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DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH AND FIRE OFFICES' COMMITTEE
JOINT FIRE RESEARCH ORGANIZATION

AN ABSOLUTE RADIOMETER OF NOVEL DESIGN

by

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Introduction

Although the differential expansion of metals has been exploited in the measurement of temperature this property does not appear to have been exploited in the measurement of radiation. A radiometer may be constructed by fixing two bimetallic strips in an apperture in a water-cooled screen (Fig. 1). As the strips are heated by radiation they deflect, their deflections may be arranged to be opposite senses so as to twist a yoke carrying a mirror, or the deflection may be in the same sense and the deflection measured by a reading telescope (Fig. 2). After the deflection has been measured the instrument may be calibrated by substituting electrical heating for the radiant heating until the same deflection is given.

Design considerations

Bimetallic strips bend into the arc of a circle of radius R when heated where (1)

$$R = \frac{t}{2KT} \quad -(1)$$

where T is the temperature change

t is the thickness of the strip

K a constant depending on the type of strip used, and varies from 3.2 - 19.3 x $10.^{-6}$ per °C

If the strip of length (Fig.3) bends into a radius R the deflection d from the original position is given by

$$d = \frac{l^2}{2R} \quad -(2)$$ where l is the length of the strip

substituting in (1) gives

$$\frac{l^2}{2d} = \frac{t}{2KT}$$

or $$d = \frac{l^2 KT}{t}$$

If the two strips are a distance δ apart and are arranged so that the displacements are on opposite senses, the angle of deflection α of a yoke will be $\frac{2d}{\delta}$; thus $\alpha = \frac{2 l^2 KT}{t\delta}$

With an optical lever of length L the deflection χ over the mirror scale is $2\alpha L$ giving

$$\chi = \frac{4 l^2 L \quad KT}{t \delta}$$

Taking L = 100 cms K = 12×10^{-6}

l = 2 cms = 0.5 cms

t = 0.2 cms

χ = 0.192 T cms

Now T must be expressed in terms of the radiation falling on the strip. If the conduction along the strip is neglected, the temperature of the strip may be found (1) as shown in Table 1.

Table 1 - Temperature of strip in terms of radiation falling on it.

Radiation Intensity cals/sq.cm/sec	0.49	0.24	0.12	0.07
Temperature °C	333	227	150	100

Combining the results of Table 1 with Expression 3 gives an upper limit for the sensitivity this is shown in Fig. 3. In practice the sensitivity will be lower than this due to the conduction loss along the strips. This loss will be greatest when a uniform temperature gradient exists along the strip. Under these conditions the rate of conduction of heat along the strip will be given by

$$\frac{K'AT}{l}$$ where A is area of cross section

K' is the thermal conductivity of the material

The heat loss by conduction per unit area of face would be given by $\frac{K'Tt}{l^2}$

A suitable value of K for bimetallic strips would be 0.025. Putting in values from the example cited, the heat loss per unit area is given by $1.2 \times 10^{-3} \times T$. These values of heat loss should be added to the intensity figures in Table 1.

Table 2 - Relation between temperature of strip and intensity of radiation allowing for conduction

Radiation Intensity cals/sq.cm/sec	0.89	0.51	0.30	0.19
Temperature °C	333	227	150	100

These corresponding values are plotted in Fig. 4.

The sensitivity could of course be increased by reducing either or both the thickness of the strips and the distance between them. It could be further increased by increasing the length of the radiometer strips. This latter method is particularly powerful as the sensitivity should increase with the square of the length of the strip.

Bibliography

LAWSON, D. I. WEBSTER, C. T. & FOX, L.L. The heating of panels by flue pipes. H.M.S.O. 1952.

