HYGIENE CRITERIA

Planning Guidelines for Humidification

Humidification and evaporative cooling

condair

Page

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Planning guidelines for correct hygiene in humidification systems

Foreword:

Hygiene plays an important role in humidification. Current rules and regulations such as VDI 6022 give useful information about design, planning, manufacture and system operation. On the one hand, humidification is indispensable in air conditioning in buildings and, on the other, fundamental microbiological relationships come into play.

These guidelines should illuminate the requirements for hygienic humidification equipment and illustrate important planning criteria.

Prehistoric living area with open architecture
and unhindered outside air exchange

Modern buildings have thick facades
and are ventilated with ventilation and air-conditioning systems.

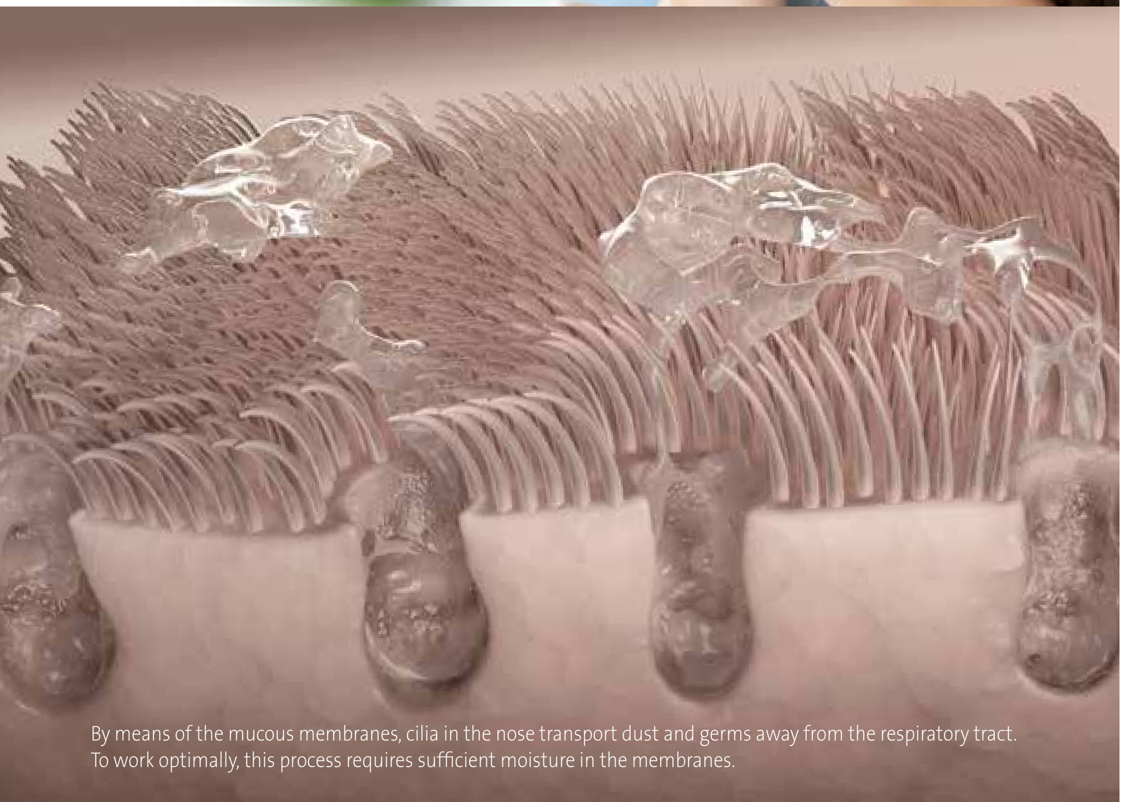
1. Air Conditioning in the Stone Age and Today

If we look back to the beginnings of building services engineering, we see that air-conditioning equipment was already available very early on. Before man even learned to build huts and houses, man sought protection in caves from the elements. These dwellings were not very homely. However, if there was a fire burning in the cave entrance, the inhabitants were safe from wild animals and the cold could be held off at least in a makeshift manner. This was how the first heating system dependent on the air in the room and serving as door air curtain was born. Although important regulations such as the German Ordinance on Furnace Installations were unknown, adequate flow of combustion air and at least a reasonably acceptable flue gas exhaust from the living area had to be ensured.
However, the proportion of fresh air was obviously large enough so that no additional devices for air supply were needed. There were also still no binding regulations for the working atmosphere. No one had yet heard of the 26° ruling and, although there was no anti-discrimination law, bullying was unknown.

Mental stress for workers — mainly freelancers at that time — at the most developed from hazards arising from wild animals or hostile people. Physical climate parameters such as temperature, humidity and brightness were weather-dependent. Appropriate relationships were determined by the individual choice of the place of work mostly by the workers themselves. Used air with high CO_2 content or unacceptable noise pollution was either not present or was not perceived as such.

