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MODERNIZED DEVICE FOR HUMAN HEAT FLUX MEASUREMENT

This paper presents the results of development of a modernized device intended for simultaneous measurement of heat flux density and temperature of human body surface by contact method. A special computer program "Termomonitor" is created for processing electronic recorder data, their storage and reproduction in a specified form on a personal computer which allows monitoring of temperature and thermal human state in real time. Device structural features, technical characteristics, flowchart and functional capabilities are shown.

Key words: heat flux, thermoelectric sensor, electronic recorder.

Introduction

General characterization of the problem. It is known that investigation of human heat release is enourmously important, since this information can bear evidence of exacerbation and rehabilitation processes alike. Therefore, development of highly sensitive heat flux thermoelectric sensors and electronic recorders of signals from these sensors is a relevant problem.

Analysis of the literature. A factor of importance in the investigation of human heat fluxes using such sensors is the accuracy and speed of recording signals from thermoelectric sensors. Previous developments of signal recorders [1-6] are characterized by a relatively high measurement error, large dimensions and a low speed and have no power supplies of their own. Later design efforts along this line resulted in creation of modern electronic recorders with processing information from thermoelectric sensors [7, 8] that have internal memory for storing the measured results and self-contained power supplies. However, the trouble with these devices is the impossibility of connecting several thermoelectric sensors at a time and the absence of simultaneous visulalization of measurements on a personal computer in real time.

Therefore, the purpose of this work is to develop a modernized medical device that allows real-time monitoring of temperature and thermal human state. Such information is important for the diagnostics of health condition.

Device design and technical characteristics

A modernized device for human heat flux measurement has been developed at the Institute of Thermoelectricity NAS and MES of Ukraine (Fig. 1).

The device is composed of electronic recorder (Fig. 1) and thermoelectric sensors (Fig. 2). The device includes special thermoelectric sensors [9, 10] which can register heat release due to evaporation from human skin surface. For this purpose, the sensors are made with air gaps between thermoelement rows, for the evaporation to take place from the sensor surface and to record in this way the real values of heat fluxes.

Fig. 1. Modernized device for human heat flux measurement: 1 − electronic recorder, 2 − thermoelectric sensor of heat flux and temperature.

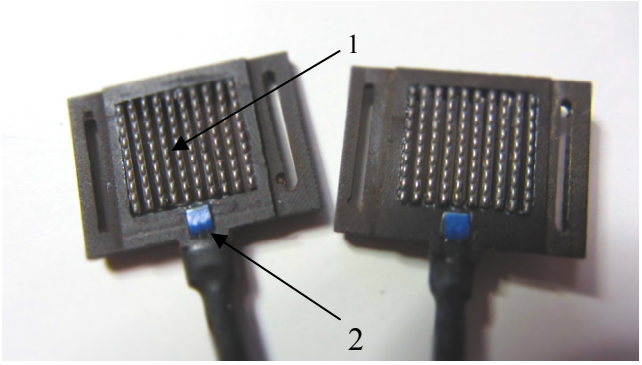


Fig. 2. Thermoelectric sensors of heat flux and temperature: 1 – thermopile for heat flux density measurement, 2 – sensor for temperature measurement.

Mounted on the device upper wall are two connectors for thermoelectric sensors of heat flux and temperature. The right side wall has a connector for microSD memory card and a miniUSB-connector for information exchange with a personal computer. The miniUSB-connector is also used for power supply to device battery.

Mounted on the case front wall is a liquid-crystal momochrome display with a resolution of 96 × 48 pixels. One pixel of display screen is matched by 10 mV of thermoelectric sensor electromotive force. The display shows plotted values of the heat flux of respective human body area in millivolts (mV) and temperature values in centigrade (°C). Thus, previous measurement data can be analyzed directly from the plots shown on the display. The presence of two thermoelectric sensors allows comparing the results of measuring the sick and healthy areas of human body surface.

Besides, the device front wall has 6 buttons for control over the device work − "LEFT", "RIGHT", "UP", "DOWN", "OK", "MENU". The “MENU” options have the following purpose:

– "START RECORDING" / "STOP RECORDING" – the device starts recording measured results into a new file, stops the respective record and saves information into memory card;
– "MODE SELECTION" – calls the submenu for selection of one of 9 information display modes in the form of real-time plots;
– "RECORDING PERIOD" – intended for selection of periodic intervals for recording measured

results into memory card file and displaying them on the device;
– "TIME/DATA" – transition to time and date adjustment mode;
– "BATTERY" – shows voltage on device supply battery;
– "HELP" – shows information on the device.

