IMPROVEMENTS IN THE GLOBE THERMOMETER

By D. F. VINCENT
Of the National Institute of Industrial Psychology, London

(With 2 Figures in the Text)

THE globe thermometer was designed by H. M. Vernon as a simple instrument that will give a more reliable measure of the comfort of a room than the ordinary wall thermometer. When the room is heated by some system of low-temperature radiation, such as hot-water pipes, and when the amount of air movement is not excessive, the globe thermometer is probably as good as any single simple instrument can be. But it has never come into general use because there are conditions under which its indications may be very misleading to the layman.

The reading of the globe thermometer is the resultant of three factors—the air temperature, the mean radiant temperature and the amount of air movement. When the equation relating these three factors to the reading of the globe thermometer had been worked out by Bedford (1936) and Bedford & Warner (1934), this instrument found a new sphere of usefulness. Air temperature is very easy, and air movement is comparatively easy, to measure; but mean radiant temperature can only be directly measured by the laborious method of integrating a series of readings made with a thermopile. In a detailed investigation of the efficiency of a system of heating and ventilation all three factors are required. Air temperature and air movement have to be measured in any case; the work of Bedford and Warner enables the mean radiant temperature to be calculated from the globe thermometer reading.

In the work carried out by the National Institute of Industrial Psychology on the heating and ventilating systems in schools and colleges, a single investigation necessitates some hundreds of globe thermometer readings, and one of its disadvantages has become very evident. The instrument needs to be left for at least 15 min. before it gives a reliable reading: it is therefore rather slow in use. As it requires no manipulation, the readings of other instruments can be taken during the period of waiting, but in practice a good deal of time is always wasted in waiting for the globe thermometers to reach equilibrium. As these investigations are necessarily costly on account of the large expenditure of time involved, any saving of time is worth while. Accordingly, it was decided to carry out experiments on the globe thermometer to see if it was possible to speed it up.

The standard form of globe thermometer decided on by Bedford and Warner, to which their equations apply, consists of a blackened copper sphere

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6 in. in diameter, with the bulb of the recording thermometer situated at the centre of the sphere. This particular design is a matter of convenience, for it enables the instrument to be made from the copper spheres that are sold for floats for flushing cisterns. A different size and shape would necessitate a re-evaluation of the constants of the Bedford and Warner equations but would have no other disadvantage.

The first experiments were made to determine the effect of *size* on the rapidity of response of these instruments. It was thought that smaller "globes" might respond more rapidly, and since it was to be an investigation of size rather than of shape, instead of spheres, copper cylinders were made up with the length equal to the diameter—5, 4, 3 and 2 in. in size. These were given a trial in the laboratory of the Institute, and in the course of a school investigation during the waste time entailed by the standard globe thermometers. It was found that the smaller "globes" did respond slightly more rapidly; but as their divergence from the air temperature was much smaller, it would have been necessary to employ more accurate thermometers which would themselves have been slower and would probably waste more time than the slight amount saved by the smaller globes.

Since cylinders are easier to make than spheres, it was decided next to try the effect of *shape*. It was found that a cylinder of about the same bulk as the standard globe gave about the same reading. The method adopted was to place the instruments which were being compared a little distance apart in the centre of a room not in use, and to take a reading after 20 min. The instruments were then changed round so that each occupied the former position of the other, whereupon a second reading was taken after another 20 min. As a thermostatically controlled room was not available, this procedure was repeated several times. It was found that to the degree of accuracy to which we customarily worked ($\frac{1}{5}$° F.), a cylinder of a length and diameter of 5 in. gave the same reading as the standard globe. This cylinder had about the same surface area as the 6 in. sphere but was about 10% less in volume. This was very convenient, since it allowed the Bedford and Warner equations to be used without any change of constants.

