

USE OF GLOBE STEREO THERMOMETER FOR EVALUATION OF IRREGULAR RADIATION LOAD

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Introduction

Till now Czech legislation lacks the methodics for measurement and evaluation of irregular temperature load. The essentials for measurement and assessment are contained in EN ISO 7730:2005 Standard. This norm results from the prediction of percentual proportion of dissatisfied persons (PPD) on the base of difference of radiation temperature of two opposite surfaces $\Delta(t_{rA} - t_{rB})$. The aim of this study was to verify globe stereo thermometer as appropriate indicator of irregular radiation load and to develop criteria for evaluation of irregular radiation load in environmental and occupational settings.

Methods

Experiments were held in climate chamber in a set of 20 persons (10 men and 10 women) and included measurement of physiological parameters, factors of environment and subjective evaluation of temperature sense impressions. Experimental persons (EPs) were dressed in uniform suit with thermal resistance 0.7 clo. The resultant temperature of globe thermometer (t_g) in the height of head was convenient in all experiments with optimal conditions for mental work in sitting position i.e. 24 °C. The difference between radiation temperature in direction of radiation t_{rA} and t_g ($\Delta t_{rA} - t_g$) in case of vertical radiation surface was in individual experimental conditions ± 0 , ± 5 , ± 10 and ± 20 °C, in case of horizontal radiation surface in range from ± 20 to ± 34 °C (radiation intensity 100 and 200 W.m⁻²). Experiments were divided into three phases by air velocity (v_a): 0.25 m.s⁻¹, 0.5 m.s⁻¹ 1.0 m.s⁻¹. In the course of experiments thermal and humidity settings were continually measured in the height of head (110 cm) i.e. t_g and stereo temperature (t_{stereo}) measured by globe stereo thermometer Jokl-Jirak and recorded into the computer.

Parameters t_a , v_a , t_{rA} a RH were measured by Indoor Climate Analyser type 1213 Bruel a Kjaer. EPs were exposed to the same conditions always in duration of 1 hour. In case of experiments EPs were sitting next to computer (in case of vertical radiation surface forehead to the source of radiation) and were solving computer games making demands on attention and short term operational memory. In the first and last experiment EPs were exposed to the optimal thermal conditions in which dry air temperature (t_a), t_{rA} and t_g were identically 24 °C. All physiological parameters values of heart frequency, skin temperature at six places on body surface and body temperature were continually measured and recorded. At the end of experiment each person filled questionnaire including total temperature sense impressions. Temperature sense impressions were expressed in scale ASHREA in range -3 (cold) to +3 (hot) (Table 1). Data was analysed by correlation and regression analysis. Program Stata v.9 was used for the statistic evaluation.

Table 1 Subjective temperature sense impressions by CSN EN ISO 7730

Evaluation	Temperature sense impressions
-3	Very cold
-2	Cold
-1	Moderately cold
0	Comfortable
1	Moderately hot
2	Hot
3	Very hot

RESULT

In all conditions stereo temperature correlated significantly ($R = 0.972$) with radiation temperature measured by the Bruel a Kjaer device (Fig. 1). The high correlation was found also between difference of radiation temperature of opposite surfaces $\Delta(t_{rA} - t_{rB})$ and $\Delta(t_{stereo} - t_g)$ (Fig. 2). Difference of radiation temperature $\Delta(t_{rA} - t_{rB})$ correlated significantly with total thermal sense impressions in experiments with hot and cold vertical radiation surface (Fig. 3a) and in experiments with horizontal radiation surface (Fig. 3b). Acceptable limits for irregular radiation load for work with energetic rate up to do 110 W.m⁻² were proposed with regard to ventilation system. For category A, B and C limit values $\Delta(t_{stereo} - t_g)$ (°C) were established on level in compliance with sense impressions of heat or cold i.e. $\pm 0,67$, $\pm 1,25$ and ± 2 by ASHREA. The limit values of $\Delta(t_{stereo} - t_g)$ were calculated on the base of formulas in figures 3a and 3b.

