Fire Research Note
No. 808

SURVEY OF FIRE-LOADS IN MODERN OFFICE BUILDINGS - SOME PRELIMINARY RESULTS

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March 1970

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SUMMARY

Some results of a survey of the fire-loads and layout of two modern office buildings are given. It is shown that for these buildings the average fire-load per unit floor area (fire-load density) is 20 kg/m^2 (4.1 lb/ft^2), and is independent of the size of room, and that in 95 per cent of the rooms the fire-load density is less than 59 kg/m^2 (12 lb/ft^2); these buildings would thus be regarded as having a low fire-load. The mean fire-load per unit window area is 55 kg/m^2 (11 lb/ft^2), and in 95 per cent of the rooms it is less than 147 kg/m^2 (30 lb/ft^2). On average the rooms are similar to those studied in recent experiments which indicate that fires in these rooms would be fire-load controlled.

KEY WORDS: Statistics, Fire-load, Offices.

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

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INTRODUCTION

The Building Research Station has recently completed a survey giving details of the contents and layout of a sample of modern office buildings in London. This survey provides valuable statistical data for current and future J.F.R.O. research on the behaviour of fire in buildings; firstly, for the prediction of fire severity (i.e. temperature and duration) which depends on the amount and type of fire-load and on the dimensions and ventilation of the room containing the fire; secondly, for the prediction of fire spread which depends in the initial stage on size and distribution of the combustible items in the room.

The note deals only with statistics necessary for the prediction of fire severity, and contains results of a preliminary analysis of just two buildings, a small sample of the available material. A more extensive analysis will be necessary to define the distribution of some statistics and will be the subject of a further paper.

The data are available in the form of detailed plans describing the layout of the furniture and rooms, together with lists of the type and weight of individual items of furniture. Details of external windows have been obtained from a separate survey, but there is no information on internal windows, partitions and walls. Thus, although the unit of subdivision in this paper will be a "room", in terms of fire resistance this unit is ambiguous. The unit of subdivision in Building Regulations is the fire compartment, with fire resisting boundaries, which in these buildings would involve a whole floor. However, internal partitions, even if their fire resistance is small, will have some influence on the course of the fire and may well be referred to in fire brigade reports of fires as defining "room of origin". Their existence is of course relevant in any analysis of the use of floor space and its subdivision and to the question of escape.

The data were first reduced to numeric form by a suitable coding procedure and then processed on a computer.

FIRE SEVERITY

Fire severity depends on the fire-load, ventilation and dimensions of the compartment or room in which the fire occurs[1]. To a first approximation fires are either controlled by the rate of ventilation, or, when well ventilated, by the amount and distribution of the fuel. In the first situation the fire duration depends mainly on the amount of fuel and the size of the window and, in the second, on the size and nature of the fire-load and its distribution. The two types of behaviour have been distinguished by the fire-load per unit window area F/Aw[1]. In a fairly shallow compartment[2], with a depth to height ratio of 1.22, the fire was ventilation controlled for $F/Aw > 150$ kg/m^2 (30 lb/ft^2) and otherwise fire-load controlled.

The most important features of the building will thus be:-

(a) Amount and characteristics of combustible material, (fuel).

(b) Area of windows

(c) Size and shape of compartments or rooms

The fuel can be described by the nature of the material, its weight, thickness and surface area, but for simplicity, in the present analysis, certain arbitrary distinctions have been made. The major part of the combustible materials are cellulosic (i.e. wood, paper, curtains etc.) and it will here be assumed that other combustible solid material has the same calorific value as wood.

In fire tests wood burns at about 0.7 mm/min and it is therefore reasonable to assume that any piece of wood or assembly of material over 100 mm thick will not be completely burned through. Observation of fire damaged offices tends to confirm this. The fire-load has therefore been classified into three main headings:-

(i) Thick fuel (thickness greater than 100 mm). It will be assumed that wooden cupboards come into this category, but steel cupboards and cabinets do not, whatever their contents.

(ii) Thin fuel (less than 100mm). This includes, for example, chairs and tables.

(iii) Extended surfaces such as wall linings and notice-boards - as weights are not available this has been done in terms of surface area.

Some pieces of furniture, such as pedestal desks, are partly thin and partly thick, and in these cases a simple estimate of the proportions has been made, based on typical examples.

THE BUILDINGS AND CHARACTERISTICS OF THE ROOMS

Two buildings were chosen at random (from a total of about 100) and between them they yielded 93 rooms. In one building the plan area was 245 m^2 and there were 5 storeys, and in the other the plan area was 490 m^2 and there were 6 storeys. The frequency distribution of floor areas is shown in Fig. 1, a skew distribution with a mean room area of 26 m^2 and a median value of 14 m^2.

Table 1 gives a breakdown of the relative position of windows in the rooms. Of the 93 rooms, 28 have been excluded for various reasons (for example because they have no exterior windows) and of the remainder a large number (49) have windows in one wall only. For these rooms the shape of the room can be described by two parameters:-

(i) the ratio of the length of the window wall to the length of the adjacent wall (room depth);

(ii) the ratio of the depth of the room i.e. the dimension perpendicular to the window wall to its height.

The frequency distributions of these quantities are shown in Figs. 2 and 3. Both are moderately skew with means of 1.30 and 1.58 respectively. These rooms are not very deep, on average, and fire behaviour would be expected to be similar to the experimental fires reported earlier[2] apart from the possibility of spread beyond the non-fire-resisting partitions.

FIRE-LOAD

(a) Fire-load/Window area

The distribution of the statistic F/Aw, the fire-load per unit window area, is shown in Fig. 4a. Some rooms have no exterior windows, and in others the source of ventilation is not known; these rooms have been excluded from this graph. A straight line is obtained when cumulative frequency is plotted against F/Aw on log-linear paper (Fig. 4b), suggesting a negative exponential distribution. This leads to the distribution

$$P(F/Aw > x) = e^{-\frac{x}{55}} \quad \text{with } x \text{ in kg/m}^2$$

$$\doteq e^{-\frac{x}{11\cdot3}} \quad \text{with } x \text{ in lb/ft}^2$$

which has been estimated from the data by maximum likelihood. This is a reasonable fit for the range of F/Aw of interest, except that for values of F/Aw between 0 and 24 kg/m^2 (0 and 5 lb/ft^2) the observed frequency is rather too small, possibly because of the exclusion of zero (or non-combustible) fire-loads.

The mean of the distribution is 55 kg/m^2 (11.3 lb/ft^2), and 95 per cent of the rooms have $F/Aw < 150$ kg/m^2 (30 lb/ft^2), the limiting value for ventilation controlled fires in shallow rooms. Thus in 95 per cent of the rooms a fire would be fire-load controlled.

