DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

AND

FIRE OFFICES' COMMITTEE

JOINT FIRE RESEARCH ORGANIZATION

FIRE RESEARCH NOTE

NO. 514

CIGARETTE SMOKING AND FIRES

by

MRS. J. M. HOGG

January, 1963

Fire Research Station.
Boreham Wood.
Herts.
('phone ELStree 1341)

F.R. Note No. 514

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

CIGARETTE SMOKING AND FIRES

by

Jane M. Hogg

SUMMARY

Fires attributed to smoking materials are a controversial subject. Critics have suggested that they should be attributed to "unknown" causes. However, correlating the fires attributed to smoking materials with the total sales of tobacco in the form of cigarettes over the period 1947 to 1961 inclusive, produced a correlation coefficient of 0.85. A similar calculation relating the fires attributed to "unknown" causes with the total sales of tobacco in the form of cigarettes produced a correlation coefficient of 0.92. The more detailed analysis undertaken here indicates that fires caused by tipped cigarettes appear to be more likely to be attributed to smoking materials, than those caused by standard cigarettes.

April, 1963.

CIGARETTE SMOKING AND FIRES

by

Jane M. Hogg

Introduction

National fire statistics for the United Kingdom have been collected annually since 1946. Every fire attended by a local authority fire brigade is recorded, and classified under several different headings; for example, by the area and time of occurrence, by the type of occupancy involved, by the cause and the extent of the fire.

The cause of fire is not always known with certainty, and the fire brigades either record the supposed cause or classify the cause as "unknown". In the fifteen year period, 1947 to 1961, 72 690 fires in buildings have been attributed to smoking materials and it is sometimes suggested that it may have been more accurate to have classified the cause as "unknown" in many instances.

The numbers of fires in buildings that have been classified as of "unknown" cause each year are shown in Fig.1 and Table 1 together with the numbers attributed to smoking materials. Similar information on outdoor fires is given in Table 2. The yearly frequencies of fires of "unknown" cause in buildings related to that in 1947 are shown in Fig.2 making possible a comparison with the changes in the total fire incidence in buildings. The rates of change in the annual frequencies of fires attributed to smoking materials and those classified as "unknown" have been similar, at least since 1950 (Fig.1), at the same time being higher than the rate of change in the total fire incidence in buildings (Fig.2). It would, therefore, appear that the actual causes of those fires recorded as "unknown" may be similar to those classified as due to smoking materials, and that the true causes of both of these sets of fire classification are not representative of all other fires in buildings.

Sales of tobacco in the form of cigarettes

The annual sales of tobacco goods are published by the Tobacco Manufacturers' Standing Committee[1]. Table 3 shows the amount of tobacco sold in the form of tipped (X_1) and standard (X_2) cigarettes each year from 1947 to 1961 and the mean daily sunshine (X_3). The mean daily sunshine was included in the study since the chance of a small source of ignition such as a cigarette igniting combustible materials is affected by sunshine.

A preliminary study showed that the total amount of tobacco sold in the form of cigarettes ($X_1 + X_2$) was very highly correlated with both fires in buildings attributed to smoking materials (Z) and fires in buildings attributed to "unknown" causes (Y). The correlation coefficient between ($X_1 + X_2$) and Z was 0.85 and that between ($X_1 + X_2$) and Y was 0.92. A causal relationship between the sales of cigarettes and fires in buildings attributed to smoking materials and "unknown" causes could therefore be expected to exist unless a further factor was influencing both the sales of cigarettes and the ignition of these fires independently. Such a factor could be a general rising of the standard of living, or a greater laxity in personal behaviour.

A more detailed analysis was undertaken in order to obtain more information concerning the apparent relationship between cigarette sales and fires attributed to smoking materials and "unknown" causes. For instance, to see whether the frequency of fires appeared to depend more upon sales of one type of cigarette than upon sales of the other.

Four sets of multiple regressions are shown in the Appendix. Sales of tobacco in the form of tipped cigarettes (X_1), in the form of standard cigarettes (X_2) and the mean daily sunshine (X_3) are the independent variables while the four dependent variables are fires in buildings attributed to smoking materials (Z), fires in buildings attributed to "unknown" causes (Y), fires not in buildings attributed to smoking materials (V) and fires not in buildings attributed to "unknown" causes (U).

