Fire Research Note

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FIRE IN A MODEL CORRIDOR WITH A SIMULATED COMBUSTIBLE CEILING
PART II - EFFECTS OF VENTILATION AND ADDITION OF OBSTRUCTIONS AT THE EXIT

by

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FIRE
RESEARCH
STATION

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SUMMARY

The effects of altering the ventilation of a long corridor 30 cm wide with a primary town gas fire at one end and the effects of the addition of obstructions at the exit on thermal radiation falling on the floor were investigated. The presence of a combustible ceiling was simulated by town gas injection through a porous burner on the ceiling. Several conclusions were reached which should apply qualitatively to fires in large scale corridors.

MINISTRY OF TECHNOLOGY AND FIRE OFFICES' COMMITTEE
JOINT FIRE RESEARCH ORGANIZATION

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1. Introduction

In Part I of this report[1], the radiative properties of town gas flames travelling along the ceiling of a corridor with an open bottom were studied. Part II now describes the effect on downward radiation of various modifications to the corridor, e.g. increasing the ventilation, inserting a floor and adding obstructions to the flow of hot gas.

2. Experiment

Details of the apparatus used are given in Part I[1] but the general layout can be seen in Fig.1. Tests were performed in which the corridor openings were changed and the thermal radiation falling on a water cooled radiometer[2] placed at 127 cm from the closed end was measured. The position of the radiometer was not changed throughout the runs. The primary gas flow rate was varied between 1 and 5 l/s. Ceiling gas was injected at the rate of 1 l/s through burner A (see Figure 1) when it was desired to simulate a burning ceiling. Figure 1 (I - XIX) shows the various configurations tested. The changes to the corridor consisted of one or more of the following: a. closing the bottom of the corridor, b. placing a curtain or a weir at the open end, c. partially opening the closed end near the primary burner, d. raising the primary burner and e. moving the primary burner towards the radiometer.

Air and flame flow patterns in the corridor were observed. Air motion was rendered visible by placing a smouldering wooden stick at different positions. Typical flow diagrams are sketched in Figure 2.

3. Discussion of results

The results are presented in the form of plots of radiometer reading versus primary gas flow rate in Figures 3 to 12. Graphs are labelled by Roman numerals referring to the nomenclature used in Figure 1. Suffixing the Roman numeral with letter A indicates the injection of 1 l/s in burner A on the ceiling.

Further experiments will be required to find to what extent the behaviour observed in this small corridor represents behaviour in a larger corridor but until scaling relations can be derived the present experiments form a qualitative exploratory survey of the effect of various arrangements of ventilation, floors etc., on downward radiation from ceiling flames.

Figure 3 shows the effect of closing the bottom of the corridor. The resulting large increase in radiation falling on the floor can be attributed to an increase in the emissivity and temperature of the flame

The lack of air in the vicinity of the primary burner produces a very luminous sooty emissive flame which travels towards the exit. The bottom layer of this flame reacts with the entering air (see Fig.2 - VIII) which is travelling along the floor in the opposite direction. This generates small eddies at the interface between the two layers with good mixing and high temperatures.

In all the runs where gas was injected in the ceiling, there was an increase in radiation to the floor. In general, at very low primary gas rates ($<$ 2 l/s), the addition of 1 l/s in the ceiling produced a larger increase in radiation to the floor than would have been produced had the gas been added directly with the primary gas. At the higher primary gas rates, ceiling injection produced about the same amount of radiation as would have resulted if it were added on to the primary gas. This fact points out the importance of the contribution of a combustible ceiling to radiation falling on the floor when the primary fire is small and has just reached and ignited the ceiling. If the primary fire is large, the combustible ceiling makes a relatively smaller contribution.

Figures 4 and 5 show that the presence of an obstruction, such as a weir or a curtain, at the open end increased downward radiation because of the deepening of the flame layer in the corridor. The flame took on a globular or cellular structure at the higher primary gas rates (see Fig.2, II - 4 l/s and III - 4 l/s) with combustion taking place on the outside surface of these globules. At the lower rates, a visible layer of soot was formed below the flame (see Fig.2, II - 2 l/s). For the deeper curtain, i.e. config. IV, the shape of the flame became quite similar to that shown in Figure 2, XVI - 4 l/s.

The effects of venting the lower part of the wall near the primary burner on thermal radiation to the floor is shown in Figure 6. A small opening (see Fig.1 - V) introduced additional air to the flame thus raising its temperature. However, the would-be increase in radiation was roughly balanced by a small drop in soot concentration and the escape of some of the hot gases and flame from the opening, (see Fig.2, V - 5 l/s). When the opening was enlarged (Fig.1 - VI), more gases and flames escaped through the opening resulting in a reduction of the radiation falling on the radiometer. Raising the opening as in Figure 1 - VII cut off the additional supply of air to the primary burner and a large portion of the flame left through the opening thus reducing radiation to about the same level as for configuration VI. Removing the top half or all of this wall caused the flames to leave at the primary gas end of the corridor and no flames travelled along the ceiling. No measurements were taken in this case.

Experiments with the closed bottom corridor were limited because of the possibility of forming an explosive mixture in the corridor if too many obstructions were placed at the exit. Figure 7 shows the effect of having an opening near the primary burner. A small opening low down (Fig.1 - IX) increased radiation slightly (above that of the configuration with no opening) because it admitted additional air to the flame, which increased the flame temperature, and allowed very little flame to escape at this end. A pulsation of the flame was also observed (see Fig.2 IX - 5 l/s). When the opening was enlarged (Fig.1 - X), a large portion of the flame escaped at this end and radiation to the floor dropped. There was a dramatic increase in radiation to the floor when configuration X was modified by the addition of a weir at the normally open end of the corridor (Fig.1 - XI). This prevented air from entering at that point and all the air supply was now sucked in at the opening near the primary burner producing a draught which pushed the flame along the floor of the corridor (see Fig.2, XI - 4 l/s). The flame became very sooty and deep and thus highly emissive. Furthermore, the flame became tilted towards the floor instead of away from it (compare Fig.2, XI - 4 l/s and VIII - 4 l/s) which gave a larger view factor between it and the radiometer. At 4 l/s, this arrangement produced the worst fire situation in the compartment in all the experiments performed, including those with ceiling gas injection.

The effect of raising the level of the primary burner on downward radiation is shown in Figure 8. There was a slight increase in radiation at the lower primary gas rates (< 2 l/s) because of the lengthening of the flame along the ceiling. At higher rates, there was a slight decrease in radiation, probably because of the lowering of flame temperature due to the lack of good mixing with air. The insertion of a weir at the open end with the burner raised to 20 cm from the ceiling (XIX) produced higher radiation at 2 and 3 l/s than those when the burner was at 33.5 cm but gave similar results at 1 and 4 l/s.

To simulate the progress of a fire in a long corridor, the primary burner was moved towards the radiometer. Without any obstructions at the exit, the radiation falling on the radiometer was slightly greater than that in configuration I. (See Fig.9). There was a pronounced increase in downward radiation when the ceiling gas was turned on, particularly at the smaller primary gas flow rates. This was due to the relatively larger increase in the luminous layer depth and length at the smaller rates. There was a small increase in downward radiation when the primary burner was moved towards the radiometer in the presence of a curtain at the open end (Fig.10). Injecting gas in burner A using the same arrangement gave about the same results as when the primary burner was farther away from the radiometer. Moving the primary burner towards the radiometer in the presence of an opening in the wall near the burner produced a large increase in radiation (compare XV and VI in Figure 11). This can be attributed to the fact that in configuration XV only wisps of flame escaped through the opening while the additional supply of air raised the temperature of the flame (see Fig.2, XV - 5 l/s).

A large increase in radiation was observed when the bottom of the corridor was closed with the burner moved towards the radiometer (see Fig.12, XII). Upon opening the wall near the primary burner (XIV), the radiation level dropped slightly due to the loss of flames through the opening (see Fig.2, XIV - 5 l/s), but it was still much higher than when the burner was farther away from the radiometer.

4. Conclusions

1. This investigation implies that a combustible ceiling contributes a great deal to the radiation level at the floor when the fire in the enclosure is in its early stages and has just ignited the ceiling.

2. The presence of a bottom to the corridor alters the aerodynamics of the flames and air in the system and produces a much higher radiation level on the floor than when the bottom is open. Until this effect has been further explored on a larger scale it is not clear to what extent data obtained for

small scale models of corridors with open bottom can be used to predict behaviour in larger corridors with closed bottom.

3. In a long corridor with a closed bottom, one of the worst possible fire situations is to have the only air inlet (such as an open door) near the fire and an elevated vent at the other end of the corridor. The resulting draught fills the corridor with flames and increases radiation to the floor to a very high level.

4. Venting the top part of the wall near a fire at one end of a corridor allows a large portion of the flames and hot gases to escape at that point and this reduces the radiation level on the floor of the corridor. Venting the same wall becomes less effective as the fire progresses down the corridor.

