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# Work in heat strain environment

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**Abstract**
Thermal load on people in general depends on the heat production in the human organism as a result of physical activity as well as environmental conditions which are affected by transfer of heat between human and the surrounding area. The resulting effect of metabolic exchanges which occur in work activities is the thermal load of organism. The paper deals with the evaluation of microclimatic conditions of of workers, who are exposed to the hot environment during their work.

**Keywords:** Strain environment, human organism, microclimatic conditions

## Introduction

Stress at workplace usually arises from an interaction of several risk factors. One of them may also be unsuitable climatic conditions. Thermal-moisture microclimate (TMM) is part of the overall microclimate in working environment, in which the most important factors are air temperature, middle temperature of the radiation, air moisture and air velocity.

At workplaces, where the values exceed acceptable microclimatic conditions due to the heat load from technological resources and at the rest of workplaces, where during extraordinary hot days work hours must be adjusted so that long-term and short-term viable TMM conditions are not exceeded. Acceptable microclimatic conditions are identified by long and short term tolerable load of the heat. Viable long-term heat load is limited by the amount of water excreted from the body through sweating and breathing, limit values for acclimated and non-acclimated employees are set out in decree [5]. Short-tolerable heat load is limited by the amount of stored heat in the body, that for acclimatized and non-acclimatized employees must not exceed 180 kJ.m$^{-2}$. This corresponds to a rise in core body temperature of 0.8 K, the rise of average skin temperature by 3.5 K and increase of heart rate to a maximum value of 150 min$^{-1}$.

Long and short periods of work acceptable at increased load of heat for men and women are determined by dependence on the energy intensity work class and the microclimatic conditions for acclimatized and non-acclimatized workers. Specific situation in the workplace is the thermal load from strong radiation from heat figures to adjust column length.

On the last page of your paper, adjust the lengths of the columns so that they are equal. Use automatic hyphenation and check spelling. Digitize or paste down figures. sources. In this case, the heat load for each exposed workplace using appropriate evaluation methods with the help of stereotemperature tg, asymmetry in radiation temperature or by WGBT indicator [3].

In case of radiant heat sources where stereotemperature at workplace exceeds 43°C or radiance exceeds 700W.m$^{-2}$, it is necessary to use protection against radiant heat.

## Bearable Heat Load

From the basic data it is possible to determine heat load by Wet Bulb Globe Temperature (WBGT) indicator by measuring of parameters derived from the data. WBGT is one of empiric indicators representing heat load, to which an individual is exposed [3, 4].

It represents a wet and ball thermometer temperatures, which combines natural ventilation temperature of the wet bulb thermometer $t_{vn}$, the resulting temperature of ball thermometer $t_g$, and air temperature $t_a$. WBGT indicator without the influence of solar radiation is calculated as:

$$WBGT = 0,7t_{nv} + 0,3t_g. \quad (1)$$

For WGBTS indicator with solar radiation applies:

$$WBGTS = 0,7t_{nv} + 0,2t_g + 0,1t_a. \quad (2)$$

**Table 1:** Reference values of WBGT heatload

| No. | Energetic outgo | | Reference value of WBGT | | | |
|---|---|---|---|---|---|---|
| | $q_M$ [W.m$^{-2}$] | M [W] | Person acclimatized on heat [°C] | | Person not acclimatized on heat [°C] | |
| 0 | M≤65 | M≤117 | 33 | | 32 | |
| 1 | 65<M≤130 | 117<M≤234 | 30 | | 29 | |
| 2 | 130<M≤200 | 234<M≤360 | 28 | | 26 | |
| 3 | 200<M≤260 | 360<M≤468 | No feeling of air moving | Feeling of air moving | No feeling of air moving | Feeling of air moving |
| | | | 25 | 26 | 22 | 23 |
| 4 | M>260 | M>468 | 23 | 25 | 18 | 20 |

No. - energetic outgo class' size according to character of work (0 - tranquility, 1 - low, 2 - medium, 3 - high, 4 - very high energetic outgo); $q_M$ - energetic outgo per body unit [W.m$^{-2}$]; M - total energetic outgo per standard person with body coverage of 1.8 m$^2$

Evaluation method of heat stress according to this indicator describes the standard STN ISO 7243 "Hot environment: Determination of worker's thermal load ratio according to WBGT indicator" [3]. This evaluation method is considered only as a screening method. It is a compromise between the exact evaluation of the heat load and the effort to carry out control measurements in industrial applications.

Direct determination of the heat load by analysing data on heat exchange between men and the environment allows to accurately assess the load and to analyse ways of protection, which is very laborious and time consuming. It requires further detailed analysis and synthesis of data about working conditions in a hot environment and about individuals, especially when the acquired data exceed benchmarks of WGBT (see Table 1).

