Analysis of thermodynamic parameters and their influence on the thermal comfort in the working environment

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Abstract. Air quality inside the building is an important measure of comfort for people living and working in it. Achieving optimal air quality requires a regulated indoor air control system, often in combination with thermal regeneration. Typical short ventilation, irregular window and door ventilation are rarely adequate. From the point of view of the thermal comfort of the environment, it is necessary to predict the development and selection of suitable systems for the thermal comfort of the environment to predict how many thermal factors will affect the population, room temperature uniformity, asymmetry of the radiation temperature, and turbulence intensity of the flowing air. People are capable of detecting heat, temperature changes can feel not only globally, but also as local heat loss on the parts of the body. Thermal comfort is given by the air temperature and radiant heat, air velocity and relative humidity in the room. The main impact of these factors on the comfort level of individuals depends on the activity and type of clothing. The bad thermal comfort is detrimental to workers' health, increasing the risk of accidents and affects adverse effects on the psyche. The assessment of impact of the working environment to human form comparing actual and optimal parameter values of the working environment.

1 Introduction

The human body is a continuous source of heat. This metabolic heat production is divided into basal and muscle metabolism. Basic metabolism is the heat produced by biological processes. Muscle metabolism arises in human activity. Heat produced by the organism must be taken to the environment or body temperature changes. The temperature inside the human body is around 37 °C, while the skin temperature may range from 31 to 34 °C depending on the surrounding environment. Differences arise over time but also by parts of the human body [1].

Indoor environments in buildings create many components. Thermal humidity, smell, aerosol, microbial and acoustic components are essential. The basic influence on people has the thermal humidity parameters of the living room. In terms of impact on human health, air

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quality seems to be the most important factor. Most of these environmental components are affected by ventilation [2].

Space temperature uniformity, asymmetry of the radiation temperature, and turbulence intensity of the flow air affect thermal comfort. People are capable of detecting heat and they can feel changes in temperature globally on the entire surface of the body but also locally on body parts. It has been shown that humans can acclimate to ambient temperature physiologically and psychologically. It is therefore important to address the issues of thermal comfort in the interiors (buildings) and to experimentally determine a suitable way of creating the optimal conditions of the environment. The goal is to ensure a sense of satisfaction from the environment and also to increase work performance and a sense of comfort [3].

2 Dantec system

ComfortSense is a multichannel system for measurement air velocity and air temperature, humidity and operative temperature. It calculates statistical values – Draught rate (DR), Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD). ComfortSense can be used for many applications including HVAC research and development, testing of ventilation equipment, building research, passenger comfort studies in the automotive and aviation industries. Thermal comfort measurements with ComfortSense comply with International Standards EN 13182, ISO 7726, 7730, ASHRAE standard 113 and ASHRAE standard 55. The ComfortSense system consists of a main frame with input channels for up to 16 probes. The omnidirectional probes measure both air velocity and temperature. The ruggedly designed probes and cables are perfectly suited for large test rooms. The draft probe is equipped with an omnidirectional thin-film sensor for measuring air velocity and a small fast-response thermistor for measuring air temperature (Figure 1).

Fig. 1. The draft probe, robust velocity temperature probe and manikin version.

The manikin version of the draft probe is very compact, with a flexible cable connection to the probe tip, making it suitable for building into a manikin for passenger comfort applications. Velocity range is 0.05 to 5 m/s, indicates up to 10 m/s and temperature is -20 to 80 °C for both types. Robust velocity and temperature probe has velocity range 0.1 to 30m/s. Humidity range is 0 – 100 %. Dantec has also operative temperature probe. The sensor element simulates a standing person when it is vertical, a sitting person when tilted 30 °C from vertical and a reclining person when in the horizontal position. Temperature range is 0 – 45 °C (Figure 2) [4].

Fig. 2. Humidity probe, operative temperature probe and main frame.

3 ASHRAE STANDARD 55

ASHRAE Standard 55 (Thermal Environmental Conditions for Human Occupancy) is a standard that provides minimum requirements for acceptable thermal indoor environments. It establishes the ranges of indoor environmental conditions that are acceptable to achieve thermal comfort for occupants. Percent dissatisfied (PD) represent percentage of people predicted to be dissatisfied due to local discomfort. Predicted mean vote (PMV) is an index that predicts the mean value of the votes of a large group of persons on the seven point thermal sensation scale. Predicted percentage of dissatisfied (PPD) is an index that establishes a quantitative prediction of the percentage of thermally dissatisfied people determined from PMV [5-7].

