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Objective

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

THE EFFECT OF CEILING HEIGHT ON THE SPACING OF HEAT-SENSITIVE FIRE DETECTORS

by

R. W. Pickard and D. Hird

Summary

The variation in the temperature of the air beneath a ceiling due to a fire has been examined for a range of ceiling heights. The results have been used to derive a relation between the spacing of fire detectors and the height of the ceiling on which they are mounted.

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1. Introduction

A method by which a suitable spacing for heat-sensitive fire detectors can be determined has been discussed elsewhere [1]. The results obtained were based on the air temperature distribution likely to occur beneath a flat ceiling mounted 8 ft above the level of the fire. With greater ceiling heights, lower air temperatures will occur at any given distance from the fire and the spacing of detectors must be reduced if the alarm is to be given at the same stage in the development of the fire.

This note describes an investigation to determine the air temperature distribution likely to occur beneath flat ceilings at heights up to 30 ft above a fire. The results have been used to obtain an empirical relation between the spacing of detectors and the ceiling height within this range.

2. Experimental

A flat ceiling 16 ft x 10 ft was constructed and mounted on scaffolding in a room where its height above the floor could be varied between 15 and 30 ft. The fires used in the experiments are described elsewhere [2] and consisted of methylated spirit burning in trays of 1, 2, and 3 ft diameter, the surface of the spirit being 2 ft above floor level.

Air temperatures were measured by means of 40 S.W.G. Chromel Alumel thermocouples set $2\frac{1}{2}$ in. below the ceiling at a central point vertically above the fire and at points up to 11 ft radially from the central point. Readings were taken at all points with the three tray sizes for ceiling heights of 13, 18 and 28 ft above the fire, except that at 28 ft only the central reading was taken with a 3 ft diameter tray.

3. Results

The radial distribution of temperature rise obtained with the 2 ft diameter fire is shown in Fig. 1 for the three ceiling heights. Similar results were obtained with the 1 and 3 ft diameter fires and showed that with ceilings up to 18 ft above a fire, the temperature rise θ at radial distances greater than 3 ft from the fire is given by the approximate relation

$$\theta = AR^{-0.5} \qquad \text{...... (1)}$$

where R is the distance from the fire and A is a constant for a given ceiling height and size of fire.

For a ceiling 28 ft above the fire the approximate relation is

$$\theta = BR^{-0.3} \qquad \text{...... (2)}$$

where B is a constant for a given size of fire.

The variation in temperature rise with height of ceiling is shown in Fig. 2 for the 2 ft diameter fire. Similar results were obtained using the 1 and 3 ft diameter fires. An analysis of results for the three sizes of fire showed that the temperature rise vertically above the fire can be related approximately to the ceiling height by

$$\theta = Ch^{-1 \cdot 6} \qquad \ldots\ldots (3)$$

where h is the ceiling height and C is a constant for a given size of fire. This agrees with the accepted formula for heated vertical jets of $\theta \propto h^{-5/3}$.

At distances of 3 ft and greater from the fire the relation between temperature rise and ceiling height varied with both the size of fire and the radial distance from the fire (Fig. 2). However, for ceiling heights between 10 and 28 ft above a fire a mean result showed that the temperature rise could be given approximately by

$$\theta = Dh^{-1} \qquad \ldots\ldots (4)$$

where D is a constant for a given size of fire and radial distance from the fire. The results for a ceiling 8 ft above a fire which were obtained using a larger ceiling (2) show that this relation may not hold for ceilings lower than 10 ft above a fire. However, Equation (4) will predict a lower temperature than is likely to occur and will therefore err on the side of safety by suggesting a lower spacing of detectors for ceilings within this range of heights than may be necessary.

4. Discussion

To be effective, an automatic fire detector should give an alarm sufficiently early to enable the fire brigade to attack the fire in its early stages. Thus the success of a detecting system will depend on the type of risk in which it is installed and on its operating characteristics. It is possible to calculate the spacing requirements of detectors to ensure that a fire will be detected before a given rate of heat output is reached regardless of the ceiling height. It may be that a fire will develop more slowly in a room with a high ceiling and therefore, a higher rate of heat output could be tolerated before the alarm is given. There is no information available on the effect of the height of the ceiling on the rate of development of the fire, so the spacing requirements will be calculated on the assumption that the fire must be detected at the same stage of development, regardless of the ceiling height.

This can be achieved if the spacing of detectors is varied with the height of the ceiling so that the temperature rise of the air at the detectors is the same for the same size of fire.