For reliable classification of the size of energy outgo it is necessary to make an objective measurement of energy outgo according to a detailed analysis of the activity. Reference values correspond to the level of exposure which workers can (under the conditions listed in Table 1) be exposed to without adverse effects on health, and these conditions should not cause accidents, as they were found no contra findings.

The introduction of methods for assessing the heat load by the WGBT indicator replace several methods of determining the heat load, because such indicator does not exist yet. Established international standard is suitable for use in industrial environments +. This standard is not suitable for assessing heat load during short time intervals, nor the evaluation of thermal comfort conditions. It is designed to assess the average effect of heat on men during the period of its effect and provides quick information. If reference benchmarks of heat load indicator are exceeded, it is necessary to lower heat load at workplace by appropriate technical measures or by organizational measures – determining the bearable work time. Setting the bearable work time can ensure compliance with viable long-term or short-term heat load. Indicative values of long and short term viable heat load are listed in the Annexes to the Decree [5].

**Practical Verification of Measuring Methodology**

Thermal-moisture microclimate has been the subject of measuring small foundry workplace, where a radiant heat sources were four furnaces. Measuring points (M1 to M4) were selected to represent place of residence of workers during the performance of their work. Measurement was carried out during a summer day with daytime temperatures from 18 to 29 °C in the morning time change. Measured parameters were air temperature ta (°C), the resulting spherical bulb temperature $t_g$ (°C), wet bulb temperature $t_{vn}$ (°C), air velocity $v_a$ (m.s$^{-1}$) and relative humidity $R_h$ (%). Digital devices with a spherical sensor $t_g$, $t_{vn}$ triple-probe for sensing $v_a$, $R_h$, $t_a$ were used.

**Table 2:** descriptive statistics: measuring points M1, M2

| | M1 | | | | M2 | | | |
|---|---|---|---|---|---|---|---|---|
| | min | $\bar{x}$ | max | $s$ | min | $\bar{x}$ | max | $s$ |
| $t_g$ | 36,3 | 36,7667 | 37,0 | 0,3011 | 33,6 | 35,1167 | 35,7 | 0,7935 |
| $t_a$ | 33,8 | 34,083 | 34,5 | 0,2483 | 32,8 | 33,450 | 35,4 | 0,9731 |
| $t_{vn}$ | 26,5 | 26,6667 | 26,90 | 0,1633 | 25,9 | 26,0333 | 26,30 | 0,1366 |
| $v_a$ | 0,10 | 0,1433 | 0,22 | 0,0468 | 0,14 | 0,2350 | 0,32 | 4,2881 |
| $R_h$ | 44,0 | 48,000 | 55,3 | 4,2881 | 44,7 | 46,750 | 51,8 | 2,5844 |

**Table 2:** Descriptive Statistics: Measuring Points M3, M4

| | M3 | | | | M4 | | | |
|---|---|---|---|---|---|---|---|---|
| | min | $\bar{x}$ | max | $s$ | min | $\bar{x}$ | max | $s$ |
| $t_g$ | 36,1 | 36,7500 | 37,4 | 0,5541 | 34,9 | 35,3500 | 35,5 | 0,2345 |
| $t_a$ | 32,2 | 33,600 | 34,6 | 1,0714 | 33,1 | 33,200 | 33,3 | 0,0894 |
| $t_{vn}$ | 26,2 | 26,6333 | 27,00 | 0,3830 | 23,2 | 25,7667 | 26,30 | 1,2580 |
| $v_a$ | 0,11 | 0,2067 | 0,28 | 0,0641 | 44,0 | 46,450 | 52,1 | 2,9541 |
| $R_h$ | 0,11 | 0,2200 | 0,32 | 0,0807 | 44,2 | 46,117 | 48,2 | 1,3318 |

Basic characteristics of the sample number of measured values (selective average $\bar{x}$, maximum, minimum and standard deviation of selection s) are listed in Table 2 and Table 3. Using the scatter chart (Figure 1 and Figure 2) the measured values of the variables at different sites of measurement are shown.