(b) Fire-load/floor area (Fire-load density)

The frequency distribution of the fire-load per unit floor area, F/Af is given in Fig. 5. This is a skew unimodal distribution with a long tail at high values of F/Af. The mean value of the distribution is 20 kg/m^2 (4.1 lb/ft^2).

The upper limit for buildings of low fire-load, adopted by the Committee for the Fire Grading of Buildings[3], in its first report, is 58.6 kg/m^2 (12 lb/ft^2). Thus according to this definition, referring to Fig. 5, about 95 per cent of the rooms in the two buildings are in the low fire-load category.

The mean fire-load density of 20 kg/m^2 (4.1 lb/ft^2) compares with the value given by Kollbrunner[4] for modern office buildings of 8 - 25 kg/m^2 (1.65 - 5.15 lb/ft^2). The value given by Halpaap[5] for administration buildings in Germany, 39 kg/m^2, (8 lb/ft^2) is rather higher possibly because of a more extensive use of wood both in the furnishings and construction of buildings in Germany.

(c) Percentage of floor area covered by furnishings

The frequency distribution of the density of coverage of the floor area by furniture, i.e. excluding carpets, is given in Fig. 6. This is an approximately normal distribution with a mean of 27 per cent. This is in agreement with an observation of Langdon and Keighley[6], that the amount of floor space occupied by furniture and equipment is 25 - 30 per cent, although this can be as high as 33 per cent in special function offices such as drawing offices and machine rooms.

(d) Thick and thin fuels and extended surfaces

The distributions of these statistics are given in Figs. 7 - 9. As may be expected, on average the thick fuel (thicker than 100 mm) forms the greater part of the fire-load.

(e) Variation of fire-load density with size of room

Room size and window area are a matter of individual building design and it is of interest to see whether building design affects room usage, i.e. do larger rooms have a lower density of furnishing? The variation of F/Af with floor area Af, is shown in Fig. 10, and it can be seen that for these data there is no correlation between the two variables. Thus the fire-load density is independent of the size of room and by implication the fire-load density in a fire compartment (i.e. one floor or more) is independent of the way in which it is subdivided.

CONCLUSIONS

A preliminary analysis of two buildings, with 93 rooms in all, has shown:

(1) In 95 per cent of the rooms the fire-load per unit window area is less than 150 kg/m^2 (30 lb/ft^2) and since the rooms were on the whole shallow the fires would be controlled by the burning characteristics of the fuel; if the partitions between rooms had sufficient fire resistance.

(2) The mean value of the fire-load per unit window area is 55 kg/m^2 (11.3 lb/ft^2) and its probability distribution is:-

$$P\,(F/Aw > x) = e^{-\frac{x}{55}} \qquad (x \text{ in } kg/m^2)$$

$$= e^{-\frac{x}{11\cdot3}} \qquad (x \text{ in } lb/ft^2)$$

(3) The mean fire-load per unit floor area is 20 kg/m^2 (4.13 lb/ft^2) but the distribution is very skew with a long tail at high values of the fire-load density.

(4) In 95 per cent of the rooms the fire-load density is less than 59 kg/m^2 (12 lb/ft^2), thus placing these buildings in the low fire-load category.

(5) The fire-load density is independent of the floor area so that the fire-load of a fire compartment is independent of the way in which it is subdivided.

(6) On average 27 per cent of the floor area is covered by furnishings.

(7) The layout of the buildings is discussed, and the frequency distributions of floor area and room shape are given.

(8) The most common and average room shapes are similar to those which have been the subject of recent experiments.

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Table 1. Relative position of external windows in rooms

Position of windows	Building 1	Building 2	Total
In one wall only	28	21	49
In two opposite walls	1	-	1
In two adjacent walls	10	2	12
Other	3	-	3
Total	42	23	65

