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A New Hybrid Thermal Comfort Guideline for the Netherlands (ISSO 74: 2014)

A.C. Boerstra[1], J. van Hoof[2,3] & A.M. van Weele[2]

1) BBA Binnenmilieu, The Hague, the Netherlands (email: ab-bba@binnenmilieu.nl)
2) ISSO / Dutch Building Services Research Institute, Rotterdam, the Netherlands
3) Fontys University of Applied Sciences, Centre for Healthcare and Technology, Eindhoven, the Netherlands

Abstract

In 2004 the first adaptive thermal comfort guideline was introduced in the Netherlands. Recently a new, upgraded version of this ISSO 74 (ATG) guideline has been developed. The new requirements are hybrid in nature as the 2014 version of the guideline combines elements of traditional non-adaptive comfort standards with elements of adaptive standards. This paper describes the new guideline and explains the rationale behind it. Also changes in comparison with the original 2004 version and issues related to performance verification are discussed. The information presented in this paper can be used by others (other countries) as inspiration material for other new adaptive comfort guidelines and standards.

Keywords: adaptive comfort, standardisation, overheating, personal control, classification

1 Introduction

During the late 1970s the first guidelines for thermal comfort were developed for use in the Netherlands, which were based on the PMV-PPD relationship and ISO-EN 7730. Since then, the Netherlands have developed successive guidelines [1,2], that include the Weighted Temperature Exceeding Hours method (GTO in Dutch) and - in analogy with international developments in the field of adaptive thermal comfort [3,4] - the Adaptive Temperature Limits method (ATG in Dutch). The latter was presented for the first time in 2004 in ISSO publication 74 and is known internationally as the ISSO 74: 2004 Dutch adaptive thermal comfort guideline. In 2012-2013 a new version was developed of the ISSO 74 guideline. This guideline will be published in 2014. This paper describes this new version of ISSO 74 and explains its practical and scientific backgrounds and gives guidance on how to apply the new guideline in practice.

2 International context

Thermal comfort contributes to overall satisfaction, well-being and performance, and is an important parameter in the building design process. In the 1970s and 1980s, the development and usage of energy balance models of the human body came within the focus of human biometeorology [5]. The most important contributor was P.O. Fanger, who created a predictive model for general, or whole-body, thermal comfort during the second half of the 1960s from laboratory and climate chamber research [6]. With his work, Fanger wanted to present a method for use by the heating and air-conditioning engineer, to predict, all those combinations of the thermal factors in the environment for which the largest possible percentage of a given group of people experience thermal comfort [7]. Fanger stated at the time that his PMV-model (Predicted Mean Vote) was intended for application by the HVAC industry in the creation of artificial climates in controlled spaces [8]. The PMV-model became the internationally accepted model for describing the predicted mean thermal perception of building occupants.

An alternative predictive thermal comfort model, primarily based on the results of field studies, is generically called the adaptive model and also has been researched since the 1960s [9,10]. According to the adaptive hypothesis, contextual factors and past thermal history modify the occupant's thermal expectations and preferences [4]. In warm climate zones or during prolonged periods with warmer weather people supposedly prefer higher indoor temperatures than in cold climate zones or during prolonged periods of colder weather. This is in contrast with the assumptions underlying comfort standards based on the PMV/PPD-model [4,11]. Note that adaptation in this context is defined as the gradual lessening of the human response to repeated environmental stimulation, and can be behavioral, physiological, as well as psychological [4]. In practice, differences in the perception of the thermal environment were found among occupants of naturally ventilated (also referred to as free-running), fully air-conditioned and mixed mode (hybrid) buildings. According to Brager and de Dear [12], the PMV-model is not applicable to naturally ventilated buildings, because it only partly accounts for thermal adaptation to the indoor environment. Therefore, a model of adaptive thermal comfort has been proposed for free-running buildings; a model that relates the neutral temperature (comfort temperature) indoors to the temperature outdoors [12,13]. This alternative or complementary model is the fundament of the adaptive comfort requirements in, for instance, ASHRAE standard 55 [14], Annex A2 of EN 15251 [15] or the CIBSE TM 51 guideline [16].

One of the challenges when redesigning the ISSO 74 guideline was to combine, whenever possible and appropriate, the non-adaptive and the adaptive approaches as described above.

3 Methods

In 2012 ISSO, the Dutch Building Services Research Institute, took the initiative to revise the first (2004) version of the ISSO 74 guideline. ISSO recruited an expert team to rewrite the existing standard (the authors of this article) and organised a supervisory commission. This commission consisted of representatives from the national government, stakeholders in the construction and HVAC industry and of indoor climate specialist from research institutes and universities.

