PHARMACEUTICAL INDUSTRY

The importance of air humidity in
production and storage

Humidification, dehumidification
and evaporative cooling

condair

The necessity of air dehumidification in the pharmaceutical industry

Companies specializing in the manufacturing, processing, and the storage of pharmaceutical products (most of which are intended for the treatment of diseases) must maintain strict hygiene standards to ensure consistently high product quality. In order to ensure the production processes run smoothly, good indoor air quality along with specific temperature and humidity levels are often required in laboratories, production, packaging and storage areas. However, these processes are constantly affected by moisture ingress from the warm and humid outside air, people, and the products themselves.

Depending on the type of pharmaceutical product and its processing, the spectrum of climatic conditions ranges from “high ambient temperature with high humidity” to “low ambient temperature with low humidity”. The more that product integrity and quality take precedence over other criteria, the more production and processing parameters must be constantly geared towards ensuring perfect product condition and quality. This is especially true for products from the chemical and pharmaceutical industries. Controlled dehumidification is one of the most important prerequisites to ensure that the highest standards are maintained at all times.

The positive effects of a stable humidity level apply not only to the application in question but also to the processing stages and the quality of the finished product. The use of effective dehumidification solutions during processing, filling, and packaging of the products concerned contributes to the necessary drying of hygroscopic substances (e.g. to prevent reactions with condensate). It also helps with the drying of storage areas or silos (e.g. as a result of cleaning operations).

A decisive quality factor in many applications is the processing of specific raw materials into powders, tablets, sugar-coated tablets, liquids, or other dosage forms. It is particularly important that the flowability of bulk materials is maintained at all times during processing in order to avoid excess moisture, especially when processing hygroscopic substances. Dehumidification systems prevent clumping or hygroscopic reactions and thus ensure an optimal process flow.

In addition to cooling the process air during the various manufacturing operations, dehumidification of the storage and logistics areas is also a constant challenge. Here, too, low and constant humidity is required to ensure the integrity of chemical and pharmaceutical products and to keep their packaging and labels intact.

Introduction to thermodynamics: How dehumidification works

Air dehumidification for a process or ensuring specified target room air conditions results in the following challenges:

Example 1: Production and packaging of tablets

Task: Dehumidification of an air volume flow to 68°F (20°C) and a humidity of ≤ 20.3 grains/lb or ≤ 20% RH for a packaging process in the pharmaceutical industry (blue curve in the psychrometric chart on the following page).

Processes of this type often require well-defined temperatures and, at the same time, very low humidity levels. Consider an outside air volume flow with a temperature of 89.6°F (32°C) and a humidity of 98 grains/lb (47% RH) (point 1) is to be dehumidified to a supplied air condition of 68°F (20°C) and a humidity of ≤ 20.3 grains/lb (≤ 20% RH). A desiccant dryer is used for this purpose. Changes in the state from the outside air to the supplied air follow the course of the blue line in the psychrometric chart.

Step 1 of air treatment consists of pre-cooling and pre-dehumidification of the air. Assuming the cooling coil flow and return temperatures are 43°F (6.1°C) and 54°F (12.2°C) respectively, air conditions of 57°F (13.9°C) and 100% RH are achieved at the coil outlet/desiccant rotor inlet. Pre-dehumidification of the air using the pre-cooler consists of a sensible cooling of the air between points 1 and 1', followed by a latent cooling from point 1' to point 2.

In **Step 2**, the air in the desiccant dryer is first dried along the line of constant enthalpy (points 2 to 3'). Then, the remaining heat in the rotor (residual heat) results in an additional sensible heat gain at the end of the drying process along the constant enthalpy line. The dry air leaving the dehumidifier has a moisture content of approximately ≤ 19.1 grains/lb and a temperature of about 111°F (43.9°C) (point 3).

Finally, in **Step 3**, the now dry air is sensibly cooled to the target temperature of 68°F (20°C) (point 4).