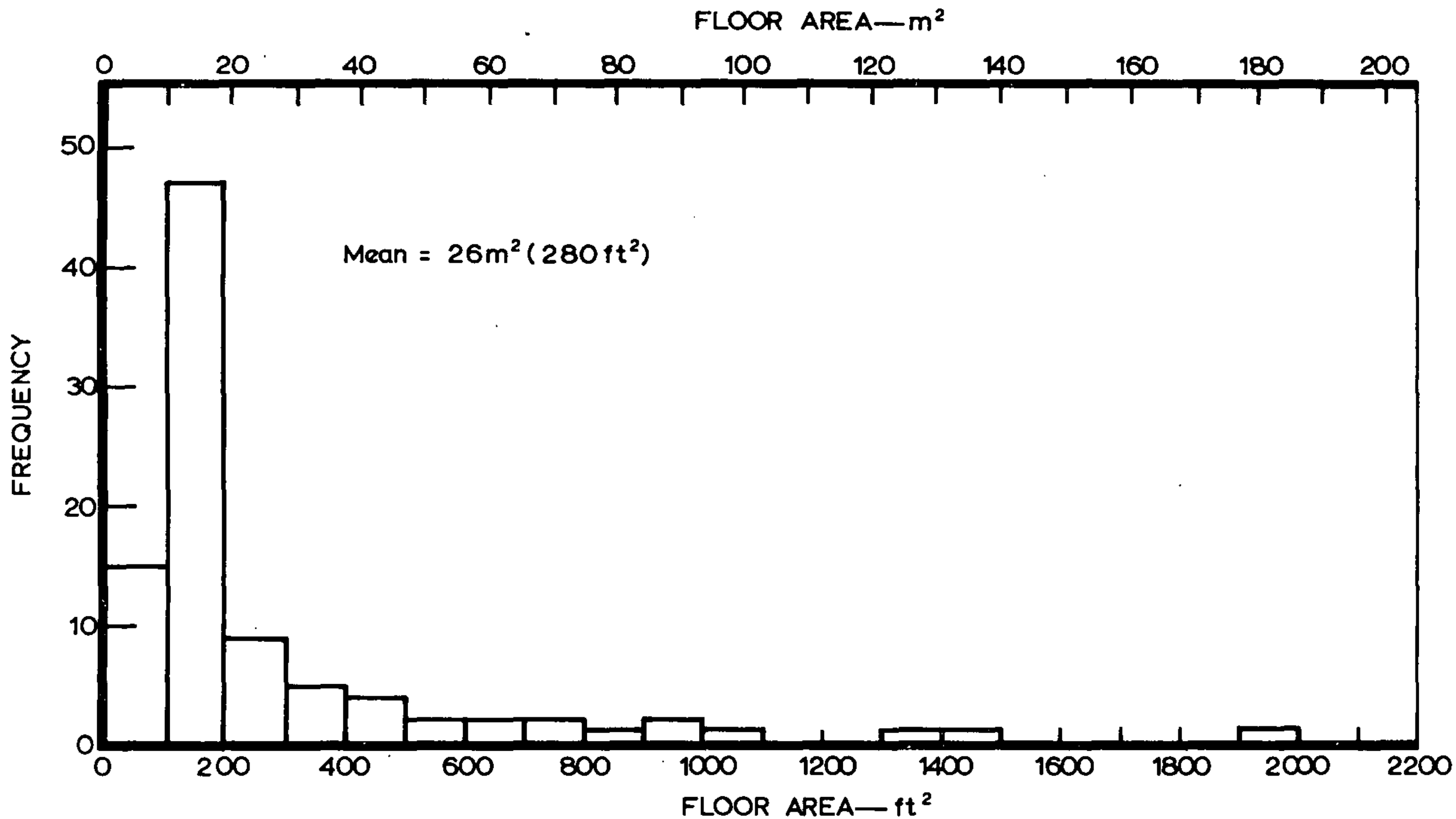

FIG. 1. FREQUENCY DISTRIBUTION OF FLOOR AREA

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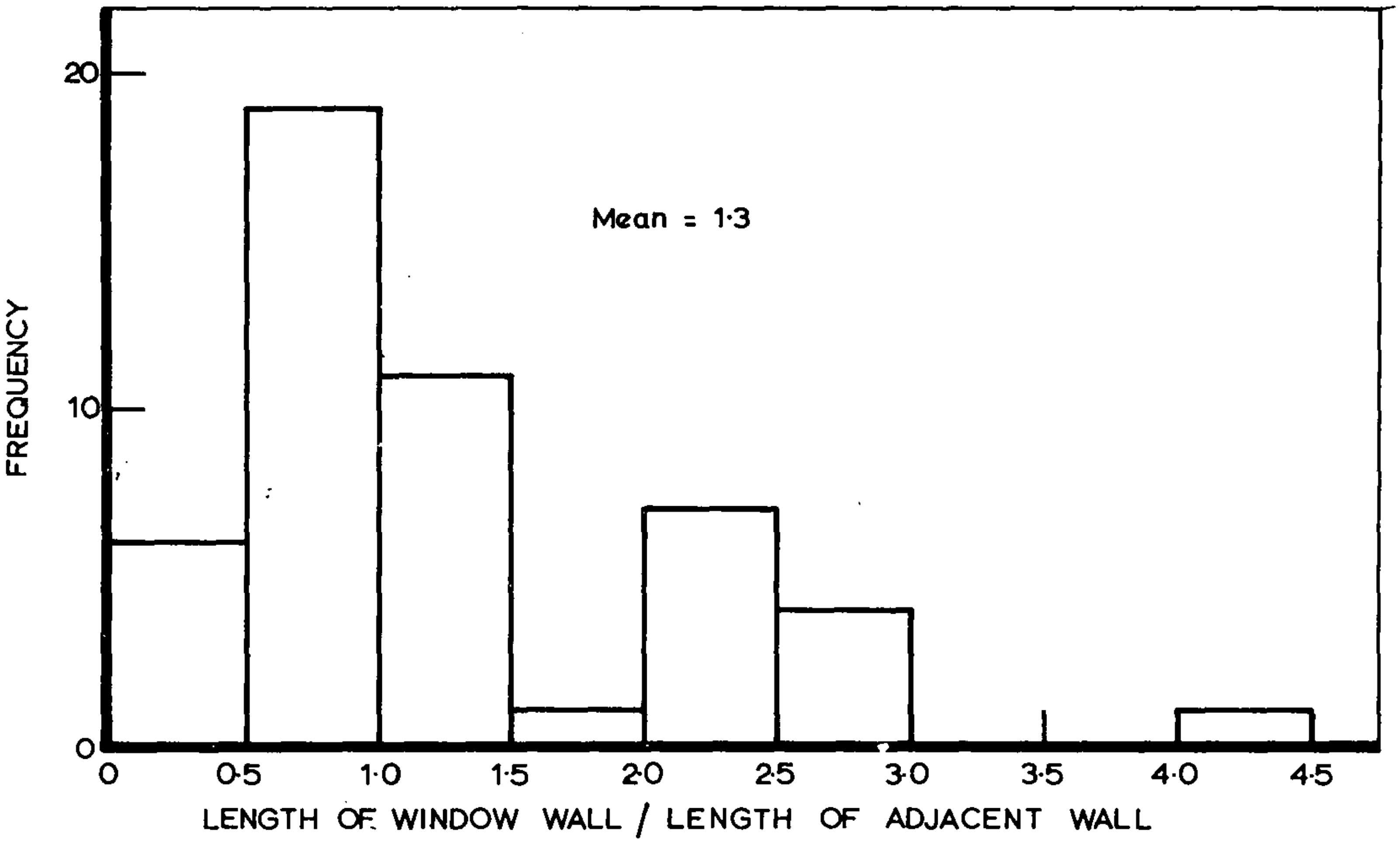

