

*Dr. Sc. L. I. ANATYCHUK^{1,2}, Ph.D. R. R. KOBYLIANSKYI^{1,2}, Dr. Sc. R. G. CHERKEZ²,
Ph.D. I. A. KONSTANTYNOVYCH², V. I. HOSHOVSKYI³, V. A. TIUMENTSEV²*

Ukraine, Chernivtsi, ¹Institute of Thermoelectricity of the NAS and MES of Ukraine,

²Yurii Fedkovych Chernivtsi National University,

Lviv, ³State Science and Production Enterprise «Termoprylad-3»

E-mail: romakobylianskyi@ukr.net

THERMOELECTRIC DEVICE WITH ELECTRONIC CONTROL UNIT FOR DIAGNOSTICS OF INFLAMMATORY PROCESSES IN THE HUMAN ORGANISM

The paper presents a thermoelectric device capable of simultaneously measuring the temperature and density of heat fluxes on the surface of a human body with the help of a developed thermoelectric sensor with a thermostated free surface, thus excluding the effect of ambient temperature on the sensor readings. A special computer programme has been developed for processing the measurement results by way of accumulating and reproducing them in a specified form on a personal computer, which enables monitoring the temperature and thermal state of a human in real time. The specific features of the device design and its technical characteristics are given.

Keywords: thermoelectric device, electronic control unit, temperature sensor and heat fluxes, inflammatory processes in the human body.

There are a large number of high-efficiency optical devices based on thermocouple sensors for radiometric measurements, e.g. Angstrom compensating pyrheliometers, etc. [1–3]. However, in this paper, heat fluxes were measured using gradient semiconductor thermoelectric sensors that have a narrow specific application in medical and biological thermometric measurements [4–8]. The peculiarity of such sensors is that they do not require compensation heaters, which can distort the temperature and heat flux distributions of the biological objects under study.

Semiconductor thermoelectric sensors of heat flux [9–15], which combine miniaturization, high sensitivity, stability of parameters in a wide range of operating temperatures and compatibility with modern electronic recording equipment, are known to be promising for testing human local heat release. The use of such sensors allows achieving high locality and accuracy of thermometric measurements. This, in its turn, makes it possible to obtain information on the characteristics of the objects under study and analyze them in detail in order to identify the inflammatory processes of the human body at an early stage.

An important factor in the study of human body heat fluxes with the help of such sensors is the accuracy and speed of recording the signals of thermoelectric sensors. Previously developed thermoelectric devices with electronic control units [16–20] have certain drawbacks, the main one being the dependence of the thermoelectric sensor readings on the ambient temperature.

This study presents the modernized thermoelectric device with an electronic control unit for diagnosing inflammatory processes in the human body. The device contains a thermoelectric sensor with a thermostated free surface to improve the accuracy of thermometric measurements for medical and biological purposes.

Design and technical characteristics of the device

The appearance of the developed thermoelectric device intended for measuring the temperature and density of the heat flux of the surface of the human body by contact method and its block diagram are shown in **Fig. 1, 2**, and its technical characteristics are given in the **Table**.

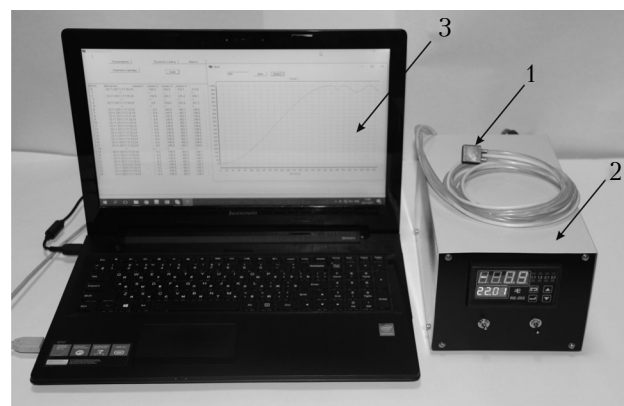


Fig. 1. Thermoelectric device with electronic control unit for the diagnostics of inflammatory processes in the human body:

1 – thermoelectric sensor of temperature and heat flux,
2 – electronic control unit, 3 – PC