Device flowchart (Fig. 3) consists of the following functional assemblies: thermoelectric sensor with a built-in temperature sensor, analog-to-digital converter (ADC) for conversion of analog sensor signals to digital ones, multiplexor for commutation of ADC digital signals and their turn-by-turn transmission to microcontroller which is used for processing digital signals, their saving into memory card, graphical visualization of information on a display and personal computer.

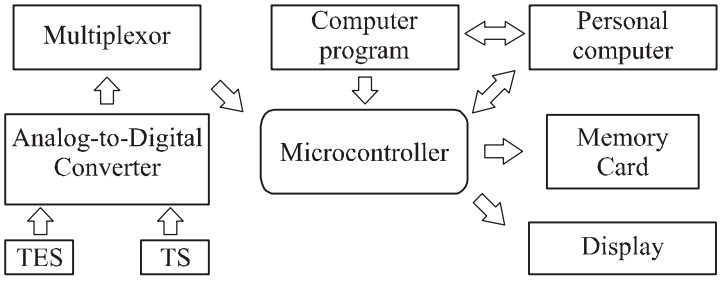


Fig. 3. Flowchart of a modernized device for human heat flux measurement: TES – thermoelectric sensor, TS – temperature sensor.

The main functional assembly of electronic signal recorder is a microcontroller operating at a frerquency up to 20 MHz which asures high processing rate of signals from thermoelectric heat flux sensor. Personal computer is used to program the microcontroller which, in turn, controls the work of other functional assemblies of the device.

The device has a power supply of its own to provide the opportunity of its use in a self-contained mode together with a patient. This, in turn, allows expanding the device functional capabilities. Device power supply is from lithium-ion battrery of capacity 1200 mA/h, assuring 48 hours of uninterrupted device work.

Technical characteristics of device for measurement of human heat fluxes are given in Table 1.