FIG. 2. ROOM SHAPE: FREQUENCY DISTRIBUTION OF THE RATIO OF LENGTH OF WINDOW WALL TO ADJACENT WALL

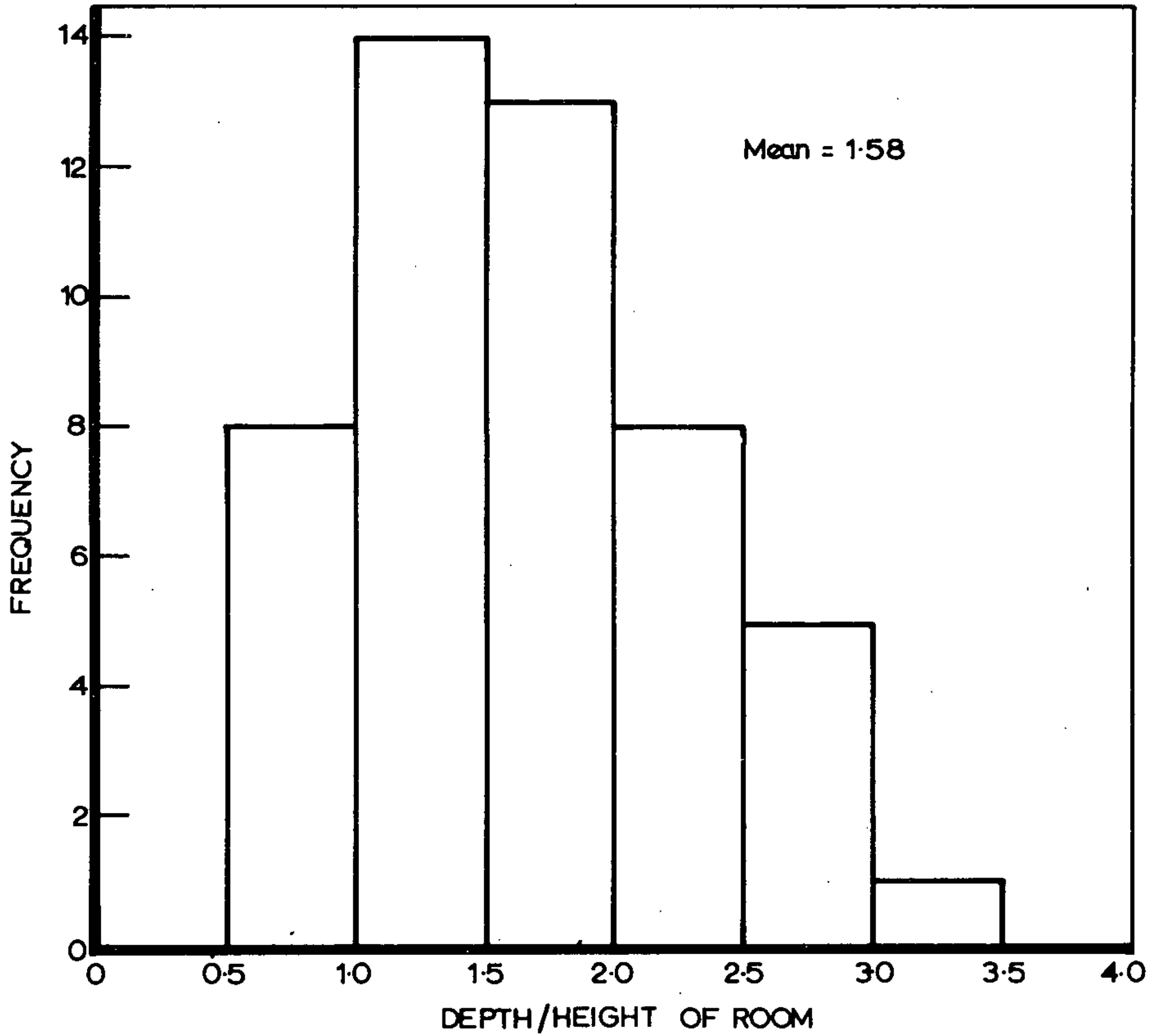

FIG. 3. ROOM SHAPE: FREQUENCY DISTRIBUTION OF THE RATIO OF DEPTH OF ROOM TO HEIGHT OF ROOM

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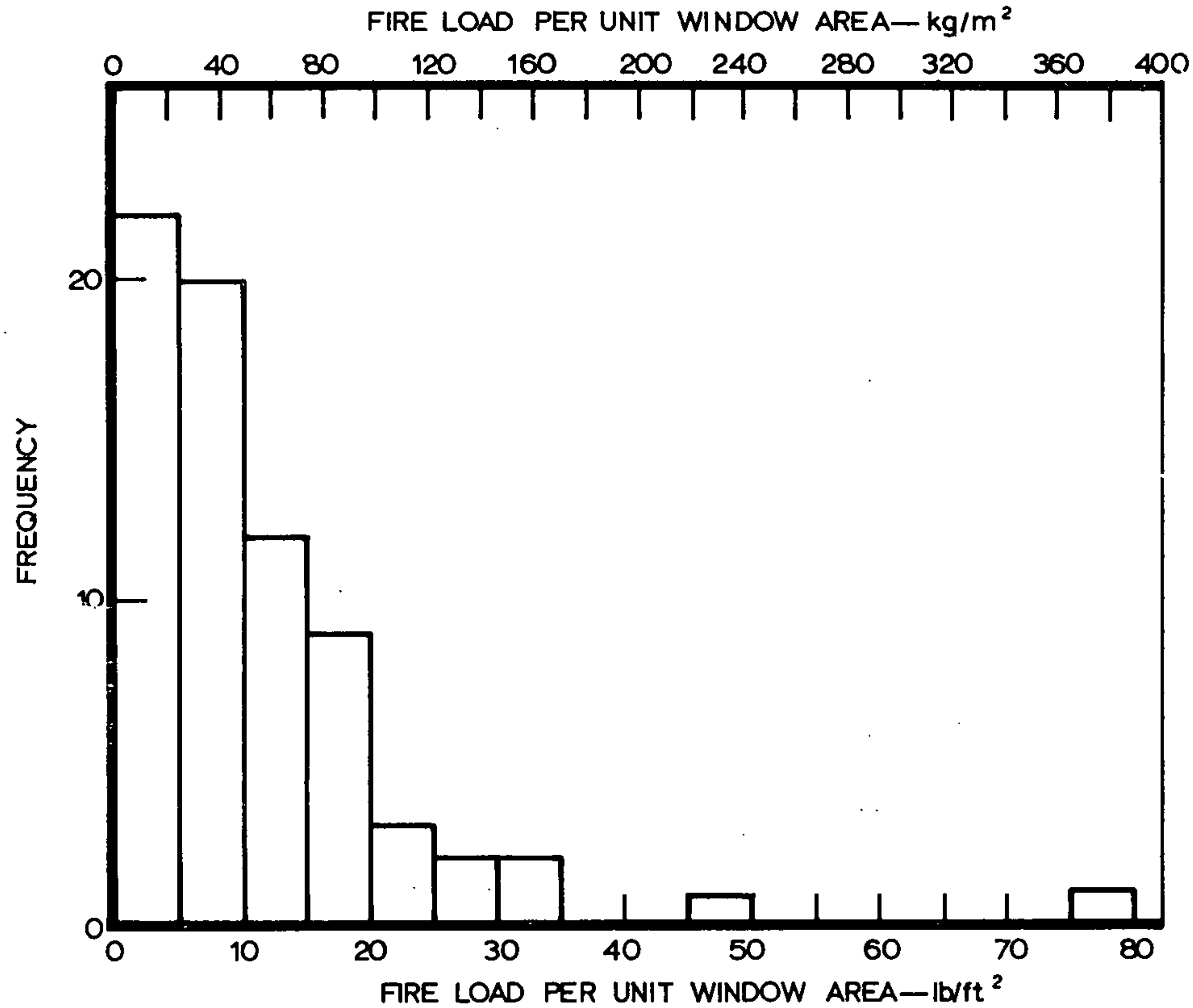

