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CONTACTLESS MEDICAL TEMPERATURE SENSOR

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Summary: The method of construction contactless temperature measurement of a body surface was offered and realized. The contactless thermometer is based on the method of integrated radiation. Thus the intensity of radiation of a part body surface, which limited to a visa field of the device, is registered and temperature of this part is determined.

1. Introduction

One of the most important characteristics of the material is its temperature. Its measurement serves as the base of checking the thermophysical condition, gives the information about the physiological processes in the organism, about occurring physical, chemical and biological phenomena in it. This requires thermal transmission between the object and the thermometer. Thermal transmission can be realized not only by contact, i.e. by means of thermal conductivity but also by radiation. Herewith the intensity of radiation of the part of the body surface is registered and the temperature of this part is defined. Noncontact methods of measurement do not influence controlled processes, are highly reproducible and quick. Use of noncontact measurement methods may be preferable and can give the essential medical effect when checking the temperature of the body of the newborn childrens. Electrooptic methods allow to measure the temperature of the object without contact by analyzing the parameters of heat radiation [1]. The essential problem of the these systems determining temperature of an object by radiation, is a remote measurement of the parameters of flow of radiation, emitted by the object. The parameters characterizing flow of radiation are: absolute quantity of this flow and its spectral distribution. That is why noncontact electrooptical meters of temperature are accordingly subdivided [1]. The energy meters receiving flow of radiation with spectrum $\Delta\lambda$, when $\Delta\lambda \to \infty$, are called the pyrometers of total radiation (radiational),. The spectral systems receiving the radiation occuring in one or several areas of spectrum are called the systems of partial radiation (monochromatic) under $\Delta\lambda \to 0$, $\Delta\lambda$=const; the systems are twocolor - when receiving the radiation in two spectral areas $\Delta\lambda_1$, $\Delta\lambda_2$; and multicolor - when working on $\Delta\lambda_1 . \Delta\lambda_2 \ldots \Delta\lambda_n$.

Spectral methods [1,2] possess enough pinpoint accuracy of measurements, allow to define the factor of radiation of the object, however are more preferred, than radiational at building portable low temperature contactless thermometers for temperature measurement of a body surface of person by following reasons:

- do not allow to provide required accuracy of measurements (0,1 °C) within the range +20...+50 °C of temperatures. This is conditioned by impossibility of broad diversity of spectral channels and low signal/noise ratio in spectral channels in consequence of small steepness in long wave region of Planck distribution at low object temperatures;

- possess enough difficulty for practical realization, not allowing optical and information-measuring part of a device to contain within the framework of small-dimensioned portable instrument.

2. System design

The functional scheme of designed noncontact thermometer is represented in Fig. 1, [3]. Radiation from the body surface 1 is collected by the focusing optical system 2, and passes to radiation receiver 3 – a pyroelectric receiver MG-30.

To reduce the inaccuracy, caused by a poor signal/noise ratio in the receiver, for determination of radiation flux a synchronous detection is used with accompanying integration. Increasing of the signal/noise ratio at the output of synchronous detector is based upon coincidence of a signal phase with phase of a detector. Pulses of synchronization required for synchrodetector, are formed under rotation of obturator 4, located before input hole of optical system, electrical motor 5 leading to its rotation and by means of LED SD and photodiode FD, as well as comparator 13.

Herewith on the receiver of radiation 3 enter the miscellaneous optical flows: for open input aperture of optical system – from measured points of a body surface, for locked – from equilibrium radiation of internal cavity obturator and input optical system.

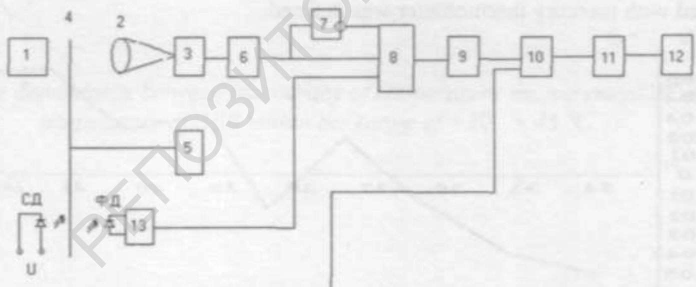

Figure 1 – Functional block of the noncontact thermometer: 1 – body surface; 2 - focusing optical system; 3 - radiation receiver; 4 –obturator; 5 – electrical drive; 6 – amplifier; 7 – inverter; 8 – junction board; 9 - a follow-up integrator; 10 – adder; 11 – analog to digital converter; 12 – indication system, 13 – comparator, 14 - balancing network, 15 – amplifier.

Leaving the receiver 3 variable signals are amplified in 6 and enter full-wave detector, including inverter 7, junction board 8 and follow-up integrator 9.

At the output of synchrodetector, thereby, the signal, characterizing difference temperatures from measured points of body surface and internal cavity of receiving system is formed, which hereinafter enters the input a adder 10. The temperature of the internal cavity pyrometer is checked by thermistor Rt, enclosed in one of the shoulders of balancing network 14. The signal of imbalance is amplified in 15 and enters an adder 10, where it is used as a reference for determination true temperature of the measured point of body surface.

From the output of 10 the signal is passed to the input of A/D converter 11, where the transformation of measured information signal into digital code occurs and the output is indicated by block 12.

3. Experimental results

The calibration of noncontact thermometer was conducted in laboratory conditions using absolutely black body (ABB) with factor of radiation ε =0,99 and checking the temperature of ABB by means of thermocouple with accuracy 0.05 °C. For increasing validity of technical features of the thermometer the averaging of 100 cycles of measurements was conducted.

