DEHUMIDIFICATION

Planning guidelines for technical building services and specialist planners

Humidification
Dehumidification
Evaporative cooling

condair

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Planning Guidelines for Dehumidification Systems

INTRODUCTION

These guidelines should support you in selecting a suitable dehumidification system for professional applications. They explain the basic principles of the two most common dehumidification technologies — dehumidification through condensation and drying through sorption. Knowledge of the operating and application limitations enables the optimal technology for the respective dehumidification task to be determined early in the planning phase. In addition, notes are provided as to which framework conditions must be clarified on-site in advance and what specifications are required to ensure proper design.

Then, some sample calculation approaches are presented.

For demanding dehumidification tasks, a specialist should always be called in, since there is a diverse range of system designs in use, and indeed larger dehumidification aggregates offer enormous potential energy savings once the correct configuration is used.

1. Terms and definitions

1.1 The gas mixture of air

In nature, air is always humid. Humid air is comprised of dry air and water vapor. The dry air is a gas mixture made up of approx. 78 vol% nitrogen, 21 vol% oxygen and 1 vol% argon.

1.2 Humidity

The term “humidity” describes the proportion of water vapor in the gas mixture of air. The water vapor content’s value may be stated in different ways. Only the values that are relevant for calculating and designing dehumidification systems are presented here.

1.3 Partial pressure of water vapor

All gases contained in the air exert a certain level of pressure within the mixture (partial pressure). The partial pressure of the water vapor is therefore the water vapor partial pressure p_P.

As a result of the water vapor partial pressure, the water vapor is distributed evenly in the air. A higher water vapor content — at the same temperature — also means a higher water vapor partial pressure.

1.4 Relative humidity

Relative humidity φ represents the relationship of the water vapor partial pressure p_P to the saturation pressure p_S at a given temperature. This enables the degree to which the air is saturated with water vapor to be determined directly. The water vapor volume required for saturation is temperature-dependent. Thus, stating the moisture content as relative humidity is only significant if the temperature is provided also.

$$P = \frac{p_P}{p_S} \text{ or } \varrho = \frac{p_P}{p_S} \times 100\%$$

$$\text{similarly } \varrho = \frac{x_P}{x_s}$$

1.5 Absolute humidity

The absolute humidity x, also referred to as moisture content, is defined as a relationship of humidity m_W to the mass of dry air $m_{AIR.}$

$$x = \frac{m_p}{m_{AIR.}} \text{ in } \frac{\text{kg } H_2O}{\text{kg}_{\text{ dry air}}}$$

Since the saturation pressure p_s is temperature-dependent, the absolute humidity x can be determined from the measurable dimensions of relative humidity φ, temperature t and total pressure p of the air:

$$x = 0.622 \times \frac{\varrho \times p_s}{P - p_s \times \varrho}$$

The absolute humidity x depends on pressure and temperature and represents a direct measurement for the water vapor content in a given volume of air.

1.6 Dew point temperature

The dew point temperature is the temperature at which condensation is first produced from a gas mixture (unsaturated, humid air) in the presence of isobaric cooling. In the h-x diagram (see page 7), the dew point lies at the intersection of line x = const. with the saturation line.

Water vapor condenses on surfaces and expanses whose temperatures are below the dew point temperature.
To dehumidify unsaturated air, the temperature of the cooler surface (=evaporator) of a condensing dehumidifier must always be below the dew point temperature.

1.7 Density

The density ϱ states the mass m of a substance which is contained in a certain volume. The density of humid air can be determined as follows:

$$\varrho = \frac{p_{AIR}}{R_{AIR} \times T} + \frac{p_P}{R_P \times T} = \frac{p \times \varrho \times p_s}{R_{AIR} \times T} + \frac{\varrho \times p_s}{R_P \times T}$$

For applications at sea level and in a temperature range of 0–35°C, however, a value of 1.2 kg/m³ can be used to calculate to sufficient accuracy.

2. Mollier's h-x diagram

Mollier's h-x diagram can be used to determine all the necessary dimensions for designing dehumidification systems. These are:

A) Density ρ in kg/m³
At the far left, the related density of humid air is provided in kg/m³ for the respectively valid total pressure of the diagram.

B) Air temperature t
The air temperature in °C is outlined on the base axis running vertically. For clarity, generally only one limited area generally, approx. from -20 to +60°C , is presented here.
On the basis of the temperature value outlined on the base axis, the reference lines run from left to right with t = constant.