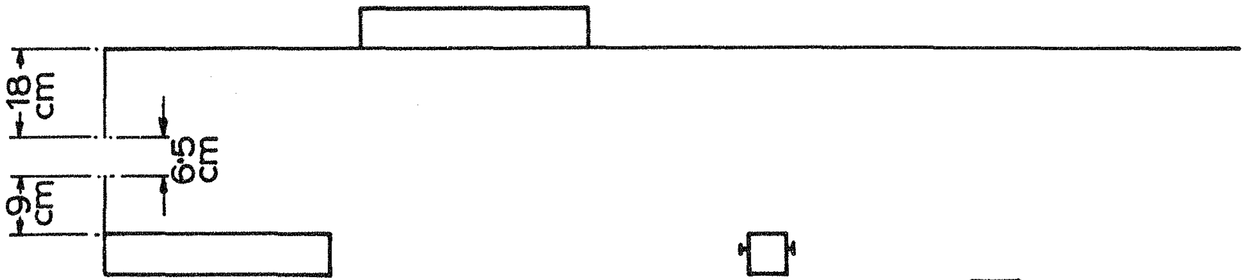
5. Placing obstructions (such as a weir or a curtain) at the exit of an open bottom corridor increases radiation from the ceiling gases because of an increase in flame depth and emissivity.

6. It is recommended that a preliminary study be made on the aerodynamics of and radiation from town gas flames in a cubical enclosure, equipped with facilities for venting and obstructing hot gas flow.

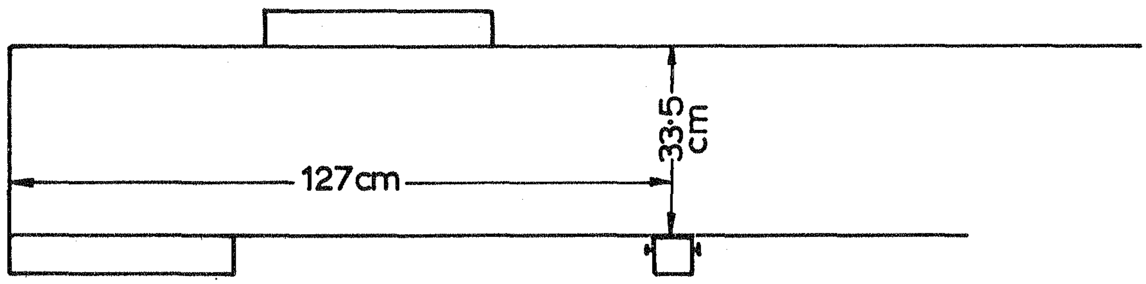
5. References

(1) ATALLAH, S. "Fire in a model corridor with a simulated combustible ceiling. Part I. Radiation, temperature and emissivity measurements." JOINT FIRE RESEARCH ORGANIZATION. F.R. Note No. 620, 1966.

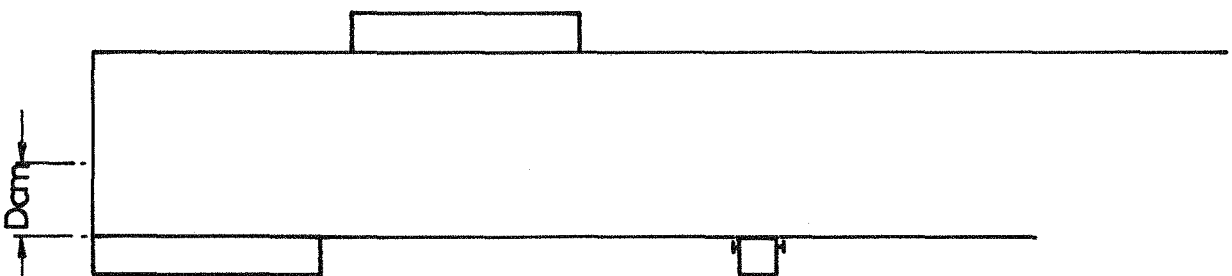
(2) McGUIRE, J. H. and WRAIGHT, H. G. H. J. Sci. Instr. 37 (1960) p.128.



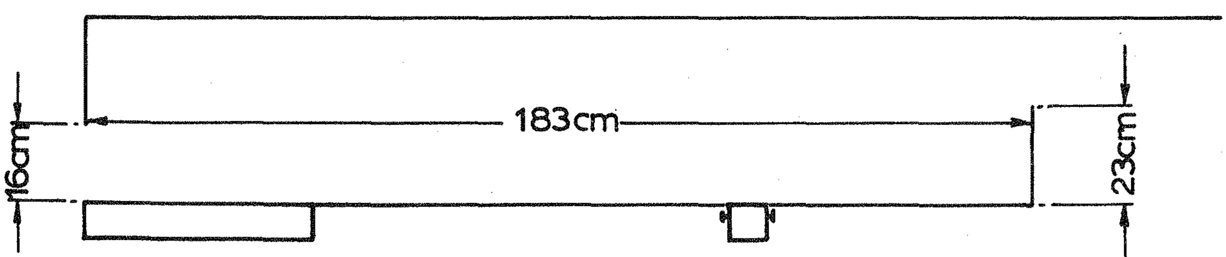
VII



VIII



IX D = 7·5cm
X D = 16cm



XI

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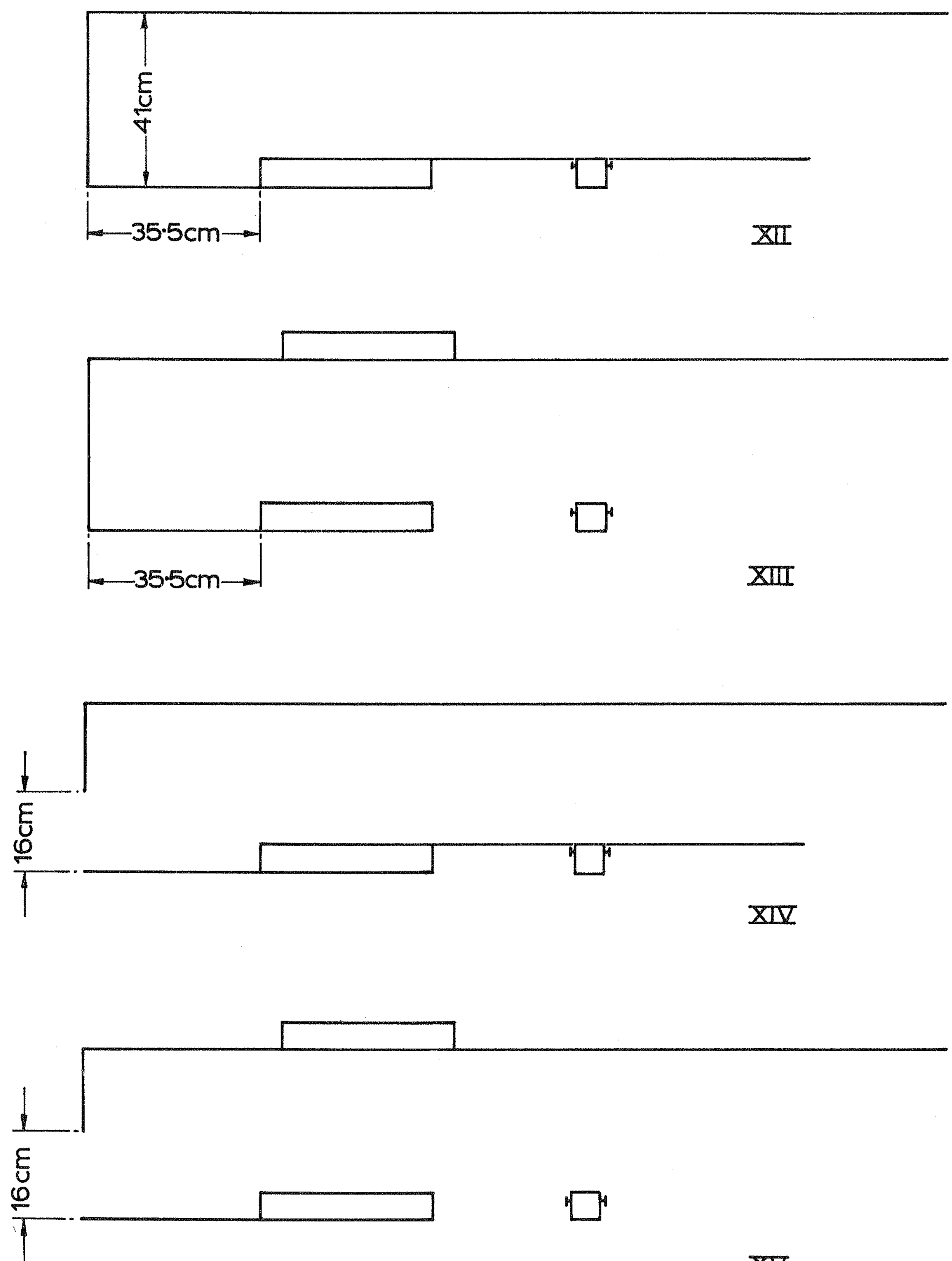

FIG.1 BASIC CORRIDOR CONFIGURATIONS TESTED (XII-XV)

