



CONTEG

white paper

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Absolute and relative humidity  
Precise and comfort air-conditioning

Trends and best practices in data centers

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# Contents

- Introduction..... 3
- Data Center Humidity Issues ..... 3
  - How does data center humidity work? ..... 3
  - Relative vs. absolute humidity..... 4
  - Separated vs. integrated data center humidity control..... 4
- Precision vs. comfort air conditioning ..... 5
  - Different technical characteristics for different goals ..... 5
  - The influence of air volume and air speed ..... 6
  - Operation and method of functioning ..... 6
  - Differences in capacity and technical design..... 8
  - Latent/sensible proportion of capacity ..... 8
  - The influence of the unit’s design characteristics on capacity..... 9
  - Case A1: Limited surface temperature and change in humidity at constant environmental temperature ..... 10
  - Case A2: Limited surface temperature and change in environmental temperature and humidity ..... 10
  - Case B: Reduced surface temperature and change in environmental temperature and humidity ..... 11
  - Differences in capacity in precision and comfort air conditioning units ..... 11
- Summary: Only correct solution can lead to the desired goal..... 13

## Introduction

**Today, air conditioning is becoming an increasingly important factor in building planning, because besides regulating the interior climate, it also contributes to the energy efficiency and operating costs of a building. Modern air conditioning technology provides a precisely tuned solution for different operational requirements and different indoor ambient types. Correct interpretation of absolute and relative air humidity values in a room without permanent presence of people (e.g. a computer room) leads to the requirement for dew point temperature control. At the same time, the choice of corresponding HVAC technology is the key prerequisite to guarantee the optimum ambient parameters for your IT equipment which is operated in this special environment.**

## Data Center Humidity Issues

It's safe to say that most data center managers aren't meteorologists, but understanding the basics of what humidity is and how it affects your server room can impact how long your computer equipment lasts and how much your electricity bill costs.

### How does data center humidity work?

Humidity is a measurement of moisture content in the air. If a data center room is too humid, condensation can build on computer components and cause them to short out. In addition, high humidity can cause condensation to form on the coils of a cooling unit, causing it to work harder to rid itself of the condensation, which in turn can lead to wasted cooling, also called latent cooling, and that costs money.

On the other hand, if humidity is too low, data centers can experience electrostatic discharge (ESD). That sort of event can shut down electronic equipment and possibly damage it. When relative humidity falls below 20%, computer parts start failing even without receiving a shock from an operator (due to triboelectric effect).

The traditional way of measuring humidity in the data center is to look at relative humidity. Relative humidity is given as a percentage and measures the amount of water in the air at a given temperature compared to the maximum amount of water that air can hold. A technical committee of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) that focuses on computer rooms historically has recommended that relative humidity be within the 40% to 55% range, but has since said that humidity should be measured by dew point rather than relative humidity. ASHRAE also said that a range between 20% and 80% is "acceptable," but still recommended the 40% to 55% range. The TIA organization recommends 35% to 65%.

However, keeping humidity in that range can be difficult because of the frequently changing conditions in the data center, such as higher temperatures due to increased load. Conditions within different parts of the data center can also vary, causing cooling units to behave differently and making humidity control more difficult.

## Relative vs. absolute humidity

Absolute humidity, also expressed as dew point, is a measure of the amount of water in the air independent of temperature. So while relative humidity drops when temperature goes up in a data center, absolute humidity stays the same. ASHRAE recommends that data centers measure humidity by dew point and fall within 5.5 to 15 degrees Celsius (41.9-59 degrees Fahrenheit), which corresponds to 40% - 75% of relative humidity at 20°C.

Why the dew point, or absolute humidity, is a better measure?

If the air at the server intake has 20° C and its relative humidity is 40%, we can think that all parameters are alright because they meet minimum requirements. However, the air heats up while it goes through a server. Its relative humidity drops down, possibly as low as to 20%, even though its absolute humidity stays the same.

You can have perfectly conditioned air going into a server and what seems to be improperly conditioned air (according to the relative humidity level) coming out, but the absolute humidity hasn't changed. If you decide to humidify the air (based on information about its low relative humidity) in order to keep its relative humidity in range from 40% to 55%, then it will cause condensation to form on the cooling coils. The unit will work harder to evaporate that moisture. Therefore, controlling absolute humidity or dew point is preferable.