With fifteen years data, only fires in buildings attributed to "unknown" causes were (at the 5 per cent confidence level) significantly dependent upon all the three independent variables (X_1, X_2, X_3) taken together: the multiple correlation coefficient being 0.95. The dependence of these fires upon the sales of tipped cigarettes (X_1) was reflected by a correlation coefficient of 0.84. The multiple correlation coefficient with X_1 and X_2 was 0.92 and the extra variation in Y attributable to the mean daily sunshine, given X_1 and X_2, produced a partial correlation coefficient of 0.56.

Fires in buildings attributed to smoking materials (Z) were also related to the sales of tipped cigarettes (X_1), the correlation coefficient being 0.97, but showed no dependence at all upon the sales of standard cigarettes. The partial correlation with mean daily sunshine (X_3), conditional upon the sales of tipped cigarettes (X_1), was 0.76, and the multiple correlation coefficient with X_1 and X_3 was 0.99.

Fires not in buildings attributed to "unknown" causes were related to the sales of standard cigarettes (correlation coefficient $r = 0.54$) but showed no dependence upon the sales of tipped cigarettes, while the partial correlation with sunshine, given the sales of standard cigarettes, was 0.75. The double regression on X_2 and X_3 produced a multiple correlation of 0.83.

Fires not in buildings attributed to smoking materials were dependent upon both the sales of tipped cigarettes (X_1) and the mean daily sunshine (X_3), but showed no dependence upon the sales of standard cigarettes. The multiple correlation coefficient on X_1 and X_3 was 0.82.

Interpretation of the results

Fires in buildings caused by tipped cigarettes appear to be equally likely to be recorded as caused either by smoking materials or by "unknown" causes, while those caused by standard cigarettes appear more likely to be attributed to "unknown" causes. Fires not in buildings caused by tipped cigarettes appear to be classified under the cause "smoking materials" only, whereas those caused by standard cigarettes appear to be classified under "unknown" causes only. In other words, fires caused by tipped cigarettes appear to be more likely to be recorded as being caused by smoking materials, than those caused by standard cigarettes. The correlation coefficients related to fires not in buildings with the mean daily sunshine alone are higher than with fires in buildings, reflecting the greater effect of sunshine on fire incidence out-of-doors than on fires in buildings. Since other weather variables, also have a greater effect on fire incidence out-of-doors than in buildings, it was to be expected that the overall multiple correlation coefficients for fires not in buildings (U and V) would be lower than for those in buildings.

The impression has been given that tipped cigarettes represent the greater fire hazard. It should be noted, however, that cigarette tobacco consumption by women has been rising sharply at the same time as the sales of tipped cigarettes[1], and women may be the chief consumers of tipped cigarettes. Tipped cigarettes, therefore, could either be more

intrinsically hazardous than standard cigarettes, or they could be being smoked under conditions which are more likely to lead to a fire, than are standard cigarettes.

Finally, the multiple regression equation relating to fires attributed to "unknown" causes, indicates (since it is impossible to have a negative quantity of fires) either that the conditions under which smoking occurred over the fifteen year period became more hazardous, or else that the relationship between sales of tobacco and these fires was non-linear.

Conclusions

The actual causes of the fires attributed to smoking materials appear to be very similar to those of fires of which the cause has been recorded as unknown. These fires attributed to smoking materials and unknown causes are, however, very highly correlated with the sales of tobacco in the form of cigarettes, especially when the effect of sunshine on fire starts has been taken into account. The relationship is stronger for fires in buildings than for those out-of-doors. The impression is given that tipped cigarettes represent a greater fire hazard than standard cigarettes but it is not possible to verify this statistically for lack of an orthogonal model.

Reference

(1) TODD, G. F. Statistics of Smoking in the United Kingdom. Tobacco Manufacturers' Standing Committee. Research Papers No.1. London, 1962, third edition.

Table 1

Fires in buildings in the U.K. attributed to smoking materials and unknown causes

Year	Smoking materials Z	Unknown cause Y	Total
1947	4 300	2 787	7 087
1948	4 103	3 010	7 113
1949	4 336	3 448	7 784
1950	3 610	3 698	7 308
1951	3 754	3 618	7 372
1952	3 876	4 708	8 584
1953	3 640	4 385	8 025
1954	3 714	4 182	7 896
1955	4 412	5 148	9 560
1956	4 440	5 736	10 176
1957	4 971	6 215	11 186
1958	5 264	5 364	10 628
1959	6 940	7 228	14 168
1960	7 132	6 312	13 444
1961	8 198	7 936	16 134

