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FIRE LOSS INDEXES

by

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FIRE
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SUMMARY

Economic justification for expenditure on fire protection measures depends upon the expected annual monetary damage due to fire. As a crude index we could express the risk as loss per square foot of floor area or as loss per hundred pounds of value at risk. With the data available these loss indexes for manufacturing industries have been calculated and presented in this note.

The values obtained in this paper indicate, in a broad sense, the relative risks in the different industrial groups considered. If they are to be of practical value the indexes require refinement in the light of further information which may become available. It is recognised that indexes are needed for each sub sector or field of activity within an industry.

The object of this paper is to stimulate discussion on the economic level for fire protection of various industries taken as a whole rather than to deal with specific risks.

KEY WORKS: Large, fires, loss, index

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

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INTRODUCTION

Economic justification for expenditure on fire protection measures depends upon the expected annual monetary damage due to fire. The latter varies from one type of building to another, depending upon the characteristics of the building and its contents. However, for a group of buildings engaged in a particular activity it may be possible to estimate an overall figure. This figure could serve as a guide for buildings within that group.

If the estimate of annual fire loss is to serve a useful purpose it needs to be related to a common base. This could be achieved by expressing the loss as an index, e.g. as loss per square foot of floor area or per hundred pounds of value at risk. This was attempted in an earlier note[1] giving figures for the manufacturing industries as a whole and using losses in large fires only. Figures for individual industries are given in this note and it has been necessary to revise some of the overall figures in the light of further information.

TOTAL FLOOR AREA AT RISK

Estimates of total working population are published in the Annual Abstract of Statistics[2]. A survey conducted by the Building Research Station has also yielded estimates of gross floor area per person[3]. These figures are reproduced in Cols 2 and 3 of Table 1, Appendix 1. Based on these two sets of figures the total floor area (gross) in all buildings has been estimated for each industry and shown in Col.4. Figures for individual establishments may differ widely depending upon the number of shifts employed and the percentage of people employed in production activity.

TOTAL VALUE AT RISK

A recent publication by the Building Research Station[4] contains estimates of gross capital stock for different years valued at 1958 replacement cost.. Estimates have been given separately for building structures and for plant and machinery. These figures are reproduced in Table 2. Based on the trend indicated by the figures the estimated value at the end of 1966 at current prices (1966) is shown in Col.7. These figures correspond roughly to the average levels for the period 1965 to 1968. No estimates are available for capital stock in the form of consumer durables and these have been assumed to be of the same order as the value of structures. Adding these estimates together the total estimated value at risk is shown in Col.8.

LOSS INDEX

The total estimated direct losses in large fires for the period 1965 to 1968 are given in a previous note[1]. Based on these figures the average annual losses in different industries are given in Col.2 of Table 3. (These averages have not been corrected for inflation). Estimates of the total floor areas and total values at risk are given in Cols 3 and 4 and the loss per square foot of floor area and the loss per hundred pounds of value in Cols 5 and 6. As data have been collected from different sources it was not possible to group certain industries in the same manner in all the tables.

The loss per square foot in large fires ranged from 2 pence in the metal and allied industries to 5.8 pence in industries manufacturing leather etc. These two groups were also at the extremes of the range of losses per £100 of value, with losses of 9.8 pence and 25 pence respectively. The loss indexes were high also in the case of the timber and furniture industries and industries concerned with paper, printing and publishing. For manufacturing industries as a whole the loss in large fires was 3 pence per square foot or 18 pences per £100 of value at risk (excluding the textile industry).

DISCUSSION

The loss indexes given in Table 3 are for large fires. Hence, they are indicative of the situation in the £10,000 plus region. Such indexes could be useful for the purpose of planning fire protection measures for industries taken as a whole since it is necessary to prevent fires from becoming large. Of course, the costs of adopting such measures would also have to be taken into consideration in evaluating the net benefits. The loss rate of 18 pence per £100 of value is based on the average annual total direct loss in large fires which represents about 60 per cent of the total in all fires. If a correction is made to allow for the smaller losses, the average rate would be about 30 pence per £100.