## Separated vs. integrated data center humidity control

There also exist some discussions regarding the usage of a separate central air handler in the data center for humidity monitoring and control rather than having multiple individual air- conditioning units with own settings.

Experience shows that especially in smaller data centers the central humidifier represents relatively high upfront capital cost. The savings are indirect, realized only as part of operational savings. In addition, in small and medium data centers the humidity control is generally more difficult because other parts of the building typically do not have controlled environment. Still, there is a case when the separate humidity control in smaller sites is advantageous: **when deploying in-row cooling units for higher density cooling applications.** In this case the central humidification control avoids the situation when one cooling unit would be cooling, the second dehumidifying and the third humidifying.

While we can only control one of the humidity values, it is desirable to work with the absolute humidity (humidity ratio) calculated from measured air temperature and its relative humidity. The reason is that data centers are fine as long as **the both temperature and relative humidity** are within the permissible range. The most important goal of humidity control is to regulate condensation. The only real danger to very warm, high moisture content air is that it will condense easily should its temperature drop below the dew point temperature.

## Precision vs. comfort air conditioning

Comfort (partial) air conditioning units maintain the temperature and humidity of offices and other rooms used by people within a range that people perceive as pleasant. Technical equipment rooms, on the other hand, generally require precision air conditioning, for here the task is primarily to dissipate high heat loads and maintain a precise environmental temperature and humidity.

### Different technical characteristics for different goals

The requirements regarding the room condition for technical equipment and rooms used by people are vastly different.

Comfort air conditioning units can heat and cool and provide unregulated dehumidification. Technical applications, on the other hand, require compliance with precise room temperatures and generally air humidity within tight limits in order to avoid the build-up of electrostatic charge. Permitted room air conditions are described in VDI 2054, for example.

Precision air conditioning units can cool and heat simultaneously and also set an exact air humidity through controlled humidification and dehumidification. At  $\pm 0.5$  Kelvin, the ranges of variation (hysteresis) induced by the control of a precision air conditioning unit are very small, and the relative humidity is adhered to with a variation of only  $\pm 3\%$ . Naturally, the precision air conditioning unit initiates the relevant functions automatically, in order that the desired room condition can be achieved precisely (see Figure 1: Necessary air conditioning measures to achieve a precise room air condition).

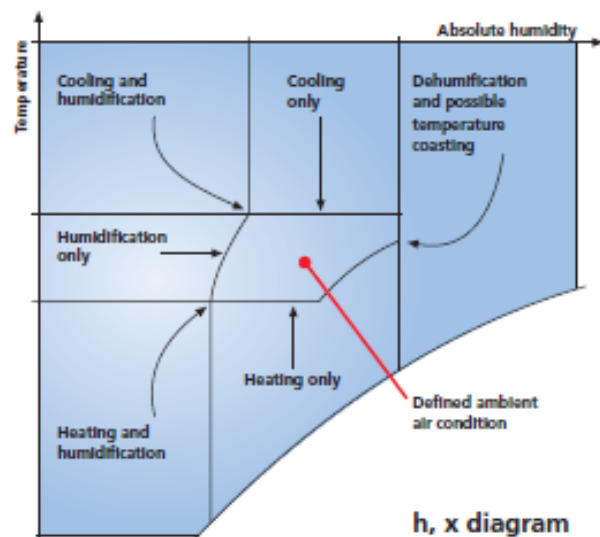


Figure 1: Necessary air conditioning measures to achieve a precise ambient air condition

## The influence of air volume and air speed

In technical equipment rooms, dangerous hotspots must be avoided. In order to achieve an optimum, thorough mixing of air and ensure that large heat loads can be dissipated, precision air conditioning units must circulate enormous quantities of air (up to 30,000 m<sup>3</sup>/h).

The areas available for installing air conditioning units in equipment rooms are small and expensive. In times when square meter prices are high, precision air conditioning systems have to provide maximum output with large volumes of air on the smallest possible footprint.

