Allowing for thermal comfort in free-running buildings in the new European Standard EN15251

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ABSTRACT
This paper describes some of the thinking behind the thermal comfort provisions of the new European Standard EN15251 (CEN: 2007) which deals with all aspects on the indoor environment. The paper will present the evidence on which its provisions are based (focusing on thermal comfort) and the advantages they present for those concerned to design buildings which use the minimum of energy.

KEYWORDS

EN15251, thermal comfort, Standards, KeepCool, ECOS

THE ADAPTIVE APPROACH TO THERMAL COMFORT

The thermal sensation of subjects is found in surveys where people are asked to reply to the question: how do you feel? They can choose as a reply one of the descriptors on the ASHRAE or the Bedford scale (Table 1). These surveys can be conducted in real buildings (known as a field-studies) or in a controlled room in a laboratory (climate chamber) where the conditions are closely control and people are subject often in stationary thermal conditions for up to 3 hours. This 'comfort vote' of the subjects is used to determine what temperature or combination of conditions they find most comfortable (the comfort temperature).

Table 1: Descriptors for the ASHRAE and Bedford scale of thermal sensation

ASHRAE descriptor	Numerical equivalent	Bedford descriptor
Hot	3	Much too hot
Warm	2	Too hot
Slightly warm	1	Comfortably warm
Neutral	0	Comfortable
Slightly cool	−1	Comfortably cool
Cool	−2	Too cool
Cold	−3	Much too cool

Although, the two scales are semantically different, especially in the implication of preference in the Bedford scale, experience has shown that subjects use the two scales in a very similar way.

The Adaptive Approach to thermal comfort (Humphreys and Nicol 1998) has been developed from field-studies of people in daily life. While lacking the rigour of laboratory experiments, field studies have a more immediate relevance to ordinary living and working conditions (deDear 1998, Humphreys, 1975, Auliciems, 1981). The adaptive method is a behavioural approach, and rests on the observation that people in daily life are not passive in relation to their environment, but tend to make themselves comfortable, by making adjustments (adaptations) to their clothing, activity and posture, as well as to their thermal environment.

Over time people tend to become well-adapted to thermal environments they are used to, and to find them comfortable. Adaptation is assisted by the provision of control over the thermal environment to give people the opportunity to adapt. This 'adaptive opportunity' (Baker and Standeven 1996) may be provided, for instance, by fans or openable windows in summertime or by temperature controls in winter. Dress codes will also have consequences for thermal design, for services provision, and consequently for energy consumption. A control band of ±2 K should be sufficient to accommodate the great majority of people (Nicol and Humphreys 2007). These customary temperatures (the 'comfort temperatures') are not fixed, but are subject to gradual drift in response to changes in both outdoor and indoor temperature, and are modified by climate and social custom. Field research can indicate the extent and rapidity of adaptation, and hence of the temperature drifts that are acceptable. During any working day it is desirable that the temperature during occupied hours in any day should vary little from the customary temperature. Temperature drifts much more than ±2 K in any day would be likely to attract attention and might cause discomfort.

Clothing and other adjustments in response to day-on-day changes in temperature will occur when a building is responding to weather and seasonal changes. These will occur quite gradually (Humphreys 1979, Nicol and Raja 1996, Morgan et al 2002), and can take a week or so to complete. So it is desirable that the day-to-day

change in mean indoor Operative temperature during occupied hours should not occur too quickly for the adaptive processes to keep pace.
During the summer months many buildings in Europe are free-running (i.e. not heated or cooled). The temperatures in such buildings will change according to the weather outdoors, as will the clothing of the occupants. Even in air-conditioned buildings the clothing has been found to change according to the weather (deDear and Brager 2002). As a result the temperature people find comfortable indoors also changes with the weather (Humphreys 1981). Thus the temperature people find comfortable can vary quite considerably depending on the climate, but any change should occur sufficiently slowly to give building occupants time to adapt.