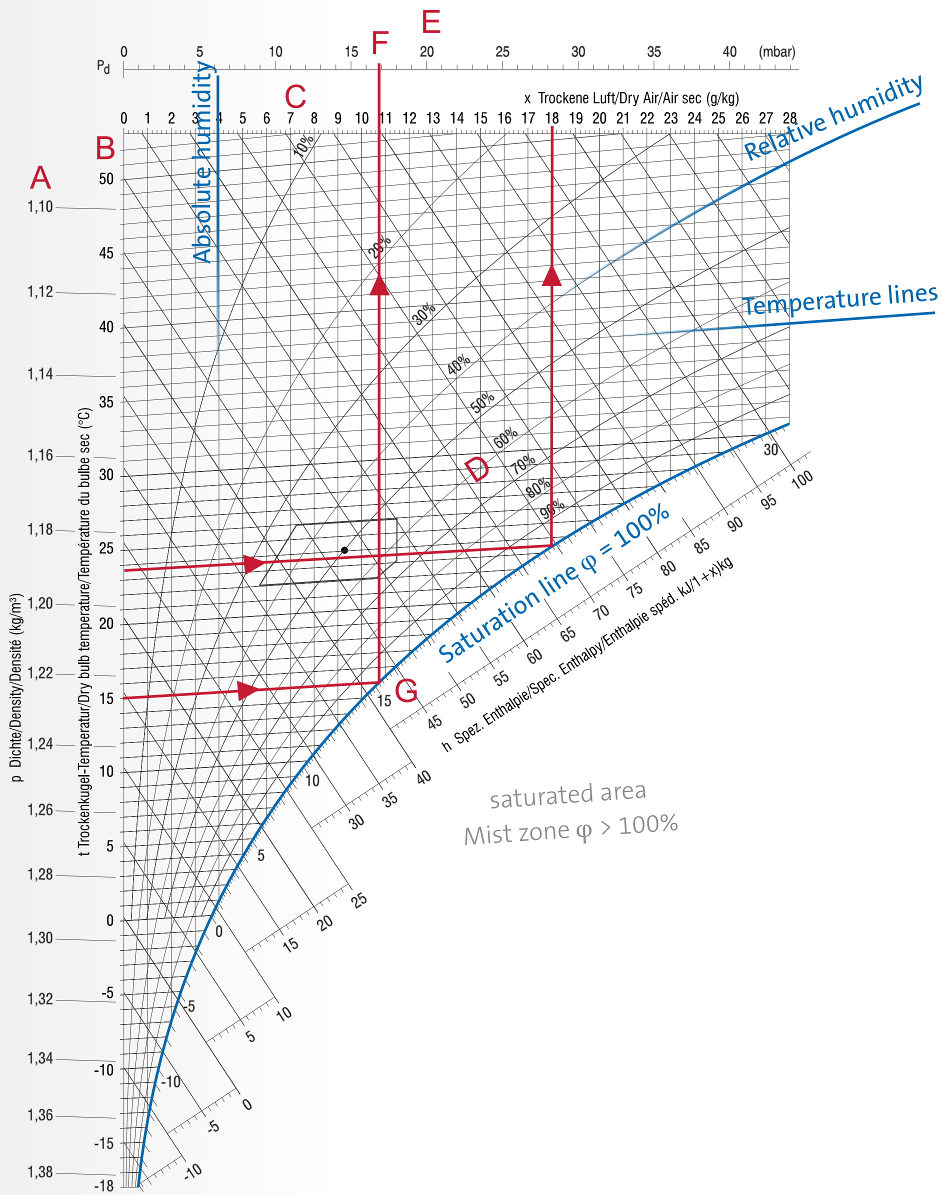
C) Absolute humidity (moisture content) x
Absolute humidity in g/kg $_{\text{dry air}}$ is shown on the upper horizontal axis. From there, the lines with x = constant run vertically downwards.

D) Relative humidity
The curves that are constructed based on the relationship between absolute water vapor content and temperature-dependent saturation water vapor quantity, running from the bottom left to the top right, describe the lines of constant relative humidity. The line φ = 100% is described as a saturation line.

E) Water vapor partial pressure p_p in mbar
The water vapor partial pressure p_p in mbar can be determined on the horizontal parallels to the absolute humidity x.

F) Saturation pressure p_s in mbar
Saturation pressure p_s in mbar is the result of the horizontal reference line from intersection temperature = 100% (saturation line)

G) Dew point temperature (Saturation temperature)
The intersection of a line x = constant with the saturation line is designated as dew point. The associated temperature, shown on the horizontal base axis is the dew point temperature below which condensation appears.

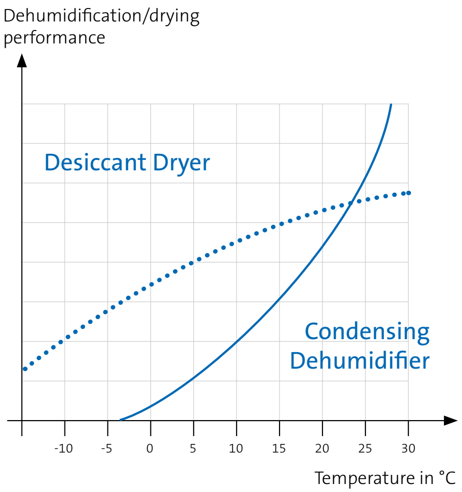


3. Dehumidification and drying methods

Two procedures are primarily used for dehumidification:

Drying through sorption
Adsorption of water vapor contained in humid air by hygroscopic surfaces (silica gel rotor).
This brochure refers only to the dehumidification and drying solutions of standalone systems. Therefore, dehumidification by means of surface coolers supplied with cold water, as used in ventilation systems, are not discussed further.

Dehumidification through condensation:
This process involves cooling the humid air below the dew point by conducting the air stream across the cold surface of a heat exchanger (evaporator of a cooling circuit).

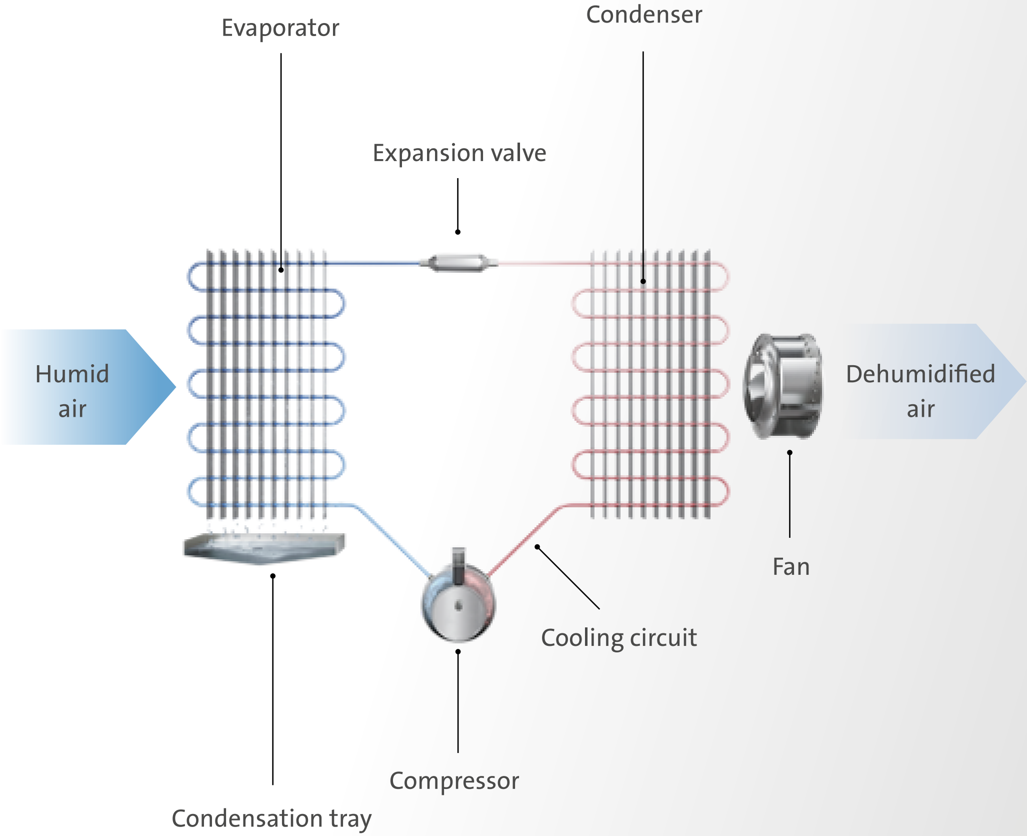


The accompanying diagram shows the operating characteristics of both systems:

Swimming pool,
Typical area of use for condensing dehumidifiers

Pharmaceutical industry,
Typical area of use for desiccant dryer

Functional description of a condensing dehumidifier



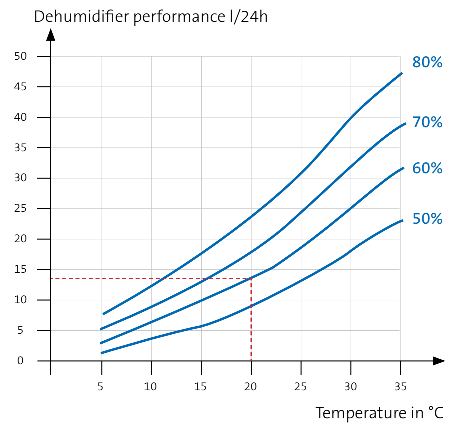
4. Condensing dehumidifiers:

Condensing dehumidifiers as ready-to-use aggregates are often used in industrial and commercial applications, and for dehumidifying swimming pools. Everywhere that air humidity levels must be kept between 45 and 60% RH, condensing dehumidifiers present an energy-efficient and cost-effective solution.
Swimming pool dehumidifiers are special types of condensing dehumidifiers. They are protected against air containing chlorine through special measures (e.g. coating of the heat exchangers) and can be equipped with additional heat exchangers for indoor heating, pool water condensers etc.
Limiting factors regarding the achievable final moisture content are mainly the characteristics of the coolant used (pressure, temperature) and the constructive layout of the evaporator-heat exchanger (bypass factor). In general, the following principle applies: condensing dehumidifiers can be usefully deployed in temperature ranges between approx. +5 and +36°C at an achievable relative humidity of 45% RH

4.1 Operation of a condensing dehumidifier
The basis of any condensing dehumidifier is a closed cooling circuit, which works in accordance with the heatpump principle. A fan sucks in the humid ambient air. This firstly passes through a filter which is installed to protect the heat exchangers, before it is conducted over the evaporator. On this cold surface, it is cooled to below its dew point, with a large proportion of the water vapor it contains being converted to condensation. The water that has become condensation is contained in a condensation tray installed under the evaporator and then diverted directly into the outflow or collected in a corresponding container. Next, the air stream which has now been dehumidified passes through the condenser, where it is heated through the condensation heat of the cooling circuit. The waste heat from the fan and the compressor is partly absorbed by the air stream conducted via the dehumidifier. As a result, the dehumidified air introduced into the area is always warmer than it was when it entered the dehumidifier.

4.2 Sizing
After the required dehumidification procedure for the specific application has been determined on the basis of calculations (see chapter 6), the appropriate dehumidifier can be selected through its corresponding performance diagram. The performance and degree of effectiveness of condensing dehumidifiers increase as the temperature goes up, and decrease as temperatures go down. In the technical documentation, with respect to perfor-

mance, generally only standard values at 30°C and 80% RH, sometimes also at 27°C and 60% RH are provided.



In many cases, only the maximum possible dehumidification performance at 35°C and 80% RH is stated. With respect to the specific application concerned, these specifications are often insufficient to enable an estimation of the selected system's capability to actually provide the required dehumidification performance under the conditions for which it was designed. Most manufacturers also supply performance diagrams to facilitate a sufficiently precise determination of the actual dehumidification capacity under the design conditions.
Example: a condensing dehumidifier is stated in the documentation as having a dehumidification performance of 40 l/24h at 30°C and 80% RH. According the calculation, the dehumidifier to be selected should have a dehumidifying capacity of 20l/24h at 20°C and 60% RH.
The actual dehumidification capacity at the required conditions is shown in the manufacturer's performance diagram.

Result: Instead of the required dehumidification performance of 20 l/24h, the system only has a capacity of 13 l/24h under the design conditions. Therefore, it would be significantly undersized. This example clarifies how important it is to always determine the necessary performance in relation to the required design conditions. Nowadays, some manufacturers choose not to Issu performance diagrams and instead supply, on request, computer-generated data sheets, which present all relevant performance data specifically related to the project.

4.3 Notes on the planning, selection and operation of condensing dehumidifiers

Check application limits: Generally speaking, condensing dehumidifiers are suitable for operation up to approx. 45% RH and a temperature of approx.
5–36°C. For conditions other than these, contact the manufacturer or use a desiccant dryer.

Design: For the design, always include the required ambient conditions in °C and % RH.

Performance specifications: Performance specifications are only significant when they are specifically related to the required design conditions. For this purpose, request the performance diagrams or computer-generated design from the manufacturer.

Electrical power consumption: Also, a comparison of the electrical power consumption, which changes dramatically in condensing dehumidifiers depending on temperature and humidity, is only useful and significant when related to the respective design conditions.

Temperature increase: All condensing dehumidifiers release the exhaust heat of the cooling circuit, fan motors and internal electricity back into the ambient air, which can lead to a minimal increase in ambient temperature or to an enormous additional thermal load — depending on the size of the system.
In many applications, this effect may be totally negligible or even desired (e.g. In the area of swimming pools), but in certain applications may lead to problems. In particular, with large facilities and temperature-sensitive applications, the temperature aspect must therefore be taken into account in the planning.

