

LIBRARY REFERENCE ONLY



Fire Research Note No. 915

THE USE OF FIRE EXTINGUISHERS IN
DWELLINGS

by

G. RAMACHANDRAN, P. NASH and MISS S. P. BENSON

January 1972

FIRE
RESEARCH
STATION

**Fire Research Station,
Borehamwood,
Herts.
Tel. 01-953 6177**

THE USE OF FIRE EXTINGUISHERS IN DWELLINGS

by

G.Ramachandran, P.Nash and Miss S.P.Benson

SUMMARY

A measure of the effectiveness of the use of extinguishers in dwellings by the occupants is obtained by comparing the performance of extinguishers with other 'first-aid' methods in common use. Official Fire Brigade Reports have been used to provide data and the measure has been made in terms of the proportion of fires put out by the use of the different methods and the average time taken by the brigades to control those fires that were not put out. It is appreciated that it was not possible to include many small fires which were neither attended by fire brigades nor reported to the organisation but it is considered that the fires attended by the brigades are likely to give a representative cross section of experience with this limitation. The analysis shows that when the occupants attack a fire before the brigade arrives the severity of the fire is reduced. In general however, they are less successful with extinguishers than with other first aid methods. There are however, indications of substantial differences between different types of extinguisher, and also between different types of other first aid methods such as to suggest that an overlap of effectiveness might exist.

KEY WORDS: Fires, dwellings, extinguishers.

Crown copyright

This report has not been published and should be considered as confidential advance information. No reference should be made to it in any publication without the written consent of the Director of Fire Research.

THE USE OF FIRE EXTINGUISHERS IN DWELLINGS

by

G.Ramachandran, P.Nash and Miss S.P.Benson

INTRODUCTION

The official fire brigade reports on fires in dwellings give data on the various methods of initial attack on the fires by the occupants and the number of fires extinguished by them before the arrival of the brigade. The reports also indicate the time taken by the brigade to control fires fought by them, the 'control time' being the period between the arrival of the brigade at the scene of the fire and the time when it is estimated that the fire is surrounded or under control so that there is no need for further supplies of fire fighting equipment. There is therefore the possibility that these data could give a measure of the effectiveness of the means used in extinguishing the fire or in shortening its subsequent duration. An assumption has been made that the fires attacked were a representative cross section of all the fires occurring in dwellings, that is, no special selection process took place in deciding whether or not to attack the fires. This may not be entirely correct since a householder may, for example, be more inclined to tackle a fire in an arm-chair than one in a fat pan.

FIRES EXTINGUISHED BY OCCUPANTS

Table 1, Appendix 1, gives the number of fires attacked by the occupants of dwellings before the arrival of the brigade and shows the different methods used, the number extinguished by them, and the percentage extinguished. The table also includes figures for fires in which no initial attack was made. The figures relate to the year 1969.

In about 52.6 per cent of the fires there was no initial attack at all by the occupants. Of these fires, only about 1.9 per cent were out before arrival of the brigade. Using some form of initial attack, the occupants were able to extinguish a considerable proportion (42 per cent) of fires.

About 44.3 per cent of all of the fires were attacked by 'sundry means', 2.9 per cent by extinguishers and a negligible percentage (0.2) by various other means eg hose reels, jets, etc.

About 6 per cent of households interviewed in connection with a fire prevention campaign said that they owned fire extinguishers¹. About 50 per cent of these extinguishers were located in the dwellings and the rest in cars or garages. Hence the proportion of fires in dwellings attacked by extinguishers

was almost equal to the proportion of dwellings equipped with extinguishers. If it is assumed that extinguishers in houses are readily available when required, it appears, therefore, that the probability of a fire starting in a dwelling does not depend upon the existence or otherwise of an extinguisher. In other words, occupants of dwellings with extinguishers (who might be regarded as more 'fire conscious' than others) are no less likely to experience a fire than those in residences without such appliances.

