УНИВЕРСИТЕТ ИТМО

New thermal comfort indices based on iso-comfort arrays

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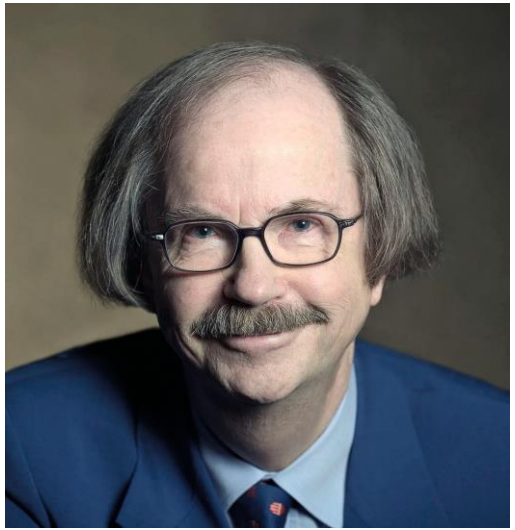
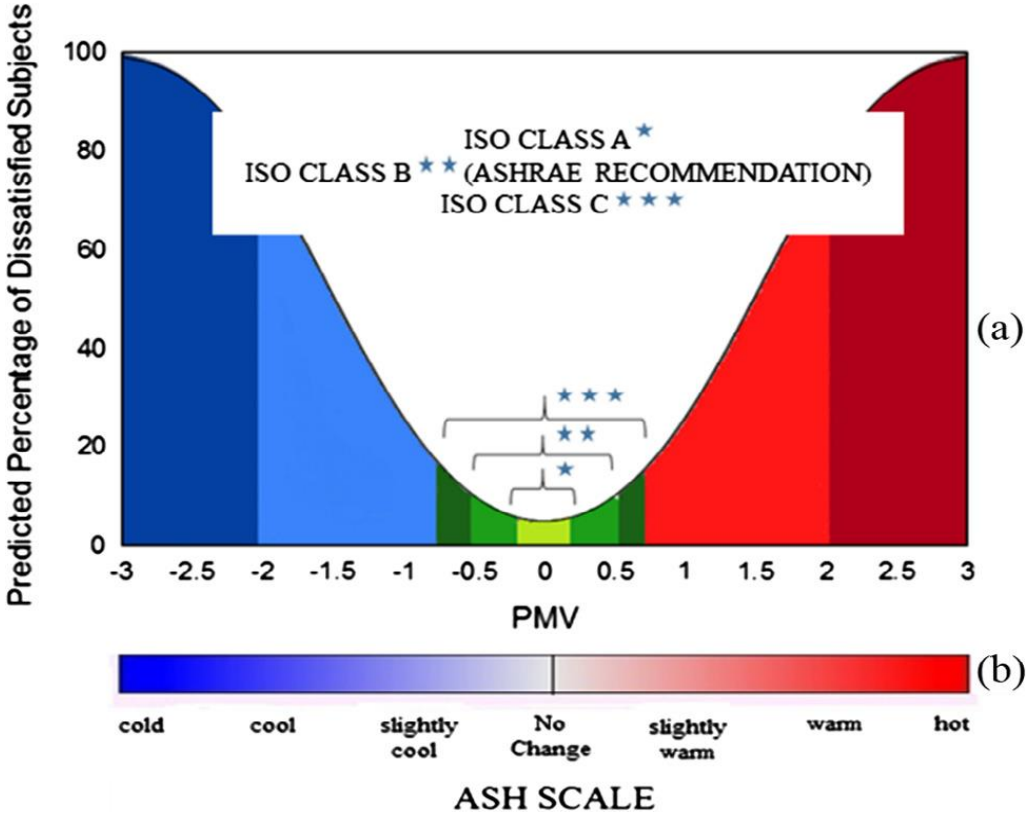
Thermal Comfort Indices by P.O. Fanger