On the other hand, modern buildings where people stay for a long time are characterized mostly by comparably thick facades and by room air conditions that are different to normal outside air. Room temperatures that are subject to only a small range of fluctuations prevail throughout the entire year. The required amounts of fresh air are provided by ventilation and air-conditioning systems or other engineering installations in the building and are produced there accordingly depending on external air conditions and room requirements.

Typical consequences of room air that is too dry are respiratory illnesses such as coughs, colds, bronchitis and sinus inflammations.



By means of the mucous membranes, cilia in the nose transport dust and germs away from the respiratory tract. To work optimally, this process requires sufficient moisture in the membranes.

2. The Need for Humidification

2.1 Comfort and Health Protection with correct Air Humidity
By heating outside air during the cold season, humidity indoors can be lowered to below 30% RH. Persons who are exposed to such dry room air over a longer period then often suffer from drying phenomena.

This mainly involves the drying of the respiratory tract mucous membranes which can no longer transport dust, dirt and pathogens quickly enough away from the respiratory tracts. The longer they stay in these places, the higher the risk of respiratory illnesses. Typical consequences are coughs, colds, bronchitis and sinus inflammations.

Even before the occurrence of acute diseases, room air that is too dry often leads to secondary phenomena such as an uncomfortable indoor atmosphere, reduced performance, exhaustion, irritated eyes or the typical scratchy feeling in the throat.

While unfavorable air temperature is felt very acutely by people, too little humidity first attracts attention mostly only because of these secondary phenomena.

Optimal air condition values for comfort and health protection lie in the range of 21–22°C and relative humidity between 40–60%. However, it must not be overlooked that the individual sensation of indoor temperature is subject to personal preferences and sharp boundaries cannot be made. In particular, there is a relationship between air humidity perceived as comfortable and the dust content of room air. This dust content can be affected by the choice of fixtures to certain extents, but clean-room air qualities are obviously not reached in regular occupied areas. Adequate humidification during the heating period therefore leads to comfortable room air quality and is conducive to health.

2.2 Required Air Humidity in comfortable Air Conditioning

In terms of the required values for minimum air humidity in comfortable ranges, there is a difference between theoretical assumption and actual practical experience. It very quickly turns out that there are only superficial contradictions here once one realizes the individual perception of comfort. The relationship between air temperature and relative humidity is apparent.

Ventilation of non-residential buildings DIN EN 13779:

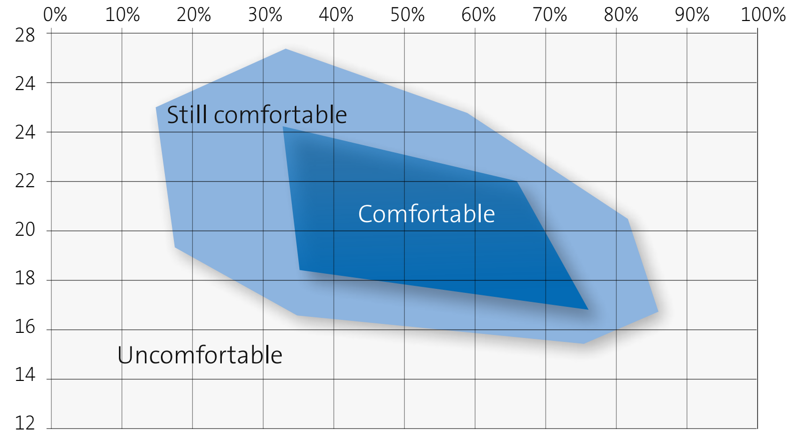
"In the range of usual room air temperatures between 20–26°C, comfort problems hardly ever arise normally if the relative humidity is between 30–70%." On the one hand, this testifies to the relationship between temperature and relative humidity and, on the other, values of the same perception of comfort are contained in the indicated value range.

2.3 Minimum Value of Relative Humidity: 40%

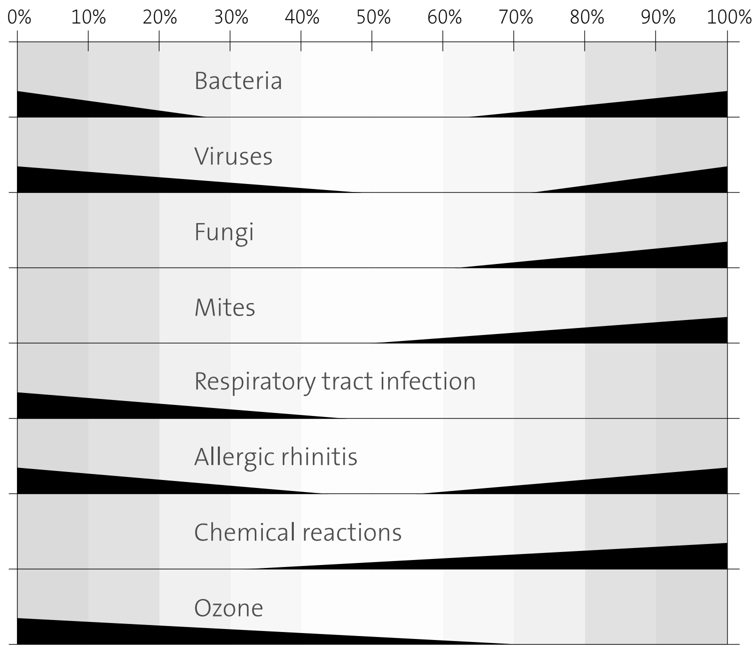
The Gebäude-Klima e.V. institute sets the lower limit of relative humidity in the comfort ranges at 40%. This value was deemed correct in terms of hygiene, comfort and productivity based on all experience and is based on comprehensive information from science and occupational medicine.