Occupants were able to put out 43 per cent of the fires tackled by sundry means, but only 27.5 per cent of those in which extinguishers were used. The difference between the two percentages has been judged to be highly significant according to the test described in Appendix 2. Individual percentages for sundry means ranged from 17 for garden hose to 70 for combinations of two or more of these methods. For extinguishers, the percentage of fires put out varied from 13 when more than one extinguisher was used to 45 for those with carbon dioxide.

An application of the significance test to the individual percentages in Table 1 would be a tedious process since there would be a standard error for the difference between the percentages of each of the pairs of methods. In addition the test would not take into consideration the differences in the relative performances of all the methods in the particular year used as a sample. For these reasons an analysis of variance test was conducted on the individual percentages. This test also is described in Appendix 2. The test assumes that the internal sampling error did not vary from one method to another though this was not strictly true in view of the variation in the number of fires attacked by each method. The analysis of variance (Appendix 2) also revealed that the variation between the three groups was highly significant. If sundry means are regarded as standard methods in view of their simplicity, extinguishers as a whole are likely to be less effective in putting out fires in dwellings.

The upper confidence limit is the statistic that really matters in regard to individual percentages. This is given by expression (4) in Appendix 2. For example, the upper and lower 95 per cent confidence limits for the proportion 0.45 extinguished by carbon dioxide extinguishers were 0.74 and 0.16. This implies that the performance of this type of extinguisher was not significantly different from the performance of any sundry means. A similar calculation shows that dry powder extinguishers are within the range of effectiveness of most of the sundry means.

FIRES FOUGHT BY BRIGADES

The figures for 1969 showing the times to control fires in dwellings fought by fire brigades after initial attack by the occupants are shown in Table 2 in Appendix 1. These were fires which the occupants failed to extinguish. Also shown in the table are control times for fires in which no initial attack was made.

Two sets of graphs were drawn from these data: Figure 1 shows the cumulative number of fires controlled by the fire brigades in a time less than t , plotted against t for each of the categories 1.1, 1.2, 2, 3 and 4 shown in Table 2. These data are also shown in Fig 2 in which they are expressed as percentages of the total number of fires in the given time range above zero.

The effectiveness of a particular method of attack is indicated by a fall in the number of fires in the appropriate category expressed as a percentage of the total number of fires, which reach longer durations before fire brigade control. From Fig 2 it can be seen that the percentage of fires in which an initial attack was made by the occupant falls from 42.2 per cent (control in 4 minutes or less) to 36.8 per cent (control in 24 minutes or less). The percentage where no initial attack was made rises from 57.8 per cent (control in 4 minutes or less) to 63.2 per cent (control in 24 minutes or less). Sundry means (for which the proportion decreases from 40 per cent to 36 per cent) are seen to be more effective than extinguishers for which the proportion remains constant at about 3 per cent.

Table 3, Appendix 1, gives the comparable results for fires attacked by 'sundry means', 'extinguishers' and 'various other means', as defined in categories 1-1, 1-2, and 1-3 of Table 2. The ratio A/B where

A = percentage of fires controlled in 4 minutes or less and

B = percentage of fires controlled in 24 minutes or less

is a measure of the effectiveness of the method of attack, the higher the ratio the more effective the method. Hence it will be seen that an initial attack by the occupier (by whatever means) is advantageous in restricting the subsequent duration of the fire. Of the means of attack used, 'sundry means' were the most effective, followed by 'various other means' and 'extinguishers' in that order.

Table 4, Appendix 1, shows the average time taken by fire brigades to control fires which occupants failed to extinguish. Here again some form of initial attack was better than no initial attack at all in reducing the subsequent duration of fire. The control time for fires initially attacked by 'extinguishers' was higher than that for 'sundry means' but it is technically difficult to judge the significance or otherwise of the difference between the two mean control times. This depends upon the probability distribution of control times which does not appear to be normal or even log normal. The mean

control time for 'other means' was the longest.