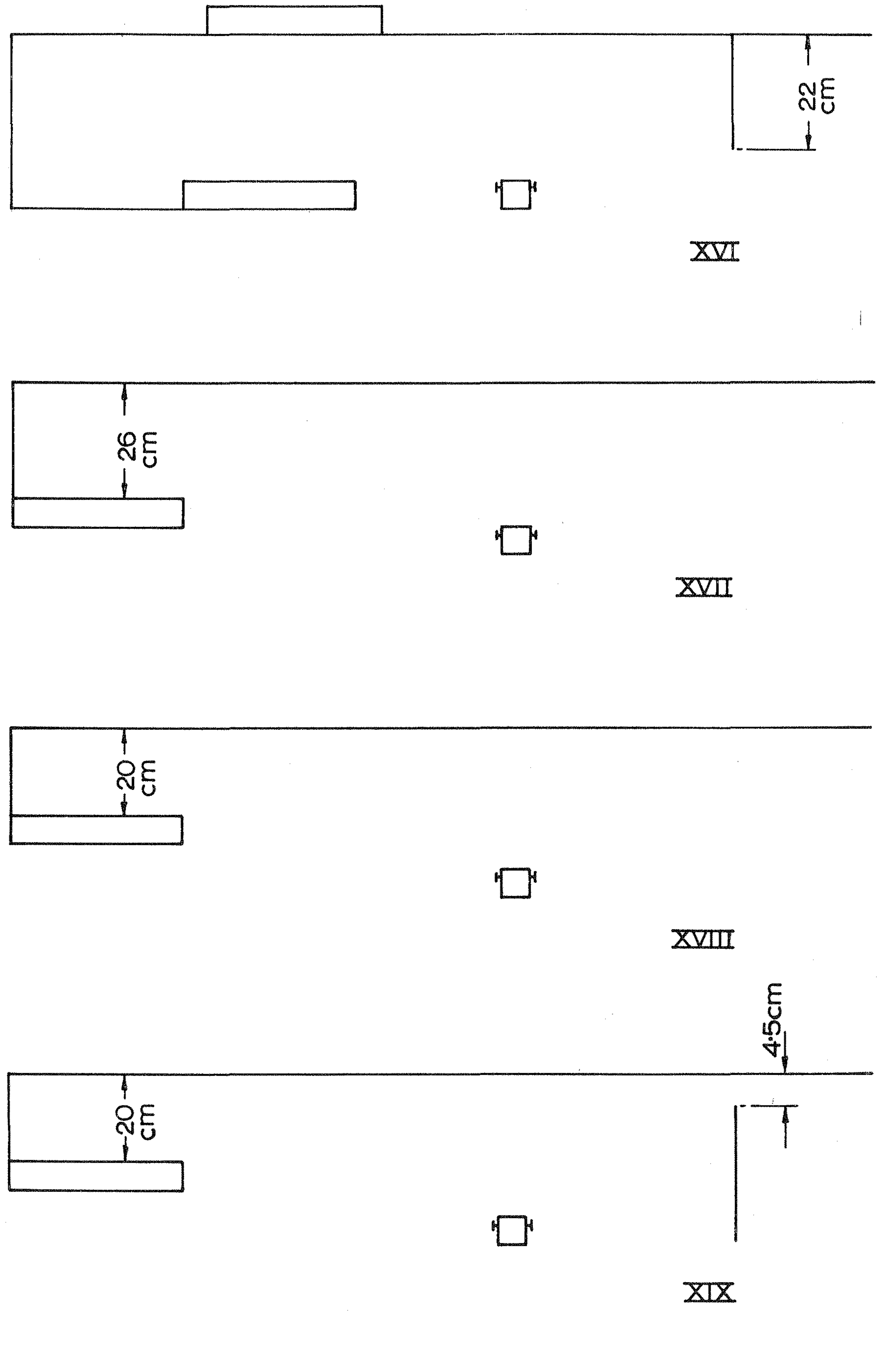

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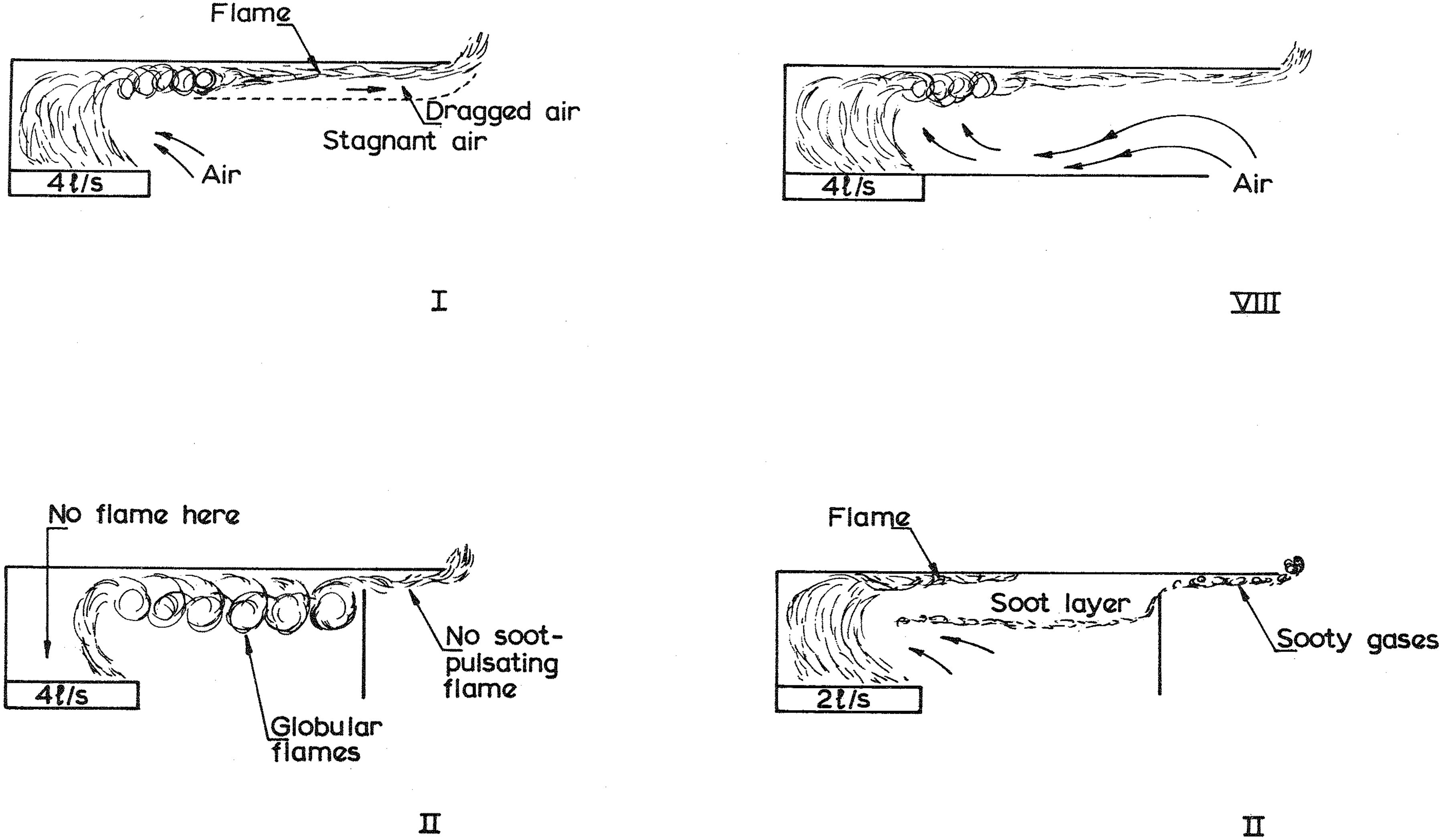
FIG. 1. BASIC CORRIDOR CONFIGURATIONS TESTED (XVI-XIX)



G.2. TYPICAL FLAME AND AIR FLOW PATTERNS IN THE CORRIDOR (I, VIII, II & II)