Scofield/Sterling Diagram

The Scofield/Sterling diagram illustrates relevant interactions in different room air humidities in terms of comfort and health protection. The hazards arising from undesirable microorganisms as well as the occurrence of specific symptoms of illness are minimal in the optimal range between 40–60% relative humidity.

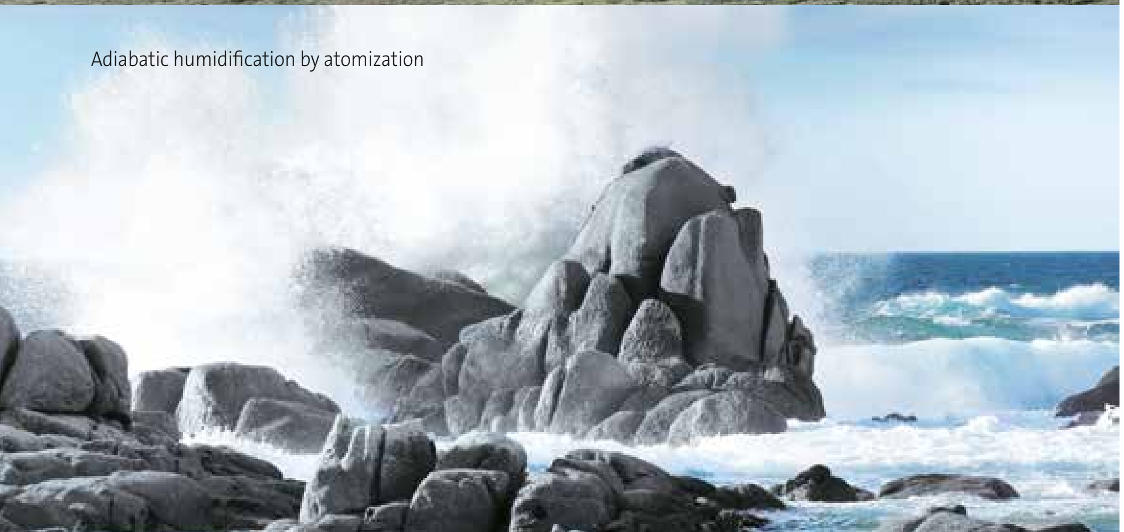


Comfort diagram



Scofield/Sterling Diagram


Adiabatic humidification by evaporation


Adiabatic humidification by atomization


Isothermal humidification with steam

3. Humidification Methods

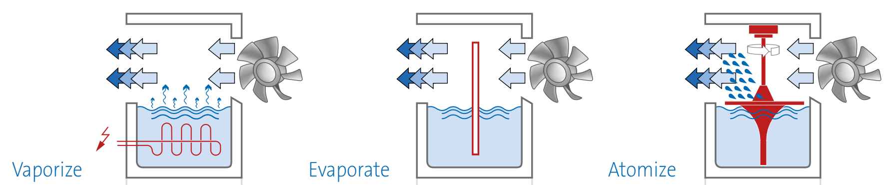
Humidification is carried out based on the three physical methods of vaporization, atomization and evaporation. Which system leads to optimal results depends on the respective application. At any rate, from the hygienic standpoint, the three methods have different requirements for the selected humidification equipment.

3.1 Vaporization
From the start, steam humidification offers the greatest hygiene safety due to the high temperature level. However, problems can arise if steam distributors are incorrectly placed or humidification distances are incorrectly measured. If existing humidification distances are very short, multiple steam distribution systems are the medium of choice. Significant reductions in humidification distances are achieved due to the quicker mixing of system air in homogeneous steam distribution.

3.2 Evaporation
The humidification distance in evaporation humidifiers is determined by the design. However, it must be ensured that biofilm growth on the evaporation bodies does not lead to microbiological contamination of system air.

3.3 Atomization
Pure atomization humidifiers represent the greatest challenge from the standpoint of hygiene. The required humidification distances can vary greatly. The most important variables are humidity increase, air temperature, air speed, flow profile and aerosol size of the atomized humidifying water. The floating behavior of water aerosols, the possibility of poor deposition associated with it and its slow evaporation make reliable calculation of the humidification distances extraordinarily difficult.