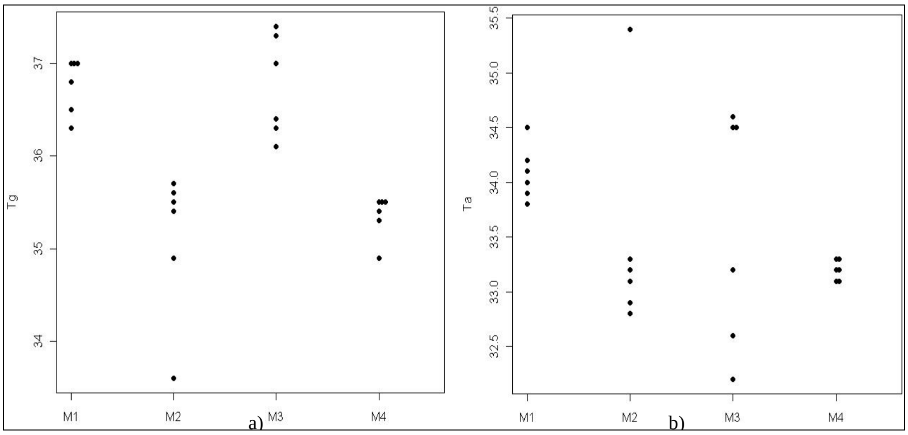


**Fig 1:** a) Resulting temperature of the ball thermometer b) Air temperature

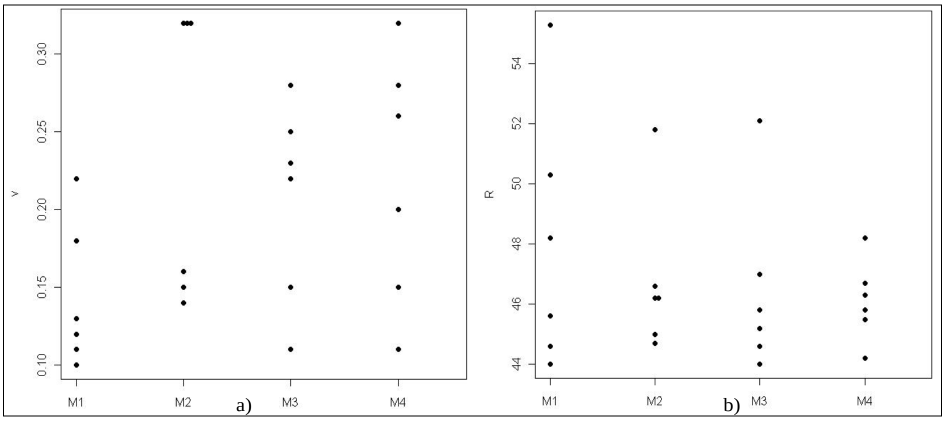


**Fig 2:** a) Air velocity, b) Relative humidity

The average median value of radiation temperature tr (°C), operative temperature $t_0$ (°C) and the intensity of radiation I (W.m$^{-2}$) for each measuring point were obtained by relations (1), (2) and are listed in Table 4. These values significantly exceeded the limit values.

**Table 4:** Values $t_r$, $t_o$, $I$

| Measuring places | $t_r$ [°C] | $t_o$ [°C] | $I$ [W.m$^{-2}$] |
|---|---|---|---|
| M1 | 38,79 | 36,44 | 46,24 |
| M2 | 36,83 | 35,14 | 32,69 |
| M3 | 39,69 | 36,65 | 52,61 |
| M4 | 37,47 | 35,34 | 37,08 |

**Table 5:** WBGT values for measuring points M1, M2, M3, M4

| Time | WBGT | | | |
|---|---|---|---|---|
| | M1 | M2 | M3 | M4 |
| 9:00 a.m. | 29,73 | 28,88 | 29,47 | 29,03 |
| 10:00 a.m. | 29,72 | 28,84 | 29,23 | 26,89 |
| 11:00 a.m. | 29,86 | 28,28 | 29,17 | 28,88 |
| 12:00 a.m. | 29,72 | 29,03 | 29,93 | 28,93 |
| 13:00 a.m. | 29,50 | 28,85 | 30,09 | 29,06 |
| 14:00 a.m. | 29,65 | 28,67 | 30,12 | 29,06 |

Calculated values for WGBT indicator according to equation (2) for the individual measuring points are listed in Table 5. Scatter plots of measured values of wet bulb thermometer temperature and the calculated values of WBGT heat load are shown in Figure 3. Table 5

