NOTE ON TWO THERMO-REGULATORS.

BY W. R. BOUSFIELD, M.A., K.C.

*(Exhibited before the Faraday Society, Wednesday, December 6, 1911,
Dr. J. A. HARKER, F.R.S., in the Chair.)*

Fig. 1 represents a regulator specially designed for an air thermostat, in which a battery of standard cadmium cells was kept. The principle is equally available for a water thermostat, though slight changes of detail would be necessary.

The source of heat to be regulated was an electric radiator, worked direct from the power mains carrying an alternating current at 240 volts. *A B* are the upper and lower surfaces of a column of mercury contained in a barometer tube. Part of this mercury column is in series with the radiators and the current from the main, which passes into and out of the mercury by platinum wires, 1 mm. thick, sealed in the glass walls of the tube. The current enters through the wire *C*, which is placed sufficiently far below the surface *A* to be always immersed. The circuit is closed by contact between the lower platinum wire *D* and the lower surface *B* of the mercury. The barometer tube communicates with the bulb *E*, which is filled with hydrogen through a cock, *F*. A cock, *C*, serves to regulate the quantity of mercury for the desired temperature, and enables the bulb *E* to be thoroughly washed out with hydrogen gas. Overheating of the thermostat expands the gas and causes the mercury surface *B* to be forced away from the platinum wire, thus cutting off the current. The reverse process takes place when the temperature falls below the mean.

The tube is furnished with two bulbs at *A* and *H*. The mean pressure in *E* must be so chosen that the mercury in *A* normally occupies about half the bulb *A*. The purpose of the bulb *H* is to supply sufficient mercury to fill the bulb *A* in case of overheating, without allowing the lower level of the mercury to be depressed to the bottom of the tube, which would permit air bubbles to pass and spoil the vacuum in *A*.

It is best to instal the regulator with the mean pressure in *E* about equal to mean atmospheric pressure. The length of the tube will then be that of an ordinary barometer. In this way the possible leakage of the mobile hydrogen through defective taps is prevented.

In such an apparatus, where the full current through the radiators from a pressure of 240 volts in the mains passes through the mercury and gives rise to a spark at *B* on breaking the contact, it was a matter of vital importance to prevent oxidation or other deterioration of the surface of the mercury. For instance, it was anticipated that nitrogen with traces of oxygen and water vapour might give rise to nitric acid and cause trouble. Hydrogen forms no compound with mercury, and was tried in the first instance. It proved completely successful. Last winter the regulator was kept working

day and night for six months, maintaining a temperature of about 18° C. No tarnishing of the mercury surface has taken place, and it seems as bright as when it was first installed.

A point of importance is that the regulation is independent of variations of atmospheric pressure, owing to the gas being completely enclosed and working against a vacuum.

To find the sensitiveness, let—

P = pressure of hydrogen in mm. of mercury.

V = volume in c.c. of bulb E .

θ = absolute temperature.

A = sectional area of tube at A in cm.².

B = sectional area of tube at B .

x = distance in mm. of mercury surface at B , below platinum point.

h = mean height in mm. of mercury level at A above platinum point.

$$P = h + \left(\frac{B}{A} + 1\right)x$$

$$\delta P = \left(\frac{B}{A} + 1\right)\delta x$$

$$\delta V = B\delta x \times \frac{1}{10} \text{ (since } x \text{ is mm.)}$$

$$PV = C\theta$$

$$\begin{aligned} C \frac{d\theta}{dx} &= P \frac{dV}{dx} + V \frac{dP}{dx} \\ &= \frac{1}{10}BP + \left(\frac{B}{A} + 1\right)V \end{aligned}$$

i.e.—

$$\frac{1}{\theta} \cdot \frac{d\theta}{dx} = \frac{B}{10V} + \frac{1}{P} \left(\frac{B}{A} + 1\right).$$

For greatest sensitiveness $\frac{d\theta}{dx}$ must be as small as possible. Hence V and A must be as large and B as small as possible. The sensitiveness is also increased by making P large, but for the reasons mentioned it is best kept at about atmospheric pressure.

If—

$$B = 0.1 \text{ cm.}^2 \quad A = 4 \text{ cm.}^2$$

$$P = 760 \text{ mm.} \quad V = 760 \text{ c.c.}$$

$$\theta = 300^\circ \text{ equivalent to } 27^\circ \text{ C.}$$

we have—

$$\begin{aligned} \frac{d\theta}{dx} &= \frac{300}{760}(0.01 + 1.025) \\ \delta\theta &= 0.4 \delta x. \end{aligned}$$

With these dimensions 1 mm. fall of the mercury contact surface at B corresponds to 0.4° C., or 0.01° C. to one-fortieth of a mm.

The sensitiveness realised depends of course upon the activity of stirring of the contents of the thermostat. The comparative sensitiveness relative to that of a regulator depending on the expansion of mercury or toluene is chiefly influenced by the fact of the small heat capacity of the hydrogen contained in the bulb and the large surface available for rapid heat exchange.

Water Bath Regulator, Fig. 2.—This is a modified form of Lowry gas regulator. It was designed in the form of a grid, so as to be placed near the side of a large water bath, in order to take up as little room as possible. The last

FIG. 1.

FIG. 2.

U-shaped limb contains mercury from *B* to *A*. The remainder, from *A* to *C*, is filled with toluene. Easy filling is secured by the use of a small tube *C*, which is sealed with a blow-pipe when the mercury and toluene are in place. It is not difficult to fuse the tube *C* when filled with toluene as the heating

DISCUSSION

263

causes the toluene to boil near *C* and fill the tube with vapour, which excludes air, so that when the tube cools it is filled with toluene right up to the end without an air bubble. *D* is the gas inlet pipe, which is closed by the expansion of the mercury. *E* is the gas outlet pipe. The tube *D* is kept in place by a rubber stopper, which permits of its ready removal. Regulation to any desired temperature is easy. The regulator is placed in the bath, which is kept at the desired temperature for a few minutes. The tube *D* is removed, and an excess of mercury poured in. When the temperature is as desired, the excess of mercury is sucked out with a filter pump through the tube *D*. Thus the right quantity of mercury is obtained corresponding to the required temperature. This form of regulator is affected by variations of gas and atmospheric pressure, but it is not difficult to secure regulation of the thermostat within $\pm 0.01^{\circ}\text{C}$.