Humidifying water microbiologically contaminated by biofilm growth may not atomize in inhaled air for humidification purposes. Water aerosols must not enter the air lines downstream of the humidification system since they get deposited there and hygienically hazardous damp surfaces can form.



HYGIENE CRITERION 1

4. Humidification distance

4.1 Measuring Humidification Distances

The humidification distance is made up of the mist zone and the subsequent expansion and mixing zone. The mist zone is the path downstream of the humidification system—from the injection to the complete admission of the quantity of steam by the system air. The expansion and mixing zone then follows it. The introduced humidity mixes evenly with the air current in this stretch. The length of the required humidification distance depends on the component following in the air direction. The correct dimensioning of the humidification distance is extraordinarily important to prevent condensation phenomena inside the air lines. Knowledge of this distance is also of fundamental significance for correct humidity control since control sensors should only be installed where there are balanced humidity values.

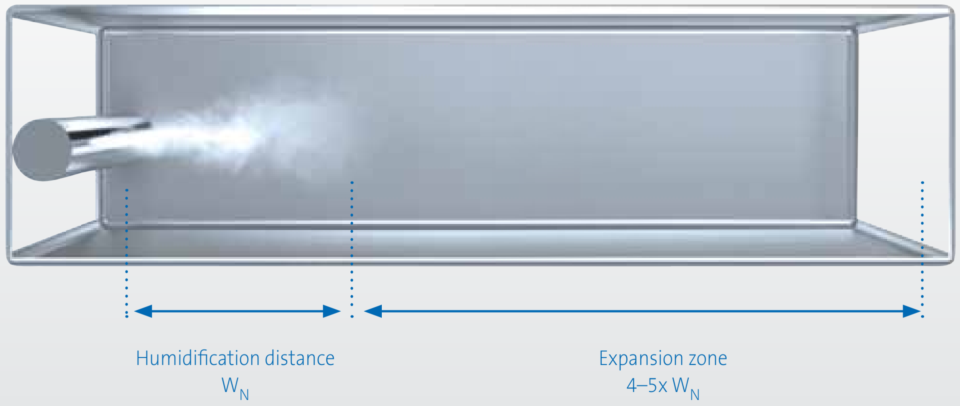
4.2 Humidification Distances in Steam Humidification

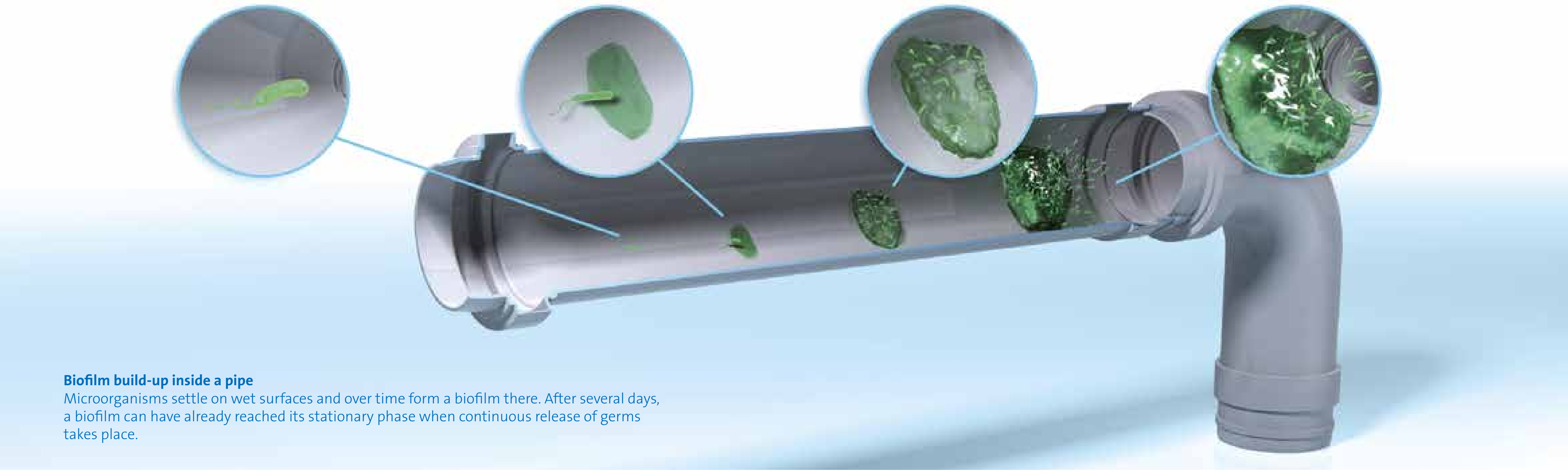
Humidification distances in steam humidification cannot automatically be determined with adequate accuracy. There are multiple steam distribution systems in cramped spaces. Significant reductions in humidification distances are achieved due to the quicker mixing of system air by extensive steam injection. At the same time, homogeneous steam distribution requirements in VDI 6022 sheet 1 are met.