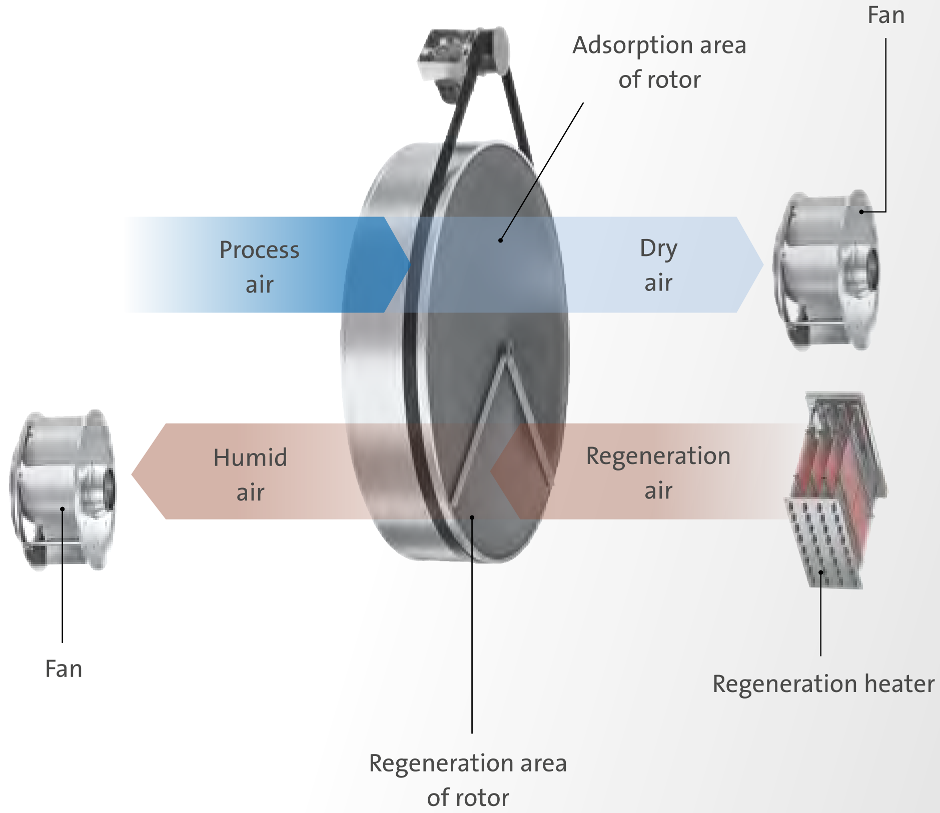
Ambient air quality: Condensing dehumidifiers are generally suitable for operation under normal ambient air conditions, e.g. not for aggressive air or air which is carrying toxic substances. Substances such as chlorine and ozone can attack parts and quickly destroy the systems. Therefore, swimming pool dehumidifiers are already protected from chlorine as standard using special measures. Some manufacturers are in a position to supply industry clients with special systems that have special protective coatings, e.g. to protect against acids or salty air.

Installation: Condensing dehumidifiers are available in either a mobile or a stationary version. Mobile systems are almost always operated with the dry air released into the ambient, while large industrial dehumidifiers can also be attached to a network of ventilation ducts. In this case, it is important to ensure sufficient available preassure.

Condensation: In most cases, the condensation generated is discharged via the outflow. Especially when it comes to high-performance systems, it is essential to ensure connection to the waste water system via a siphon.

Special versions: Specialized manufacturers supply special versions such as temperature-neutral models, special coatings for operation under aggressive ambient conditions, special types of IP protection, heating packs, high and low temperature versions.

Functional description of a desiccant dryer



5. Desiccant dryers

Desiccant dryers are used wherever condensing dehumidifiers physically reach their limits and compliance with minimum absolute humidity or water vapor levels is required. In this technology, the water vapor level is no longer stated in % RH, rather always in the absolute humidity x in g/kg of dry air or in the associated dew point temperature in °C.
The principle of sorption refers to the capacity of certain substances to bind water vapor to its surface. The inner surface of these substances is in a scale of between 600 and 1,000 g/m². An extremely low water vapor partial pressure exists in the immediate surroundings of these chemical substances. Due to the laws of thermo-dynamics, water vapor diffuses from areas of higher partial pressure (in this case from ambient air) to areas of lower partial pressure (sorbent). Silica gel, aluminum oxide or sometimes molecular sieves are used as sorbents. The further examination focus exclusively on adsorption using silica gel, as this is by far the most widely-used sorbent on the HVAC market.

5.1 Operation of a desiccant dryer

Humid ambient air (process air) is sucked out by a fan and conducted through an adsorption rotor. The adsorption rotor consists of a corrugated and finely laminated storage mass with an enormous inner surface, which is coated with the highly hygroscopic silica gel. The entire cross section of the rotor is divided into a drying sector of 270° and a regeneration sector of 90°. The sectors are insulated from each other. A continual, slow turning of the adsorption rotor is carried out by the motor, the turning speed is in the range of 5–30 turns per hour. The air stream to be dried is continuously conducted through the drying sector of the rotor. In the process, the water vapor it contains is almost fully adsorbed. The 90° regeneration sector of the rotor is conducted into the counter-current of regeneration air, which was previously heated to approx. 120°C via a regeneration pack. As a result, adsorbent water vapor bound in the rotor is forced back out and discharged to the outside with the humid air stream. The regeneration air current amounts to approx. 1/3 of the process air stream. This adsorption/desorption process can be repeated as often as required without the degree of effectiveness of the sorbent being significantly influenced. The adsorption capacity of silica gel is that much high that dew points of -70°C can easily be attained.

5.2 Regeneration

In order to force out and discharge adsorbent water vapor bound in the rotor, the adhesive powers operating on the surface of the sorbent must be removed. To do this, the regeneration air stream must be heated accordingly. This is carried out by means of an upstream regeneration heater. With smaller desiccant dryers, the regeneration heating is always carried out using electricity. In the case of larger aggregates, the regeneration heater can be operated as follows:

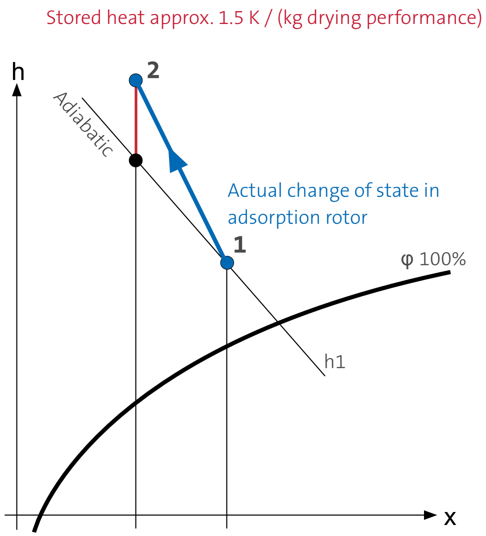
- Electrically (standard)
- Using steam
- Using hot water
- Combination of electrical and PWW heat pack
- Combination of electrical and steam or hot water heat pack