Proposal of criteria for evaluation of irregular radiation load

The difference between the resultant temperature of globe thermometer (t_g) in the height of head and ankle must not be more then:

- 2 °C for category A
- 3 °C for category B
- 4 °C for category C

Assymetry between radiation temperature and temperature of the horizontal and vertical radiation surfaces must not exceed the values in tables 2 and 3.

Table 2 Limit values of temperature difference ($t_{stereo} - t_g$) for vertical radiation surface

Category	VERTICAL RADIATION SURFACE		
	$t_{stereo} - t_g$ (°C)		
	Min	Optimum	Max
A	0.6	2.1	3.6
B	-0.5		4.7
C	-1.9		6.2

Table 3 Limit values of temperature difference ($t_{stereo} - t_g$) for horizontal radiation surface

Category	HORIZONTAL RADIATION SURFACE		
	$t_{stereo} - t_g$ (°C)		
	Min	Optimum	Max
A	2.8	4,0	6.8
B	1.4		8.2
C	-0.5		10.2

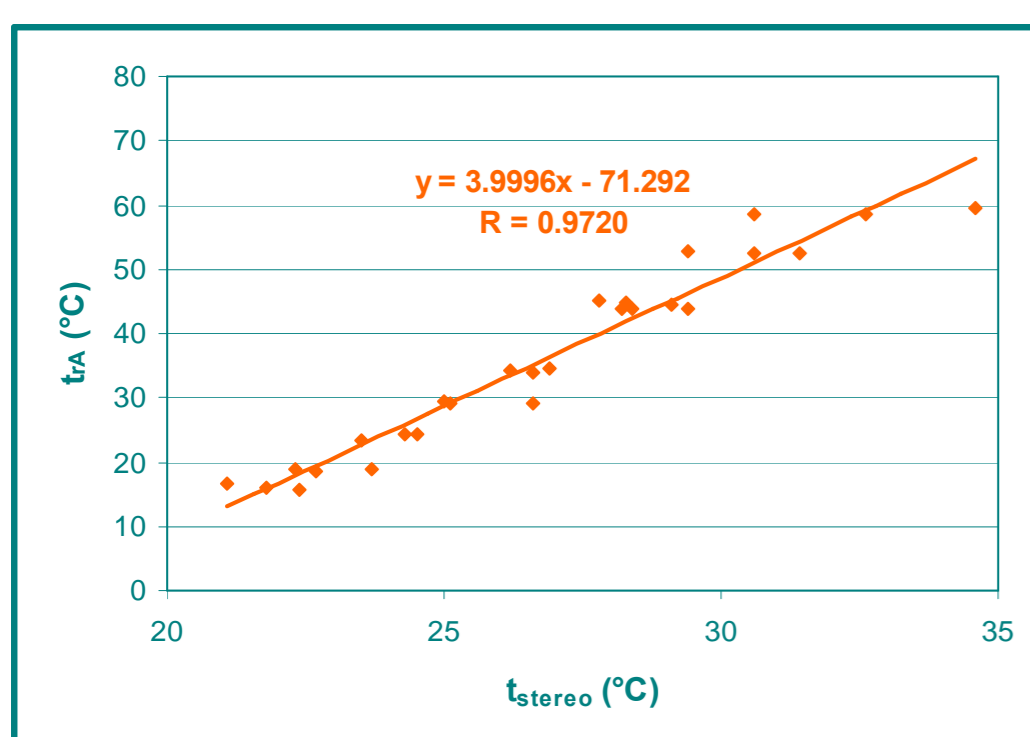


Figure 1 Relationship between radiation temperature (t_{rA}) and stereo temperature (t_{stereo}) for all levels of air velocity