$\Sigma Y^2 = 396\ 231\ 659$

$\Sigma Z^2 = 381\ 153\ 002$

$\Sigma X_1 Y = 980\ 807.8$

$\Sigma X_2 Y = 14\ 733\ 808.9$

$\Sigma X_3 Y = 299\ 398.79$

$\Sigma X_1 = 987\ 425.8$

$\Sigma X_2 = 14\ 444\ 756.9$

$\Sigma X_3 = 295\ 331.74$

$\Sigma Y = 73\ 775$

$\bar{Y} = 4\ 918.333$

$\Sigma Z = 72\ 690$

$\bar{Z} = 4\ 846$

Table 2

Outdoor fires in the U.K. attributed to smoking materials and unknown causes

Year	Smoking materials V	Unknown cause U	Total
1947	7 400	4 499	11 899
1948	4 270	3 783	8 053
1949	9 904	7 664	17 568
1950	2 798	3 704	6 502
1951	2 918	3 464	6 382
1952	4 804	6 316	11 120
1953	4 255	6 825	11 080
1954	3 238	5 650	8 888
1955	7 060	10 132	17 192
1956	6 508	13 384	19 892
1957	6 757	9 712	16 469
1958	4 676	6 512	11 188
1959	28 292	24 532	52 824
1960	9 304	8 420	17 724
1961	12 130	10 818	22 948

$\Sigma U^2 = 1\ 445\ 665\ 395$

$\Sigma V^2 = 1\ 432\ 951\ 998$

$\Sigma X_1U = 1\ 729\ 598.0$

$\Sigma X_2U = 25\ 198\ 276.8$

$\Sigma X_3U = 519\ 992.29$

$\Sigma X_1V = 1\ 779\ 946.7$

$\Sigma X_2V = 22\ 830\ 756.0$

$\Sigma X_3V = 480\ 403.5$

$\Sigma U = 125\ 415$

$\bar{U} = 8\ 361$

$\Sigma V = 114\ 314$

$\bar{V} = 7\ 620.933$

Table 3

Cigarette sales and the mean daily sunshine in the U.K.

Year	Tobacco sales in the U.K. (million lbs. manufactured weight) in the form of cigarettes		Sunshine in England & Wales mean hours per day (X_3)
	Tipped (X_1)	Standard (X_2)	
1947	1.1	192.1	3.97
1948	1.3	182.7	4.12
1949	2.0	175.9	4.63
1950	3.1	178.6	3.94
1951	1.7	189.1	3.98
1952	1.7	192.3	4.10
1953	2.0	196.6	4.04
1954	3.0	201.0	3.52
1955	3.6	207.5	4.47
1956	5.7	209.8	3.88
1957	10.1	211.2	4.04
1958	18.2	206.9	3.52
1959	24.3	206.0	4.63
1960	32.6	206.6	3.84
1961	41.2	201.9	4.07

$\Sigma X_1^2 = 3\,864.68$ $\quad \Sigma X_1 = 151.6$ $\quad \bar{X}_1 = 10.11$

$\Sigma X_2^2 = 585\,279.64$ $\quad \Sigma X_2 = 2958.2$ $\quad \bar{X}_2 = 197.21$