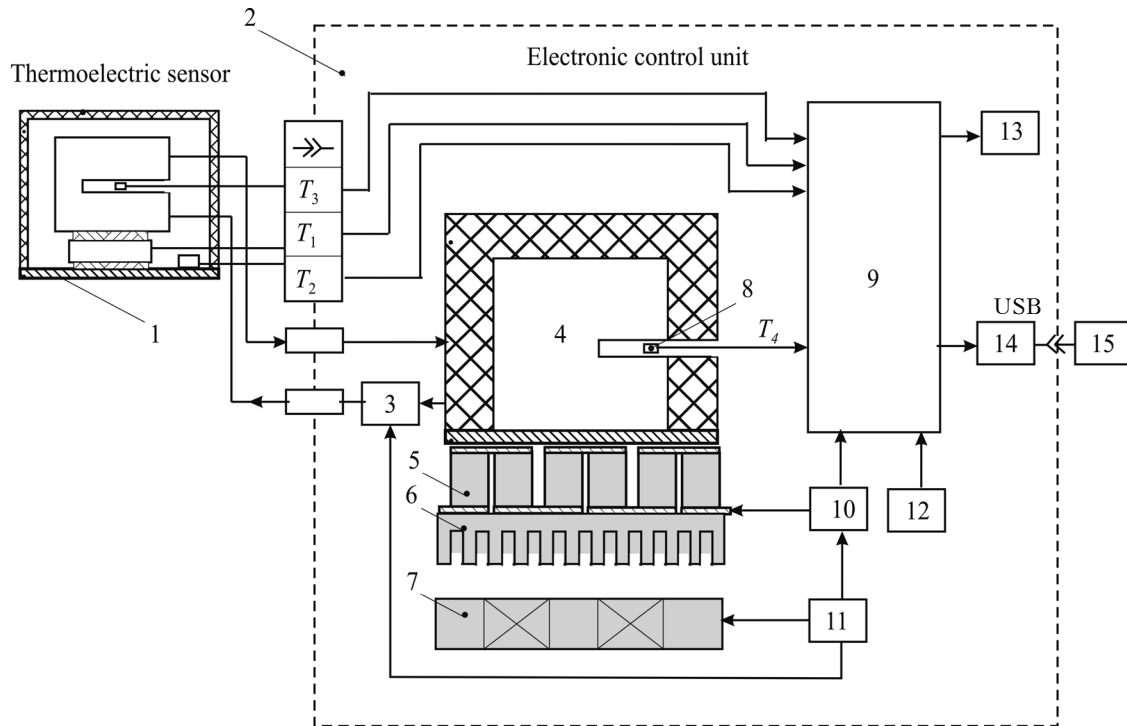


Fig. 2. Block diagram of the thermoelectric device:

1 – sensor with a thermostated free surface (**Fig. 3**); 2 – control unit; 3 – liquid pump; 4 – thermostat (150 ml) with a heat-conducting copper bottom; 5 – thermoelectric cooler (40×40×4 mm); 6 – air cooler; 7 – the fan; 8 – temperature sensor T_4 of liquid in thermostat (platinum microthermistor); 9 – measuring and master controllers of type RE-202; 10 – electronic commutator; 11 – power supply pump 3, fan 7 and cooler 5; 12 – power supply for measuring and master controllers 9; 13 – digital display; 14 – RS485/USB interface converter; 15 – personal computer

Technical characteristics of the device

Technical characteristics of the device	Parameters value
Temperature range of the thermoelectric sensor	+20...+40°C
Discreteness of setting and measuring of the temperature	0.01°C
The thermostat temperature setting error	± 0.01°C
Temperature measurement error	±0.5°C
The range of measuring the density of the heat flux	0.1 – 500 mW/cm ²
The density of the heat flux measuring error	±5%
Measurement speed	10 – 20 sec
AC power supply 50 Hz	220 V
Power (at a power supply of ~ 220 V)	10 W
Power supply from a DC source	12 V
Power (at 12 V power supply)	40 W
Number of thermoelectric sensors	1
Overall dimensions of the thermoelectric sensor	20×20×10 mm
Overall dimensions of the electronic control unit	260×160×120 mm
Time to reach operating mode	30 min
Length of hoses and cables	2 m
Weight of the device	3 kg

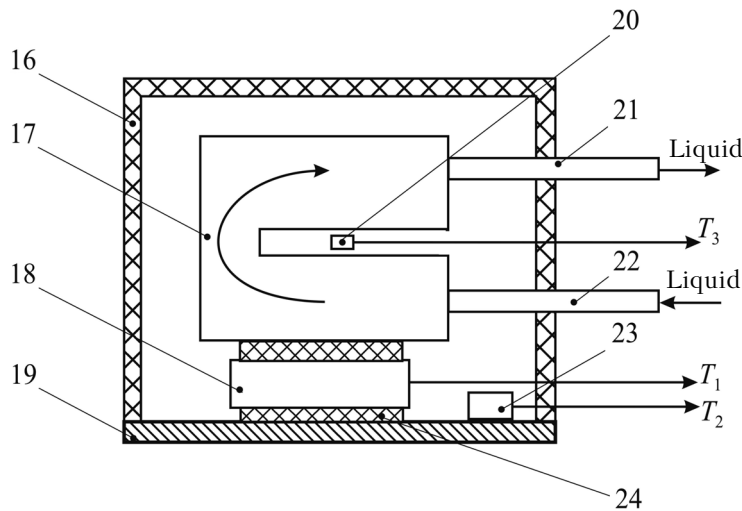


Fig. 3. Block diagram of a temperature and heat flux thermoelectric sensor:

16 – ebonite insulating jacket; 17 – copper liquid radiator (15×15×6 mm); 18 – thermoelectric sensor (10×10×2.4 mm); 19 – copper base of the sensor (thickness 0.3 mm); 20 – sensor of copper radiator temperature T_3 ; 21, 22 – inlet and outlet fittings (Ø4 mm); 23 – sensor of copper base temperature T_2 ; 24 – layer of heat-conducting paste

The device consists of two main functional units: a thermoelectric temperature and heat flux sensor 1 with a thermostated free surface and an electronic control unit 2. On the front panel of the electronic control unit there are measuring and driving controllers of the PE-202 type with a digital display, as well as “Network” and “Thermostat” toggle switches. The rear panel contains a thermoelectric sensor connector, thermoelectric sensor hose connections, 12 V battery terminals, a 220 V connection and a USB connector.

Principle of operation of the device

The device converts the heat flux and human body temperature into equivalent electric signals by means of a thermoelectric sensor; those signals being shown at the digital display of the electronic control unit in units of heat flux density (mW/cm^2) and temperature ($^{\circ}\text{C}$).

The proposed device works as follows. After placing the thermoelectric temperature and heat flux sensor on the object under test and turning on the “Network” toggle switch, voltage from the power supply 12 is fed to the PE-202 measuring and driving controllers (Fig. 2). In this case, the first channel on the digital monitor shows the value of the heat flux q passing through the thermoelectric sensor, the second channel shows the temperature T_2 of the surface of the object being tested, the third channel shows the temperature T_3 of the copper radiator of the thermoelectric sensor, and the fourth channel shows the temperature T_4 of the liquid in the tank 4. The heat flux

from the tested object passes through the thermoelectric sensor and heats the copper radiator 17 (see Fig. 3), its temperature T_3 increases, while the EMF of the thermoelectric sensor 18 decreases and, accordingly, the heat flux decreases. The amount of heat flux will also vary with the temperature of the environment. To eliminate the dependence of the heat flux on internal and external temperature, a thermostat 4 is provided in the schematic (see Fig. 2) which is turned on with the “Thermostat” toggle switch along with a liquid pump 3 and a fan 7, and through an electronic switch 10 voltage is applied to the TEC 5. The values of the temperature sensor 23 readings are compared with those of the set temperature T_{set} , which is preset in PE-202. The uncoordinated signal controls the value and direction of the current of the electronic switch 10 in such a way that the TEC 5 stabilizes the

liquid temperature with the accuracy of $\pm 0.01^{\circ}\text{C}$. The liquid pump 3 pumps the circulating liquid through the copper radiator 17 and its temperature is also stabilized with the accuracy of $\pm 0.01^{\circ}\text{C}$ for the entire thermostat operation period. With such a temperature stability of the radiator 17, the heat flux will also be stable and will be determined only by the value of the heat flux from the object under study.

If necessary, one can record all the measured values in the internal memory of the device, and then, connecting the PC and using a computer programme, read the results of the measurement and build the corresponding graphs of the dependencies of these values on time, and also make the necessary calculations with the help of the developed computer programme.

Conclusions

A thermoelectric device with an electronic control unit for diagnosing the inflammatory processes in the human body proposed in this study has the ability to store, process and visualize the measurement results on the display of the device and a personal computer in real time. The developed design of a thermoelectric temperature and heat flux sensor with a thermostated free surface excludes the effect of the ambient temperature on the sensor readings.

The proposed device is intended for monitoring the temperature and thermal state of a human body in the real time, which is of vital importance for diagnosing inflammatory processes and various diseases at the early stages.

