

A NEW CORRELATION BETWEEN PREDICTED MEAN VOTES (PMV) AND PREDICTED PERCENTAGES OF DISSATISFIED (PPD)

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ABSTRACT

According to former results of Fanger the predicted percentage of people dissatisfied with a given indoor climate (PPD) is never less than 5 %. This 5 % consist of 2,5 % of dissatisfied people due to heat-discomfort and 2,5 % due to cold-discomfort corresponding to a predicted mean vote (PMV) of 0. Results of laboratory and field measurements reveal a minimum of 15 PPD at a PMV of 0,5. A simple reason for that discrepancy is the definition of PPD and is detailed in the paper. Consequences hereof are either the acceptance of higher dissatisfaction percentages or (much better): the necessity for individual climate control.

INTRODUCTION AND METHODS

In the international standard ISO 7730 (1) besides others the correlation between predicted mean votes (PMV) and predicted percentages of dissatisfied (PPD) according to Fangers' results in (2) is described. A rather relevant consequence hereof is the statement that even at optimal thermal conditions always a minimum rate of complaints of 5 % exists, consisting of 2,5 % dissatisfied due to heat-discomfort and 2,5 % due to cold-discomfort. On the other side results of field measurements, e.g. by Schiller (3) and Croome (4) as well as laboratory measurements by Fraunhofer-Institute for Building Physics (IBP) (5,6) reveal minimum rates of complaints of 15 - 20 %. There is a simple and obvious reason for that discrepancy which will be detailed here. The method is analysing the original definition of PPD in (2).

RESULTS

Figure 1 represents the original results of Fanger: the predicted percentages of those who are expected to complain of too cold or too warm sensation as well as the sum of these (PPD), in relation to the predicted mean votes (PMV). As described in (2) the basis for figure 1 were measurements on nearly 1300 subjects who were asked for their thermal votes when exposed to different thermal conditons. The point is that the correlated percentages of dissatisfied were not found by questionnaires but by definition. Those voting -2 and -3 of the seven point comfort scale were defined as "dissatisfied by cold sensation" and those voting +2 and +3 as "dissatisfied by warm sensation".

The results of draught measurements by IBP on ca. 100 subjects are presented in figure 2 in a similar way as in figure 1. The dots correspond to results, described in (5) and the circles to those in (6). In both cases subjects were asked for their thermal vote and additionally whether they were dissatisfied by cold sensation. Compared with figure 1 a shift of the $PPD_{\text{too cold}}$ -curve to the right is found. The PPD_{total} -curve is shifted to the right and upward. In a few cases thermal conditions in (5) were on the warm side and fit well to the results of figure 2 (not drawn here).

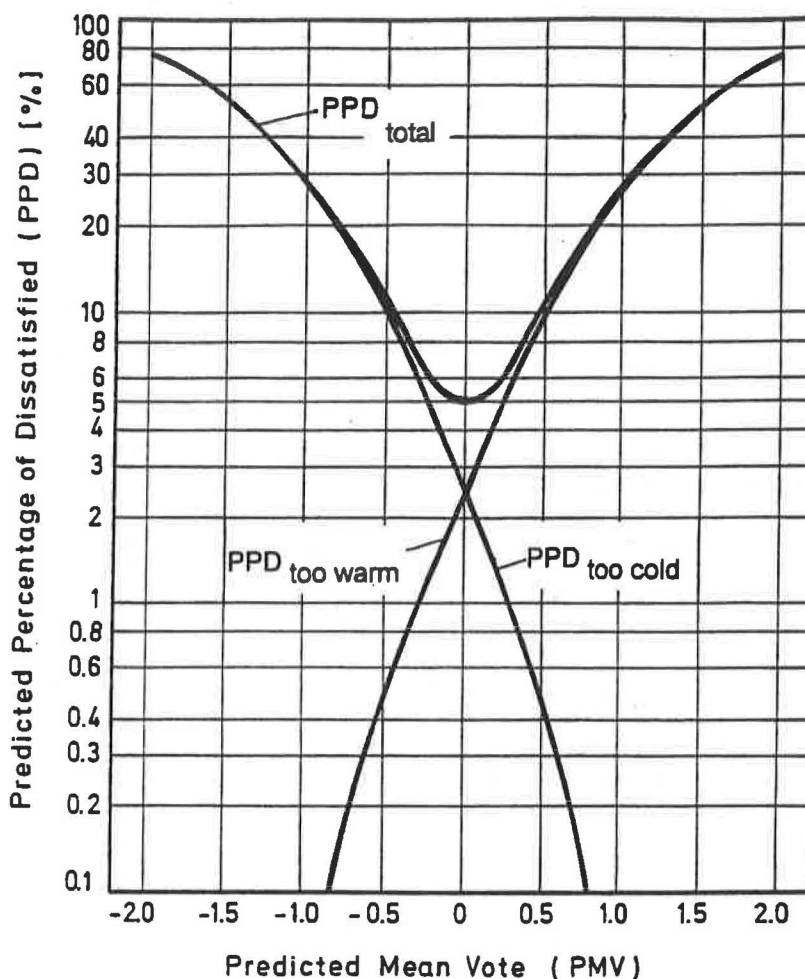


Figure 1 Predicted percentages of those who will complain of too cold or too warm sensation as well as the sum of these (PPD), relative to the predicted mean votes (PMV) according to Fanger (1,2).