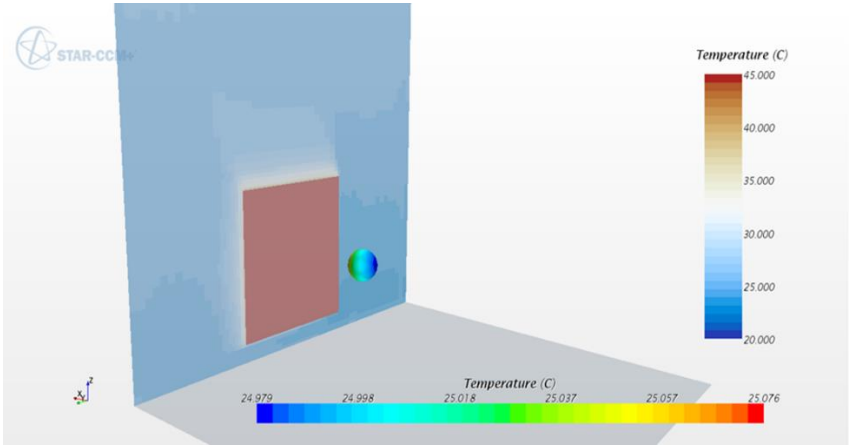
P.O. Fanger

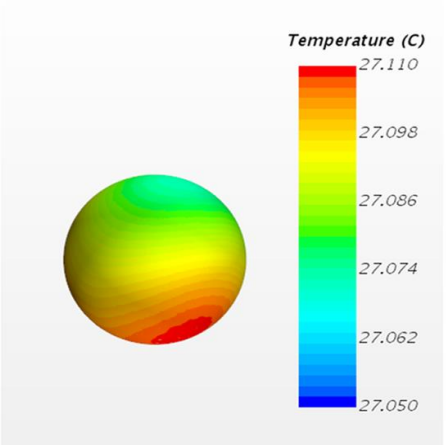


PMV – PPD relation

Radiative factor of thermal comfort

Globe thermometer





CFD modeling

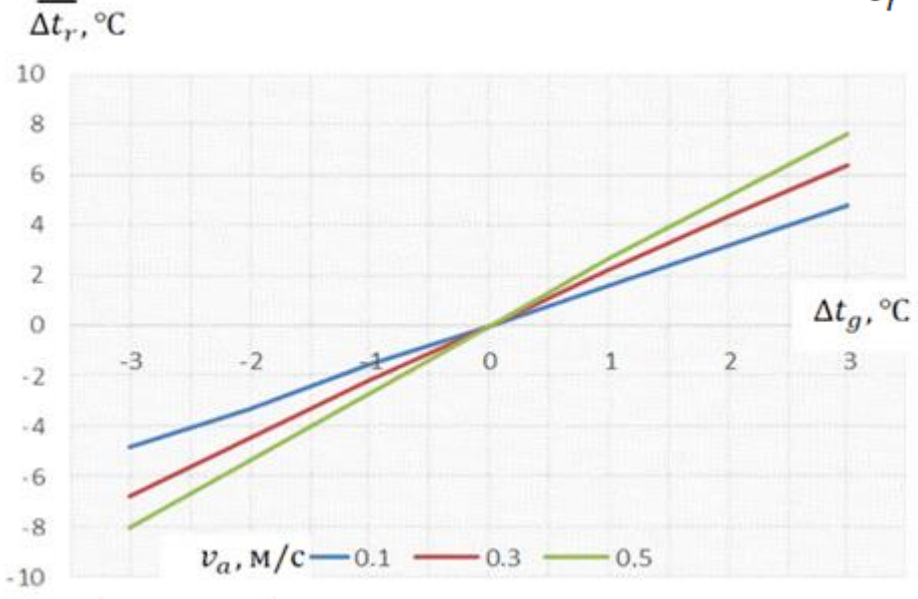
Mean radiative temperature

УНИВЕРСИТЕТ ИТМО

New factors:

- ***mean radiative temperature difference***
- ***globe thermometer temperature difference***

$$\overline{t_r} = \left[(t_g + 273)^4 + \frac{1{,}1 \cdot 10^8 \cdot v_a^{0,6}}{\varepsilon D^{0,4}} \cdot (t_g - t_a) \right]^{\frac{1}{4}} - 273.$$