It was decided next to find out the effect of the thickness of the metal. First a 5 in. cylinder was built of 0·005 in. hard-rolled copper foil. This gauge is about the thinnest that can be used for self-supporting cylinders. The cylinder and a standard globe were placed on either side of a source of high-temperature radiation (an electric fire) about 2 ft. away. Readings of the thermometers were taken every half-minute until a state of equilibrium had been attained. The radiant was then removed and readings were taken every half-minute till the instruments were again in equilibrium with their surroundings. It was found that after heating up, the two instruments showed different equilibrium temperatures, but the equilibrium temperatures after cooling down were the same. Readings taken at different distances from the radiant gave similar results. This effect might have been anticipated, since under the heating up conditions a rapid gain in heat on the hot side of the instrument was balanced by a rapid loss on the cold side and the greater thermal conductivity of the thicker metal would be certain to affect the redistribution of the heat. (This experiment suggests that a globe thermometer is of doubtful value in the vicinity of a high-temperature radiant, but as in our work it is extremely unlikely that we shall ever want to use them under such conditions it is not very important to us.) The cooling down readings showed that the thin metal cylinder reached a state of equilibrium more quickly than the thick metal globe.

Since it is safe to assume that if one of a pair of instruments will cool down to a state of equilibrium with its surroundings more quickly than the other, then it will also more quickly attain a state of equilibrium when it has

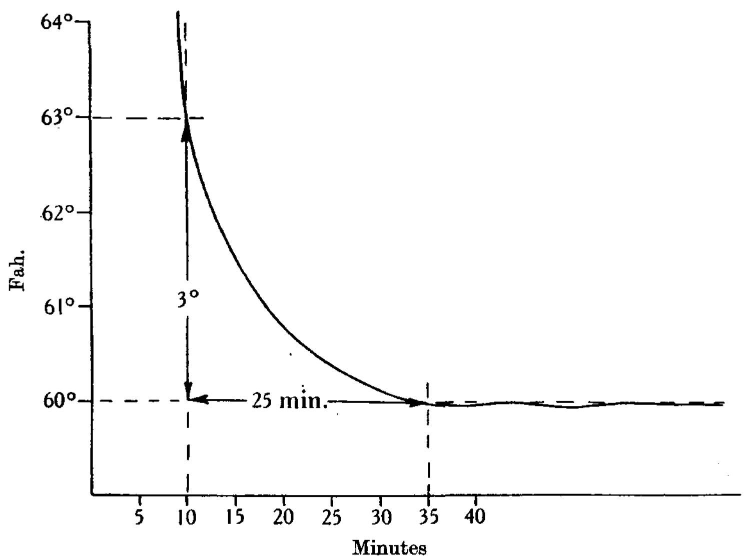

Fig. 1.

to warm up to its surroundings, it was decided to make all comparisons by cooling only. The Institute's work usually involves a large number of globe thermometer readings at different positions and at different times in the same room; an examination of our records shows that 3° is about the maximum change. Thus the time taken for an instrument to cool through 3° to reach a state of equilibrium with its surroundings forms a convenient basis for comparison. A typical cooling curve is shown in Fig. 1, where readings are taken to $\frac{1}{10}$° F. It will be seen that the exact time at which it reaches a state of equilibrium is uncertain. This is partly due to the flatness of the curve at the end and partly to the fact that without thermostatic control it is not possible to keep the conditions in a room constant to within $\frac{1}{10}$° F. for more than a few minutes. To avoid this complication it was decided to accept as

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equilibrium a temperature $\frac{1}{10}°$ higher than the lowest part of the curve. The comparison time was the time taken by the instrument to cool down to the accepted equilibrium temperature from a temperature 3° higher.

Fig. 1 shows how this time was obtained from the curve and it is the average of times found by three separate experiments that is quoted in Table I. It will be seen that the minimum of 15 min. for the standard globe is rather optimistic.

Table I. *Cooling times of globe thermometer*

	Bulb of thermometer and interior of globe bright.	Bulb of thermometer and interior of globe blackened	
	Without fan min.	Without fan min.	With fan min.
Standard globe	28	—	—
0·005 in. cylinder	26	16	11
0·002 in. cylinder	—	11	8

Cooling time of thermometer in air: 6½–7 min.

It was reasoned that as the air inside the globe would be practically still, the interchange of heat between the metal of the globe and the thermometer bulb would be chiefly by radiation and that blackening the inside of the globe and the thermometer bulb would accelerate the interchange.

Table I shows the effect of blackening.