COMFORT IN BUILDINGS

In buildings which are in free-running (FR) mode indoor conditions will follow those outdoors but will be modified to a greater or lesser extent by the physical characteristics of the building and the use which building occupants make of the controls (windows, shading devices, fans etc) which are available to them. In a successful building these actions, together with the changes which the occupants make to their own requirements – mainly through clothing changes – mean that occupants are able to remain comfortable most of the time. The function of a standard is to define the indoor conditions which occupants will find acceptable for any given outdoor condition.
Humphreys (1979) showed that the temperature which occupants of FR buildings find comfortable (Bedford scale) or neutral (ASHRAE scale) is linearly related to the monthly mean of the outdoor temperature. Others researchers have since found similar results (e.g. deDear and Brager 2002). The SCATS survey based in 5 European Countries has increased the accuracy and applicability of the model by showing that it was the running mean of the daily mean outdoor temperatures which correlated best with indoor comfort (McCartney and Nicol 2002) and that for European offices the linear relationship is:

$$T_c = 0.33T_{rm} + 18.8 \qquad (1)$$

Where T_c is the optimal indoor operative temperature for comfort and T_{rm} is the running mean of the daily mean outdoor temperature. Full definitions of the running mean temperature are given in McCartney and Nicol (2002) and in chapter 1 (section 1.6) of the CIBSE Guide A (2006). It should be mentioned that this relationship strictly applies to the subjects who took part in the SCATs surveys and the buildings they occupied, but it closely matches the relationship presented by deDear and Brager from their survey of buildings throughout the world and this suggests that it has general applicability.
In Figures 1 and 2 below we present for two climates and typical years the evolution of external air temperature and the internal operative comfort temperatures.
Adaptive Operative Comfort Temperature is calculated according to Eqn 1; Fanger Operative Comfort Temperature is calculated using the formulas presented in ISO 7730 and assuming the following values of the input variables:
thermal resistance of the clothing = 0.5 clo
metabolic rate = 1.4 met
air velocity = 0.15 m/s
relative humidity = 50%
This corresponds to general practice, where building planners have to make an assumption on those values adopting an average reasonable value for all the season, and hence obtaining a constant value for the Comfort Temperature.

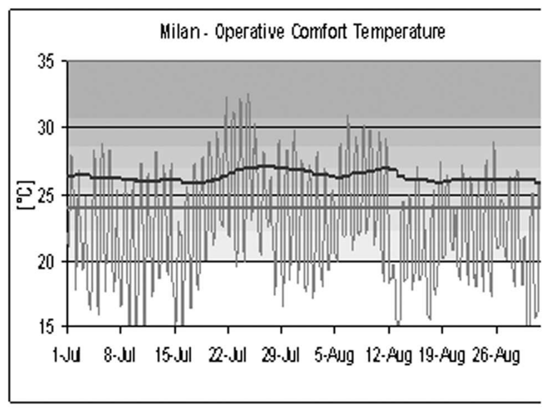

Figure 1: Adaptive Operative Comfort Temperature (in blue) and Fanger Operative Comfort Temperature (in red) for standard summer outdoor temperatures in Milan (in grey)

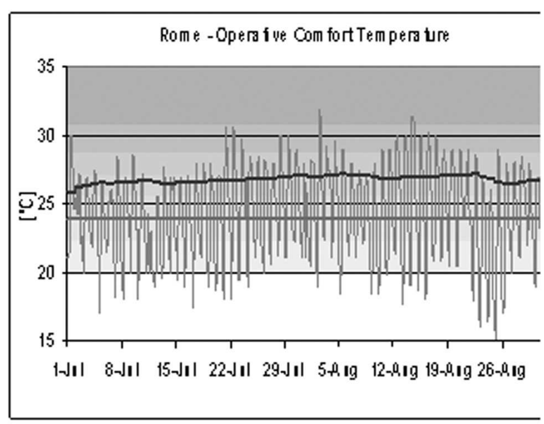

Figure 2: Adaptive Operative Comfort Temperature (in blue) and Fanger Operative Comfort Temperature (in red) for standard summer outdoor temperatures (in grey) in Rome

Having defined an optimal comfort temperature T_c, the question arises of how far the temperature of a space can deviate from T_c before discomfort will occur. Nicol and Humphreys (2007) have analysed the data from SCATs to show that 'the temperatures at which discomfort will not be unduly intrusive are up to ±2 K above or below the appropriate comfort temperature', which makes this a sensible limit for a comfort zone. Figure 3 is from CIBSE (2006) and includes the comfort zone for buildings that are heated or cooled (HC) as well as FR buildings.

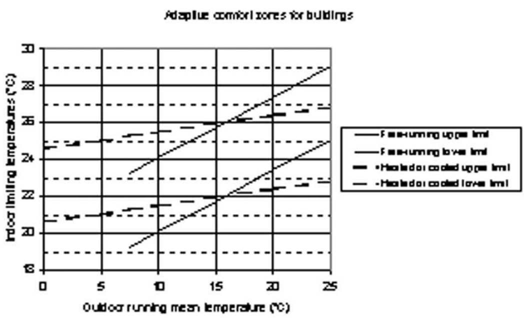

Figure 3: comfort zones for buildings in free running mode (continuous lines from equation 1 ± 2 K) and heated or cooled mode (dashed lines) from CIBSE (2006).