Example 2: Raw material store for vaccines

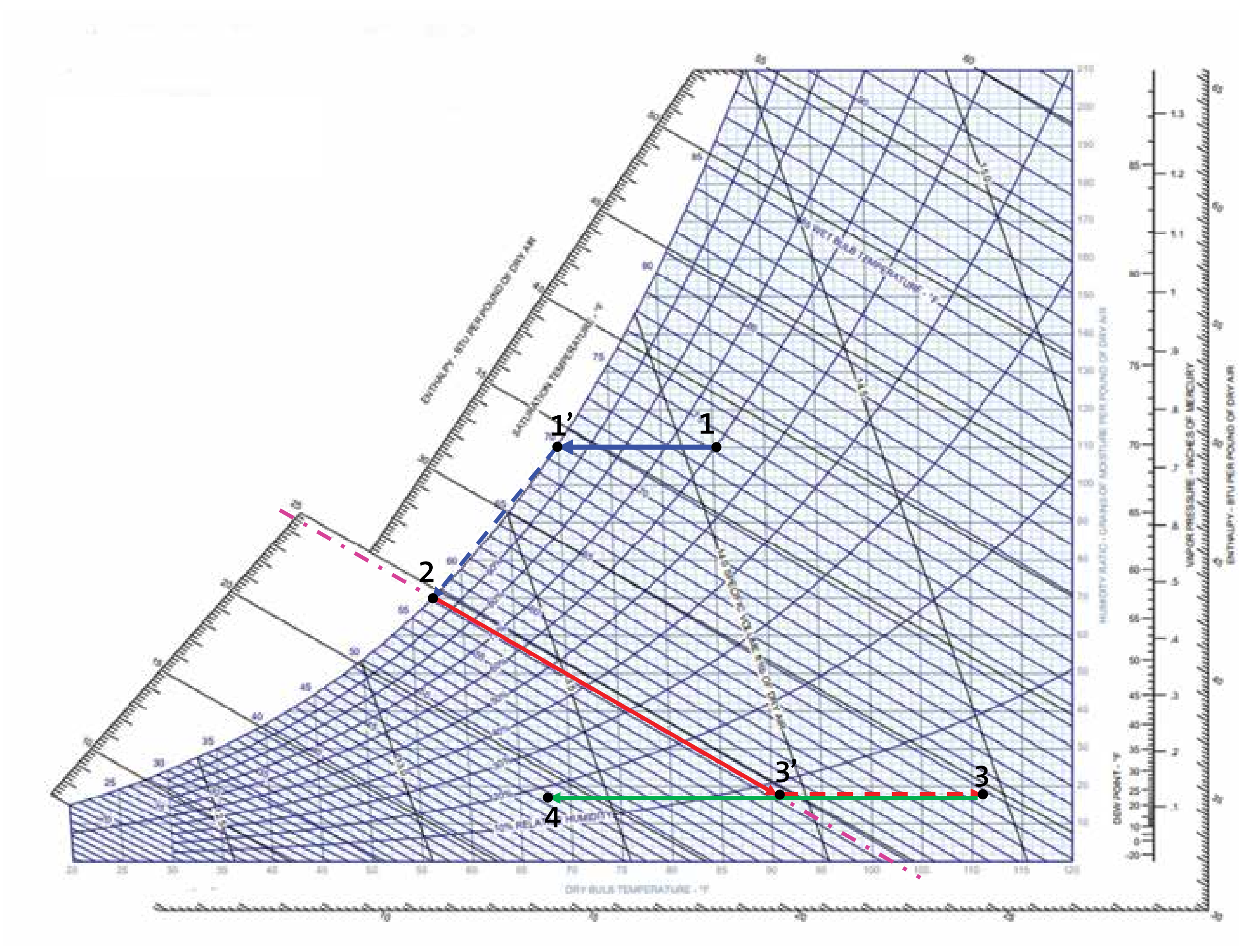
Task: Ensuring a humidity of 50% RH (51.1 grains/lb) at a room temperature of 68°F (20°C) in a vaccine raw material store (not shown in the psychrometric table).