An explanation for the discrepancy of figures 1 and 2 can be found by using table 1. This table presents the original Fanger data of reference (2) and additionally in columns 10, 12 and 15 some new analysis. In column 10 the mean votes out of columns 3 - 9 are calculated. The numbers of columns 10, 11, 13 and 14 and some statistical smoothing of the results lead to figure 1. In column 11 according to Fangers' definition the percentages of columns 3 (vote -3) and 4 (vote -2) are added.

If the definition for "dissatisfied by cold sensation" would include the votes -1 as well, as added in column 12, the drawing of the values of columns 10 and 12 will result in the solid curve of figure 2. That means a simple explanation for the questionnaire results found in (5) and (6) is a new definition of discomfortably cold sensation: it includes the votes -3 (cold), -2 (cool), -1 (slightly cool). Because in reference (5) a shift of the $PPD_{\text{too warm}}$ -curve could not be found for the total discomfort sensation (too cold and too warm), in column 15 the new results of column 12 (too cold) and the original results of column 13 (too warm) are added and drawn in figure 2.

Table 1 Distribution of Thermal Sensation Votes (%) out of (2) and new results.

Amb. Temp	Number of Subjects	Votes							Mean Votes	Dissatisfied				
		-3	-2	-1	0	+1	+2	+3		Cold (-3) and (-2)	Cold (-3) and (-2) and (-1)	Warm (+2) and (+3)	Total (-3), (-2) and (+2), (+3)	Total (-3), (-2) and (+2), (+3)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
18,9	80	42,4	36,3	16,2	3,8	1,3	-	-	-2,15	78,7	94,9	-	78,7	94,9
20,0	80	28,8	48,7	15,0	7,5	-	-	-	-1,39	77,5	92,5	-	77,5	92,5
21,1	144	12,5	30,5	45,2	10,4	1,4	-	-	-1,42	43,0	88,2	-	43,0	88,2
22,2	80	8,8	33,7	31,2	26,3	-	-	-	-1,25	42,5	73,7	-	42,5	73,7
23,3	144	5,6	11,1	47,2	33,3	2,1	0,7	-	-0,82	16,7	63,9	0,7	17,4	64,6
24,4	80	-	3,8	22,5	62,5	11,2	-	-	-0,18	3,8	26,3	-	3,8	26,3
25,6	144	0,7	2,1	18,1	57,5	18,8	2,8	-	0,06	2,8	20,9	2,8	5,6	23,7
26,7	80	-	-	3,8	57,5	31,2	5,0	2,5	0,45	-	3,8	7,5	7,5	11,3
27,8	144	-	-	4,2	38,8	41,0	14,6	1,4	0,71	-	4,2	16,0	16,0	20,2
28,9	80	--	-	-	17,5	41,3	30,0	11,2	1,35	-	-	41,2	41,2	41,2
30,0	80	-	-	-	25,0	45,0	26,3	3,7	1,09	-	-	30,0	30,0	30,0
31,1	80	-	-	-	8,8	38,7	36,3	16,2	1,6	-	-	52,5	52,5	52,5
32,2	80	-	-	-	5,0	16,3	50,0	28,7	2,03	-	-	78,7	78,7	78,7