Mean radiative temperature difference

vs

globe thermometer`s temperature difference

$$\Delta t_r = t_r - t_a$$

$$\Delta t_g = t_g - t_a$$

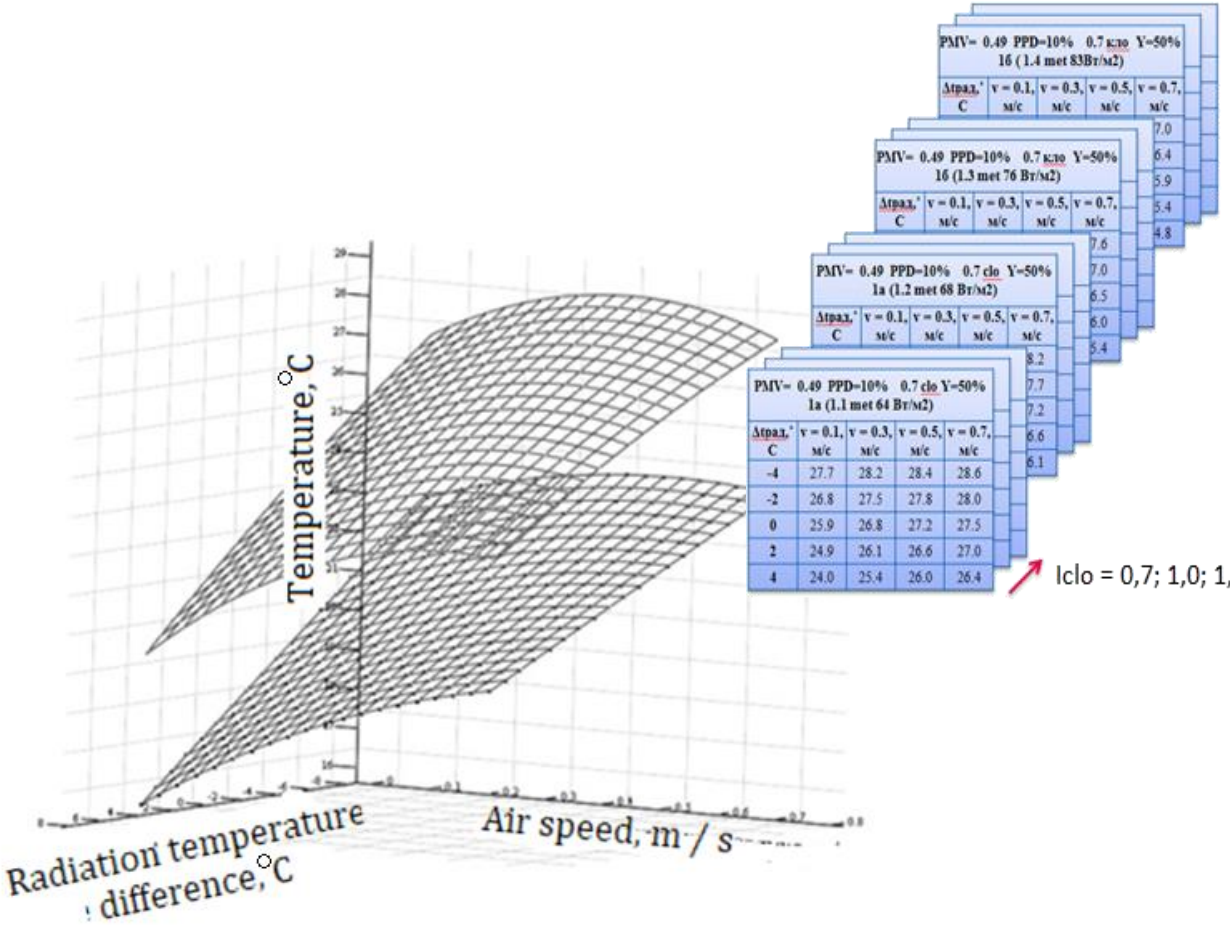
Formation of iso-comfort arrays

УНИВЕРСИТЕТ ИТМО

PMV = +0.49				
Δt_r, ˚C	v = 0.1, m/s	v = 0.3, m/s	v = 0.5, m/s	v = 0.7, m/s
-8	27.60	27.63	29.27	27.65
-4	25.81	26.29	28.10	26.63
0	23.98	24.92	26.90	25.59
4	22.12	23.52	25.67	24.51
8	20.356	22.08	22.901	23.41
PMV = -0.49				
Δt_r, ˚C	v = 0.1, m/s	v = 0.3, m/s	v = 0.5, m/s	v = 0.7, m/s
-8	23.23	23.72	23.94	24.066
-4	21.45	22.40	22.81	23.06
0	19.63	21.04	21.65	22.03
-4	17.89	19.65	20.46	20.97

