THE MEASUREMENT OF INTRAVENOUS TEMPERATURES.

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PLATE 16.

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The temperatures of various parts of the body, as determined with the ordinary clinical thermometer are, in general, different, and the differences are not always consistent. We cannot assume, therefore, that such measurements give a true index of the mean internal temperature of the body, which may perhaps best be identified with the temperature of the blood flowing in large blood vessels. Moreover the instrument itself is not free from objection. Its heat capacity is sufficiently great to lower appreciably for some time the temperature of tissue with which it comes in contact, and its response is too slow to follow fluctuations found with more sensitive apparatus. Although measurements made with a clinical thermometer are doubtless quite satisfactory for most purposes, it is possible that, for certain kinds of experimental work, fairly accurate determinations of blood temperatures may prove interesting. Apparatus which has been devised for this purpose by the author is described below.

The temperatures are measured by a thermoelectric method, in which one makes use of the fact that the discontinuity of electric potential at a junction of two dissimilar metals depends only on the nature of the metals and the temperature of the junction. A closed circuit of two metals contains, of course, two opposed junctions. If the second of these junctions is kept at a known constant temperature, the resultant thermoelectric force in the circuit is the difference between the potential discontinuities at the two junctions, and this is a function of the temperature of the first junction only.

This thermoelectromotive force may be used in either of two ways to measure temperature. It may be measured directly by means of galvanometer, potentiometer, and standard cell, or it may be allowed to maintain a current in the circuit which, according to Ohm's law, will be proportional to the voltage, and which may be measured by the galvanometer deflection. Each of these ways has certain advantages. In the present case the temperature range is small, being only about 5°C. above and below normal, which may be taken as 37.5°C., and the resistance of the circuit is fixed. For these reasons, and in the interest of simplicity and quickness of operation, the galvanometer deflection method was adopted. To use this method to best advantage the second thermocouple is kept constantly at 37°C. by means of a special thermostat.

The apparatus consists essentially of the unit containing the couple to be placed in the body, which is referred to as the needle unit; the portable thermostat; the cable connecting the needle unit with the thermostat; and the galvanometer with necessary switches, etc. Each of these parts is described below in detail.

The Needle Unit.

The longer unit shown in Fig. 1 is the needle unit. The couple consists of two No. 40 single-silk-covered wires, one of copper, the other of constantan, contained in the central tube of spring steel which has an external diameter of 0.7 mm. and an internal diameter of about 0.3 mm. At the needle end the wires are connected together and to the tube with solder. The technique of making this soldered joint required considerable study. It was found that a good seal could be made without allowing the solder to join the two wires together or to the tube over a length of more than 1 mm. At the other end the wires are soldered to the copper screw and the constantan center pin of the connecting plug. The steel tube lies within a hypodermic needle (external diameter 1.4 mm.), sufficient space being left between them to allow blood to flow into the glass pipette. A flow of blood shows that the needle has been properly inserted into the blood vessel and brings the needle quickly to temperature equilibrium. In the figure the tube containing the couple is shown protruding from the needle, but in practice it will be withdrawn to the best position by means of the adjusting screw. All metal parts except the electrical contacts are nickel-plated and polished. The two units shown in Fig. 1 are interchangeable, the resistance of each being 21.86 $\pm$ 0.02 ohms and the correction factor for lack of uniformity of the constantan being about 1.002.

The Flexible Cable.

Either of these units is connected to the couple contained in the thermostat by means of a flexible cable about 4 meters long. The copper and constantan conductors consist each of several No. 40 wires, each group sewed up in narrow silk ribbon. They are surrounded by a helical spring 4 mm. in diameter of piano steel wire which is covered with diagonally woven silk braid. This cable is not injured by crumpling or pulling, and is so light and flexible as not to interfere with the operator's use of the needle. The resistance is 34 ohms. The ends are provided with small receptacles, the terminals of which are of copper and constantan, to fit the connecting plugs of the needle unit and the thermostat. These receptacles also serve to connect the external metal parts of the needle unit through the steel spring of the cable to the ground plate of the thermostat.

The Thermostat.