5.3 Stored heat

The storage material of the rotor is heated through the application of the rotor with high temperatures around 120°C to force out the adsorbent water vapor bound in the rotor. The change of state of the drying sector therefore is not ideally carried out through an adiabatic process at constant enthalpy. The remaining heat in the rotor is designated stored heat and leads to overheating of the dry air flow by approx. 1.5 K per g/kg of drying performance. In the case of an assumed stored heat of 1.3 K/g/kg, this overheating amounts, e.g. in a drying process of 12, to 4.5 g/kg $_{\text{dry air}}$: 1.3 K/g/kg x (12 – 4.5)g/kg = 9.75 K.

Knowledge of this fact is important for the assessment of the integration of a desiccant dryer into the overall air conditioning strategy of the area to be dried. In the manufacturer's technical calculations, the stored heat is already taken into consideration and the actual temperature of the dry air stream is stated.

The following diagram shows the change of state on drying through adsorption.

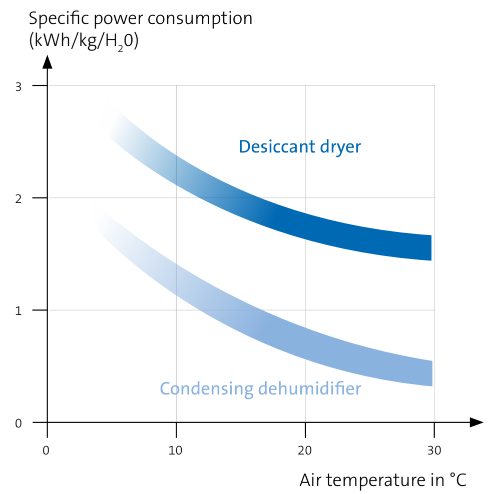


5.4. Sizing

Desiccant dryers are normally used in much more sensitive areas than condensing dehumidifiers. For this reason and from the perspective of the high heat output and system-related higher specific forms of power consumption, this should always be calculated using a computer.

5.5 Notes on the planning, selection and operation of desiccant dryers

Areas of application: Unlike condensing dehumidifiers, whose area of application is limited by the system limits of the respective cooling circuit being used, desiccant dryers are not subject to any limitations with respect to temperature and humidity. However, due to the system, their specific power consumption is always higher than that of any condensing dehumidifier. They should therefore be deployed where particularly low supply air humidity levels (< 6g/kg) or low ambient temperatures justify increased energy consumption or where condensing dehumidifiers are no longer adequate for the dehumidification task. The following diagram by Thiekötter presents a rough comparison from the viewpoint of specific power consumption between condensing dehumidifiers operated using coolants and desiccant dryers with purely electrically operated regeneration.



Connection: The different air flows of the desiccant dryer must be conducted through ventilation ducts. This is generally carried out using spiral ducts. The humid air duct going outside should be insulated. If external air is used as process air, care must be taken to ensure that the humid air outlet is sufficiently far away from the external air outlet. The humid air must always be conducted outwards.

Regeneration: Larger desiccant dryers feature the possibility of using various media for regeneration of the rotor. If possible, for the purposes of maximum energy efficiency, on-site media such as steam, hot or warm water should be used for or to support the regeneration.

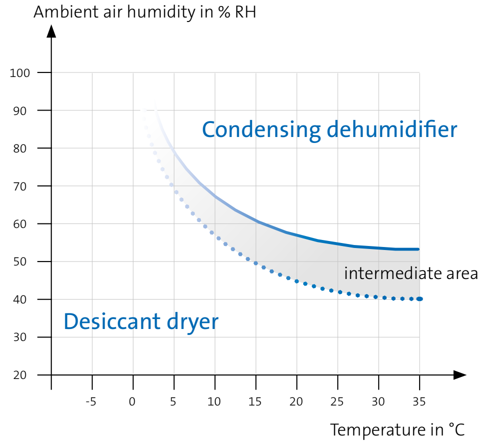
Temperature control: To reach especially low supply air humidity levels, surface coolers must be installed upstream if necessary. In temperature-sensitive areas, the supply air temperature must be regulated directly via the dryer by means of an aftercooler, as necessary in combination with a post-heating pack. Ideally, the manufacturer of the desiccant dryer should deliver the required modules, ready to be connected, built-in to the dryer housing. When untreated external air is being dried, a pre-heater should be provided for protection from frost.

Heat recovery: When larger desiccant dryers are being used, in view of the higher energy consumption of the regeneration heater due to the system, the on-site installation of a heat recovery unit is recommended. In this process, prior to discharge to the outside, the heated humid air is conducted through a crossflow heat exchanger, where it releases the majority of the heat energy it contains to the air flow which is needed for regeneration. As a result, the energy consumption of the regeneration heater can be significantly reduced.

Air-cooled condensers: Under corresponding ambient conditions, an air-cooled condenser can be used on the humid air side. As a result, the humid air discharge via ventilation ducts can be omitted. This is effective at low to medium ambient temperatures.

5.4. Summary
In the preceding chapters, the physical bases underlying the two most common dehumidification technologies were explained, and notes on planning and applications provided.

Ultimately, the decision as to which of the two systems is most suitable must be made on a case-by-case basis.



The diagram above provides a rough overview of the areas in which the use of desiccant dryers makes sense. In particular with respect to dehumidification tasks that are at the limits regarding the parameters of temperature and final humidity, a specialist should always be called in for further assessment and for the selection of the appropriate system.

6. Calculation basis

The aim of any use of dehumidifiers is always to control the moisture content of the air. A few formulas and calculation methods are sufficient for calculation. Which calculation approach must be chosen depends to a large extent on the planned application of the dehumidification system. Possible applications may include:

- Simple control/reduction of ambient air humidity, e.g. in warehousing, to protect against corrosion, in archives, etc.
- Protection from the formation of condensation on cold surfaces, e.g. pipes and installations in the water supply area, food industry, etc.
- Product drying
- Ensuring optimal conditions in production processes.
- Drying of external air including Direct temperature control via the dryer.
- Use in low temperature range, e.g. ice skating rinks and cold-storage rooms

Discharge through evaporation of certain water vapor volumes, e.g. in swimming pools, but also in water supply.