Now if the temperature at a height h_1 and radial distance r_1 from a given fire is θ_1 and at a height h_2 and radial distance r_2 from the same fire is θ_2, then from Equations (1) and (4)

$$\frac{\theta_1}{\theta_2} = \frac{h_2}{h_1}\sqrt{\frac{r_2}{r_1}} \qquad \ldots\ldots (5)$$

The same standard of protection will be afforded at the two ceiling heights if $\theta_1 = \theta_2$ or

$$r_2 = r_1 \left(\frac{h_1}{h_2}\right)^2 \qquad \ldots\ldots (6)$$

Fig. 3 shows the variation in spacing with height of ceiling for a detector with unit spacing at a ceiling height of 10 ft above the fire.

Equation (2) shows that for ceiling heights greater than 18 ft above the fire it may be necessary to reduce the spacing to an even greater extent than that suggested by Equation (6).

5. Conclusions

It has been shown that air temperatures near the ceiling of a room due to a fire are approximately inversely proportional to the ceiling height, where this is between 10 and 28 ft above the fire. If a certain standard of protection is to be maintained, the spacings of fire detectors must be reduced as the ceiling height is increased. An approximate relation between the spacing of detectors and the ceiling height has been derived for flat ceilings up to 18 ft above the fire.

References

(1) Hird, D., Pickard, R. W. and Ross, W. Thermal tests on some heat-sensitive fire detectors. F.R. Note No. 275/1957.

(2) Pickard, R. W., Hird, D. and Nash, P. The thermal testing of heat-sensitive fire detectors. F.R. Note No. 247/1957.

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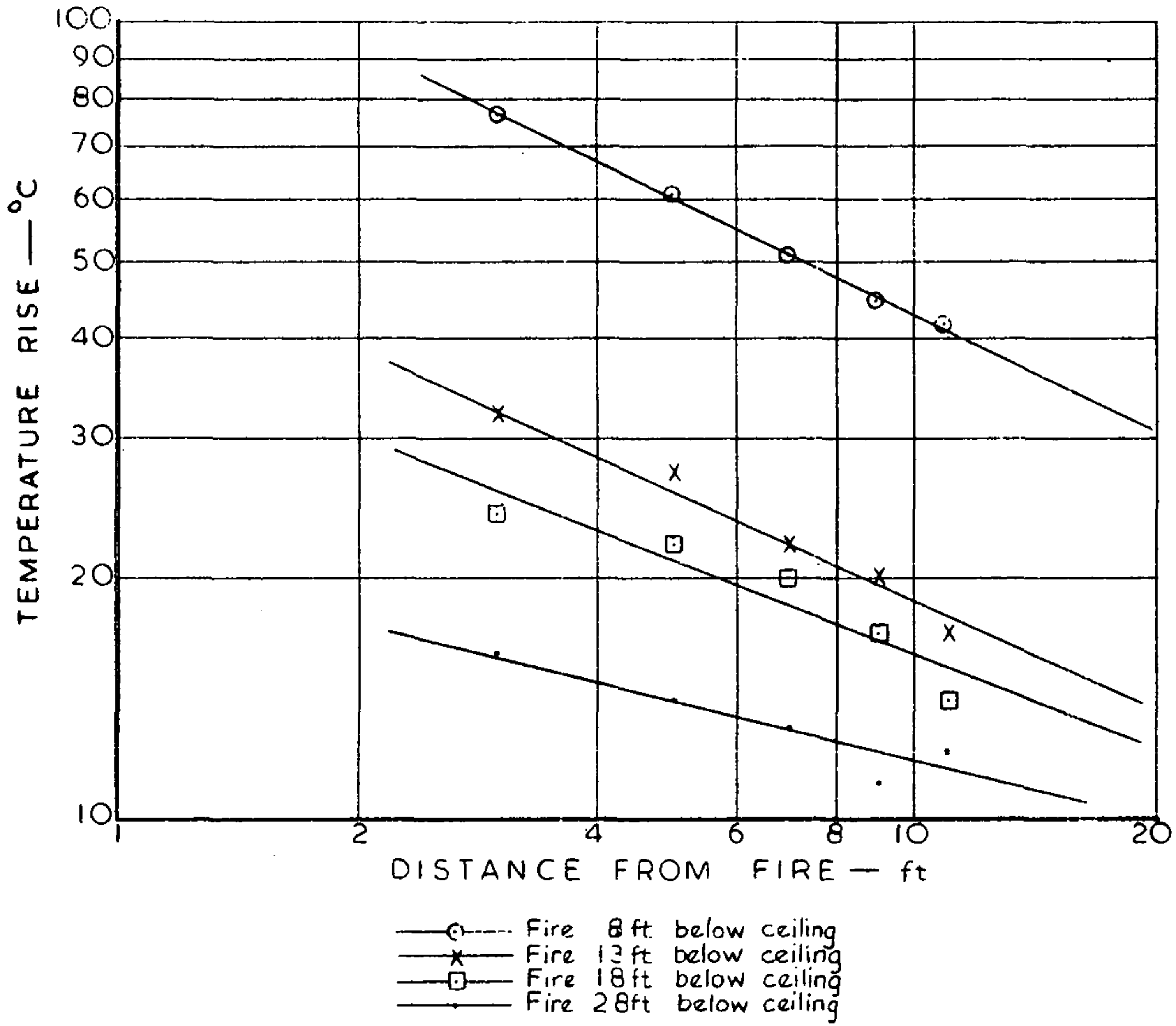

