Optimal (Comfortable) Operative Temperature Estimation Based on Physiological Responses of the Human Organism

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Problems following the application of optimal operative temperatures estimated on the basis of PMV and the necessity to apply correct values in the new Czech Government Directive No. 523/2002 Code led to experiments based on the physiological human body response instead of solely people's feelings in a given environment. On the basis of experiments on 32 subjects (university students) it has been possible to estimate: a) the total balance of hygrothermal flows between the human body and the environment, b) the optimal operative temperature as a function of the subject's activity, c) the thermoregulatory range for each optimal operative temperature, i.e. maximal (category C_{max}) limited by the onset of sweating, minimal (category C_{min}) limited by the onset of shivering (category C can be applied to naturally ventilated buildings), optimal (comfort level – category A) defined by time constant 0.368 (can be applied to air conditioned buildings), and submaximum (decreased comfort level – category B) defined by time constant 0.632 (can be applied to buildings with basic air conditioning systems).

Keywords: thermal comfort, microenvironment, hygienic regulations, PMV problems, thermoregulatory ranges.

1 Introduction

The provision of optimal hygrothermal conditions, i.e. above all an optimal operative temperature (calm air and air temperature reaching radiant temperature) is the principal condition for healthy human life in the interior of a building. The optimal operative temperature has in the past been calculated from the PMV (Predicted Mean Value) (see e.g. EN ISO 7730 Moderate Thermal Environment) estimated on the basis of a positive reaction from 80% of the persons presents. The feelings of human beings are very subjective values, impacted by many other factors in addition to hygrothermal conditions, e.g. by indoor interior colors, a person's mood, etc. In addition, due to the way in which PMV is experimentally estimated and proved in other experimental works (see Fishman, Pimbert 1979, Newsham, Tiller 1995), it is approximately valid for the neutral zone only. The further away from the neutral zone the more the real values depart from the values calculated from PMV, see Fig. 1. What is more, the greater a person's activity, the bigger the difference. The application of high activity values is thus impossible in practice.

In Fig. 2 the mean thermal sensation vote is plotted against the operative temperature for a range of velocities. Each point represents the mean vote of thirty two subjects. The correlation between the operative temperature and the mean thermal sensation vote is high, with a correlation coefficient of 0.97 ($n = 5$). There is no significant difference between the sexes. The solid curve is the regression line for the individual vote ($n = 80$). For comparison, the dotted line represents

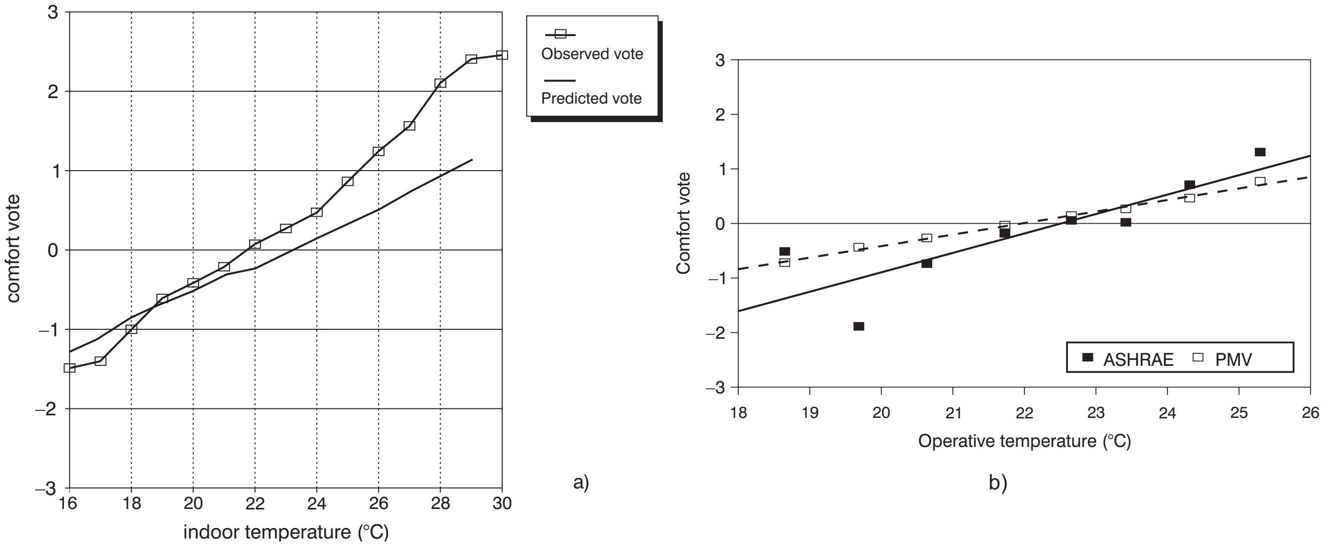

Fig. 1: a) Comparison of mean thermal comfort votes (ASHRAE scale) with predictions by the PMV model in an English office building (Fishman and Pimbert, 1979), activity 80 W·m^{-2}, clothing 0.64 up to 0.82 clo; b) Comparison of mean thermal comfort votes (ASHRAE scale) with predictions by the PMV model in a building (Newsham and Tiller, 1995), activity 70 W·m^{-2}, clothing 0.78±0.21 clo.

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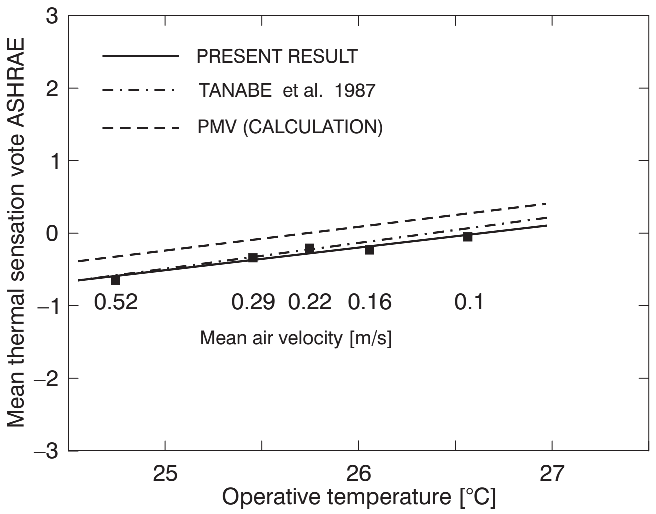

Fig. 2: Mean thermal sensation vote versus operative temperature for Japanese college-age subjects (Tanabe et al. 1987)

the results for 172 Japanese subjects in conditions of low air movement reported by Tanabe (1987), and the dashed line represents the calculated PMV values.

Further important results are drawn from research at Reading University (Croome et al.1993). These results take into account the opening and closing of doors, i.e. the ventilation rate, see Fig.3.

When the windows and the door were closed, the mean thermal sensation tended to be on the warm side of neutral. When the windows and doors were open, the votes were spread widely over the thermal sensation scale. However, the calculated PMV values corresponding to the tests were close to the neutral point for most of the test conditions. This suggests that, in this investigation, PMV underestimates the thermal impression for the case when the windows and doors are shut, and undervalues the change in thermal impression for the two cases.