It would be useful to estimate the reduction in the values of the loss indexes due to fire protection measures like sprinklers. This needs to be assessed individually for each of the industrial groups or if possible for each of the sub-groups within groups. No doubt, by stratifying the population of buildings, there is a possible gain by way of reduced variation within groups at the cost of an increase in the variation between groups. At the same time, however, the number of observations available for each stratum gets smaller, imposing a statistical limit to the number of groups. The value of fire protection at micro-economic levels could be evaluated if sufficient data became available; however, the detail is unlikely to be available in the foreseeable future.

The loss indexes estimated in this note are regarded as constants for groups of industries (as in Table 3). This may be true as a first approximation if one is interested in a group of buildings, rather than individual buildings. The indexes take into consideration the probability of fires becoming large, but not the probability of fire originating. According to Blandin[5] the frequency of fires is related to the value of risk according to the formula

$$F = K X^{\alpha} \qquad \ldots\ldots(1)$$

where F is the frequency, K and α constants depending on the nature of the risk and X the value at risk. The value of α was found to be about 0.55 for all industries taken together. It is reasonable to expect a similar relationship between the frequency of fire and the physical size of the building, since, if value is evenly distributed, size and value would be related.

It is likely that a similar power relationship exists between loss in a fire and the size of a building. For example, consider risks with a high frequency of sprinklers[6]. These are manufacturers of food, drink, tobacco, chemicals and allied products, the textile industry and industries concerned with paper, printing, furniture, timber and rubber, departmental stores, variety stores and dealers in scrap and waste materials. Considering these occupancies as one group (because of limitations on the number of observations) one can draw a graph as in Fig.1. In this figure the average large fire loss for each of several ranges of floor areas has been plotted (only those floor area groups which had five or more fires have been used). The data relate to large fires in 1965. The relationship is of the form

$$\bar{L} = K^{1} A^{\lambda} \qquad \ldots\ldots(2)$$

where $\bar{L}$ is the average loss, A the total floor area, λ a constant depending upon the presence or absence of fire protection measures like sprinklers and K^1 another constant which absorbs all the unknown initial conditions causing a fire to become large. The value of λ appears to be about 0.58 for sprinklered buildings and 0.66 for non-sprinklered buildings in the same industrial categories as those for sprinklered buildings.

Figure 1 has been introduced in this paper purely for purposes of illustration. The values of λ are at present no more than tentative. In about 50 per cent of the cases sprinklers either did not operate or they operated but did not control the fire. The main reasons in these cases were either that the system was shut off for maintenance or repairs, or that the fires originated in non-sprinklered portions of the building. A sprinklered building is perhaps likely to have a higher value at risk per square foot than a non-sprinklered building. In spite of these factors contributing to the losses the graph shows a considerable gain attributable to sprinklers, and this would be likely to be larger if all factors were taken into consideration. It is hoped to improve the precision of these estimates for λ when sufficient data become available for each industrial group.

The frequency of fires and the expected loss in a fire appear to depend upon the size of the building and the value at risk in the building and its contents. The sizes of buildings involved in fires are indicated in the fire reports, but no information is available on the frequency distribution of buildings at risk according to size and value. With these links missing, any assessment of the economic value of fire protection measures must be inconclusive. In order to collect the required statistics it is necessary to conduct special surveys. One such survey has already been initiated in the case of manufacturers engaged in spinning, doubling and weaving of manmade fibres and in the textile finishing trade. A sample of firms has been requested to furnish information in the form shown in Appendix 2. Data collected so far are being analysed.

