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

SOME RADIATION CHARACTERISTICS OF A GAS-FIRED PANEL

by

D. L. Simms and Joan Miller

Summary

The measured distribution of intensity from a proprietary type of gas-fired panel has been found to agree closely with the distribution calculated using Lambert's cosine law. Near to the panel convective heating modifies this conclusion and a map of the convection currents is given. The area parallel to the plane of the panel over which the heating is uniform to within 90 per cent is never less than 9 sq. in.

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Mr Lick

The work referred to in FR Note 217 was carried out with town gas and is therefore obsolete. We cannot be sure that North Sea gas would give identical values. I recommend the Note should not now be lent out

[signature]
21/11

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1. Introduction

A proprietary type of gas-fired surface combustion heater, 1 ft square, has been used at the Fire Research Station as a source of radiant heat for many experiments. Particular applications have been the work on the ignition of materials and on the small-scale spread of flame test.

Little information on its radiation characteristics is available except for its spectral distribution (1) (Figure 1). The radiation spectrum is close in form to that of a black body. No information on whether it radiated as a grey body was available.

There have been few or no attempts to verify that Lambert's Law holds at high temperatures for large radiating areas, though Barker and Kinoshita did some work at lower temperatures (2). Nevertheless there has been a considerable amount of work published on the calculation of configuration factors (3) which depends upon this law.

Radiant intensities from the panel are not calculated using configuration factors but directly using radiometers (4) as there is some convective heat transfer. During the course of work on the ignition of materials the times taken to ignite for different sizes of specimen were found to be different and it was thought that this might be due to the area of uniform radiation being less than that predicted by Lambert's Law or by the interference of convective heat effects. This paper describes some work on the experimental determination of configuration factors and the measurement of the size of uniform areas of radiation.

2. Experimental method and results

The apparatus used is shown in Plate I. Measurements of the intensity of radiation from the gas-fired panel were made using a water cooled thermopile (4) with a Thwing type pyrometer (5) to monitor the system. Variations in panel temperature during any one set of readings were corrected by adjusting the gas flow so that the pyrometer reading was constant.

The radiant panel was switched on and allowed to reach equilibrium; the pyrometer reading was then constant. The distribution of radiant intensity on the horizontal plane through the normal axis of the panel was first measured (Figure 2). Three of these positions were then explored in the vertical plane as well, Figure 3. The distribution of intensity along the central axis perpendicular to the face of the panel was then measured using different settings of the pyrometer (Figure 4). The apparatus was then removed and a pointer placed in position along the central axis. A parallel beam of light was then thrown across the system and an image of the convection currents obtained on a screen (Figure 5). The edge of the area in which convection currents occur is shown in Figure 6.

3. Discussion of results

3.1. Configuration factor

The configuration factor ϕ of a square radiator at any point may be computed from tables (2).

The intensity of radiation I received by an element from the panel is given by the well-known expression

$$I = \varepsilon \phi \sigma (T^4 - T_o^4)$$

where ε is the emissivity of the radiator

T the absolute temperature of the radiator

T_o the absolute temperature of the enclosure.

The value of I has been measured and the value of ϕ may be calculated. The ratio I/ϕ is then given as $\varepsilon \sigma (T^4 - T_o^4)$. This is a constant for any given panel setting. The constancy of the expression I/ϕ is therefore a measure of how nearly the gas fired panel obeys the configuration factor laws, in Table 1 the value of I/ϕ is given for the three sets of readings taken.

Table 1

Value of I/ϕ as a function of position from the radiant panel

Distance of central axis of panel horizontal - in.	Pyrometer reading - 1·15 mv											
	Distance from panel - in.											
	4	6	7	8	9	10	11	12	15	18	24	30
0	12·7	12·3	12·6	12.0	12·0	12·3	12·3	12·4	11·5	10·6	11·1	11·9
1	12·7	12·3	-	-	-	12·2	-	12·7	-	-	-	11·9
2	12·7	12·3	-	-	-	12·0	-	12·7	-	-	-	-
3	12·7	12·5	-	-	-	12·2	-	12·4	-	-	-	12·9
4	12·5	12·7	-	-	-	11·9	-	12·5	-	-	-	-
5	12·6	12·4	-	-	-	11·9	-	12·5	-	-	-	12·3
6	11·5	11·5	-	-	-	12·2	-	12·7	-	-	-	-

Distance of central axis of panel horizontal - in.	Pyrometer reading - 1·15 mv									
	Distance from panel - 6 in.									
	-6	-5	-4	-2	0	1	3	4	5	6
-6	12·5	12·6	12·3	-	-	-	-	-	-	-
-5	12·2	12·2	12·5	12·6	13·3	15·0	16·8	17·5	18·8	18·9
-4	12·2	11·3	12·5	-	-	-	-	-	-	-
-3	14·9	12·2	12·4	12·5	13·2	15·2	16·6	18·1	20·1	23·7
-2	11·7	12·0	-	-	-	-	-	-	-	-
-1	11·6	11·9	12·0	12·1	13·1	14·7	16·5	16·7	16·1	22·0
0	11·5	11·5	11·9	12·3	12·8	14·4	16·5	17·6	19·9	20·1
1	11·6	11·8	-	-	-	-	-	-	-	-
2	11·5	11·9	12·1	12·3	12·9	14·5	17·5	18·2	20·6	21·1
3	11·7	11·9	-	-	-	-	-	-	-	-
4	11·6	12·0	12·2	12·6	13·1	14·5	16·9	18·6	22·4	22·1
5	11·4	11·6	-	-	-	-	-	-	-	-
6	11·1	11·1	11·6	12·1	12·6	13·5	15·1	16·0	18·9	18·8

Table 1 (contd.)