This may be due to three main reasons. The first reason is the assumed steady state laboratory conditions used in the derivation of the PMV equation. The second is the oversimplified approach to the assessment of the metabolic rate of the occupant. The occupants rarely sat in the room for a long period, say one hour, without moving around. The third reason is the sensitivity of PMV to clo values (Croome et al. 1993). It can be concluded that the PMV equation overpredicts the neutral temperature by as much as 2 K and underpredicts the comfort requirement when air temperature deviates from neutrality.

Humphreys and Nicol (2000) have suggested that there may be formulaic errors in such a complex index as PMV, with two contributing factors:

1) *Steady state approximation*. PMV, like other indices of warmth, is a steady state heat exchange equation, and therefore its application to the office environment can only be an approximation. Recent research shows that among an office population the temperature of the fingers varies extensively and rapidly, indicating that the thermal state of the bodies of office workers is in continual flux (Humphreys et al. 1999). This suggests that it is better to regard the people a soon as being in dynamic thermal equilibrium rather than in a steady thermal state. By extension, the same is likely to be true of other and more varied pursuits. Thus, any index built on steady state assumptions is of limited relevance to normal living. Indices that exlude thermoregulation cannot therefore simulate real life conditions.

2) *Inaccurate numerical formulae for steady state*. Most indices have errors in the numerical values used in the equations, such as the convective and radiant heat transfer coefficients, skin temperature and sweat rates that are assumed in comfort conditions. These contribute to formulaic errors and additionally there are numerical errors attributable to conceptual simplifications. For example, although the calculation of PMV is based on calculated skin temperature and sweat rate but when considering external conditions to be neutral, PMV is based solely on a hypothetical heat load. This results in the same body thermal states being attributed different PMV values in different environments (Humphreys and Nicol 1996). Conceptual and numerical approximations add to the formulaic error. And, no thermoregulatory ranges can be estimated, from the PMV system.

For these reasons we decided to estimate the optimal operative temperatures on the basis of the physiological response of the human organism.

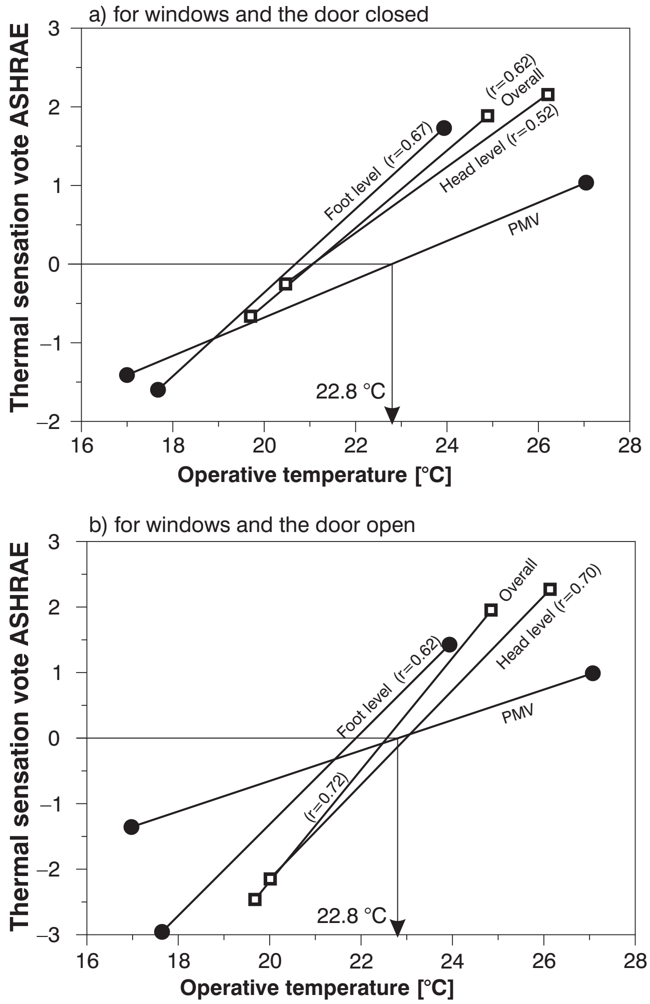

Fig. 3: Effect of operative temperature on thermal sensation vote, activity 1.2 met, clo value results from neutral temperature 22.8 °C, rh = 40–55 %, mean radiant temperature equals air temperature (Croome et al. 1993)

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2 Mathematical model of the physiological body response

The total heat rate production and its distribution into individual components during heat exchange between the human body and the environment are shown in Fig. 4, where $q_m = M - W$ = metabolic heat (see Jokl 1989). q_{res} and $q_{ev,d}$ are the components of the heat rate from the organism due to respiration and due to skin moistening (evaporation), when the human body is in the thermal neutral zone. The heat flow q_{dry} represents the component transferred from the organism through the clothing layer with total thermal resistance $R_{t,\,wa}(q_{dry} = q_c + q_r)$. The regulatory process within the neutral zone is achieved mainly by vasodilation and vasoconstriction changing the body's internal resistance into thermoregulatory and adaptational heat flux q_{tr} and q_a to the skin surface. q_{tr} and q_a is the heat flux regulating the instantaneous value of the skin temperature during the subject's interaction with the environment, q_{tr} is the organism's immediate response to changes in the microclimate or metabolic heat changes; q_a is the reaction shift due to adaptation to heat in summer and cold in winter. $q_{tr}+q_a$ may be negative (heat loss) or positive (heat gain). It is the transient heat flow – even in the thermal neutral zone – that is called "quasi-stationary", to be distinct from the hyperthermia and hypothermia zone.

$q_{tr}+q_a$ represents the rates of heat storage or heat debt accumulation. When the body is in a steady-state thermal balance with the environment, these therms are equal to zero. However we can consider the state of the subject in the neutral zone by non-steady-state conditions due to periodical changes of the metabolic heat rate, q_m, or short thermal excitations in time followed by changes in the internal thermal resistance of the body within the neutral zone.

The temporary characteristics of each non-steady process are determined, in addition to the thermal resistances $R_{t,i}$ and $R_{t,wa}$, by the human body heat capacity, C_t. The values characterizing the heat exchange are: T_{sk}, T_{core} and T_g. The internal thermal resistance, $R_{t,i}$,also determines the changes in thermoregulation and the adaptational heat, $q_{tr}+q_a$, which is necessary for maintaining the skin temperature within physiological values if the core temperature is to remain constant ($T_{core} = 36.7 \pm 0.4$ °C).

The heat flow balance, as presented in the model shown in Fig. 4, can be expressed by a thermal flux equation at the subject-environment boundary. Thus (if heat conduction is neglected):

$$q_{dry} = \frac{1}{R_{t,wa}}(T_g - T_{sk}) = q_m - q_{res} - q_{ev} + q_{tr} + q_a = q_i - q_{sw} \;\; [\mathrm{W \cdot m^{-2}}] \tag{1}$$

where $q_{ev} = q_{ev,ins} + q_{ev,sens} = q_{ev,ins} + q_{sw}$ [W · m^{-2}],
$q_m - q_{res} - q_{ev,ins} = q_i$ [W · m^{-2}],
$q_{sw} = 0.6(q_m - 58.14)$ [W · m^{-2}],

= the quantity of excreted perceptible but mostly invisible sweat. This was estimated by weighing during the experiments as a mean value for the whole range.