REFERENCES

1. https://www.newport.com/medias/sys_master/images/h3b/hb5/8796989751326/1936-R-2936-R-Power-and-Energy-Meter-Datasheet.pdf.
2. https://www.photonics.byu.edu/pm1835.parts/MODELS_1835-C_&_e2876.pdf.
3. http://www.mhzelectronics.com/ebay/manuals/thorlabs_pm320e_power_&_energy_meter_manual.pdf.
4. Ladyka R.B., Moskal D.N., Didukh V.D. [Semiconductor heat flux meters in the diagnostics and treatment of arthropathy]. *Meditsinskaya tekhnika*, 1992, vol. 6, pp. 34-35 [Rus].
5. Ladyka R.B., Dakaliuk O.N., Bulat L.P., Miagkota A.P. [Use of semiconductor heat flux meters in diagnostics and treatment]. *Meditsinskaya tekhnika*, 1996, vol. 6, pp. 36-37. [Rus]
6. Demchuk B.M., Kushneryk L.Ya., Rublenyk I.M. [Thermoelectric sensors for orthopedics]. *Termoelektryka*, 2002, vol. 4, pp. 80-85. [Ukr]
7. Patent of Ukraine 53104. Sensor for preliminary diagnostics of inflammatory processes in mammary glands. A. Ashcheulov A.A., Klepikovskiy A.V., Kushneryk L.Ya., Rarenko A.I., Cherchenko V.I., 2003. [Ukr]
8. Ashcheulov A.A., Kushneryk L.Ya. [Thermoelectric device for biomedical instant diagnosis]. *Technologiya i konstruirovaniye v elektronnoi apparature*, 2004, vol. 4, pp. 38-39. [Rus]
9. Anatychuk L.I. *Termoelementy i termoelektricheskiye ustroystva. Spravochnik* [Thermoelements and thermoelectric devices. Handbook]. Kyiv, Naukova dumka, 1979. [Rus]
10. Anatychuk L.I., Lozinskii N.G., Mikitiuk P.D., Rozver Yu.Yu. [Thermoelectric semiconductor heat flux meter]. *Pribory i tekhnika eksperimenta*, 1983, vol. 5, p. 236. [Rus]
11. Anatychuk L.I., Bulat L.P., Gutsal D.D., Miagkota A.P. [Thermoelectric heat flux meter]. *Pribory i tekhnika eksperimenta*, 1989, vol. 4, p. 248 [Rus]
12. Anatychuk L.I., Kobylanskyi R.R., Konstantynovych I.A. [Calibration of thermoelectric heat flux sensors]. *Proc. of XV International Scientific and Practical Conference "Modern information and electronic technologies"*, Odessa, Ukraine, 2014, pp. 30-31. [Ukr]
13. Kobylanskyi R.R., Boichuk V.V. [The use of thermoelectric heat flux meters in medical diagnostics]. *Naukovy visnyk Chernivetskogo universitetu: zbirnyk naukovykh prats. Fizyka. Elektronika*, 2015, vol. 1, iss. 1, pp. 90-96. [Ukr]
14. Anatychuk L.I., Kobylanskyi R.R., Konstantynovych I.A., Lysko V.V., Pugantseva O.V., Rozver Yu.Yu., et al. [Calibration bench for thermoelectric heat flux sensors]. *Termoelektryka*, 2016, vol. 5, pp. 71-79. [Ukr]
15. Anatychuk L.I., Kobylanskyi R.R., Konstantynovych I.A., Kuz R.V., Manik O.M., Nitsovych O.V., et al. [Technology for manufacturing thermoelectric microthermopiles]. *Termoelektryka*, 2016, vol. 6, pp. 49-54. [Ukr]
16. Gischuk V.S. [Electronic recorder of signals from human heat flux sensors]. *Termoelektryka*, 2012, vol. 4, pp. 105-108. [Ukr]
17. Gischuk V.S. [Electronic recorder with processing signals from thermoelectric heat flux sensor]. *Termoelektryka*, 2013, vol. 1, pp. 82-86. [Ukr]
18. Gischuk V.S. [Modernized device for human heat flux measurement]. *Termoelektryka*, 2013, vol. 2, pp. 91-95. [Ukr]
19. Anatychuk L.I., Ivashchuk O.I., Kobylanskyi R.R., Postevka I.D., Bodiaka V.Yu., Hushul I.Ya. [Thermoelectric device for temperature and heat flux density measurement "ALTEC-10008"]. *Termoelektryka*, 2016, vol. 1, pp. 76-84. [Ukr]
20. Anatychuk L.I., Yuryk O.E., Kobylanskyi R.R., Roi I.V., Fishchenko Ya.V., Slobodianiuk N.P., et al. [Thermoelectric device for the diagnosis of inflammatory processes and neurological manifestations of vertebral osteochondrosis]. *Termoelektryka*, 2017, vol. 3, pp. 89-102. [Ukr]

