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New approaches of heat fluxes determination in the workplace in situ

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ABSTRACT

Article describes the suggestion of measurement method of heat flux density by heat line plate application in area, specifically in workplaces. It presents description of the technical process of measuring system construction for the heat flux density measuring and the method of measured values evaluation in area. Optimization of workstation position is possible with size and direction measuring of heat fluxes in workplace. It is possible to optimize the position in so called optimum state zone of heat fluxes. Determination of heat flux density enables to qualify thermal stress and thermal comfort in workplaces and it is illustrated in examples.

1. Introduction

Thermal comfort and thermal discomfort are two diametrically opposed conditions, which one feels in the internal environment of buildings [14–16]. Boundary between the subjectively perceived states of perception of the human satisfaction with the environment should be verified by objective measurements [12,13]. The purpose of this paper is to describe a measuring system for determining the density of heat flux in the environment. It is necessary to determine size of a heat flux density, place, direction and the length of heat flux source for ergonomic evaluation of climatic environment state in workplaces. We can determine the thermal exposition of environment. Table 1 shows the human interaction with thermal environment in two positions of perception – thermal comfort and thermal discomfort. It is necessary to quantify the values (with measuring) for evaluation of thermal component with radiation and flowing “in situ” in workplace (Table 2).

The evaluation of measured value (from the first column in Table 1) is based on the heat balance factors which are acting between human and thermal environment – internal production of heat (M), heat transfer by radiation (R), heat conduction (C), evaporation (skin –E, respiration – E_{res}) and flowing – respiration (C_{res}). Monitoring of heat transfer radiation uses the measuring instruments in units “watt per square meter” in work environment (steel industry, glass industry, heating system etc.) [10,11,3]. The evaluation consists of determination of either absolute or effective heat fluxes created by radiation. Measuring of heat flux density is possible with the measuring system. The technical solution and application of measuring system is subject of this article. The main principle of suggested device is application of heat plate in area.

2. Methods

This article describes the technical process of measuring system construction for the heat flux density measuring and the method of measured values evaluation in area. Optimization of workstation position in workplace is possible with size and direction measuring of heat fluxes. Determination of heat flux density enables to qualify thermal stress and thermal comfort in the workplaces.

2.1. Current state of measuring equipment

Heat plates are used for heat flux density measurement. They are sensitive sensors which allow the precise measurement and they are situated to construction (material) which generates resistance to the heat flux. The heat goes through the plate thickness and temperature gradient is constituted by heat flux density. The sensor plates (heat plates) for heat flux density measuring are thermocouple in substrate. They provide analogue signals in millivolt. These signals are transferred by conductor to the analyser. The evaluation of radio – convention heat flux by application of heat flux plate is possible in the following cases:

- measurement of solar radiation (pyranometer),
- measurement of heat flux in sheathing of buildings (determination of heat transfer coefficient in construction “U”),
- measurement of heat flux in soil,
- measurement of human exchange heat in health care, designing

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Table 1
Interaction of person with thermal environment – their elements [19].

Thermal comfort = balance between person and environment should be ensured by:	Thermal discomfort – discomfort creates:
– Indoor temperature θ_i	– Heat radiation asymmetry
– Medium radiation temperature θ_r	– Excessive temperature gradient of air
– Air flow velocity v_a	– Drafts, air flow
– Partial pressure of water vapour p_a	– Draught, air flow
– Isolation of human clothing I_{cl}	– Too hot or cold floor
– Resistance of clothing against the evaporation of sweat R_{cl}	– Too hot or cold ceiling
– Human metabolism M	
– Occupation – activity W	

clothing, etc.

Proposed solution of measuring system for heat plates is possible to determine the value of heat flux density q ($W\,m^{-2}$) and direction of dominant heat flux in area and it is suitable for description of thermal state workplace. Legislation of Slovak Republic presents following requirements:

- head irradiation of worker with radiant heat has not to be bigger than 200 $W\,m^{-2}$,
- protection of radiant heat is used near the sources which temperature exceeds 43 °C or if the radiation exceeds 700 $W\,m^{-2}$ [18].
- Measuring heat flux density (q) enables in workplaces:
- direct determination of measured parameter in relation to surroundings [$W.m^{-2}$],
- determination of heat radiation from appliance or behind protective screen.