There are some very simple and uncritical applications, e.g. humidity control in mostly closed areas with no internal humidity sources or special requirements, where the appropriate system can certainly be determined using a rough calculation. Apart from these cases, in the professional area of application, dehumidification systems should always be carefully calculated and designed. Before the different calculation types are presented, the following chapter will firstly provide an overview of the data required for calculation and design.

6.1 Specifications required for the planning and design of dehumidification systems in the industrial and commercial sectors
Application/description of dehumidification task:
When an exact specification of the planned application is provided, the appropriate dehumidification technology can often be determined in the first step.

Area volume in m^3

Target conditions following dehumidification in °C and % RH / required absolute final humidity in $g/kg_{dry\ air}$

Most unfavorable temperature and humidity values in °C and % RH before dehumidification / initial humidity in $g/kg_{dry\ air}$

Mechanical ventilation: If available, specifications on volume stream and supply air conditions (summer).

External air conditions in summertime:
Is necessary for calculating the moisture load introduced by the external air, be it

through mechanical EXT input or infiltration.

System location: Is required by the manufacturer to determine the extreme values of the external air conditions, if these values are not provided by the customer.

Height above sea level: The thermodynamic framework conditions change as the geodetic height increases, i.e. with decreasing air pressure. Mainly relevant for very sensitive applications and very elevated installation locations.

Specification on internal moisture loads: Humidity emitted by products, through production, cleaning processes, etc.? Number of people in the area?

Open expanses of water: If available, specification of water temperature and water surface for calculation of evaporation.

Air conditioning: Is a temperature control system available on-site? How temperature-sensitive is the application? Is post-cooling necessary?

Drying of external air: If external air must be dried all year round, alongside the extreme values for the summertime, the conditions for the case of winter must also be provided, as a pre-heater may need to be installed for protection from frost.

6.2 Specifications required for the planning and design of swimming pool dehumidifiers

Pool surface in m^2

Area volume in m^3

Pool water temperature in °C

Ambient temperature in °C: The ambient temperature should always be at least 2 K above the water temperature!

Types of use:
E.g. private bath, therapy pool, whirlpool, etc. The type of use has a significant influence on the movement of the water surface and thus on evaporation. This is taken into account in the calculation through a corresponding activity index.

Duration of use in h/day

Specifications on disinfection method used:
Alongside chlorine, other chemicals, such as ozone, are increasingly being used for disinfection. These can be very aggressive towards the parts used in dehumidifiers, so that special coatings are required.

Sample calculation

6.3 Approximate design of a dehumidification system

Specification of dehumidifier performance in accordance with area volume

P_D [l/h] = Dehumidifier performance
V_A [m^3] = Area volume
f = 2 to 3 should be used as a rough factor

$$P_D = \frac{V_A \times f}{1{,}000}$$

For simple applications without special requirements or for an initial rough estimate of the system size, detailed calculations often do not have to be used. Here, a simple, rough calculation on the basis of personal experience is sufficient. The formula can be used for areas of humidity of up to 50% RH.

Required specifications:
Area volume V in m^3
Target ambient conditions in °C and % RH
Factors based on experience:
f = 1.5 with an assumed air exchange of approx. 0.3 $\frac{1}{h}$, e.g. for storage areas, cellars
f = 2.0 with an assumed air exchange of 0.5 $\frac{1}{h}$, e.g. for regulating air conditioning in the area
f = 4.0 if large volumes of humidity have to be discharged, e.g. following water damage

Calculation:
Area volume V_A = 1,200 m^3
storage, low air exchange, so for f = 1.5 $\frac{1}{h}$ can be applied
Ambient conditions approx. 20°C and 55% RH

$$p_D = \frac{1{,}200\ m^3 \times 1.5}{1{,}000} = 1.8\ l/h$$

A dehumidifier that has a performance of at least 1.8 l/h at 20°C and 55% RH is needed.

This method should only be used for rough estimates.
For complex dehumidification tasks, a detailed calculation taking into account all inner and outer loads must always be used.
The calculation factors are based on personal experience and can be specified differently for each manufacturer.

Sample calculation

6.4 Basic method for calculating dehumidifier/dryer performance

In order to control the ambient air humidity, all inner and outer moisture loads must be known or calculated. The required performance of the condensing dehumidifier or desiccant dryer selected is a result of the total of all inner and outer loads.

Dehumidifier performance

$$P_D = \dot{m}_{V\,total} = \dot{m}_{V\,internal} + \dot{m}_{V\,external}$$

Water vapor entry through ventilation

$$\dot{m}_{H\,ventilation} = p \times V \times n \times (x_{EXT} - x_{TGT})$$

$\dot{m}_{Ventilation}$ [g_w/h] = water vapor entry through ventilation

P_D [l/h] = Dehumidifier performance

V [m³] = area volume

n = air exchange $\frac{1}{h}$ or $\frac{V_{EXT}}{V_{AREA}}$

X_{TGT} [g_w/h] = Absolute humidity of external air at target conditions

X_{EXT} [g_w/h] = Absolute humidity of external air in summertime

External moisture loads are e.g. mechanical ventilation with proportion of external air, infiltration of external air through openings in the building, water vapor diffusion through brickwork etc.
Accordingly, internal moisture loads are: Humidity emitted by people, open expanses of water, humidity from materials, production and cleaning processes, etc.