EN15251 AND TEMPERATURE LIMITS IN FREE RUNNING BUILDINGS

The preamble of the European Energy Performance of Buildings Directive (EPBD) states: "(...) the displaying of officially recommended indoor temperatures, together with the actual measured temperature, should discourage the misuse of heating, air-conditioning and ventilation systems. This should contribute to avoiding unnecessary use of energy and to safeguarding comfortable indoor climatic conditions (thermal comfort) in relation to the outside temperature." Ensuring that both energy savings and a good indoor environment are targeted is essential (Varga and Pagliano 2006). The European Standard EN15251 *Indoor environmental input parameters for design and assessment of energy performance of buildings- addressing indoor air quality, thermal environment, lighting and acoustics* seeks to define minimum standards for the internal environment in buildings to complement the EPBD. A major consideration of this norm is to ensure a correct definition of thermal comfort. The revision of the International Standard EN ISO 7730 made in 2005 acknowledges the importance of adaptation mechanisms: "In warm or cold environments, there can often be an influence due to adaptation. Apart from clothing, other forms of adaptation, such as body posture and decreased activity, which are difficult to quantify, can result in the acceptance of higher indoor temperatures. People used to working and living in warm climates can more easily accept and maintain a higher work performance in hot environments than those living in colder climates."

But it does not provide explicit guidance on how to treat differences in comfort conditions in naturally ventilated (NV) and mechanically cooled (AC) buildings. For this reason it is important that EN15251 embodies the latest thinking about comfort in the variable conditions of real NV buildings, allowing designers to take advantage of occupants' natural ability to adapt conditions to their liking. This not only optimises the interaction between occupants and the building to ensure comfort but also enables designers to maximise energy saving by allowing indoor conditions to track those out of doors. EN15251 makes a distinction between buildings which are HC and those which are FR. Thus NV buildings will be HC during the heating season and FR during the summer; AC buildings are HC throughout the year. In Standard EN15251, the comfort zone for HC buildings is defined in a similar way to in EN ISO 7730 (2006) but with differentiation of buildings in categories rather than classes. EN15251 recommends values of PMV comprised within the interval -0,5 to +0,5 for new buildings and renovations (category II) and within -0,7 to +0,7 for existing buildings (category III);

EN15251 uses the results of the SCATs survey to define the limits of temperatures in NV (or FR) buildings in the "summer" season, divided into categories defined as shown in table 1. The width of the acceptable zones allowed in each category is shown as a deviation from the value which is calculated from Eqn. 1. The applicability of the zones is assumed to be for values of T_{rm} between 10°C and 30°C.

EN15251 has also introduced (as ISO 7730) an allowance for air movement which can mean that the upper limit of acceptable temperature can be raised when substantial air movement is present such as might occur when a fan is in use.

EVALUATION OF THERMAL CONDITIONS FOR COMPLIANCE WITH EN15251

There are two methods suggested in the EN for evaluating the thermal comfort conditions during an entire season:

1. Percentage outside range: the proportion of the occupied hours during which the temperature lies outside the acceptable zone during the season.
2. Degree hours criterion: The time during which the actual operative temperature exceeds the specified range during occupied hours is weighted by a factor depending on the number of degrees by which the range has been exceeded.

Table 2: Suggested applicability of the categories and their associated acceptable temperature ranges.

Category	Explanation	Suggested acceptable range
I	High level of expectation only used for spaces occupied by very sensitive and fragile persons	± 2K
II	Normal expectation (for new buildings and renovations)	± 3K
III	A moderate expectation (used for existing buildings)	± 4K
IV	Values outside the criteria for the above categories (only acceptable for a limited periods)	

Acceptability of the space on the 'percentage' criterion is on the basis that the temperature in the rooms representing 95% of the occupied space is not more than 3% (or 5% - to be decided on national level) of the occupied hours a day, week, month or year, outside the limits of the specified category.
Subjective evaluation may also be used to evaluate existing buildings and methods, for assessing and reporting this are suggested.

CONCLUSIONS

The new European Standard EN 15251 has been framed to allow the natural variability of the indoor climate in free running buildings to be matched to the natural ability of people in well designed buildings with adequate occupant control, to change their room conditions to suit their needs. This will mean that buildings can be designed which are both comfortable and can make full use of passive, low energy cooling and heating technologies.

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