Pyrometer reading - mv	Distance from panel - in.											
	4	6	7	8	9	10	11	12	15	18	24	30
0·85	8·77	8·65	8·72	8·42	8·47	8·55	8·45	8·34	8·35	8·7	8·57	8·8
1·05	11·2	10·6	10·9	10·6	10·6	10·7	10·6	10·8	10·3	10·6	10·5	11·1
1·15	12·7	12·3	12·6	12·0	12·0	12·3	12·3	12·4	11·5	11·6	11·1	11·9
1·25	13·9	15·9	13·6	13·4	13·4	13·4	13·4	12·9	13·3	12·9	12·9	13·3
1·35	15·2	14·7	14·3	14·6	14·5	14·5	14·0	14·0	14·3	14·7	14·3	14·5

For the first and third set of readings, i.e. those in the central horizontal plane, in Table 1 the constancy of I/ϕ for any set of pyrometer readings is sufficiently good for any slight deviation to be due to local irregularities in the radiant surface of the panel.

With the second set of readings in Table 1, i.e. those taken in a vertical plane, the ratio I/ϕ is constant only in the lower portion of the plane. The deviations from constancy which occur in the upper part of the plane follow the pattern of the convection currents mapped in Figure 6. It is safe to conclude therefore that the cosine law does not break down but that near to the panel the radiant heat is supplemented by convected heat from the spent gas and air of the panel.

3.2. Size of uniform area

The radiation from a perfect panel would be uniform in two planes, its own and the plane at infinity. For practical purposes, uniformity of radiation to within 90 per cent over an area is sufficient. From Figure 2, the intensity of radiation is uniform over about 3 inches on either side of the central axis of the panel in the horizontal central plane. At 8 inches away from the panel the convection currents have disappeared from the vertical plane and an equal height, 6 inches, is uniformly irradiated. Within 8 in. of the panel the height of uniform irradiance may be as little as 3 inches due to convection currents, but total area of uniform irradiance is always greater than 9 square inches.

4. Conclusions

The transfer of heat to a point by this proprietary type gas-fired panel obeys the configuration factor laws where the transfer is solely radiative but near the panel there is supplementary heating by convection of an approximately equal amount from hot gas. These experiments therefore show that, Lambert's cosine law may be applied to a radiator of this type and that the intensity distribution may be calculated away from the convective heating zone from the configuration factors. The radiation is uniform in intensity over an area of about 9 square inches close to the panel; beyond 8 inches the size of the area increases rapidly with distance.

5. Acknowledgment

Figure 6 was obtained by P. L. Hinkley and Miss P. C. Cheshire.

References

1. Roberts, A. L. and Long, R. First report on radiant heating, GRB 15/5 Gas Research Board, London, 1948.

References (contd.)

2. Barker, A. H. and Kinoshita, M. Report of research on the effect of the shape and surroundings of a hot surface on the radiation from it. University of London, University College, Department of Heating and Ventilating Engineering, Bulletin No. 1. London, 1923, Unwin Bros. Ltd.

3. McGuire, J. H. Heat transfer by radiation. Fire Research Special Report No. 2. Department of Scientific and Industrial Research and Fire Offices' Committee. H.M.S.O. London, 1953.

4. Simms, D. L. and Pickard, R. W. Thermopiles for measuring high intensity radiation. Joint Fire Research Organization. F.R. Note No. 83/1953.

5. Foote, P. D., Fairchild, C. O. and Harrison, T. R. Technologic papers of the Bureau of Standards No. 170, Pyrometric Practice, Washington Government Printing Office, 1921.

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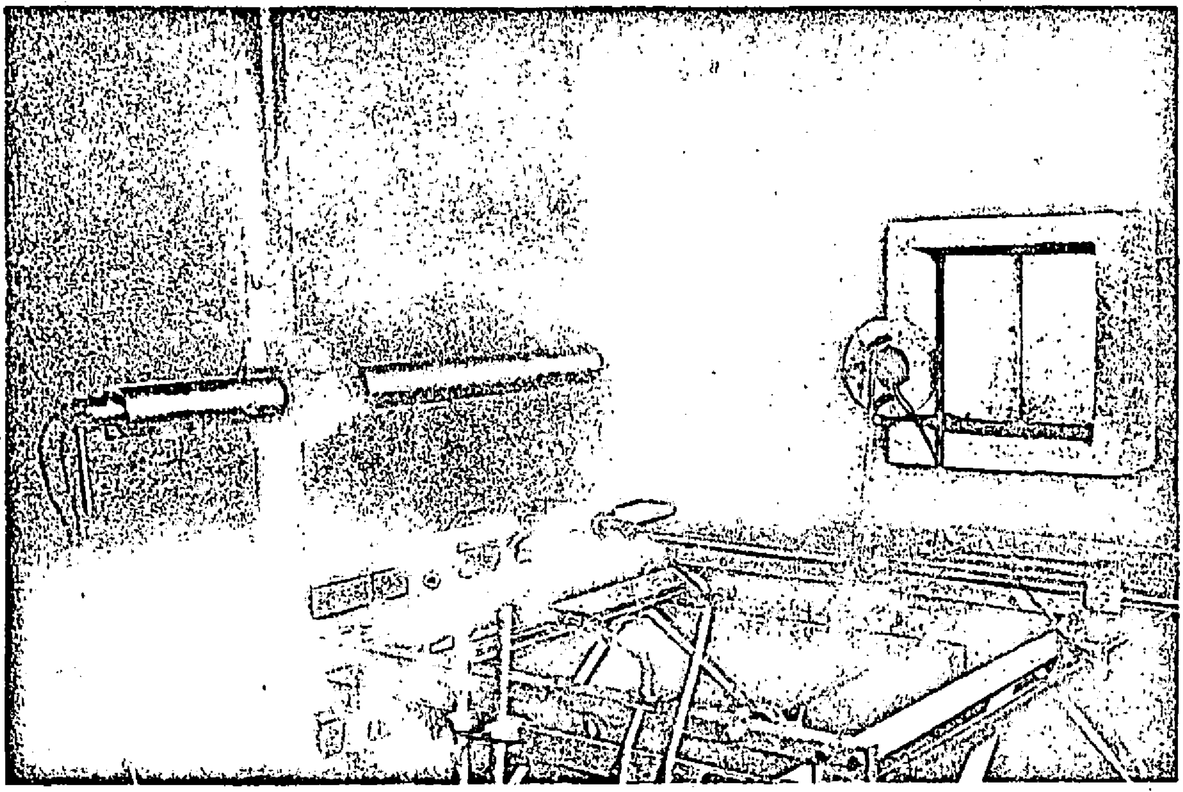

