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

A PRELIMINARY EXAMINATION OF THE BYELAW REQUIREMENTS FOR STRUCTURAL FIRE PRECAUTIONS IN DWELLINGS OF MORE THAN TWO STOREYS

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1. Introduction

It has been suggested that the Model Byelaws for the fire requirements for the external walls of multistorey flats are too restrictive. Model Byelaw 40 specifies that the fire resistance of these walls be one hour and Model Byelaw 47 specifies that either the vertical separation between windows be three feet or the horizontal projection between storeys be two feet.

It would be an economy to use types of external walling which do not conform to these conditions in the construction of multistorey dwellings, and the Joint Fire Research Organization undertook to investigate the effect on the fire hazards of relaxing these standards for external non-load bearing walls. The two types of hazard considered were, the spread of fire from floor to floor and the exposure of one building to radiation from an adjacent burning building. Full-scale experiments were not possible and so work with models was carried out instead. The scaling laws which these obey have as yet been only partly investigated, but the experiments were useful in revealing the factors likely to affect the fire hazard in a full-scale room, though not necessarily their relative importance.

2. The spread of fire from floor to floor

The present standards for floors allow little heat to be conducted from storey to storey through the ceiling of a burning room. Heat may be transferred to an upper room through the windows by radiation and convection from the flames and hot gases.

2.1. Experimental procedure and results

A 1/5th scale model was constructed of asbestos wood to represent two rooms one above the other, each 15 x 15 x 9 feet (Figure 1). The same side of both rooms was left open and the desired window openings and separation obtained by blanking off part of the side with asbestos wood.

The lower room had a wooden floor and was furnished with 6 in. cubical boxes open on one side and made of 1 in. timber to give a fire load of about 6 lb/sq.ft. which is similar to that of a normal domestic occupancy. The upper room was furnished as in earlier tests [1].

The contents of the lower room were ignited and the time for which the flames came from the lower opening was noted. With a 50 per cent opening this was about twenty minutes and with a 90 per cent opening about fifteen minutes. The distribution of radiation at the upper opening was found to be fairly uniform when there was a 90 per cent opening in the lower room. The amount of heat entering the upper room is thus approximately proportional to the area of the upper opening.

Tests were carried out with no separation and with a 3/5ths foot separation between the openings and with a 2/5ths foot projection with no separation. In these tests the opening in the lower room was about 90 per cent of the wall area of one side. In the tests with no vertical separation, furniture near the opening in the upper room was ignited, though the actual origin of ignition could not be observed through the flames in front of the window, and the fire quickly spread to involve the entire room. Either a 3/5ths foot vertical separation or a 2/5ths foot horizontal projection was sufficient to prevent ignition of the furniture (Plate 1).

2.2. Interpretation of results

Only a qualitative interpretation of these results can be attempted here.

Heat is transferred into the upper room by convective heat transfer and by radiation from the flames and hot gases. The flame velocity increases with the height of the room, so that any convective heat transfer would increase with scale of the room.

The flames from the lower window cover the whole of the upper window and this happens in full-scale fires. The configuration factor of the flames with respect to the opening will therefore be the same for the models and full-scale. The thickness of the flames, however, is greater in a full-scale fire so that the emissivity and therefore the intensity of radiation are also greater. This intensity will be approximately proportional to the flame thickness.

If the thickness of flame is T, the height of the flame is H, the width W and the velocity of gases in the flame V.

then the rate of burning of the gases is proportional to T.W.V.

This, for equal burning rates per unit area of room surface is proportional to L^2, where L is the linear scale factor.

Now $W \propto L$

and $V \propto H^{\frac{1}{2}}$

$\therefore$ $T \propto L/H^{\frac{1}{2}}$

if H is proportional to L,

then $T \propto L^{\frac{1}{2}}$

Probably H is proportional to a fractional power of L, since the flames of a small fire are generally relatively taller. That is, T increases more rapidly than $L^{\frac{1}{2}}$ and the radiation for the full-scale test may be as much as twice as that for the models. Heat transfer by radiation is thus a more important factor than convection and needs closer investigation; a safe situation on the small-scale may not be safe on full-scale.

There was little difference in intensity of radiation entering the window in the upper room whether a projection was used or not, but ignition occurred only without a projection. With no projection there was probably less chance of cooling ventilating currents getting between the flames and the room and there might have been a greater chance of flames entering and causing pilot ignition.