4.3 Humidification Distances in Adiabatic Humidification

The humidification distance in adiabatic humidification systems such as hybrid humidifiers or various evaporators is determined based on the design. It is significantly more difficult to determine it in high-pressure and ultrasonic atomizers. The most important variables are humidity increase, air temperature, air speed, flow profile and especially the aerosol sizes of the atomized humidifying water. It is precisely the possibility of poor deposition and slow evaporation of water aerosols that make it extraordinarily difficult to determine humidification distances. There is virtually no reliable information that would allow us to make a binding assessment. Only if no water aerosols are discharged from an adiabatic humidification system is reliable humidification distance calculation possible.

Diagram of a humidification distance





Biofilm build-up inside a pipe
Microorganisms settle on wet surfaces and over time form a biofilm there. After several days, a biofilm can have already reached its stationary phase when continuous release of germs takes place.

HYGIENE CRITERION 2

5. Preventing Biofilms

5.1 Hazards arising from Biofilms

The supply water for humidifiers should have the microbiological quality of drinking water. Therefore, 100 CFU/ml at most are allowed. Even this low number of microorganisms settles in water lines, on evaporation bodies or in the wet areas of humidifiers and can form a massive biofilm there over the course of the time. This happens unnoticed as long as the biofilm, over the course of several days to months, has accumulated thickly and has reached its stationary phase. From this time onwards, the biofilm continuously releases germs, and the uncontrolled contamination of the humidifying water or system air follows.

5.2 Where can Biofilms arise during Humidification?

Hygienically hazardous biofilms can settle and propagate on virtually all surfaces moistened with water. Especially at risk are:

- water supply lines to humidifiers
- water lines inside humidification systems
- evaporation bodies
- droplet separators
- water basins
- humidifier chambers

5.3 How can Biofilms be prevented during Humidification?

The formation of biofilms can be contained or prevented with appropriate steps. In this regard, individual measures do not serve the objective; only a combination of all hygiene-related measures are ultimately guaranteed success. The following are especially important here:

- hygienic humidifying water
- regular cleaning and disinfection
- no stagnation in the water lines
- hygiene measures for microbial reduction

Cross-section of a biofilm that has been deep-frozen for analytical purposes and taken from an investigated high-pressure humidifier.

Massive Biofilm Growth
(also from an investigated high-pressure humidifier)
Apparent biofilm on a pressurized water humidifier that had built-up right into the humidifier basin.

Air-borne mold spores of Penicillium and Aspergillus niger from a germ-infested air-conditioner.

Algae

Algae are single or multiple-celled organisms related to plants that predominantly live in water. Humidifiers are put at risk from infestation from green and brown algae in particular. These can lead to defense reactions (fever) or allergies in the human body.