Beforehand the authors were told that the new thermal comfort guideline had to differ in several ways from the original guideline:

- The new guideline had to be better tuned in with the adaptive thermal comfort approach as described in Annex A2 of EN 15251; this implied that the new requirements had to be based on the SCATs database (in analogy with the requirements in Annex A2 of EN 15251) instead of on the RP 884 database (as was the original version of ISSO 74);
- The new ISSO 74 was supposed to also give guidance for optimal temperatures outside the cooling season (during the heating season);

- The new ISSO 74 - whenever possible and appropriate - had to integrate and combine adaptive and non-adaptive requirements; which should make the new guideline truly hybrid;
- Ideally the new guideline also had to take into account the beneficiary effects of personal control.

The expert team started with a review of the international (adaptive) thermal comfort literature. Also several innovative thermal comfort standards from abroad were analysed, including:

- the American ASHRAE standard 55 [14];
- the European EN 15251 standard (in particular, Annex A2) [15];
- the British CIBSE TM 52 guideline [16];
- the Swiss SN 180 guideline [17];
- the Chinese GB/T 50785 standard [18].

The new requirements and the new proposals for verification procedures were developed during interactive meetings / workshops with the stakeholders in the supervisory commission. And several draft versions of the new ISSO 74 guideline were commented upon by the different stakeholders in the supervisory commission.

4 The revised guideline

In this paragraph we describe the revised version of the ISSO 74 guideline.

In order to find out which limits one has to use for the operative temperature in a specific building one has to determine two aspects:

1. whether one deals with a type α or a type β situation (room, building), and:
2. what classification level should be used (class A, B, C or D).

One should use the decision scheme presented in Figure 1 in order to find out whether the α or β requirements should be used. In the context of the revised guideline, α refers to free-running situations in summer with operable windows and other adaptive opportunities for the occupants, whereas β refers to summer situations that primarily rely on centrally-controlled cooling.

Note: In Figure 1 an early exit option is described entitled 'Temperature limit correction for unusual clo/met value'. This will not be explained in detail, but in order to get a first indication on what kind of temperature correction to use given unusual high metabolism or clothing values, please refer to Olesen [23].

The temperature requirements themselves are presented in the Figures 2 to 5. In order to know which schemes to use one first has to decide which classification level is applicable given the situation. In order to determine this, one should use the data presented in Table 1.

