CONTROL

Planning Guidelines for Humidification

Humidification and evaporative cooling

condair

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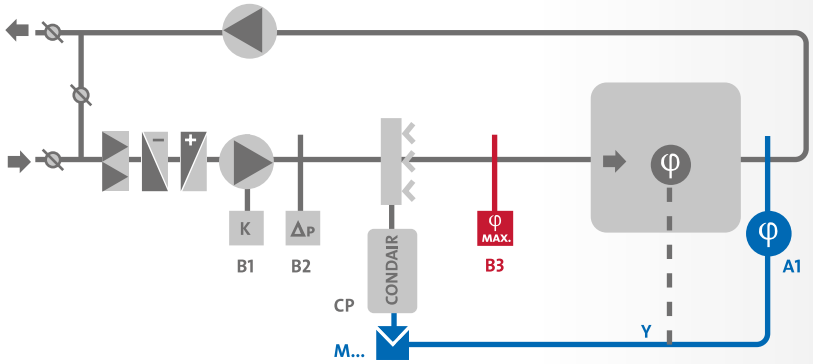
Planning Guide for the Control of Humidification Systems

FOREWORD

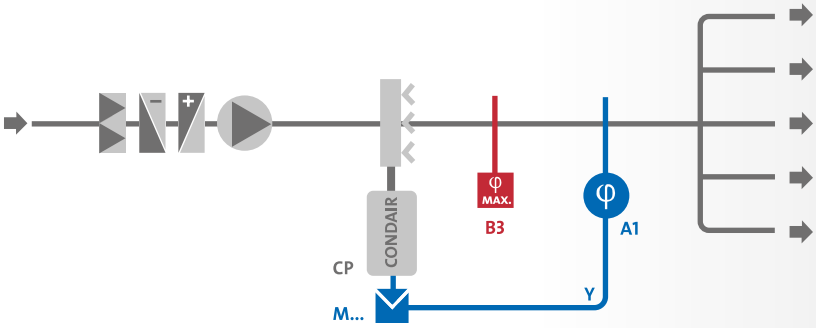
This guideline should help you choose the right humidity control. The individual descriptions are examples and should illustrate the basic principles. The schematic diagrams show the relationships relating to humidity control. Control sequences that go beyond these will not be discussed here. There are manifold system concepts that are usually encountered in practice.

The control regimes are therefore not complete solutions that can be implemented in all cases in the described way. A control engineer must be consulted to help you in your planning.

Room and Exhaust Air Humidity Control



Input air humidity control



A1 = humidity control sensor
B1 = fan monitoring
B2 = differential pressure switch
B3 = humidity – maximum humidistat