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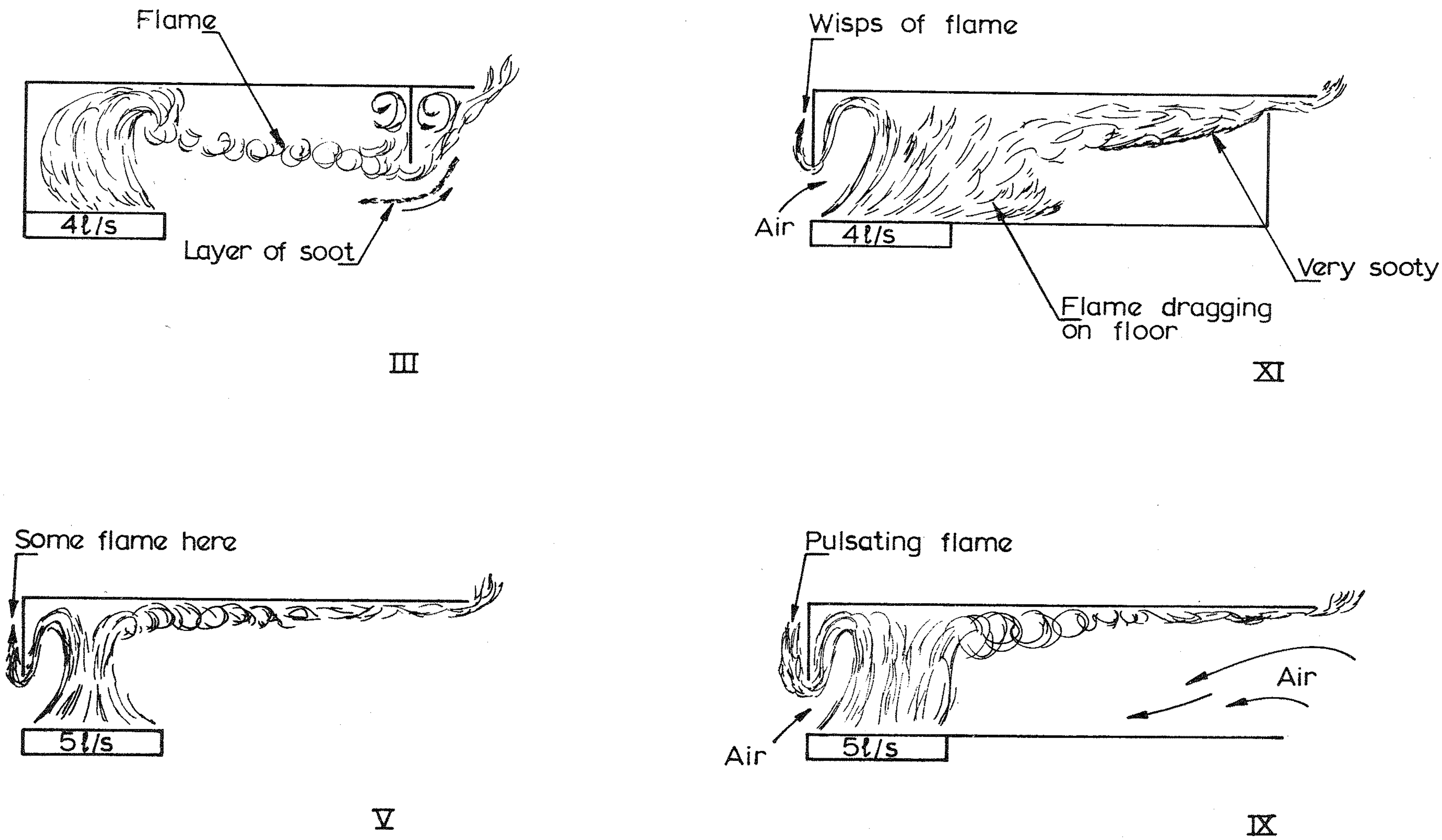
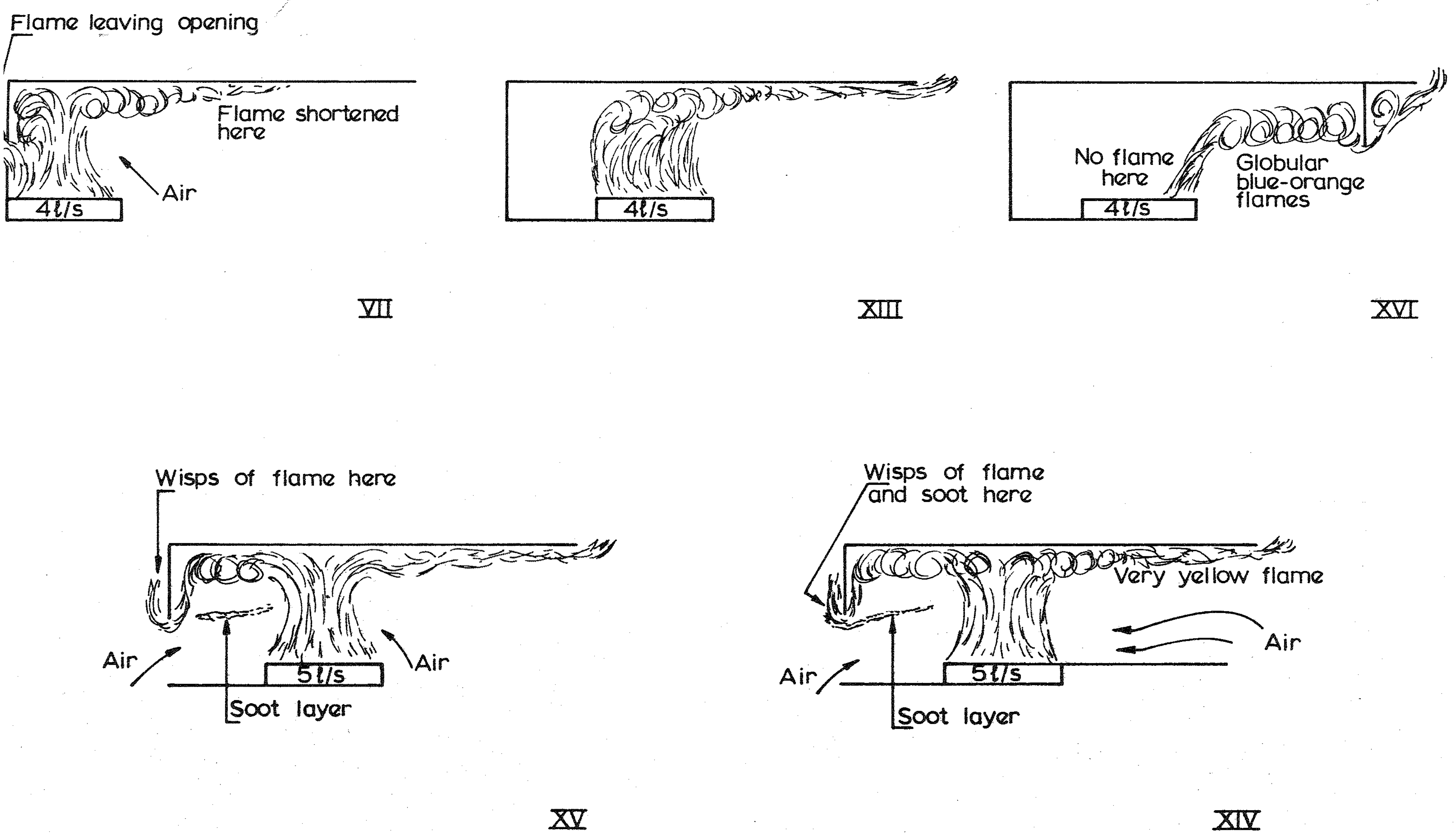
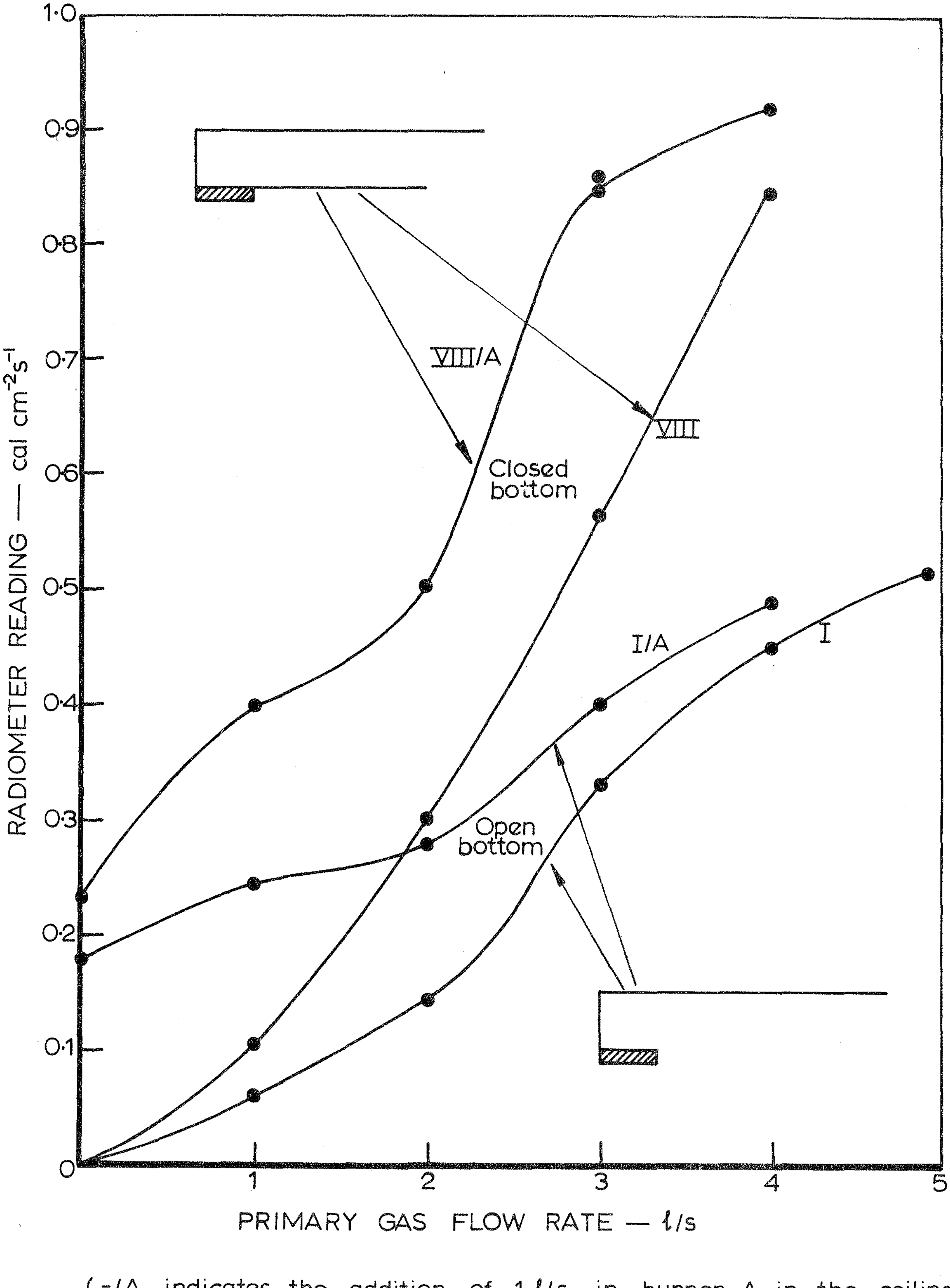