FIG. 4a. FREQUENCY DISTRIBUTION OF THE FIRELOAD PER UNIT WINDOW AREA

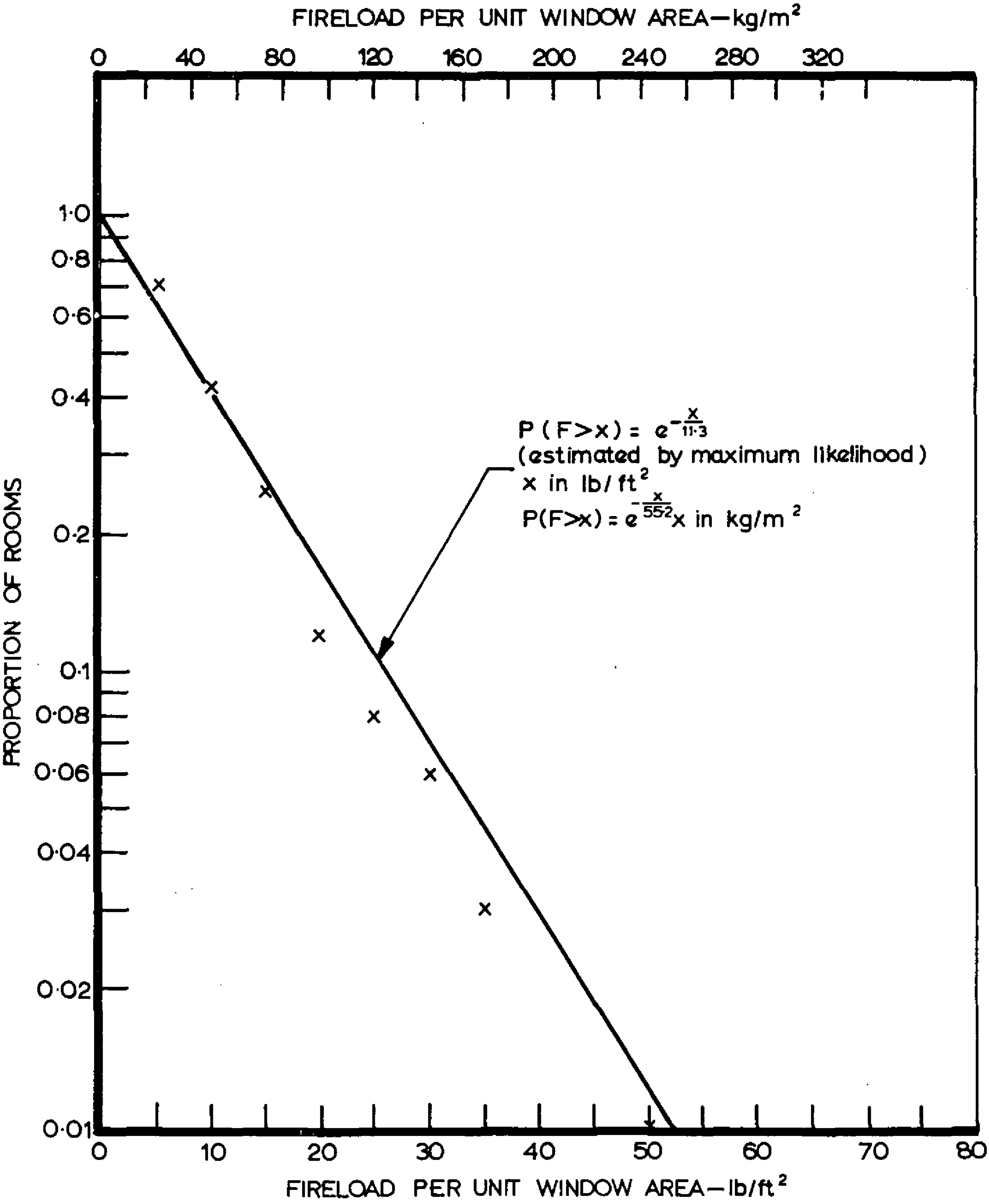

FIG. 4b. DISTRIBUTION FUNCTION OF FIRELOAD PER UNIT WINDOW AREA

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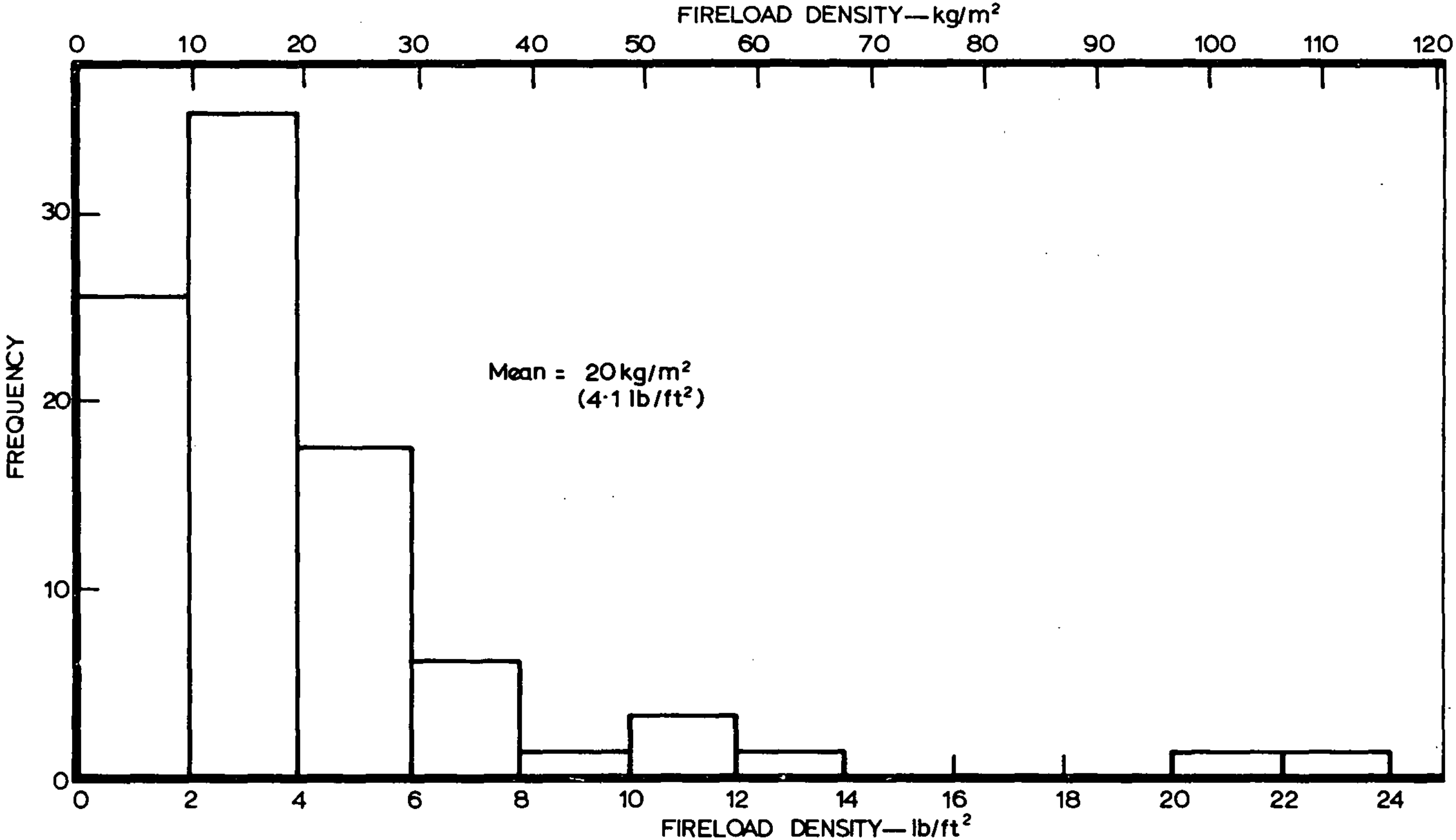