1. Types of Humidity Control

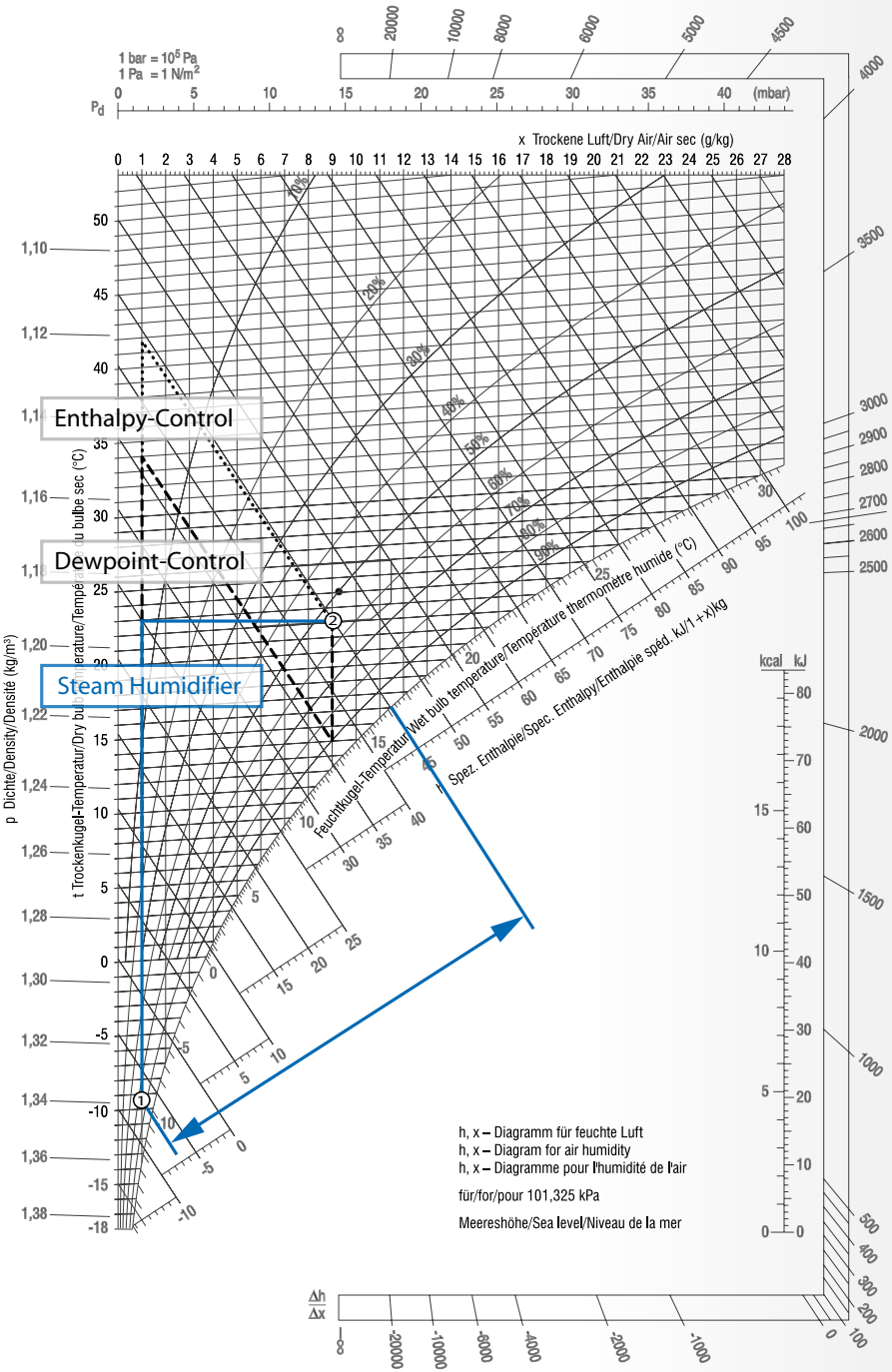
A distinction is commonly made between room or exhaust air humidity control and supply air humidity control. Which control variants are used depends on the respective installation concept and the task.

1.1 Room and Exhaust Air Humidity Control

Room or exhaust air humidity control is preferable for use in air conditioners. The control sensor here is placed in the room itself or in the air exhaust duct. The large distance between steam distributor and humidity sensor normallyensures that the air mixes well. The controlled system in this type of humidity control is characterized by its large storage mass, and it simplifies a stable control mode.

1.2 Supply Air Humidity Control

Supply air humidity control is used where this is necessary for system engineering reasons. This includes, for example, central humidification with subsequent zone branching which must be rehumidified individually. Even room or exhaust air humidity controls can have the control engineering properties of a supply air humidity control if the room volume is very small or air exchange rates are very high. In this type of control, the control sensor is placed in the air supply duct downstream of the steam distributor. Due to the low storage mass between steam distributor and humidity sensor, the rating of the controlled system is usually high.


Enthalpy-Control
Dewpoint-Control
Steam Humidifier
x Trockene Luft/Dry Air/Air sec (g/kg)
Pd
1 bar = 10⁵ Pa
1 Pa = 1 N/m²
(mbar)
p Dichte/Density/Densité (kg/m³)
t Trockenkugel-Temperatur/Dry bulb temperature/Température thermomètre sec (°C)
Feuchtkugel-Temperatur/Wet bulb temperature/Température thermomètre humide (°C)
Spez. Enthalpie/Spec. Enthalpy/Enthalpie spéd. kJ/(1+x)kg
kcal kJ
Δh/Δx
h, x – Diagramm für feuchte Luft
h, x – Diagram for air humidity
h, x – Diagramme pour l'humidité de l'air
für/for/pour 101,325 kPa
Meereshöhe/Sea level/Niveau de la mer

2. Selection of the suitable Control System

The selection of the suitable control system for a certain application depends on the controlled system, permissible control tolerance, humidity increase and supply air temperature.

