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# EVALUATION OF HEAT STRESS WORKPLACES

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# HODNOTENIE PRACOVISK S TEPELNOU ZÁŤAŽOU

INTEGRATED SAFETY OF THE ENVIRONS

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***ABSTRAKT***
*Príspevok sa zaoberá monitorovaním pracoviska, kde technologické zariadenia produkujú teplo počas horúcich letných dní. Merania tepelno-vlhkostnej mikroklímy prebiehalo počas dennej pracovnej zmeny a bolo realizované na 5 vybraných meracích miestach. Meranie, spracovanie výsledkov a interpretácia boli realizované podľa platnej legislatívy SR.*

***KĽÚČOVÉ SLOVÁ:*** *horúce prostredie, tepelno-vlhkostnej mikroklíma, meranie, hodnotenie.*

***ABSTRACT***
*The paper deals with monitoring of workplace where technological equipment produces heat during hot summer days. The thermo-hygric microclimate measurement took place during daily work shift, and was carried out at 5 choosen measuring points. The measurement, result processing and interpretation was carried out according to the valid legislation of Slovak Republic.*

***KEYWORDS:*** *Hot environment, thermo-hygric microclimate, measuring, evaluation.*

## INTRODUCTION

Physical quantitiesof thermal-moisturemicroclimate(temperature, relative humidity, air velocity) definessubjectivefeelings ofcomfortordiscomfort. In extreme casesthey can be qualified as apollutantswithnegative effectson human health. Basicinformationandgeneral requirements for theinternalenvironmentof buildingsas well as details and requirements forhygrothermalmicroclimate

are stated in the Ministry ofHealth of the SlovakRepublicNo 99/2016 Z. z.[1]. Monitoring of parameters ofheat-moisture microclimate was conductedto assessconformity/non-conformity with valid legislationin theinterior ofhotproduction facility.

## 1 PRACTICAL MEASUREMENT OF THERMAL ENVIRONMENT

Monitoring of thermo-hygricmicroclimatew as carried out using the Testo400, to whichtri-functional probe was attached, three-level globe Vernon-Jokl thermometer. Use dequipmentmeets ISO7726 requirements for accuracy. Based on the movement of workers during the irworkshift, five measuring points were selected. These most frequent places were then monitored for 6 hours. Along with measuring points, activities of workers were also analyzed and later served in overall evaluation of the measurement. Because there are two major sources of radiant heat in operation, variable air speed and people moving freely, environment was evaluated as a heterogeneous and non-stationary. Therefore it was necessary to perform measurement sat three levels: head (1.7 m), abdomen(1.1 m), ankles(0.1 m). Results obtained from two measurement points were put into table and basic statistic was implied in calculation.

Outside climatic situation of workplace is also a part of the monitoring of thermo-hygricmicroclimate. During the measurement there was a sunny day and the outdoor air temperature was between29and34 [°C]. Relative humidity was about 40 [%] and air velocity was about 6 [$m.s^{-1}$].

## 2 EXPERIMENTAL MEASUREMENTS OF THERMO - HYGRICMICROCLIMATE

Three basic physical quantities of thermo-hygric microclimate were measured - Rh relative humidity [%], the dry air temperature ta [°C] and air velocity va [$m.s^{-1}$] with measuring device Testo 400. Measurements took place in 5 measuring locations M1, M2, M3, M4, M5 during 6 hours. Measured values of thermo-hygric microclimate were processed in MS Excel. Basic statistical functions such as: min (the lowest value of the set of values), max (maximum value of the set of value|, average (arithmetic mean arguments), stdev (standard deviation), median (middle value of a group of numbers), var (variance values), mode (most frequently occurring value in a group of numbers) were used. Measured values of dry air temperature, air velocity and relative humidity at each measuring points and at all three levels were statistically processed in MS Excel program (Table 1).Graphical processing of data obtained by measuring of Testo 400 is shown on the Figure 1, 2, 3.