2.2. Heat transfer in the space and the reasons for the measurement of heat fluxes

In the interiors of buildings, the heat spreads by convection, conduction and radiation. Imagine a three-dimensional space of coordinates (x, y, z) and there is a person in an activity. Climatic conditions of space are non-stationary by the influence of:

- non-stationary conditions in the exterior and adjacent interiors; a heat flux takes place between our three-dimensional space and surrounding through building structures,
- in the interior of the considered space, there can be made a fluctuation of climate conditions by machines' activity or other technology of environment (heating system, lighting, ventilation, air conditioning, etc.), thereby it also changes the heat flux in the interior.

Spread of heat fluxes in the space (in the air) may be varied. Heat fluxes have the following parameters [6]:

- its size - value ($W\,m^{-2}$),
- direction (with respect to coordinates x, y, z),
- spatial distribution,
- exposure – contact time,
- features: what is the nature of the heat fluxes – the heat flux by circulation (convection) Q_c or the heat flux by radiation Q_r.

The measurement of the total heat flux density by convection and radiation in situ may be performed by using heat plate to measure the heat fluxes density. Heat flux sensor was originally designed to measure the value U in building structures (walls). In evaluation of comfort parameters or environmental factors are determining factors: air temperature, relative humidity, airflow, temperature of surrounding areas, barometric pressure and operative temperature. In areas, where the temperature is in -homogenous, it is suitable to determine heat flux.

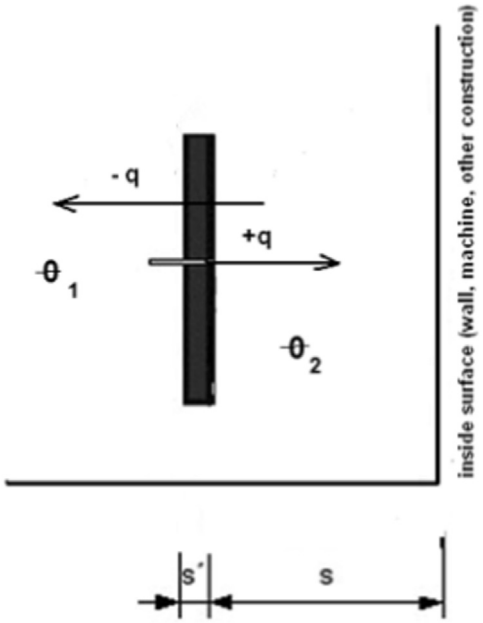

Fig. 1. Measuring principle of q value in area (in one direction). q – Heat flux [$W\,m^{-2}$] θ_1,θ_2 – Air temperature at either side of plate [°C] s´- The plate thickness [m] s – Distance from heat radiating surface.

2.3. Measuring principle, heat flux sensor plates

Heat flux plates are sensitive sensors permitting precise measurement of heat fluxes density (q) - energy per time and surface.

Use of heat flux plates ALMEMO:

Heat flux plates are used in a wide variety of areas in the natural sciences and applied technology.

(1) To determine heat loss through walls in buildings, pipework, cold stores, heat storage systems. (U value)
(2) Calorimetry, measuring the thermal characteristics of substances.
(3) Technical applications in which temperature difference is used as a control variable [1].
(4) The other suggested possibility (Fig. 1) is the determination of heat flux density q ($W\,m^{-2}$) – radiant and convection component in certain distance from surface in workplace atmosphere.

2.4. The technical solution point of the heat flux density measuring system in area

Total value measurement of heat flux with convection and radiation in situ is possible to realize with commercially produced of heat flux sensor plate. This technical solution is presented in Fig. 2.

Heat plates are used for measuring system. This system is free – hanging in area. The stand is used for hanging. Plates attaching for one direction measuring (hanging) is done by thermally insulated adhesive tape and thermally non-conductive fibre (minimally thermal influencing). Measured value of heat flux density (q_x) is information transferred by cable from plate to measuring device with digital output (identification-communication unit). Finding of measured value is instantaneous or with continuous record for time period. Measuring system is possible to construct for measurement of heat flux density in two directions (x, y) with two heat plates or in three directions (x,y,z) with three heat plates. Every plate is used for measuring of quantity in