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A DISC-TYPE RADIOMETER

by

C. T. Webster and A. J. Gregsten

Summary.

A radiometer is described for the measurement of radiation intensities up to about 2 cal cm^{-2} sec^{-1}. It consists of a thermocouple soldered to a copper disc receiving element, both faces of which are covered with thin asbestos paper. A calibration curve showing confidence limits is derived.

INTRODUCTION

In many investigations there is a need for a simple device which may be easily made in a laboratory, and which will give repeatable results for the measurement of radiation intensities over the range 0 - 2 cal cm^{-2} sec^{-1}. This need has been particularly felt in fire research investigations in which a number of heat transfer problems arise. In earlier investigations the device used was a gold disc, blackened on the side to which a thermocouple was brazed and left bright on the other side. Several difficulties were found with this device. At intensities of radiation sufficient to raise the disc to 500°C the carbon black was burnt off, and when platinum black was used there was a change in emissivity. Further, though gold does not generally tarnish in the laboratory it was found that the bright sides of the discs were quickly covered by a film taken up from the atmosphere; this film altered the emissivity of the bright side and therefore the characteristics of the device for the determination of radiation intensities.

Experiences with the gold disc radiometer showed the value of a disc receiver with a thermocouple attached, but it was essential that both surfaces should maintain a constant emissivity under all conditions of use. Moreover the device should be cheap and easily made. The instrument described in this paper fulfils both these requirements, and has been found to be sufficiently repeatable to warrant the use of a standard calibration curve, thus obviating the need for calibrating each freshly made instrument.

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A DISC-TYPE RADIOMETER

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Description of copper disc radiometers

The radiometer is made by silver-soldering a 22 S.W.G. chromel-constantan thermocouple to a 1 in. diameter 26 S.W.G. copper disc. The construction of the radiometer, which is illustrated in Figure 1 is fully described in Appendix 1.

Calibration

Four radiometers were arranged, together with an absolute radiation calorimeter (1), on a frame mounted in front of a one foot square gas-fired radiant panel the temperature of which was maintained at approximately 800°C (Plate 1). The faces of the radiometers to which the thermocouples were attached were placed towards the radiant panel. The frame enabled any instrument to be brought quickly into position normal to the centre of the radiant panel, and at any desired distance from it. The individual E.M.F.'s from eight radiometers are recorded in Tables 1 and 2.

Four of the radiometers were then put into daily use in the laboratory, and after three months were re-examined; the results are given in Table 3. One of the radiometers was tested after using for a year (Table 4).

Table 5 recorded the calibration of a newly made radiometer which was examined by the National Physical Laboratory. The radiometer was also examined at the National Physical Laboratory for selectivity by measuring its sensitivity to radiation from sources at 200°C and 1,000°C relative to its sensitivity to the radiation from a tungsten-filament lamp. Since the sensitivity varies considerably with intensity it is convenient to express the results in terms of the relative intensities of the different kinds of radiation which are required to produce equal open circuit E.M.F.'s.

TABLE 6

Relative intensities for equal E.M.F.'s

Source	2850°K	1000°C	200°C
	1·00	0·76	0·61

The intensities required to produce the open-circuit E.M.F. values quoted in Table 5 may thus be obtained for the 1000°C and 200°C sources by multiplying the intensity values by the appropriate factor in Table 6. By interpolation, the conversion factor for the 800°C source is 0.73.

The experimental results for copper/asbestos discs shown in Tables 1-3, taken together, give a good fit to a parabola of the form

$$I = aE + bE^2$$

where I is intensity in cals/cm^2/sec
E is E.M.F. in millivolts

The values of the constants a and b were found by the method of least squares to be

$$a = 0{\cdot}019.$$
$$b = 0{\cdot}001.$$

and these values have been used in plotting the curve of the equation in Figure 2. The standard error of the results based on the best fitting parabola is 0·029 cal/cm^2/sec, and therefore the 95 per cent confidence limits are approximately ± 0·05 cal cm^{-2} sec^{-1}. These are shown dotted in Figure 2. Thus for a given E.M.F. from a copper/asbestos disc radiometer, made according to the specification given in the appendix 19 times out of 20, the corresponding intensity of radiation will be between the upper and lower limits of the curve of Figure 2.