The thermostat is shown in Figs. 2 and 3. A and B are the walls of a flask of Pyrex glass, the space between which is filled with mercury which serves both as the constant temperature bath and, by its change of volume and consequent change of level in tube D, as the temperature regulator. The flask is wrapped in several layers of asbestos paper through the second one of which is sewed the resistance wire for warming the bath electrically. One end of this wire is connected to a binding post on top of the thermostat and to the metal sleeve E which is cemented to the glass tube D and which carries the adjusting screw F with its sharp pointed platinum wire through which contact with the mercury is made. The other end of the resistance wire is connected to another binding post and to the platinum wire sealed into the flask at L. The flask with its wrapping sets in an ordinary pint thermos bottle, the space above the flask being filled with non-conducting material. The thermocouple consisting of the constantan wire from plug H and the copper wire from a copper binding post is set in wax in the glass tube *C*. The space between *B* and *C* contains mercury, above which is a packing of cloth. The copper screw of plug *H* is connected to another copper post on top of the thermostat. All posts and other metal parts having to do with the thermoelectric circuit are attached to the upper disc, *I*, of hard rubber, while the posts for heating current are set in the lower disc *K*. The metal plate *J* between these discs may be grounded. The heating current, therefore, cannot leak into the thermoelectric circuit. The cap *G* protects the screw *F* from accidental change of adjustment.

The resistance wire for the heating current has a resistance of about 28 ohms and is operated from the 110 volt lighting circuit through an external series resistance consisting of a 25 watt, 110 volt lamp. When the mercury makes contact with screw *F* the heating current is short-circuited through the mercury. With the regulator set for a temperature of 37°C., the room temperature being 20°C., the heating is *on* about 6 seconds and *off* about 10 seconds. A calculation shows that the mean fluctuation in temperature of the mercury bath could not exceed 0.02°C. under the worst conditions, but since the heat is introduced at the outer surface of the flask—the only place where heat can escape from the flask—there is no consistent flow of heat through the mercury and therefore probably only a negligible fluctuation of temperature at the middle, and this is further decreased by the presence of the mercury between *B* and *C*. The use of the mercury contact to short-circuit the heating current rather than to operate a relay has a distinct advantage in that there is no arc when the contact is broken. The currents and voltages which can be handled in this way without arc are, however, small and had to be found by preliminary experiments. This thermostat has been run almost continuously for several months and though the mercury surface is exposed to air, it is still perfectly clean and bright. Its action has been studied with a high sensitivity galvanometer and no temperature fluctuations have been found.

The Galvanometer.

A Leeds and Northrup type R galvanometer 2500-a is used, since the sensitivity is such that the desired range of temperature covers the 50 cm. scale at a distance of 1 meter, the damping is critical, and the period is only 5 seconds. It is mounted in a box backed by a grounded metal plate which is fastened to the wall. The galvanometer is packed in cotton and the box provided with copper posts for external connection.

The external circuit from the thermostat through the switches to the galvanometer, including binding posts, wire terminals, etc., is of copper. A 50 ohm copper resistance is mounted with the switches to provide critical damping for zero readings, and to correct for slight stray thermoelectric forces in the galvanometer. The switch is mounted on a metal ground-plate. The insulated connecting wires are protected against leakage by being wrapped with copper wires fitted with terminals for connection to the ground-plates of switch, galvanometer, and thermostat.

Preliminary Tests of the Apparatus.

Calibration curves were taken with a large water bath, stirred by a motor, the temperatures being read with a microscope on a Bureau of Standards thermometer divided to 0.1°C. The curves are smooth and consistent to within 0.01°C. save for a few isolated points the worst of which are within 0.02°C. of the curve. The apparatus is therefore not more in error than the thermometer readings, probably much less. Readings accurate to 0.01°C. are obtained when the needle is immersed in water to a depth of only 3 mm., and equilibrium is reached within the normal time of damped swing of the galvanometer. Placed in the left ventricle of the heart of a rabbit, equilibrium was reached with the same degree of promptness after the flow of blood into the pipette was established. It is therefore safe to assume that the error in intravenous measurements will not be greater than 0.01°C.

EXPLANATION OF PLATE 16.