Apart from the rating of the humidity-controlled system, the selected control equipment as well as the control parameter setting, the control quality of a humidity control loop is also greatly affected by the humidifier itself.

Over-dimensioned humidifier capacities can have unfavorable control characteristics in the bottom partialload range.
In this case, it must be ensured that continuous output control is also possible in the bottom partial-load range.

A distinction is made in humidification between "isothermal" humidification (steam) and "adiabatic" humidification (atomization, evaporation). Although steam humidification, strictly speaking, is not exactly an isothermal change of condition, the minor warming of air that occurs is disregarded when considering control principles.

On the other hand, a noticeable temperature drop occurs in adiabatic humidification. This must be balanced by suitable damper registers and therefore is also taken into account in the selected control strategy.

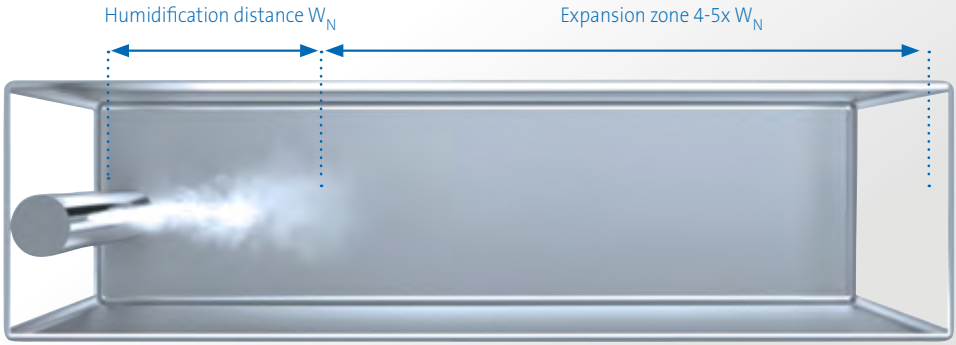


Diagram of a humidification distance

2.1 Isothermal Humidification

Steam humidification is usually characterized as isothermal. The fact that it is not exactly an isothermal process in the thermodynamic sense has already been pointed out. A minor temperature increase (F value 0.12 k/g steam) occurs due to the addition of steam to the system air. This low value is usually disregarded. However, note that the steam distributor's heat emission can also heat the system air. The extent of this heating depends on the selected steam distribution system and, if applicable, must be taken into account when planning the system.

2.1.1 Effect of the Humidification Distance on Control Quality

The humidification distance has special significance in steam humidification. The water vapor coming from the steam distribution pipes first of all condenses in the air current and is visible as mist over a certain distance (humidification distance). This is followed by the expansion and mixing zone where uniform mixing of the system air takes place with the injected volume of steam. This circumstance alone must be taken into account when sizing humidification distances for a hygienic operating mode.

Optimal control results depend on optimal humidity distribution in the mounting location of the sensing elements. The humidification distance depends on different factors and forms the basis for establishing the required minimum distances to downstream system parts and sensing elements.
Please consult qualified equipment manufacturers for reliable information about the length of humidification distances and the required minimum distances.

2.1.2 How the Humidification Distance can be shortened?

To some extent, condensation is aided by the contact of the water vapor with the cooler system air. However, the main reason for condensation is the unfavorable distribution of the steam through the duct cross-section along a steam distribution pipe. The required humidification distances are not available in retrofits in particular. In these cases, the use of multiple steam distribution systems often leads to success. Homogeneous distribution of the water vapor can occur as much as possible on the entire air current at appropriately short humidification distances.
A useful scale for evaluating steam distribution is the homogeneity index which can be easily determined.

2.1.3 Steam Humidifier with Electrode Heating

In an electrode evaporator, metal elements (electrodes) are immersed directly in the humidifier water in a steam cylinder. When the electrodes are placed under voltage, a current begins to flow between the electrodes and this current depends on the water's electrical conductivity. The water is thereby used as an electrical heating element and converts the electrical energy to heat. As the immersion depth of the electrodes increases, electrical resistance decreases and current consumption increases. Steam output can thus be controlled continuously by changing the water level from approx. 20% to 100%.