The humidity input by people is oriented towards their level of activity and the ambient temperature. See VDI 2078, table A1 for details. For example, the following values are provided for an ambient temperature of 20°C:
$\dot{m}_{VPerson}$ at activity level I to II (light, sitting or standing): 35 g_W/h
$\dot{m}_{VPerson}$ at activity level III (moderately heavy): 110 g_W/h
$\dot{m}_{VPerson}$ at activity level IV (heavy): 185 g_W/h

To calculate the amount of water vapor emitted by a still, open surface of water through evaporation (e.g. in the water supply area), the following is sufficiently accurate $\dot{m}_{VPRpool} = \varepsilon \times A \times (p_S - p_P)$.
ε = empirically determined evaporation coefficient for still evaporation of an open, still water expanse in g/(h x mbar x m²)
A = Pool water surface in m²
p_S = Saturation vapor pressure in mbar, related to pool water temperature
p_P = Partial pressure of water vapor in mbar, related to ambient air temperature

The necessary values for p_S and p_P can be taken from corresponding tables, or determined using diagrams. All other internal and external moisture loads, e.g. humidity emitted by products, production processes, infiltration through gaps in insulation etc. must also be determined or requested from the customer.

Example:
In the production area of an industrial operation, to protect the machines and control cabinets installed there, an ambient air humidity of max. 50% RH at a temperature of 20°C should be maintained. There is an open water pool with a surface of 250 m² to supply the fresh water required by some production processes. The maximum temperature of the water is 15°C. The total area volume is 15,000 m³.
In the facility, 15 people carry out exceptionally heavy physical activities. The area is supplied with 12,000 m³/h of external air through a ventilation system. For the summertime, the design must cater for extreme values of 32°C and 40% RH. Otherwise, there are no further internal moisture loads.

Required specifications:
p = 1.2 kg/m³
V = 15,000 m³
n = 12,000 m³ / 15,000 m³ = 0.8
x_{EXT} = 12.1 $g_W/kg_{dry\ air}$
x_{TGT} = 7.36 $g_W/kg_{dry\ air}$

Calculation:
$\dot{m}_{VPRventilation}$ = 1.2 kg/m³ x 15,000 m³ x 0.8 1/h x (12.1 – 7.36) $g_W/kg_{dry\ air}$
= 68,256 g_W/h

$\dot{m}_{VPRperson}$ at activity level III (relatively heavy) at 20°C
= 110 g_W/(h x person) x 15 people = 1,650 g_W/h
A_{pool} = 250 m²
p_S = 17.04 mbar
p_P = 11.7 mbar
ε = 5

$\dot{m}_{VPRpool}$ = 5 g/(h x mbar x m²) x 250 m² x (17.04 – 11,7) mbar = 6675 g_W/h

$P_D = \dot{m}_{VPRtotal}$ = ($\dot{m}_{VPRventilation}$ + $\dot{m}_{VPRperson}$ + $\dot{m}_{VPRpool}$)
= (68,256 + 1,650 + 6,675) g_W/h
= 76,581 g_W/h
= 76.58 kg/h

Result: The dehumidification system to be selected must feature a dehumidification performance of 76.58 kg/h or 1,838 kg/d at 20°C and 50% RH.

Sample calculation

6.5 Calculating dehumidifier/dryer performance to avoid going below dew point

An area where dehumidification systems are often used is in the prevention of condensation on cold system parts, pipes, fittings. For this application, it is sufficient to prevent the temperatures of the cold parts from going below the dew point.

This can also be carried out using the dew point sensor, which is mounted on a system part that is at risk. The dehumidification system only enters into operation if there is a risk of the part going below the dew point temperature. This method can be used if no further moisture loads are present and a general decrease in ambient air humidity is not required.

To calculate this, the target dew point temperature is taken into consideration

$t_{DP,TGT} = t_S - 2$

t_S [°C] = surface temperature of the part to be protected in °C. In the case of pipes, the temperature of the medium flowing through the pipes can be used.

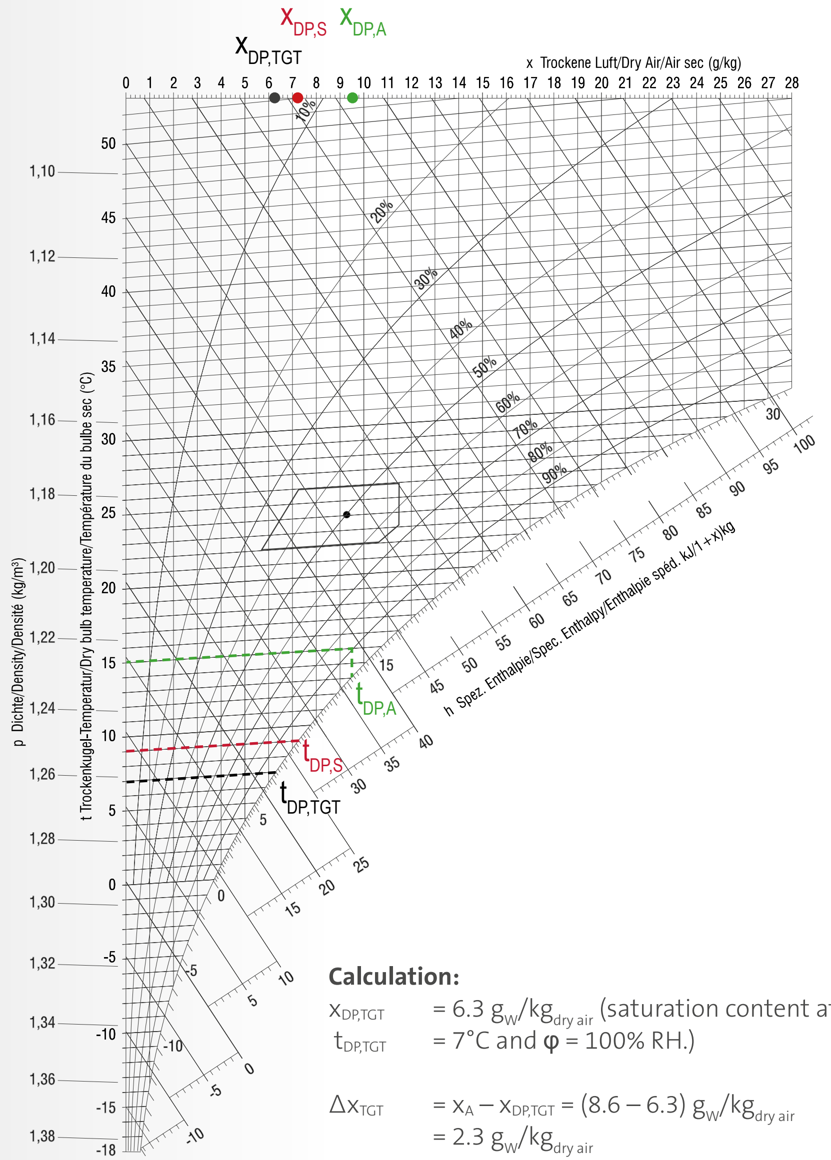
$t_{DP,TGT}$ [°C] = target dew point temperature. This should be at least 2 K below the surface temperature of the part to be protected.