Therefore, the outlet air speeds of up to 3 m/s are four times higher than with comfort air conditioning units.

Where comfort air conditioning is concerned, the movement of air in the room must be imperceptible, as far as possible, in order to avoid draughts. For this reason, comfort air conditioning units are optimized to create pleasant room conditions with small quantities of air (300 to 2,000 m<sup>3</sup>/h) and very low air speeds (0.2 to 0.5 m/s). Due to these low air volumes, comfort air conditioning systems generally operate with a control hysteresis of +/- 1.5 Kelvin.

The air volume and air speed have an influence on the noise level of the units – another important factor for comfort in room air conditioning. Simply put, a 6 dB(A) reduction in the noise level is perceived as a halving of the volume, regardless of the initial variable. In this way, even minor changes to the noise level achieve large effects. Modern comfort air conditioning systems operate with a noise level of 22 to 35 dB(A). Due to their technical design, precision air conditioning units produce considerably higher noise levels.

## Operation and method of functioning

Precision air conditioning units have to constantly dissipate high heat loads around the clock, 365 days a year. In order to create a tailor-made, optimum climate for sensitive technical equipment, numerous parameter settings can be undertaken. The operating parameters of a precision air conditioning unit require in-depth technical understanding and specialist expertise. The requirements for comfort air conditioning, on the other hand, can vary dramatically depending on the purpose of the room, the time of day and the weather conditions. In comfort air conditioning systems, time-based changes in temperature set-points and on-off cycles can simply be set to suit the individual.

The energy efficiency of air conditioning systems makes a large contribution to the total operating costs of a building. Modern comfort and precision air conditioning units (*see table 1*) satisfy these more exacting requirements with high COP<sup>1)</sup> values of over 5.3.

<sup>1)</sup> The Coefficient of Performance (COP) describes the ratio of (cooling) capacity to the effective power consumption of the unit.

	<b>Precision air conditioning</b>	<b>Comfort air conditioning</b>
<b>Application</b>	Air conditioning for technical applications	Room air conditioning for human requirements
<b>Nominal cooling/heating capacity per individual air conditioning unit</b>	5-150 kW (partially modular)	2-30 kW
<b>Proportion of capacity sensible/latent</b>	85~100% / 0~15 %	50~70% / 30~50 %
<b>Control accuracy</b>	$\pm 0.5$ K / $\pm 3$ % rel. hum.	$\pm 1\sim 2$ K
<b>Humidity regulation</b>	Controlled humidity (e.g. to avoid electrostatic charge)	Unregulated dehumidification (for comfortable environmental cooling)
<b>Air volume</b>	5,000-30,000 m <sup>3</sup> /h	300-2,000 m <sup>3</sup> /h
<b>Air outlet speed</b>	2-3 m/s	0,2-0,5 m/s
<b>Noise level in room</b>	45-70 dB(A)	20-40 dB(A)
<b>Diversity of options</b>	Very large, due to individual production	Lower, due to mass production
<b>Operator controls</b>	Technical and complicated	Intuitive and simple
<b>Method of operation</b>	Permanent operation	Cyclical operation with time-dependent set-point changes

Table 1: A comparative overview of precision and comfort air conditioning

## Differences in capacity and technical design

When selecting and designing precision and comfort air conditioning units, it is essential to take into consideration differences in capacity, which arise from different designs of the cooling and control technology.

Further we explain why the selection of particular cooling units should not be based solely on the nominal capacities mentioned in the catalogue sheets.

## Latent/sensible proportion of capacity

The total cooling capacity of an air conditioning unit consists of both latent and sensible capacity. As a rule, a cooling process removes water from the room air - it dehumidifies. The capacity required for dehumidification is referred to as latent capacity (the environmental temperature remains roughly constant). The proportion of capacity that brings about a lowering of the temperature (which must not fall below dew-point) is known as the sensible capacity (see Figure2):

$$\text{Total cooling capacity} = \text{Latent cooling capacity (dehumidification)} + \text{Sensible cooling capacity}$$