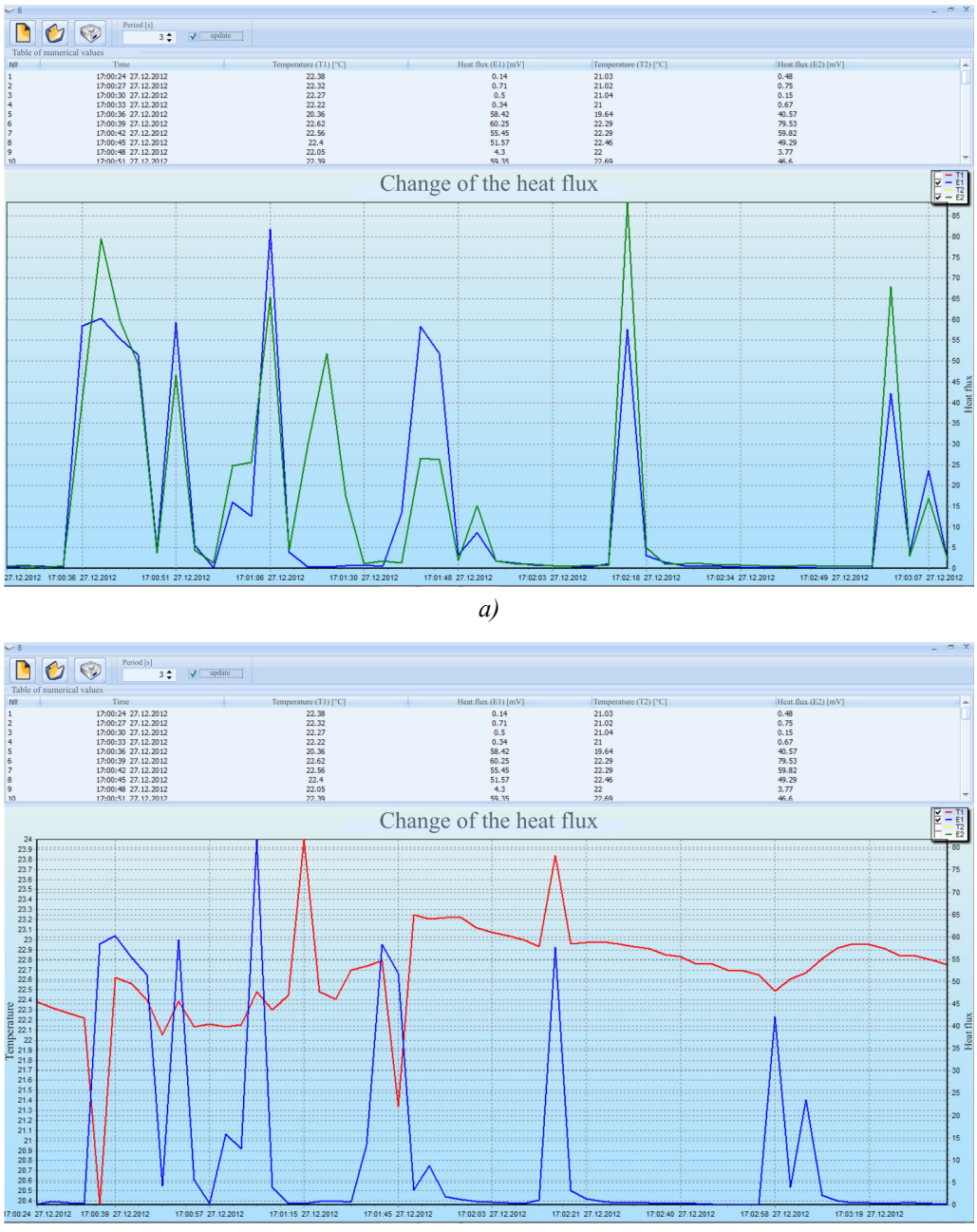
Table 1

Technical characteristics of device for measuring human heat fluxes

№	Technical characteristics of device	Parameter values
1.	Operating temperature range of thermoelectric sensor	(0 ÷ 50.15) °C
2.	Time of measuring heat flux value	(100 ÷ 300) s
3.	Mesaurement time range for storing on memory card	1 ÷ 3600 s
4.	Number of measurement channels (thermoelectric sensors)	2
5.	Temperature measurement accuracy	± 0.1 °C
6.	Device supply voltage	3.6 V
7.	Device power consumption	~ 100 mW
8.	Dimensions of heat flux thermoelectric sensors	(0.02 × 0.015 × 0.0025) m
9.	Electronic recorder dimensions	(0.09 × 0.055 × 0.025) m
10.	Weight of heat flux thermoelectric sensor	0.01 kg
11.	Device weight	0.12 kg
12.	Time of uninterrupted device work	48 hours

Description of device computer program

Device computer program (Fig. 4 *a, b*) is written in Delphi programming language. The program allows exchanging data with the electronic recorder through USB-interface. Data exchange takes place according to HID-protocol (Human Interface Device), enabling device connection to personal computer without the neeed for installing additional drivers.



a)

b)

Fig. 4. Interface of "TermoMonitor" computer program for processing electronic recorder data, their storing and reproduction in specified form on personal computer:
a) a change in heat flux of 2 thermoelectric sensors is represented;
b) a change in heat flux and temperature of the 1st thermoelectric sensor is represented.

Selecting the mark “DATA UPDATE” in computer program runs a cycle which sends requests for data transfer from the electronic recorder. In response to these requests, the recorder sends data

package on temperature and heat flux of thermoelectric sensors with a prescribed time interval. The obtained data package is processed, following which the information is displayed on a personal computer in the form of tables and plots.

On pressing the button "SAVE", all data from the table are converted into "row" values (ordinary text), divided by dot and comma and written into a file with "csv" extension which can be opened using any program for work with electronic tables (Microsoft Excel, etc). On opening the file with such program, the "csv"-format is decoded into a data package with a floating point, which enables information dosplay in the form of a table and the respective plots on a personal computer.

Conclusions

1. A modernized device is developed that allows simultaneous measurement of temperature and heat fluxes with recording information on their values in real time for 48 hours. The device has a capability of connecting several thermoelectric sensors at a time and provides visualization of sensor signals both on a display and on a personal computer in the form of time-dependent plots. Information transfer to a personal computer for its further processing according to prescribed algorithm is foreseen.
2. Special "TermoMonitor" computer program is developed for processing data from electronic recorder of thermoelectric sensor signals, their storage and reproduction in a prescribed form on a personal computer.
3. The device performs monitoring of temperature and thermal human state, which allows early revealing the inflammatory processes of human organism, various diseases and express-diagnostics during mass health examination.

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