FIG. 1. RADIAL DISTRIBUTION OF TEMPERATURE FOR 2FT DIAMETER FIRE

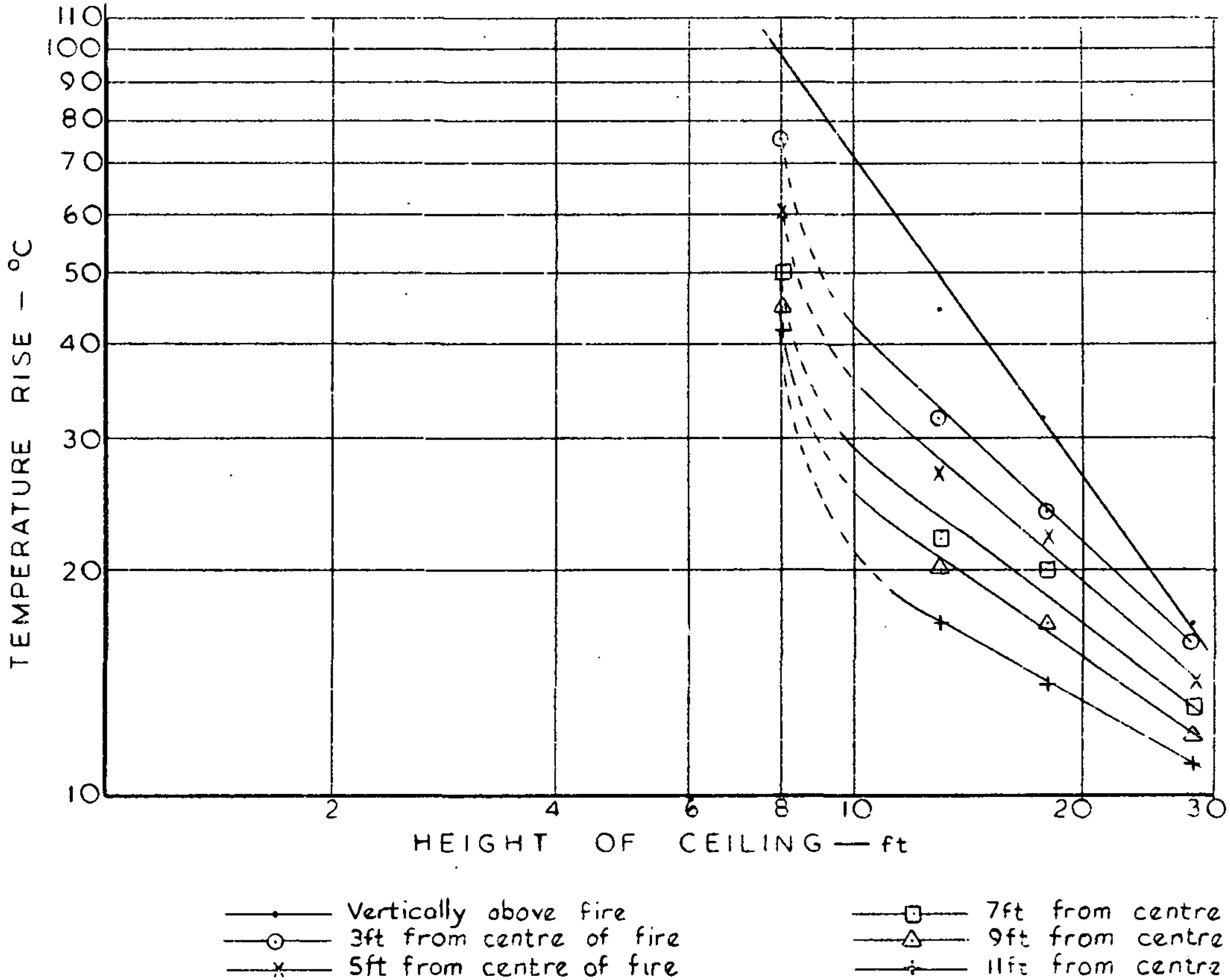

FIG. 2. VARIATION IN TEMPERATURE RISE WITH HEIGHT OF CEILING