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2.1.4 Resistive Steam Humidifier

In an evaporator with resistance heating, the water is heated with electrical heating elements just like in an immersion heater. Steam generation takes place independently of the water's electrical conductivity. For this reason, fully de-ionized water can also be used. Output control is done by controlling current flow through the heating elements. Consequently, steam release can be controlled continuously from 0% to 100%. Steam humidifiers with resistance heating are especially suitable if everything depends on quick and precise steam output control.

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2.1.5 Steam Humidifier with Gas Heating

Instead of an electric current, natural gas is used as the heating medium for steam generation. Downstream from the gas burner, the hot combustion gases pass through a heat exchanger that heats up and vaporizes the humidifying water in a water tank. Modulating fan burners make continuously adjustable steam generation in a large output range possible. Natural gas is a comparably suitable fuel. Gas-heated steam humidifiers are therefore especially appropriate for larger steam outputs.

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2.1.6 Multiple Steam Distribution System for even Humidity Distribution

Optimal control results depend on uniform humidity distribution in the control sensor's mounting location. Therefore, it must be installed at an adequate distance from the steam distributors. Multiple steam distribution systems promote quick and uniform mixing of the system air and shorten the required mounting clearances to the control sensors. In cramped spaces, they therefore contribute to optimal control characteristics.

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2.1.7 Pressure Steam Humidifier for Existing Steam

In contrast to electric steam humidifiers which generate depressurized steam, pressure steam humidifiers use existing steam from a steam main. This steam is normally generated by a central steam boiler and injected into the ventilation ducts by suitable valve equipment and steam distribution systems.

Pressure steam humidifiers can also provide large humidification capacities without difficulty. Due to the low effective dead time, they are very suitable for high control requirements.

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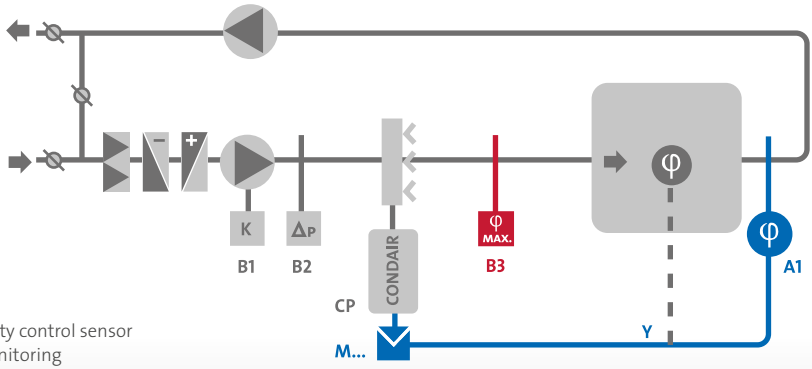


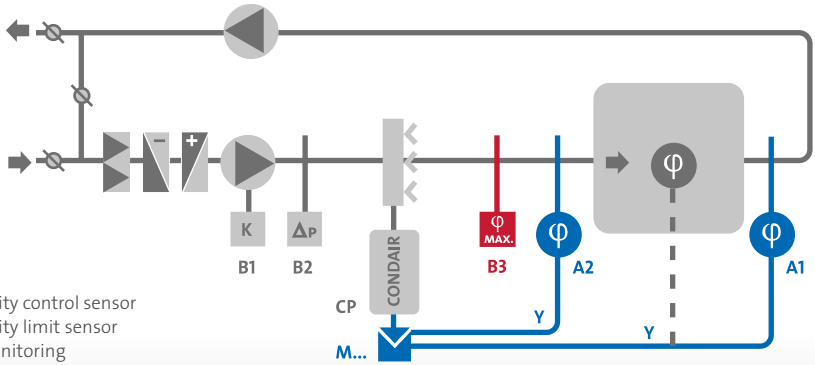
A1: Humidity control sensor
B1: Fan monitoring
B2: Differential pressure switches
B3: Safety humidistat

2.1.8 Exhaust Air Humidity Control in Steam Humidification

Function:
The control sensor (A1) is installed in the room or, even better, in the air exhaust duct. The safety humidistat (B3) is placed at an adequate distance in the air supply duct and is used for shutting down the humidifier in case of fault.