DISCUSSION

The percentages of fires extinguished by the occupants in the year 1969 were 21.4 for all buildings², 20.7 for dwellings and 21.7 for buildings other than dwellings. The difference between the last two percentages is not statistically significant. Hence, in the early stages of growth, a fire in a dwelling does not appear to be less severe than a fire in a building other than a dwelling. Problems of early fire fighting are equally difficult in both the occupancies. Of course, among non-dwellings, industrial buildings could be of a different nature in regard to fire risk.

Occupants of dwellings generally suffer from lack of training or knowledge in fire fighting methods. With a frequency of 27 per cent, cooking appliances are the leading sources of ignition of fires in dwellings. Often, these fires are not handled efficiently³. An extinguisher, if available, may be located at a considerable distance from the place of origin of the fire resulting in a delay in its use at the time of a fire. The use of an extinguisher also requires some training. All these factors may affect the performance of an extinguisher with the result that simpler methods, ie, sundry means, give better results. Availability of more than one extinguisher in a dwelling could cause some confusion which might result in the low efficiency indicated in Table 1. It is, however, unlikely that a second extinguisher would be used unless the first had been unsuccessful and these fires are likely to be too large for the extinguishers.

On the whole extinguishers may not be as effective as sundry means for dealing with fires in dwellings but there may be exceptions among them. There was no significant difference between carbon dioxide and any sundry means in putting out fires. Dry powder extinguishers were also not significantly less effective than most of the sundry means. The mean control time for fires initially attacked by this type of extinguisher was less than the mean for fires attacked by sundry means. The mean for carbon dioxide extinguishers might have fallen just within or outside the confidence limits for the mean of sundry means but this could be judged only by further research into the statistical properties of the control times. The mean control times were also low for extinguishers with carbon tetrachloride and 'other vaporizing liquids'.

The number of observations available for assessing the effectiveness of 'other means' of initial attack was very small. For extinguishers, the sample size was large but still much smaller than the size for sundry means. Conclusions about individual types of extinguishers are less secure since they are based on small samples.

CONCLUSIONS

In about 47.4 per cent of fires in dwellings attended by brigades, an initial attack is made on the fires by the occupants. In 44.3 per cent of these cases, the fire is attacked by 'sundry means', in about 2.9 per cent with some form of extinguisher and in about 0.2 per cent-with various 'other means'. According to the results of a fire prevention campaign only about 3 per cent of the households have extinguishers located on their premises. Hence the probability of a fire starting in a dwelling and requiring a call to the brigade does not appear to depend upon the existence or otherwise of an extinguisher.

Compared with 'no attack', all methods of initial attack show some advantage either in extinguishing the fire before the arrival of the brigade or in reducing the time taken by the brigade to control it.

'Sundry means' appear to be the most effective of methods to deal with fires in dwellings. Generally speaking, extinguishers are not so effective. This may be partly due to lack of training in the use of extinguishers but it is also possible that the appliances are located at a considerable distance from the place of origin of the fire or that they are too small to deal with the fires. However, carbon dioxide and dry powder extinguishers may be within the range of effectiveness of 'sundry means'.

The numbers of observations available for analysing the performance of individual extinguishers and 'other means' were small. Hence the conclusions drawn in this paper about these specific methods of initial attack should be regarded as tentative.

REFERENCES

1. CHAMBERS, E.D. and JESSOP, Carolyn M. Fire extinguishers in private dwellings. Department of the Environment and Fire Offices' Committee Joint Fire Research Organization. F.R.Note No.904.
2. United Kingdom Fire and Loss Statistics, 1969. H.M.Stationery Office.
3. CHAMBERS, E.D. Behaviour when faced with fat pan fires. Ministry of Technology and Fire Offices' Committee Joint Fire Research Organization. F.R.Note No. 654