*Table 1:Statistical processingof the measuredvalues on workplaceM1*

| Function | $R_h$ [%] | | | $t_a$ [°C] | | | $v_a$ [m/s] | | |
|---|---|---|---|---|---|---|---|---|---|
| | Head | Abdomen | Ankles | Head | Abdomen | Ankles | Head | Abdomen | Ankles |
| min | 32,2 | 32,7 | 31,3 | 29,7 | 29,6 | 25,4 | 0,03 | 0,01 | 0,02 |
| max | 48,6 | 46,8 | 47,1 | 36,7 | 36,1 | 36,1 | 0,51 | 0,71 | 0,66 |
| average | 39,30 | 38,34 | 39,13 | 33,01 | 32,74 | 31,99 | 0,19 | 0,2 | 0,18 |
| stdev | 3,31 | 3,13 | 3,39 | 1,264 | 1,13 | 1,41 | 0,06 | 0,08 | 0,08 |
| median | 39,3 | 38 | 38,9 | 33,05 | 32,8 | 32,2 | 0,24 | 0,23 | 0,25 |
| var | 10,98 | 9,83 | 11,52 | 1,6 | 1,28 | 1,98 | 0,004 | 0,01 | 0,01 |
| mode | 36,2 | 39,4 | 38,4 | 33 | 33,2 | 32,2 | 0,26 | 0,25 | 0,25 |
| Mean value Φ | $\Phi_{Rh}$ [%] | | | $\Phi_{ta}$ [°C] | | | $\Phi_{va}$ [m/s] | | |
| | 38,78 | | | 32,62 | | | 0,19 | | |

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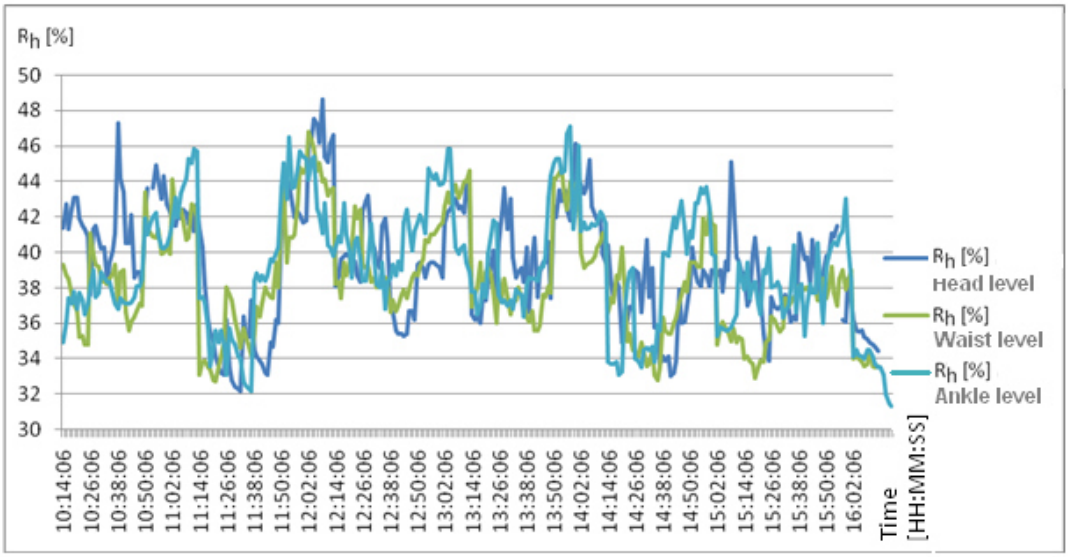