Heat flux within the human body can be represented as (see model in Fig. 4):

$$q_m - q_{res} + q_{tr} + q_a = G_{t,ti}(T_i - T_{sk}) = \frac{1}{R_{t,ti}}(T_i - T_{sk}) \;\; [\mathrm{W \cdot m^{-2}}] \tag{2}$$

where $G_{t,ti}$ is total body thermal conductance, which can be expressed by Eq. (3):

$$G_{t,ti} = \frac{q_m - q_{res}}{T_i - T_{sk}} + \frac{q_{tr} + q_a}{T_i - T_{sk}} = G_{t,m} + G_{t,i} \;\; [\mathrm{W \cdot m^{-2} \cdot K^{-1}}] \tag{3}$$

where $G_{t,i}$ is internal thermal conductance and $G_{t,m}$ is metabolic thermal conductance.

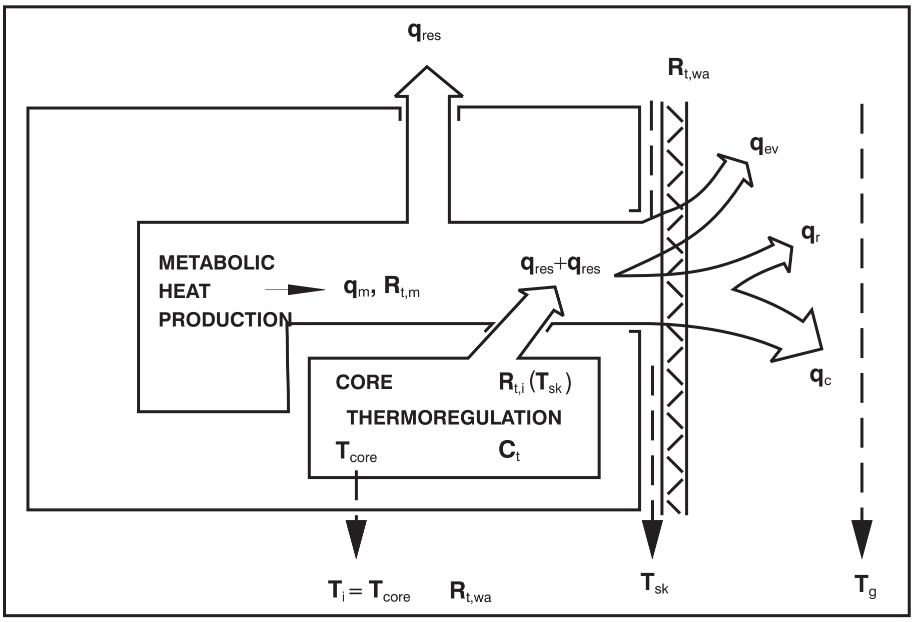

Fig. 4: Total heat rate production and its distribution in individual components during heat exchange between the human body and the environment (q_m metabolic heat, q_{res} respiration heat, q_{tr} thermoregulatory heat, q_e evaporative heat, q_c convective heat, q_r radiant heat, $R_{t,wa}$ total thermal resistance of clothing, R_t total internal thermal body resistance, C_t thermal body capacity, T_i deep body temperature, T_{core} core body temperature, T_{sk} skin temperature, T_g globe temperature

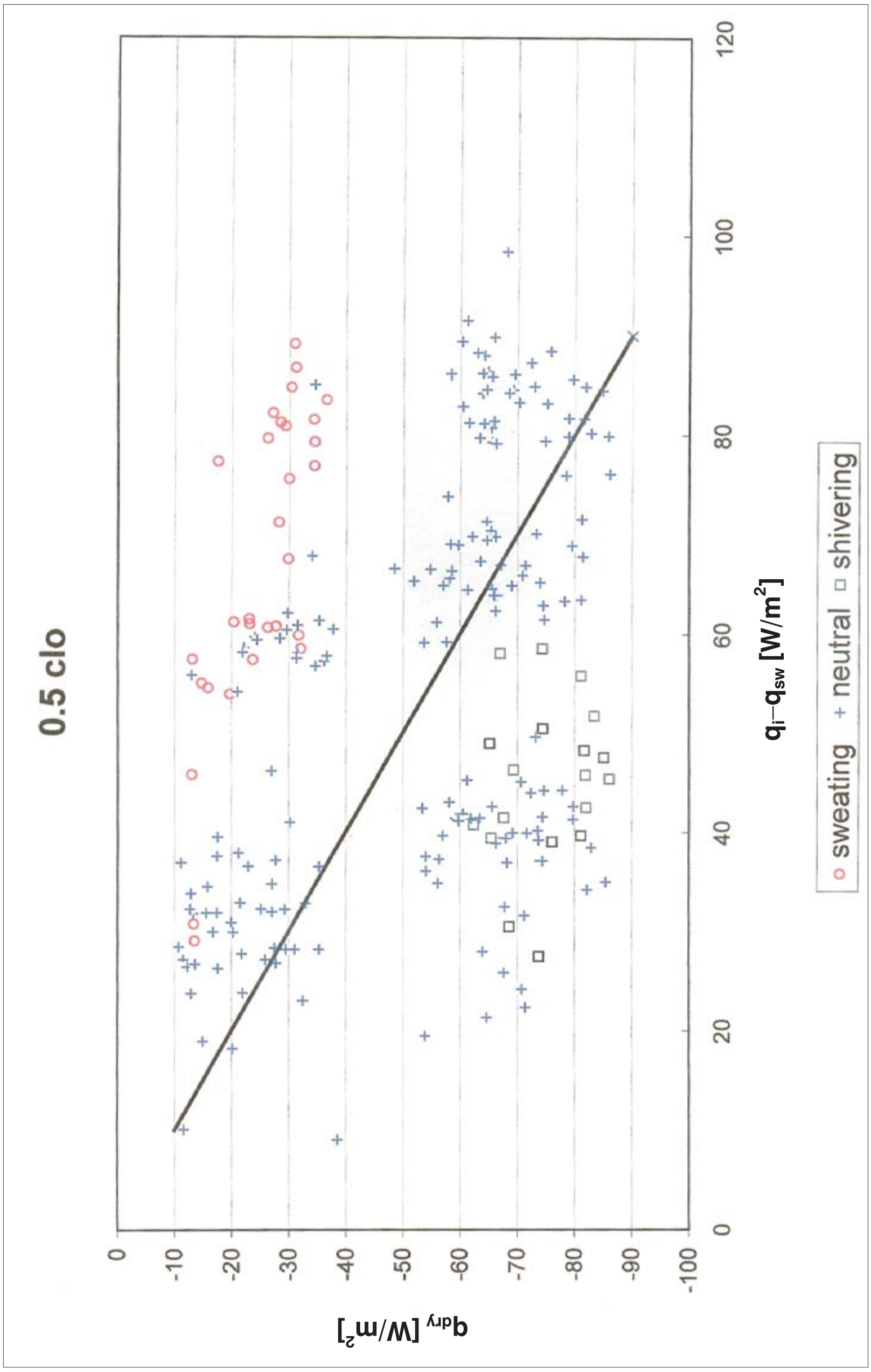

Fig. 5: Graph of the relationship $q_{dry} = f(q_i - q_{sw})$ for clothing 0.5 clo, points from experiment, optimal values are on the line $q_{dry} = q_i - q_{sw}$