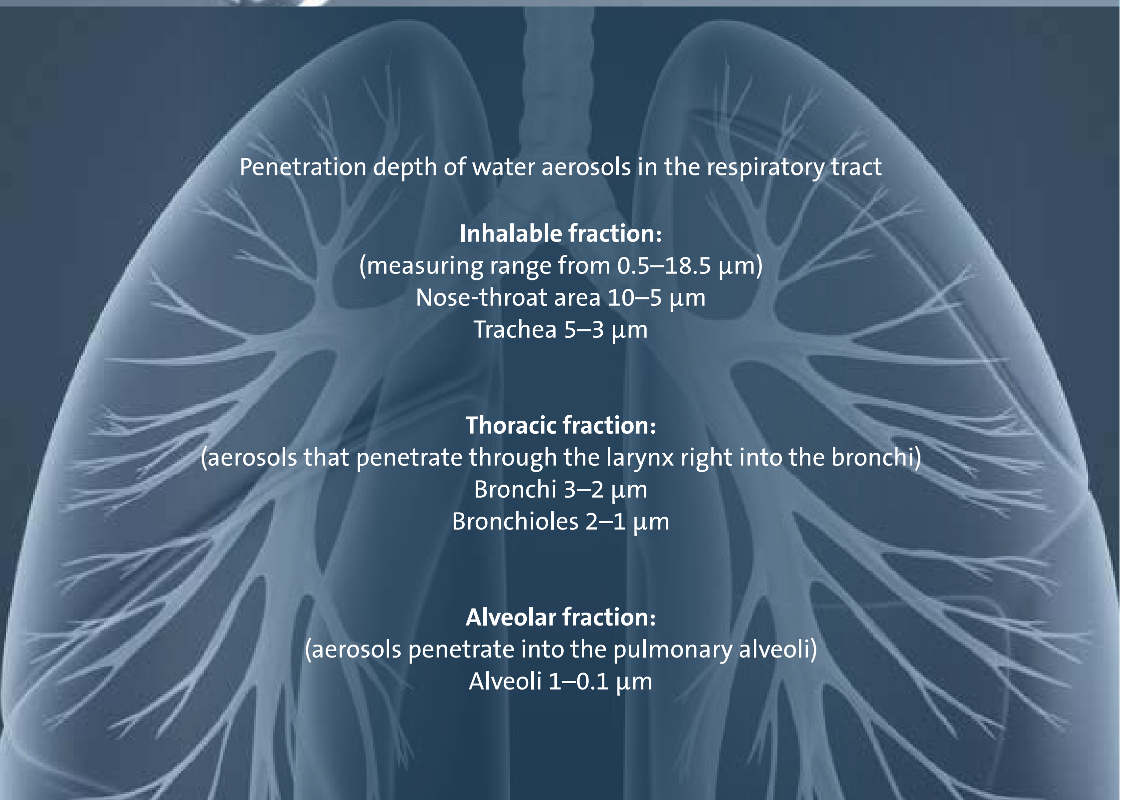
Fungi

Fungi generally form visible colonies, known as blooms, that can spread widely even on smooth surfaces.
They settle predominantly on damp areas or on the system's blowout openings, and generally begin to release spores after only a few weeks. If these spores enter human respiratory tracts they can form colonies there too and cause mycotic infections.

Bacteria/viruses

Bacteria cause unpleasant odors and the build-up of slime in the systems. Rod-shaped bacteria, such as legionella, can cause fatal infections or spread pathogenic germs that attack the human immune system.

Viruses are also spread in the air, settle in or on host cells and damage the foreign organism via their own genomes in the latter's cells.



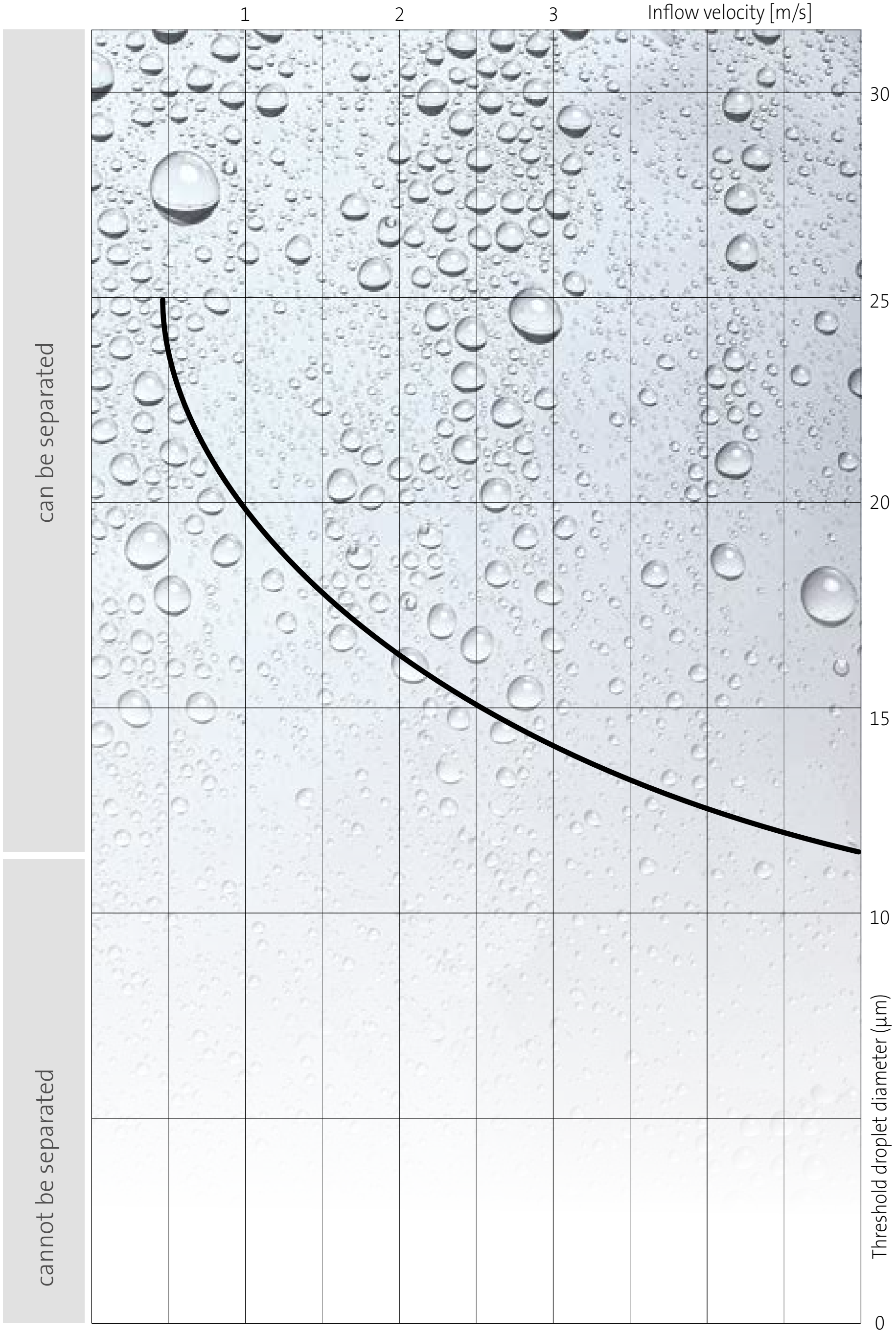
HYGIENE CRITERION 3

6. Water Aerosols

6.1 Water Aerosols as Health Hazards
Water aerosols in air conditioners are generally problematic. They can constitute a health hazard and therefore must not enter the air duct system:

- Water aerosols can deposit in air lines and form hygienically problematic damp surfaces.
- Germs end up in the inhaled air with the aerosols in the case of microbiological contamination of the humidifying water.
- Due to their small size, it is very difficult and sometimes impossible to separate water aerosols. Due to their typically floating behavior, they are carried over far distances through the ventilation ducts, without fully evaporating, and can ultimately end up in inhaled air.

6.2 Water Aerosols in conjunction with Biofilms
Depending on their size, inhaled water aerosols get into the respiratory tract at different depths. Microbiologically contaminated humidifying water causes harmful germs to be carried deep into the respiratory tract. Therefore, water aerosols must be viewed as a very sensitive matter precisely when there is existing biofilm build-up.



Droplet separator diagram

6.3 Clinical Knowledge about the Hazard Potential of Water Aerosols

Repeated cases of exogenous allergic alveolitis (EAA) due to inhaled contaminated water aerosols from atomizing humidifiers have already been demonstrated in clinical studies. The pulmonary disease EAA is caused, among others, by organic dust, mold fungi, yeast and bacteria, and manifests as fever with cough and shortness of breath. It can be life-threatening to weakened persons.

6.4 Water Aerosols are dealt with in VDI 6022 Sheet 1

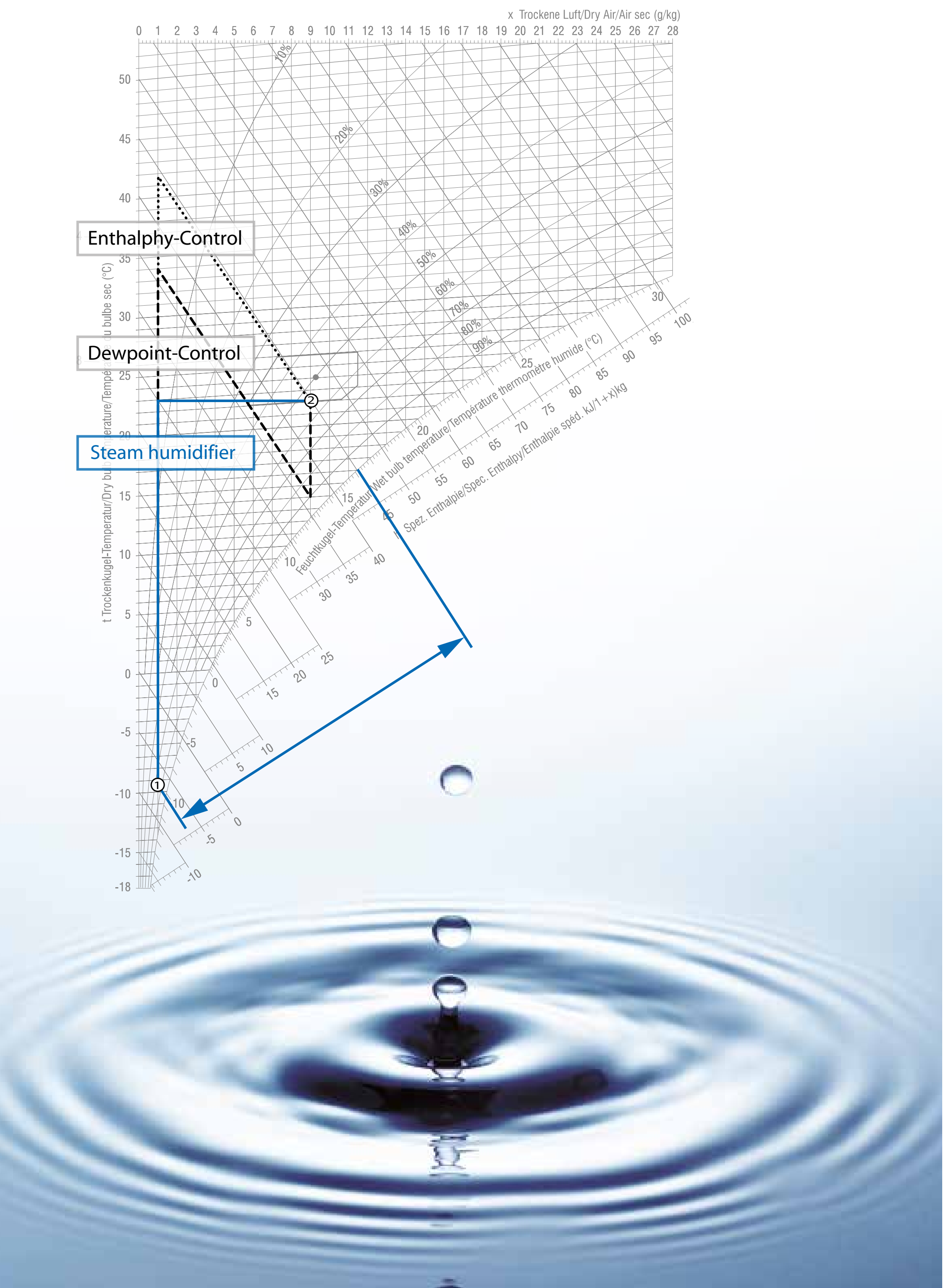
Humidifiers must be designed and operated pursuant to VDI 6022 sheet 1 so that water aerosols cannot end up in the air duct system.