PLATE. I. APPARATUS USED IN EXPERIMENTS

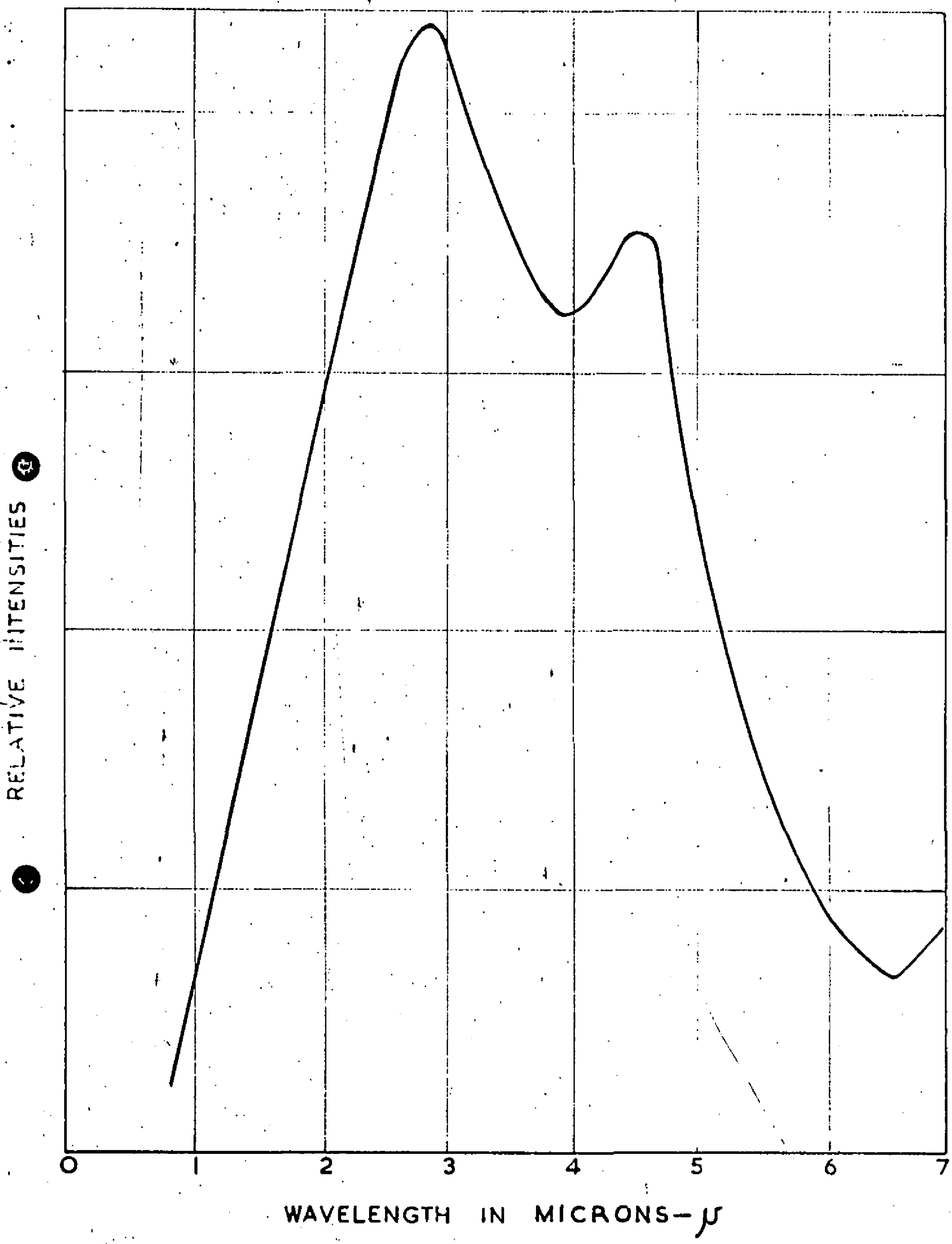

FIG.1. SPECTRAL EMISSION OF A RADIANT PANEL