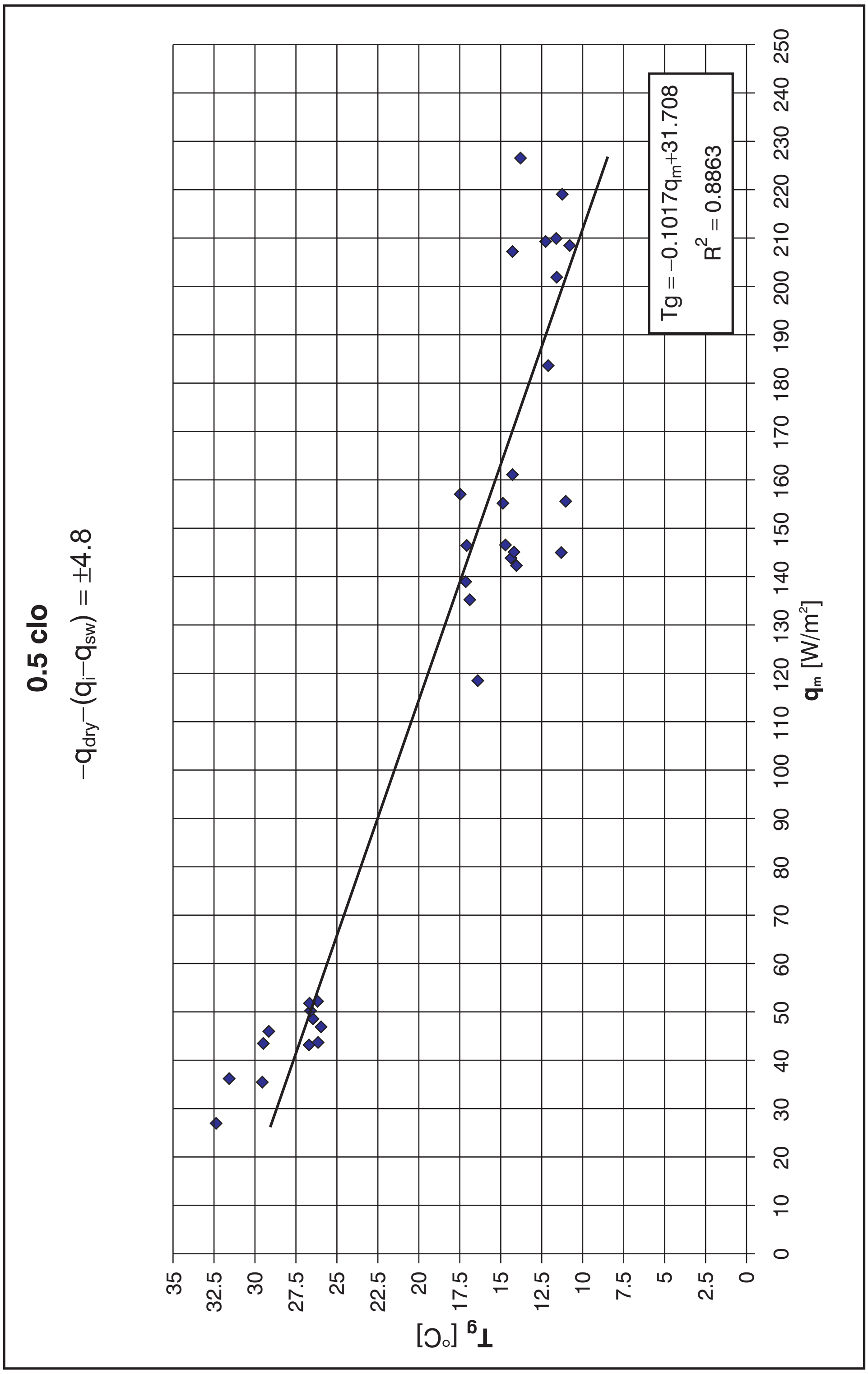

Fig. 6: Graph of the relationship $T_g = f(q_m)$ for optimal values transferred from graph on Fig. 5 within the range $q_{dry} - (q_i - q_{sw}) = \pm 4.8$, where the value ± 4.8 W·m^{-2} represents the minimal thermoregulatory heat

Thermoregulation and adaptational heat flux first affects the skin temperature, T_{sk}. The internal thermal resistance value, $R_{t,i} = 1/G_{t,i}$, characterizing the vasodilatation and vasoconstriction process, can be calculated from the equation:

$$R_{t,i} = \frac{T_i - T_{sk}}{q_{tr} + q_a} \; [\mathrm{W^{-1} \cdot m^2 \cdot K}] \quad (4)$$

3 Experimental estimation of mathematical model parameters

An experiment over the course of several years was undertaken in a climatic chamber, leading identification of the parameters in Eq. (1) and (4).

The experimental subjects were male university students. Each of them underwent six experiments lasting about three hours at four levels of activity: (1) sitting in a chair, (2) sitting on a bike-ergometer without pedaling, (3) pedaling on a bike-ergometer with a 40 W load and (4) pedaling on a bike-ergometer with a load of 1 W per kg body mass (for as long as he was able to continue). Metabolic heat production during each activity was measured by an indirect calorimetric method. Mean skin temperature, heat rate and body water loss were estimated continuously during each experiment.

Two sets of clothing were used by the subjects: lightweight (pyjamas) and heavier clothing (an anti-g suit for fighter pilots). The results of the anti-g suit experiments will be presented in a separate report.

There were no differences between the air temperature and the surface wall temperatures – it can be assumed that the overall temperature equals the operative temperature. Six temperatures were chosen (29±3 °C and 14±3 °C, which determine the temperature ranges where some of the subjects started to leave the neutral zone and appeared to begin sweating or shivering). The originally chosen range of temperatures 8, 11, 14, 17, 20, 23, 26, 29, 32 °C was found to be excessive, and so they were reduced.

Within the comfort range the relative humidity was maintained corresponding to a partial water vapour pressure from 700 to 1850 Pa. The onset of sweating and shivering was always assessed by the same person. Experiments were carried out in all seasons of the year, thus reflecting the seasonal adaptation effect on maximal and minimal thermoregulatory heat, i.e. it was possible to determine adaptational heat. However it became evident that the seasonal adaptation effect can be neglected (Jokl, Moos 1992), being lower than 0.2 °C (i. e. within the range of experimental error in measuring the temperatures). The same finding has been described by other authors (see Fanger 1970). The results were only accepted from subjects within the thermal neutral zone with the thermoregulatory heat constant.