Received 24.11 2017

Акад. НАНУ, д. ф.-м. н. Л. І. АНАТИЧУК^{1,2}, к. ф.-м. н. Р. Р. КОБИЛЯНСЬКИЙ^{1,2},
д. ф.-м. н. Р. Г. ЧЕРКЕЗ², к. ф.-м. н. І. А. КОНСТАНТИНОВИЧ²,
В. І. ГОШОВСЬКИЙ³, В. А. ТЮМЕНЦЕВ²

Україна, м. Чернівці, ¹Інститут термоелектрики НАН та МОН України,

²Чернівецький національний університет ім. Ю. Федьковича;

м. Львів, ³ДНВП «Термоприлад-3»

E-mail: romakobylanskyi@ukr.net

ТЕРМОЕЛЕКТРИЧНИЙ ПРИЛАД З ЕЛЕКТРОННИМ БЛОКОМ КЕРУВАННЯ ДЛЯ ДІАГНОСТИКИ ЗАПАЛЬНИХ ПРОЦЕСІВ ОРГАНІЗМУ ЛЮДИНИ

Представлено термоелектричний прилад, здатний одночасно вимірювати температуру і густину теплових потоків поверхні тіла людини за допомогою розробленого термоелектричного сенсора з термостатованою вільною поверхнею, що виключає вплив температури оточуючого середовища на покази сенсора. Розроблено спеціальну комп'ютерну програму для обробки результатів вимірювань, їх накопичення і відтворення у заданому вигляді на персональному комп'ютері, що дає можливість здійснювати моніторинг температурного та теплового стану людини у реальному часі. Наведено особливості конструкції приладу та його технічні характеристики.

Ключові слова: термоелектричний прилад, електронний блок керування, сенсор температури і теплового потоку, запальні процеси організму людини.

DOI: 10.15222/ТКЕА2017.6.44
УДК 537.32

Акад. НАНУ, д. ф.-м. н. Л. И. АНАТЫЧУК^{1,2},
к. ф.-м. н. Р. Р. КОБЫЛЯНСКИЙ^{1,2}, д. ф.-м. н. Р. Г. ЧЕРКЕЗ²,
к. ф.-м. н. И. А. КОНСТАНТИНОВИЧ², В. И. ГОШОВСКИЙ³,
В. А. ТЮМЕНЦЕВ²

Украина, г. Черновцы, ¹Институт термоэлектричества НАН и МОН Украины,
²Черновецкий национальный университет им. Ю. Федьковича;
г. Львов, ³ГНПП «Термоприбор-З»
E-mail: romakobylianskyi@ukr.net

ТЕРМОЭЛЕКТРИЧЕСКИЙ ПРИБОР С ЭЛЕКТРОННЫМ БЛОКОМ УПРАВЛЕНИЯ ДЛЯ ДИАГНОСТИКИ ВОСПАЛИТЕЛЬНЫХ ПРОЦЕССОВ ОРГАНИЗМА ЧЕЛОВЕКА

Представлен термоэлектрический прибор, способный одновременно измерять температуру и плотность тепловых потоков поверхности тела человека с помощью разработанного термоэлектрического датчика с термостатированной свободной поверхностью, исключаяющей воздействие температуры окружающей среды на показания сенсора. Разработана компьютерная программа для обработки результатов измерений, их накопления и воспроизведения в заданном виде на персональном компьютере, что позволяет осуществлять мониторинг температурного и теплового состояния человека в реальном времени. Приведены особенности конструкции прибора и его технические характеристики.

Ключевые слова: термоэлектрический прибор, электронный блок управления, сенсор температуры и теплового потока, воспалительные процессы организма человека.

РЕЦЕНЗЕНТЫ НОМЕРА

Горох Геннадий Георгиевич, канд. техн. наук, заведующий научно-исследовательской лабораторией, Белорусский государственный университет информатики и радиоэлектроники, г. Минск

Добровольский Юрий Георгиевич, докт. техн. наук, доцент, Черновицкий национальный университет им. Ю. Федьковича

Круковский Семен Иванович, докт. техн. наук, начальник отдела, НПП «Электрон-Карат», г. Львов

Михайлов Сергей Ростиславович, канд. техн. наук, доцент, НТУУ «Киевский политехнический институт имени Игоря Сикорского»

Пудов Алексей Олегович, канд. физ.-мат. наук, старший научный сотрудник, Харьковский физико-технический институт

Сафронов Павел Сергеевич, канд. техн. наук, доцент, Одесский национальный политехнический университет

Томашик Василий Николаевич, докт. хим. наук, ученый секретарь, Институт физики полупроводников им. В. Е. Лашкарёва НАНУ, г. Киев

Трофимов Владимир Евгеньевич, канд. техн. наук, доцент, Одесский национальный политехнический университет