Area of application:
- direct room humidification
- air conditioning systems with predominantly recirculating air operation (lower Δx!)
- constant volume flow

Settings:
Regulator: humidity setpoint
Safety humidistat: max. 80% rel. humidity (lower if possible)



A1: Humidity control sensor
A2: Humidity limit sensor
B1: Fan monitoring
B2: Differential pressure switches
B3: Safety humidistat

2.1.9 Exhaust Air Control with Continuous Humidity Restriction for Steam Humidification

Function:

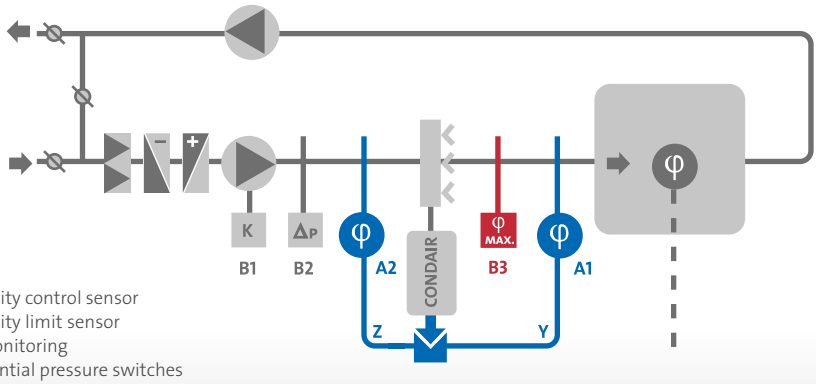
The control sensor (A1) is installed in the room or, even better, in the air exhaust duct. Limit sensor (A2) and safety humidistat (B3) are placed at an adequate distance in the air supply duct. Once the supply air humidity approaches the permissible value, the continuous humidity restriction has priority over the humidity control. The safety humidistat switches off the humidifier in case of fault.

Area of application:

- greater proportion of outside air (higher Δx!)
- low supply air temperature (cooling mode)
- variable volume flow
- rehumidification of individual temperature zones

Settings:

Regulator: humidity setpoint; limitation setpoint
Safety humidistat: max. 80% rel. humidity (less if possible), but in any event above the limitation setpoint!



A1: Humidity control sensor
A2: Humidity limit sensor
B1: Fan monitoring
B2: Differential pressure switches
B3: Safety humidistat

2.1.10 Supply Air Humidity Control with continuous output Setting in Steam Humidification

Function:
The control sensor (A1) is installed in the air supply duct downstream of the humidifier. The sensor for the continuous output setting (A2) is installed in the air supply duct directly upstream of the humidifier. As the humidity upstream of the humidifier approaches the humidity setpoint, the continuous output setting has priority over the humidity control. The continuous output setting depending on the air humidity before humidification acts as a stabilizer on the control circuit in the partial-load range. The safety humidistat switches off the humidifier in case of fault.

Area of application:
Central humidification with several subsequent zone branches (during rehumidification of individual zones, then exhaust air humidity control).
Important: Central humidification and every temperature zone must have its own safety humidistat! In very small room volumes or very high rate of air exchange (for example, digesters, laboratories), the exhaust air humidity control itself can behave like a supply air humidity control.

Settings:
Regulator: humidity setpoint, setpoint for the output setting (not below the humidity setpoint!) Safety humidistat: max. 80% RH (less if possible), but in any event above the humidity setpoint!

2.1.11 Important Information for the Control of

Steam Air Humidifiers

Required safety elements

- safety humidistat
- differential pressure switches
- belt monitoring
- flow controllers

Safety humidistats:

If for any reason the maximum permissible humidity is exceeded, safety humidistats should switch off the humidifier. Safety humidistats should not fulfill any control functions. They must therefore be provided in addition to the required control sensors and must always be placed as the first measuring element downstream of the steam distributor.

Placement of humidity sensors and humidistats:

Pay attention to uniform mixing of the system air. Therefore, place humidity sensors and humidistats at an adequate distance from the steam distributor—for best results, as far as possible. In any event, at least consider recommended minimum distances as guide values. If necessary, install a multiple steam distribution system for cramped spaces or short distances!