3.1 Graph construction of $T_g = f(q_m)$

The measured values are plotted as $q_{dry} = f(q_i - q_{sw})$ in Fig. 5, where for optimal values the linear equation: $q_{dry} = q_i - q_{sw}$ [$\mathrm{W \cdot m^{-2}}$] representing equilibrium is valid. Practical application of this graph is very difficult; but the relationship $T_g = f(q_m)$ is useful. Therefore the linear relationship from Fig. 5 was transferred into the graph in Fig. 6 by plotting a regression line through the points limited by the equation $-q_{dry} - (q_i - q_{sw}) = \pm 4.8$ [$\mathrm{W \cdot m^{-2}}$] in Fig. 6.

The value of ±4.8 $\mathrm{W \cdot m^{-2}}$ of the regression line is the minimal thermoregulatory heat, i.e. it represents maximal vasoconstriction in human body, and can be estimated from the minimum value for internal thermal conductivity of the human body (see Fig. 7), which equals 9.07 $\mathrm{W \cdot m^{-2} \cdot K^{-1}}$ (for core body temperature T_i = 36.6 °C, skin temperature T_{sk} = 30.5 °C and q_m = 45.7 $\mathrm{W \cdot m^{-2}}$).

$$q_{tr,\min} = G_{t,i,\min}(T_i - T_{sk}) = 1.57(36.6 - 30.5) = 9.6 \ \mathrm{W \cdot m^{-2}},$$

i.e. ±4.8 $\mathrm{W \cdot m^{-2}}$,

where

$$G_{t,i,\min} = G_{t,ti,\min} - G_{t,m,\min} = 9.07 - 7.5 = 1.57 \ \mathrm{W \cdot m^{-2} \cdot K},$$

$$G_{t,m,\min} = \frac{q_m}{T_i - T_{sk}} = \frac{45.7}{36.6 - 30.5} = 7.5 \ \mathrm{W \cdot m^{-2} \cdot K}.$$

3.2 Estimation of thermoregulatory range

The widest thermoregulatory range, i.e. from optimum up to the onset of visible sweating can be estimated by plotting the regression line into the points of the onset of sweating. However, to ensure comfort we need lower values, without visible sweating occurring. This area is between the line of the optimum value and the tangent from the origin (which is the intersection of the line of the optimum and the regression line of the onset of sweating) to the area of beginning of shivering (see Fig. 8). These tangents are analogous to the thermoregulatory range of category C according to CR 1752-1998.

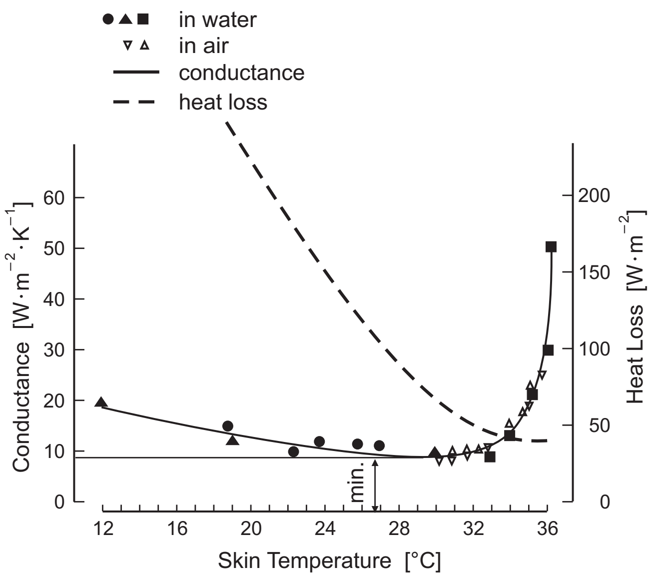

Fig. 7: Human body thermal conductance $G_{t,ti}$ and human body heat loss as a functionof skin temperature T_{sk} for a resting subject during daytime (q_m = 45.6–57.4 $\mathrm{W \cdot m^{-2}}$) (Burton, Bazett 1936, Du Bois et al. 1952, Lefevre 1898, Liebmaster 1869) (from Itoh et al. 1972)

For categories A and B it must be taken into consideration that the human body is a thermoregulatory mechanism in the surrounding environment balancing the operative temperature changes by thermoregulatory heat flows in the human so that equilibrium can be achieved, and this must take place at three levels (by analogy with technological mechanisms) (see Fig. 9):

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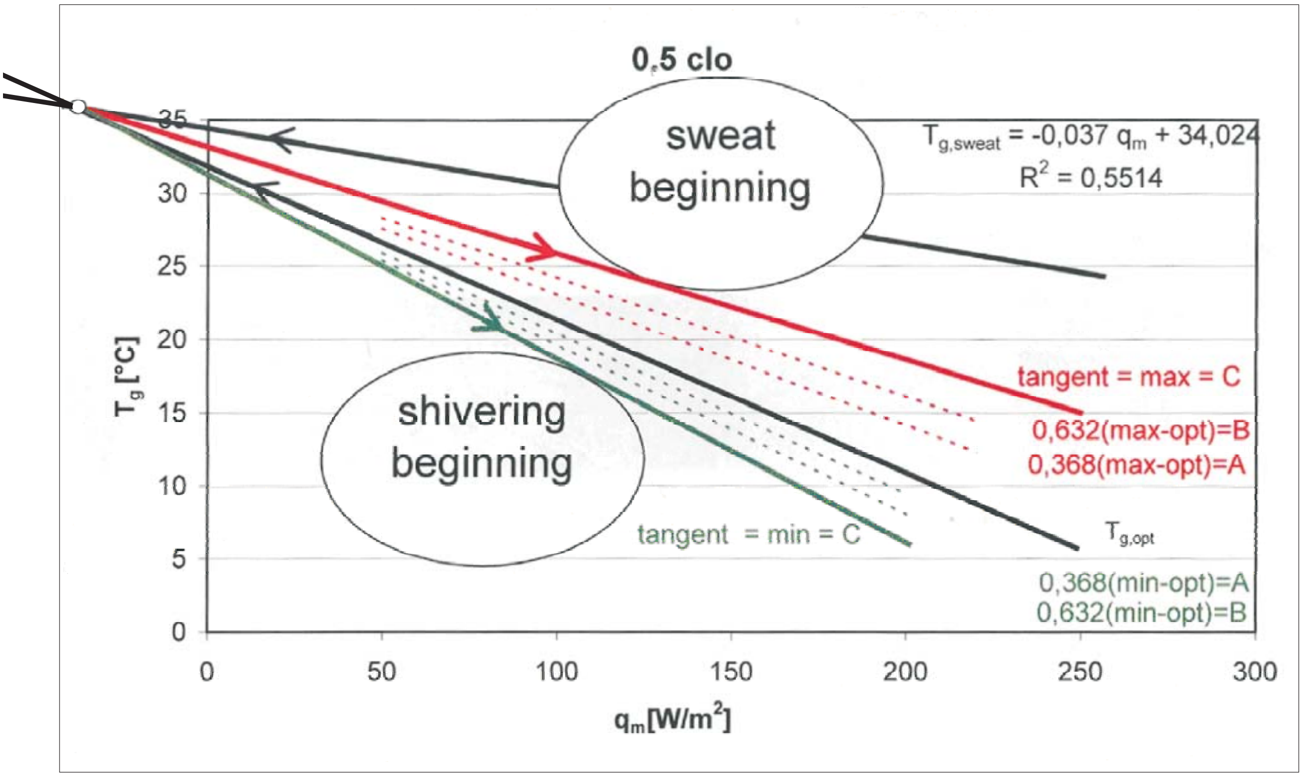