APPENDIX 1

Table 1 Fires extinguished by occupants

	Method of attack	Number of fires attacked	Number of fires extinguished	Percentage extinguished
1.1	Initial attack made by sundry means as follows:			
	Buckets	7,998	2,752	34
	Smothering	2,386	1,218	51
	Garden hose	902	154	17
	Sand, earth etc.	384	194	51
	Immersion	204	108	53
	Beating	172	118	68
	Stirrup pumps	22	10	45
	Other small means	2,496	1,192	48
	Two or more of above	736	516	70
	Removal	5,038	2,488	49
	All sundry means	20,338	8,750	43
1.2	Initial attack made by extinguishers of the following type:			
	Dry powder	412	142	34
	Water	356	68	19
	Carbon Tetrachloride	158	46	29
	Foam	84	26	31
	Other vaporizing liquids	70	12	17
	Carbon Dioxide	58	26	45
	More than one extinguisher	46	6	13
	Extinguisher + sundry means	134	36	27
	All extinguishers	1,318	362	27
1.3	Initial attack made by various other means, eg hose reels jets etc.	68	12	18
2.	All fires with initial attack	21,724	9,124	42
3.	All fires with no initial attack	24,152	454	1.9
4.	All fires	45,876	9,578	21

Table 2 - Fires attacked by different means - Distribution of control times

		Number of fires controlled in time interval						
		1-4	5-9	10-14	15-19	20-24	25-99+	Total
	Time to control fire, t, (min)							
1.1	Initial attack made by sundry means as follows:							
	Buckets	2,790	1,674	426	152	66	138	5,246
	Smothering	718	350	62	22	6	10	1,168
	Garden hose	254	234	118	48	22	72	748
	Sand, earth etc	126	56	2	4	2	0	190
	Immersion	56	32	4	2	0	2	96
	Beating	38	12	4	0	0	0	54
	Stirrup pumps	2	4	2	2	0	2	12
	Other small means	742	360	114	34	22	32	1,304
	Two or more of above	136	58	14	2	2	8	220
	Removal	1,594	712	152	34	14	44	2,550
	Totals	6,456	3,492	898	300	134	308	11,588
1.2	Initial attack made by extinguishers of the following type:							
	Dry powder	154	76	22	8	6	4	270
	Water	108	100	38	8	12	22	288
	Carbon Tetrachloride	46	46	8	6	2	4	112
	Foam	24	18	10	2	0	4	58
	Other vapourizing liquids	24	22	8	0	0	4	58
	Carbon Dioxide	12	12	2	0	2	4	32
	More than one extinguisher	10	14	2	2	2	10	40
	Extinguisher + sundry means	36	36	16	0	2	8	98
	Totals	414	324	106	26	26	60	956

Table 2 (cont'd)

		Number of fires controlled in time interval						
		1-4	5-9	10-14	15-19	20-24	25-99+	Total
	Time to control fire, t, (min)							
1.3	Initial attack made by various other means, e.g. hose reels, jets etc.	18	14	6	0	2	16	56
2.	All fires with initial attack	6,888	3,830	1,010	326	162	384	12,600
3.	All fires with no initial attack	9,416	7,890	2,844	1,280	742	1,526	23,698
4.	All fires	16,304	11,720	3,854	1,606	904	1,910	36,298

Table 3

Comparison of fires controlled in 4 min
or less with those controlled in 24 min or less

	Method	A 4 min or less (percentage)	B 24 min or less (percentage)	Ratio A/B
2	Initial attack made by occupant	42.2	35.5	1.19
3	No initial attack by occupant	57.8	64.5	0.90
1.1	Initial attack by sundry means	39.6	32.8	1.21
1.2	Initial attack by fire extinguishers	2.5	2.6	0.96
1.3	Initial attack by various other means	0.1	0.1	1.00