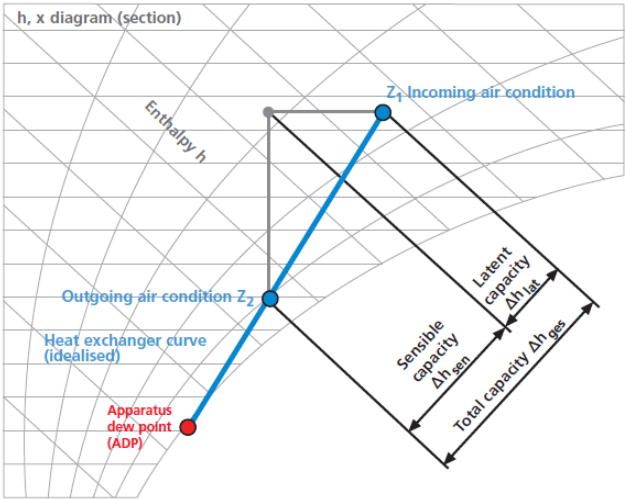


Figure 2: Total capacity = latent + sensible capacity



Devices designed for air conditioning in technical rooms must dissipate large heat loads at relatively constant humidity, and are therefore optimized for sensible capacity. Accordingly, the proportion of latent cooling capacity lies between only 0 and 15%, while sensible capacity is between 85 and 100% (see Figure 2: *Proportion of capacity in precision/comfort air conditioning units*). This difference in proportion between latent and sensible capacity is one of the key differences between precision and comfort air conditioning systems.

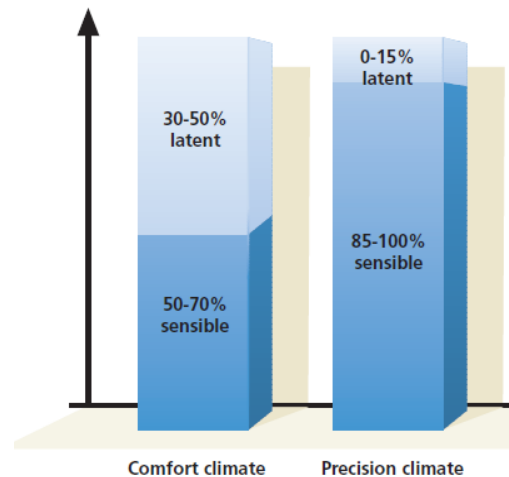


Figure 3: Proportion of capacity in precision/comfort air-conditioning units

### The influence of the unit's design characteristics on capacity

Air-conditioning units are designed to work in a particular temperature and humidity range for the incoming and outgoing air condition. Consequently, when designing the technical cooling characteristics of these units, a broad or narrow range is selected for the desired evaporation temperature. The resulting so-called Apparatus Dew Point ADP (surface temperature of the evaporator) depends upon the evaporator used and the air volume conveyed through the evaporator. If we combine the incoming air condition and the ADP in an h-x diagram, we obtain the idealized cooling curve, with the outgoing air condition slightly above the ADP. If we then change one of the influencing variables – the environmental temperature and/or humidity of the incoming air – the ADP may shift. This may result in serious changes in performance in terms of the unit's total cooling capacity and the ratio of latent to sensible capacity.

The design and control of the cooling circuit can influence whether the evaporation temperature (= ADP) should be maintained at a virtually constant level (i.e. subject to a lower threshold) or whether it should be variable.

### Case A1: Limited surface temperature and change in humidity at constant environmental temperature

If the relative humidity of the air entering the unit falls whilst the temperature of incoming air and the ADP remain constant, the proportion of latent capacity will also drop. The sensible capacity remains roughly the same. The proportion of latent capacity in relation to total capacity becomes greater, whereas the total capacity itself drops as a result of the decreasing latent capacity (see Figure 4: Limited surface temperature + change in humidity at constant environmental temperature).