Fig. 8: How to obtain thermoregulatory ranges (see the text for an explanation)

– level A, corresponding to the time constant 0.368 $\Delta T_{o,\,tr,\,max}$
– level B, corresponding to the time constant 0.632 $\Delta T_{o,\,tr,\,max}$
– level C, corresponding to the time constant 1.000 $\Delta T_{o,\,tr,\,max}$

Level A is valid for building interiors with the highest requirements, and can only be attained with the use of air conditioning systems. Level C is valid for building interiors with the lowest requirements, usually only naturally ventilated. Level B covers other buildings, where air conditioning is necessary only in some cases.

The time constant according to control theory characterizes the system response, (the response of the human

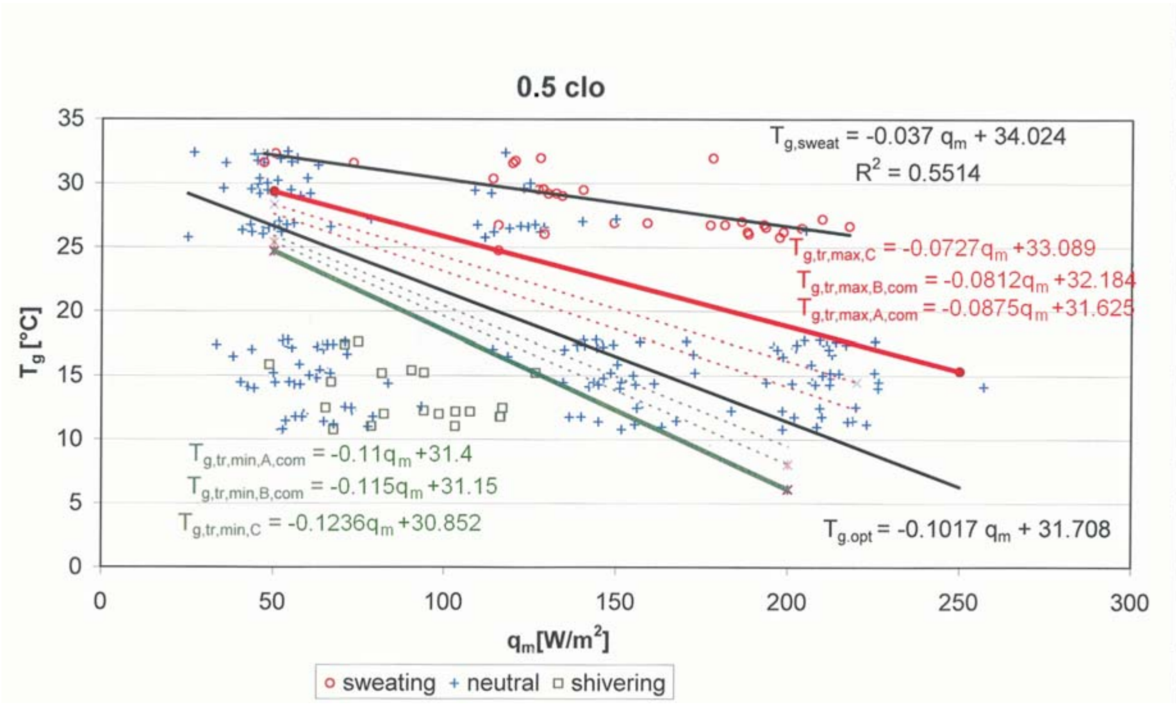

Fig. 9: Graph of the relationship $T_g = f(q_m)$ with the regression line of onset of sweating and the thermoregulatory range for levels (categories) A, B, C for warm (towards the onset of sweating) and for cold (towards the onset of shivering)

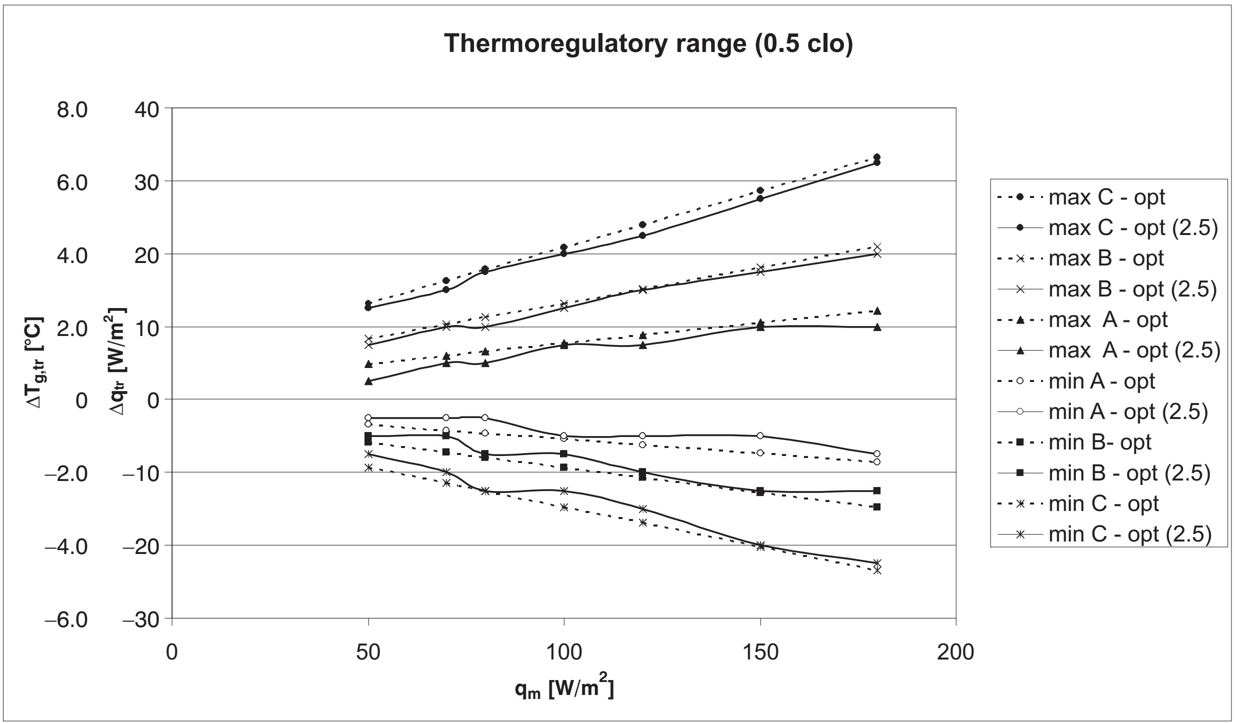

Fig. 10: Thermoregulatory changes as transferred from graph on Fig. 7 and rounded up to 0.5 °C for practical application (see also Table 1)

organism) to the operative temperature changes, and is equal to the product of system thermal resistance R and its thermal capacity C:

$$\text{time constant} = R{\cdot}C,$$

where $R = R_{ti} + R_{twa}$ [$W^{-1}{\cdot}m^2{\cdot}K$].