Example: in an area of a water supply facility with an area volume of 900 m³, a temperature of 15°C and an ambient air humidity of 80% RH, the pipes that are used for cold fresh water have to be prevented from the occurrence of condensation. The water temperature is 9°C. The area is watertight, there are no other moisture loads.

Required specifications:
V_A= 900 m³; t_A= 15°C; φ_A= 80% RH; t_S= 9°C (pipe surface temperature)

Based on the h-x diagram opposite, the following values are shown:
$x_A = 8.6\ g_W/kg_{dry\ air}$
$t_{DP,A}$= 11.5°C (dew point temperature at t_A= 15°C and φ_A = 80% RH)
x_S = 7.2 gW/$kg_{dry\ air}$ (saturation content at t_S= 9°C and φ=100% RH)
Thus, on the surface of the system parts the difference of $x_A - x_S$ condensates from:
$\Delta x = x_A - x_S = (8.6 - 7.2)\ g_W/kg_{dry\ air} = 1.4\ g_W/kg_{dry\ air}$

To avoid the water vapor turning into condensation on the system parts, dehumidification to a dew point temperature of 2 K below the surface temperature is required.



Calculation:

$x_{DP,TGT}$ = 6.3 $g_W/kg_{dry\ air}$ (saturation content at $t_{DP,TGT}$ = 7°C and φ = 100% RH.)

$\Delta x_{TGT} = x_A - x_{DP,TGT} = (8.6 - 6.3)\ g_W/kg_{dry\ air}$
$= 2.3\ g_W/kg_{dry\ air}$

This gives a dehumidifier performance of
PD = 1.2 kg/m³ x 900 m³ x (8.6 – 6.3) $g_W/kg_{dry\ air}$
= 2,484 g_W/h
= 2.48 kg/h.

Result: The chosen dehumidification system must feature a dehumidification performance of 2.48 kg/h or 59.5 kg/d at 15°C and 80% RH.

7. Energy-efficient control with dew point or surface sensors

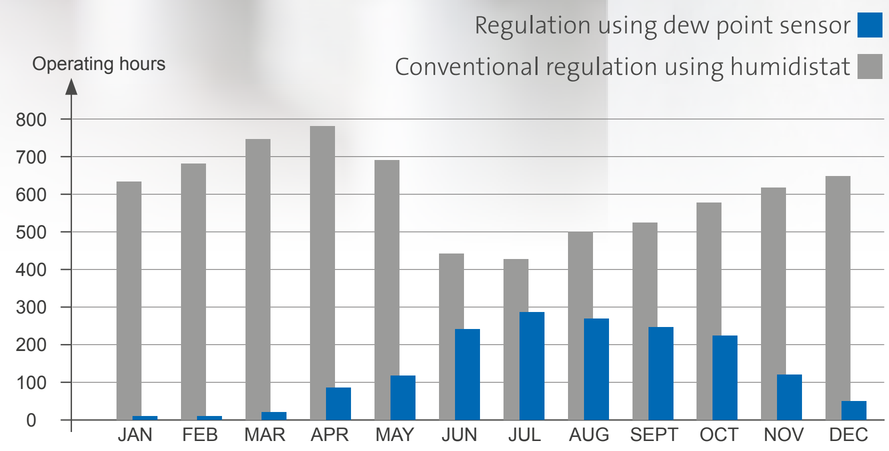
Humidity is not directly regulated due to the inertia which, although distinctive in nature, is always present. Compressor and fan operation are activated via corresponding measuring and regulation functions in condensing dehumidifiers and the registration pack and fan in desiccant dryers.
The following possibilities are available for the control of dehumidifying systems independent of humidity:

Humidistat: Available as electronic or mechanical version in many different models. Both ON/OFF operation and activation of compressor or regeneration pack without deactivation of fan possible.

Dew point sensor: Dehumidification system is activated when dew point is undercut.

Combined temperature/humidity sensor: If necessary, an additional temperature control.

The example on the opposite page in which dew point and ambient air humidity regulation are compared under identical conditions shows the enormous potential energy savings offered by a professional design tailored to the application, combined with the corresponding regulation strategy.



Exemplary reduction of operating hours through needs-optimized regulation in a waterworks

8. Recommended conditions in accordance with areas of application

Sector	Area of application	Relative humidity	Temperature
Antiquities	Storage and repair	45–50%	20–24°C
Automotive industry	Manufacturing	45–55%	22–25°C
	Car spraying plant	50–55%	22–25°C
Library	Book warehouse	40–50%	21–25°C
	Reading rooms	35–55%	21–25°C
Hospital	Operating room	50–60%	22–26°C
	Patients' rooms	40–50%	20–22°C
	Nursery	50%	24°C
Furniture industry	Veneer storage	50–60%	15–18°C
	Furniture production	40–50%	18–22°C
	Manufacture of clamping plates	50–55%	12–20°C
	Wooden furniture storage	50–55%	12–18°C
Fashion	Tannery	65–70%	10–20°C
	Storage of furs	50–60%	5–10°C
	Spinning mill / Silk	50–65%	20–25°C
Museums	Paintings	40–55%	18–24°C
Paper industry	Storage	50–60%	15–20°C
	Rotary printing	60%	20–25°C
	Screen printing	50–60%	22–24°C
	Processing (binding/cutting)	50–60%	22–30°C
Pharmaceutical industry	Raw material storage	30–40%	21–27°C
	Penicillin production	60%	25°C
	Tablet press	35–50%	21–27°C
Clean room technology	Electronic equipment for microscopy	40–45%	22°C
	Wafer production	40–45%	22°C
Confectionery industry	Storage of yeast	60–75%	0–5°C
	Flour storage	50–60%	15–25°C
	Chocolate storage	60–65%	18–21°C
	Dried fruit storage	50%	10–13°C
	Sugar storage	35%	25°C
Tobacco industry	Raw tobacco storage	60–65%	21–23°C





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