If the value of the constants in expressions (1) and (2) are obtained for a given section of an industry the expected annual loss L_y due to large fires in any building (of given value X and size A) in that section could be written as

$$L_y = PKK^1 \; X^{\alpha} \; A^{\lambda} \qquad \ldots\ldots(3)$$

where P is the probability of the fire becoming large. Since the value at risk in the building is X spread over an area A the average value per square foot in the building is $v = \frac{X}{A}$. We can rewrite (3) as

$$L_y = PKK^1 v^{\alpha} A^{\lambda+\alpha}$$

$$= CA^{\lambda+\alpha} \qquad \ldots\ldots(4)$$

where $C = PKK^1 v^{\alpha}$.

From (4) we have

$$R_1 = \frac{L_y}{A} = CA^{\lambda+\alpha-1} \qquad \ldots\ldots(5)$$

in which R_1 is the annual loss per unit area.

If $(\lambda+\alpha-1)$ were close to zero as indicated by the overall values of λ and α and could be neglected, R_1 would be strongly dependent upon the value of C which involves v, a factor varying from building to building even within a section of the industry. If $\bar{v}$ is the average value at risk per square foot in the industry as a whole (Col.7 of Table 3) and $\bar{R}_1$ the macro value of the index (Col.5 of Table 3) it may be easily verified that

$$\frac{R_1}{\bar{R}_1} = \left(\frac{v}{\bar{v}}\right)^{\alpha} \text{ or}$$

$$R_1 = \bar{R}_1 \left(\frac{v}{\bar{v}}\right)^{\alpha} \qquad \ldots\ldots(6)$$

Expression (6) could be used for calculating a crude estimate of the loss index for a particular building.

We can write from (5)

$$R_2 = \frac{L_y}{X} = PKK^1 \ v^{\alpha-1} \ A^{\lambda+\alpha-1} \qquad \ldots\ldots(7)$$

The annual loss per unit value at risk (R_2) (again neglecting $\lambda+\alpha-1$) is thus proportional to $v^{\alpha-1}$.

Since α is less than unity

$$R_2 \propto v^{-\beta} \ (\beta = 1 - \alpha) \qquad \ldots\ldots(8)$$

where β is a positive fraction. Following (6) we can write

$$R_2 = \bar{R}_2 \left(\frac{v}{\bar{v}}\right)^{-\beta} \qquad \ldots\ldots(9)$$

R_2 is smaller than the macro value $\overline{R}_2$ for $v > \overline{v}$ and greater value than $\overline{R}_2$ for $v < \overline{v}$. This apparent paradox arises from the probability that a fire in a large building is more likely than one in a single room or a small building to be discovered and extinguished before involving the whole building. The proportion destroyed in a small building would therefore be expected to be greater than the proportion destroyed in a large building.

If further information were available it would be possible to improve the values of $\overline{R}_1$, $\overline{R}_2$, $\overline{v}$ and α and obtain their standard errors. With such estimates of the parameters, R_1 and R_2 could be calculated with more precision. It is also necessary to check whether, for individual industries $(\lambda + \alpha - 1)$ is sufficiently close to zero to ignore the dependence on the size of the building.

An estimate of $\overline{v}$ for each industrial group is given in the last column of Table 3. These estimates are all that is possible at present although it is recognised that the group covered by each is too broad for them to be of immediate practical value. The next step is to obtain the values of $\overline{v}$, λ and α for each industry or sub-section of the industry and separately for sprinklered and non-sprinklered buildings. As already mentioned, it is necessary to conduct special surveys for a complete economic assessment.

In the absence of fire fighting of any kind (free burning fire), in the deterministic sense (as distinct from stochastic) most of the value at risk would be destroyed in a large fire so that the value of λ would be close to unity. At the worst λ would be equal to unity which would correspond to the complete destruction of the property. It is not possible for λ to be greater than unity. Normal fire fighting by the brigades appears to have reduced the value of λ to 0.66 for buildings without sprinkler protection in the industries considered in the paper. With sprinklers the value of the constant is likely to be reduced further to say 0.58. The theoretical value $\lambda = 0$ would correspond to a situation in which there were no large fires whatever the size of the building.