G. 2. TYPICAL FLAME AND AIR FLOW PATTERNS IN THE CORRIDOR (III, XI, V & IX)



G. 2. TYPICAL FLAME AND AIR FLOW PATTERNS IN THE CORRIDOR (VII, XIII, XVI, XV & XIV)



(-/A indicates the addition of 1 ℓ/s in burner A in the ceiling)

FIG. 3. EFFECT OF CLOSING BOTTOM OF CORRIDOR

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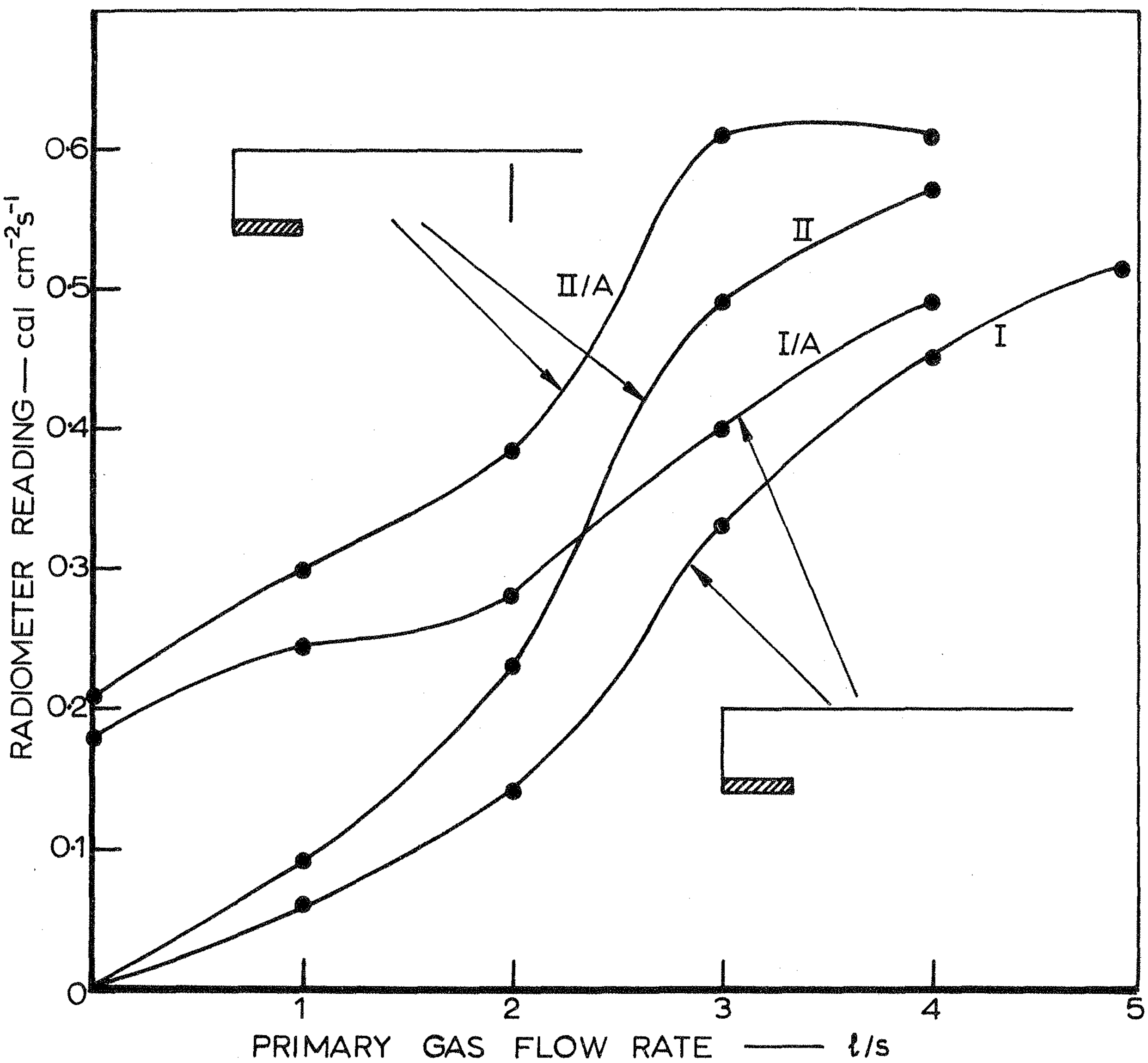
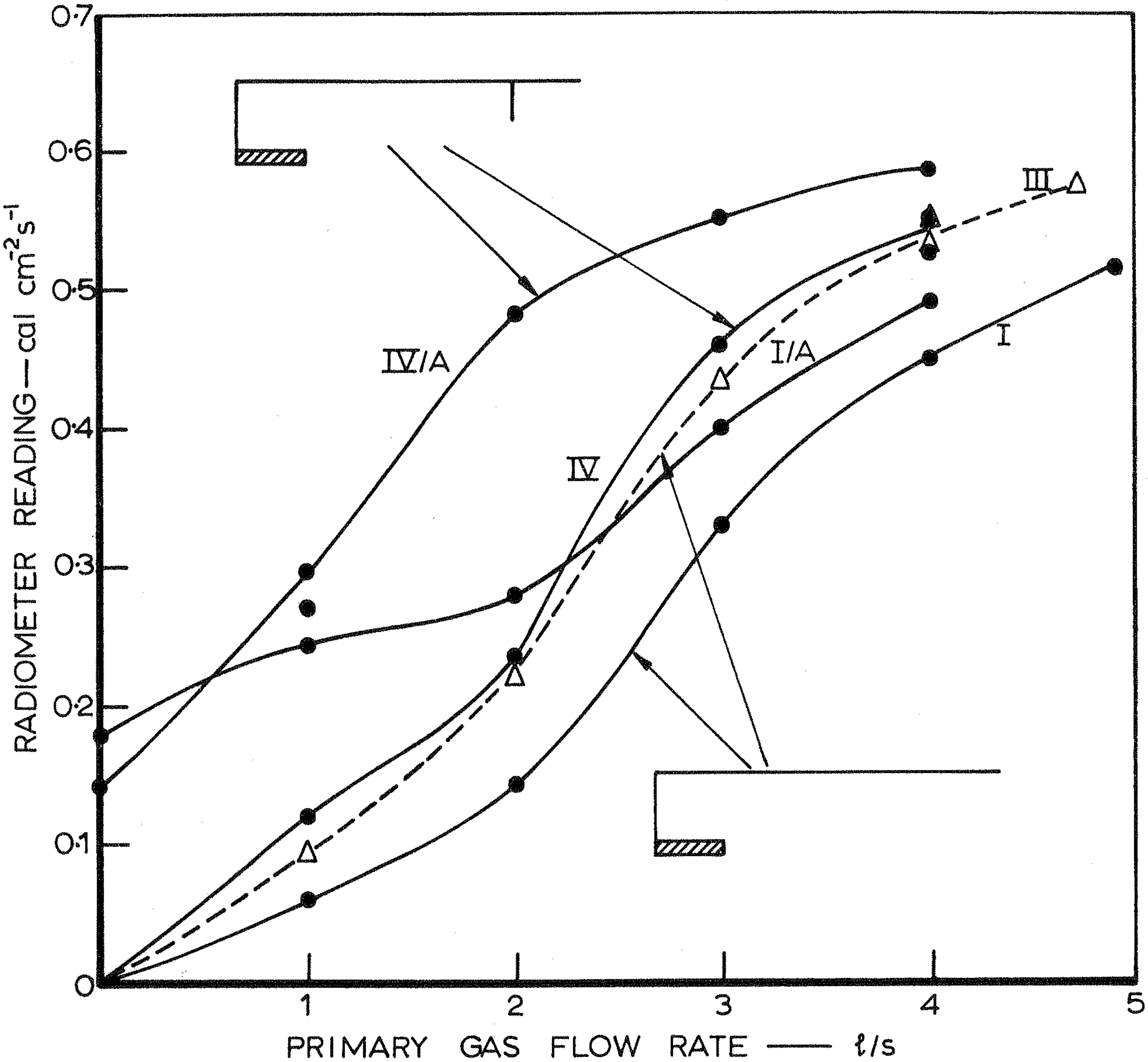
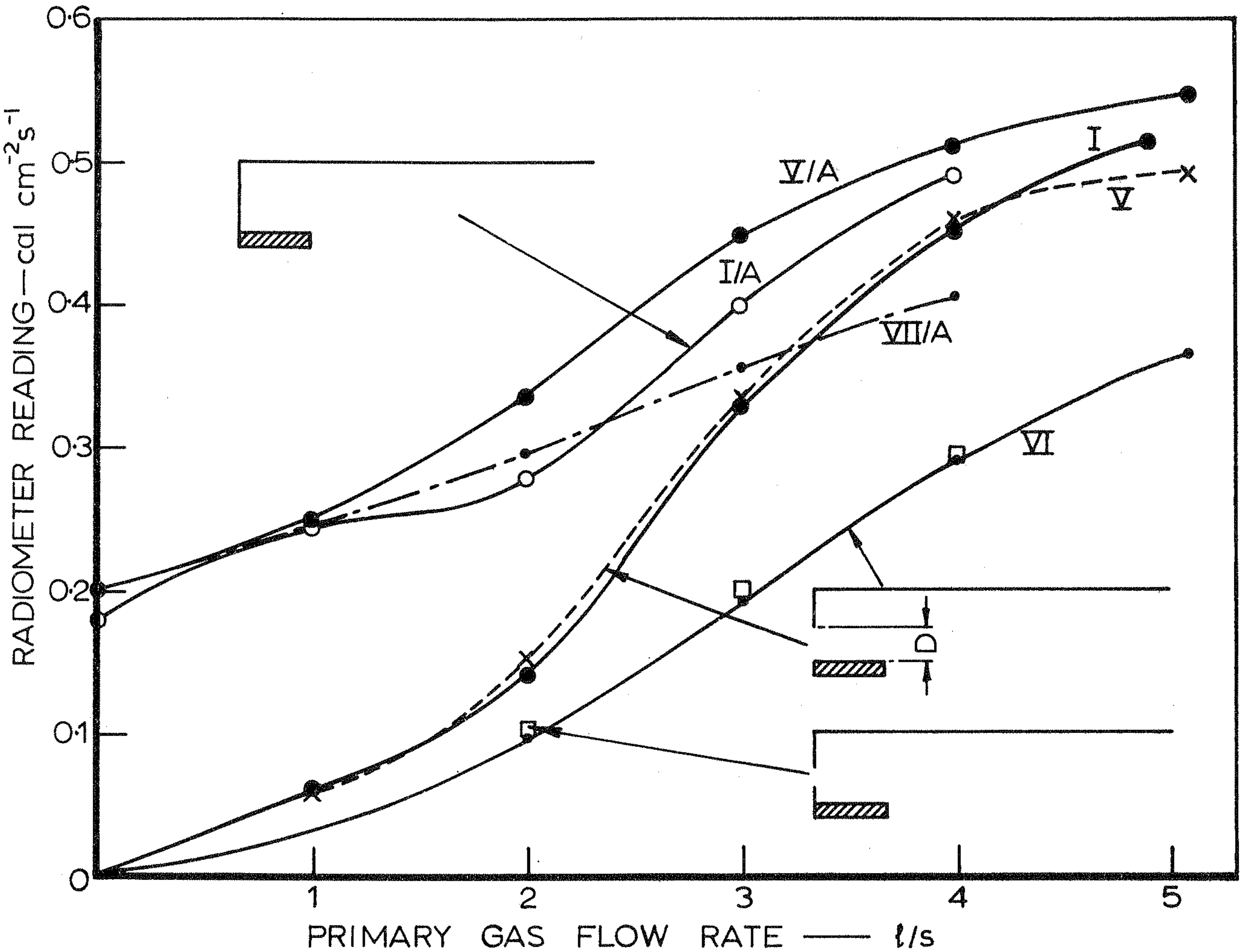