Comfort class: B
Activity: 1.1 met
Clothes: 1.0 clo

Iso-comfort arrays data base



PMV= 0.49 PPD=10% 0.7 clo Y=50%
1a (1.1 met 64 Вт/м2)

Δтрад, °C	v = 0.1, м/с	v = 0.3, м/с	v = 0.5, м/с	v = 0.7, м/с
-4	27.7	28.2	28.4	28.6
-2	26.8	27.5	27.8	28.0
0	25.9	26.8	27.2	27.5
2	24.9	26.1	26.6	27.0
4	24.0	25.4	26.0	26.4

PMV= 0.49 PPD=10% 0.7 clo Y=50%
1a (1.2 met 68 Вт/м2)

Δтрад, °C	v = 0.1, м/с	v = 0.3, м/с	v = 0.5, м/с	v = 0.7, м/с
-4	8.2	7.7	7.2	6.6
-2	7.6	7.0	6.5	6.0
0	7.0	6.4	5.9	5.4
2	6.4	5.9	5.4	4.8
4	5.9	5.4	4.8	4.3

PMV= 0.49 PPD=10% 0.7 clo Y=50%
1б (1.3 met 76 Вт/м2)

Δтрад, °C	v = 0.1, м/с	v = 0.3, м/с	v = 0.5, м/с	v = 0.7, м/с
-4	7.0	6.4	5.9	5.4
-2	6.4	5.9	5.4	4.8
0	5.9	5.4	4.8	4.3
2	5.4	4.8	4.3	3.8
4	4.8	4.3	3.8	3.3

PMV= 0.49 PPD=10% 0.7 clo Y=50%
1б (1.4 met 83Вт/м2)

Δтрад, °C	v = 0.1, м/с	v = 0.3, м/с	v = 0.5, м/с	v = 0.7, м/с
-4	5.4	4.9	4.3	3.8
-2	4.9	4.3	3.8	3.2
0	4.3	3.8	3.2	2.7
2	3.8	3.2	2.7	2.2
4	3.2	2.7	2.2	1.8

Iclo = 0,7; 1,0; 1,3 clo

PMV= -0.49 PPD=10% 0.7 clo Y=50%
1a (1.1 met 64 Вт/м2)

Δтрад, °C	v = 0.1, м/с	v = 0.3, м/с	v = 0.5, м/с	v = 0.7, м/с
-4	24.3	25.3	25.7	25.9
-2	23.4	24.6	25.1	25.4
0	22.5	23.9	24.5	24.8
2	21.5	23.2	23.9	24.3
4	20.7	22.4	23.3	23.8

PMV= -0.49 PPD=10% 0.7 clo Y=50%
1a (1.2 met 68 Вт/м2)

Δтрад, °C	v = 0.1, м/с	v = 0.3, м/с	v = 0.5, м/с	v = 0.7, м/с
-4	5.4	4.9	4.3	3.8
-2	4.9	4.3	3.8	3.2
0	4.3	3.8	3.2	2.7
2	3.8	3.2	2.7	2.2
4	3.2	2.7	2.2	1.8

PMV= -0.49 PPD=10% 0.7 clo Y=50%
1б (1.3 met 76 Вт/м2)

Δтрад, °C	v = 0.1, м/с	v = 0.3, м/с	v = 0.5, м/с	v = 0.7, м/с
-4	3.4	2.9	2.3	1.8
-2	2.9	2.3	1.8	1.3
0	2.3	1.8	1.3	0.8
2	1.8	1.3	0.8	0.3
4	1.3	0.8	0.3	-0.2

PMV= -0.49 PPD=10% 0.7 clo Y=50%
1б (1.4 met 83 Вт/м2)

Δтрад, °C	v = 0.1, м/с	v = 0.3, м/с	v = 0.5, м/с	v = 0.7, м/с
-4	1.3	0.8	0.3	-0.2
-2	0.8	0.3	-0.2	-0.7
0	0.3	-0.2	-0.7	-1.2
2	-0.2	-0.7	-1.2	-1.7
4	-0.7	-1.2	-1.7	-2.2