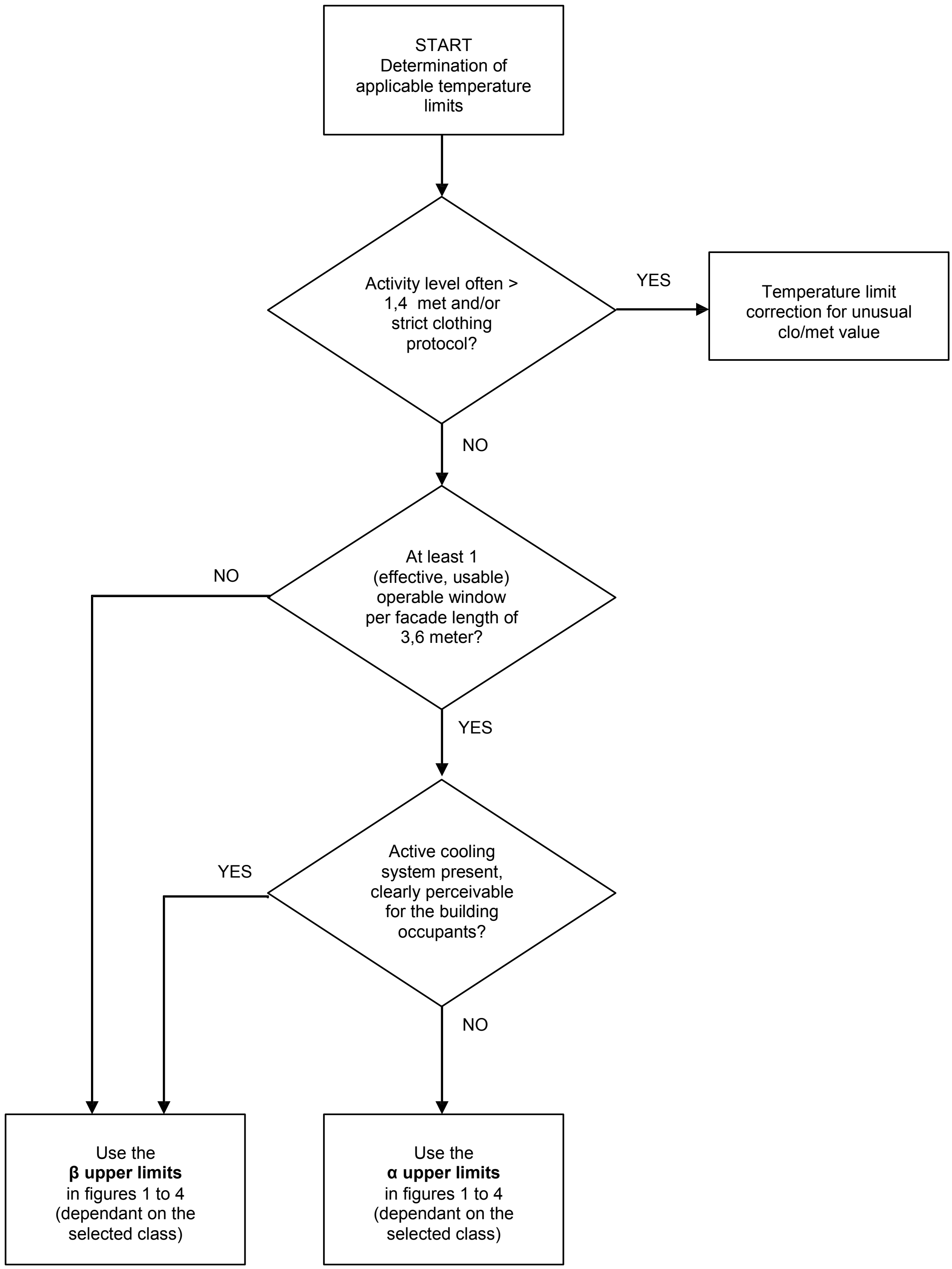

Figure 1. Decision scheme from ISSO 74:2014 that describes how one can determine whether the α or the β upper limits should be used

Table 1. Description of the 4 classification levels

Class (bandwidth)	Explanation	Percentage Dissatisfied	PMV analogy (bandwidth)
A	High level of expectation. Select this category as reference when designing spaces for people with limited load capacity (for instance, extra sensitive people) or when extra luxury is asked for.	max. 5%	-
B	Normal level of expectation. Select this category as reference when designing or measuring new buildings or in the case of substantial renovations	max. 10%	-0.5 < PMV < +0.5
C	Moderate level of expectation. Select this category as reference in the case of limited renovations or when measuring older existing buildings	max. 15%	-0.7 < PMV < +0.7
D	Limited level of expectation. Select this category as reference in the case of temporarily buildings or limited use (for instance, 1 to 2 hours of occupation per day)	max. 25%	-1.0 < PMV < +1.0

As far as the details of the figures are concerned:

On the x-axis we find the running mean outdoor temperature Θ_{rm}. In accordance to EN 15251 [15], this unit is defined as the exponentially weighted running mean of the daily mean external air temperature Θ_{ed} and is calculated with the following equation:

$$\Theta_{rm} = (1- 0,8).\{\Theta_{ed\,-1} + (0,8).\ \Theta_{ed\,-2} + (0,8)^2\ \Theta_{ed\,-3} + ...\}$$

This equation can be simplified to:

$$\Theta_{rm} = (1- 0,8).\Theta_{ed\,-1} + 0,8.\ \Theta_{rm-1}$$

Where:

Θ_{rm} = Running mean temperature for today;

Θ_{rm-1} = Running mean temperature for previous day;

Θ_{ed-1} is the daily mean external temperature for the previous day;

Θ_{ed-2} is the daily mean external temperature for the day before and so on.

The following approximate equation (with a 7 day 'horizon') can be used whenever records of daily mean outdoor temperature are not available:

$$\Theta_{rm}= 0,253.\{\Theta_{ed\,-1}+0,8.\Theta_{ed\,-2} +(0,8)^2.\Theta_{ed\,-3}+(0,8)^3.\Theta_{ed\,-4} +(0,8)^4.\Theta_{ed\,-5} +(0,8)^5.\Theta_{ed\,-6} +(0,8)^6.\Theta_{ed\,-7}\}$$

On the y-axis of the figures we refer to the operative temperature indoors (not the air temperature). This implies that also radiant temperature effects are taken into account.