4 Experimental setup

We have a laboratory of chemical analysis. This workplace has three devices, which have furnaces with heating up to 1 500 °C. We have several systems to ensure optimal working conditions. The laboratory is oriented to the South-East side. Roller shutters are installed on the windows to regulate the intensity of sunlight during the day when the laboratory is most used. Floor heating is used to provide heat, ceiling cooling to ensure the cold. The ventilation of the laboratory is ensured by circulating air through the ceiling spouts. We also use a ceiling air-conditioning unit to reduce room temperature. If all three devices are in full operation, room temperature rises rapidly. Workers are subject to varying temperature changes in a relatively short time in this laboratory. Laboratory space is 3 m high (Y), wide is 4.5 m (X) and long 8 m (Z). The basis of experimental verification of laboratory environment parameters will be the monitoring and graphical comparison of PMV, PPD, velocity, humidity and operating temperature. The standard STN 73 0540-3 determines the optimal values of environmental parameter according to the purpose of use. Setting the room measurement and parameters is in the Dantec program. It is possible to set the room size, location of the measuring probes in the space, display options. The natural state of the environment, the working status of the various analysers, the use of the air-conditioning unit, the draft and various weather conditions can be simulated using the laboratory's technological equipment.

5 Results of measurement

Measurement of environmental parameters was performed during simulated loads. The first measurement was in full operation (PP), load conditions were monitored at full operation of two machines without cooling by an air conditioning unit or natural ventilation. The second measurement was the condition using the air conditioning unit. In this measurement, the effect of air conditioning was measured at the maximum (C) and minimum (D) setting of the unit. The maximum temperature setting was 29 °C and minimum 22 °C. Measurement PP – ambient temperature 20 °C, relative humidity 37 %, wind velocity 10 km/h, measurement C and D – ambient temperature 11 °C, relative humidity 82 % and wind velocity 10 km/h. The graphical method is used to evaluate the PVM and PPD indices, which display individual experimental measurements and allow instant comparison with the permissible and optimal value. Evaluation of relative humidity - optimal value according to STN 73 0540-3 determines 30 – 70 %, we measured for PP measurement value 27.2 %, for C - 40.10 % and for D 34.14 %. Measurement PP does not meet the requirements in the standard. Evaluation of operative temperature - optimal value according to STN 73 0540-3 determines 20 – 24 °C, we measured for PP measurement value 25.08 °C, for C – 24.48 °C

and for D 22.25 °C. Condition D complies with the norm. It is cooling by the air conditioner at 22 °C. Load PP and C - the measured values exceed the optimal value. Figure 3 shows the evaluation of the PPD and PMV parameters and their interdependence, which meets the requirements of the ASHRAE 55 Index Standards at the thermal comfort limits. For PPD 10 % (OPTIMUM value) and 20 % (POTENTIAL value) of dissatisfied persons in the given thermal state of the environment and PMV In the range of $-0.5 < PMV < 0.5$ (OPTIMUM value) and $-1 < PMV < 1$ (PERMIT VALUE).

Fig. 3. Index PDD a PMV – measurement PP.

Figure 4 shows that load measurements "C" and "D" under the conditions of simulated load comply with the ASHRAE 55 standard for PMV and PPD.

Fig. 4. Index PDD a PMV – measurement C and D.

6 Conclusion

Ensuring thermal comfort is a challenging task in an investigated laboratory. Analysers must be kept at a minimum temperature of 300 – 600 °C even out of operation. This means that the space is constantly heat-laden regardless of the working activity. The analysers are heated at 1 000 – 1 500 °C during operation. When the samples are incinerated, there is a smell that needs to be removed from the space. The sun shines until the afternoon on that side. The ventilation outlet is in the ceiling at the window. The temperature in the laboratory is kept constant at 24 °C regardless of the operation. We mainly ensure the safe operation of the instruments and a constant temperature in the room. The greatest load was caused by incorrectly adjusting the ceiling slats and lamellas on the ventilation unit.

We have optimized these settings using the Dantec system and we have eliminated such adverse effects on human health. The feeling of thermal comfort for all workers at the same time is difficult but possible with good set of systems and personnel arrangement. We will examine the effect of turning the outer blinds to room temperature and the effect on thermal comfort. We will create lamella settings based on the intensity of sunlight, which will be automatic and integrated into the Intelligent Building Control System.

The research is supported by the European Structural Funds – project ITMS: 26220220048 (50%) and by the project KEGA No. 042ŽU-4/2016” Cooling by physical and chemical processes”.

References

1. K. Parsons, *Human Thermal Environmentals*, CRC Press, 635 p. (2014)
2. S. Carlucci, *Thermal Comfort Assessment of Buildings*, Springer-Verlag Mairland, (2013)
3. STN 73 0540-3:2012: *Tepelná ochrana budov. Tepelnotechnické vlastnosti stavebných konštrukcií a budov. Časť 3: Vlastnosti prostredia a stavebných výrobkov*
4. <https://www.dantecdynamics.com>
5. <http://shop.iccsafe.org/media/wysiwyg/material/8950P219-sample.pdf>
6. P. Vician, M. Holubčík, M. Palacka, J. Jandačka, J. *AeaNMiFMaE* 2016 7p., (2016)
7. P. Nemec, M. Smitka, M. Malcho, *Scientific world journal*, **2014** (2014)
8. P. Nemec, M. Malcho, J. Jandačka, *AIP Conference Proceedings*, **1558** (2013)