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NEW DEVELOPMENTS IN INTERNATIONAL STANDARDS FOR THE INDOOR THERMAL ENVIRONMENT

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ABSTRACT

Both on the international level ISO (International Standard Organisation), CEN (European Standard Organisation) and on the national level ASHRAE (American Society of Heating, Refrigerating and Air Conditioning Engineers) are new concepts for standards on the indoor thermal environment being proposed.

First of all recommendations for acceptable thermal environments will be specified as classes. This allows for national differences in the requirements and also allow for designing buildings for different quality levels. This will also require a better dialog between the client (builder, owner) and the designer. It is also being discussed how people may adapt to accept higher indoor temperatures during summer in natural ventilated (free running) buildings. A proposal for a whole year evaluation of the indoor thermal environment will also be included in a revision.

The standards will be based on requirements to the general thermal comfort (PMV, Operative temperature) and local thermal discomfort (radiant temperature asymmetry, draught, vertical air temperature differences, floor surface temperatures). One critical issue is the effect of air velocity. On one hand increased air velocity has a beneficial effect at warm temperatures, but on the other hand increased air velocity may result in draught sensation. Another issue is to what extend the requirements to humidity must be included in a standard for thermal comfort.

KEYWORDS: Thermal comfort, Standards, PMV, Adaption, Draught.

1. INTRODUCTION

The main purpose of most buildings and installed heating and air conditioning systems is to provide an environment that is acceptable and does not impair health and performance of the occupant. The knowledge on the thermal climate parameters, their influence on the occupants and the influence of buildings and systems on these parameters are to day relatively well known and established in international standards. To be able to evaluate thermal comfort criterias for the relevant thermal parameters must be known together with methods for prediction (design stage) or measurements at these parameters (commissioning and operation stage). Also during testing and development of new products there is a need for testing and evaluating the impact on thermal comfort.

The paper presents some of the criteria which are being proposed in existing international standards or standards in progress. Issues like air velocity, adaption, humidity and yearly performance are being discussed.

2. CRITERIA FOR THERMAL COMFORT

The environmental parameters which constitute the thermal environment are: Temperature (air, radiant, surface), humidity, air velocity and the personal parameters: clothing together with activity level..

Criteria for an acceptable thermal climate is specified as requirements to the general thermal comfort (PMV-PPD or operative temperature (air- and mean radiant temperature), air velocity, humidity) and to local thermal discomfort (draught (mean air velocity, turbulence intensity, air temperature) vertical air temperature differences, radiant temperature asymmetry, surface temperature of the floor). Such requirements can be found in standards and guidelines like EN ISO 7730 [1], CR 1752 [2] and ASHRAE 55-92 [3].

For most of the thermal parameters it has been possible to establish a relation between the parameter and a predicted percentage of people finding the conditions unacceptable. People may be dissatisfied due to the general thermal comfort (PMV, Operative temperature) and/or dissatisfied due to local thermal comfort parameters (draught, radiant asymmetry etc). To day there exist no method for combining these percentages of dissatisfied persons to give a good prediction of the total number of persons finding the environment unacceptable. The chosen level of thermal comfort may be influenced by what is technical possible, economy, energy use, environmental pollution and performance. Therefore it is suggested in the revision of ISO EN 7730 and ASHRAE-55 to specify different levels of acceptance like in CR 1752. Individual countries or a contract between client and designer can then specify which levels must be used. Table 1 gives recommended levels of acceptance for three classes of environment [3].

Table 1: Three categories of thermal environment. Percentage of dissatisfied due to general comfort and local discomfort (CR 1752 [3].)

Category	Thermal state of the body as a whole		Local Thermal Discomfort			
	PPD %	Predicted Mean Vote	Draught Rate, DR %	Vertical Air Temp. difference %	Warm or Cool Floor %	Radiant Temperature Asymmetry %
A	< 6	-0.2 < PMV < + 0.2	<15	< 3	< 10	< 5
B	< 10	-0.5 < PMV < + 0.5	<20	< 5	< 10	< 5
C	< 15	0.7 < PMV < + 0.7	<25	< 10	< 15	< 10

For the general thermal comfort (operative temperature) and air velocity the corresponding criteria for the three classes are listed in Table 2 for a couple of typical spaces. The optimal temperature is the same for all three classes but the acceptable range will change. For the design of heating systems and heat load calculations the lower value in the range should be used, and for cooling the upper value.

The criteria based on the three classes in Table 1 are in Table 3 listed for the other local discomfort parameters (radiant temperature asymmetry, vertical air temperature differences and floor surface temperatures.

Table 2: Criteria for operative temperature and mean air velocity for typical spaces.