FIG. 5. FREQUENCY DISTRIBUTION OF FIRELOAD DENSITY—FIRELOAD PER UNIT FLOOR AREA

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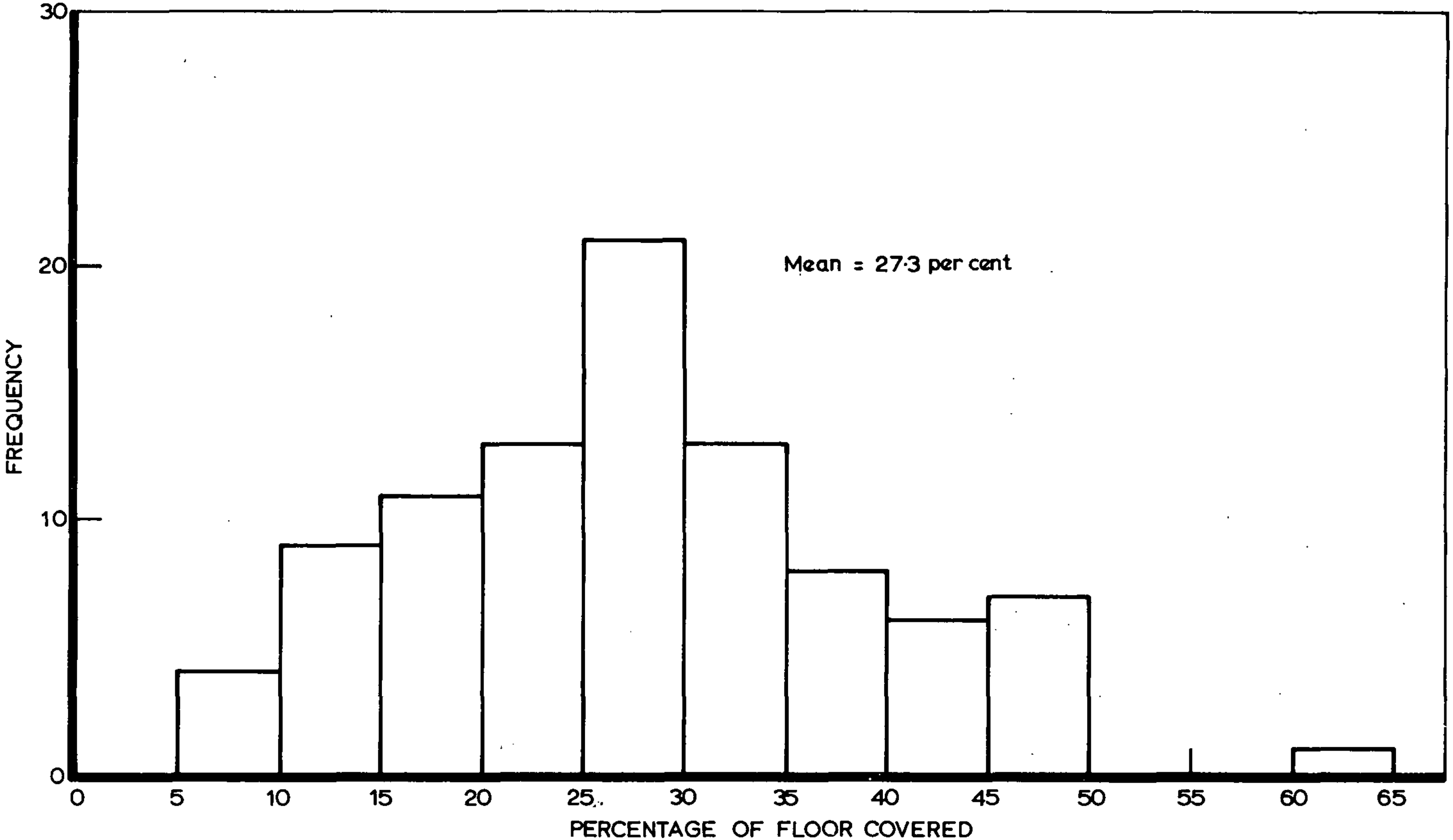

