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Letter to the Editor

EXPERIMENTAL STUDIES OF ACOUSTOTHERMOGRAPHY POTENTIALITIES[1)]

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A report is presented on the first experimental study of the potentialities of remote sounding of temperature by recording thermal acoustic noise. A fluctuation sensitivity of 0.3° was attained at a 30 second integration time constant. Theoretic estimates indicate the possibility of further improving the sensitivity by a factor of 3.

The present report describes experimental studies of the possibility of mapping the internal temperature of various objects by measuring their thermal acoustic radiation. The feasibility of such internal temperature measurements was first mentioned in [1]. The acoustothermometric method features a better spatial resolution and a greater depth of sounding than those of radiometric measurements due to the acoustic wave having a significantly shorter wavelength and considerably lower attenuation, than electromagnetic waves. Another advantage of acoustothermometry is the possibility of measurements in media with high electric conduction, such as metals, semiconductors, electrolyte solutions.

Experiments were carried out on an installation of the type used in [3]. A 1 cm × 1 cm plate of lithium niobate was used as the piezoelectric transducer; the basic frequencies of halfwave resonance are 1.3 MHz and 6.5 MHz. The experimental set-up was oriented to receiving signals from water and biologic objects. Acoustic matching was provided by quaterwave plates of potassium chloride and magnesium. Measurements were taken in a rectangular 1.5 m × 1.5 m × 0.7 m tank filled with water, such dimensions excluding the incidence (at the receiving aperture of the acoustic receiver) of signals reflected from the tank's side walls. The acoustic receiver and the object under study were positioned in water at a spacing of about 5 cm from one another to exclude the acoustic receiver temperature changes due to heat transfer from the object under study which would complicate the experimental data interpretation. Bodies of a sufficient blackeness to acoustic radiation and well acoustically matched to water were used as the object under study. Measurements were taken of a human hand closed into a fist and a plasticene disc of 15 cm diameter and 5 cm thickness (previously cooled to − 10 °C). The main advantage of using a human hand is its known and fairly constant internal temperature during the time of measurement (3 to 5 minutes) maintained by the bloodstream; the advantage of a plasticene disc is that its acoustic parameters approximate those of water (sound velocity of 1.5×10^5 cm/s, density of 1.4 g/cm^3), and also its high attenuation (about 15 dB/cm at 1.3 MHz) providing the blackness of such a disc to acoustic radiation. Thermoresistors were embedded into the disc to monitor the internal temperature during measurements, with the first sensor placed at a depth of 0.3 mm from the surface and the second sensor immersed at a 5 mm depth. Before measurement the disc was exposed to the cold for a long time so that the temperature was one and the same throughout its bulk. Experiments were carried out as follows: the acoustic receiver was immersed into the water tank (the water temperature was 23.5 °C) and after an hour interval (to ensure thermal equilibrium) the output signal was recorded on a logger at an integration time constant of 30 seconds. Fig. 1 shows a typical record (curve 1) of the measurement results with an acoustothermometer. At $T = 5$ minutes a human hand clenched into a fist was brought into the receiver field of view: as can be noted, the readings rose to about 36 °C (the first temperature was also monitored by mercury thermometer). In 3 minutes the hand was removed out of the receiver's field of view and after a transition process the readings returned to the initial level. The results of these measurements were used to calibrate the measurement set-up.

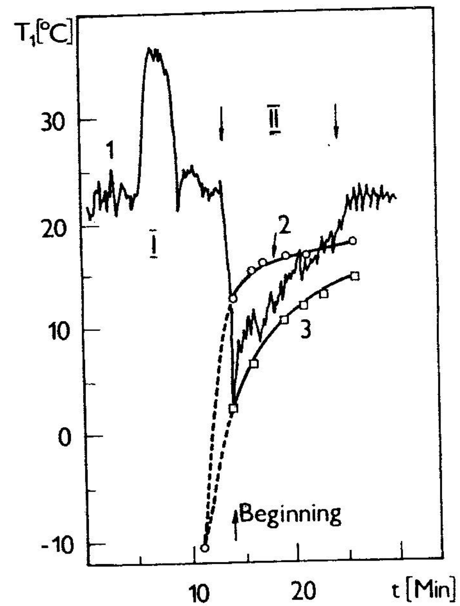

Fig. 1

At the moment of time $T = 12$ minutes the cooled plasticene disc was placed within the receiver's field of view and kept there till $T = 27$ minutes. As evident from Fig. 1, during this interval the signal, which is proportional to the disc temperature, increased, with the thermodynamic temperatures at the disc flat surface turned toward the receiver and in the disc bulk rising at different rates (curves 2 and 3, respectively).

Comparison of the kinetics of acoustic and thermodynamic temperature changes within the plasticene disc at a depth of 5 mm (curve 3) and not on its surface (curve 2). This agrees with 15 dB/cm acoustic attenuation at a frequency of 1.3 MHz (and therefore, the emission) of the main part of the noise acoustic energy.

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A critical parameter of any temperature meter is its sensitivity which may be evaluated by the noise track width, as traditionally done in radiometry [2]. As seen in Fig. 1, the noise track width is about 5 °C, this corresponding to 0.8 to 0.9 standard deviation, as defined in radiometry. Comparison of this result with theory, taking into account a 30 seconds integration time constant used in these experiments, indicates that the accuracy attained is about 10 times worse that maximally attainable, as predicted by theory [4]. This discrepancy is apparently due to the imperfection of the electronic part of the receiving system used in these experiments; the results obtained with a more perfect system operated at a frequency of 6.5 MHz corroborate this statement: the sensitivity of the more perfect system was about 0.2 °C at the same integration time constant value.

Thus, the work experimentaly demonstrated the feasibility of sounding the internal temperature inside objects by their acoustic radiation. The methodology described, along with radiometry, may find wide application in biology, medicine and industry.

REFERENCES

[1] Babiy, V. I.: In: Morskiye geofizicheskiye issledovaniya, Sevastopol, 1974, No. 2 (65), pp. 189—192.

[2] Troitsky, V. S., Gustov, A. V., Belov, I. F. et al.: — Soviet Physics — Uspekhi, *134* (1981), 155.

[3] Bowen, T.: US Patent 4385634, 1983.

[4] Gulyaev, Yu. V., Godik, E. E., Dementienko, V. V. et al.: — Soviet Physics — Doklady, *183* (1986), 1495.

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