Rules of thumb:

1. Always provide safety humidistats.
2. Install own safety humidistats for central humidification and rehumidification in individual temperature zones.
3. Do not set safety humidistats higher than 80% RH.
4. Always set the safety humidistat higher than the control setpoint (min. 10% RH) (Important: Pay attention to measuring accuracy and switching hysteresis!).
5. Always place the safety humidistat as the first measuring element downstream of the steam distributor.
6. As a minimum, adhere to the recommended minimum distances for humidity sensors and humidistats. If necessary, use a multiple steam distribution system for cramped spaces or short distances.
7. Use additional safety devices for air flow monitoring (belt monitoring, differential pressure switch, flow controller).
8. Over-dimensioned steam humidifiers (electrode heating) exhibit poor control characteristics in the lower partial-load operation.
   Solution: resistance heating
9. In case of higher control requirements or exhaust air humidity control, use steam humidifiers with resistance heating.

2. 2 Adiabatic Humidification

Adiabatic humidification technologies basically offer the possibility of room/exhaust air humidity control and supply air humidity control. Due to the ensuing temperature drop because of the removal of the heat of evaporation from the system air, humidity control can only be carried out in conjunction with temperature control. The conventional control procedures are dew point control or enthalpy control.

Which procedure gives optimal results mainly depends on the controllability of the humidification system used.

2.2.1 Effect of the Humidification Distance on Control Quality

The humidification distance in adiabatic humidification systems is often defined by the overall length of the humidifier based on the design. However, if devices that atomize aerosols in the air current are used and these aerosols are incompletely deposited (high-pressure or ultrasonic humidifiers), the humidification distance must also be taken into account here.

Regardless of the hygiene issues, the same basic principles described in 2.1.1 apply in this case. However, due to the low energy content of the atomized water, humidification distances longer than those used in steam humidification are used.

2.2.2 Recirculating Spray Humidifier (Air Washer)

In recirculating spray humidifiers, the humidifier water is in an open basin and is sprayed from there by a circulation pump through nozzle assemblies in the humidifier housing. This evaporates a portion of the water which must be tracked using a float control in the basin. In addition, a portion of the concentrated humidifier water is drained from the basin and is likewise fed through the float control. Besides the actual operating purpose to wash toxic substances from the air, air washers were also used before for humidification in particular. Due to today's awareness of hygiene, these type of devices are now only seldom used in humidification. Continuous control of humidification output is not possible with these systems or is possible only in very restricted terms.

2.1.3 Contact Humidifier (Trickle Humidifier)

Here, the humidifying water trickles through a contact body. The system air passes through the humid contact body and the humidifying water partially evaporates on the surface of the contact body. Just like in recirculating spray humidifiers, these systems are also used less and less in humidification because of the awareness of hygiene. However, a more sensible application is possible in the field of adiabatic exhaust air cooling. Continuous control of humidification output is not possible with these systems or is possible only in very restricted terms.

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2.2.4 High-Pressure Humidifier

Using a high-pressure pump, the humidifying water is atomized into fine water aerosols at pressures up to over 100 bar(g). Humidification occurs through partial evaporation of this mist in the air current. Humidifying water that does not evaporate must be discharged through droplet separators. In high-pressure humidifiers, particular care should be taken to ensure that hygienic humidifying water is atomized in the inhaled air. Germ formation in the nozzle chambers must be prevented. To what extent continuous control of the humidification output is possible depends on the pump equipment and atomizing nozzles used. A minimum volume of water that restricts the variable operation in the bottom range is necessary for faultless function.

2.2.5 Ultrasonic Humidifier

In ultrasonic humidifiers, special ceramic oscillating elements are located on the bottom of an open water basin. These are electrically excited and they generate high-frequency vibrations. Because of this, very fine droplets are expelled on the water surface, taken up by the air current sweeping by and carried into the system air to be humidified. These droplets evaporate in the air current over a specific distance. Ultrasonic humidifiers are considered very sensitive in hygienic terms. Continuously adjustable control of humidification output is possible.

2.2.6 Hybrid Humidifier

This involves a combination of atomization and evaporation. The humidifying water is first atomized in a humidification chamber into fine water droplets at low pressure and it evaporates partially in the air current. The remaining water droplets are collected by downstream ceramic elements and re-evaporate there. The injected humidifying water is thereby very well exploited. This device technology is characterized by a high degree of hygiene safety. Combining atomization and evaporation makes continuously adjustable humidification possible over the entire output range.