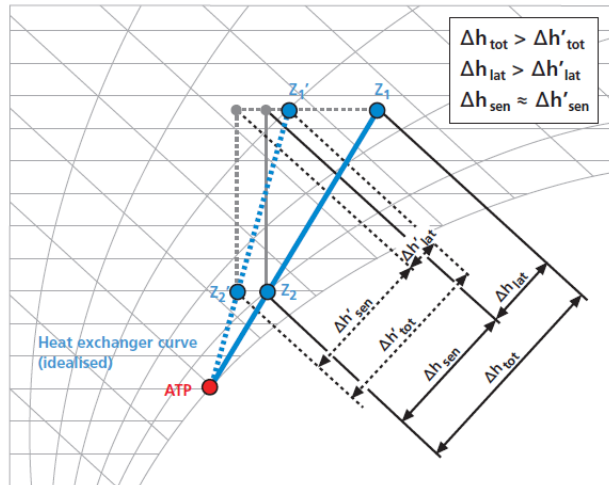


Figure 4: Limited surface temperature + change in humidity at constant ambient temperature

### Case A2: Limited surface temperature and change in environmental temperature and humidity

The lower the temperature of the air entering the unit (environmental temperature) whilst the ADP remains constant, the smaller the effective temperature difference at the heat exchanger. If the air flow rate through the heat exchanger remains constant, the unit's total capacity will fall. Both the latent and sensible cooling capacities of the unit decline (see Figure 5: Limited surface temperature + change in environmental temperature and humidity).

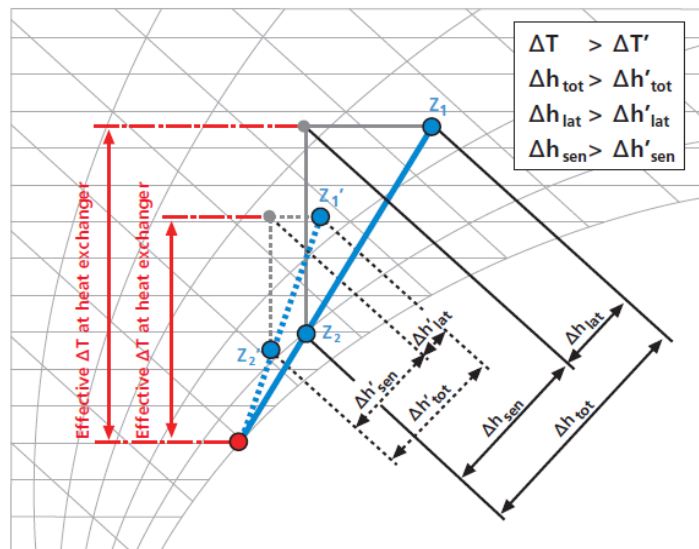


Figure 5: Limited surface temperature + change in ambient temperature and humidity

## Case B: Reduced surface temperature and change in environmental temperature and humidity

If the evaporation temperature and thus the ADP is not subject to a lower threshold, it will drop when the temperature of the air entering the unit falls. The effective temperature difference at the heat exchanger remains larger compared with Case A2, but the total capacity sinks, because the cooling capacity of the evaporator drops as the evaporation temperature decreases (see Figure 6: Reduced surface temperature + change in environmental temperature and humidity).

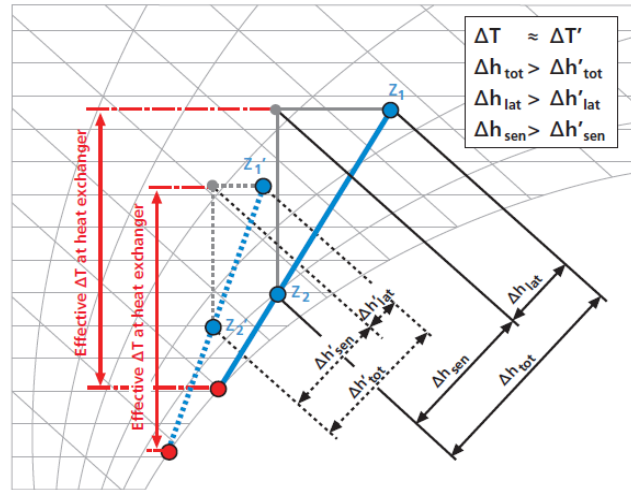


Figure 6: Limited surface temperature + change in humidity at constant ambient temperature

## Differences in capacity in precision and comfort air conditioning units

If we compare air conditioning units whilst taking the technical cooling relationships explained above into consideration, we can see large differences in terms of their performance capabilities.