Conclusions

A disc-type radiometer, calibrated against an absolute instrument for the measurement of radiation intensity, has been described which will give the value of the intensity falling on it to within about ± 5 per cent over the central part of its range (0·5 - 1·5 cal/cm^2/sec). Two of these radiometers (Tables 4 and 5), independently tested, fall well within the confidence limits of the standard curve obtained from the original experimental work. The copper/asbestos disc made to the specification described may therefore be used to predict intensities of radiation of up to 2 cal cm^{-2} sec^{-1} to within ± 5 per cent.

PC.

APPENDIX 1

Detailed specification for the construction of copper/asbestos disc radiometers

Thermocouple wire : 22 S.W.G. chromel
22 S.W.G. constanten

Copper disc : 28 S.W.G. 1 in. diameter

Solder : silver solder M.P. 750°C (approx.)

Asbestos paper : thickness = 0·01 in. Weight per unit area = 5·16 oz/sq.yd ± 5 per cent.

Sodium Silicate Adhesive: An aqueous syrup of composition between $Na_2O : 3{\cdot}2\ SiO_2$ and $Na_2O : 3{\cdot}4\ SiO_2$, having a specific gravity between 1.41 and 1.43.

Method of construction

Solder the ends of the thermocouple wires to one face of the copper disc at diametrically opposite points near the edge (Figure 1). After soldering, thoroughly clean the disc on both sides with emery cloth, and then dip for about ½ minutes in a cleaning mixture consisting of 4 parts by volume conc. sulphuric acid to 1 part chromic acid or sodium dichromate. After washing and drying the discs, care being taken not to handle the surfaces of the copper with the fingers, prepare some 1 in. diameter asbestos paper discs by holding a piece of the paper tightly together with a spare copper disc and tearing round the edges. Lay the copper disc on a pad of clean blotting paper thermocouple side down and apply a drop of the silicate syrup to the centre of the disc. The size of the drop should be such that its diameter is between ¼ in. and 5/16 in. in not less than 15 seconds after placing. Lay an asbestos paper disc on top and work it round and round with the finger, spreading the silicate all over the surface until it becomes tacky, then centralise and press firmly into position. Repeat for the other side of the disc, taking care to press the asbestos paper well down all over the slight bulges where the wires are soldered on. The disc will then be ready for use after about an hour, and can be mounted in whichever way is convenient for the work in hand. A generally useful form is shown in Figure 1. It is essential that the radiometer be always used with the thermocouple towards the source of radiation.

References

(1) A radiation calorimeter for the absolute measurement of radiation intensities between 0·4 and 12·5 watts/cm^2. Lawson, D. I. and McGuire, J. H. F.R. Note No. 37/1953.

TABLE 1

First group of four copper/asbestos discs

Intensity cal cm^{-2} sec^{-1}	E.M.F.			
	C/A 1 mv.	C/A 2 mv.	C/A 3 mv.	C/A 4 mv.
1.87	35.0	34.4	35.0	35.5
1.42	29.6	29.0	29.9	30.0
1.22	27.2	26.6	27.4	27.6
1.06	24.6	24.6	25.2	25.4
0.93	22.6	22.4	23.0	23.0
0.82	21.4	21.0	21.2	21.4
0.63	17.7	17.4	17.6	17.7
0.52	15.4	15.0	15.5	15.5
0.38	12.0	12.0	12.0	12.0
0.29	10.0	10.0	10.0	10.0
0.16	6.2	6.1	6.2	6.2

TABLE 2

Second group of four copper/asbestos discs

Intensity cal cm^{-2} sec^{-1}	E.M.F.			
	C/A 5 mv.	C/A 6 mv.	C/A 7 mv.	C/A 8 mv.
1.85	34.6	35.0	34.4	33.6
1.48	30.0	30.0	30.0	29.2
1.26	27.2	27.8	27.0	26.4
1.12	25.4	25.7	25.0	24.4
0.97	25.0	25.4	22.7	22.4
0.87	21.2	21.7	21.1	20.6
0.67	18.0	18.0	17.9	17.5
0.54	15.5	15.6	15.4	15.0
0.38	12.0	12.4	12.0	12.0
0.30	10.0	10.0	10.0	10.0
0.16	6.2	6.3	6.1	6.0