Fig. 1. The longer unit is the needle unit, the end of which is inserted into the blood vessel. The small tube inside the pipette and needle contains the two wires of the thermocouple. The shorter unit is used for taking mouth temperatures.

Figs. 2 and 3. The thermostat which maintains the second thermocouple at a constant temperature.

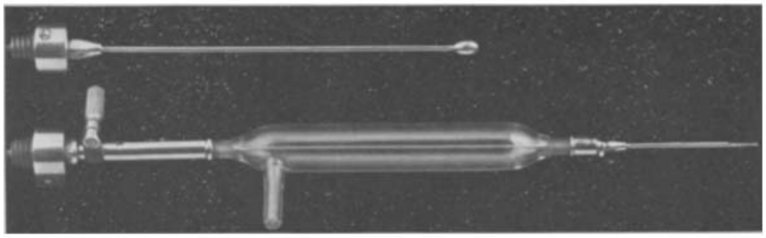
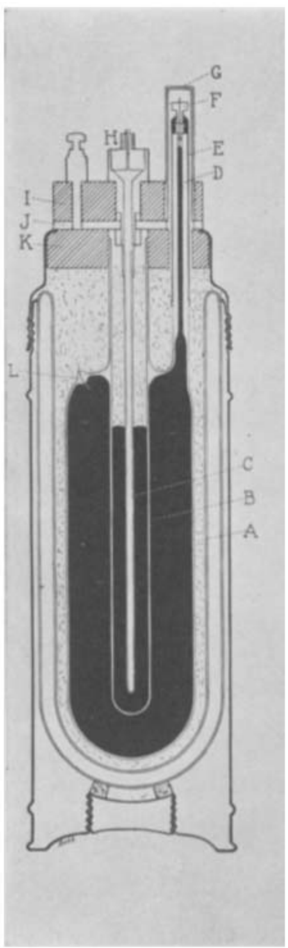


FIG. 1.



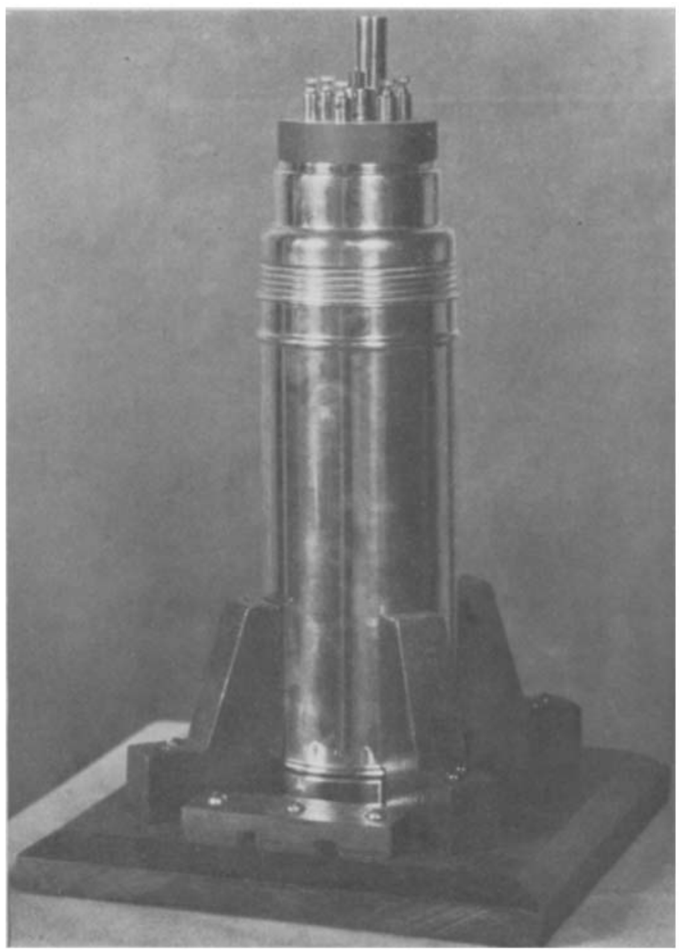


FIG. 2. FIG. 3.

(Clark: Measurement of intravenous temperatures.)