in the air compared to the total or maximum moisture the air can hold at a given temperature.



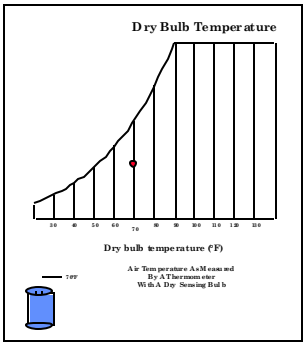


- **Grains of Moisture**

  Grains of moisture is the unit of measurement of the amount of moisture in the air.

- **Dry Bulb Temperature - °C or °F.**

  The *dry-bulb temperature* is the temperature of the air as measured by an ordinary household thermometer.



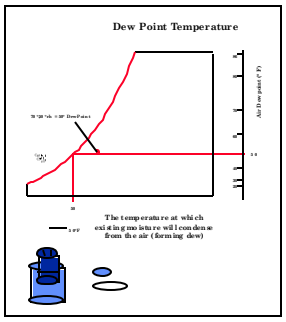
- **Wet Bulb Temperature - °C or °F**

  The Wet-Bulb temperature is the temperature of the air as measured by an ordinary thermometer whose glass bulb is covered by a wet wick/cloth.

  Airflow around the wick causes the evaporation of moisture thus lowering the temperature and producing a reading lower then that on the dry bulb thermometer.

- **Dew Point Temperature**

  Dewpoint temperature is the temperature at which moisture condenses on a surface.

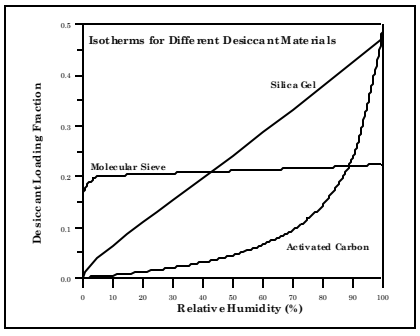


- **Desiccants**

  Can either be solid or liquid. A desiccant is a material that posses affinity for water vapor greater than that of air. Desiccants are of 2 types.

Absorbents

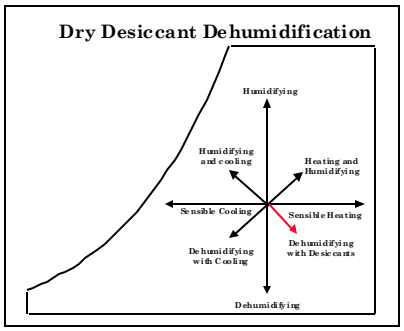
Absorbents are generally liquids or solids which become liquid as they absorb moisture, i.e. they undergo a physical or a chemical change as they collect moisture. Lithium Choride (LiCl) and Sodium Choride (NaCl) are typical examples of absorbents.



Adsorbents

Adsorbent do not under go any physical or chemical change when they come in contact with moisture. Water is adsorbed or held on the surface of the material and in the pores, Adsorbents are mostly solids. Typical examples of Adsorbents used for dehumidification are silica gel, molecular sieve and activation alumina.

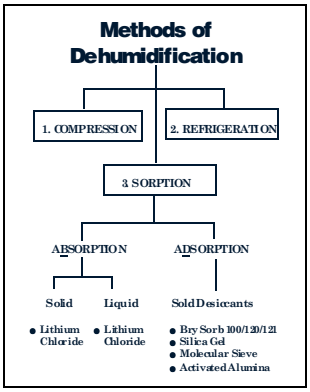
The ideal desiccant would have an infinitely high surface area for collecting moisture, and an infinitely low mass, since the required heating and cooling energy is directly proportional to the mass of the desiccant and the mass of the machinery which presents the desiccant to the air-stream. The heavier the desiccant assembly compared to its capacity, the more energy it will take to change its temperature—which accomplishes dehumidification.



- **Psychrometric Chart**

The psychrometric chart is a tool which simplifies the measurement of air properties in a graphic presentation of several interrelated air parameters brought together.