*Figure 1: Overallprogress of relative humidity*

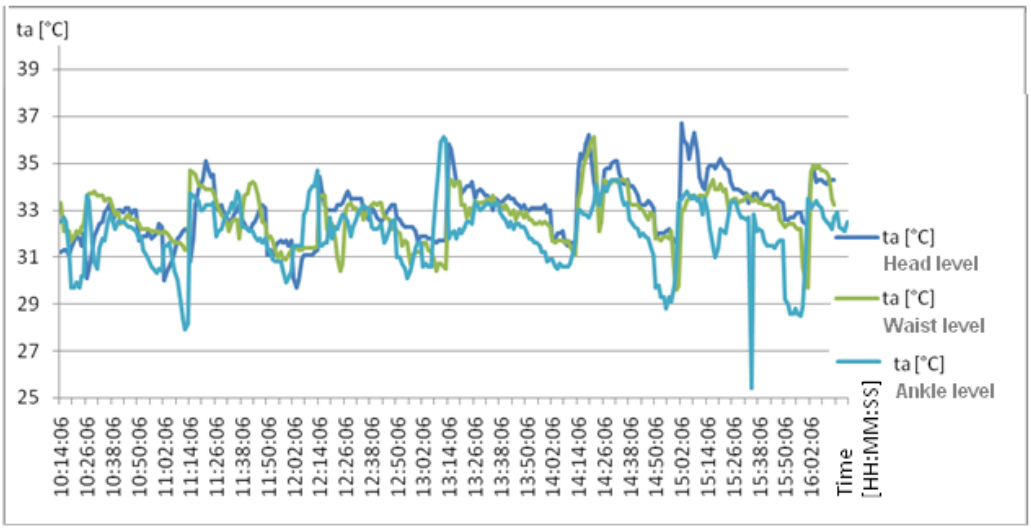


*Figure 2: Overallprogress of dry air temperature*

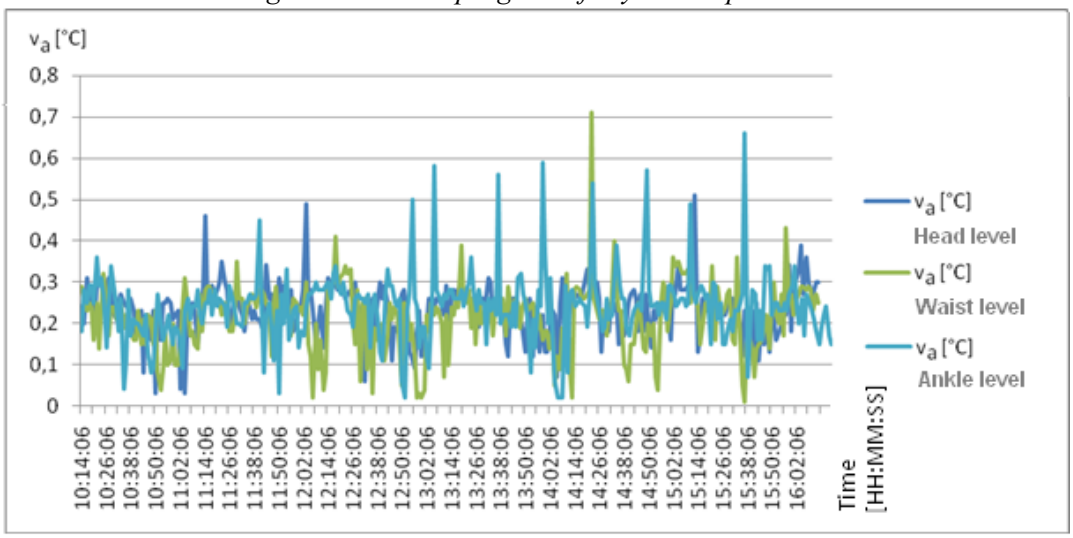


*Figure 3:Overallprogress ofair velocity*

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## 3 GLOBE TEMPERATURE

Temperature measurement obtained by globe thermometer was conducted in order to determine the approximate amount of mean temperature radiation $t_{r,m}$ [°C] by using the three level Vernon-Jokl thermometer. Black ball thermometer is used to derive the approximate value of mean temperature radiation from the observed simultaneous temperatures readings of globe temperature ($t_g$) [°C], air temperature and air velocity surrounding the sphere [2, 3].

Measurements done with this device were conducted at 2 measuring locations during working shift. The values of global temperature, measured by Vernon-Jokl were statistically processed. Graphical processing of data obtained by measuring of global temperature can be seen in Figure 4. On the horizontal axis measuring time is shown while on vertical axis the final temperature of the globe temperature is shown.

