Joint **IMEKO TC-1 & XXXIV MKM Conference 2002**
Wrocław, 8 - 12 September 2002

Ewa DZIUBAN*

HUMAN BODY TEMPERATURE MEASUREMENT- CLASS PROGRAM

Training class concerning "Human body temperature measurement" supports adequate part of lectures on Medical Measurements led by author on IX semester of speciality Metrology and Measurement Systems, faculty of Electrotechnics and Computer Science at Technical University of Rzeszow.

Author established the program of class with the aim of familiarising students with IR radiation thermometers (pyrometers): their basic principles (infrared theory), construction and basic metrological problems (spectral range, field of view, resolution, accuracy and errors). Recently the infra- red (IR) radiation thermometers for medical application are intensively advanced and wildly distributed.

Key words: infra-red technique, human body temperature, class program.

1. INTRODUCTION

Measurements of either internal body temperature or skin temperature are important in medical practise. In human organism thermal balance at temperature level (37.00± 0.75°C) must be maintained for optimum cellular function. Physiologic thermoregulation is a complex central and peripheral interaction that attempts to balance body heat gain against loss. Heat production mechanisms are motor activity, shivering, metabolic thermogeneration while heat loss mechanisms are conduction, convection, radiation, evaporation [3].

Recently the infra- red (IR) radiation thermometers for medical application are intensively advanced and wildly distributed. They are based on the non-contact method, which related to human body measurements has an advantage: does not disturb the natural psychophysical processes of organism as well as the field of

* Technical University of Rzeszow, W. Pola 2 str., 35-959 Rzeszów, Poland,
e-mail: edziuban@prz.rzeszow.pl

temperature. For to familiarise students with IR thermometers (pyrometers) author established the program of class concerning their basic principles, metrological problems and practical measurement of human body temperature.

2. BASIC PRINCIPLES

Pyrometers (IR radiation thermometers) operate on the basis of Planck's radiation law:

$$P = \frac{2hf^3}{c^2} \frac{1}{exp\left(\frac{hf}{kT}\right) - 1} df\, d\Omega \quad (1)$$

where P is radiant power, h is Planck's constant, f is frequency, c is velocity of light, T is temperature and k is Boltzmann's constant .

They utilise the relationship between the temperature of blackbody (emissivity factor ε =1.0) and its radiant power. The distribution of radiation is a function of both the temperature and the wavelength (frequency), fig.1. On the figure the area under each curve represents the total power radiated at the associated temperature. When temperature is increased the radiation intensity increases whereas the wavelength associated with the peak of radiated power (highest point of the curve) shifts towards the shorter wavelength (higher frequencies).

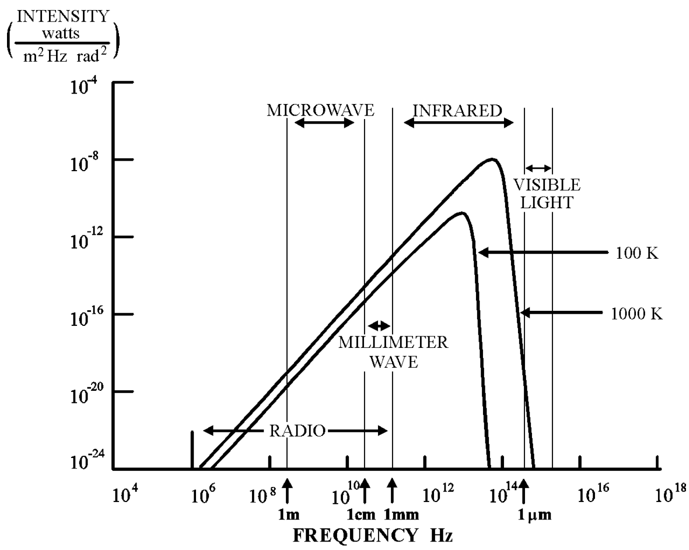

Fig 1. Radiation intensities for blackbody [3]

For the human body temperature (ca 300K) the spectral distribution of black body radiation attains a maximum in IR range. Then the maximum wavelength λ is 9.66μm [4], according to Wien's Displacement law:

$$\lambda = 2899/\ T\ [\mu\mathrm{m}] \tag{2}$$

Researchers give the value of human skin emissivity ε as a near unity (0.98±0.01) and state that ε is independent on pigmentation of the skin in the visible spectrum [1, 2]. Emissivity remains constant over the surface and wavelength in the case of measurement on human skin.