FIG. 6. FREQUENCY DISTRIBUTION OF PERCENTAGE OF FLOOR COVERED BY FURNITURE

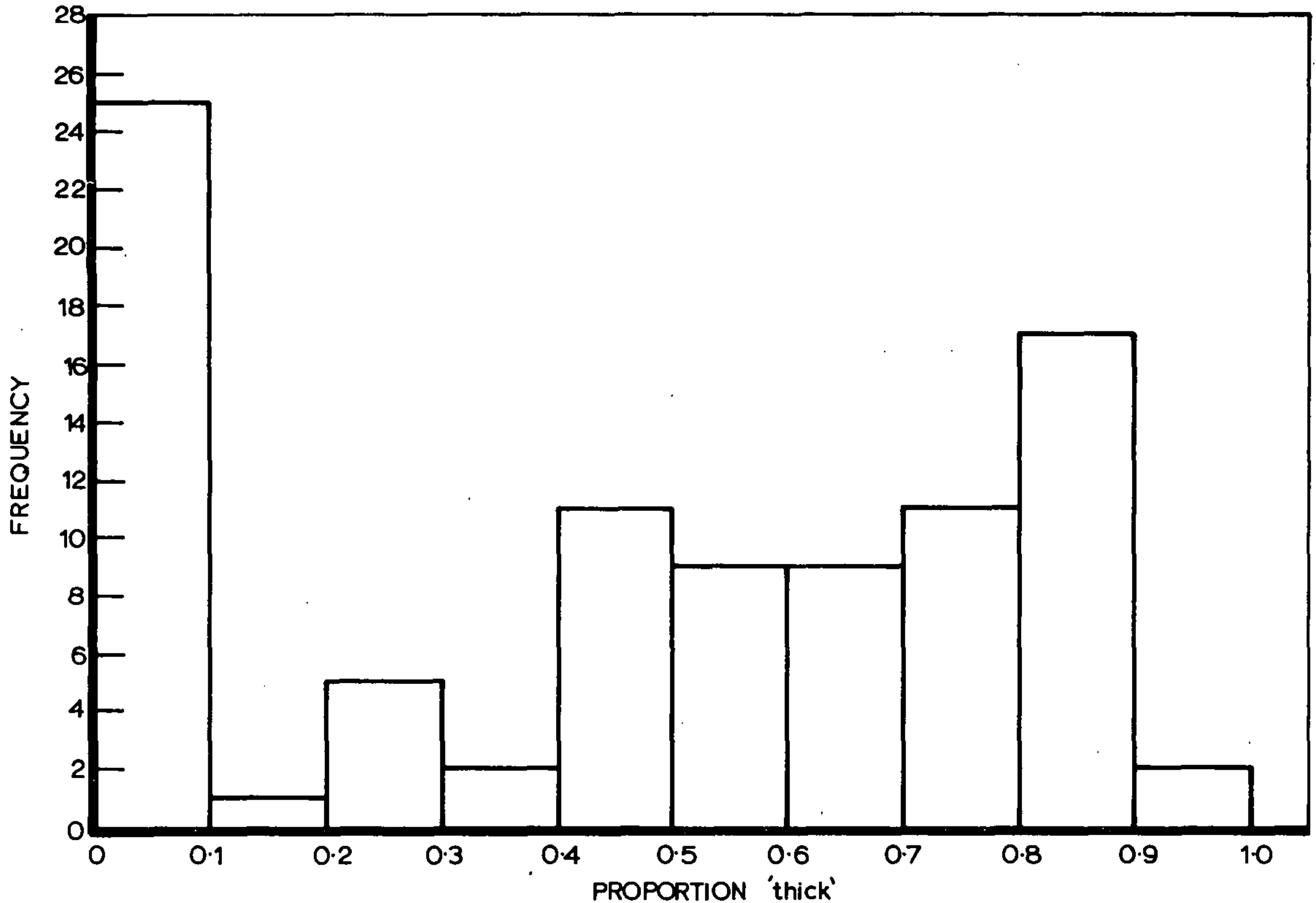

FIG.7. FREQUENCY DISTRIBUTION OF PROPORTION OF FIRELOAD CLASSIFIED AS 'THICK'

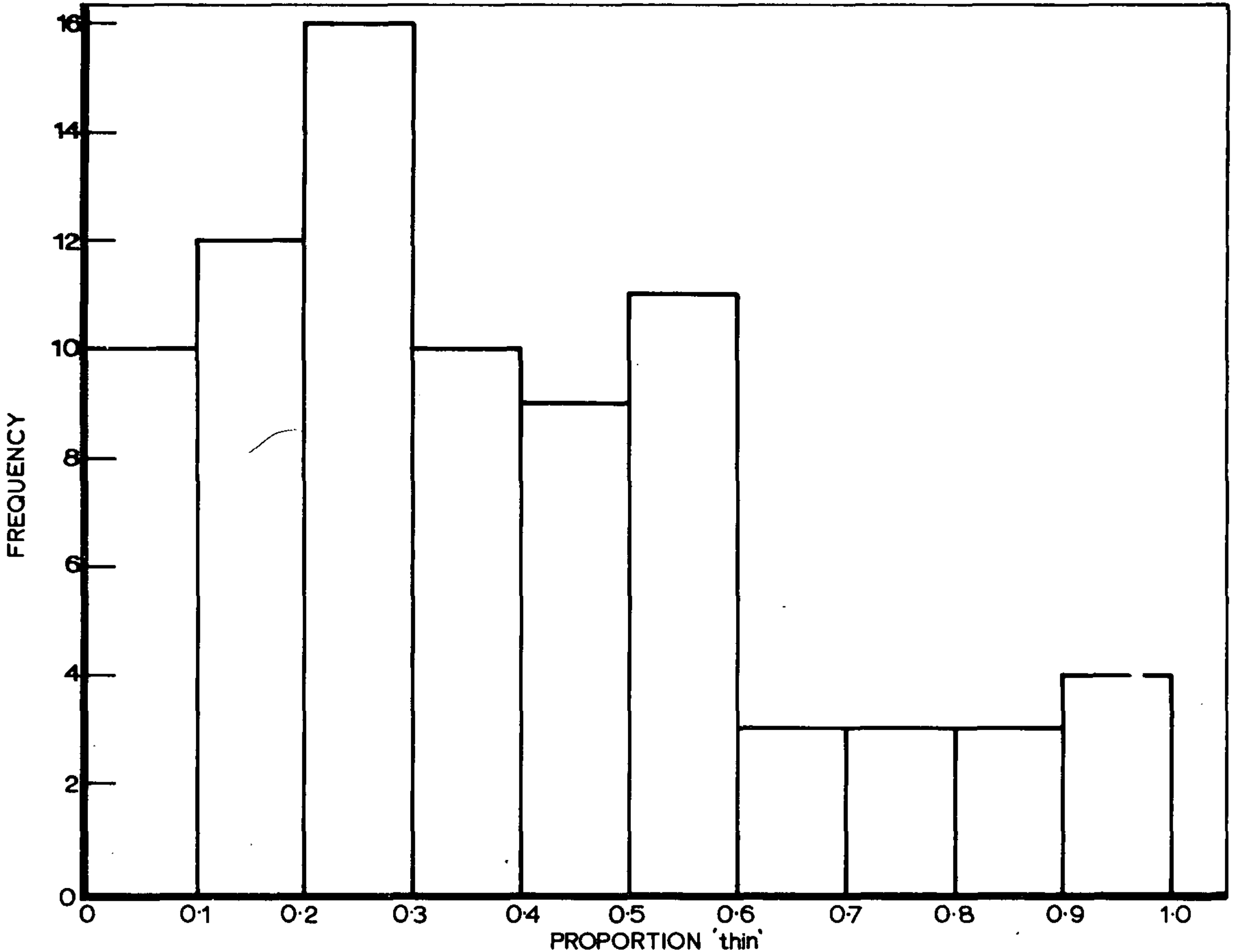

FIG.8. FREQUENCY DISTRIBUTION OF PROPORTION OF FIRELOAD CLASSIFIED AS 'THIN'