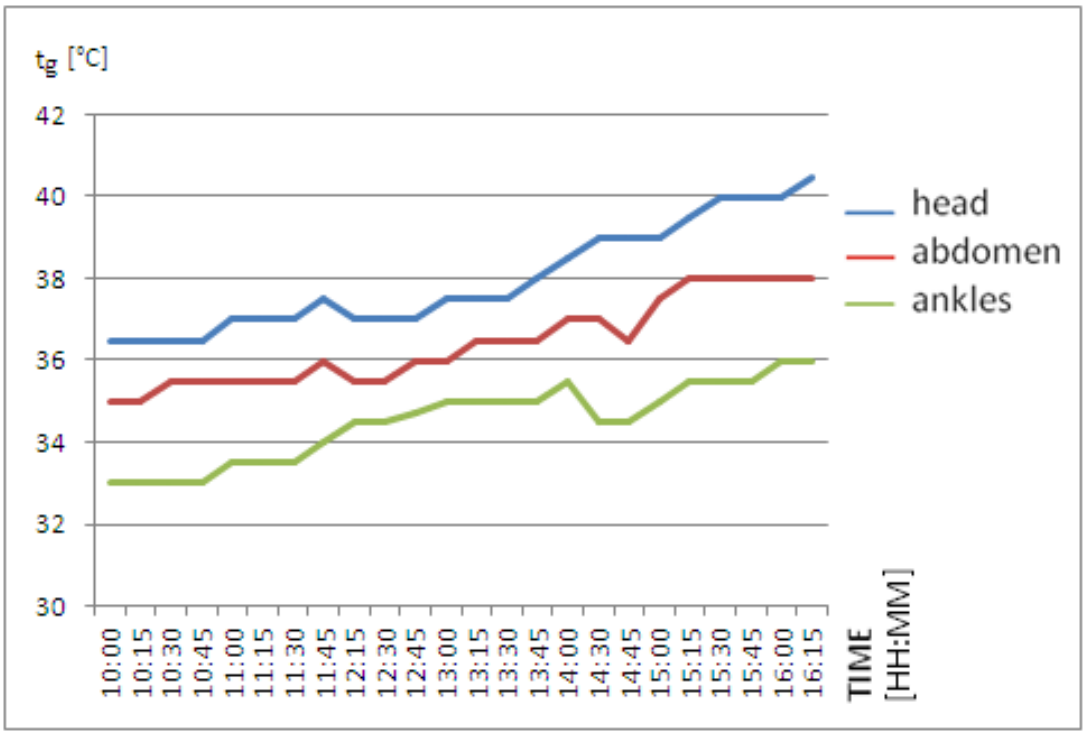


*Figure 4:Overallprogress ofglobe temperature*

## 4 EVALUATION OF MEASURED RESULTS

At present time in Slovakia the basic criteria for evaluating environmental parameters of indoor environment parameters are [4]: $t_g$, $R_h$, $v_a$. Operational temperature $t_o$ [°C] is the uniform temperature of black space in which exchange of the same amount of heat transferred by radiation and convection in the actual non-homogeneous environments between human and environment occurs.

Operational temperature can be directly substituted for the resulting spherical bulb temperature when the air velocity $v_a < 0.2$ [$ms^{-1}$] [5]. Table 4 shows the optimal and acceptable conditions of heat and moisture microclimate for hot and cold time during the year stated in standard of wear by decree of the Ministry of Health of the Slovak Republic č.99/2016 which includes the details of health protection againstheat and cold load at work . Warm period of the year is defined as the period with average daily outdoor air temperature higher than 13 °C.

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*Table 4: Optimal and acceptable conditions ofmicroclimate for the warm period of year [1]*

| Work class | Operative temperature $t_o$ [°C] | | Tolerable air velocity $v_a$ [m.s$^{-1}$ ] | Tolerable relative humidity $R_h$ [%] |
|---|---|---|---|---|
| | optimal | tolerable | | |
| 1a | 20 – 24 | 17 – 26 | < 0,3 | 30 to 70 |

Values $t_o$, $R_h$, $v_a$are used for standardclothing$R_{cl}$=0.3 to 0.5[clo].

Based on thestatisticalprocessingandcalculationresultsforeachmeasurement location wereobtained.(Table.5).There results were then compared with the limitsstated in the legislation [1].

*Table 5:Assessment criteria*

| Measuring location | Mean value | | | |
|---|---|---|---|---|
| | $t_0$ [°C] | $R_h$ [%] | $v_a$ [m/s] | $t_g$ [°C] |
| **M1** | 37,38 ± 0. 5 **Not acceptable** | 37,25 ± 3 **Acceptable** | 0,27 ± 0.05 **Acceptable** | 37,38 ± 0. 5 |
| **M2** | 34,61 ± 0. 5 **Not acceptable** | 37,25 ± 3 **Acceptable** | 0,23 ± 0.05 **Acceptable** | 34,61 ± 0. 5 |
| **M3** | 33,31 ± 0. 5 **Not acceptable** | 37,77 ± 3 **Acceptable** | 0,21 ± 0.05 **Acceptable** | 33,31 ± 0. 5 |
| **M4** | 31,94 ± 0. 5 **Not acceptable** | 41,42 ± 3 **Acceptable** | 0,20 ± 0.05 **Acceptable** | 31,94 ± 0. 5 |
| **M5** | 30,56 ± 0. 5 **Not acceptable** | 40,19 ± 3 **Acceptable** | 0,22 ± 0.05 **Acceptable** | 30,56 ± 0. 5 |

## 5 DISCUSSION

In areas designated for long-term stay of people, optimal conditions for heat-moisture microclimate in hotandcold times during year are provided. Warm period of the year is stated as period during which average daily outdoor air temperature is 13°C or higher. When average daily temperature falls during two consecutive day's below13°C, the studied area is then evaluated according to the values for cold time period of the year. Optimal and acceptable conditions of thermal-moisture microclimate are determined according to work classes where total heat production of the body is evaluated.

## 6 CONCLUSION

Nowadays tropical days are more frequent and hot summer days are increasing the temperature inside of the building. That is why ventilation and air conditioning systems are common. In many manufacturing plants temperature and humidity are provided by air conditions. In the workplaces where hot industrial facilities produce heats and where are not able to provide optimal temperature by air conditions they must be provided at least natural ventilation.

## 7 ACKNOWLEDGMENT

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