FIG. 4. EFFECT OF PLACING A WEIR AT THE OPEN END



III = 13cm curtain
IV = 22cm curtain

FIG. 5. EFFECT OF PLACING A CURTAIN AT THE OPEN END



V — D = 7·5cm

VI — D = 16cm

VII = □

FIG. 6. EFFECT OF HAVING AN OPENING NEAR THE PRIMARY BURNER

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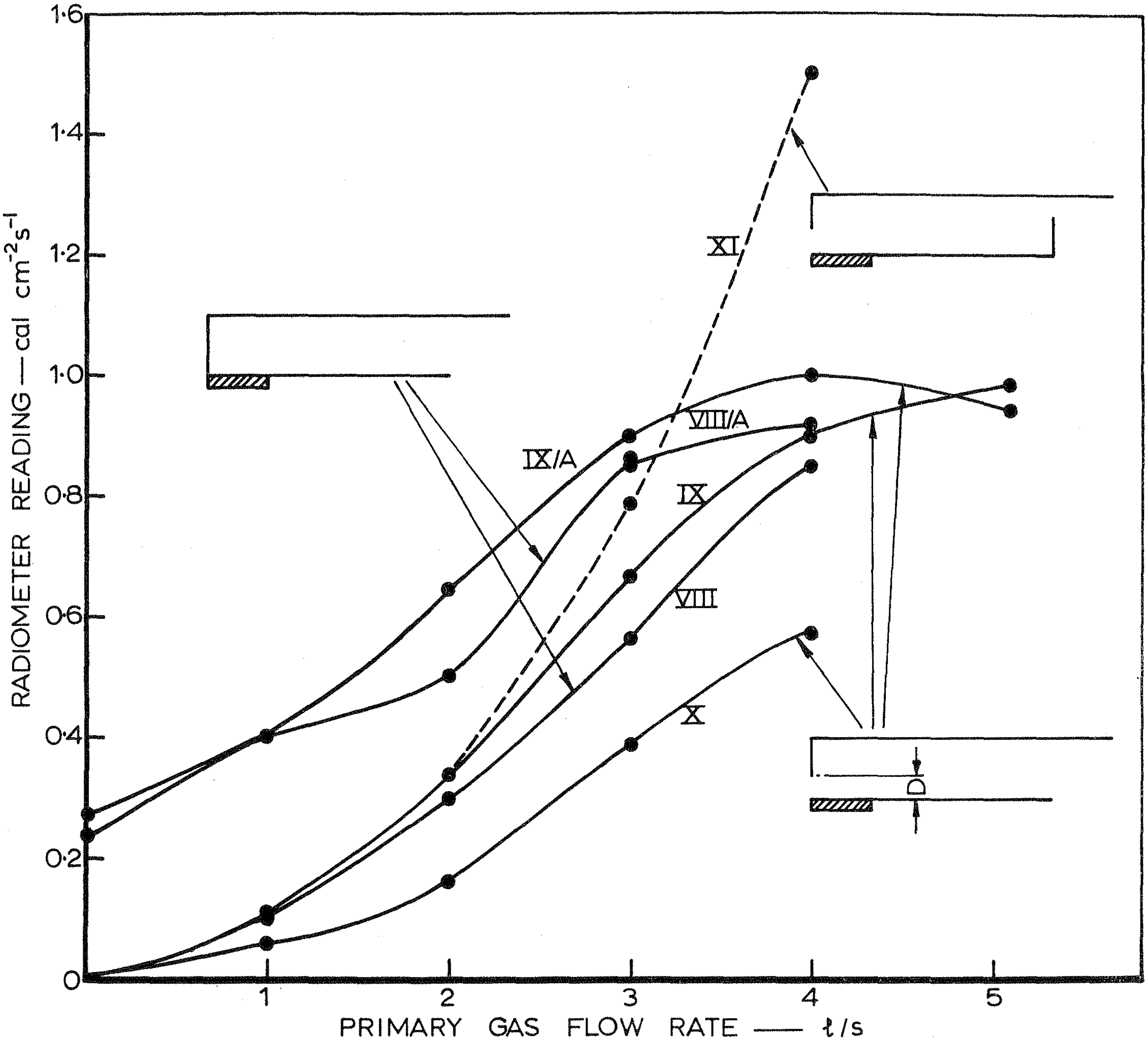