3. Exposure hazard

3.1. Experimental procedure and results

Exposure hazards must be considered for a building from two points of view; first, the ease with which the building can be ignited if a nearby building is on fire, and secondly, the hazard presented if the building is itself burning.

The experiments of section 2 suggest that radiation from a fire in a compartment of a building having a fire load of 6 lb/sq.ft. would last nearly half an hour and experiments were carried out to find the intensity of radiation that would ignite a room within this time.

The source of radiation used was a 3 foot square, gas fired, radiation panel. The model, similar to those used in previous work was a 1/10th scale room containing wood and fibre insulating board furniture, a wooden floor and a pilot flame to represent either a gas fire, or a flying brand (Figure 2). Two window openings were investigated, the areas of which were 33 per cent and 100 per cent of the larger side of the model room. In preliminary experiments, the window opening was glazed and curtains were used. It was found that there was much variation in the time taken for the glass to crack and fall out of the frame and since glass absorbs about 2/3rds of the incident radiation this variability had a great effect on the results of the experiments. It was therefore decided to simulate the worst possible conditions, that is, the immediate cracking and falling out of the glass, by leaving the window unglazed. The curtains charred away without affecting the rest of the room and were dispensed with in the main experiments.

Two different sets of wall lining board were used, fibre insulating board to represent the most hazardous lining and plasterboard, which is probably little different from a traditional type of room with wallpaper.

The intensities of radiation which caused ignition in the rooms within half-an-hour are given in Table I.

Table I

Intensities of radiation required to ignite model rooms lined with fibre insulating board and plasterboard

Wall lining	Percentage window opening	Radiation $cal/cm^2/sec$	Time to ignite minutes
Fibre insulating board	33 100	0·56 0·21	27 25
Plasterboard	33 100	0·88 0·21	22 24

With the smaller window opening ignition usually occurred when the pilot flame ignited combustible gases produced by the thermal decomposition of the contents of the room, while, with the larger opening, there was spontaneous ignition of one of the articles of furniture.

3.2. Interpretation of results

It is probable that at the initial stages of heating, the heat loss from the system scales linearly except for convection; this latter will increase with the size of the room.

For this reason the predicted exposure hazard for full-scale rooms, calculated from these experimental results, will probably be overestimated.

The predictions given are based on the assumption that the small-scale and full-scale rooms ignite by the same process.

A burning building may be considered as a black body radiator at a temperature of 1000°C (2) (3). The intensity of radiation, I, at any point on an adjacent building is given by:-

$$I = \frac{W}{100} \phi \sigma T^4$$

where

W = percentage window opening of burning building.
ϕ = configuration factor for the whole facade of the burning building at the point considered.
σ = $1 \cdot 37 \times 10^{-12}$ cal/°C^4/cm^2/sec.
T = 1273°K.

Since for any value of ϕ there is a corresponding value of the distance of separation the safe distance can be calculated from

$$\phi = I_s \frac{100}{W} \times \frac{1}{3 \cdot 6}$$

where I_s is the maximum safe intensity.

Thus the safe distance of separation depends on the window opening of the burning building and on I_s, which varies with the window opening of the exposed building. Values of the safe distance of separation are given in Table II for a burning building with a square facade.

Table II

Safe separation in terms of height of burning building

Percentage window opening of burning building	Percentage window opening of exposed building	
	33	100
33	0·3	1·2
100	1·0	2·1

If two adjacent buildings have 100 per cent and 33 per cent window opening, the risk of spread is slightly greater if the one with 33 per cent is burning but the difference is small compared with errors due to assumptions made in calculating the safe distances and may be ignored. The necessary separations for a variety of conditions are shown in a general form in Figure 3.

The horizontal spread of fire between units in this type of building is always less rapid than the vertical spread, though this would be more rapid in maisonettes than in flats. If two vertically stacked maisonettes are radiating, the approximate ratio of the breadth of the fire area to its height will be 0·5. If only one maisonette is on fire the exposure hazard will be that of a small dwelling.

For dwellings of more than four storeys it is most unlikely that the fire will spread fast enough vertically for all floors to be burning at once. The safe distances given by Figure 3 would therefore err heavily on one side of caution for a high building.