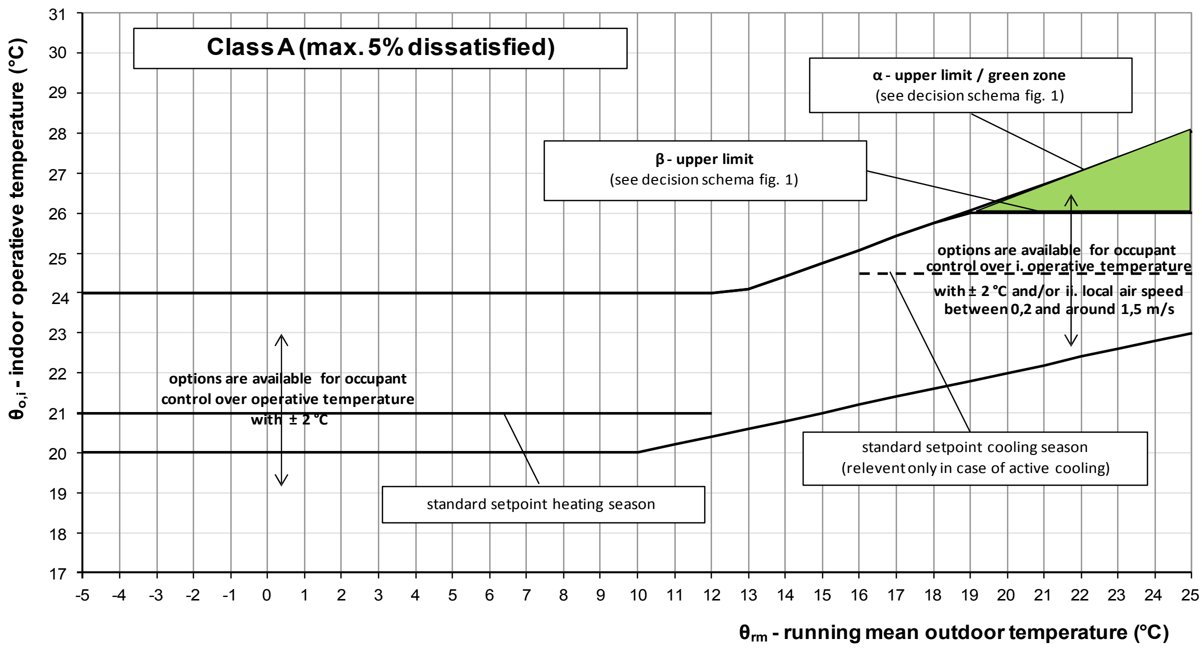

Figure 2. Class A requirements in ISSO 74:2014 for the operative temperature indoors in relation to the running mean outdoor temperature