Thermoregulatory changes are shown in Fig. 10 as transferred from Fig. 9 and also rounded up to 0.5 °C for practical application. For a complete list of values, see Table 1.

Table 1: Optimal operative temperatures and thermoregulatory range as a function of man's activity q_m

°C	50 [$W{\cdot}m^{-2}$]	70 [$W{\cdot}m^{-2}$]	80 [$W{\cdot}m^{-2}$]	100 [$W{\cdot}m^{-2}$]	120 [$W{\cdot}m^{-2}$]	150 [$W{\cdot}m^{-2}$]	180 [$W{\cdot}m^{-2}$]
sweat	32.2	31.4	31.1	30.3	29.6	28.5	27.4
sweat – opt	5.6	6.8	7.5	8.8	10.1	12.0	14.0
sweat – opt (0.5)	5.5	6.5	7	8.5	10	12	13.5
Max	29.3	27.9	27.2	25.8	24.4	22.3	20.2
max C – opt	2.7	3.4	3.7	4.3	4.9	5.9	6.8
max C – opt (0.5)	2.5	3.0	3.5	4.0	4.5	5.5	6.5
max B (0.632)	28.3	26.7	25.9	24.3	22.6	20.2	17.7
max B – opt	1.7	2.1	2.3	2.7	3.1	3.7	4.3
max B – opt (0.5)	1.5	2.0	2.0	2.5	3.0	3.5	4.0
max A (0.368)	27.6	25.8	24.9	23.1	21.3	18.6	15.9
max A – opt	1.0	1.2	1.4	1.6	1.8	2.2	2.5
max A – opt (0.5)	1.0	1.0	1.0	1.5	1.5	2	2.5
opt	26.6	24.6	23.6	21.5	19.5	16.5	13.4

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°C	50 [W·m^{-2}]	70 [W·m^{-2}]	80 [W·m^{-2}]	100 [W·m^{-2}]	120 [W·m^{-2}]	150 [W·m^{-2}]	180 [W·m^{-2}]
min A (0.368)	25.9	23.7	22.6	20.4	18.2	14.9	11.6
min A – opt	-0.7	–0.9	–1	–1.1	–1.3	–1.5	–1.8
min A – opt (0.5)	-0.5	–0.5	–0.5	–1.0	–1.0	–1.5	–1.5
min B (0.632)	25.4	23.1	21.9	19.6	17.3	13.8	10.4
min B – opt	-1.2	–1.5	–1.6	–1.9	–2.2	–2.6	–3.1
min B – opt (0.5)	-1.0	–1.0	–1.5	–1.5	–2.0	–2.5	–3.0
min	24.7	22.2	21	18.5	16	12.3	8.6
min C – opt	–1.9	–2.4	–2.6	–3.0	–3.5	–4.2	–4.8
min C – opt (0.5)	–1.5	–2.0	–2.5	–3.0	–3.0	–4.0	–4.5

4 A comparison between optimal values and thermoregulatory ranges with accepted values

The proposed optimal temperatures and their thermoregulatory ranges were compared with the values according to ISO 7730 (Moderate thermal environments ISO 7730-1984 (E)), CR (1752) (1998) and ISO/DIS 7730 (2003), ANSI/ASHRAE Standard 55-2004.

The comparison between the above proposed operative temperatures and the values according to CR 1752 and ISO/DIS 7730 is presented in Table 2 and in Fig. 11. There is agreement on operative temperatures for 50 W·m^{-2}, 70 W·m^{-2} and 80 W·m^{-2}. For higher activities the values differ: the greater the activity, the greater the operative temperature difference. The findings are in agreement with the experiments (sitting persons in the neutral zone) on which the PMV value is based.

A comparison between proposed optimal operative temperatures and the values according to ISO and ANSI/ASHRAE is presented in Table 3 and Fig.12. There is evident agreement for low activities (the graph is also based on ISO 7730).

5 Discussion

The optimal operative temperatures derived from PVM values (from the 1970's) are now not fully acceptable. It is more precise to use optimal operative temperatures based on the physiological human body response and not based only on people's feelings. This has been proved by experimental

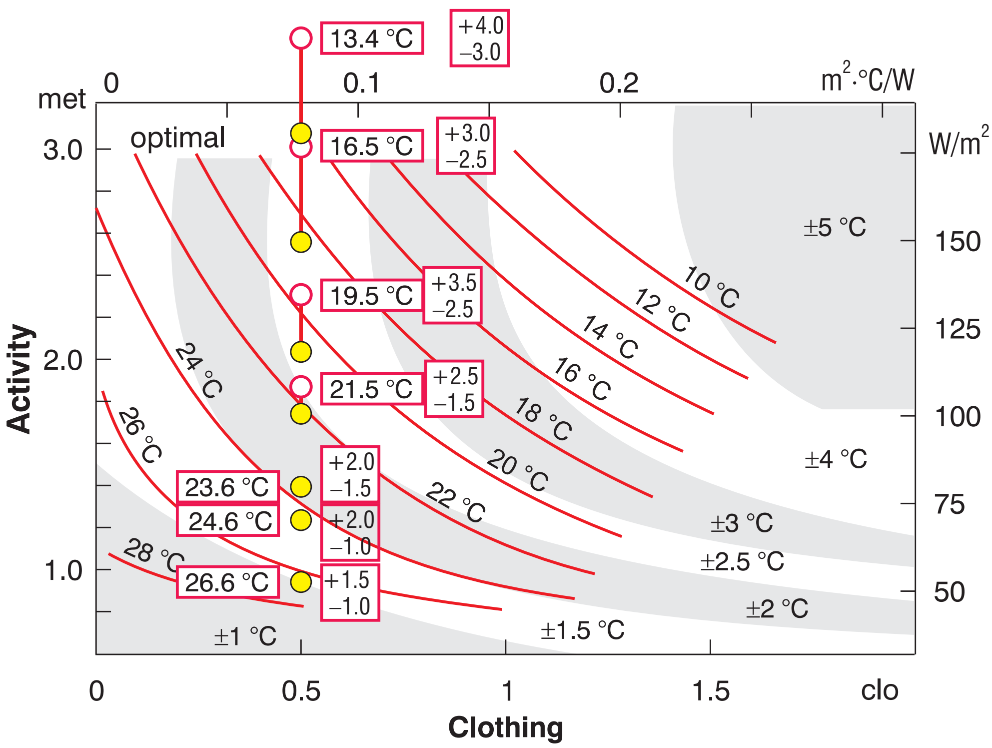

Fig. 11: Comparison between experimentally found optimal operative temperatures and the values in ISO 7730 (the values presented in the graph correspond to temperatures only, not to activity)