$\Sigma X_3^2 = 247.5529$ $\quad \Sigma X_3 = 60.75$ $\quad \bar{X}_3 = 4.05$

$\Sigma X_1X_2 = 30\,899.66$

$\Sigma X_1X_3 = 612.026$

$\Sigma X_2X_3 = 11\,968.236$

APPENDIX

$Sx_1^2 = 2\ 332.51$
$Sx_2^2 = 1\ 883.16$
$Sx_3^2 = 1.5154$

$Sx_1y = 235\ 188.5$
$Sx_2y = 184\ 395.2$
$Sx_3y = 610.04$

$Sy^2 = 33\ 381\ 617$

$Sx_1z = 252\ 772.2$
$Sx_2z = 109\ 319.7$
$Sx_3z = 937.24$

$Sz^2 = 28\ 897\ 262$

$Sx_1u = 462\ 070.4$
$Sx_2u = 464\ 766.6$
$Sx_3u = 12\ 061.54$

$Su^2 = 397\ 070\ 580$

$Sx_1v = 624\ 613.2$
$Sx_2v = 286\ 511.0$
$Sx_3v = 17\ 431.8$

$Sv^2 = 561\ 772\ 625$

Class of fire	Regression coefficient on X_1 b_1	Regression sum of squares RSS_1	Correlation coefficient r_1	Regression coefficient on X_2 b_2	Regression sum of squares RSS_2	Correlation coefficient r_2	Regression coefficient on X_3 b_3	Regression sum of squares RSS_3	Correlation coefficient r_3
Y	100.8	23 714 209	0.84	97.9	18 055 603	0.74	402.56	245 578	*
Z	108.4	27 392 716	0.97	58.05	6 346 140	*	618.48	579 661	*
U	198.1	91 536 180	*	246.8	114 705 066	0.54	7 959.3	96 001 549	*
V	267.8	167 262 584	0.55	152.1	43 590 854	*	11 503.1	200 519 765	0.60

*Not significant at the 5 per cent level.

Multiple regression on fires in buildings attributed to "unknown" causes

	x_1	x_2	x_3	y	check
I	0.233251	0.100212 0.188316	-0.01954 -0.12474 1.5154	2351.885 1843.952 610.04	2352.1989 1844.1158 611.4111
II A_1 B_1	0.233251 1	0.100212 0.429632	-0.01954 -0.0837724	2351.885 10083.065	2352.1989 10084.4108
III A_2 B_2		0.145262 1	-0.116345 -0.800932	833.5069 5737.9556	833.5359 5738.1552
IV A_3 B_3			1.420579 1	1474.6454 1038.0594	1476.0660 1039.0594

$b_3 = 1038.0594$

$b_2 = 6569.3706$

$b_1 = 7347.6135$ RSS = 30 027 604 $R^2_{123} = 0.8995$

$R_{123} = 0.95$

$b_2 = 5737.9556$

$b_1 = 7617.8557$ RSS = 28 496 835 $R^2_{12} = 0.8537$

$R_{12} = 0.92$

$b_1 = 10083.065$ RSS = 23 714 209

Source of variation	df	Sum of squares
Regression on X_1	1	23 714 209
Regression on X_2/X_1	1	4 782 626
Regression on $X_3/X_1, X_2$	1	1 530 769
Residual	11	3 354 013+
Total	14	33 381 617

$r_1 = 0.84$

$r_{2.1} = 0.70$

$r_{3.12} = 0.56$

+Hence the estimated chance variation (S^2) = 304 910

Multiple regression on fires in buildings attributed to 'smoking materials'

Source of variation	df	Sum of squares
Regression on X_1	1	28 392 716
Regression on X_3/X_1	1	872 122
Residual	12	632 424
Total	14	28 897 262

$r_1 = 0.97$
$r_{3.1} = 0.76$

RSS on X_1 and X_3 = 28 264 838

$R_{13} = 0.99$

b_1 = 10900.504

b_3 = 759.03118

Multiple regression on fires not in buildings attributed to "unknown" causes

Source of variation	df	Sum of squares
Regression on X_2	1	114 705 066
Regression on X_3/X_2	1	159 986 225
Residual	12	122 379 289
Total	14	397 070 580

$r_2 = 0.54$
$r_{3.2} = 0.75$

RSS on X_2 and X_3 = 274, 691, 291

$R_{23} = 0.83$

b_2 = 31679.7112

b_3 = 10567.0233

Multiple regression on fires not in buildings attributable to 'smoking materials'

Source of variation	df	Sum of squares
Regression on X_3	1	200 519 765
Regression on X_1/X_3	1	179 711 381
Residual	12	181 541 479
Total	14	561 772 625

$r_3 = 0.60$
$r_{1.3} = 0.71$

RSS on X_3 and X_1 = 380 231 146

$R_{31} = 0.82$

b_1 = 27772.2279

b_3 = 11861.2045

The multiple regression curve of fires attributed to 'smoking materials'

$$Z_i' = 4846 + 109.005x_{1i} + 759.031x_{3i} + e_i$$

Year	Fires attributed to smoking materials	
	Actual frequencies	Given by the regression curve
1947	4300	3803
1948	4103	3939
1949	4336	4402
1950	3610	3998
1951	3754	3876
1952	3876	3967
1953	3640	3954
1954	3714	3669
1955	4412	4455
1956	4440	4236
1957	4971	4837
1958	5264	5326
1959	6940	6833
1960	7132	7138
1961	8198	8250