TABLE 3

Repeat of first group of discs after three months

Intensity cal cm^{-2} sec^{-1}	E.M.F.			
	C/A 1 (2) mv.	C/A 2 (2) mv.	C/A 3 (2) mv.	C/A 4 (2) mv.
1.96	35.0	35.5	35.2	36.0
1.51	30.8	31.0	31.0	31.2
1.16	26.0	26.0	26.0	26.2
0.89	22.2	22.2	22.2	22.2
0.54	16.0	16.0	16.0	16.0
0.36	11.9	12.0	12.0	12.0
0.18	7.0	7.0	7.0	7.1
0.11	4.6	4.6	4.7	4.6

TABLE 4

Repeat of C/A 8 after one year

Intensity cal cm^{-2} sec^{-1}	E.M.F. C/A 8 (2) mv.
0.215	8.3
0.36	12.0
0.60	17.5
1.06	25.0
1.41	29.8

TABLE 5

Calibration of a copper/asbestos disc by the National Physical Laboratories

Measured intensity (2650°K source) cal cm^{-2} sec^{-1}	E.M.F. mv.	Calculated intensity (800°C source) cal cm^{-2} sec^{-1}
0.053	2	0.04
0.119	4	0.09
0.194	6	0.14
0.275	8	0.20
0.378	10	0.28
0.468	12	0.34
0.581	14	0.43
0.715	16	0.52
0.857	18	0.63
1.002	20	0.73
1.17	22	0.85
1.36	24	0.99
1.58	26	1.15
1.82	28	1.33