A constant supply of fresh air through a ventilation system leads to a defined humidity supply in the summer because the ventilation unit does not pre-dehumidify the outside air sufficiently. In this process, 1,177 CFM of preconditioned outdoor air with a humidity of 71.4 grains/lb is introduced into the room. This corresponds to a humidity load of 15.3 lb/hr (=60min/hr *(1,177 CFM* 0.075 lb/ft^3 * (71.4 - 51.1) grains/lb / 7,000 grains/lb)).

For continuous dehumidification of indoor air, a condensing dehumidifier with an airflow of 2,472 CFM is installed in a decentralized location in the room. It draws air with a humidity of 51.1 grains/lb into the room and dehumidifies it to a humidity of 39.2 grains/lb. This corresponds to a dehumidification capacity of 16.1 lb/hr and compensates for the moisture introduced by the fresh air intake.

After this brief introduction to the theoretical principles, further examples of air drying in the pharmaceutical industry are given on the following pages. More detailed information on typical areas of application, operating principles and properties of adsorption dryers can be found on the next pages.

Desiccant Drying Process
Example 1



Protecting hygroscopic raw materials, preserving active substances

Even slight deviations from the "ideal" moisture content of the raw materials can have an impact on the specific properties of the materials used and on the entire production environment in which they are processed. Particularly, during further processing, previous and subsequent storage, excessive room humidity can reduce the desired efficiency of the raw materials in the process and also impair the conveying and transport routes during processing, e.g. due to clumping. As a result, the desired end product may not be produced or alternatively produced with a reduction in quality. The assessment of the optimum humidity of the ambient air during a chemical or pharmaceutical process depends directly on the overall process. Often, "physical" effects are involved.

For example, the special flow and pouring characteristics of powders or granules must be kept at a constant functional level during production. This is particularly true for hygroscopic materials such as common salt, sodium or potassium hydroxides, nitrates, sulfates, phosphates, and a variety of active pharmaceutical ingredients.

Condensation can also have negative effects on powders that are processed into coatings or chemical plastics. These can absorb many times their own weight in liquid and, if oversized, can "block" further processing or result in unusable end products.

In industrial chemical or pharmaceutical processes it is therefore of utmost importance to reduce the humidity and to adjust it precisely to the appropriate parameters.

Ensuring the flowability of bulk materials

Severe fluctuations in air humidity or generally excessive humidity of bulk materials in the production environment can greatly impair or even completely destroy the flowability of the materials to be conveyed. This applies in particular to granular or powdered materials. To prevent hygroscopic bulk materials from sticking to belts or presses, or blocking conveying paths by forming lumps, the ambient air in the chemical or pharmaceutical industry must be pre-dehumidified to the specific product and process conditions. This can be reliably achieved with modern, state-of-the-art, adsorption dryers. The pre-dehumidified indoor air ensures that the flowability of the raw materials is maintained from storage in the silos through transport on the conveyor belts to final storage.

In this way, the processing quality can be maintained, and possibly reduce the maintenance costs of the installation.

Hygienic production conditions

Condensate contamination
Precise and application-optimized air dehumidification plays a decisive role in maintaining high hygiene standards, as required in the pharmaceutical and chemical industries. In the manufacture of perishable products, temperatures in production rooms, as well as in laboratories and storage rooms, are usually kept at a low level. Therefore, whenever the room needs to be accessed, warmer air and moisture enters the room. This moisture can quickly condense on the ceilings, walls, or on the surfaces of equipment and furnishings. Places with permanent moisture accumulation are a breeding ground for the growth of microorganisms such as fungi and bacteria.

Condensing moist air has a similar negative effect, especially on the metallic components of appliances and furnishings. This promotes the development of corrosion damage, poses the risk of contamination by condensation, and thus makes it difficult to comply with the necessary hygiene regulations.

How corrosion occurs
Sufficiently dry air prevents iron from rusting. However, when moisture settles on the metal, oxygen (O_2) and water (H_2O) react to form hydroxide ions (OH^-). To balance the electrons required for this reaction, the iron oxidizes, that is, it gives up its electrons, which are then absorbed by the oxygen. This process produces iron oxide, i.e. rust. Where electrons have been withdrawn, an electron deficiency occurs and positively charged iron ions (Fe^{2+}) are released. The latter migrate into the water droplets where they combine with the negatively charged hydroxide ions (OH^-). In the first step, iron(II) hydroxide is formed as a result of different charges. Further reactions with water, oxygen, and hydroxide ions result in ever more continuous reactions from which iron(III) oxide and iron(IV) oxide are formed. They settle on the metal surface and give rust its typical appearance. Unlike metals such as aluminum, the process only stops when there is no more iron.