870 °C

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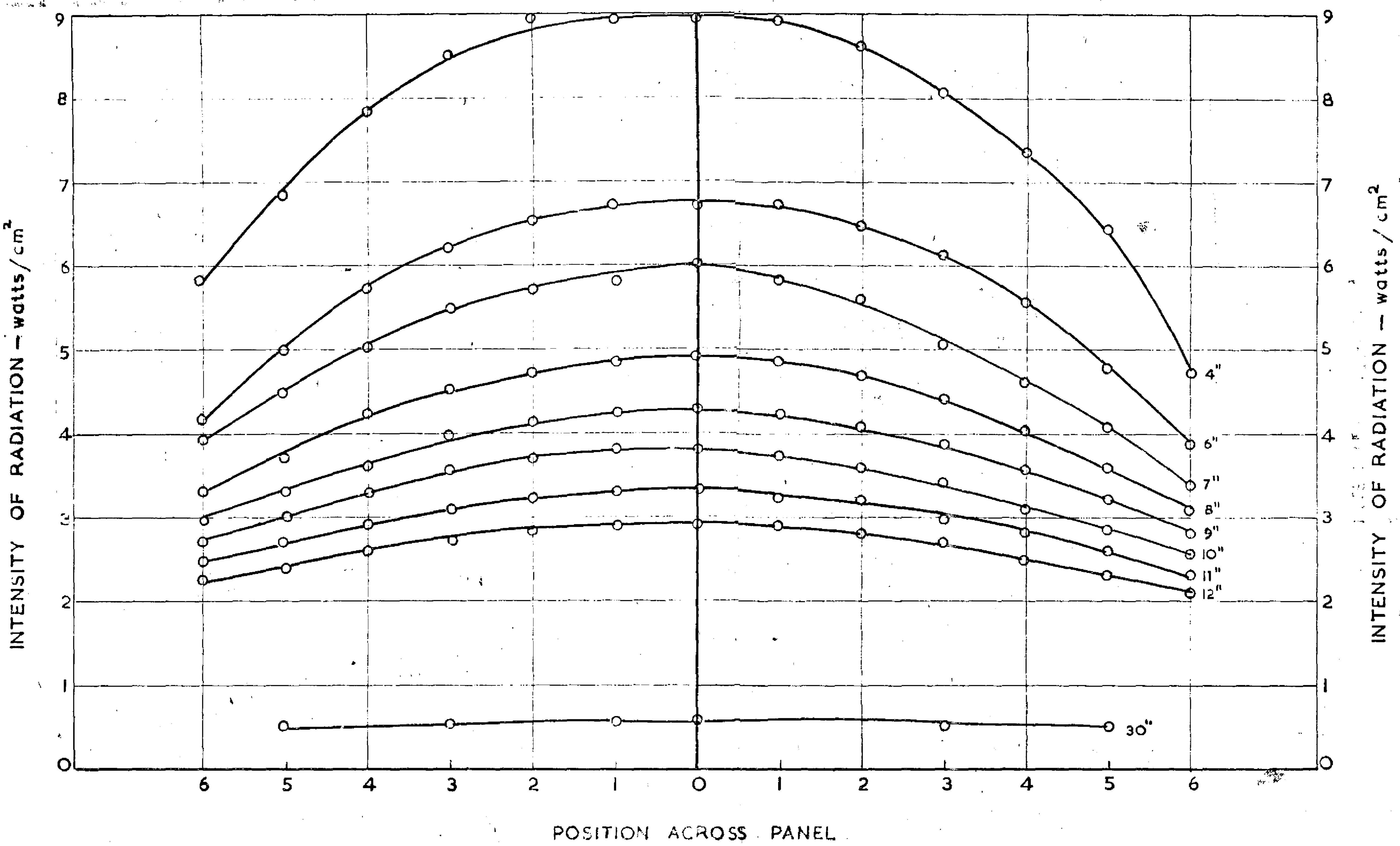