In equation (1) α is an index reflecting the annual frequency of fires for a given size or value of building and if α were unity the frequency would be proportional to area. A value greater than unity implies that if X or A is doubled the chance of a fire increases by a factor of more than 2. This would be expected for some conditions since in reality the quantity at risk is proportional to the volume. Using volume instead of area, the maximum value of α would become $3/2$ if the risk of fire originating were the same in all parts of the building. But usually in a factory building sources of ignition, materials stored and such factors vary depending upon the usage of the floor space for production, storage or office purposes. It is likely that α is less than unity as indicated by the overall figure of 0.55 obtained by Blandin for industries in France.

In view of the theoretical possibility that both λ and α are less than unity, the exponent for A in (5) or (7) is likely to be a fractional power. As indicated by the overall figures of λ and α the power could be even closer to zero so that dependence of the indexes on the size of the building could be ignored. But dependence on the value density of the building and contents (v) appears to be strong.

CONCLUSION

As a crude index of fire risk we could express the annual loss relative to a base like total floor area or value at risk. An estimate of the index for a given industry group may be obtained by dividing the total annual loss in buildings of that group by the total area or value in all the buildings at risk in the group. From available data it appears that the annual direct loss per square foot in large fires ranged from 2 pence in metal and allied industries to 5.8 pence in industries manufacturing leather etc. The annual losses per £100 of value ranged from 9.8 pence to 25 pence in the same two industries respectively. In the economic grouping used by the Central Statistical Office the group headed by leather includes fur which is costly, and tanneries in which the frequency is high. The frequency of large fires is also quite high in this group[7]. It may be worthwhile to study the causes leading to such high losses in the industry, though this is beyond the scope of this paper. The loss indexes were high in the case of the timber and furniture industries and industries concerned with paper, printing and publishing. They were also higher than might be expected in the bricks, pottery and glass group; this industry has a high fire risk associated with packing materials. It should be emphasised that the figures quoted in this paper have been based only on such statistics as were available to the author. They were necessarily incomplete and should not therefore be used to derive insurance rates.

For individual buildings there are strong reasons to believe that the (annual) loss indexes depend more on the value at risk than the size of the building.

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APPENDIX 1

Table 1

Total floor area at risk

Industry	Total working population, 1966 (000)	Gross floor area per person (sq. ft)	Total estimated gross floor area at risk (sq.ft million)
(1)	(2)	(3)	(4)
Food, drink, tobacco	841	286	241
Chemicals and allied industries	528	410	216
Metal manufacture	619	339	210
Engineering and electrical goods	2337	252	643
Ship building and marine engineering	214		
Other metal goods	596	258	154
Vehicles	861	251	216
Textiles	810	336	272
Leather, leather goods, fur	60	87	5
Clothing and footwear	552	164	91
Bricks, pottery, etc.	352	204	72
Timber, furniture, etc.	296	272	81
Paper, printing and publishing	648	265	172
Total*	8714	-	2373

*Excludes other miscellaneous industries.

Table 2

Total value at risk

Gross capital stock at 1958 replacement cost						(£ thousand million)	
Industry	1961	1962	1963	1964	1965	Estimated value of fixed assets at the end of 1966 (1966 prices)	Estimated total value at risk at the end of 1966 (1966 prices)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Food, drink, tobacco							
Plant and machinery	1.03	1.08	1.12	1.18	1.23	1.64	4.80
Building	1.02	1.06	1.11	1.15	1.20	1.58	
Chemicals and allied industries							
Plant and machinery	2.15	2.26	2.35	2.45	2.56	3.41	6.25
Building	0.92	0.96	0.99	1.03	1.07	1.42	
Iron and steel							
Plant and machinery	1.61	1.73	1.79	1.87	1.96	2.66	4.66
Building	0.70	0.73	0.74	0.76	0.77	1.00	
Other metals, engineering and allied industries							
Plant and machinery	4.97	5.14	5.31	5.43	5.60	7.37	15.35
Building	2.67	2.76	2.86	2.94	3.03	3.99	
Bricks, pottery, glass, cement etc							
Plant and machinery	0.38	0.41	0.44	0.47	0.50	0.69	1.55
Building	0.26	0.28	0.29	0.31	0.32	0.43	
Timber, furniture and construction							
Plant and machinery	0.53	0.56	0.60	0.64	0.68	0.93	2.07
Building	0.38	0.39	0.40	0.42	0.43	0.57	
Paper, printing, publishing							
Plant and machinery	0.89	0.92	0.95	0.99	1.01	1.32	2.86
Building	0.49	0.51	0.53	0.55	0.58	0.77	
Leather, clothing and other manufacturing industries							
Plant and machinery	0.49	0.50	0.52	0.54	0.57	0.76	2.20
Building	0.51	0.52	0.53	0.54	0.55	0.72	
Total*							
Plant and machinery	12.05	12.60	13.08	13.57	14.11	18.78	39.74
Building	6.95	7.21	7.45	7.70	7.95	10.48	