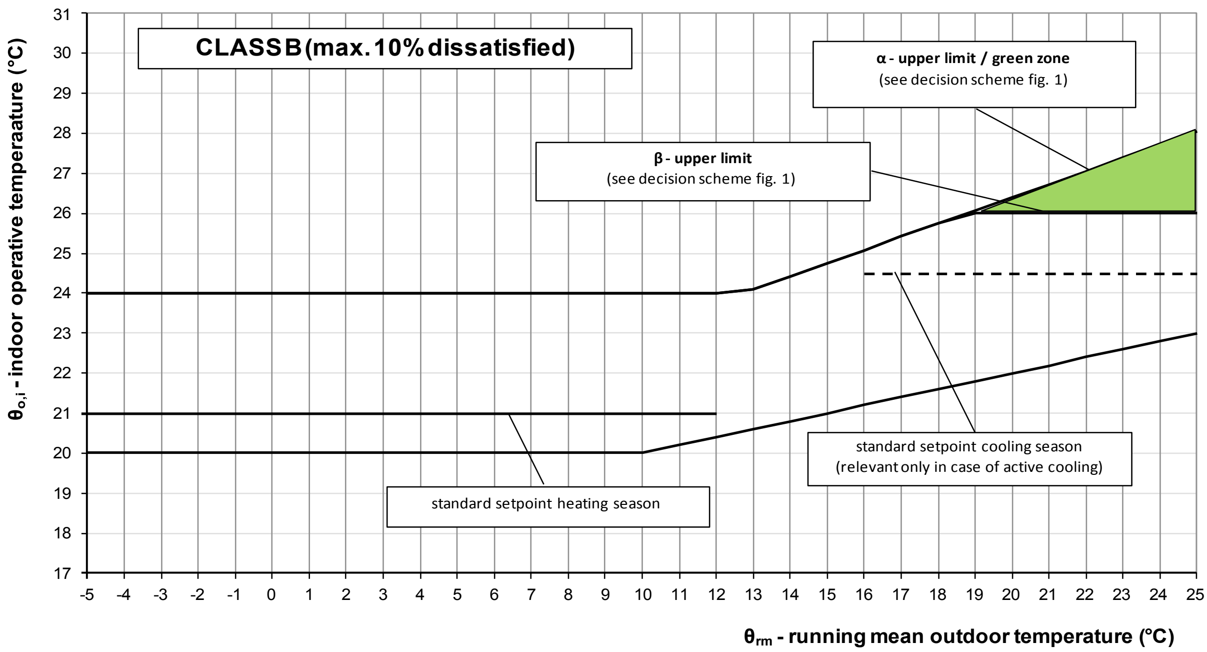

Figure 3. Class B requirements in ISSO 74:2014 for the operative temperature indoors in relation to the running mean outdoor temperature

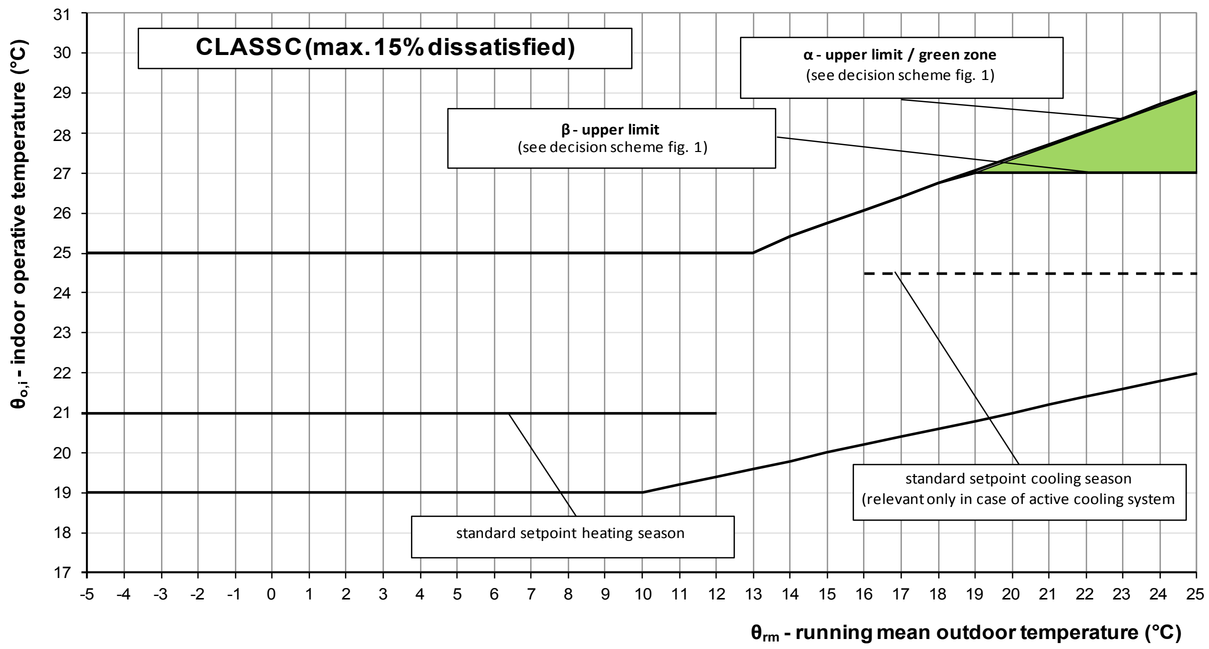

Figure 4. Class C requirements in ISSO 74:2014 for the operative temperature indoors in relation to the running mean outdoor temperature