FIG.2. DISTRIBUTION OF RADIATION IN HORIZONTAL PLANE THROUGH CENTRE OF PANEL

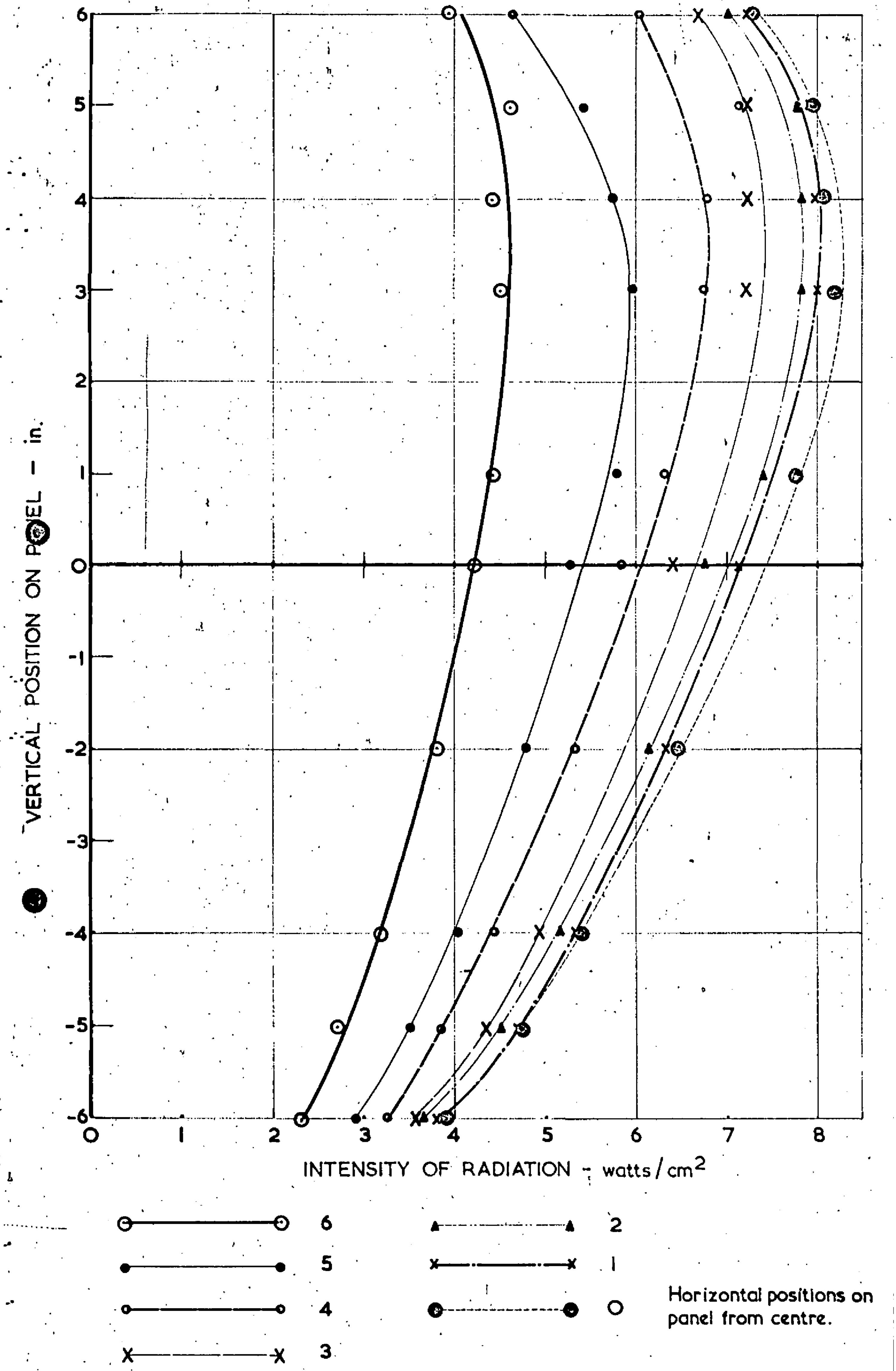

FIG. 3a. DISTRIBUTION OF RADIANT INTENSITY AT 6" FROM PANEL IN VERTICAL PLANE.