M = 1,1; 1,2; 1,3; 1,4 met

Equivalent comfort temperature

Equivalent temperature by Madsen T. L. (ASHRAE trans. - 1984. - T. 90):

$$t_{eq} = 0.55 * t_a + 0.45 * \bar{t}_r + \frac{0.24 - 0.75\sqrt{v_a}}{1 + I_{cl}}(36.5 - t_a)$$

New index: ***equivalent comfort temperature:***

$$\boldsymbol{t_{eqc}} = 0.55 * t_{ac} + 0.45 * \bar{t}_{rc} + \frac{0.24 - 0.75\sqrt{v_{ac}}}{1 + I_{cl}}(36.5 - t_{ac})$$

Equivalent comfort temperature data base

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Comfort class: B Activity: 1.1 met Clothes: 1.0 clo

Calculation example

PMV = +0.49				
Δt_r, °C	v = 0.1, m/s	v = 0.3, m/s	v = 0.5, m/s	v = 0.7, m/s
-8	24.5	24.1	23.7	23.4
-4	24.5	24.2	23.9	23.7
0	24.4	24.4	24.2	23.9
4	24.4	24.5	24.5	24.2
8	24.4	24.6	24.6	24.4
	Mean value **24.2**		Deviation 0.3	

PMV = -0.49				
Δt_r, °C	v = 0.1, m/s	v = 0.3, m/s	v = 0.5, m/s	v = 0.7, m/s
-8	20.4	20.1	19.8	19.4
-4	20.4	20.3	20.0	19.7
0	20.4	20.5	20.2	20.0
4	20.4	20.6	20.5	20.2
8	20.4	20.7	20.7	20.5

PMV = + 0.49			
	0.7 clo	1.0 clo	1.3 clo
1.1 met	25.7	24.2	22.8
1.2 met	25.3	23.8	22.3
1.3 met	24.5	22.9	21.3
1.4 met	23.8	22.1	20.4

PMV = - 0.49			
	0.7 clo	1.0 clo	1.3 clo
1.1 met	22.7	20.3	18.2
1.2 met	21.8	19.5	17.3
1.3 met	20.5	18.0	15.6
1.4 met	19.4	16.8	14.2

Comfort class: B

Summarized data

Equivalent comfort temperature calculation (RU Patent No 2682872)

УНИВЕРСИТЕТ ИТМО

Comfort class ISO 7730	Thermal sensation PMV	Equivalent comfort temperature
A	+0.19	$t_{eqc} = 47.69 * 0.67^{met} * 0.76^{clo}$
	-0.19	$t_{eqc} = 56.10 * 0.58^{met} * 0.70^{clo}$
B	+0.49	$t_{eqc} = 43.23 * 0.73^{met} * 0.80^{clo}$
	-0.49	$t_{eqc} = 66.49 * 0.51^{met} * 0.65^{clo}$
C	+0.69	$t_{eqc} = 40.69 * 0.77^{met} * 0.82^{clo}$
	-0.69	$t_{eqc} = 72.58 * 0.47^{met} * 0.62^{clo}$

Index:

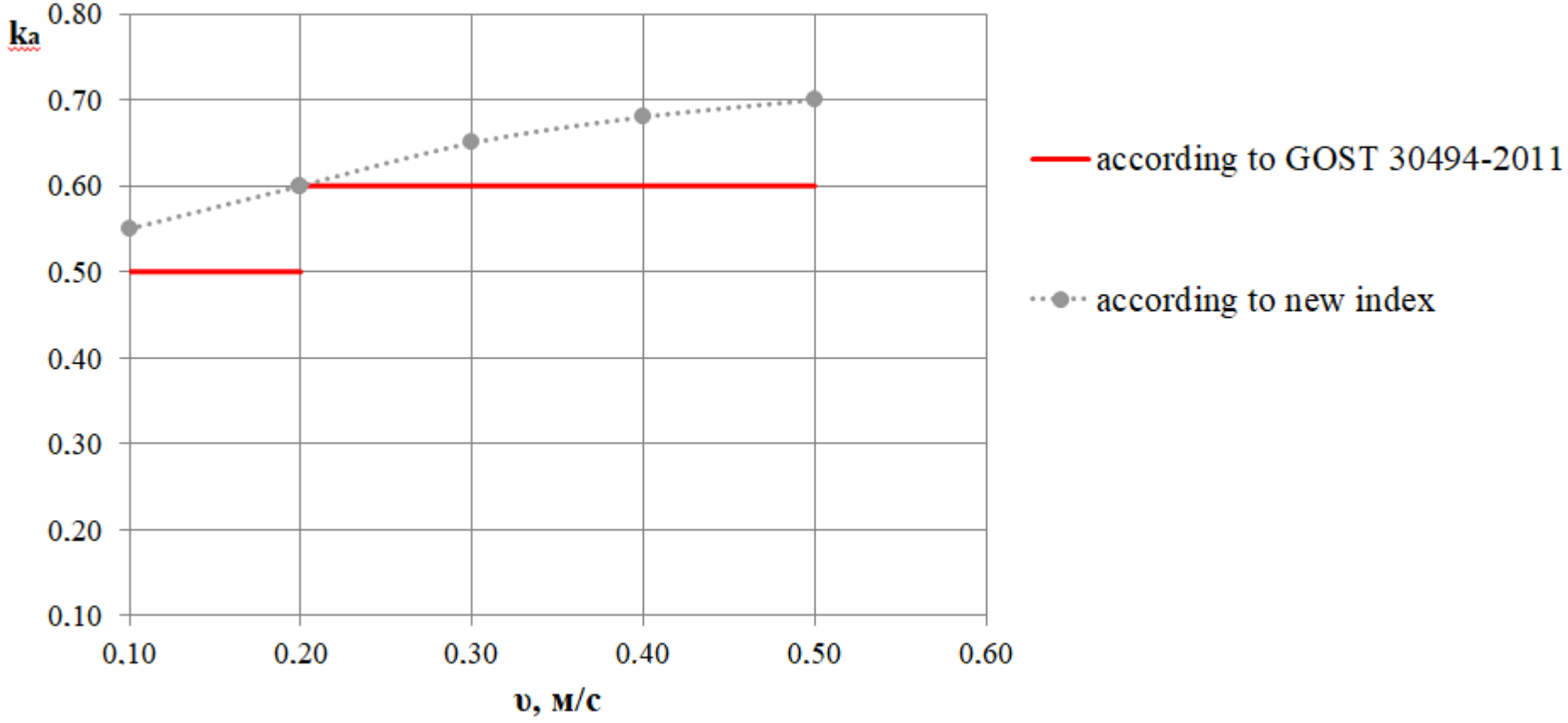
Operative (*resulting, effective*) comfort temperature

	0.1	0.2	0.3	0.4	0.5	
-6	18.47	18.95	19.29	19.46	19.65	Iso-comfort array
-4	17.60	18.25	18.61	18.88	19.07	
-2	16.69	17.51	17.98	18.30	18.54	
0	15.78	16.74	17.30	17.66	17.94	
2	14.95	16.01	16.65	17.07	17.41	
4	14.11	15.25	15.98	16.46	16.82	
6	13.34	14.50	15.26	15.81	16.21	
	0.1	0.2	0.3	0.4	0.5	
-6	15.77	16.61	17.19	17.54	17.85	Operative comfort temperature
-4	15.8	16.69	17.21	17.60	17.87	
-2	15.79	16.73	17.28	17.66	17.94	
0	15.78	16.74	17.30	17.66	17.94	
2	15.85	16.79	17.35	17.71	18.01	
4	15.91	16.81	17.38	17.74	18.02	
6	16.04	16.84	17.36	17.73	18.01	
Mean value	15.84857	16.74429	17.29571	17.66286	17.94857	
Deviation	0.097541	0.078285	0.07413	0.072736	0.069144	
Weight ratio for t_a	**0.55**	**0.61**	**0.65**	**0.68**	**0.7**	
Weight ratio for t_r	**0.45**	**0.39**	**0.35**	**0.32**	**0.3**	

New index

$$t^*_o = k_a \cdot t_a + (1 - k_a) \cdot t_r$$
$$k_a = -0.64 \cdot v^2 + 0.76 \cdot v + 0.48$$