Nevertheless emissivity variations in hospital conditions (wounds, scarves, grease and sweat) change estimated ε value and may cause measurement uncertainty. It can be evaluated by term:

$$\Delta T = T_s - T_r = T_r \left[\sqrt[4]{\frac{1}{\varepsilon}} - 1 \right], \tag{3}$$

where: T_s is skin temperature and T_r is reading temperature.

3. MEASUREMENT CONDITIONS AND PARAMETERS OF PYROMETER

During temperature measurement in the classroom (20-22ºC, regular humidity) the nonisothermal environment (cold windows, hot lights, draught) should be avoided because it may cause additive heat fluxes that are reason of artifacts. Moreover it is necessary to keep the measuring surface clean and dry for not to change emissivity factor ε.

Students, subjected to measurement should relax for a short time for to attain the thermal balance with environment. Participants declare subjectively their state of health and fettle. Technical parameters of the IR pyrometer are: range of temperature 0 to 300°C, adjustable emissivity in span 0.1 to 1.0, resolution 1°C and spectral response 8 to 14μm.

4. PROGRAM

The program of class is composed of the measurements of skin temperature, the determination of unknown emissivity, the comparison two radiation pyrometers and the evaluation of systematic error.

Before skin measurements students recognise the technical and metrological parameters of the pyrometer: temperature range, resolution and accuracy, band of spectrum, field of view. Then they adjust the emissivity (adequate to skin value) the background correction and choice feature of signal processing (kind of reading).
Students characterise their fettle and state of health and than measure temperature at selected points on the body.

Statement of unknown factor of emissivity is led using test element, thermostat , pyrometer with adjustable emissivity and standard mercury thermometer. Scheme of measuring system is presented on figure 1. Temperature of material is maintained constant in thermostat and measured using standard mercury thermometer and pyrometer simultaneously. The emissivity corrector of pyrometer is adjusted until the display shows the correct temperature. This emissivity value can be used for future measurement of this sample.

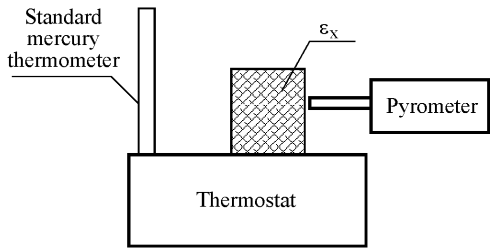

Fig. 2. Scheme of measuring system

Comparison two radiation pyrometers and calculation of the systematic error due to false adjusted or stated emissivity is led using test element, thermostat, standard mercury thermometer, pyrometer with adjustable emissivity and pyrometer with ε = 0.95. Temperature of sample in thermostat is taken by mercury thermometer and both pyrometers with ε = 0.95. Then the wrong emissivity is adjusted and measurement is taken again. The error of adjustable pyrometer is evaluated accordingly to term (3) than the corrected result of measurement can be given.

LITERATURE

[1] FRADEN J., *Medical infrared thermometry (review of modern techniques),* Temperature Its Measurement and Control in Science and Industry (TIMCSI), 1992, 6, 2, 823-830.
[2] LOVE T. J., in: SHITZER A., EBERHART R. C. (ed.), *Heat transfer in medicine and biology*, Plenum Press, 1985, vol. 2, 334-340.
[3] VAUGHAM M. S., in: WEBSTER J. G. (ed.), *Encyclopedia of medical devices and instrumentation*, Wiley & Sons, New York 1988, 2723-2748.
[4] WEBSTER J. G., in: WEBSTER J. G. (ed.), *Medical instrumentation application and design*, Houghton Mifflin Company, 1992, 88-92.