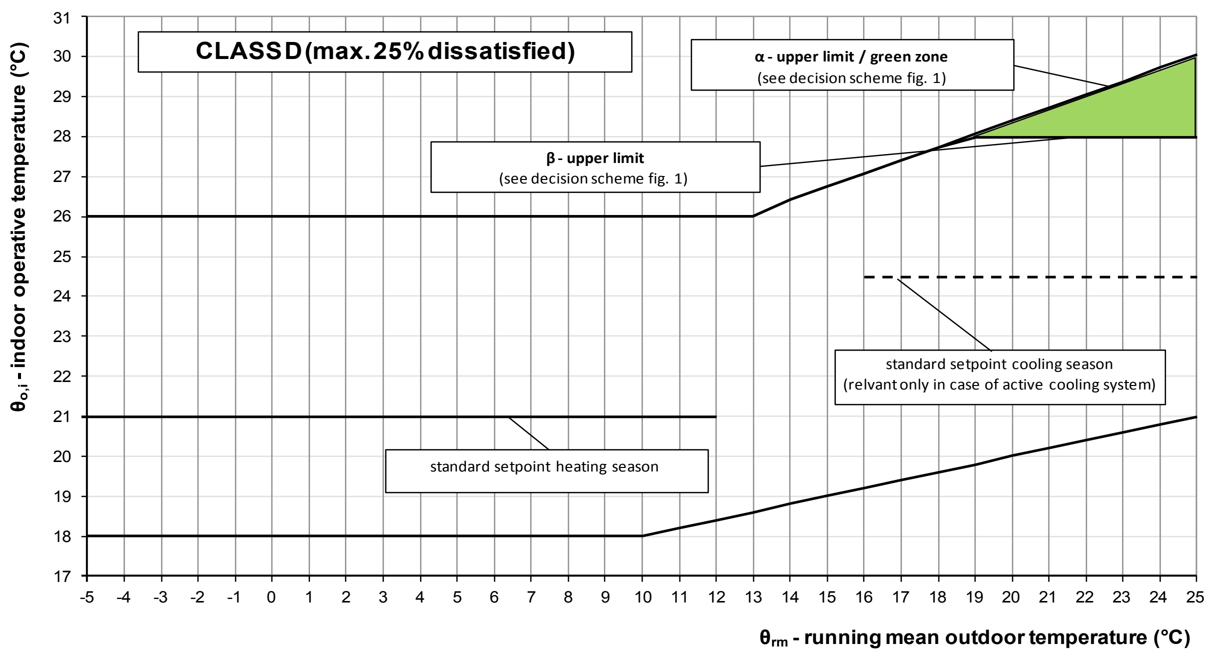

Figure 5. Class D requirements in ISSO 74:2014 for the operative temperature indoors in relation to the running mean outdoor temperature

5 Explanation and Discussion

The lines in the figures refer to the upper and lower limits for the operative temperature indoors. The operative temperature is not allowed to go over the upper limits or under the lower limits, at least not during normal occupancy times. For a further explanation of the lines and for the equations behind the lines (Table 2).

Table 2. Equation behind the class A, B, C and D lines as presented in the Figures 2 to 5 (based upon [15,16,19,20])

		Requirements indoor operative temperature (°C)		
		Winter	**In-between-seasons**	**Summer**
General	Setpoint line	21		24.5
Class A (PD approx. 5%)	Upper limit	See class B (+ occupant control requirement, ± 2 K)		
	Lower limit	See class B (+ occupant control requirement, ± 2 K)		
Class B (PD approx. 10%)	Upper limit	24*	$18.8 + 0.33 \cdot \neg_{rm} + 1$**	type β spaces: 26* type α spaces: $18.8 + 0.33 \cdot \neg_{rm} + 1$
	Lower limit	20*	$20+0.2.(\neg_{rm}-10)$***	
Class C (PD approx. 15%)	Upper limit	25*	$18.8 + 0.33 \cdot \neg_{rm} + 2$**	type β spaces: 27* type α spaces: 18.8 + $0.33 \cdot \neg_{rm}+2$
	Lower limit	19*	$19+0.2.(\neg_{rm}-10)$***	
Class D (PD approx. 25%)	Upper limit	26****	$18.8 + 0.33 \cdot \neg_{rm} + 3$**	type β spaces: 28**** type α spaces: 18.8 + $0.33 \cdot \neg_{rm}+3$
	Lower limit	18****	$18+0.2.(\neg_{rm}-10)$***	

* *based upon the standard class B and C winter limits mentioned in EN-ISO 7730*
** *based upon the SCATs database comfort temperature equation [15] and the P-equations presented in [16] and [19]*
*** *lower limits summer are derived by extrapolation; with starting point x = $\neg_{rm}$ of 10 °C and y = lower limit winter [20] (different for each class) and end point x = $\neg_{rm}$ of 25 °C (maximum value x-axis given the Dutch outdoor climate) and y = lower limit summer [20] (also different for each class)*
**** *new (non-adaptive) limit values for the new class D, in line with the limits mentioned in [18]*