Corrosion damage
Condensation quickly forms on the often very large surfaces of pipes and fittings through which cold water flows: the lower the temperature of these surfaces, the greater the risk of condensation forming. The consequences of this can be significant and costly. Over time, the prolonged exposure to moisture causes rust to form in the affected areas. Furthermore, depending on the position of the pipes, the condensate can also reach the production or storage containers below and, depending on the function of the plant components in the production process, cause considerable damage.

The use of desiccant dryers, prevents condensation, corrosion damage and mold formation thus preventing permanent damage to products and production facilities.

Improvement of production quality and consistency

Spray drying for the production of powdered pharmaceuticals

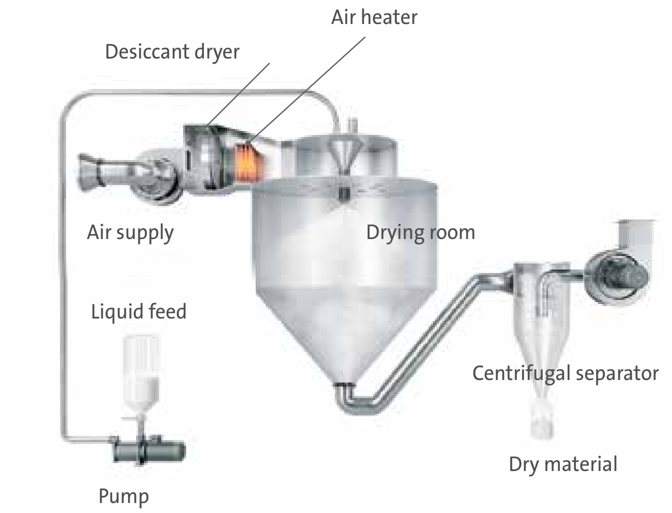
In many sectors of the pharmaceutical industry and in chemistry, products are transformed into powders through industrial processes. These powders enter the market as finished products or are used as raw materials for the manufacture of other products, such as tablets, sugar-coated tablets or medicinal powders.

The spray-drying process has played an essential role in the production of these high-quality powders for many decades. It is very efficient, gentle on the product and is also suitable for the continuous production of large quantities of powder, e.g. from solutions or suspensions. The spray drying process is based on a massive enlargement of the surface of the base substance from which a powder is to be obtained.

In the first step, a liquid, often pre-dried by evaporation, is pulverized into very fine droplets, which increases its surface area by a factor of 1,000. At the same time, in the second step, air that has been previously filtered, heated and dried is introduced into the process. The hotter and drier this air is, the higher the drying speed.

Within a very short time, the air stream completely removes the water from the finely atomized droplets, binds it as steam and removes it from the process. By absorbing the water, the process air is humidified and thus cooled. In the final step, the now powdered final substance is separated from the air flow in a centrifugal separator and can now be further processed.

In addition to the pharmaceutical and chemical industries, this process is also frequently used in the food industry.



Adsorption dryers are ideally suited for the spray drying process. During the desiccant drying process, not only is the humidity of the process air reduced, but the air is also heated. This heating benefits the spray drying process, as heating the hot air requires large amounts of energy. This significantly improves the efficiency and cost-effectiveness of the spray drying process.

Selecting the right dehumidification technology

As shown earlier in the brochure, the dehumidification process presents a wide variety of challenges. Depending on the type of production, subsequent processing and storage of active ingredients and raw materials, the spectrum of climatic conditions ranges from "high temperature with low humidity" to "low temperature with low humidity".

