THERMAL EXPANSION OF INVAR SURVEYING TAPES

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A new method for determining the coefficients of linear thermal expansion of invar (1) geodetic surveying tapes has been developed by Peter Hidnert and R.K. Kirby of the National Bureau of Standards. Based on a determined relationship between the electrical resistance and the temperature for each invar tape, the NBS technique consists principally of measurements of expansion and electrical resistance of the tape when heated by passing a direct current through it without changing the temperature of the laboratory. The new method is not only more precise but also much more rapid and convenient than the previous method, which required measurements at different ambient temperatures.

For accurate determinations of long distances with geodetic tapes, as in measurements of base lines by the U.S. Coast and Geodetic Survey, the coefficient of thermal expansion of each tape is needed in order to calculate the lengths at various atmospheric temperatures. Over the past half century, NBS has determined the coefficients of expansion of many invar tapes for government agencies. The measurements are carried out in a specially designed underground laboratory. Until now, the length of each tape was measured at several different constant temperatures from 5°5 to 35° C. by comparison with a distance laid off with a 5-meter steel standard maintained at 0° C. by packing it in melting ice. To obtain the various constant temperatures, it was necessary to change the temparture of the entire laboratory. Several days were allowed for the equipment to reach equilibrium conditions at each temperature. Furthermore, additional time and effort were spent in making the large number of precise measurements of length and temperature that were required.

In the new NBS method, the temperature of the laboratory is held constant at a convenient temperature. The tape, under a specified tension, is supported in the same manner as used in the field, but it is electrically insulated from the supporting apparatus. Micrometer microscopes are focused on the terminal graduations of the tape, and the change in length or linear expansion is observed directly when the tape is heated by passing a direct current through it. The electrical resistance corresponding to each observation for linear expansion is determined by a potentiometer method. Measurements of the lengths of the tape by means of the 5-meter steel standard are no longer needed for expansion determinations. The temperature coefficient of resistance of the tape is used to convert the observed changes in resistance to temperature changes. Then, from the length of the tape, the observed changes in length, and the corresponding temperature changes, the coefficient of linear thermal expansion is calculated. The temperatures at which the observations apply are obtained by adding the determined temperature changes to the initial temperature of the tape as determined by thermometers hung in close proximity to the tape.

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(1) Invar is a nicked steel containing about 36 percent nickel. Its coefficient of linear expansion is very small at ordinary temperatures.

The temperature coefficient of resistance of each tape can either be obtained exprimentally or computed from an empirical relationship derived at NBS between the temperature coefficient of resistance and the mass resistivity of invar tapes. The mass resistivity is easily determined by multiplying the resistance per unit length by the mass per unit length.

Coefficients of expansion of five 5-meter invar tapes obtained by the new method have been found to be in good agreement with those obtained from the same tapes by the old method. The probable errors of the coefficients of expansion determined by the new method are approximately 0.01×10^{-6} per degree centigrade and are less than the probable errors of the coefficients of the same tapes by the former method.