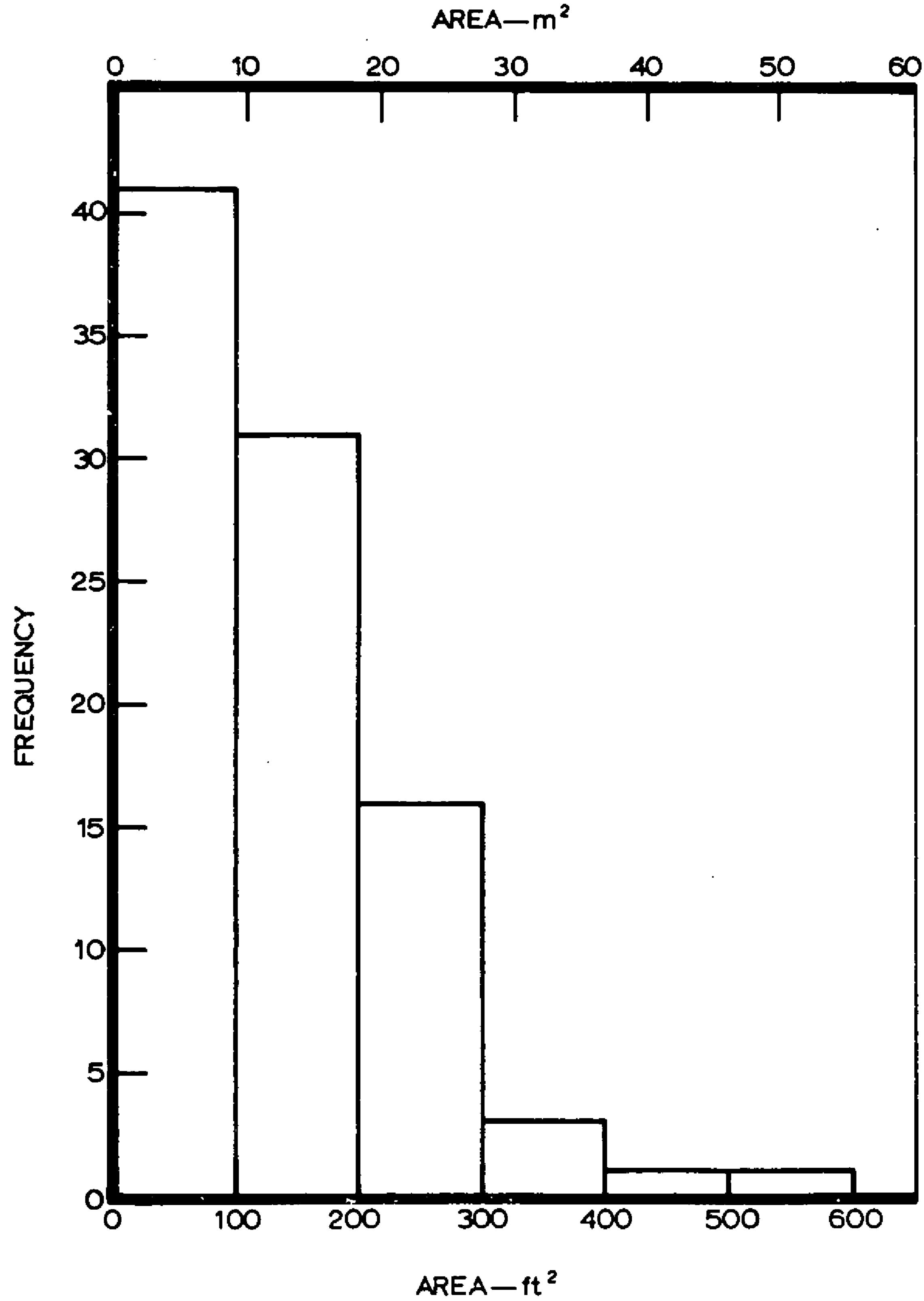

FIG. 9. FREQUENCY DISTRIBUTION OF AREA OF EXTENDED SURFACE FIRELOAD

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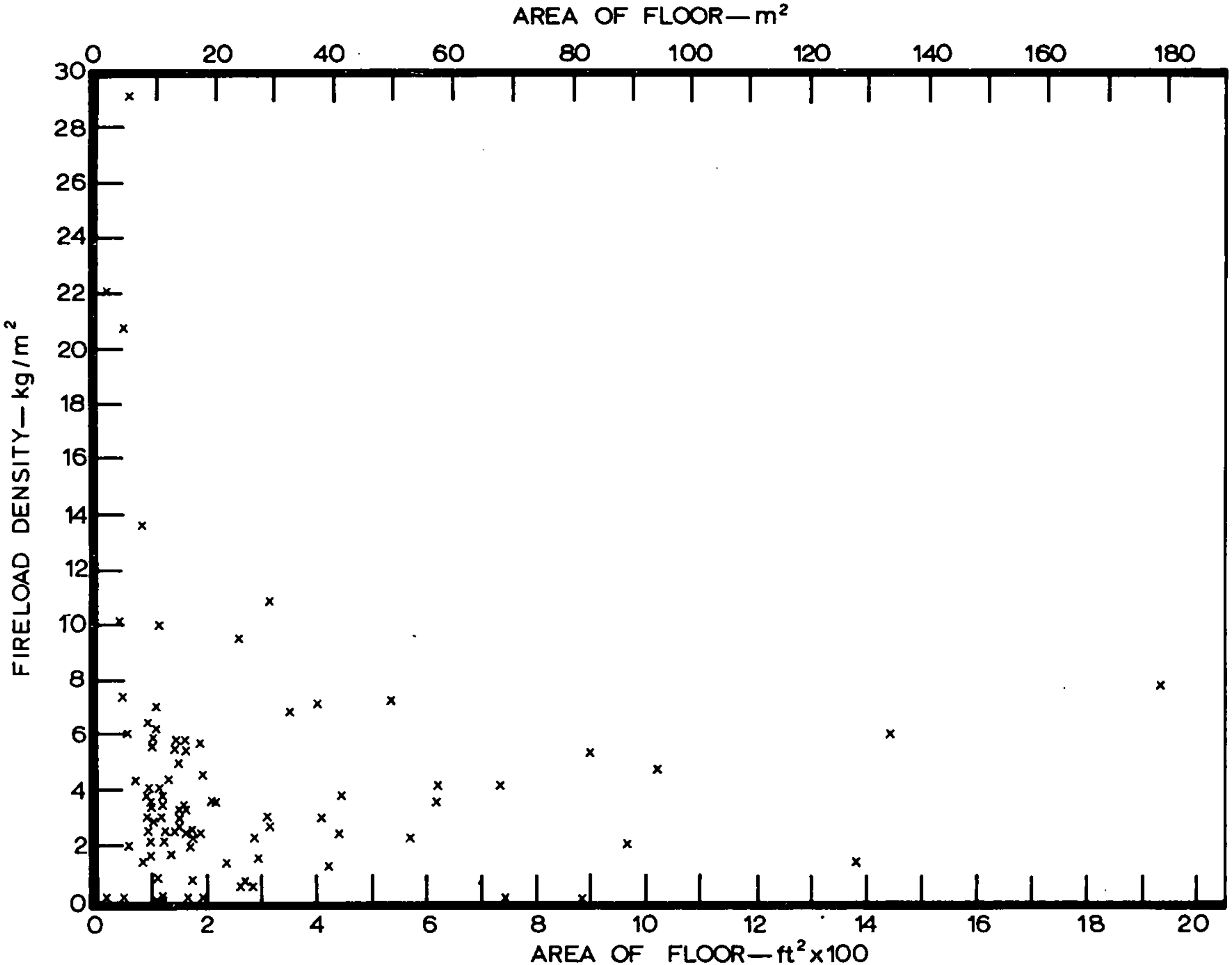

FIG. 10. CORRELATION OF FIRELOAD DENSITY AND AREA OF ROOM