Table 4

Mean control time

	Method of attack	Mean control time (minutes)
1.1	Initial attack by sundry means	
	Buckets	6.5
	Smothering	5.3
	Garden hose	11.3
	Sand, earth etc.	4.4
	Immersion	7.1
	Beating	4.2
	Stirrup pumps	22.1
	Other small means	7.0
	Two or more of above	7.9
	Removal	5.3
	All sundry means	6.5
1.2	Initial attack by extinguishers	
	Dry powder	6.1
	Water	10.2
	Carbon tetrachloride	7.2
	Foam	12.1
	Other vaporizing liquids	7.7
	Carbon dioxide	10.3
	More than one extinguisher	16.0
	Extinguisher + sundry means	10.0
	All extinguishers	8.9
1.3	Initial attack by other means	15.9
2	All fires with initial attack	6.7
3	All fires with no initial attack	9.0
4	All fires	8.2

Appendix 2

Significance test for proportions

Out of n observations let p be the proportion having a given attribute. According to wellknown results in statistical theory p is normally distributed with a standard error $\sqrt{p(1-p)/n}$, if n is large and p is not too close to 0 or 1. If p_1 and p_2 are two proportions from two different populations of large observations n_1 and n_2 , the variance of the difference ($p_1 - p_2$) is

$$v_d^2 = \frac{p_1 q_1}{n_1} + \frac{p_2 q_2}{n_2}$$

where $q_1 = 1 - p_1$ and $q_2 = 1 - p_2$. Hence

$$t = \frac{p_1 - p_2}{v_d}$$

is normally distributed. The difference ($p_1 - p_2$) is significant at 5 per cent level if $t > 1.96$ and highly significant (1 per cent level) if $t > 2.58$. For the problem considered in the text.

$$p_1 = 0.430$$

$$p_2 = 0.275$$

n_1 = No. of fires attacked by sundry means = 20,338 and

n_2 = No. of fires attacked by extinguishers = 1,318

Analysis of Variance

In the case where the observation is a proportion p it is better to perform the analysis of variance on the value obtained by the transformation¹

$$\theta = \sin^{-1} \sqrt{p} \quad \dots(1)$$

With the 19 values for θ corresponding to the 20 methods of attack the following results were obtained.

Analysis of Variance Table for θ

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	'F' value
Between the three groups (1.1, 1.2 and 1.3 in Table 1)	2	948.00	474.00	6.95
Within groups (error)	16	1091.80	68.24	
Total	18	2039.80		

'F' value was significant at 0.01 level. The random error was 8.26 ($= \sqrt{68.24}$). If p_0 is the proportion of fires extinguished by a particular method, the upper confidence limit of

$$\theta_0 = \sin^{-1} \sqrt{p_0} \quad \dots(2)$$

is

$$\theta_{uo} = \theta_0 + t\sigma \quad \dots(3)$$

where

t = the 't' distribution value for 16 degrees of freedom for the chosen level of significance and