4. Conclusions

The experiments with models described in this paper suggest that openings in the outer walls of buildings should be separated either by wall or by projection. At present, the model Bye-Laws require that these should be a 3 foot vertical separation or a 2 foot horizontal projection. There is no suggestion from these experiments that these might be relaxed.

With the usual fire load in domestic occupancies, the vertical separation is not likely to be subjected to fire conditions for more than half-an-hour, it might therefore be possible to relax the present requirements for one hour fire resistance.

The separation of buildings to minimize the exposure hazard depends on the area of the openings in their facades. Safe separations have been calculated for a number of cases; for buildings of more than four storeys these will be too restrictive. The major difficulty in assessing the reliability of these predictions of the exposure hazards using models lies in judging how far scaling affects the means by which ignition occurs.

5. Acknowledgments

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6. References

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(2) Lawson, D. I. and Hird, D. Radiation from burning buildings. F.P.A. Journal No. 18. London, 1953.

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PLATE.I. EFFECT OF BALCONY ON FLAMES FROM MODEL ROOM

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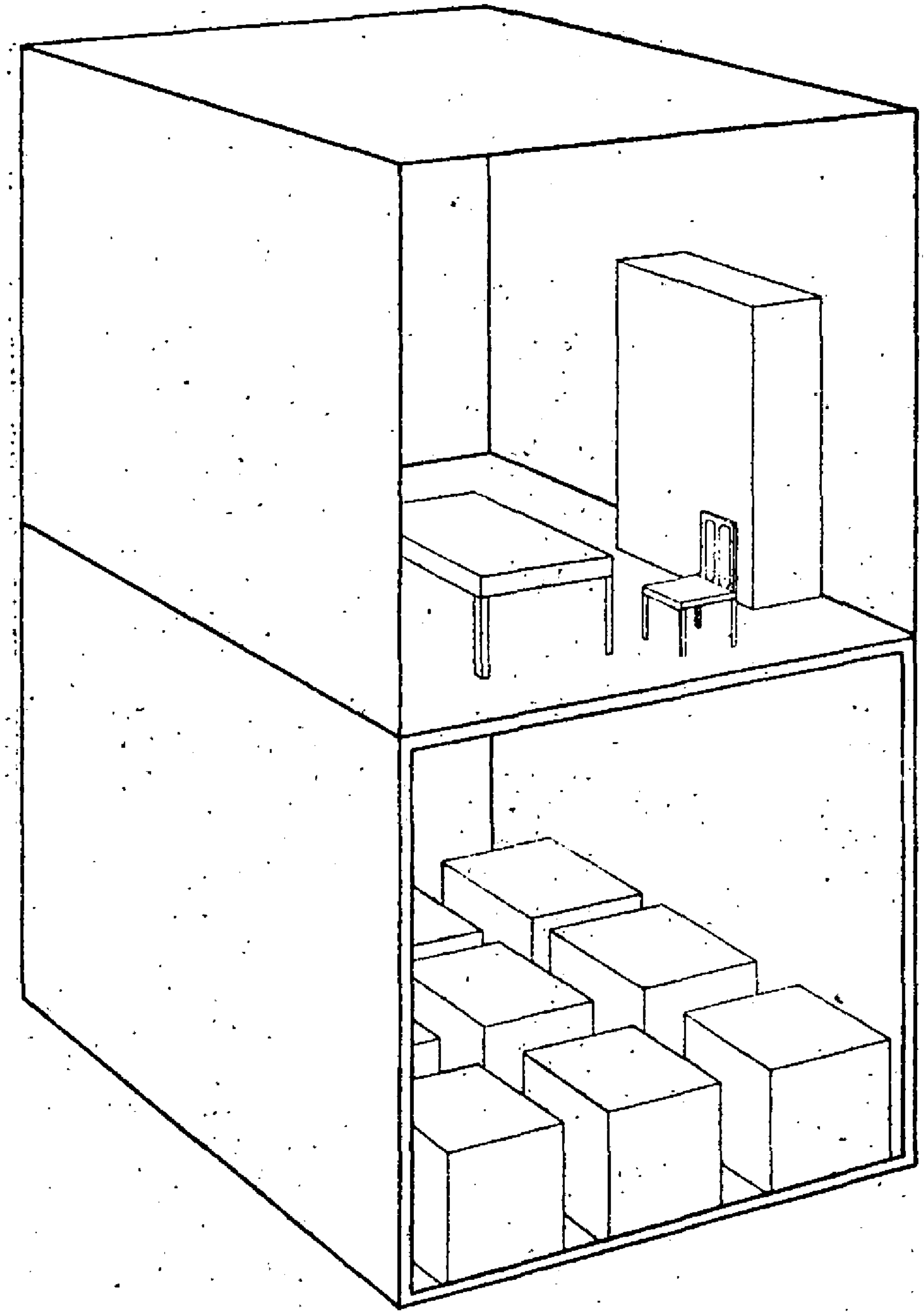