Note that the class C and D upper limits of Table 2 for the in-between-seasons (type α and type β spaces) and the summer season (type α spaces only) as mentioned in Table 2 are the same as (for Class C) the adaptive category I and (for class D) the category II upper limit lines presented in Annex A2 of EN 15251. Please note that the class A requirements are the same as those used for class B. A special workshop with the supervisory commission revealed that it does not make much sense within the Dutch context (see also [22]) to use stricter requirements than the class B ones (referring to a -0.5 < PMV < +0.5 bandwidth or a PPD=10% situation) mentioned in EN-ISO 7730. The group decided not to copy the relatively strict class A (-0.2 < PMV < +0.2 / PPD=6%) requirements from EN-ISO 773O, but, instead, to define the highest quality level, in analogy with the approach of FiSIAQ [21] in terms of options for occupant control.

If a building and its HVAC system is designed and operated in such a way that the operative temperature normally stays between the class B limits as mentioned in Table 2: it is a class B building. If the building and its HVAC system is designed and operated in such a way that the operative temperature normally stays between these limits and occupants (at room level or workstation level) can control local temperatures with ± 2 K (both in summer and winter; round the set-points mentioned in Table 2 - see also the dotted lines in Figures 2 to 5) than a building is regarded as a class A buildings. In some cases only occupant control over room temperature during the winter will be provided for (think of adjustable thermostats on radiators). In that case we speak of class B+ buildings.

The positions of the diagonal upper limits for the in-between-seasons and the summer season (type α spaces only) were determined with the P-equation as presented in the CIBSE TM 52 guideline [16]:

The likelihood of discomfort from heat (generally accepted as ASHRAE vote = +2 or +3) has been derived from a logistic regression analysis based on comfort surveys in European office buildings (Nicol and Humphreys, 2007). It gives the proportion P of subjects voting 'warm' or 'hot' on the ASHRAE comfort scale (the accepted definition of discomfort from heat) as (see Figure 9):

$$P = \frac{e^{(0.4734\, \Delta T_{\text{diff}} - 2.607)}}{1 + e^{(0.4734\, \Delta T_{\text{diff}} - 2.607)}} \tag{7}$$

(Screendump from CIBSE guideline TM 52)

With this P-equation (and the percentage of dissatisfied requirements for the different classes mentioned in row 3 of Table 1 in mind) one can determine the following:

- As long as the operative temperature indoors is not more than 1 K higher than the (outdoor temperature dependant) comfort temperature (as defined by [19] and as mentioned in Annex A2 of EN 15251 [15]), the percentage of people that is dissatisfied (that feels warm or hot and scores +2 or +3 on the 7-point ASHRAE scale of thermal sensation) is not higher than about 10% (rounded off from 10.59%);
- As long as the operative temperature indoors does not exceed the comfort temperature by more than 2 K, the percentage of people that is dissatisfied (that scores +2 or +3) is not higher than about 15% (rounded off from 15.97%);
- As long as the operative temperature indoors is not more than 3 K higher than the comfort temperature, the percentage of people that is dissatisfied (that scores +2 or +3) is not higher than about 25% (rounded off from 23.38%).

It is this P-equation that allows us to make a connection between the non-adaptive and the adaptive requirements as used in respectively EN-ISO 7730 and EN 15251. With as end result the hybrid reference limits as presented in the figures 2 till 5.

One might argue in this context that the theoretical or Predicted Percentage of Dissatisfied (PPD) as determined in lab experiments (the rationale behind the non- adaptive EN-ISO 7730 limits) is not the same as the Actual Percentage of Dissatisfied (APD) as determined during field explorations (the rationale behind the adaptive EN 15251 limits and the P-equation presented in CIBSE TM 52). Especially because of the disturbing, additional effect of local thermal discomfort (such as, draft) that normally is not corrected for when translating PDs as found in lab situations to PD’s in real live situations. We decided that in this case it is not a problem to assume that PPD and APD are the same as the main issue here is overheating / thermal discomfort in summer and normally than draft and other local discomfort is less of an issue.

6 Verification guidance

The new ISSO 74 guideline also describes how one can verify in practice whether a building’s thermal performance is as planned, in the design phase or during the use phase. Both in the context of regular projects and design & built (PPP/ DBFMO) projects.

It is beyond the scope of this article to describe the details of the verification chapter. We limit ourselves by just describing how simulation and long term measurements results can be presented according to the new ISSO 74. Figure 6 provides an ‘output example’.

