European Standardisation on Thermal Environment

The thermal environment is one of the most important factors for people's health, comfort and performance indoor as well as outdoor. The present paper will focus on requirements in international standards for thermal comfort. One of the first standards on thermal comfort was ASHRAE Standard 55. The basic standard for comfort on the European level is ISO EN 7730, which defines an index for thermal comfort, PMV/PPD and specifies acceptable criteria for local thermal discomfort from radiant temperature asymmetry, air velocity (draught), vertical air temperature differences and floor temperatures. Based on this basic standard a more applicable standard was developed in Europe as EN16798-1/2. A similar standard ISO 17772-1/2 was developed in parallel by ISO. The standard also includes other indoor environmental factors air quality, lighting and acoustic. Based on the basic standard ISO EN 7730 it was possible in EN16798-1/2 to establish recommended criteria for thermal comfort at different categories (levels of expectations) by using the PMV/PPD index. This method has been supplemented with a method called the Adapted Approach to be used outside the heating season in buildings with no mechanical cooling, operable windows, no dress codes and mainly sedentary activity.

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Introduction

Standardisation in relation to the thermal environment goes back many years, where mainly national standards like ASHRAE 55 (thermal comfort, first issue 1966) and ACGIH established in 1962 the first Threshold Limit Values for industrial workplaces. Internationally the standardization work started in 1978 under ISO TC 159 Ergonomics; SC 5 Ergonomics of the Physical Environment formed a new Working Group WG1 Ergonomics of the thermal environment. This working group covers all aspects of the influence of the thermal environment on people like heat stress, cold stress, thermal comfort, physical and thermal physiological measurements etc. The first standard ISO 7243 was dealing with heat stress and the use of WBGT based on the ACGIH standard. This was soon followed by the most cited standard for thermal comfort ISO 7730.

Standard 16798-1/2 part on Thermal Comfort

To be flexible and possible adoption worldwide the standard recommends criteria for thermal comfort in 3-4 different categories. The standard also includes two methods for estimating the appropriate temperature requirements i.e. the PMV-PPD approach and the adaptive approach.

There are specified some boundary conditions for the two methods depending on the availability of a cooling system.

The PMV-PPD approach

The PMV-PPD approach can be used for buildings with an active cooling system. **Table 1** shows the recommended operative temperatures for typical sedentary work during winter and summer. The categories are related to the level of expectations the occupants may have. A normal level would be "Medium". A higher level may be selected for occupants with special needs (children, elderly, handicapped, etc.). A lower level will not provide any health risk but may decrease comfort.

Table 1. *Recommended temperature ranges for dimensioning and hourly calculation of cooling and heating energy in four categories of indoor environment.*

Category	Thermal state of the body as a whole		Heating season (winter) 1 clo	Cooling season (summer) 0.5 clo
	PPD, %	PMV	Operative temperature range, °C	Operative temperature range, °C
I	< 6	-0.2 < PMV < +0.2	21.0 – 23.0	23.5 – 25.5
II	< 10	-0.5 < PMV < +0.5	20.0 – 24.0	23.0 – 26.0
III	< 15	-0.7 < PMV < +0.7	19.0 – 25.0	22.0 – 27.0
IV	< 25	-1.0 < PMV < +1.0	17.0 – 25.0	21.0 – 28.0

Recommended temperature ranges for the four categories of indoor environment recommended for sedentary work (1.2 met) in ISO 16798-1. Air velocity is assumed below 0.1 m/s and the relative humidity is 40% for heating seasons and 60% for cooling seasons.

This will work for establishing design values for dimensioning of heating and cooling systems by using the lower value in heating season for the heating system and the upper value in cooling season for the cooling system. It also gives the operation range as it is acceptable to have the temperature drift in the recommended range.

The standard also includes recommendations to avoid local thermal discomfort from a non-uniform environment. Recommended criteria are in **Table 2** shown for Draught, Vertical Air Temperature differences, floor surface temperatures and radiant temperatures asymmetry.

These values are also used for design of building systems. Draught can come from two high air velocities from the ventilation or air conditioning system and from down draught from windows in winter. Vertical air temperatures can be caused by non-uniform temperature distribution from ventilation and air conditioning. The recommended floor temperatures are used for design of floor heating/cooling systems. Radiant temperature asymmetry can be caused by heated/cooled ceilings, badly insulted exterior envelops, and direct sunshine through windows.

The Adaptive method

According to EN 16798-1 in **Figure 1** recommended ranges of indoor operative temperatures are presented for buildings without mechanical cooling systems as function of the outdoor running mean temperature, defined below. This alternative method only applies for office buildings and other buildings of similar type (e.g. residential buildings) used mainly for human occupancy with mainly sedentary activities, where there is easy access to operable windows and occupants can freely adapt their clothing to the indoor and/or outdoor thermal conditions, where thermal conditions are regulated primarily by the occupants through opening and closing of openings (windows) in the building envelope.

During the summer season and during the shoulder seasons (spring and autumn) so-called adaptive criteria (upper and lower temperature limits that change with the running mean outdoor temperature) shall be applied (see the cat. I, II and III upper and lower limits in **Figure 1**).

During the winter season, the same temperature limits shall be applied as presented for buildings with mechanical cooling systems.

The temperature limits presented in Annex B1.2 should be used for the dimensioning of passive means to prevent overheating in summer conditions. Some examples are dimensioning and orientation of windows, dimensioning of solar shading systems and of the thermal capacity of the building. Where the adaptive temperature limits presented in **Figure 1** (upper limits) cannot be guaranteed by passive means, then mechanical cooling should be used. In such cases the design criteria for buildings with mechanical cooling should be used.