OPTIONS, TECHNOLOGIES AND EQUIPMENT



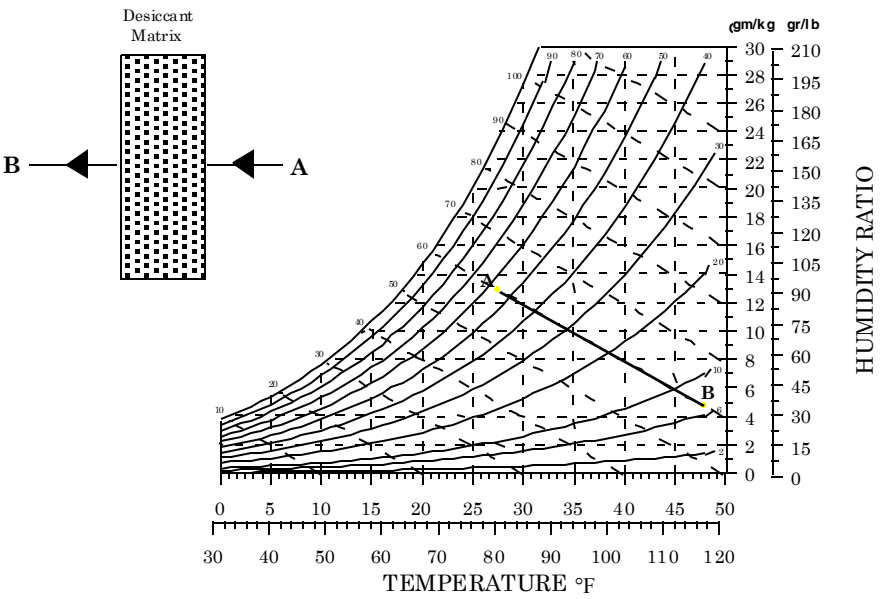
USING COMPRESSION TO DRY AIR

As air is compressed, the dew-point or temperature at which water will condense is raised. Therefore, to get dry air we need to find a way to cool the compressed air. But costs can be prohibitive because equipment, space, and auxiliary equipment are necessary for the process. However, if compressed air is already used in the primary operation and only very small amounts of dry air are needed for humidity control, compression may be a feasible route to dry air.

USING REDUCED TEMPERATURES TO DRY AIR

Lowering air temperature decreases the air's ability to hold moisture. Thus, the air can be made drier by cooling it. However cooling air just to dry it is usually not practical. An exception might be when cool air is needed anyhow, that air's dryness satisfies the needed moisture conditions, and enough conditioned air is available. Normally, this method is reserved for applications where outdoor air is being dried to levels only slightly lower than the incoming ambient-that is, the system air.

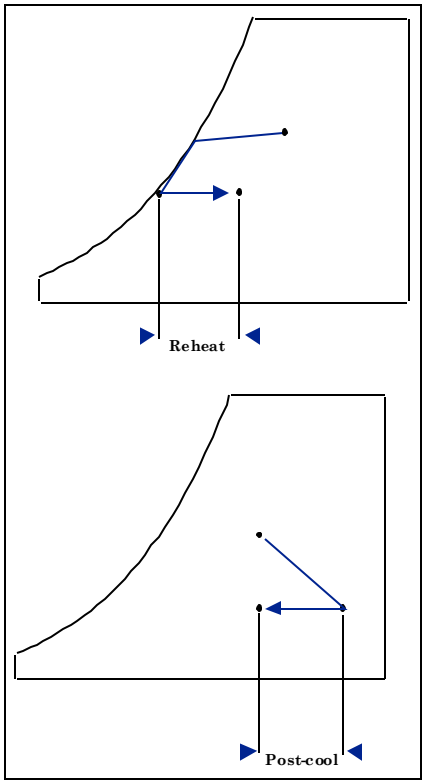
USING DESICCANTS TO DRY AIR



Basic Air Desiccation Process

The most simple, straightforward way to obtain dry air is to use desiccants-that is, adsorbants or materials that have a natural affinity for water. A desiccant is able to take up the additional moisture given up by the air without changing its size or shape. So an air stream can pass through a desiccant bed and become significantly drier without elaborate cooling, compression, cooling water, or other complex systems or controls. After the drying task is complete, the desiccant is regenerated via heat. Then the desiccant is ready to dry more air.

Comparing Desiccants to Convention Cooling
(Desiccant Dehumidification Vs. Mechanical Refrigeration)



Both desiccant dehumidifiers and mechanical refrigeration systems can remove moisture from the air, so the question is - which type is best suited for a given application? There really are no simple answers to this question but there are several generally accepted guidelines which most dehumidifier manufacturers follow:

– Both desiccant-based and refrigeration-based dehumidification systems work most efficiently when used together. The advantages of each compensate for the limitations of the other.

– Refrigeration-based dehumidification systems are sometimes more economical than desiccant based dehumidifiers when higher temperatures and humidity in the conditioned space is acceptable. In general, mechanical refrigeration systems are seldom used for applications below 50% RH at about 22°C or for a dewpoint lower than 11°C.