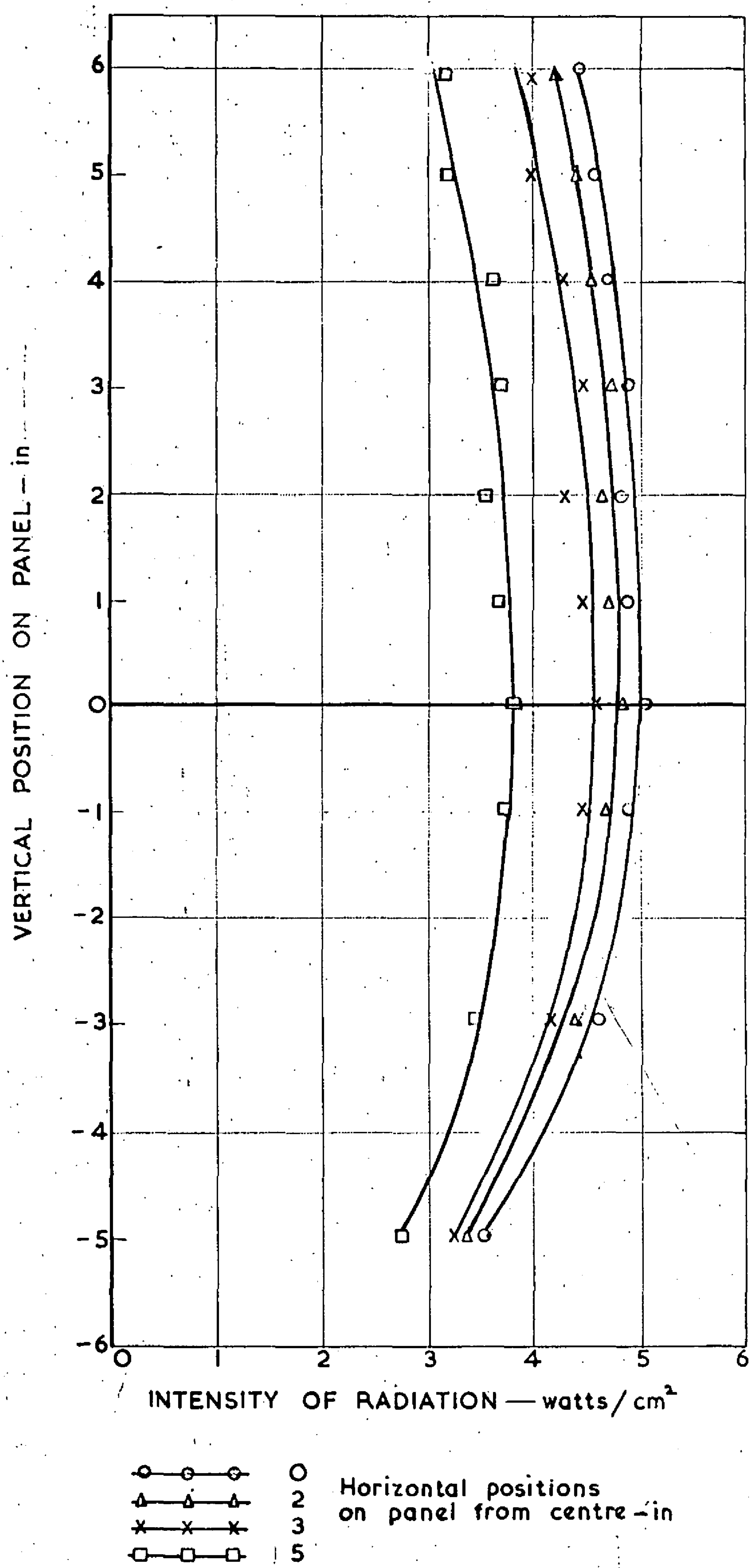

FIG. 3b. DISTRIBUTION OF RADIANT INTENSITY AT 8" FROM PANEL IN VERTICAL PLANE

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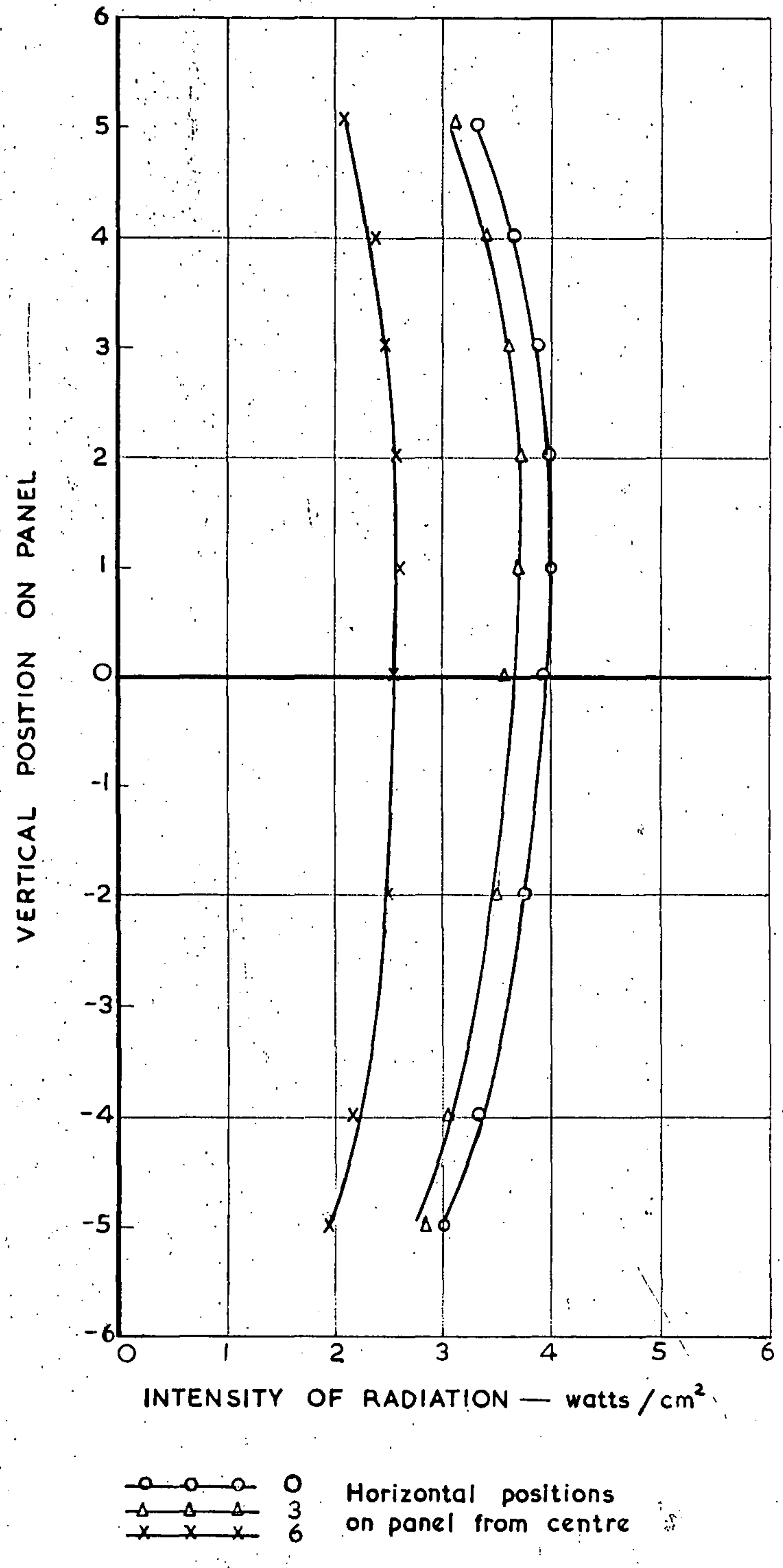

