A COMPENSATION CIRCUIT FOR MEASURING THE COEFFICIENT OF THERMAL EXPANSION

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The modulation method of investigating thermal expansion is intended for direct measurement of the coefficient of thermal expansion on wire specimens. In this method temperature oscillations about a mean value are produced in the specimen and the amplitudes of the oscillations of temperature and length of the specimen are determined. When this method is employed it is convenient to use the compensation circuit described below. In this case the determination of the coefficient of thermal expansion is facilitated and the sensitivity can be increased.

The compensation method of measurement consists essentially of the following. The wire specimen is composed of two parts—the test specimen ABC and a specimen FBDE with a known coefficient of thermal expansion (Fig. 1). The two parts are heated independently by direct current from rectifiers 1 and 2. Alternating current from a low-frequency generator 3 causes temperature oscillations of opposite phase in the portions ABC and FBDE. In the measurements the relationship established between the amplitudes of the temperature oscillations in the two portions of the specimen is such that the total amplitude of the oscillations of the length of ABD is zero. This is achieved by regulating the alternating components of the current in the supply circuits. In this method of measurement the photomultiplier and amplifier, previously used for measuring the amplitudes of the oscillations of length of the specimen, are used as a null detector. A low-voltage photodiode can be used instead of the photomultiplier.

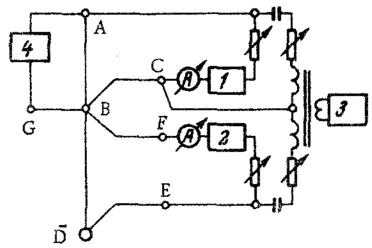
Calculation of the coefficient of thermal expansion requires a knowledge of the lengths of the portions AB and BD and the amplitude of the temperature oscillations in the two portions of the specimen. The amplitudes of the temperature oscillations are determined from the relationship between the electrical resistance of the specimens and the temperature or from the known specific heat [1]. In the second case it is easy to obtain calculation formulas for use with the compensation circuit. The amplitude of the temperature oscillations is proportional to the amplitude of the oscillations of the supplied power and is inversely proportional to the specific heat of the specimen, and the amplitude of the power oscillations is proportional to $i_0 u$ (i_0 is the constant component of the current through the specimen, u is the drop of the alternating voltage on the specimen). Hence, when compensation is obtained we have the relationship

$$\alpha_1 i_{01} u_1 l_1 / m_1 c_1 = \alpha_2 i_{02} u_2 l_2 / m_2 c_2 .$$

Here α is the coefficient of thermal expansion, l, m, and c are the length, mass, and specific heat, respectively, of the specimens. The subscripts 1 and 2 refer, respectively, to the investigated specimen and the specimen with known expansion coefficient. The specimen FBDE is at constant mean temperature and all the quantities, except i_{01}, u_1, u_2, c_1, and α_1 are constants which are known or can easily be measured. Hence

$$\alpha_1 = K u_2 c_1 / i_{01} u_1 .$$

The alternating voltage on the specimens is measured by a tube voltmeter 4 connected in parallel with the portions AG and EG (the tap BG is made to exclude the effect of the voltage drop when the alternating current flows along the portions BC or BF). The quantity m_2 corresponds to the mass of the portion BDE.



Thus, measurements of the coefficient of thermal expansion by means of the compensation circuit reduce to establishment of zero amplitude of oscillations in the length of the composite specimen ABD and measurement of the direct current and alternating voltages on the two portions of the specimen. With the compensation circuit the coefficient of thermal expansion can be determined even when the amplitudes of the temperature oscillations are about 0.1° C. In this case the oscillations of the length of the specimen are of the order of 10^{-5} cm and the sensitivity is 10^{-7} cm. The compensation circuit is very convenient for practical use. The thermal expansion of platinum at high temperatures has been investigated by this method [2].

In the investigation of thermal expansion by the modulation method there may be significant distortion of the results due to two effects. The first is the variation of the eleastic properties of the specimen with the temperature. When heavy weights are used the oscillations of length of the specimen with oscillations of its temperature may be partially due to periodic changes in the modulus of elasticity. The second effect is due to changes in tension of the specimen due to acceleration of the weight extending the specimen. Hence, it is essential that the acceleration of the end of the specimen should be much less than the gravitational acceleration and the weight should not be too heavy. Calculations show that these two effects can be made insignificant by a reduction in the weight. The frequency of temperature modulation should not be too high.

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