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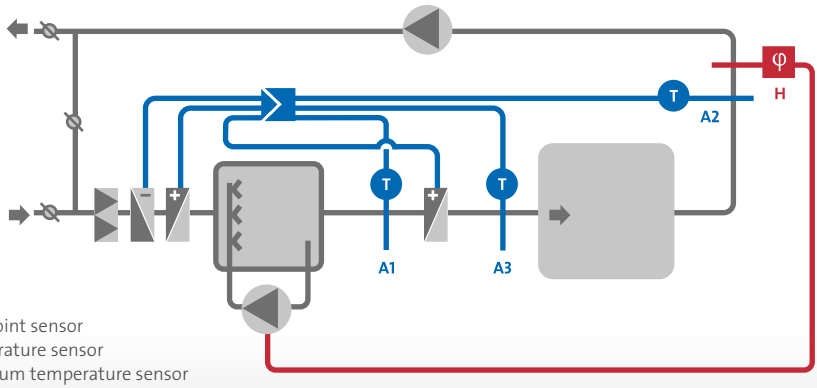


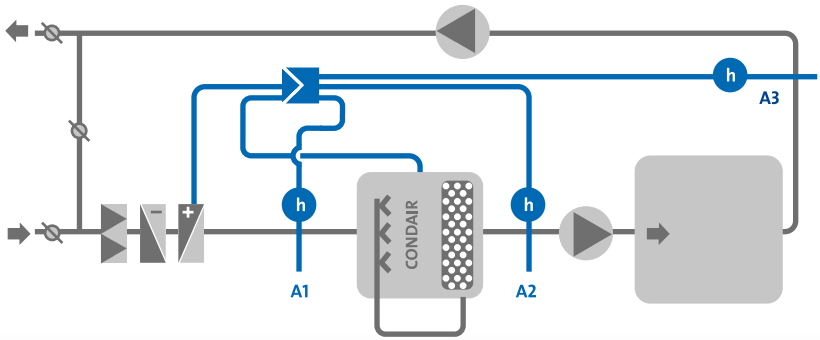
A1: dew point sensor
A2: temperature sensor
A3: minimum temperature sensor
H: humidistat

2.2.7 Dew Point Control (Exhaust Air Control with suction-side Humidifier Layout) in Adiabatic Humidification

This type of control is mainly used in recirculating spray humidifiers (air washers) and contact humidifiers. The humidification system here is installed between preheater and reheater. A room or exhaust air humidity control with suction-side humidifier layout is described below as an example. The sensor layout must be adjusted accordingly in deviating system concepts or supply air humidity control.

Function:
The dew point sensor (A1) controls preheater and cooler and keeps the dew point constant. The room or exhaust air temperature sensor (A2) controls the reheater (in supply air humidity control, the sensor (A2) is installed in the air supply duct).
The minimum temperature sensor (A3) likewise acts on the reheater and ensures that the system does not fall short of a minimum permissible supply air temperature. The humidistat (H) switches off the humidifier once the target humidity is reached (for example, washer pump).
Since oversaturation of the air does not occur because of the evaporation principle, a safety humidistat is usually not needed.

Area of application:
- Circulating spray humidifier (air washer)
- Contact humidifier (trickle humidifier)



A1: enthalpy sensor
A2: enthalpy sensor
A3: enthalpy sensor

2.28 Enthalpy Control (Exhaust Air Control with suction-side Humidifier Layout) in Adiabatic Humidification

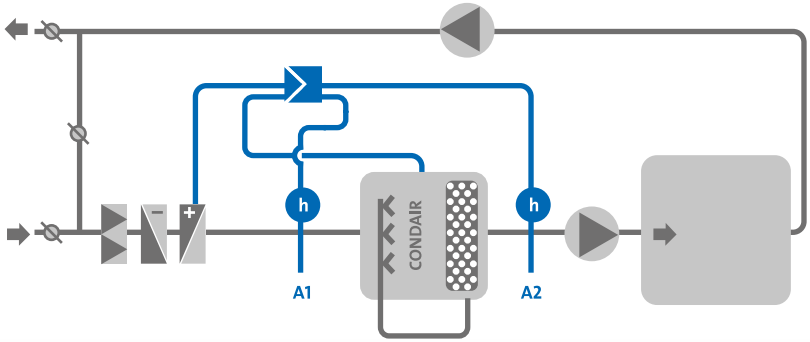
In adiabatic humidification systems that allow continuously adjustable output control, optimal results are achieved using enthalpy control. A distinguishing feature of enthalpy control is that a preheating radiator which heats the system air until the target enthalpy is reached is installed only upstream of the humidification system. Controlled humidification then takes place until the desired air condition is reached. An additional reheater is not required in the humidification operation. This control procedure offers the great advantage of allowing very cost-effective humidification operation with small quantities of flush water. Moreover, hygiene safety is boosted by comparably minor exhaust air relative humidity.