FIG.3c. DISTRIBUTION OF RADIANT INTENSITY AT 10" FROM PANEL IN VERTICAL PLANE

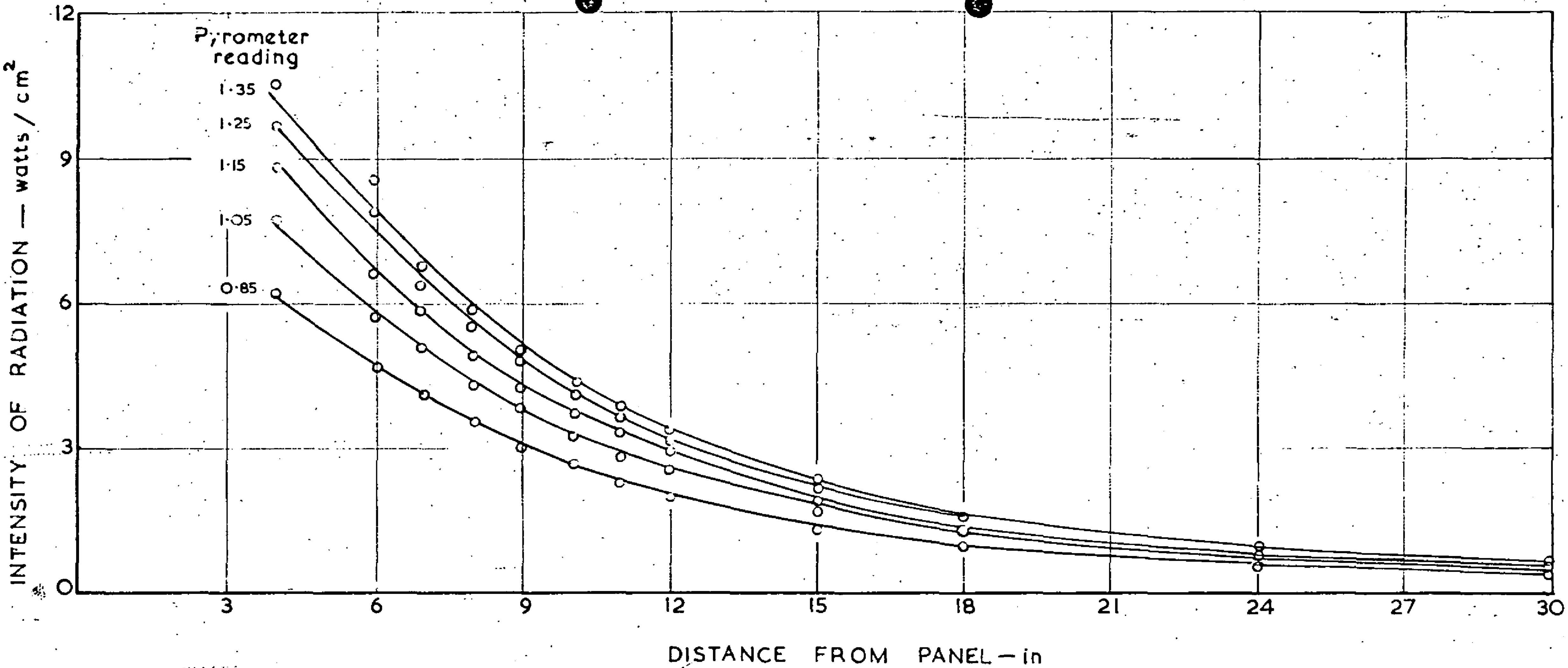

FIG. 4. DISTRIBUTION OF RADIATION ALONG CENTRAL AXIS OF PANEL FOR DIFFERENT PANEL TEMPERATURES