$$\sigma = 8.26$$

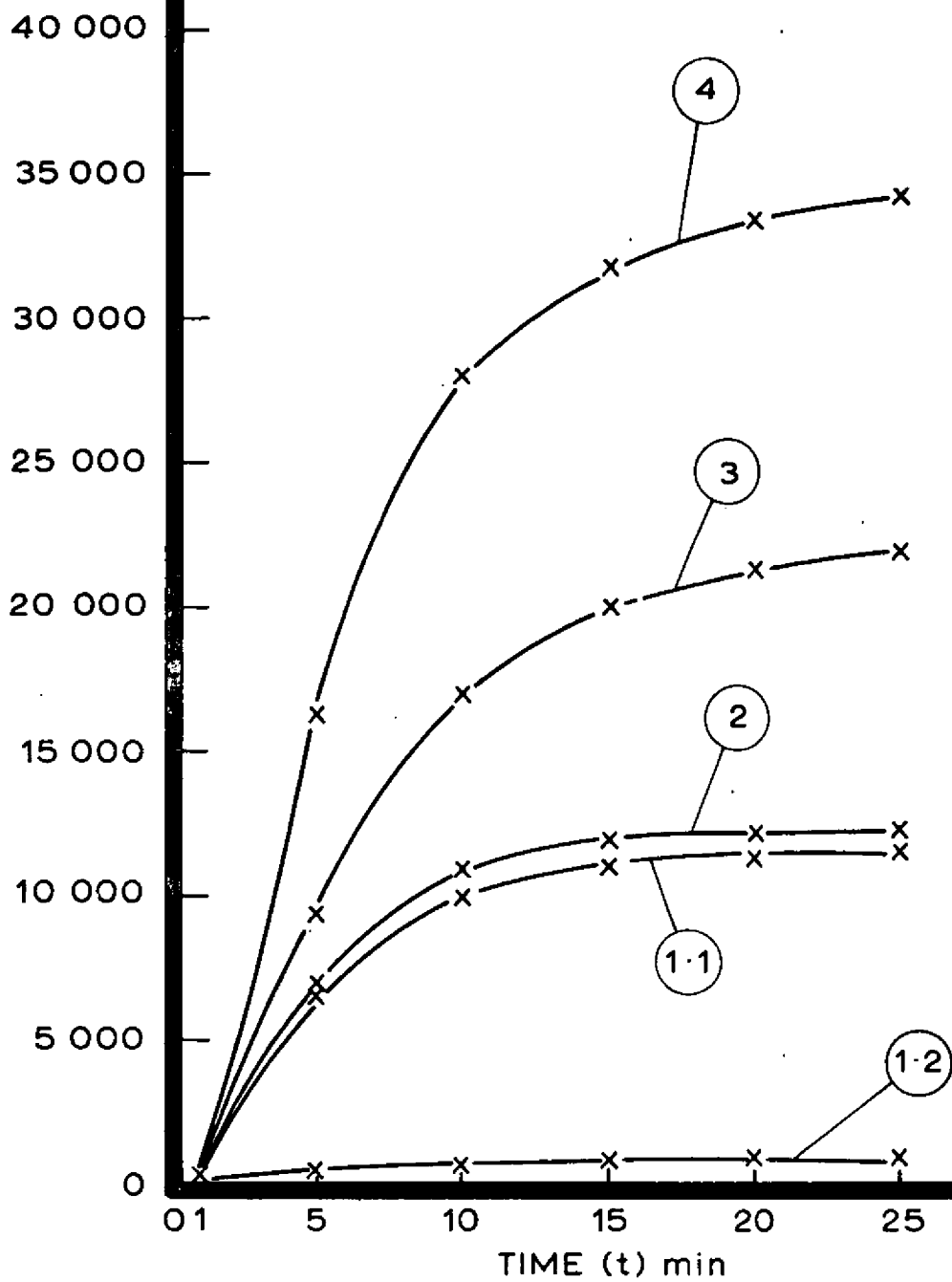
Hence the upper confidence limit for p_0 , from (1), (2) and (3) is

$$\begin{aligned} p_{uo} &= \sin^2 \theta_{uo} \\ &= \sin^2 \left\{ \sin^{-1} \sqrt{p_0} + t\sigma \right\} \quad \dots(4) \end{aligned}$$

Reference:

1. EISENHART, C Inverse Sine Transformation of Proportions. Chapter 16, Selected Techniques of Statistical Analysis, Statistical Research Group, Columbia University, McGrawhill, 1947