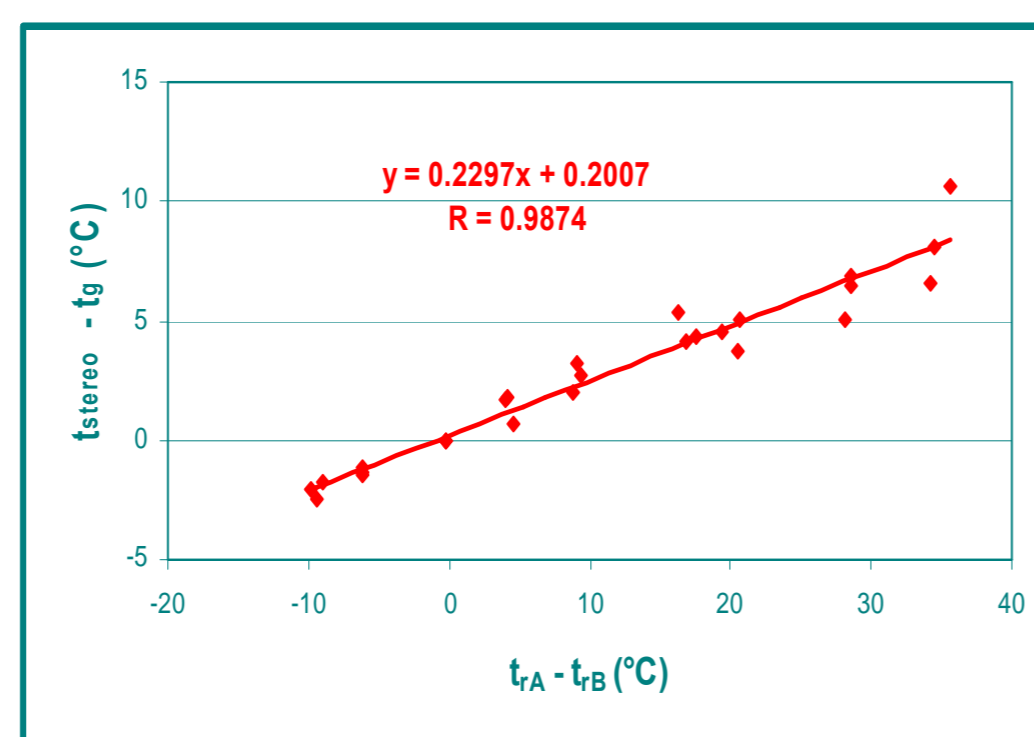


Figure 2 Relationship between differences of temperature ($t_{stereo} - t_g$) and ($t_{rA} - t_{rB}$) for all levels of air velocity