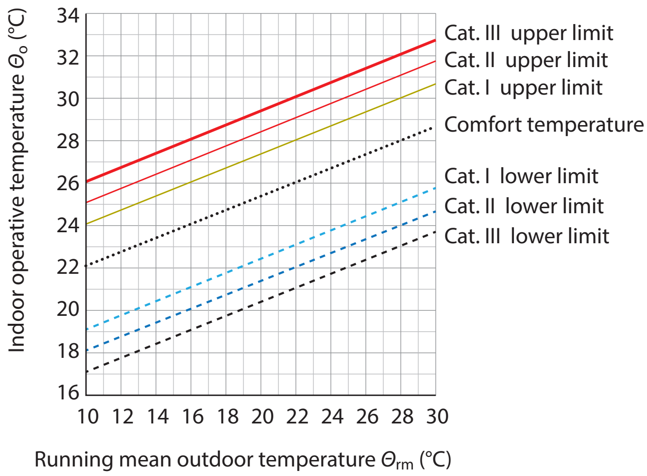

Figure 1. Default design values for the indoor operative temperature for buildings without mechanical cooling systems as a function of the exponentially-weighted running mean of the outdoor temperature.

Table 2. *Local thermal discomfort design criteria.*

Category	Draught			Vertical air temperature difference (head-ankle)		Range of floor temperature		Radiant temperature asymmetry				
	DR (Draught Rate)	Maximum air velocity [a] Winter	Maximum air velocity [a] summer	PD	Temp. Differ.[b]	PD	Range	PD	Warm ceiling	Cool wall	Cool ceiling	Warm wall
	[%]	[m/s]	[m/s]	[%]	[K]	[%]	[°C]	[%]	[K]	[K]	[K]	[K]
I	10	0.10	0.12 [c]	3	2	10	19 to 29	5	< 5	< 10	< 14	< 23
II	20	0.16	0.19 [c]	5	3	10	19 to 29	5	< 5	< 10	< 14	< 23
III	30	0.21	0.24 [c]	10	4	15	17 to 31	10	< 7	< 13	< 18	< 35

[a] Assuming an activity level of 1.2 met, a turbulence intensity of 40 % and an air temperature equal to the operative temperature of around 20°C in winter and 23°C in summer.

[b] Difference between 1,1 and 0,1 m above the floor.

[c] When the air temperature is above 25°C higher maximum air speeds are allowed and often even preferred (draught becomes pleasurable breeze); but only under the condition that occupants have direct control over the air speed.

Note that **Figure 1** already accounts for people's clothing adaptation, therefore it is not necessary to estimate the clothing values when using the adaptive method.

In landscaped (open plan) offices most occupants have only limited access to operable windows and therefore typically reduced personal control over window openings, e.g. if there are workplaces placed in the middle of the room, away from direct access to operable windows. Therefore, the adapted method may not apply.

The following approximate formula shall be used where records of daily running mean outdoor temperature are not available:

$$\Theta_{rm} = (\Theta_{ed\ -1} + 0.8\ \Theta_{ed\ -2} + 0.6\ \Theta_{ed\ -3} + 0.5\ \Theta_{ed\ -4} + 0.4\ \Theta_{ed\ -5} + 0.3\ \Theta_{ed\ -6} + 0.2\ \Theta_{ed\ -7})/3.8$$

Where $\Theta_{ed\ -i}$ (i=1...7) are the daily mean outdoor air temperature for previous days (i=1...7).

It is often discussed under which boundary conditions you may use the adapted approach. Below is the wording used in similar standards (ASHRAE 55, ISO 17772-1/2).

ASHRAE 55: This method defines acceptable thermal environments only for occupant-controlled naturally conditioned spaces that meet all of the following criteria:

a. There is no mechanical cooling system (e.g., refrigerated air conditioning, radiant cooling, or desiccant cooling) or heating system in operation.
b. Representative occupants have metabolic rates ranging from 1.0 to 1.5 met.
c. Representative occupants are free to adapt their clothing to the indoor and/or outdoor thermal conditions within a range at least as wide as 0.5 to 1.0 clo.
d. The prevailing mean outdoor temperature is greater than 10°C (50°F) and less than 33.5°C (92.3°F).

ISO 17772-1: This adaptive method only applies for occupants with sedentary activities. Without strict clothing policies where thermal conditions are regulated primarily by the occupants through opening and closing of elements in the building envelop (e.g. windows, ventilation flaps, roof lights, etc.). This method applies to office buildings and other buildings of similar type used mainly for human occupancy with mainly sedentary activities, where there is easy access to operable windows and occupants can freely adapt their clothing to the indoor and/or outdoor thermal conditions.

NOTE 1 The field studies behind the method were conducted in office buildings

Increased air velocity

Under summer comfort conditions with indoor operative temperatures >25°C artificially increased air velocity can be used to compensate for increased air temperatures according to **Table 3** only if the increased air velocity is under personal control. The correction value depends on the air speed range of the appliance.

Table 3. *Indoor operative temperature correction ($\Delta\Theta_o$) applicable for buildings equipped with fans or personal systems providing building occupants with personal control over air speed at occupant level.*

Average Air Speed (v_a) **0.6 m/s**	Average Air Speed (v_a) **0.9 m/s**	Average Air Speed (v_a) **1.2 m/s**
1.2°C	1.8°C	2.2°C

Conclusion

The criteria for thermal comfort been the same as in the previous standard EN 15251 and are worldwide accepted. There are still issues on when the adapted approach may be used. It is also unclear if you can use the adapted approach part of the summer and use PMV-PPD during the part where mechanical cooling is used.

There is a need to establish a yearly indicator for thermal comfort that can be held against the yearly energy performance. This will be part of the revision of EN16798-1/2.

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