Type of building/ space	Clothing Cooling season (summer) clo	season (winter) clo	Activity met	Category	Operative Cooling season (summer) °C	Temperature Heating season (winter) °C	Mean Air Velocity Cooling season (summer) m/s	Heating season (winter) m/s
Office	0,5	1,0	1,2	A	24.5 ± 0.5	22.0 ± 1.0	0,18	0,15
				B	24.5 ± 1.5	22.0 ± 2.0	0,22	0,18
				C	24.5 ± 2.5	22.0 ± 3.0	0,25	0,21
Cafeteria/ Restaurant	0,5	1,0	1,4	A	23.5 ± 1.0	20.0 ± 1.0	0,16	0,13
				B	23.5 ± 2.0	20.0 ± 2.5	0,20	0,16
				C	23.5 ± 2.5	20.0 ± 3.5	0,24	0,19
Department Store	0,5	1,0	1,6	A	23.0 ± 1.0	19.0 ± 1.5	0,16	0,13
				B	23.0 ± 2.0	19.0 ± 3.0	0,20	0,15
				C	23.0 ± 3.0	19.0 ± 4.0	0,23	0,18

Table 3. Recommended categories for local thermal discomfort parameters

Category	Vertical air temp. diff. K	Floor surface temperature °C	Radiant temperature asymmetry K			
			Warm ceiling	Cool ceiling	Cool wall	Warm wall
A	< 2	19 - 29	< 5	< 14	< 10	< 23
B	< 3	19 - 29	< 5	< 14	< 10	< 23
C	< 4	17 - 31	< 7	< 18	< 13	< 35

3. THERMAL COMFORT FACTORS

In the revisions of ISO EN 7730 and ASHRA-55-92 the influence and use of the following factors are being discussed in details.

3.1 Air velocity

The air velocity in a space can lead to draught sensation, but may also lead to improved comfort under warm conditions. The draught model, which are included both in ASHRAE Standard 55 and ISO EN 7730, is listed below:

$$DR=((34-ta)*(v-0.05)^{0.62})*(0.37*v*Tu+3.14)$$

where:

DR is the draught rating, i.e. the percentage of people dissatisfied due to draught;

t_a is the local air temperature in °C;

v is the local mean air velocity in m/s; and

Tu is the local turbulence intensity in per cent.

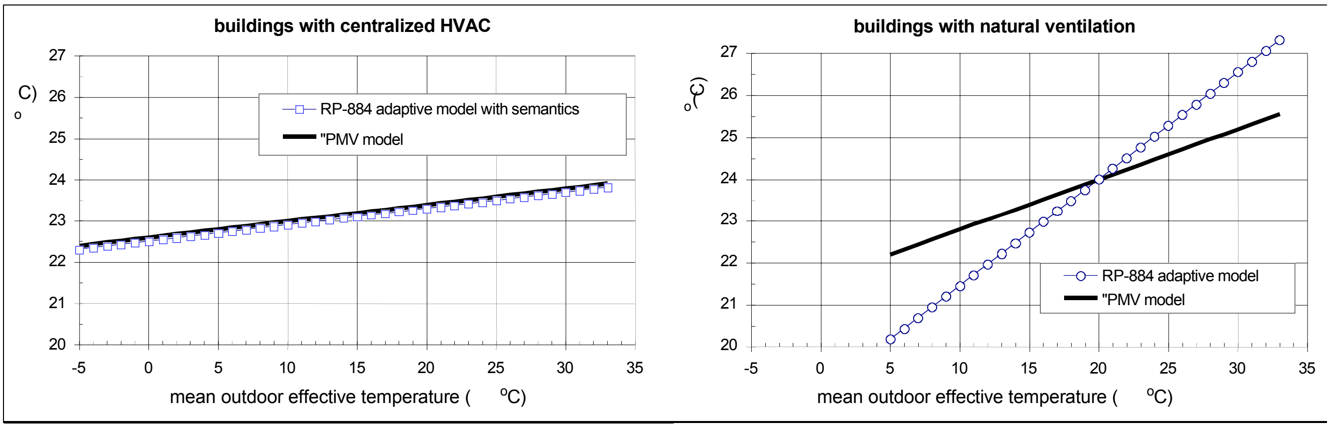
Recent studies by Griefhahn [4] indicate that this model must be modified to take into account length of exposure and activity level. Studies by Toftum et. al. ([5], [6],[7],[8])show additional influence of the velocity directions. The two studies do not agree completely with the above draught model. According to Griefhahn the models predict too low DR percentages while according to Toftum et. al. it predicts too high values.

The study by Toftum et. al. [8] has also verified the diagram in ASHRAE 55-92, where an elevated ambient temperature may be compensated by an increased air velocity if the occupant has individual control (ceiling fans, open windows).

3.2. Adaptation

Several extensive field studies summarised by DeDear and Brager [9] show that in buildings with HVAC systems the PMV-model works fine (Figure 1). The studies also show that in natural ventilated buildings (free running, no mechanical cooling) people seem to adapt (behavioural psychological) and can accept higher indoor temperatures than predicted by the PMV-model. Both in the revision of EN ISO 7730 and ASHRAE 55-92 it is being discussed how these results can be integrated in the standards.