– Desiccant-based systems are more economical than refrigeration systems at lower temperatures and lower moisture levels. Typically, a desiccant dehumidification systems is utilized for applications below 45% RH down to less than 1% RH. Thus, in many applications, a DX or chilled water pre-cooling coil is mounted directly at the dehumidifier inlet. This design allows for removal of much of the initial heat and moisture prior to entering the dehumidifier where the moisture is reduced even further.

EQUIPMENT

There are four typical equipment configurations for desiccant dehumidifiers:

- Liquid spray-tower
- Solid packed tower
- Solid granular based
  - Rotating horizontal bed
  - Multiple vertical bed
- Fluted Media Based

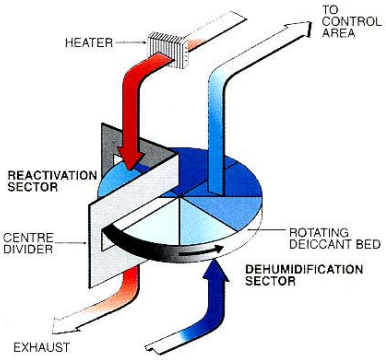
In this article, we will focus on the solid granular based and fluted media based dehumidifiers as currently they are the two most used dehumidifier types.

SOLID GRANULAR BASED

Rotating horizontal bed

In this device, dry, granular desiccant is held in a flat, segmented rotary bed that rotates continuously between the process and reactivation airstreams. As the bed rotates through the process air, the desiccant adsorbs moisture. Then the bed rotates into the reactivation airstream, which heats the desiccant, raising its vapor pressure and releasing the moisture to the air.

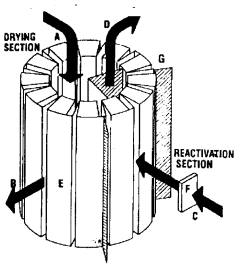
The process and reactivation air heats and cools the desiccant to drive the adsorption-desorption cycle. The moisture is removed through a process of continuous physical adsorption on a continuous basis (both, counter flow and parallel flow options are available).



The adsorption of moisture and reactivation of desiccant take place continuously and simultaneously without any cross mixing of the process and reactivation air streams.

To increase capacity, the manufacturer can either increase the diameter of the rotating bed to hold more desiccant, or increase the number of beds stacked on top of one another. Both options are not practical if very large volumes of air need to be dehumidified. If the desiccant is evenly loaded through the trays, the rotating horizontal bed provides a fairly constant outlet moisture level, and a high airflow capacity can be achieved in less floor space than with dual-tower unit.

The rotating horizontal bed design offers a low first cost. The design is simple, compact and easy to produce as well as install and maintain.



MVB Operating Principle

Modular Vertical Bed (MVB)

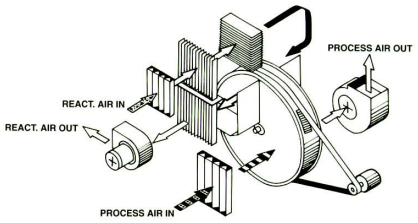
The Modular Vertical Bed (MVB) design is a 'fairly new' but 'proven' concept with the combined better features of packed tower and rotating horizontal bed designs in an arrangement that is well suited to atmospheric pressure dehumidification applications, and yet can achieve very low dewpoints. The single or double tower is replaced by a circular carrousel with eight or more vertical beds (towers) that rotate, by means of a drive system, between the process and reactivation air streams.

This design can achieve low dewpoints because leakage between process and reactivation air circuits is almost negligible. Also because the beds are separate and sealed from one another, the pressure difference between process and reactivation is not so critical; so airstreams can be arranged in the more efficient counter-flow pattern for better heat and mass transfer. Like the rotating bed, the ratcheting, semi-continuous reactivation of the desiccant provides a relatively constant outlet air moisture condition on the process side, reducing the "sawtooth" effect that can occur in packed tower units.

The "MVB" design allows for low replacement cost of desiccants as well as large savings in energy and performance improvements at low dew points, especially if the equipment incorporates a heat pipe heat exchanger in the regeneration air circuit.

FLUTED MEDIA BASED DEHUMIDIFIERS

Another dehumidifier design uses a rotating fluted wheel/rotor to present the desiccant to the process and reactivation airstreams. This is sometimes called a fluted media/honeycomb type dehumidifier. The desiccant is impregnated/ synthesised on "honeycomb" like corrugated rotor. The principle of operation is the same as the solid desiccant (granular) based system.