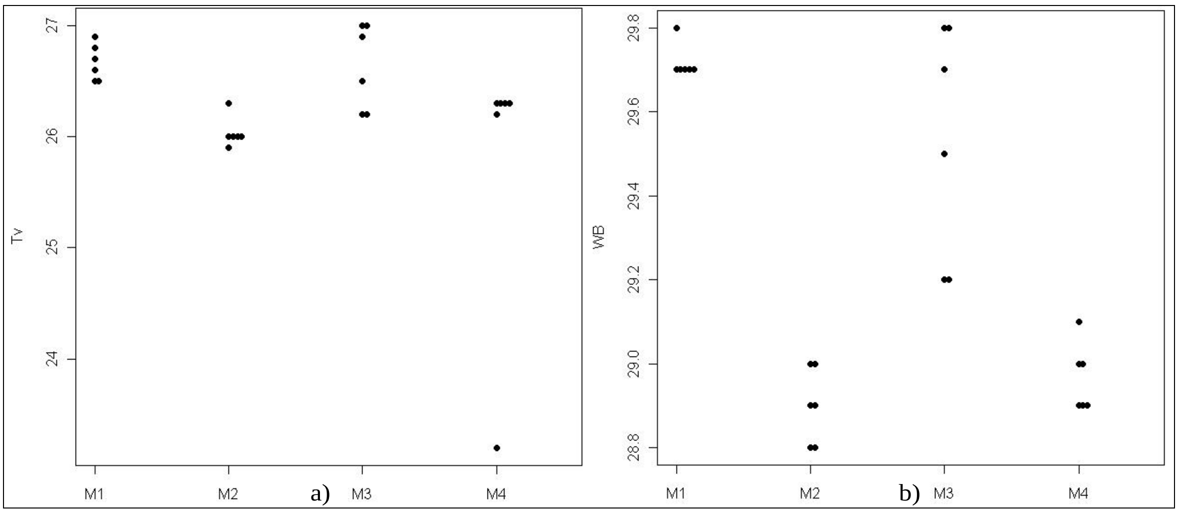


**Fig 3:** a) Temperature of wet bulb thermometer, b) WBGT indicator

The values of the thermal load indicator by WGBT are compared with benchmark WGBT indicators, which are listed in Table 2. By comparing the values significant differences were found, on these basis it is necessary to draw the appropriate technical, health, organizational and other measures.

**Discusion And Conclusion**

Hot environment weakens the physical and mental performance. If the values of microclimatic variables are beyond the permissible values the work time must be adjusted in order to meet long-and short-term tolerable heat load. The most effective protection against heat load is combination of various methods - technical regulation or administrative regulation, and personal protective equipment (cooling, breathable clothes), water refreshment (hydration), breaks in work time. Acclimatization is another option – it is a result of physiological adaptation process. Acclimatization can be achieved either artificially by controlled repeated exposure in the acclimatization chamber, or naturally by progressive prolongation of intervals of performed work in hot environment.

The aim of our paper was to monitor and evaluate parameters of thermal and humid microclimate under real conditions of an engineering company and to determine satisfaction or dissatisfaction of employees relating to microclimatic conditions on their workplaces through a questionnaire survey. The results of the survey can be instrumental for the company management in elimination of potential drawbacks in the sense of a principle of continuous improvement also in the sphere of microclimatic conditions with the aim to ensure high level of hygiene, quality and safety of working environment.

The employer should create a hospitable working environment in the long term by taking care of his employees in such a way as to motivate them to high work performance. A suitable or comfortable working environment is of its relevant significance and brings not only positive results in the form of high working performances, but also in the form of satisfied employees. The increasing labour productivity as well as the quality of the provided services reflect a positive working climate. Similarly, a quality of working environment motivates and encourages activity, expecting creative improvement of performance. Thus, the expectations of the organization could be fulfilled in case, if the expectations of its employees are fulfilled.

In creating and maintaining a good market position, it is a very important factor for companies to provide employees with a working environment tailored to their capabilities and needs. Nowadays, when there is a strong competition among employers, the employer can gain competitive advantage even through the optimal working environment and the satisfied employees.

Appropriate workplace conditions ("well-being") are indispensable for manufacturing production, as workers are the most valuable resource of the enterprise, which is still true, at today's high automation, and at the onset of the so-called "4th Industrial revolution ", the employees health protection must be ensured above all because workplace comfort affects not only health, but also productivity of employees.

The article should contribute to the thermo-humidity microclimate as a major part of the working environment. The aim of this article was to emphasize the importance of the people sources, to show the evaluation methods of microclimate conditions and contribute to the discussion of high actual, though still neglect areas, which could have a major impact on the competitive skills of the company. With global climate change and looming reality, designing low energy buildings needs to consider capricious climate variations at play. In a warming world, heating energy demands should reduce while cooling energy demands rise. What is anticipated is that with economic growth, occupant expectations of indoor environments would rise, leading these climate changes to contribute most to rising cooling demands.

The main challenge for the future is to find ways how to influence comfort criteria by designing and operating such buildings so that users can be satisfied while avoiding buildings becoming 'cold domains' closed off from the natural environment.

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