IX — D = 7·5cm
X — D = 16 cm

FIG. 7. EFFECTS OF SOME CHANGES TO THE CORRIDOR WITH CLOSED BOTTOM ON RADIATION TO THE FLOOR

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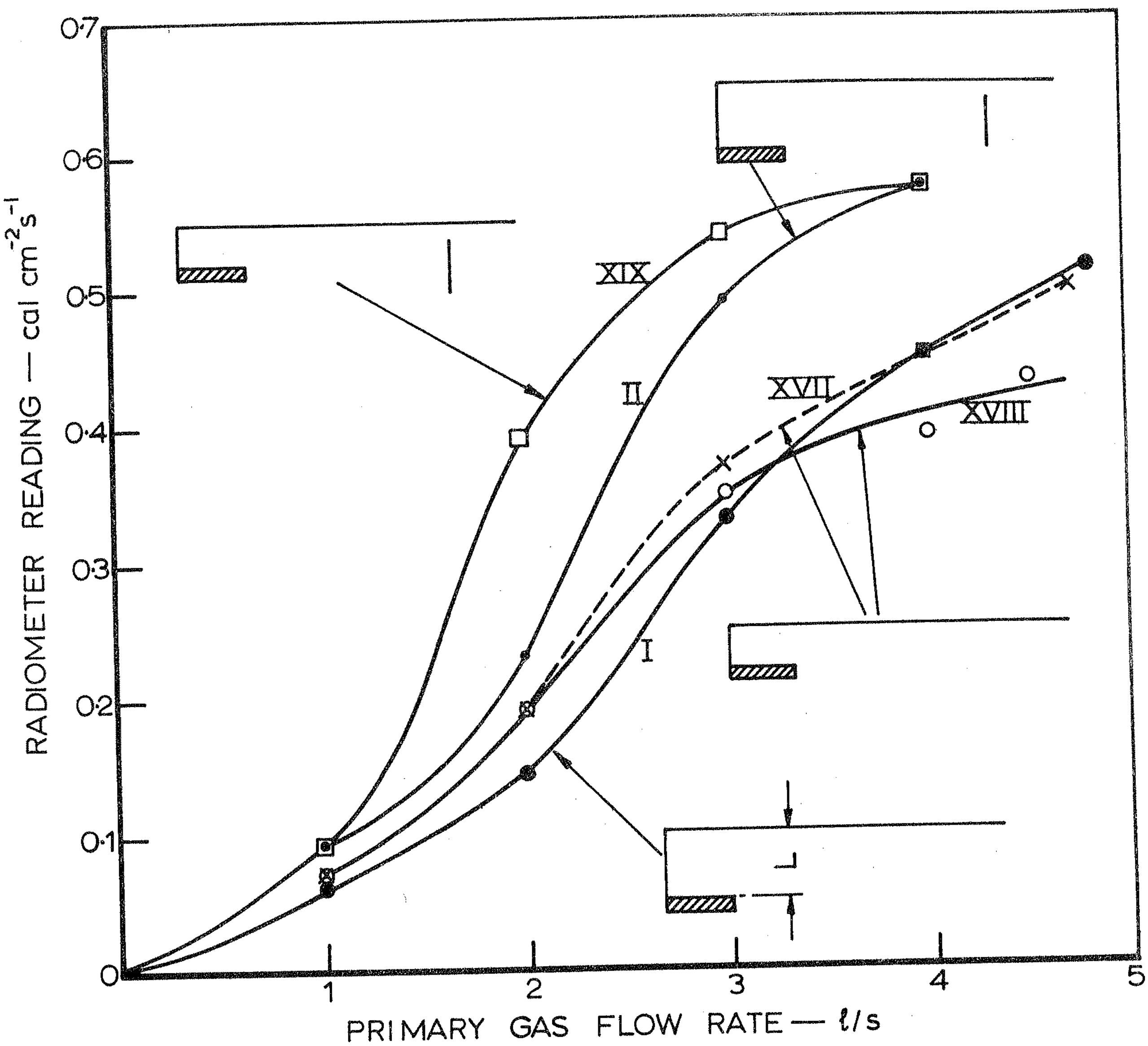

I — L = 33·5 cm
II — L = 33·5 cm
XVII — L = 26 cm
XVIII — L = 20 cm
XIX — L = 20 cm

FIG. 8. EFFECT OF RAISING PRIMARY BURNER

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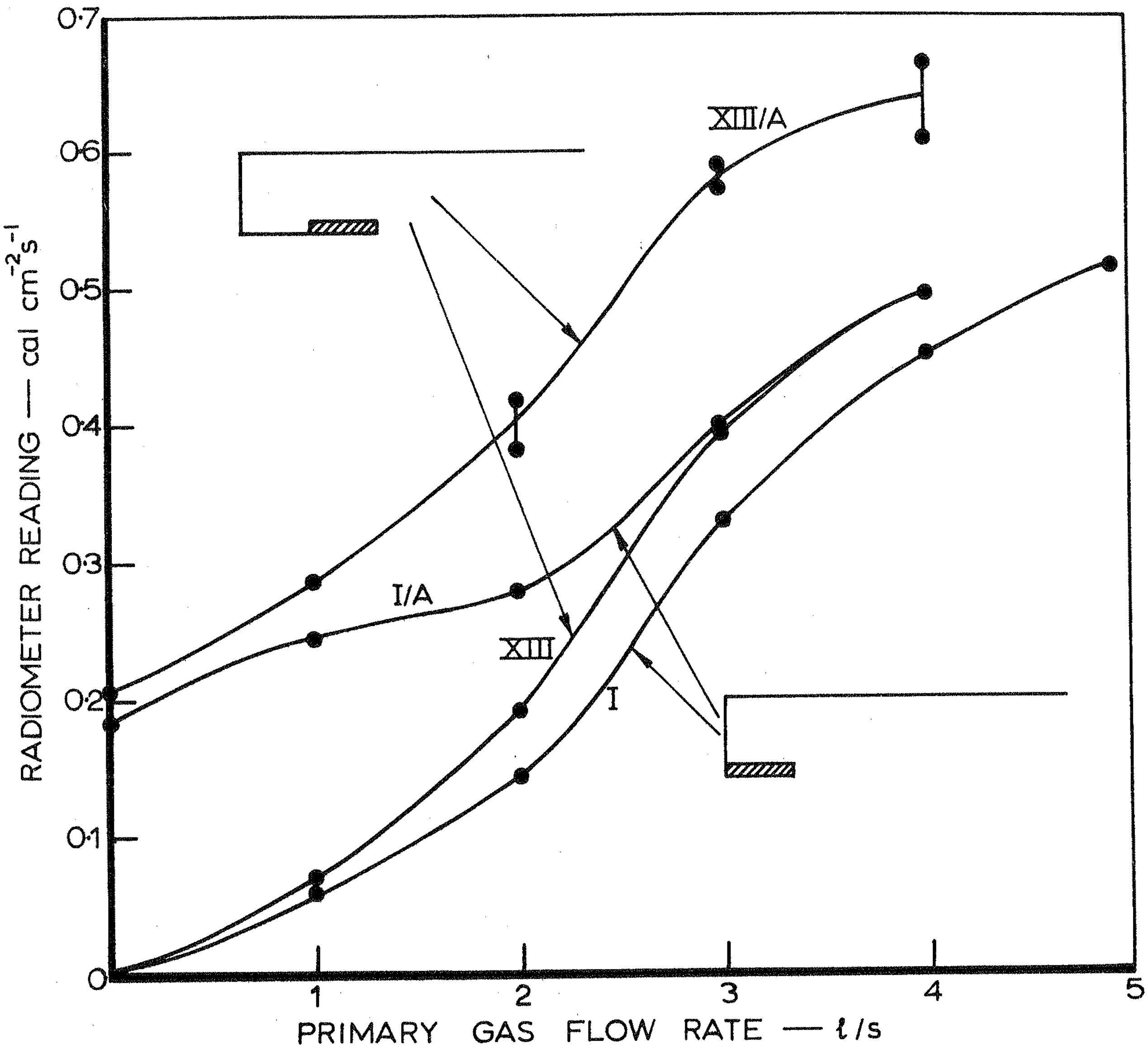