Fig. 1. Comparison of the RP-884 adaptive models' predicted indoor comfort temperatures with those predicted by the PMV model.



3.3. Personal control

Only by personal control is it possible to compensate for individual difference in preference and then increase the level of acceptance. How this should be taken into account in existing standards and by design of HVAC systems are also being discussed. One way of personal control is change of clothing. Table 4 shows the effect of changing different garments.

3.4. Humidity

The influence of the humidity on the preferred ambient temperature is in the comfort range relatively small (EN ISO 7730, ASHRAE-55-92). In EN ISO 7730 a humidity range of 30 – 70 % RH is recommended, but mainly for indoor air quality reasons. In ASHRAE-55-92 the lower limit is a dew point temperature of 2 °C and the upper limit a 18 °C (winter) or 20 °C (summer) wet bulb temperature. Requirements for indoor acceptable indoor air quality (Berglund [11], Fang et. al. [12]) will, however, specify a more narrow range for the humidity. But should this be taken into account in a thermal comfort standard ?

Table 4: Thermal insulation for garments. and changes of optimum operative temperature necessary to maintain a thermal sensation at neutral when various pieces of garments are added (or removed) at light mainly sedentary activity (1,2 met), (ISO 9920, [10].

Garment Description	Thermal Insulation clo	Change of Operative Temp. K
Panties	0,03	0,2
T-shirt	0,09	0,6
Short sleeves shirt	0,15	0,9
Normal shirt, long sleeves	0,25	1,6
Shorts	0,06	0,4
Normal trousers	0,25	1,6
Light skirts (summer)	0.15	0,9
Heavy skirt (winter)	0,25	1,6
Thin sweater	0,20	1,3
Light, summer jacket	0,25	1,6
Normal jacket	0,35	2,2

4. LONG TERM EVALUATION OF THE GENERAL THERMAL COMFORT CONDITIONS

If criteria has to be met 100% of the time of occupancy also under extreme weather conditions the heating- and /or cooling capacity of any HVAC installation would be relatively high. Economical and/or environmental considerations lead to allow the thermal conditions for a limited time to exceed the recommended ranges.
By computer simulation, comfort conditions are often tested over longer periods of time, for different types of buildings and/or HVAC design. The need is here to give a number for the long term comfort conditions for comparison of designs. For these purposes the following method is recommended.
The time during which the actual PMV exceeds the comfort boundaries is weighed with a factor which is a function of the PPD. Starting from a PMV-distribution on a yearly bases and the relation between PMV and PPD the following is calculated:

Weighing factor $$wf = \frac{PPD_{actualPMV}}{PPD_{PMV\lim it}}$$

The weighing hours are totalized for a characteristic working period during one year.

Warm period: $\Sigma wf\ x\ time$ hours, where $PMV > PMV_{limit}$
Cold period: : $\Sigma wf\ x\ time$ hours, where $PMV < PMV_{limit}$

The summation of the product “weighing factor + time” is called “weighing time” in hours. The values may be used for the evaluation of long term comfort conditions. An acceptable weighing time like 100 t0 150 hours may be specified.

DISCUSSION AND CONCLUSION

Some important issues, when evaluating thermal comfort, is being discussed during the ongoing revision of standards.. Fulfilling the given criteria does not mean 100% acceptance. Due to individual differences it may be very difficult to satisfy everybody in a space.

Individual control of the thermal environment or individual adaptation (clothing, activity) will increase the level of acceptance.

The above criteria show some restrictive requirements to the air velocity due to the sensation of draught. In warm environments it may, however be beneficial for the total comfort to increase the air velocity above these levels. This effect is partly included in the use of the PMV-index. From existing studies on the effect of increased air velocity it is not clear if the level of acceptance is the same, when increasing the air velocity by warm temperatures or by decreasing the temperature level. It is however important that the increased air velocity is under individual control.
Field studies have shown that for heated and air conditioned buildings the use of the PMV-PPD index agrees with the results. But for "free running" buildings in warm climates, where you in the summertime must rely on natural ventilation by window openings or fans, there seems to be an additional adaptation, which cannot be explained alone by the adaptation of clothing. It may be due to partly adaptation of the activity, which is very difficult to measure in the field, and partly due to another level of expectations.
Another issue is if it should be allowed for some periods of time to have conditions outside the specified criteria or must the thermal environment 100% of the time be inside the given range? For each of the thermal comfort factors it may be possible from measurements or calculations to calculate a factor " %-dissatisfied x time" to take into account how long time and by how much the conditions deviates from the established comfort criteria. For such factor(s) additional criteria may be establish or the values should be given as a measure of environmental quality.

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