Table 2: A comparison between experimentally found operative temperatures and the values in CR 1752 and ISO/DIS 7730 (2003) in categories A, B, C (0.5 clo, 1.2 met)

Category	CR + ISO/DIS	Jo/Ka
A (air conditioning)	24.5 ± 1.0	24.6 + 1.0 – 0.5
B (air conditioning and natural ventilation)	24.5 ± 1.5	24.6 + 2.0 – 1.0
C (natural ventilation)	24.5 ± 2.5	24.6 + 3.0 – 2.0

works (Fishman, Pimbert 1979) and shown when ISO values have been applied in practice. The greater a person's activity, the greater the discrepancy in the optimal temperature. Because of this discrepancy, the new Czech Government Directive No. 523/2002 Code is based on the values presented here, and not on ISO/DIS 7730, which is based on PMV. The absence in the directive of adaptation to heat and cold, e.g. as a result of staying in a heated room in winter and in air-conditioned cars in summer, results in the same optimal operative temperatures for winter and for summer; the temperatures are differentiated only by different clothing.

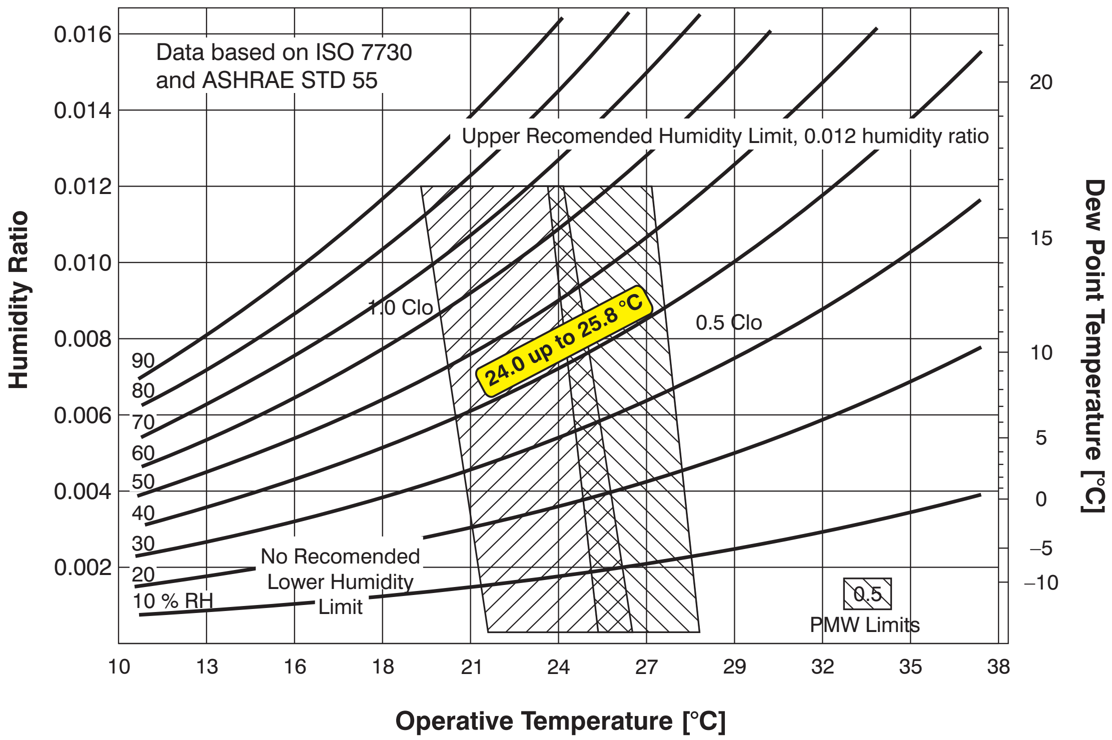

Fig. 12: Comparison between experimentally found optimal operative temperatures and the values in ANSI/ASHRAE

Table 3: A comparison between experimentally found operative temperatures and the values in ISO and ANSI/ASHRAE (clothing 0.5)

q_m	[W·m–2]	50	70	80	100	120	150	180
	[met]	0.86	1.20	1.38	1.72	2.07	2.59	3.10
Jo/Ka [°C] (B)		26.6 +1.5 –1.0	24.6 +2.0 –1.0	23.6 +2.0 –1.5	21.5 +2.5 –1.5	19.5 +3.0 –2.0	16.5 +3.5 –2.5	13.4 +4.0 –3.0
ISO 7730 (1984)		26.6±1.5	24.5±1.5	23.6±2.0	22.3±2.0	20.6±2.5	18.5±2.5	16.4±2.5
CR 1752, ISO/DIS 7730 (2003) [°C] (B)		–	24.5±1.5	23.5±2.0	–	–	–	–
ANSI/ASHRAE 55 (1992) $T_{o\,active} = T_{o\,sedentary} - 4.5\,(met - 1.2)$ [°C]		–	24.5	23.7	22.2	20.6	18.2	16.0

Remark: (B) means category

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6 Results

The mathematical model (Fig. 4) shows the role of various heat flows produced by the human body as it interacts with the environment. All the heat flows must be in mutual equilibrium if the human body is to stay homoiotherm. Practical application of this graph is very difficult, and $T_g = f(q_m)$ is a more useful relationship (Fig. 6). This equilibrium forms the basis for optimal operative temperature estimation (Fig. 5). The experimental data on the onset of sweating and the onset of shivering enable the thermoregulatory ranges to be estimated (Fig. 8). The thermoregulatory area is between the line of the optimum and the tangent from pole, defined as the intersection of the line of optimum and the regression line of the onset of sweating, to the field of the onset of sweating (upper limit, level C_{max}) and to the field of the onset of shivering (lower limit, C_{min}). It is interesting and in agreement with human feelings that the thermoregulatory field for cold is smaller than the thermoregulatory field of the warm area – the human body is more sensitive to temperature decreases in the cold area. The question is how to sub-divide the thermoregulatory range into categories (A, B and C). Instead of qualified assumption, it is proposed to base the categories on control theory. The human body behaves like any other system to which control theory can be applied. It is proposed that the human body time constant is used to differentiate the categories. The following values were used: time constant 0.368 $\Delta T_{0,tr,max}$ (A), 0.632 $\Delta T_{0,tr,max}$ (B) and 1.0 $\Delta T_{0,tr,max}$, which correspond to categories A, B and C (Fig. 6). Category A can be applied to air conditioned buildings and category C to naturally ventilated buildings. As a result, two previously separate methods of assessment can be merged, those for air conditioned buildings, based on PMV, and these for natural ventilated buildings, based on mean monthly outdoor temperature. The results have been compared with the values according to ISO 7730, CR (1752) (1998), ISO/DIS 7730 (2003) (Table 2 and 3), and with the ANSI/ASHRAE Standard (Table 3). Most importantly however, it was possible to base the new Czech Government Directive No. 523/2002 Code (Table 3) on these new findings, which have been used to derive the compulsory microclimatic condition for workplaces in the Czech Republic.

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