The multiple regression curve of fires attributed to "unknown" causes

$$Y_i' = 4918.333 + 73.476x_{1i} + 65.694x_{2i} + 1038.059x_{3i} + e_i$$

Year	Fires attributed to "unknown causes"	
	Actual frequencies	Given by the regression curve
1947	2787	3838
1948	3010	3390
1949	3448	3525
1950	3698	3067
1951	3618	3695
1952	4708	4030
1953	4385	4272
1954	4182	4095
1955	5148	5552
1956	5736	5245
1957	6215	5826
1958	5364	5599
1959	7228	7140
1960	6312	6970
1961	7936	7532

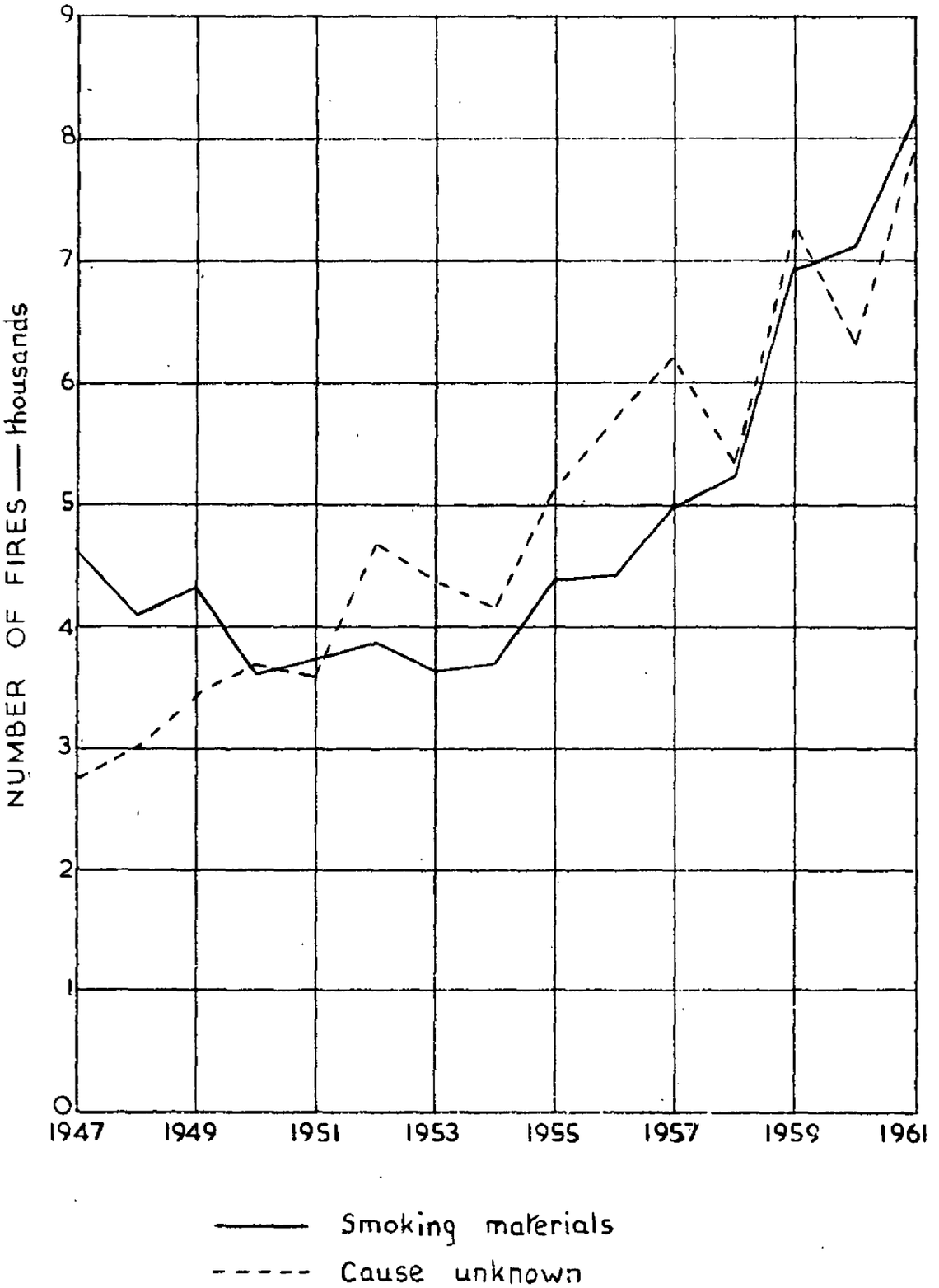

FIG.1. FIRES IN BUILDINGS IN THE U.K. ATTRIBUTED TO SMOKING MATERIALS AND UNKNOWN CAUSES

1/4897 F.R.514

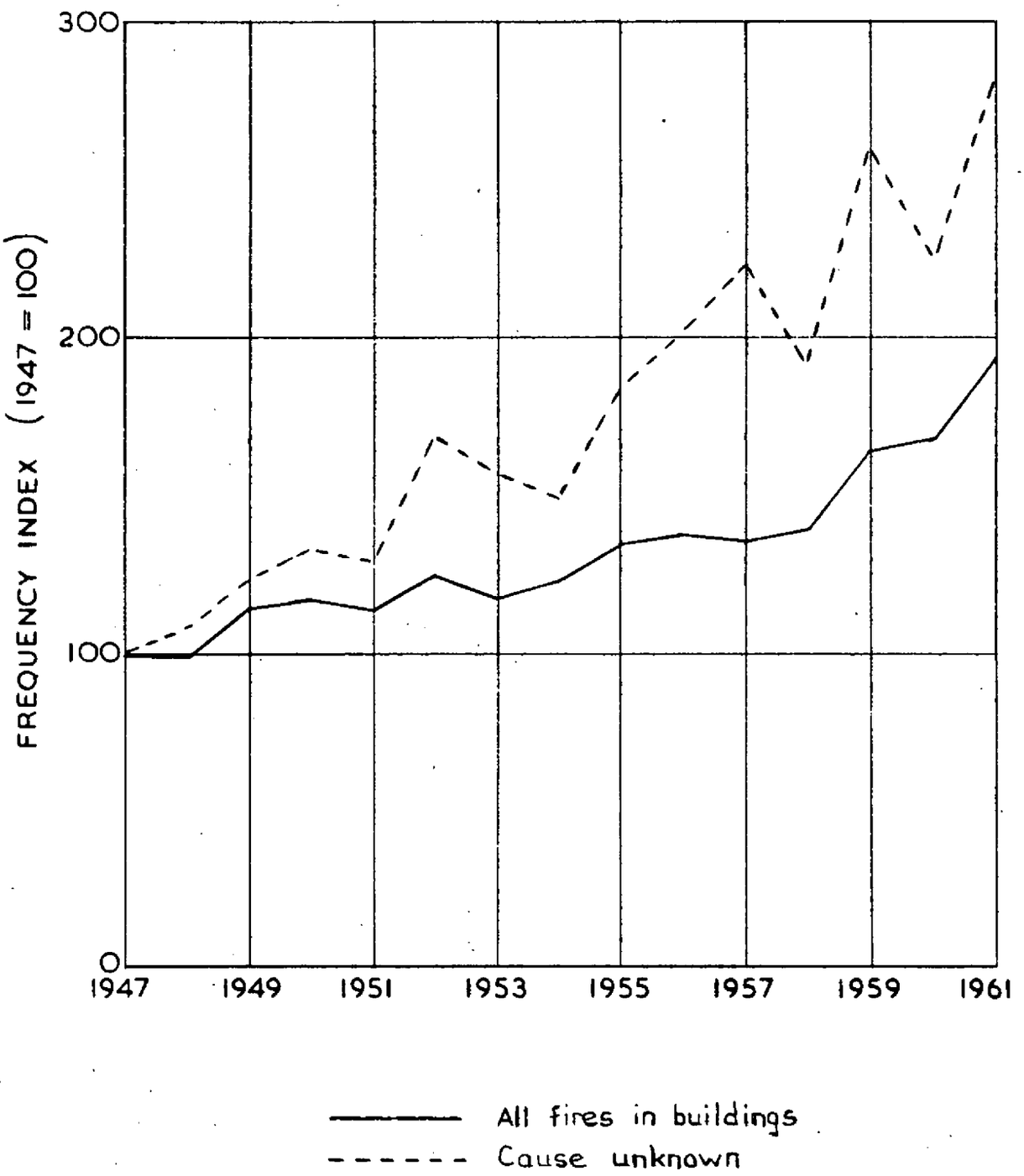

FIG.2. THE FREQUENCIES OF ALL FIRES IN BUILDINGS AND FIRES IN BUILDINGS OF UNKNOWN CAUSE RELATED TO THE FREQUENCIES WHICH OCCURRED IN 1947

/4898 F.R.514