Function:

The enthalpy sensor (A3) measures the exhaust air enthalpy and compares this with the specified setpoint. The enthalpy sensor (A1) controls the preheater until the target enthalpy is reached. The adiabatic humidifier is likewise controlled through the enthalpy sensor (A3). The enthalpy sensor (A2) has a safety function and limits the humidifier output at excessively low air temperatures (suitable functionality of the controller required!). The use of an additional safety humidistat in the air supply duct may be necessary in humidifiers which atomize water directly in the air ducts (high-pressure and ultrasonic atomizers). Important: Fan heat and room thermal loads must be considered during planning since they have an effect on humidifier enthalpy. If this is too low, the evaporation output decreases.

Settings:

- hybrid humidifiers
- adiabatic humidification systems which allow continuous control of humidification output.



A1: enthalpy sensor
A2: enthalpy sensor

2.2.9 Enthalpy Control (Input Air Control with suction-side Humidifier Layout) in Adiabatic Humidification

As long as system engineering requirements make it necessary, supply air control is also possible in adiabatic humidification systems. However, due to the low storage mass between steam distributor and humidity sensor, the rating of the controlled system is higher. This type of control is especially suitable for a combination of central adiabatic humidification with higher humidification output and adjacent zone rehumidification using electrical steam generators. The rehumidification, in turn, can then take place with an exhaust air humidity control. Incidentally, this variant offers the already previously described benefits of enthalpy control in continuously adjustable adiabatic humidification systems.

Function:
The enthalpy sensor (A2) measures the supply air enthalpy compared to the specified set-point. The enthalpy sensor (A1) controls the preheater until the target enthalpy is reached. The adiabatic humidifier is likewise controlled through the enthalpy sensor (A2). The use of an additional safety humidistat in the air supply duct may be necessary in humidifiers which atomize water directly in the air ducts (high-pressure and ultrasonic atomizers). Important: As long as the enthalpy sensor (A2) is installed downstream of the supply air fan, fan heat must be taken into account since it has an effect on humidifier enthalpy. If this is too low, the evaporation output decreases.

Area of application:
- hybrid humidifiers
- adiabatic humidification systems which allow continuous control of humidification output.

2.2.10 Important Information for the Control of
Adiabatic Humidifiers

Required safety elements
- safety humidistat (in high-pressure and ultrasonic atomizers)
- belt monitoring
- differential pressure switch
- flow controller

Safety humidistats:
If for any reason the maximum permissible humidity is exceeded, safety humidistats should switch off the humidifier. Safety humidistats should not fulfill any control functions. They must therefore be provided in addition to the required control sensors and must always be placed as the first measuring element downstream of the humidification system.

Placement of humidity sensors and humidistats:
Pay attention to uniform mixing of the system air. Install humidity sensors and humidistats at an adequate distance from the humidification system—for best results, as far as possible.

Rules of thumb:
1. Dew point control for adiabatic humidifiers without continuous output control (recirculating spray humidifier, contact humidifier).
2. Enthalpy control for adiabatic humidifiers with continuous output control.
3. Always consider fan heat and room thermal loads in humidifier layout.
4. Ensure uniform air flow. If necessary, install perforated sheets or rectifiers upstream of the humidification systems.
5. Install safety humidistats in high-pressure and ultrasonic humidifiers.
6. Install own safety humidistats for central humidification and rehumidification in individual temperature zones.
7. Do not set safety humidistats higher than 80% RH.
8. Always set the safety humidistat higher than the control setpoint (min. 10% RH) (Important: Pay attention to measuring accuracy and switching hysteresis!).
9. Always place the safety humidistat as the first measuring element downstream of the humidifier.
10. Provide adequate minimum distances for humidity sensors and humidistats.
11. Use additional safety devices for air flow monitoring (belt monitoring, differential pressure switch, flow controller).

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