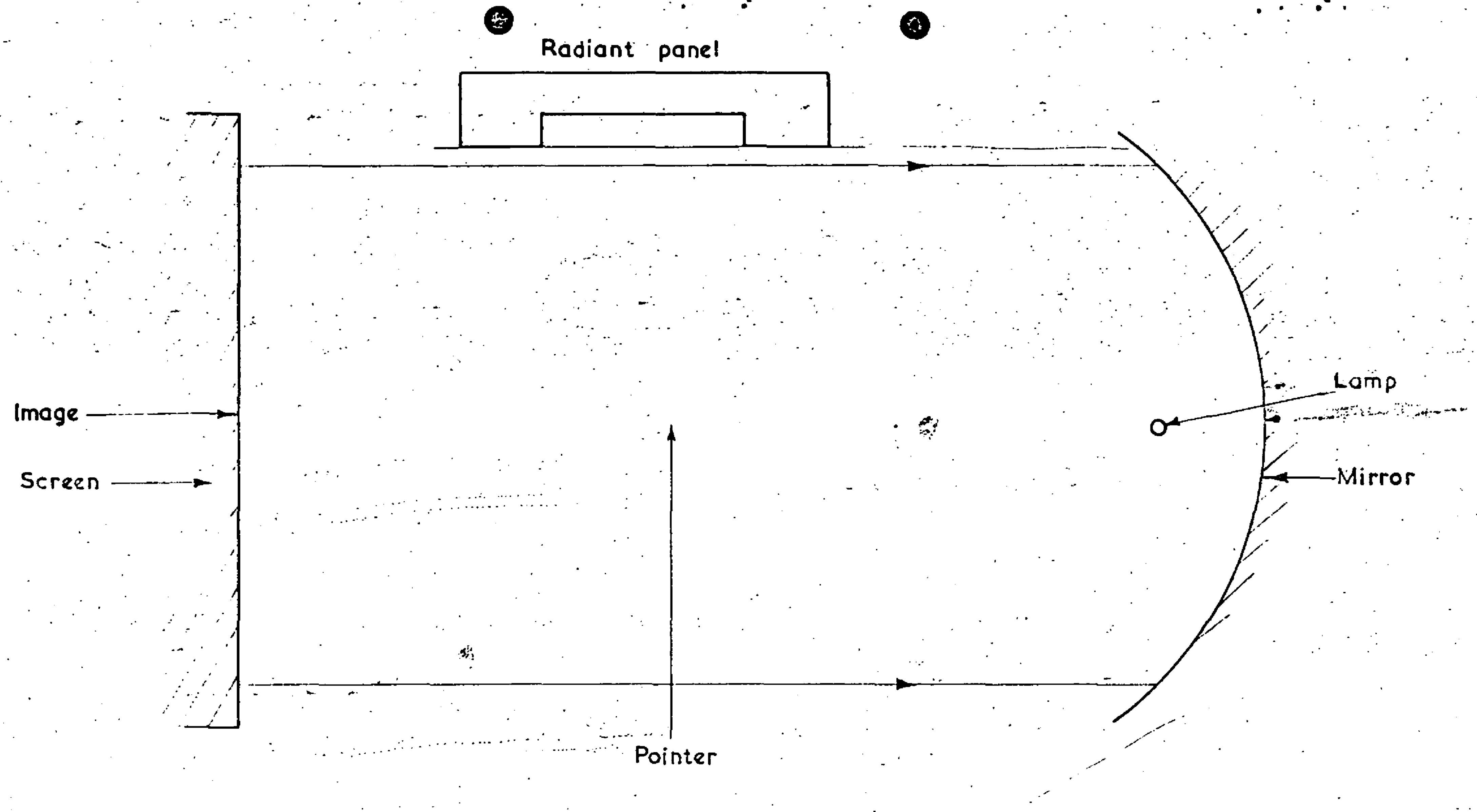

FIG. 5. APPARATUS FOR OBSERVING CONVECTION HEATING FROM FURNACE

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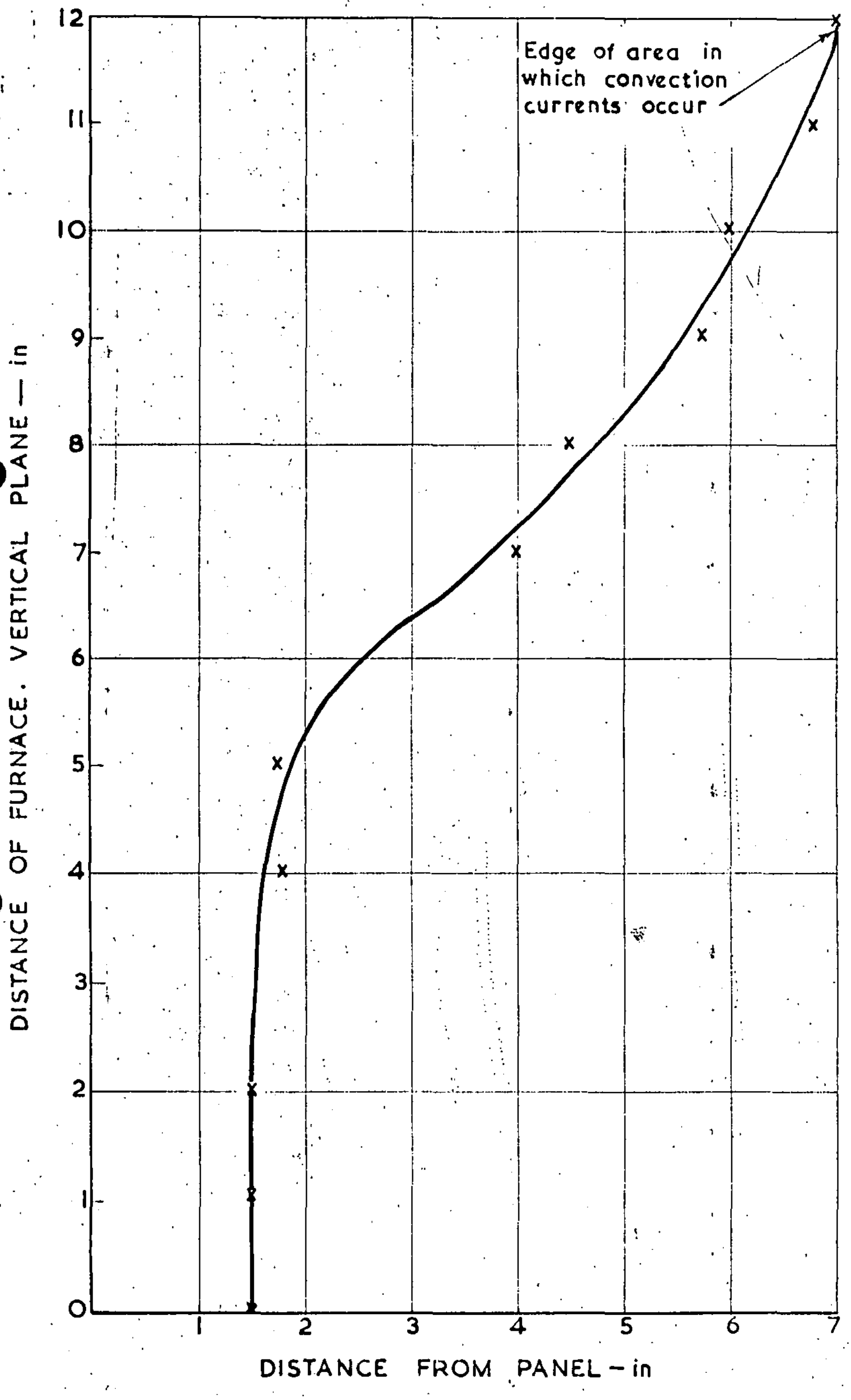

FIG.6. EDGE OF CONVECTION ZONE FROM RADIANT PANEL