There were organized studies with designed thermometer on noncontact measurement of the temperature of water surface, with the factor of radiation ε =0.98 close to the factor of radiation of human body (ε=0,96...0,98). The temperature of water was checked by the mercury thermometer with 0.1 °C accuracy.

The temperature was measured within the range of +34...+42 °C. For each temperature 10 measurements were conducted with interval 3-5 seconds, then the average value for 10 measurements was calculated and inaccuracy of measurements as compared with mercury thermometer was defined.

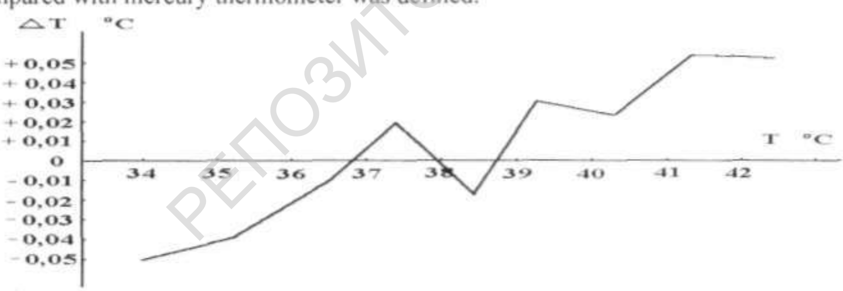

Fig. 2 – The dependence between inaccuracy of temperature measurement Δ T and the temperature of an object (water) within the range of +34...+42 °C.

These results are presented in Figure 2. It can be seen from the figure that inaccuracy of temperature measurement in this range is lying within T= ± 0.05 °C. This value forms instrumental inaccuracy of temperature measurement under exactly known factor of water radiation, equal (ε=0.98). Factor of radiation of human body depending on conditions of skin, moisture purities, presence of fat and other factors may change within ε=0,96.-.0.98. If we do not know the exact factor of human body radiation it can give the additional inaccuracy. On theoretical estimations such inaccuracy will be equal: ΔT= ± 0.1...0,2 °C.

There were performed contactless temperature measurements of absolutely black body (ABB), factor of radiation is ε =0,99, for different temperatures within the range of +20...+45 °C . The temperature checking of ABB was realized by means of thermocouple with accuracy 0.1 °C. Graph of the dependency between inaccuracy of measurement Δ T and the temperature of ABB within the range of +20...+ 45 °C is represented in Fig. 3. It is shown on the graph that in this range of temperature instrumental inaccuracy of the thermometer is restricted within ΔT= ± 0.6...0,7 °C.

Results of contactless temperature measurements of water (the factor of radiation ε =0,98) for the temperature within the range of +20...+ 45 °C is presented in Fig.4. In this range of temperatures instrumental inaccuracy of the thermometer during determination of the water temperature, as well as for ABB is lying within ΔT= ± 0.5...0,7 °C.

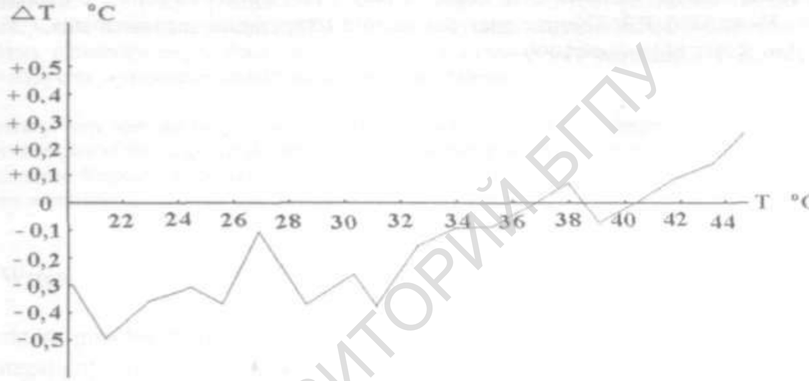

Figure 3 The dependence between inaccuracy of temperature measurement ΔT and the temperature of ABB within the range of +20...+ 45 °C.

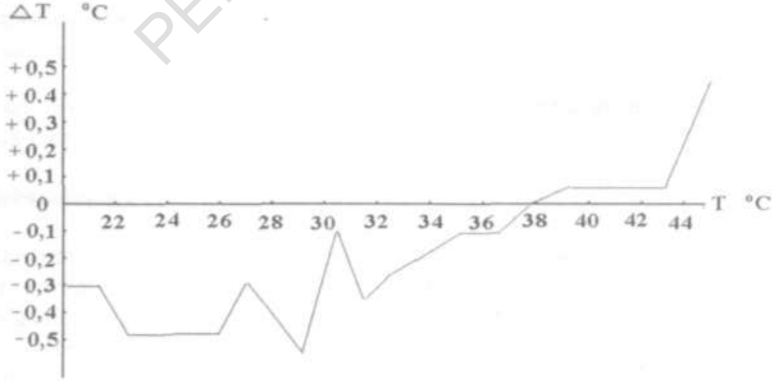

Figure 4. The dependency between inaccuracy of temperature measurement Δ T and the temperature of an object (water) within the range of +20...+ 45 °C .

Experimental results show that designed contactless thermometer possesses instrumental inaccuracy of measurements not worse than 0,1°C. However, inaccuracy of contactless measurement a temperature of human body will depend not only on instrumental inaccuracy of a pyrometer, but also on accuracy of the knowledge of a body radiation factor. For a more detailed clarification of factor influence on accuracy of temperature measurement, undertaking of additional experimental studies is required.

References

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