Conditions of Thermal Comfort

Influence of Humidity and Temperature on Personal Well-Being

Preface

Thermal comfort is an important concept for climate control systems and beyond. When does one feel comfortable, at what conditions does one feel discomfort and when does it get dangerous? This Application Note gives three approaches to determine a comfort zone and define limits: Comfort Zones according to ASHRAE, to ISO and the concept of Heat Index.

With the knowledge of comfort conditions climate controlling systems may be designed to be more to the needs of the user, being more efficient and this way save energy. As it comes clear in this document, relative humidity and temperature play an important role, and hence the well-being may be improved by simply applying a humidity and temperature sensor.

Basic Considerations

Thermal comfort is defined as that condition of mind which expresses satisfaction with the thermal environment. A lot of empirical data has been collected on how these parameters are defined. This Application Note gives a short introduction on thermal comfort especially in respect of humidity and temperature.

The factors that have relevant influence on the thermal comfort of occupant's spaces can be divided in environmental and personal factors.

Environmental factors:

- temperature
- thermal radiation
- humidity
- air speed

Personal factors:

- personal activity and condition
- clothing

Considering these factors climate systems can be made more apt to the needs of users on one hand, but also more efficient on the other hand. And if such a system is using energy only if it is really needed – thus energy consumption may be reduced.

Personal Factors

Perception of the environmental conditions and the feeling of comfort are related to metabolic heat production, its transfer to the environment, and the resulting adjustments of body temperature. For defining a comfort zone of external parameters it is important to know the activity of an individual person: Are people sitting and working in an office, are they doing sports in a gym, are they sick in a hospital or are they hiking somewhere outdoor?

A second parameter is clothing – through its insulating properties it is an important parameter of body heat conservation or loss and hence for feeling thermal comfort. Clothing is changing to a great extent by the season and outdoor weather conditions. Therefore, the limits for external parameters defining a comfort zones are made dependent of the season. Conditions for comfort given in this document refer summer and winter clothing that typically are worn in European or North-American countries.

Because of individual differences, it is impossible to specify a thermal environment that will satisfy everyone. Conditions stated in this document will ensure that 80% or more of the occupants will find the environment thermally acceptable. The conditions of comfort were found by studies of North American and European subjects. Recent studies with Japanese subjects led basically to the same results. Therefore, it can be assumed that these conditions of comfort can applied with good approximation in most parts of the world.

External Factors – Comfort Zone by ASHRAE

Thermal radiation and air speed are mainly out door effects which are difficult to control and measure. Therefore, literature on thermal comfort focuses on humidity and temperature.

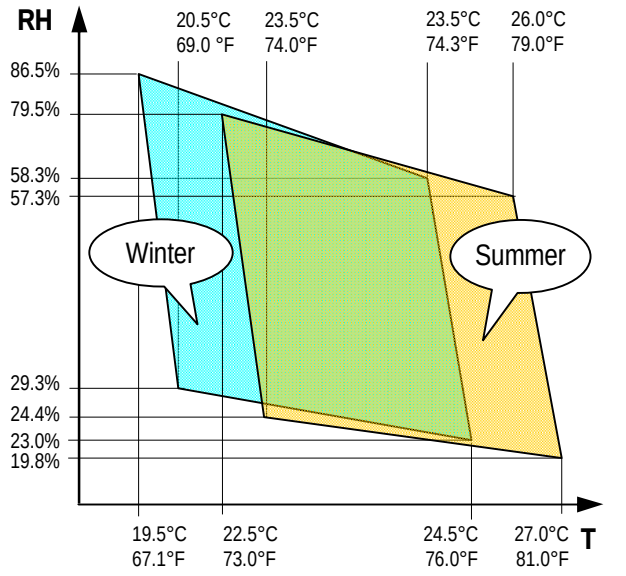

Figure 1 Relative humidity (RH) / temperature (T) diagram based on comfort zone according to ASHRAE 55-1992.

The thermal experience by an individual not only depends on temperature but also on humidity: The higher the humidity the higher the experienced temperature. This effect is based upon the fact that at higher humidity the bodies cooling system by transpiring water on the skin is reduced.

ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) in its publication on thermal environmental conditions for human occupancy has defined a comfort zone for winter and summer season[1]. This definition of comfort zone is somewhat complex but can be transformed by some approximation to a zone which only depends on relative humidity and temperature – see Figure 1.

The effect of feeling higher temperature with high relative humidity is reflected by slanting boundaries of the comfort zone for the upper and lower temperature limits.

This has an impact on HVAC control systems: Energy can be saved when indoor spaces are monitored for both humidity and temperature, because e.g. when humidity is low, a higher temperature is acceptable and cooling is not necessary. In a system which only is controlled by temperature, unnecessary heating or cooling may be done even if conditions still are within the comfort zone.