FVB Operating Principle

The process air flows through the flutes formed by the corrugations, and the desiccant in the structure adsorbs the moisture from the air. The rotating desiccant bed picks up moisture, and well before "saturation" the rotor/wheel rotates into the reactivation segment where it is heated to drive off the moisture.

The fluted design has its own advantages as it is comparatively light weight and has a smaller foot print.

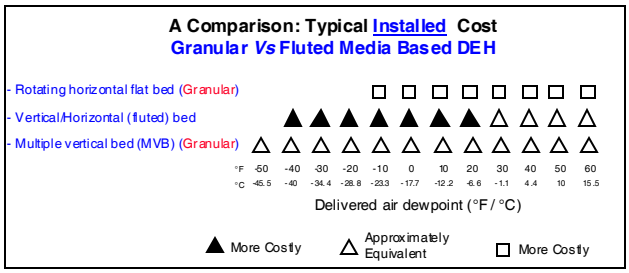
The fluted design is the preferred option where space is a limitation and there is a leeway to sacrifice "performance" slightly.

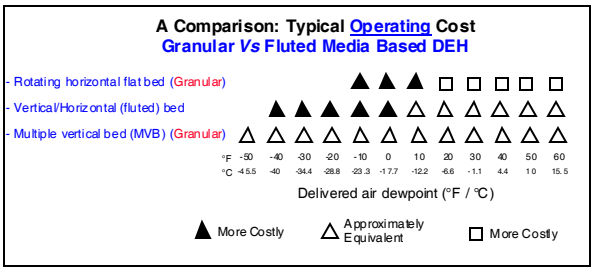
One has to also keep in mind the higher replacement cost of the rotor compared to the desiccant in the granular systems.

Comparing desiccant dehumidifiers

All desiccant dehumidifiers can be made to work in virtually any application suited for desiccant dehumidifiers. The limitations of each configuration can be overcome and benefits of each design optimized by careful application

engineering. No firm statement can be made about the limits of performance or amount of energy consumed or mechanical reliability of different dehumidifier types outside of a particular set of installation circumstances. ***Good application engineering, in addition to the dehumidifier type, makes a dehumidification installation reliable, efficient and low in first cost.***





Some of the criteria which a design engineer must cater for while designing a system are:

- **Installed cost**

  The initial cost of the dehumidifier itself is sometimes a small fraction of the cost of the installation or the running cost. Different configurations vary in their need for additional support infrastructure viz, utilities, chilled water, floor space etc.

- **Operating cost**

  The initial cost of mechanical systems is often much less as compared to their cost of operation and maintenance. The main operational cost of a dehumidification system is heat for reactivation and cooling of the desiccant and process air. Today, dehumidifiers are designed to take advantage of low-cost energy sources for these utilities. Often reactivation energy cost can offset installed cost differences in a matter of months, yielding enormous financial benefits over the typical 15 to 30 years life of this equipment. Also, designs incorporating energy recovery systems have an advantage over dehumidifying systems without energy recovery.

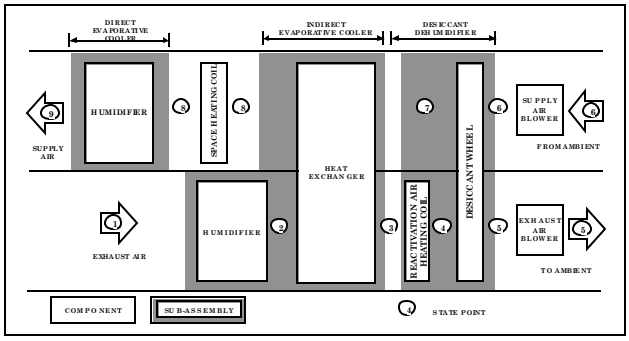
- **Design assumptions**

  Engineers and manufacturers make different assumptions concerning a given application. The selection of equipment configurations and size is completely dependent upon these assumptions. Often reasons for widely varying selections are the result of incomplete or erroneous data available to the system designer.

Conclusion

Before we close, let us take a look at the equipment for the next millenium . . . . . **Two wheeled systems or**

Desiccant Based Cooling (DBC) Systems



Desiccant ventilation has come of age and has moved from 'research' to commercialisation. Desiccant based evaporative cooling system provide environment friendly technology for comfort airconditioning with added advantage of simple robustness and low power consumption.

Having understood the basic operating principle of various desiccant based dehumidifiers, it is evident that today the user has unlimited options in desiccant dehumidification systems depending on his needs. Each of the systems or applications discussed here can be a subject of a the full length article in itself.

(Readers can get in touch with the author for detailed information on any of the equipment/application discussed in the article)