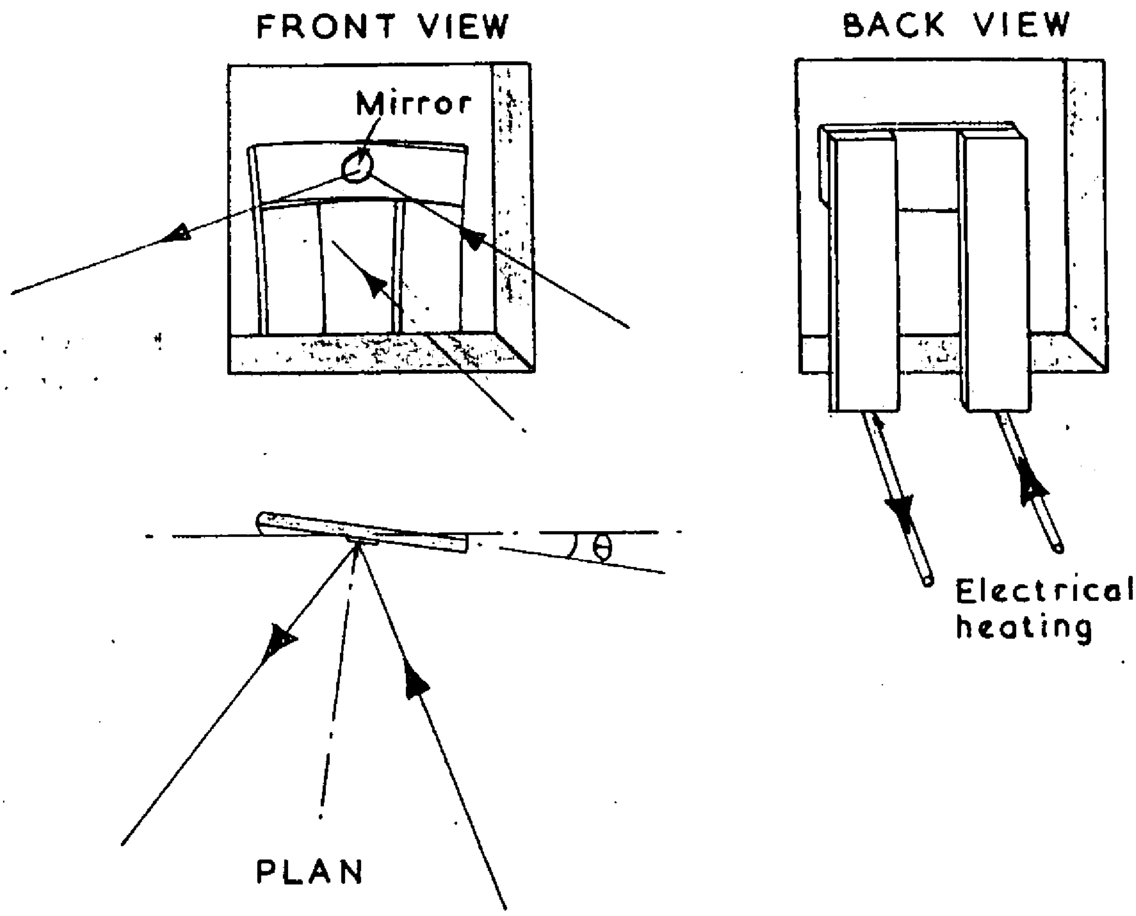

FIG. 1. RADIOMETER ARRANGED AS MIRROR INSTRUMENT

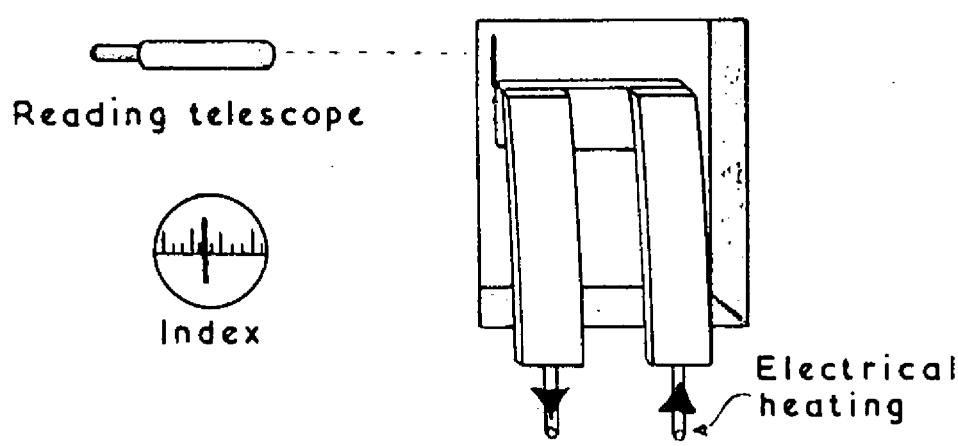

FIG. 2. RADIOMETER ARRANGED TO USE READING TELESCOPE

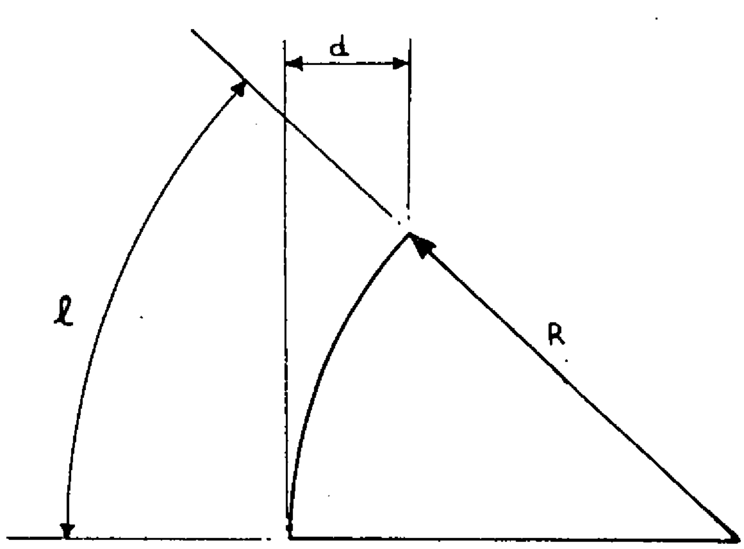

FIG. 3.

