X. AN IMPROVISED ELECTRIC THERMOSTAT CONSTANT TO 0.02°.

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IN these days of elaborate physical apparatus it may be of interest to describe a simple thermostat which can be made easily from material at hand and is sufficiently constant for most purposes. The apparatus, shown in the photograph, was required for an investigation expected to extend over twelve months or more and needing only moderate constancy.

The principle of the stirrer, on which the success of the thermostat depends, was suggested by Mr S. Bradshaw, to whom the author is indebted, also, for much kind assistance in making the apparatus (Plate I). The stirrer comprises a solenoid, A, with an iron plunger, B, mounted on a glass tube carrying an ordinary cork bung, shown in dotted outline, at its lower extremity. The upper part of the glass shaft bears two rubber corks, C and D, that strike the left arm of the brass lever, E, whose right arm carries a cylindrical plumbago contact. As the stirrer reaches the lower end of its stroke, the cork, C, pulls over the lever, causing the plumbago contact to engage with a similar contact, F, above. The current from the 110 volt supply now flows through the solenoid, raising the plunger until the cork, D, throws the lever back again, breaking the circuit and allowing the plunger to fall. To render the lever stable in either position, it is made top-heavy by means of the weight, G, carried on a stout wire soldered to the lever near its pivot.

For temperatures up to 25°, a 16 c.p. carbon lamp is sufficient as a heater. For higher temperatures a more powerful lamp may be employed, or an auxiliary one continually alight. The brass parts of the lamp are protected from the water by a short piece of 1 inch rubber tubing.

As pointed out by Lewis [1922], the heater should be placed near the thermo-regulator, M, which is similar to an ordinary toluene thermo-regulator for gas. This was made from a stout glass test-tube of about 50 cc. capacity when sealed to about 3 inches of 4 mm. glass tubing. To this was joined about 6 inches of 1 mm. bore capillary tube, having a short wider tube at its open end. About 2 inches from the upper end of the capillary, a short piece of 4 mm. tube, N, was sealed at right angles. The wider tube, joining the capillary and bulb, was then bent through 180° near its junction with the bulb. The bulb contains toluene and some mercury which also fills the

capillary tube. The height of the mercury in the latter is adjusted by sliding, within the side tube, a short piece of capillary tube bearing a platinum contact at its sealed end. The joint between the side tube and its piston is closed by a sleeve of rubber tubing. The other platinum contact is carried at the end of a piece of glass tube, O, drawn out so as to pass vertically within the wider end of the capillary tube and rest on the constriction, with the contact projecting into the capillary tube.

These two contacts are connected, by mercury seals, in series with a 4 volt accumulator and the magnetic cut-out for the heater. For the cut-out, a discarded high-resistance telegraph relay, P, was fitted with iron wire dippers and two mercury cups in circuit with the heater. However, almost any high-resistance electro-magnet and armature could be adapted. By using an accumulator to actuate the cut-out, there can be no fouling of the mercury in the thermo-regulator, and it is unnecessary to provide for an up-and-down motion of the upper platinum contact. The capacity of the accumulator is immaterial, as it can be charged while in use through a single lamp, the potential difference across its terminals remaining at 4 volts. Actually a 40 ampere-hour accumulator will last a month without recharging. The capacity of the bath is about 5 litres. A constant level is maintained by the Marriott's bottle shown on the left.

Had the temperature remained constant within 0.1° , expectations would have been fulfilled. Consequently, it was astonishing to find that the variations were limited to 0.02° . The observations recorded below extended over a period of nearly 24 hours. The maximum variation occurs within a short period corresponding to, but lagging behind, the heating cycle. By bringing the heater right up to the thermo-regulator, probably even this small variation would be diminished. The disadvantage of doing so, when working for very long periods, lies in the chance of the mercury in the cut-out being fouled on account of the greater number of breaks. During the period under observation only one reading was made differing by more than 0.01° from the mean, and this was only 0.05° greater.

The solenoid, $4\frac{1}{2}$ inches long, with a pasteboard tube, allowing $\frac{1}{8}$ inch clear space round the iron core, is wound with about eight layers of No. 27 single cotton covered wire insulated with shellac varnish. The core is made from gas pipe, $\frac{3}{4}$ inch diameter, the same length as the solenoid, turned down to about $\frac{3}{8}$ inch thickness. Or it could be made from sheet iron. The glass shaft passes through two rubber corks in the ends of the core and is supported by guides, Q and R, constructed of sheet brass. It is convenient to make the glass shaft in two pieces joined by a cork, shown at the level of the heating lamp.