FIG. 9. EFFECT OF MOVING PRIMARY FIRE TOWARDS RADIOMETER. NO OBSTRUCTIONS AT OPEN END

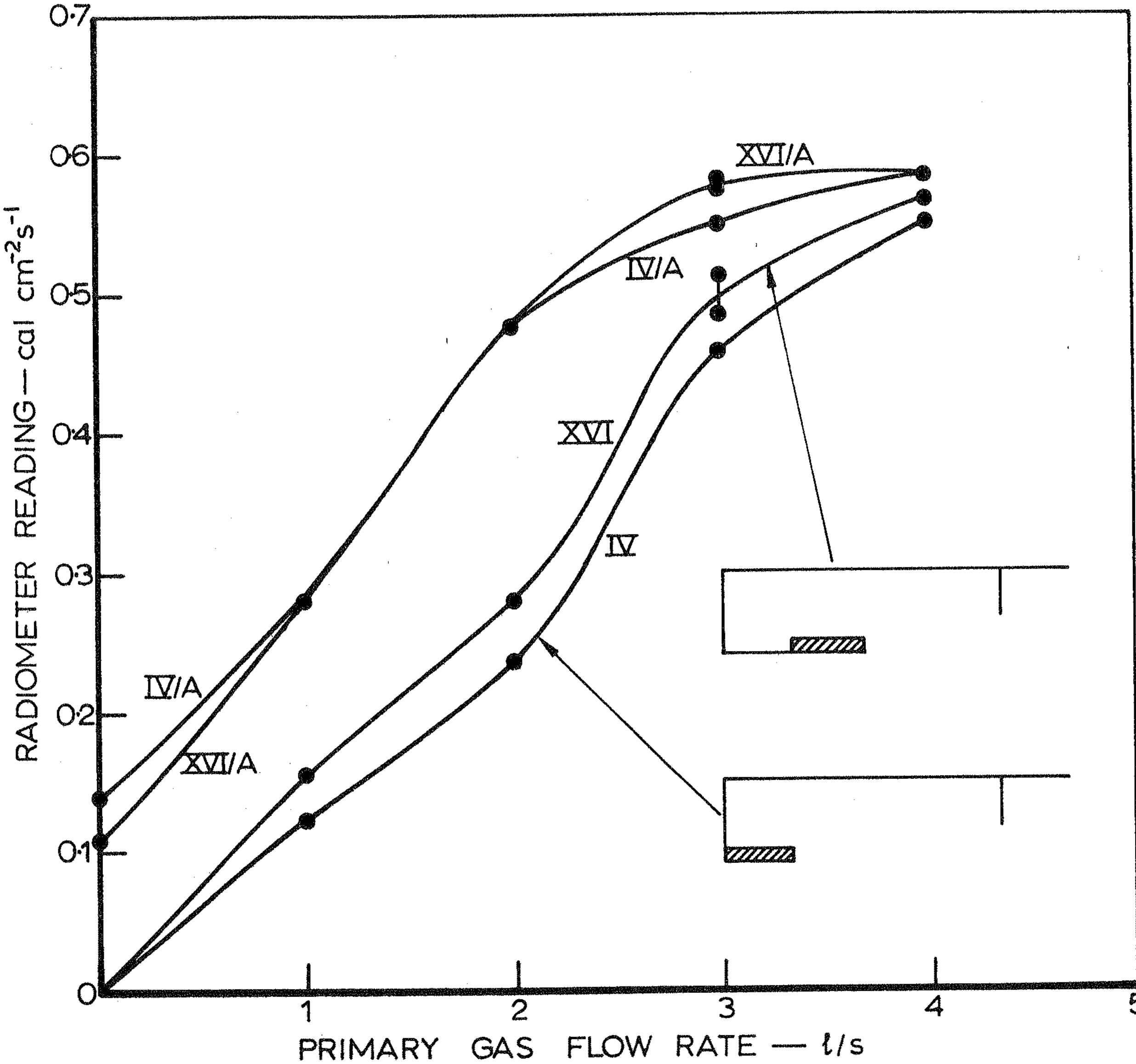

FIG. 10. EFFECT OF MOVING PRIMARY FIRE TOWARDS THE RADIOMETER IN THE PRESENCE OF A CURTAIN AT THE OPEN END

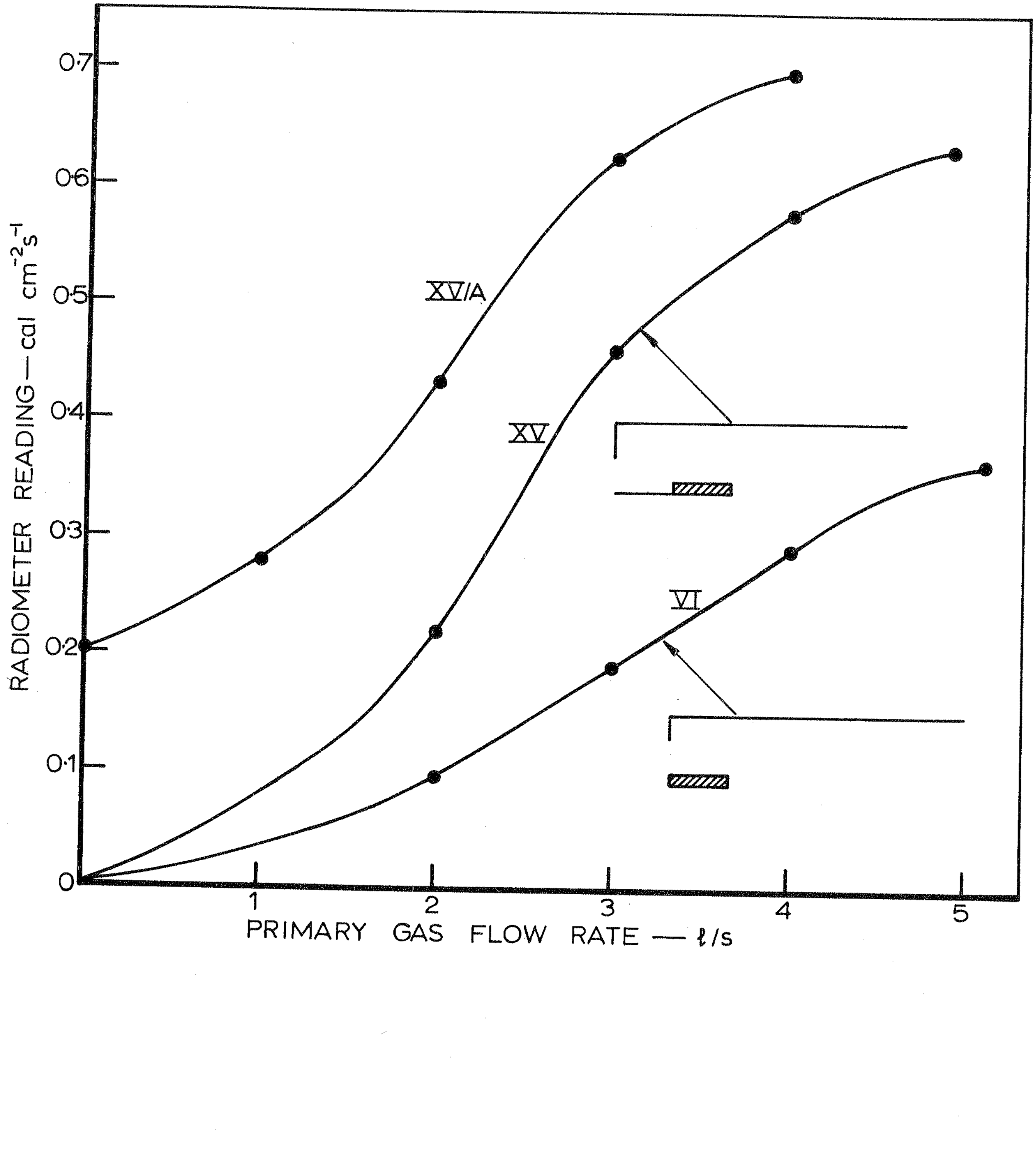

FIG. 11. EFFECT OF MOVING PRIMARY FIRE TOWARDS THE RADIOMETER IN THE PRESENCE OF AN OPENING NEAR THE PRIMARY FIRE (OPEN BOTTOM CORRIDOR)

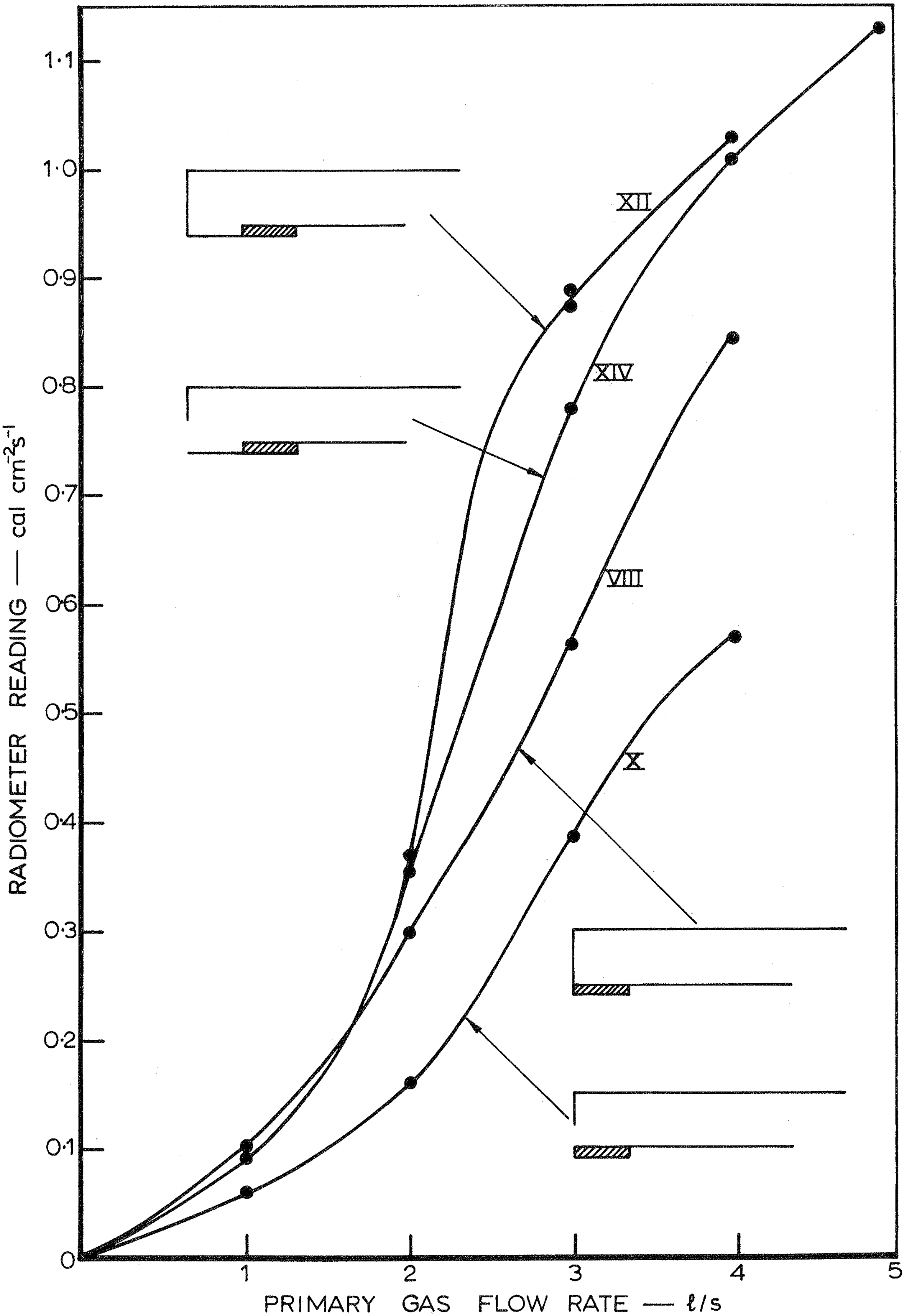

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FIG. 12. EFFECT OF MOVING PRIMARY BURNER TOWARDS