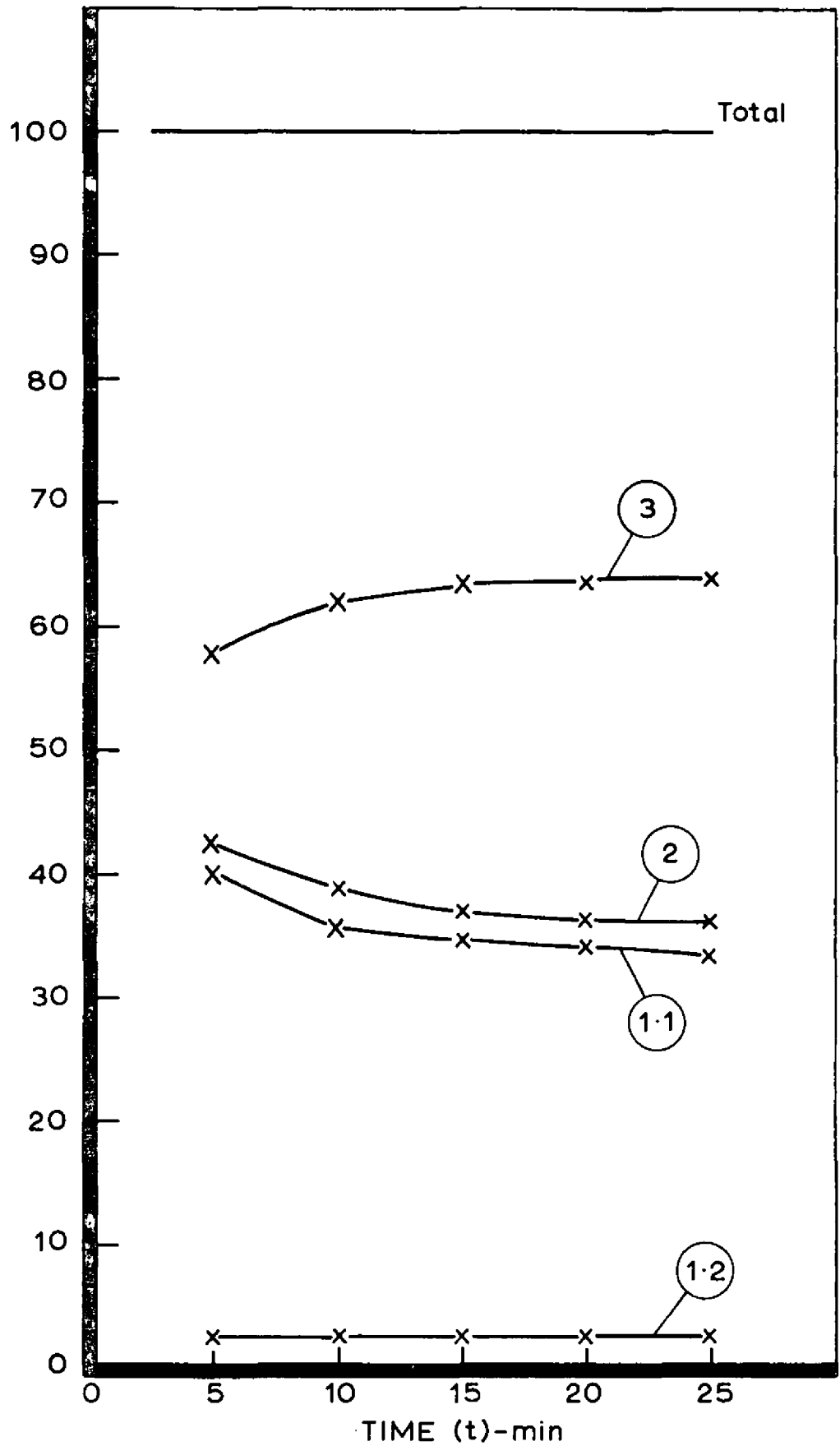
CUMULATIVE No. OF FIRES CONTROLLED BY
THE FIRE BRIGADE IN TIME LESS THAN t



- 1-1. Initial attack made by sundry means
- 1-2. Initial attack made by extinguishers
- 2. Total number of fires with initial attack
- 3. Total number of fires with no initial attack
- 4. Total number of fires

FIG. 1. NUMBERS OF FIRES
CONTROLLED BY DIFFERENT MEANS

CUMULATIVE PER CENT OF FIRES CONTROLLED IN TIME LESS THAN t
 (TOTAL NUMBER OF FIRES=100)



- 1-1. Initial attack made by sundry means
- 1-2. Initial attack made by extinguishers
- 2. Total number of fires with initial attack
- 3. Total number of fires with no initial attack

FIG. 2. PERCENTAGES OF FIRES CONTROLLED BY DIFFERENT MEANS