6.5 Possibilities for the Separation of Water Aerosols

Customary droplet separators fail when it comes to separating small water aerosols from the air current. Due to their low mass, they adapt very easily to air direction changes and cannot be separated through the action of centrifugal force. In any event, there is a hazard potential due to biofilm growth in all separator devices.

Typical droplet separator diagram

Water aerosols with droplet diameters below the limit drop size cannot be separated. They cross the separator and penetrate into the system air or inhaled air. The water aerosols hazardous to the respiratory tract and just described on page 18, for all practical purposes, are not held back due to their small size.



HYGIENE CRITERION 4

7. HUMIDITY CONTROL

7.1 Control Concepts for Hygienic Humidification

From the standpoint of hygiene, the proper control of humidification systems is of great importance. Falling short of the dew point in ongoing system operation must be avoided and no condensate should be deposited in the air duct system. Humidification of air, however, always means changing the state of matter from water to steam. Unsuitable control concepts can also promote the reversal of this change of the state of matter. A look at the h,x diagram illustrates the different thermodynamic processes of the individual humidification methods. In view of these different processes, we can rule out a universal solution for the control of humidifiers from the start.

7.2 Control of Steam Humidifiers

Steam humidification is an almost isothermal process. Only a very small increase in air temperature due to the humidification process occurs. For this reason, only the humidity values of system or room air are usually considered in humidity control.

7.3 Control of Adiabatic Humidifiers

Considerable cooling of the humidified air takes place in the adiabatic humidification methods of atomization and evaporation. Therefore, humidity control in these cases can only take place in conjunction with air temperature control.

Recommended control strategies	Isothermal	Adiabatic — continuously adjustable	Adiabatic — not continuously adjustable
Room/exhaust air humidity control	■		
Space/exhaust air humidity control with continuous input air limitation	■		
Supply air humidity control with continuous output setting	■		
Dew point humidity control			■
Enthalpy supply air humidity control		■	
Enthalpy exhaust air humidity control		■	

Reliable evidence of hygiene includes all hygiene-related relationships. This includes long-term microbiological stability, preventive hygiene measures as well as a hygiene-oriented maintenance concept.

HYGIENE CRITERION 5

8. Evidence of Hygiene

8.1 Long-Term Microbiological Measurements, Hygiene Certificates and Type Tests

Different evidence of hygiene can be used for the evaluation of humidification systems. Humidification systems should normally work fault-free from the technical and hygienic standpoint over many years.

As a comestible, inhaled air should meet the hygiene requirements which are placed on foodstuffs. Apart from compliance with technical standards and pertinent rules and regulations, individual hygiene requirements play an important role. From experience, they are especially high for inhaled air.

Type tests that confirm only technical and structural compliance of devices and components with specific guidelines and the like do not constitute evidence of hygienic operation. An important prerequisite of hygiene safety is that all microbiological and hygiene-related requirements are extensively considered and evaluated.

This also includes preventive measures for the containment of germ growth as well as diligent maintenance and servicing activities performed based on present knowledge. An assessment of the hygiene quality of humidification systems is therefore only possible if all the requisite hygiene attributes are considered and fulfilled:

- compliance with technical guidelines
- effective hygiene measures for microbial reduction
- regular cleaning and disinfection

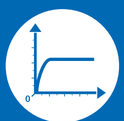
9. The five Hygiene Criteria

To ensure hygienic humidification, build-up of germs in the humidifier and entry of germs into the system air or inhaled air must be prevented.
Regardless of the humidification method used, the 5 hygiene criteria described above must be met overall. When deciding on specific humidification equipment, a diligent review of the planned equipment technology and hygiene measures is recommended. Lastly, reliable evidence of hygiene can be consulted to appraise the hygienic operation of humidification systems.

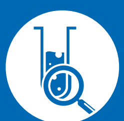
Hygiene criterion 1:
Size humidification distances correctly

Hygiene criterion 2:
Prevent formation of biofilms

Hygiene criterion 3:
Prevent entry of water aerosols



Hygiene criterion 4:
Provide system-compatible humidity control



Hygiene criterion 5:
Evidence of hygiene for all hygiene-related properties

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