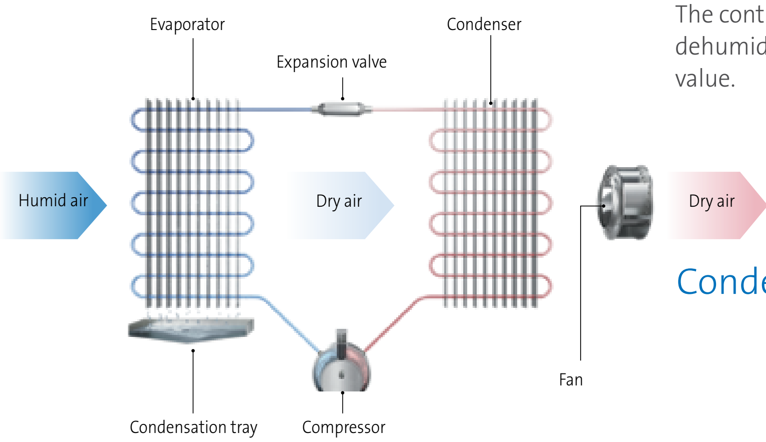
One way to dehumidify air is to operate ventilation units with integrated water coolers. In this case, the outside air drawn into the ventilation unit is cooled down significantly in the cooler, thus dehumidified and then introduced into the room. This type of dehumidification, however, is often only suitable to remove excess humidity in warm and humid weather. In addition, the humidity values that can be achieved from an economic point of view often do not meet the required target conditions and the air must be dehumidified further. To significantly reduce the operating costs for air dehumidification, secondary dehumidification units are typically used. They either dehumidify a required partial air volume or are installed directly in the room. There, they constantly draw in room air, which is filtered, dehumidified and then supplied back into the space as dry supply air.

Both methods of dehumidification have advantages and drawbacks and must be tested and evaluated for each application. For direct in-space installation, in addition to the internal moisture load, the external moisture load, e.g. frommechanical ventilation in summer,must also be taken into account. The dehumidifiers used for this purpose are available as condensing dehumidifiers and desiccant dryers.

Condensing dehumidifiers

These dehumidifi ers are ready-to-use units typically usedin standard dehumidifi cation processes in which a relative air humidity of 45% RH and above is to be maintained at a room temperature of around 50 to 95°F (10 to 35°C). The units contain a refrigerating machine with compressor, evaporator and condenser. As shown in the fi gure below, the fan draws humid room air into the unit, fi lters it and then passes it through the evaporator. Liquid refrigerant flows in this evaporator, removes heat from the air and evaporates it. This cools the air to the point where its temperature drops below its dew point and condensate forms. The lower the temperature in the evaporator, the more water is removed from the air as condensate and the drier the air becomes. The water is collected in a condensate tray and discharged into the drain.

The now dehumidified but cool air then fl ows through the condenser of the refrigerating machine. There, it is heated by the condensation heat and fl ows back into the room as dehumidifi ed supply air. The continuity of this process allows to constantly dehumidify the room air to the desired setpoint value.



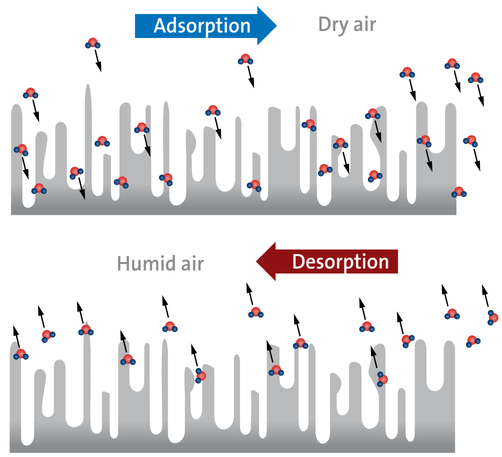
Condensation dehumidification — operating principle

Desiccant dryers
These dehumidifiers are used when low humidity below about 40% RH is to be achieved at often very low temperatures. It would be too costly and energy-intensive to use a condensing dehumidifier for this purpose. Desiccant drying uses the properties of silica gels to dehumidify the air by lowering its temperature significantly below the dew point.