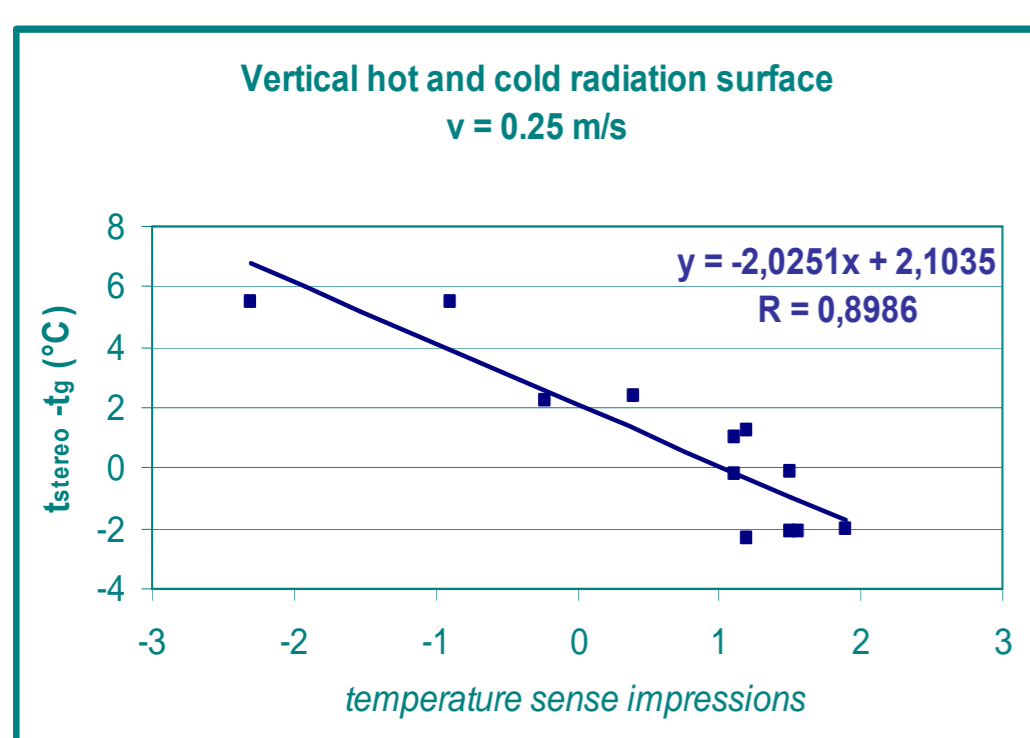


Figure 3a Relationship between differences of temperature ($t_{stereo} - t_g$) and temperature sense impressions for vertical radiation surface

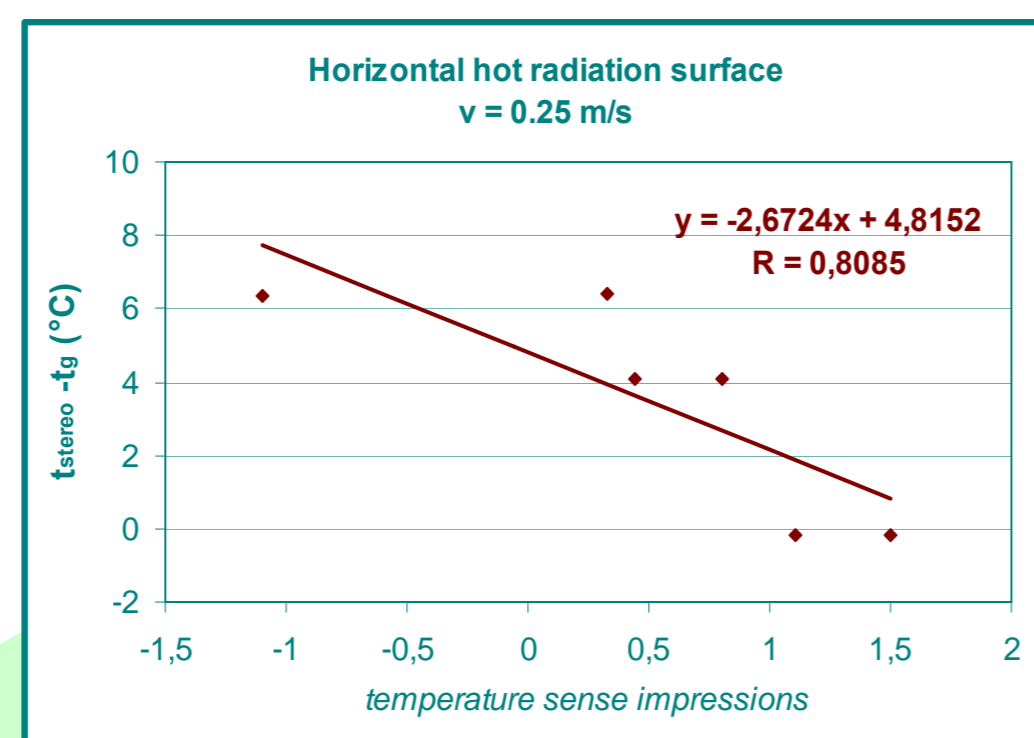


Figure 3b Relationship between differences of temperature ($t_{stereo} - t_g$) and temperature sense impressions for horizontal radiation surface

Discussion

Impression of temperature sense is a highly subjective matter. Women perceived temperature as colder than men in all experiments under the same conditions (4). From this reason our proposal is based also on response of physiological indicators and results of investigation of mental function.

Conclusion

Proposal for evaluation of irregular radiation-convection load was elaborated on the base of investigation of subjective impressions, physiological response of organism and mental function in a set of 20 experimental persons within 540 experiments under the exactly defined conditions in climatic chamber. Limit values for category A should be required for workplaces with domination of intellectual work in sitting position. Limit values for category B should be required for all workplaces with permanent stay of persons if the conditions for category A are not met. Limit values for category C should be acceptable only for workplaces without permanent stay of persons with duration of stay shorter than 4 hours per work shift.

