

A SIMPLE METHOD OF DETERMINING THE ABSOLUTE DILATATION OF MERCURY.

BY ARTHUR L. FOLEY,

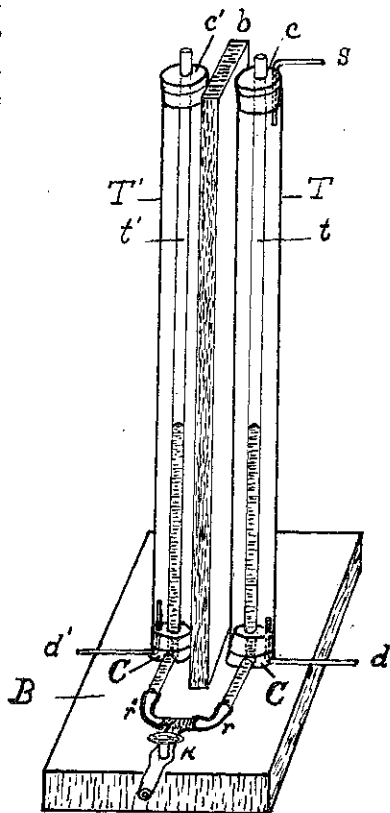
Professor of Physics in Indiana University.

It is the writer's opinion that the experiment of determining the absolute dilatation of mercury should never be attempted in the high school laboratory, and he is not convinced that it should be undertaken by first year college students. A record of the work of the larger Universities of the world shows that the experiment is not given in many of them, and of the ten per cent that do give it only a few place it in the work of the first year. However, there are a few high schools and several colleges in the United States where the experiment is given. Most of these schools use the method of equilibrating columns, and apparatus like or similar to that used by Regnault. Such apparatus is somewhat difficult to set up and take down, and in doing so the tubes are very likely to be broken and mercury wasted. Consequently the apparatus is usually fixed up once for all. The student needs only to put in the ice, turn on the steam, take a few readings and supply in a formula. He can not see "the inside of things" and he may really know little or nothing about the fundamentals of the method.

The apparatus proposed in this paper is much simpler than that used by Regnault or Dulong and Petit, and in the hands of the beginner is just as likely to give satisfactory results. A simple form of the apparatus is shown in the accompanying figure. To a heavy wooden base (B) is fastened in a perpendicular position a board (b) about a meter long. This board serves a double purpose. It supports the two glass tubes for the mercury columns (or their jackets), and it acts as a screen to prevent heat passing from one to the other. A glass tube (t) of whatever length is desired, is bent at right angles about 15 cm. from its lower end and connected by means of a rubber tube (r) to a similar glass tube (t') on the other side of the board (b). It is very convenient to have a stopcock (k) connected by the rubber tubes (r) and (r') to (t) and (t'), so that mercury can be drawn from the tubes without disturbing the apparatus. The rubber connecting tubes would be objectionable were the highest degree of accuracy sought for; but where the apparatus is in the hands of the inexperienced they are almost a necessity. Where

the tubes (t) and (t') are welded together or made from a single piece of glass, considerable care is necessary in supporting them so that they shall at all times be free from mechanical strain; and the apparatus is troublesome to take down and clean.

A glass tube (T) of a larger diameter serves as a jacket for the steam which enters through a tube (s) passing through the cork (c). The cork (C) at the lower end of the tube is cut away as shown; (d) is a drip to drain the jacket of condensed steam. The tube (t') on the other side of the board may be jacketed in the same way, and instead of passing steam through this jacket (d') may be connected to a water tap, and the jacket supplied with running water. Or the jacket may be filled with ice. In packing the ice in the jacket it must be remembered that the end of the mercury column must be kept in sight. It will answer fairly well to use only large pieces of ice on the side of the jacket next the cathetometer, which is used to measure the heights of the mercury columns. A better way is to make out of a strip of tin a sort of collar or cylinder with open ends, and of such a length that it will drop in between the mercury column and the jacket and give a small space free of ice. Several of these can be placed in the jacket at points where it is desired to make a measurement. Very good results may be obtained by entirely dispensing with the jacket on the left and leaving the mercury column exposed to the air, and taking its temperature with a thermometer held against the column with rubber bands.



The method is very simple. Into one of the tubes, say (t') is poured a quantity of mercury sufficient to stand several centimeters high in each arm. After the lapse of a sufficient time to permit the two mercury columns to assume the temperature of their baths their heights are carefully measured by means of a cathetometer. More mercury is then poured in the tubes and under the same temperature conditions as before, the heights of the columns are again measured. The difference in the heights before and after adding the mercury together with the temperature difference of the two arms, are all the data required. Many independent readings may be made by adding or removing mercury, or changing the temperature of the baths.

Regnault found that the coefficient of expansion of mercury increased with the temperature and could be approximately expressed by the equation

$$c = a + bt$$

where a and b are constants and t the temperature. He found that the value of b is so small that for temperatures between 0°C and 100°C the term involving it may be neglected, and the coefficient considered constant. Assuming this to be true and calling h_t and $h_{t'}$ the difference in the heights (before and after adding mercury) of the mercury columns at temperatures t and t' respectively.

$$\begin{aligned} h_t &= h_0 (1 + at) \\ h_{t'} &= h_0 (1 + at') \end{aligned}$$

where h_0 is the difference in the heights at a temperature of 0°C ; that is, the length at 0° of the added mercury column.

Eliminating h_0 and solving for a ,

$$a = \frac{h_{t'} - h_t}{h_t t' - h_{t'} t}$$

Where the temperature $t = 0$

$$a = \frac{h_{t'} - h_0}{h_0 t'}$$

Using the method described and the last equation, a value of the coefficient a can be obtained by any reasonably careful observer which is in error by less than one half of one per cent. If long mercury columns are used, so as to give larger values of h_t and $h_{t'}$, the error can be made still less. Indeed, one may, where no cathetometer is available, determine the value of h_t and $h_{t'}$ with ordinary meter sticks, placing one in each of the jackets and holding it against the mercury columns with rubber bands. If

heights are estimated to tenths of a millimeter and long mercury columns are used, the method will give results in error by less than three per cent.

It will be observed that the method above outlined is free from several sources of error more or less troublesome in the methods of Regnault, and Dulong and Petit. There are no portions of the mercury column (the part to be measured) exposed so that the temperature can not be constant throughout, and the heights of the columns are not measured from some assumed point of equilibrium in a horizontal connecting tube. There can be no trouble from convection currents, and surface tension troubles are completely eliminated. The latter fact enables one to use a tube of small bore, and therefore, a relatively small quantity of mercury, though the tube be made as long as desired. A small column comes to the temperature of the enclosure more rapidly than one of larger diameter. In short, many sources of errors are eliminated, and but one, that I think of is introduced. This is the error due to viewing the column through the glass walls of the jacket. This error is not so serious as it would appear at first thought. If the jacket walls are reasonably true, and not very thick, the error in any case is not large, and it can be partially corrected by turning the jacket about its axis and viewing the mercury column through different portions of the glass wall. The error is still further reduced by taking measurements of the mercury column at several different heights. To increase the accuracy of the method one may replace the glass jackets with metal jackets provided with a number of small windows up and down the tube. These windows can be covered with very thin microscope coverglass or sheets of mica, and the mercury column can be viewed through the window. Results obtained by this method will be published later.

PROPOSED AMENDMENT TO C. A. OF S. AND M. T.

Central Association of Science and Mathematics Teachers, Proposed Amendment to the Constitution. To amend Article X and Amendment I by substituting "one dollar and twenty-five cents" for "one dollar" wherever used in connection with "School Science" and "official organ."