New operative temperature wight ratio



Operative temperature: 3 calculate methods

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ANSI/ASHRAE Standard 55

$$t_o = \frac{t_r + t_a \cdot \sqrt{10v}}{1 + \sqrt{10v}}$$

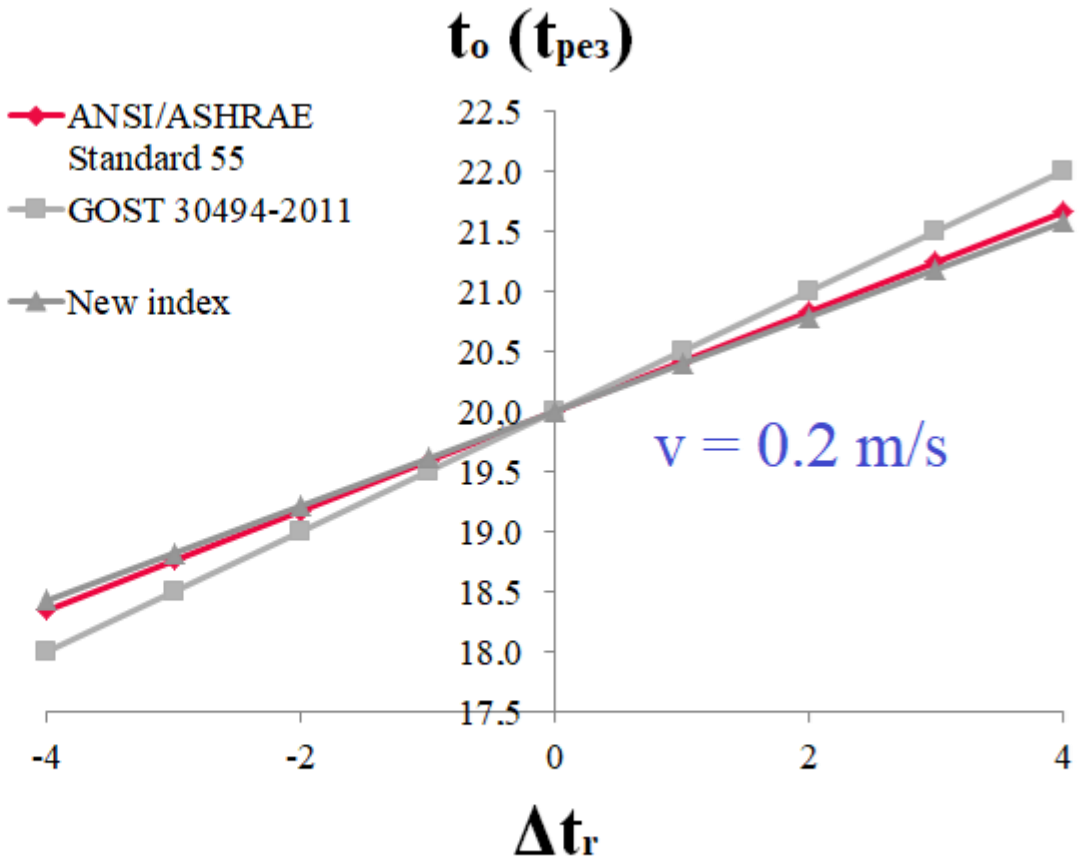
GOST 30494-2011

$$t_o = \frac{t_a + t_r}{2} \; for \; v \le 0.2$$

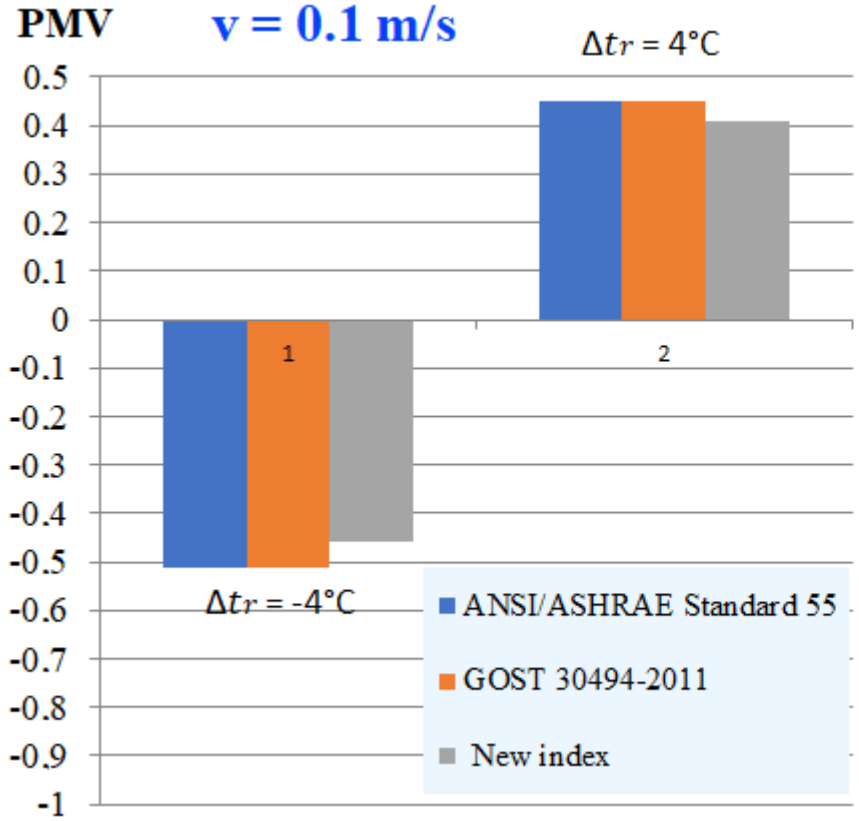
$$t_o = 0.6t_a + 0.4t_r$$

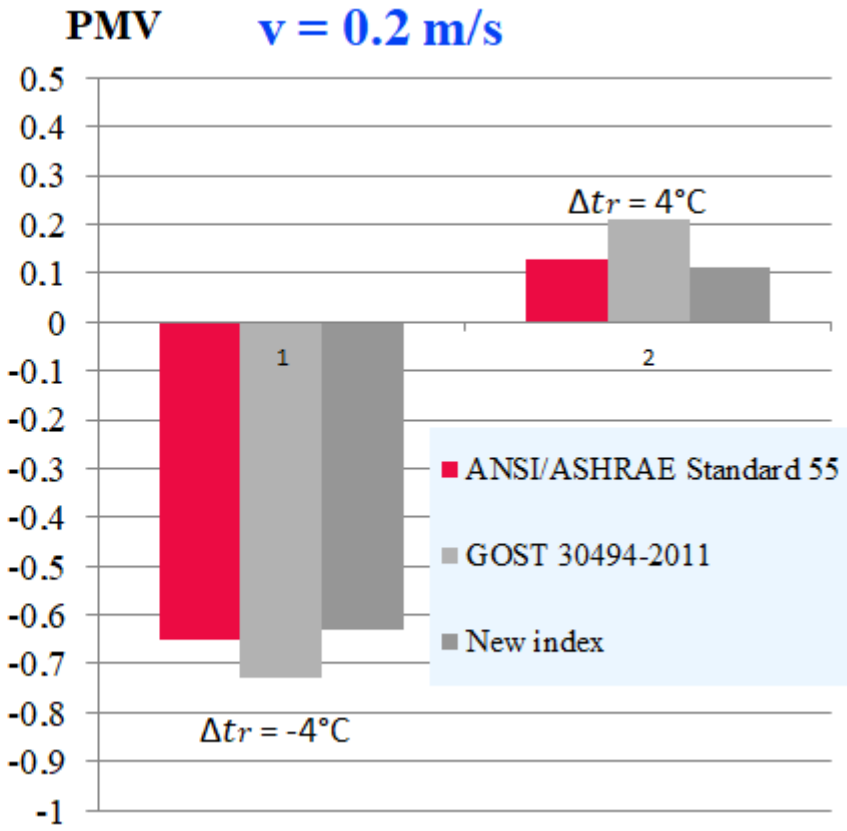
New index

$$t^*_o = (-0.64v^2 + 0.76v + 0.48) \cdot t_a + (0.64v^2 - 0.76v + 0.52) \cdot t_r$$



Predicted mean vote of thermal comfort based on operative comfort temperature (t_a = +23°C)





Conclusions

1. New concepts have been introduced:
- isocomfortable parameters matrix;
- equivalent comfort temperature;
- radiation temperature difference;
- the temperature difference of the ball thermometer;
- operational (resulting) comfortable temperature.

2. Generalized calculated expressions for the premises microclimate parameters of three comfort classes according to ISO 7730 have been obtained and patented.

3. New weighting factors were obtained for determining the operating temperature based on the method of P.O. Fanger.

4. It is shown that the use of a new method for calculating the operating temperature leads to an increase in the expected thermal comfort level in the room.

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Thank you for attention

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