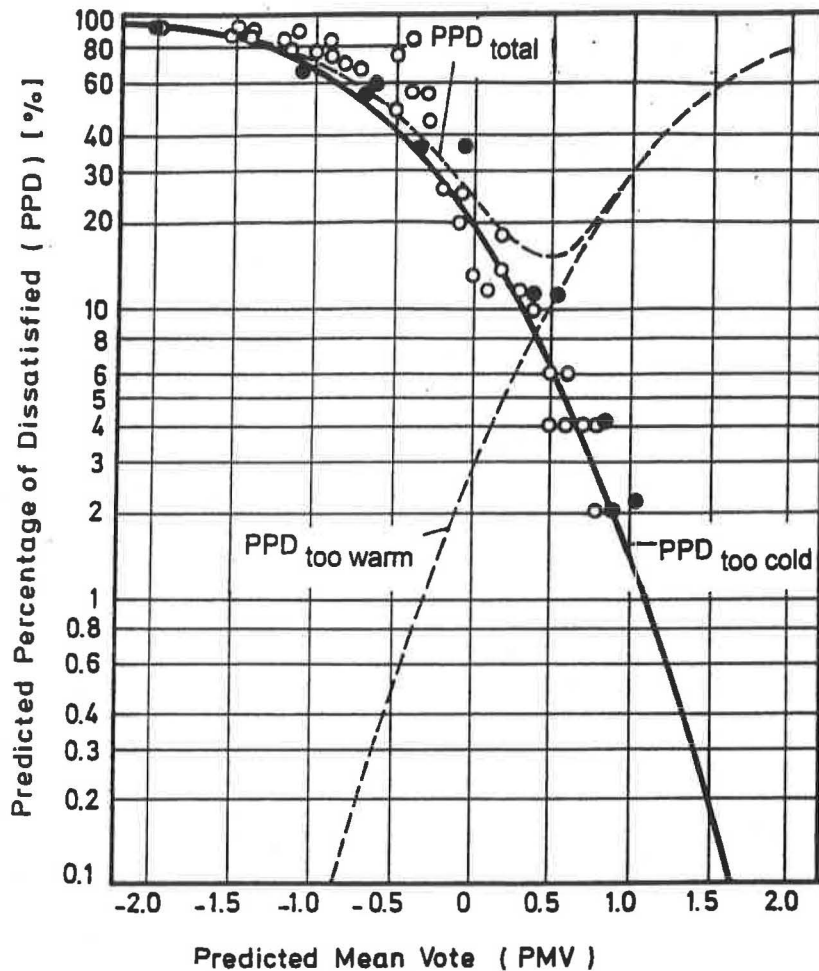


Figure 2 Predicted percentages of those who will complain of too cold or too warm sensation as well as the sum of these (PPD), relative to the predicted mean votes (PMV) according to draught measurements in (3), dots and in (4), circles.

Figure 3 summarises these findings. The original and the new PPD/PMV-curves are drawn. Besides the shift to the right (warmer side) an increase of the minimum rate of complaints of 5 % to 15 % is most relevant. According to these results it is proposed that the now valid formula in (1)

$$\text{PPD} = 100 - 95 \cdot e^{-(0,03353 \cdot \text{PMV}^4 + 0,2179 \cdot \text{PMV}^2)} \quad (1)$$

where PPD the predicted percentage of dissatisfied, PMV the predicted mean vote might be changed to

$$\text{PPD} = 100 - 84,3 \cdot e^{-[-0,01 (\text{PMV}-0,4)^4 + 0,5479 \cdot (\text{PMV}-0,4)^2]}$$

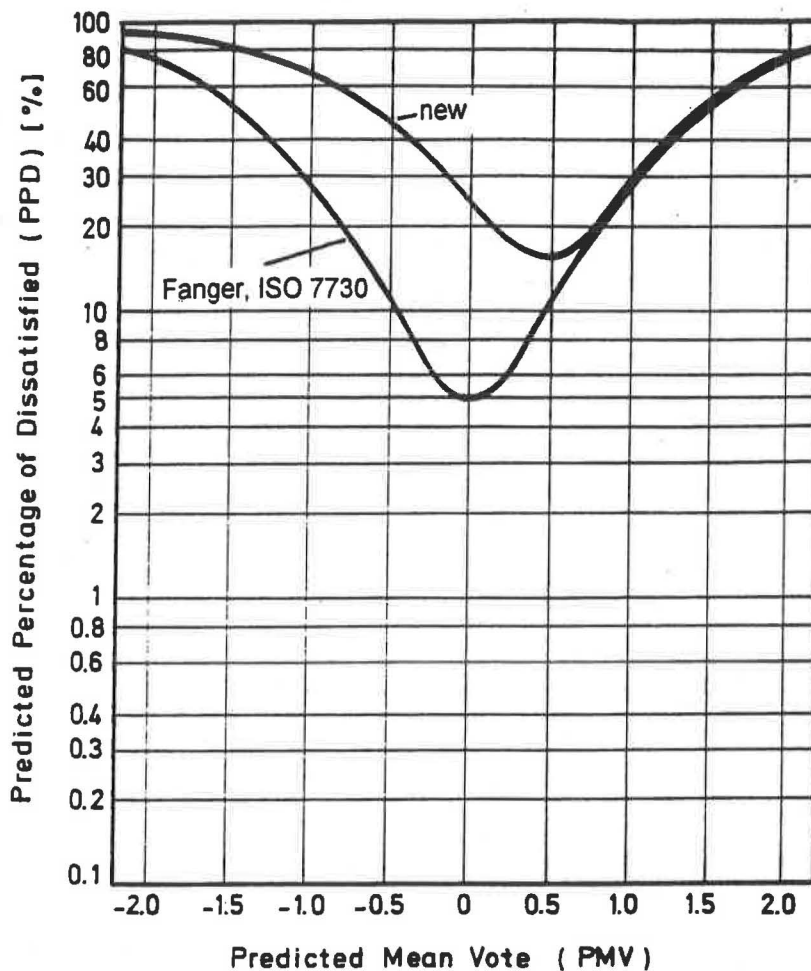


Figure 3 Predicted percentages of dissatisfied (PPD), in relation to predicted mean votes (PVM) according to Fanger (1,2) and according to the new results

DISCUSSION

The proposed shift of the ISO 7730 PPD/PMV-curve to the warm side and to higher PPD-values for the cold side as well as an increase of the minimum rate of complaints from 5 % to ca. 15 % is based on measurements with ca. 100 subjects. A higher number, at least for investigations of the warmer conditions, might be advisable. Anyhow, the new results correspond well with the results of field measurements, e.g. in references (3,4). Consequences hereof are either the acceptance of higher percentages of dissatisfied or much better: the necessity for individual climate control, as proposed in (7).

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