Precision air conditioning units must dissipate permanent, sensible heat loads at a constant room temperature. Thus, the dimensions of the air conditioning unit must be based solely on the sensible proportion of capacity. Moreover, sufficiently high air circulation must be provided for, in order to prevent the formation of hotspots in the room.

**Regulated-output (inverter-controlled) comfort air conditioning units** generally enforce a lower limit for the cooling-air or evaporation temperature, in order to avoid unpleasantly low air outlet temperatures.

However, this temperature limitation results in a considerable decrease in the effective temperature difference at the evaporator when the environmental temperature falls. As a result of this decrease, the effective sensible and latent cooling capacity drops.

In certain circumstances, the total capacity reaches only around 50 % of the nominal capacity at the desired operating point.

If regulated-output comfort air conditioning units are employed in technical applications, they must be dimensioned larger in accordance with the required room conditions.

**Non-regulated output comfort air conditioning units (on/off)** or regulated-output units with reducible ADP do not set a lower threshold for the cooling-air or evaporation temperature over a broad range. They can reach considerably lower evaporation temperatures when the environmental temperature falls. As the evaporation temperature also falls when the environmental temperature drops, the temperature difference at the heat exchanger remains greater in relation to the limited cooling-air temperature. In other words, the capacity of these devices does not fall to the same extent as it does in units with a lower threshold for the ADP, because the temperature difference at the heat exchanger remains correspondingly greater. A reduction in capacity is characterized by a lowering of evaporator cooling power as the evaporation temperature falls. These units are therefore more suitable for use in rooms with a low temperature.

The nominal conditions for the specified capacity of precision and comfort air conditioning units differ. As a rule, the catalogue specifications of precision air conditioning units are based on room air conditions of 24 °C/50% relative humidity. The nominal capacities of comfort air conditioning units, on the other hand, apply at 27 °C/48%.

The table 2 below shows the differences in total capacity that can already result if performance data of comfort air conditioning units are adapted to the room air condition 24°C/50% relative humidity.

Capacity comparison of precision and comfort air conditioning systems at a room air condition of 24 °C/50% rel. hum.

	<b>Precision air conditioning</b>	<b>Comfort air conditioning</b>	
		<b>ADP unlimited</b> (e.g. on/off devices)	<b>ADP limited</b> (e.g. inverter devices)
Catalogue capacity	10.0 kW (24°C/50 %)	10.0 kW (27°C/50 %)	10.0 kW (27°C/50 %)
Total capacity	10.0 kW	9.5 kW	7.0 kW
Latent capacity	0.5 kW	3.0 kW	2.5 kW
Sensible capacity	9.5 kW	6.5 kW	4.5 kW

Table 2: Capacity comparison of precision and comfort air conditioning systems at a room air condition of 24 °C/50% rel. humidity

## Summary:

### Only correct solution can lead to the desired goal

Room temperature and relative humidity exert a considerable influence on the performance data of partial air conditioning units with a lower threshold for the surface temperature. Units in which the surface temperature may drop to a greater extent may also be considered for use in rooms with low temperatures.

However, here too, the reduction in capacity must be taken into consideration. If an air conditioning system designed for people's comfort is subject to stringent requirements, e.g. low sound emissions, low air speeds and pleasant room conditions in relation to the outside air temperature, comfort air conditioning units must be employed. If, however, the requirements facing the air conditioning are concerned with the regulated control of relative humidity, increased control accuracy for the room temperature combined with high sensible capacity and intensive air distribution in the room, precision air conditioning units are the preferred technology.

Frequently, comfort air conditioning units are used in precision air conditioning areas because of cost. But if the operating conditions differ considerably from the nominal conditions, checking the performance capabilities of the units is crucial. People and machines require different room air climates. Decision-makers should take account of this fact by ordering the most suitable solution for the application in question – from the precision or comfort air conditioning line.

#### Related resources:

- 1) Internal documents and resources – keywords: relative and absolute humidity, precise cooling
- 2) STULZ GmbH publication library
- 3) [searchdatacenter.techtarget.com](http://searchdatacenter.techtarget.com)