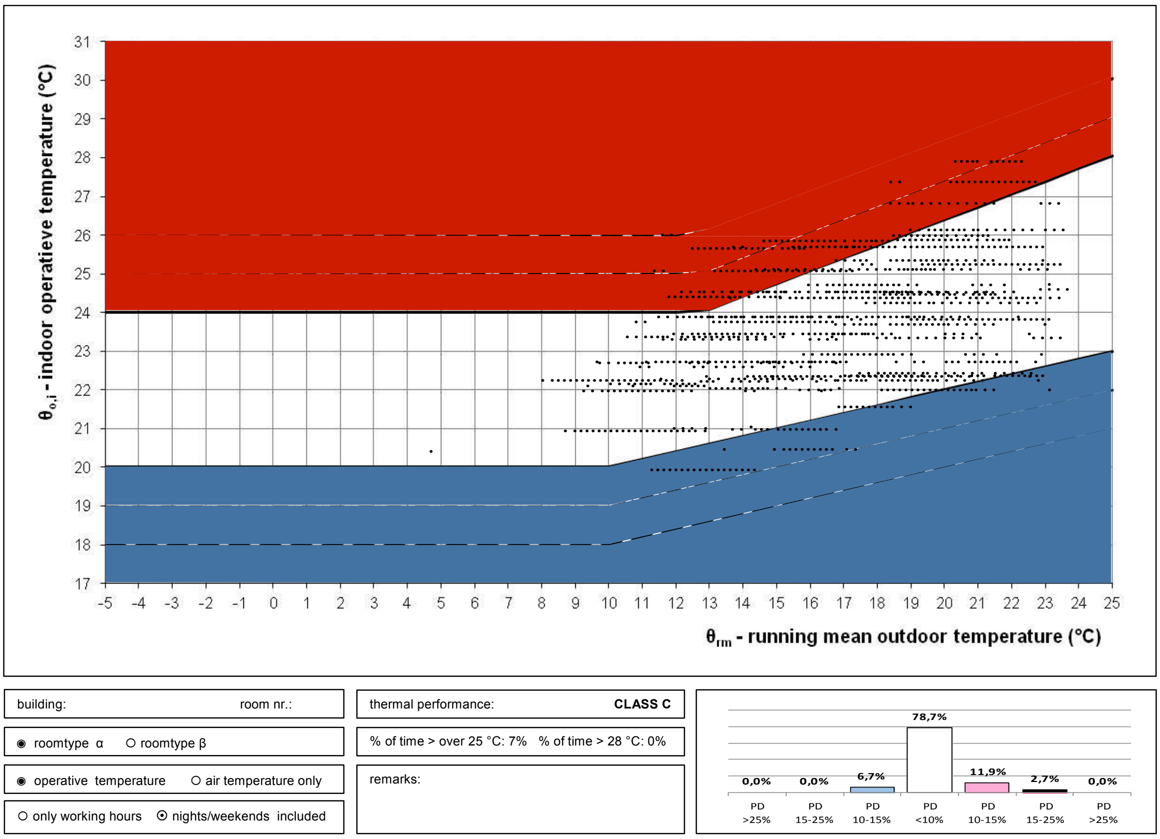

Figure 6. The ISSO 74: 2014 format for the presentation of simulation or measurement results (colors refer to anticipated average thermal sensation at different rmot - indoor temperature combinations)

Note that this graph was specifically designed so also non-technical stakeholders (decision makers) can easily understand whether a building is performing as planned (and for instance, not too warm in summer).

For more background information on the new standard and the verification chapter (all in Dutch) see [24].

7 Conclusion

The upgrade version of the ISSO 74 adaptive thermal comfort guideline differs in several way from the 2004 version:

- The new guideline generally better tunes in with the adaptive thermal comfort approach as described in Annex A2 of EN 15251; the new requirements are based on data of the SCATs database instead of on the RP 884 database;
- The guideline also gives guidance for optimal temperatures during the heating season;
- The guideline works with extra class D / category IV criteria; and it introduces a new approach for class A / category I situations (taking into account the beneficiary effects of personal control);
- The guideline integrates adaptive and non-adaptive requirements (with graphs that combine both horizontal 'Fanger upper limits' with diagonal 'Humphreys limits'). This is why the new guideline was named 'hybrid'.

So far, the new (draft version of the) guideline has been tested only for a few projects. But the first signs are promising. The 2014 version of ISSO 74 appears to be much easier to apply in practice (especially due to the new verification chapter). Therefore, we expect that the new version of the guideline will help convince professional parties involved in building and HVAC system design to more often for adaptive (hybrid) thermal comfort.

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