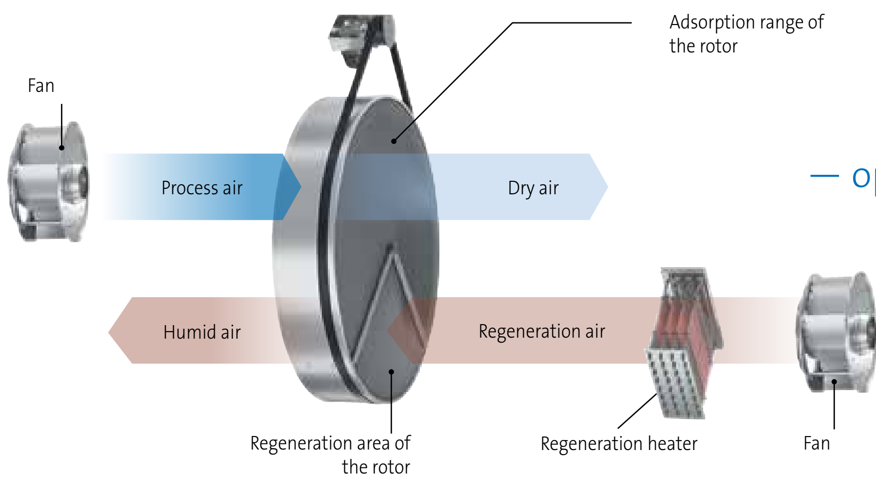
A desiccant dryer consists of a rotary heat exchanger, air filters, two fans for conveying the process air and the regeneration air, a heater for heating the regeneration air and the associated control (see figure below).

The process air fan conveys the air to be dried into the unit. After passing through an air filter, the air reaches the slowly rotating sorption rotor. This consists of more than 82% silica gel on an air-permeable glass fiber honeycomb structure. The silica gel is very hygroscopic due to its extremely large inner surface area of up to 244,121 sqft/ounce. Therefore, it can absorb large amounts of water from the process air at the surface and store it in its inner structure.

Two processes occur simultaneously as the air flows through the sorption rotor. The effective dehumidification of the process air can lead to a significant increase in air temperature depending on the intensity of the dehumidification. Therefore, it is often necessary to cool the now dehumidified but warm air before it is returned to the room.



For this dehumidification process to work, the sorption rotor must be continuously regenerated. This means that the moisture stored in the silica gel must be constantly removed. This is done with regeneration air coming from the other side and flowing through the sorption rotor in the opposite direction to the process air. The regeneration air is heated and thus dried to such a low relative humidity that water can be expelled from the silica gel and bound in the air as vapor (desorption). The now humid regeneration air leaves the desiccant dryer and is blown out to the outside air after an additional heat recovery, if necessary. Electrical energy is used to heat the regeneration air via a PTC heater.



Desiccant drying — operating principle

Desiccant dryer **Condair DA series**

Condair desiccant dryers of the DA series are used wherever very low humidity levels are desired such as in industrial drying processes or in very low temperature range processes. The silica gel-based sorption rotor allows for a safe and practically wear-free operation down to air temperatures of -22°F (-30°C) under optimal operating conditions, while achieving minimum residual moisture. The silica gel used as a drying medium is non-respirable and non-flammable.

Condair DA series desiccant dryers are available in standard versions, with dehumidification capabilities from 7 to 44 lbs/hr for process air flows from 300 to 2400 CFM.

Condair DA 300N– 2400N
Desiccant dryers that can be configured in different ways to meet the individual needs of our customers especially for use in production areas and large rooms.

Nominal drying capacity*
7-44 lb/h.

* at 68 °F (20 °C) - 60% RH

One important consideration at an early stage in the planning process is the often necessary after-cooling of the dried but also heated process air. In order to achieve the desired supply air temperature, pre- and/or post-cooling modules may be required. The desiccant dryers are delivered ready to be connected to cooling modules by others or can be equipped with these modules at the factory for installation in the ductwork.

All standard models have electrical PTC heating elements for the regeneration process. The self-regulating properties of PTC heating elements provide protection against fusing and thermostat interruptions.

DA desiccant dryers come equipped with a PLC with touch screen which allows the control of humidity and increase operational reliability by monitoring the internal components. They can also be controlled via the on site BMS.

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