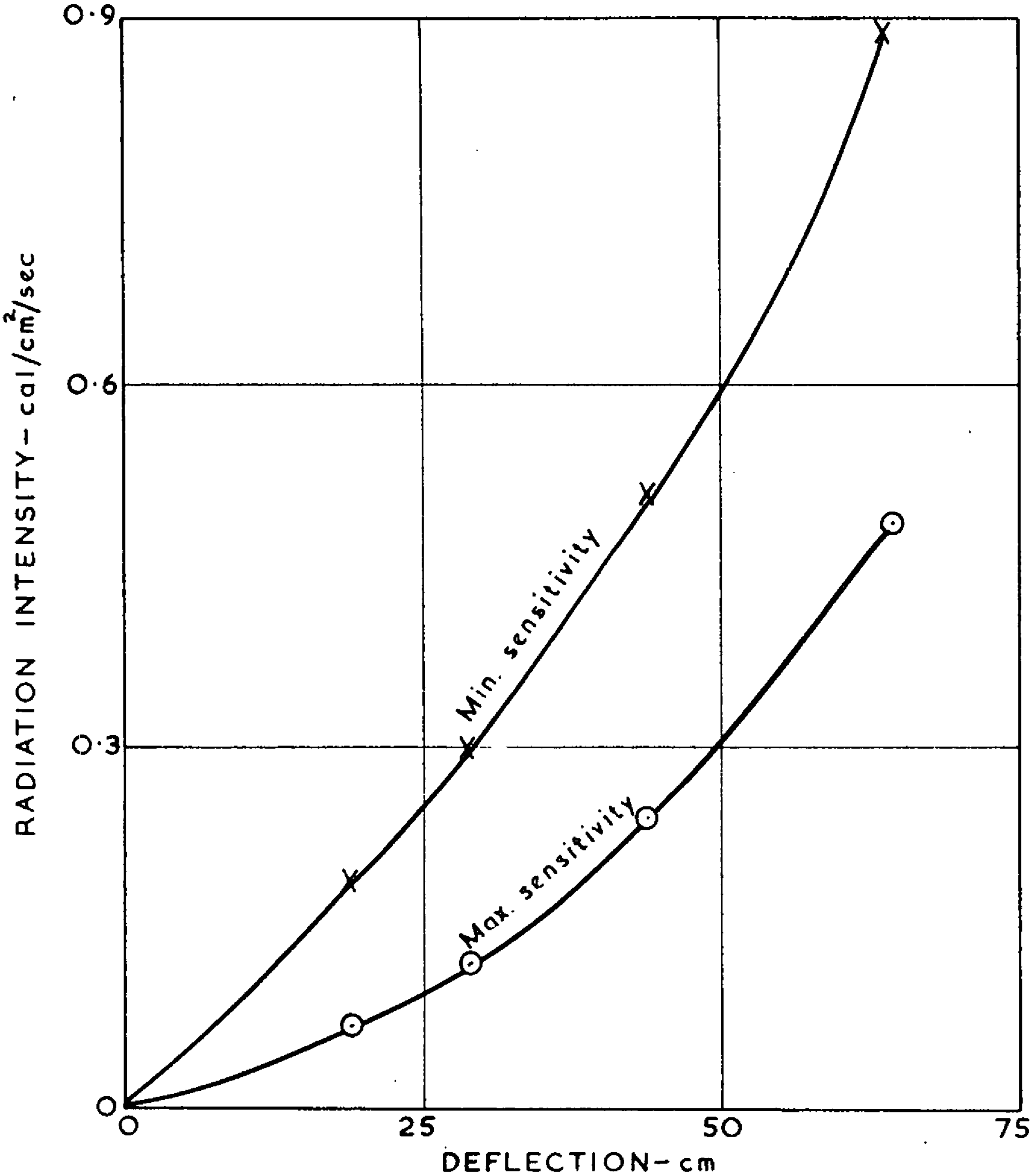

FIG. 4. COMPUTED SENSITIVITY CURVES FOR RADIOMETER