*Excludes textiles

Table 3

Loss indexes (large fires)

Industry	Average annual loss in large fires (£ thousands)	Total estimated gross floor area at risk (sq. ft million)	Total value at risk (£ thousand million)	Annual loss per sq.ft of floor area R_1 (pence)	Annual loss per £100 of value at risk R_2 (pence)	Value at risk per sq.ft of floor area $\bar{\bar{v}}$ (£)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Food, drink, tobaccos	2715	241	4.80	2.7	13.6	19.9
Chemicals and allied industries	3383	216	6.25	3.8	13.0	28.9
Metal manufacture, engineering, electrical goods, ship building marine engineering and other metal goods	8201	1007	20.01	2.0	9.8	19.9
Vehicles	2109	216	N.A.	2.3	N.A.	N.A.
Textiles	5217	272	N.A.	4.6	N.A.	N.A.
Leather, leather goods, fur clothing and footwear	2315	96	2.20***	5.8	25.3	22.9***
Bricks, pottery etc.	1153	72	1.55	3.8	17.9	21.5
Timber, furniture etc.	1834	81	2.07	5.4	21.3	25.6
Paper, printing, publishing	2886	172	2.86	4.0	24.2	16.6
Overall	33340 (30149*) (28913**)	2373*	39.74**	3.0*	17.5**	18.9**

*Excludes "other manufacturing industries" but includes "textiles"

**Excludes "textiles" but includes "other manufacturing industries"

***Includes "other manufacturing industries"

N.A. Not available

APPENDIX 2

SURVEY ON COSTS AND BENEFITS OF FIRE PROTECTION MEASURES IN INDUSTRIAL BUILDINGS

FORM 1

This form is intended to be a preliminary enquiry providing information on the sizes, ages etc, of industrial establishments at risk. Of the buildings referred to in this form one (or more if necessary) will be selected for subsequent survey(s) of the fire protection systems and methods in use.

1. Name of the firm:

2. Full postal address:

3. Trade(s) carried on:

4. Employment:

Total number employed

Male	Female

of which

number employed on production activity

Male	Female

5. Number of shifts employed:

6. Number of production units:

   Spindles ....

   Looms ....

7. (a) Total value of all the buildings (estimated) £ as on

   (b) Total value of all the contents (estimated) £ as on

8. Total floor area of all the buildings sq.ft of which

   area utilised for production sq.ft and

   area utilised for storage sq.ft.