FOR A 2FT DIAMETER FIRE

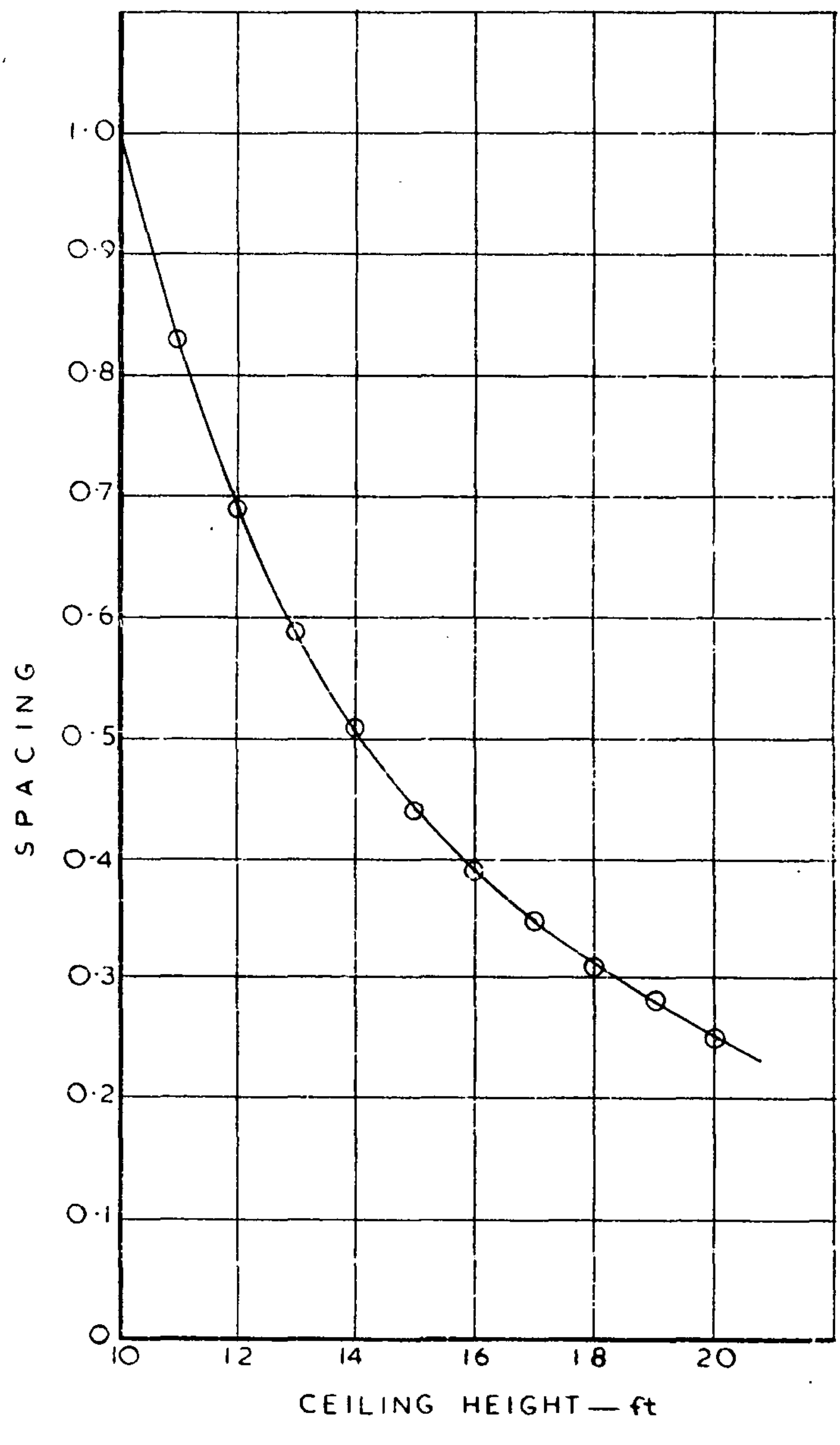

FIG. 3. EFFECT OF CEILING HEIGHT ON SPACING

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