FIG. 1. ARRANGEMENT FOR TESTS IN SECTION 2

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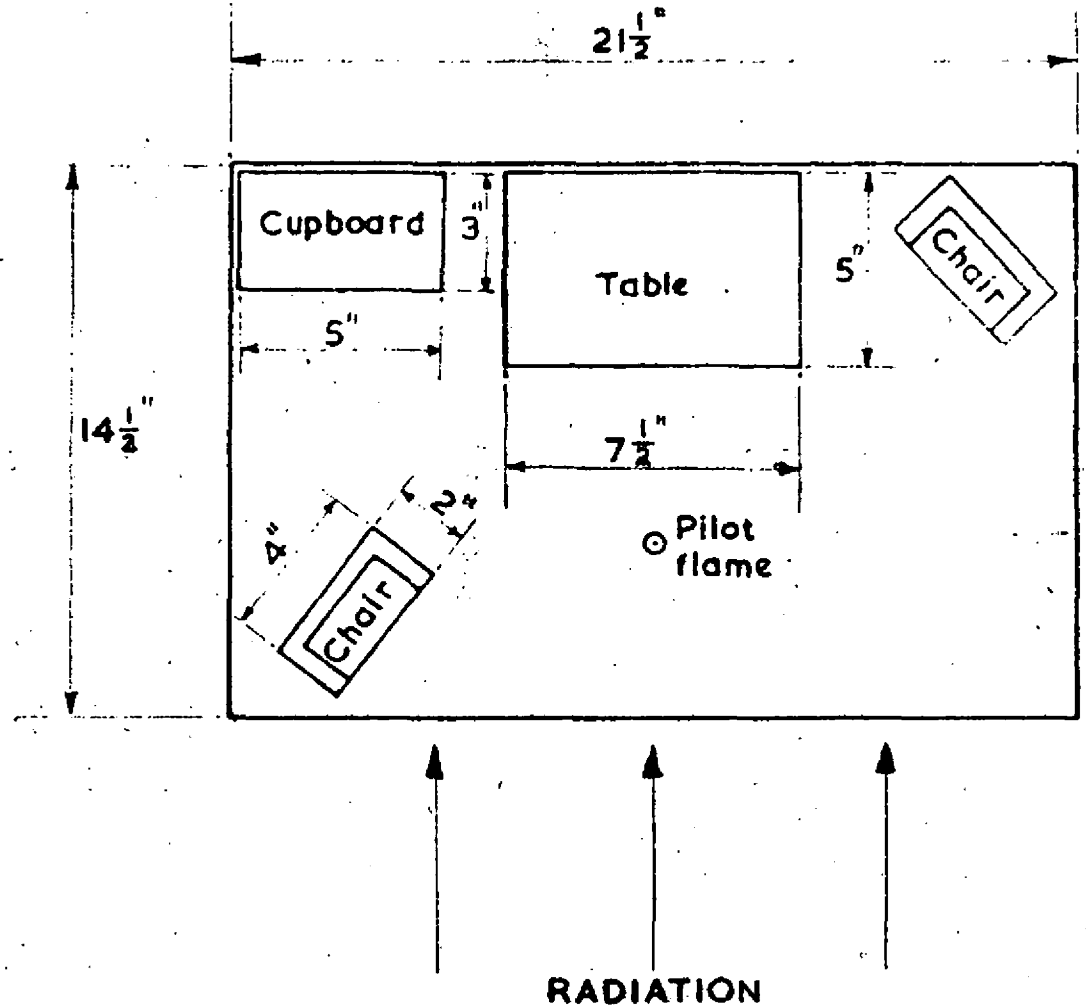
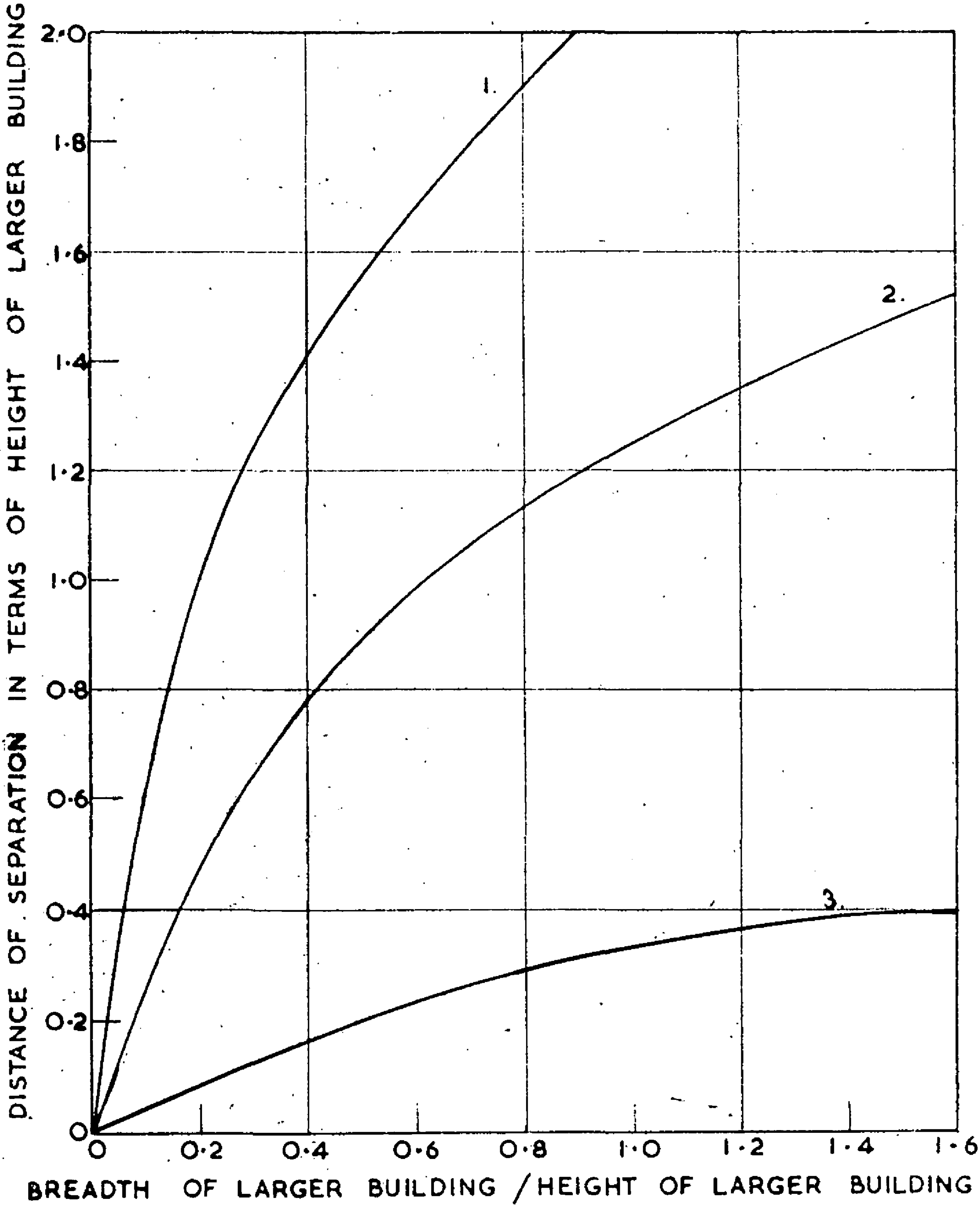


FIG. 2. DIAGRAM SHOWING ARRANGEMENT OF FURNITURE IN $\frac{1}{10}$ SCALE ROOM



1. Both buildings with 100 % window opening
2. One building with 100 % and one with 33 % window opening
3. Both buildings with 33 % window opening

FIG. 3. MINIMUM SEPARATION BETWEEN TWO BUILDINGS, WITH VARIOUS WINDOW OPENINGS, IN TERMS OF THE HEIGHT OF THE LARGER BUILDING