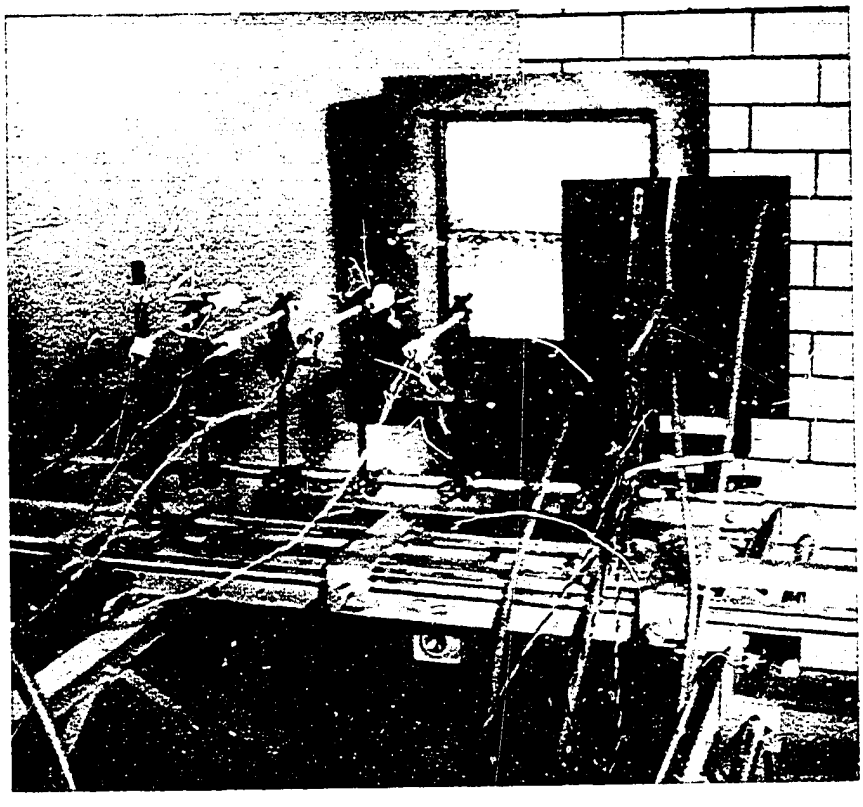
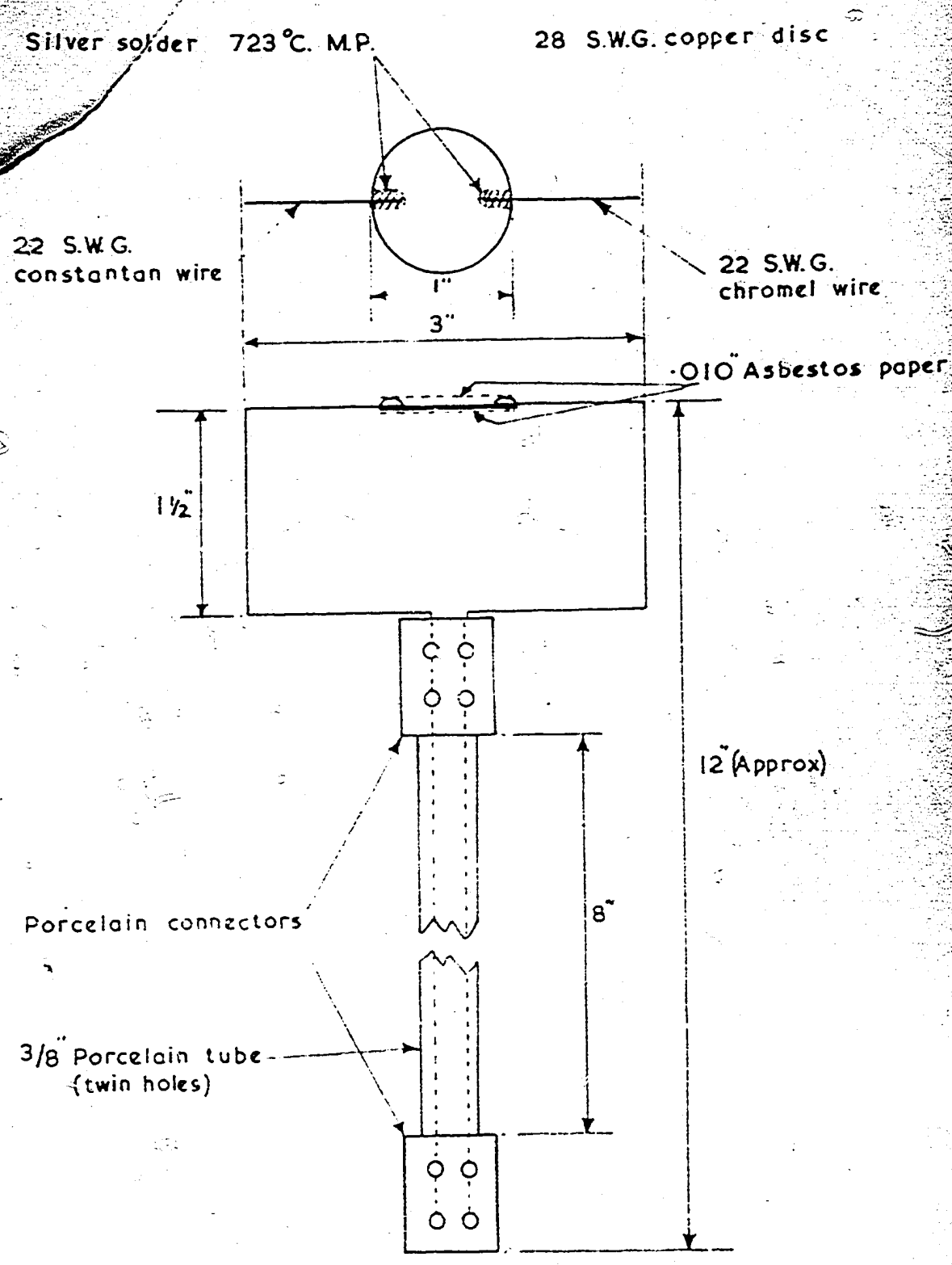
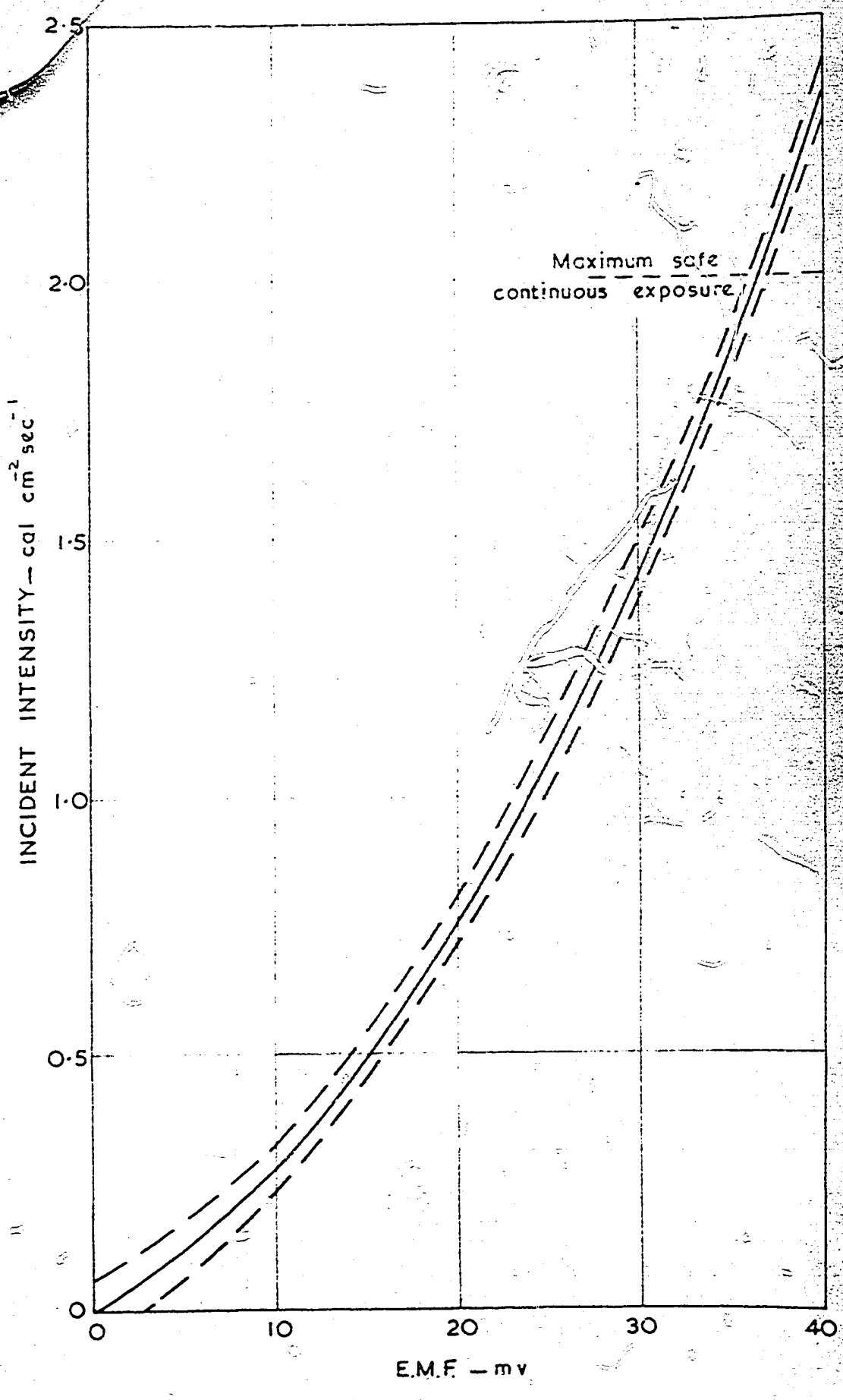


PLATE I. COPPER ASBESTOS DISCS AND ABSOLUTE RADIATION CALORIMETER.



G.I. CONSTRUCTION OF A COPPER DISC RADIOMETER



G.2. STANDARD CALIBRATION CURVE FOR A COPPER/ASBESTOS DISC RADIOMETER WITH 95% CONFIDENCE LIMITS

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