The thinnest copper foil that we were able to obtain was 0·002 in. A 5 in. cylinder of this material was too delicate for any but the most gentle handling, so it was suspended in a cradle of hard-drawn iron wire which gave a maximum of protection with a minimum of screening. Table I shows that the thinner metal gives a further reduction in cooling time.

Since the experiment of blackening the inside of the globe and the bulb of the thermometer seems to indicate that the interchange of heat is mainly by radiation, it was decided to try the effect of mechanical agitation of the air inside the instrument. A cylinder of the thinner metal in a protecting cradle was built with a small fan that could be rotated from the outside. This is shown in Fig. 2. Spun by hand, this fan would rotate for 5–10 sec. Though it was intended that in practice this fan should be rotated by a motor if it proved satisfactory, during these experiments it was always spun by hand. The last figures in Table I show that with the 0·002 in. copper cylinder and the fan the instrument attains equilibrium nearly as quickly as the thermometer itself does when open to the air.

Clearly greater rapidity of response could only be obtained by improvements in the thermometer. So far the thermometers used were the standard type supplied by Messrs Hicks of Hatton Garden, London, for use in globe thermometers. They are a robust type of thermometer with a spherical bulb; and as they are subdivided to $\frac{1}{5}°$ F. the bulbs are necessarily rather large. Messrs Hicks were approached to design a thermometer of suitable shape and more rapid response, and they were able to produce one, employing clinical

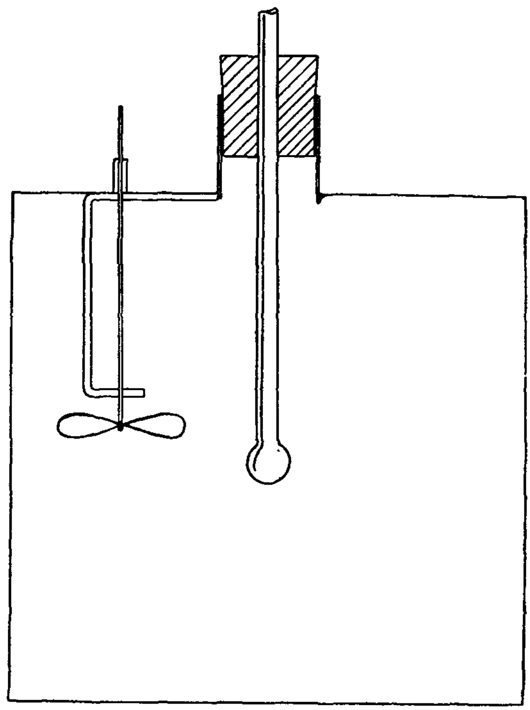

Fig. 2.

thermometer tubing with a magnifying index, which we found very satisfactory. Although more fragile than the standard type, a set of these instruments has been in use for about 6 months without any breakages. Table II shows how these thermometers effect a further saving of time of about 3 min. Comparative tests show that the new thermometers record the same equilibrium temperature as the standard type, the smaller bulb making no difference to the functioning of the instrument.

Table II. *Cooling time of improved thermometer in* 0·002 *in. cylinder, blackened inside*

Bulb of thermometer bright	
Without fan	With fan
10 min.	5½ min.
Bulb of thermometer blackened	
Without fan	With fan
8 min.	5½ min.

Cooling time of thermometer in air 4–4½ min.

From these experiments it may be concluded that:

(*a*) The standard globe thermometer made from a cistern float and having

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a bright interior requires about 25 min. to attain equilibrium when an accuracy of 0·1° F. is required.

(*b*) A "globe" thermometer with an envelope of copper 0·002 in. thick and having a blackened interior and with the thermometer bulb blackened takes about 4 min. longer to reach equilibrium than its thermometer would take in the open air.

(*c*) Mechanical circulation of the air enclosed within the globe reduces the time to about 1½ min. longer than its thermometer would take in the open air.

REFERENCES

BEDFORD, T. (1936). *Rep. Industr. Hlth Res. Bd, Lond.*, no. 76.

BEDFORD, T. & WARNER, C. G. (1934). *J. Hyg., Camb.*, **34**, 458.

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