9. (a) Number of fires in which the buildings were involved so far:

(b) Total estimated loss in all the fires £

10. For each separate building the following information should be provided:

Serial No. of the building	1	2	3	4	5
Particulars of the building					
Age (years)					
No. of storeys					
Total floor area (sq.ft)					
Floor area utilised for production (sq.ft)					
Floor area utilised for storage (sq.ft)					

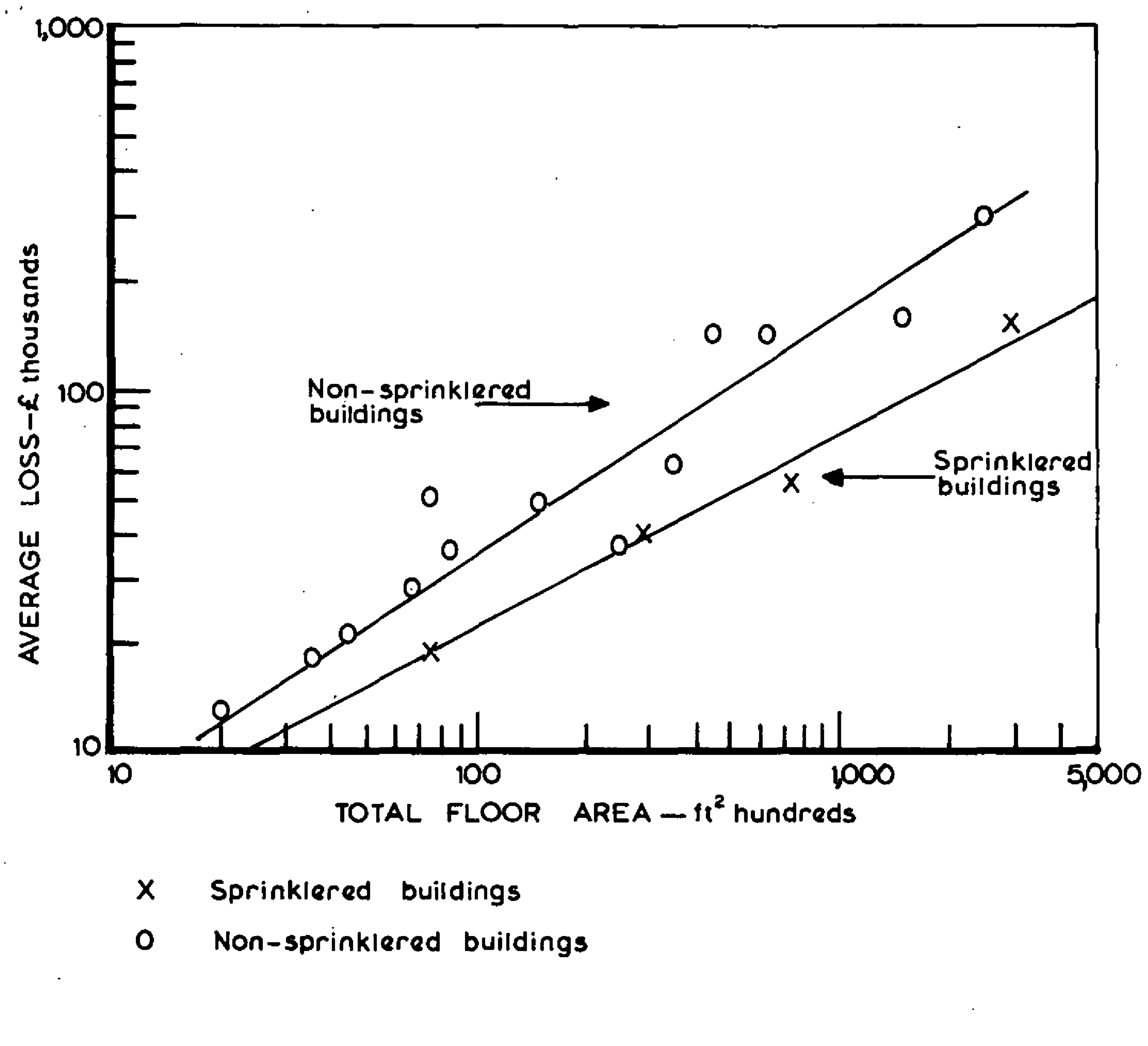

FIG. 1. LARGE FIRES IN SPRINKLERED AND NON-SPRINKLERED BUILDINGS 1965
TOTAL FLOOR AREA AND LOSS