The contact lever, E, is the only part of the stirrer needing careful construction. It is fashioned from 18 gauge sheet brass. The pivot bearing is a piece of brass tube, $\frac{1}{8}$ inch long, sweated through the lever at its centre of mass, and ground with a little emery and oil to fit smoothly over the shank of a

round-headed brass screw forming the pivot. The mass of the weight, G, is about 25 g. One end of the bearing abuts against a brass plate screwed to the base-board, the other against the flange of the screw, which is adjusted so that the lever just swings easily, without looseness, between the two stops, K and L, jacketed with rubber tube. The thin steel springs, H and J, are carefully bent so that their pressures increase or diminish very gradually and evenly throughout the stroke. They engage the under side of the lever and the lower one should project upwards to the level of the end of the upper one. The pressures of the springs are adjusted by means of the screws seen near their centres, and must be only sufficient just to absorb the energy of the lever as it is brought to rest against the stops. To prevent sparking at the pivot, with consequent roughening of the bearing, the current is conveyed to the lever through a short piece of flexible wire soldered to it, as shown in the photograph.

(a) Thermometer remote from thermo-regulator

θ	T		
	h.	m.	s.
23-52°	3	5	0 p.m.
.51		7	0
.50		7	30
.51		8	0
.52		9	0
23-50	3	17	0
23-50	3	45	0
23-50	4	0	0
23-51	4	15	0
23-52	10	30	0 a.m.
23-52	10	50	0
.52		53	0
.53		54	0
23-515	11	5	0
23-52	11	39	0
.51		39	30
.505		40	0
.51		40	10
.52		40	20
.525		41	0
.52		41	20
23-52	12	26	0 p.m.
.51		26	30
.50		27	0
.51		27	20
.52		27	30

(b) Thermometer near thermo-regulator

θ	T		
	h.	m.	s.
23-515°	12	30	0 p.m.
.505		30	30
.505		31	0
.515		31	30
.52		32	0
.515		32	10
.51		32	30
.51		33	0
23-51	1	10	0
.515		11	0
.51		11	20
.51		12	0
.505		12	20
.51		13	0
23-515	2	12	30
.51		12	50
.50		13	10
.50		13	30
.505		14	0
.51		14	10
.515		14	30
.51		14	50
.505		15	0

The induction in the solenoid causes a powerful spark at each break and a great deal of trouble was experienced with the contacts. When first set up, the apparatus worked for several hours, but the metal contacts used soon became corroded. Mercury contacts in oil lasted only about 48 hours. Finally,

cylindrical plumbago contacts, 8 mm. in diameter, as used for magneto brushes were adopted. The lower one fits firmly in a clip soldered to the lever. The upper contact slides tightly in a thin split metal cylinder, which fits loosely in a short vertical piece of glass tube, clamped to the base-board, and has a projection at the top to prevent the contact holder dropping through the glass tube. The flexible wire bringing the current is soldered to this projection. The position of the upper plumbago rod in its holder is adjusted so that, when the lever is in the contact position, the lower rod has raised the upper one about $\frac{3}{16}$ inch above its resting position. Thus, at each make and break, the lower contact pushes the upper one up and down, and upon this motion the efficiency of the apparatus appears to depend. Probably carbon contacts would serve nearly as well as plumbago ones.

Even with this arrangement, however, the apparatus could hardly have been regarded as satisfactory, owing to excessive sparking. Ultimately the device was adopted of allowing a small current, just insufficient to raise the plunger, to flow through the coil constantly. Only the extra current, necessary to actuate the stirrer, is passed through the contacts. With this arrangement, the coil is always on a closed circuit, and the smaller induced current, due to breaking the extra current, discharges through the closed circuit, almost entirely avoiding the spark. The constant current flows through an 8 c.p. carbon lamp, and the size of the bung is then adjusted so that its buoyancy is sufficient just not to float the plunger. The extra current passes through an 8 c.p. lamp or preferably, a 16 c.p. lamp with a resistance (which may be made of iron wire), about 150 ohms, adjusted so that the plunger moves regularly with the required power. The position of the corks, C and D, is adapted to the length of stroke, about $2\frac{1}{2}$ inches.

The only attentions the apparatus requires are to give a drop of oil to the pivot, the brass springs and the sliding contact holder, and to sand-paper the surfaces of the plumbago contacts about every 48 hours. Occasionally the pivot screw, or those of the springs, may need a fraction of a turn. The guides of the shaft are best lubricated with vaseline. At the time of writing the thermostat has been running smoothly for over a month.

REFERENCE.

Lewis (1922). *Trans. Farad. Soc.* 17, 1.