Comfort zone according to ISO7730

Another approach for defining the comfort zone is done by the standard ISO7730[2]. It neglects the fact that higher temperatures can be borne at low humidity. Therefore its upper and lower temperature limits are vertical. This approach can be used in less demanding applications for simpler implementation of air-conditioning algorithms.

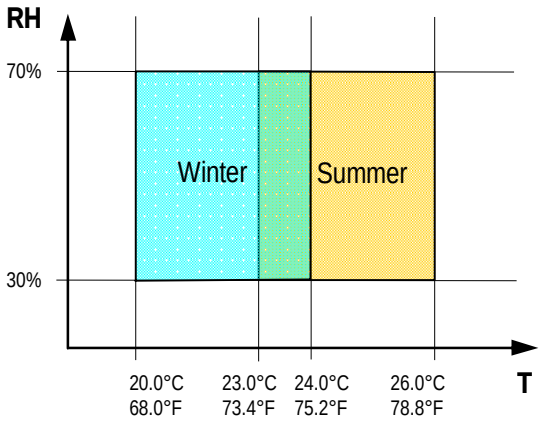

Figure 2 RH/T diagram showing the comfort zone according to ISO7730

[1] ASHRAE Standard: Thermal Environmental Conditions for Human occupancy: ANSI/ASHRAE 55-1992

[2] ISO Standard: Moderate thermal environments- Determination of the PMV and PPD indices and specification of the conditions for thermal comfort: ISO7730

While simple temperature ranges are given per season the relative humidity is set between 30%RH and 70%RH in winter and summer time, respectively. The limits are set to decrease the risk of unpleasantly wet or dry skin, eye irritation, static electricity, microbial growth and respiratory diseases.

Heat Index – Alert in the Extreme

At high humidity, high temperature conditions, the well-being may be controlled with the concept of Heat Index. Heat Index indicates how the human body feels temperature.

The heat index is based on subjective measurements and is only meaningful above 25°C and 40%RH. The most popular definition of the Heat Index is the one of the *National Weather Service and Weather Forecast Office* of the *National Oceanic and Atmospheric Administration* (NOAA). The Heat Index in °C is given by

$$HI = c_{00} + c_{10}t + c_{01}U_w + c_{11}tU_w + c_{20}t^2 + c_{02}U_w^2 + c_{21}t^2U_w + c_{12}tU_w^2 + c_{22}t^2U_w^2$$

with the following coefficients:

c_{00}	-8.7847	c_{02}	-0.0164
c_{10}	1.6114	c_{21}	$2.2117 \cdot 10^{-3}$
c_{01}	2.3385	c_{12}	$7.2546 \cdot 10^{-4}$
c_{11}	-0.1461	c_{22}	$-3.5820 \cdot 10^{-6}$
c_{20}	-0.0123		

Table 1 Coefficients for Heat Index formula

Figure 3 displays the Heat Index as a function of relative humidity and temperature.

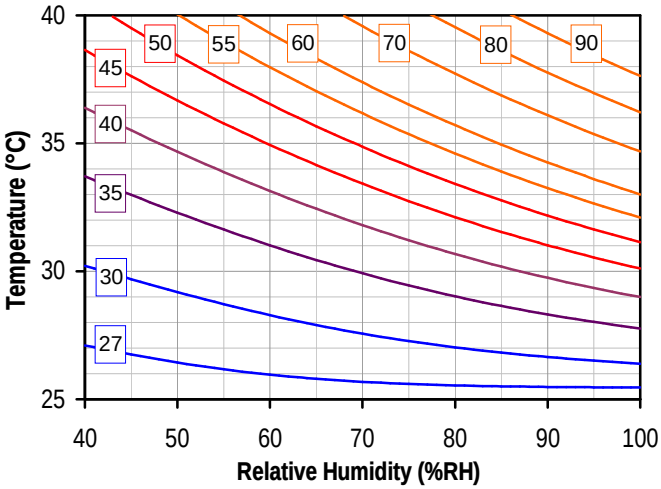

Figure 3 Heat Index in °C.

The meaning of the values is defined as follows:

< 30°C:	no discomfort
30 – 40°C:	some discomfort
40 – 45°C:	great discomfort
> 45°C:	dangerous
> 54°C:	heat stroke imminent

Revision History

Date	Version	Page(s)	Changes
27 May 2003	0.1	1 – 3	Initial release
25 May 2005	1.0	1 – 3	Changed company address
27 June 2009	1.1	1 – 3	Addition of address in China, layout changes
21 February 2010	2.0	1 – 3	Complete rework of the document, addition of the concept of Heat Index

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