DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

AND

FIRE OFFICES' COMMITTEE

JOINT FIRE RESEARCH ORGANIZATION

FIRE RESEARCH NOTE

NO. 528

THE EFFECT OF WEATHER CONDITIONS ON THE SPREAD OF FIRE IN BUILDINGS IN ENGLAND AND WALES FROM 1951 TO 1961

by

JANE M. HOGG

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F. R. Note No. 528

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SUMMARY

Two measures of fire spread have been used to test whether the kind of weather conditions which affected the number of fires occurring in buildings in the years 1951 to 1961, inclusive, also affected the resultant spread of fire. The amounts of sunshine and rainfall appear to affect the spread of fire, but vapour pressure, which had been found to influence fire starts had no measurable effect on fire spread.

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Introduction

Certain weather conditions appear to affect the number of fires which occur in buildings and are attended by the brigades. More fires seem to occur if the amount of sunshine increases, if the vapour pressure falls, or if the amount of rainfall decreases(1).

The annual fire loss in terms of property damaged and destroyed, in lives lost and injuries sustained, depends not only on the number of fires which occurred, but also on the extent to which these fires spread. It is possible that the same weather effects which contribute towards the ignition of fire also contribute towards the spread of fire.

Measures of fire spread

Information on weather conditions in the period 1951-1961 has been obtained from Meterological office data and is given in Tables 1-3.

The estimated cost of fires from direct damage in the United Kingdom is published monthly by the British Insurance Association (Table 5). This cost divided by the number of fires which occur in buildings in England and Wales (Table 4) ought to provide a measure of the average size of fires* in any given month in England and Wales (Table 6), which can then be compared with the weather conditions which occurred in that month. This measure is referred to as the "average cost of fire estimate."

An alternative measure of the spread of fire in buildings in a month in England and Wales is given by the percentage of fires extinguished using hose reel jets, power pumps and hydrants (Table 7), henceforth referred to as the fire spread index.

Both of these measures of spread are depicted in Fig. 1 by relating the annual data to that of the base year 1951.

The relationship with weather conditions

An analysis of covariance was employed in order to ensure that any changes in patterns of behaviour by brigades or the public over the years or months would not confuse the results. A summary of the analysis is given in the Appendix.

It appears that the percentage of fires in buildings which required extinction by hose reel jets, power pumps and hydrants increased when the amount of sunshine increased and when the amount of rainfall decreased, but was not affected by changes in vapour pressure. On the other hand, the 'average cost of fire estimate' was apparently quite insensitive to variations in the amount of sunshine. Fig. 2 compares the actual data on fire spread with that which would have resulted if the amounts of sunshine and rainfall had never varied around the average over the years 1951 to 1961. This shows the effect of weather on the fire spread index.

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*The estimated cost of fires in England and Wales is not published, but there is no reason to suppose that changes in the cost of fires in England and Wales is not proportional to changes in the cost of fires in the United Kingdom.

The amount of variation in fire incidence and in the fire spread index which can be accounted for by changes in the amount of sunshine and rainfall were very similar. The correlation coefficients between fire incidence and sunshine, and between the fire spread index and sunshine are 0.55 and 0.51 respectively, whilst the correlation coefficients between fire incidence and sunshine and rainfall, and between the fire spread index and sunshine and rainfall are 0.62 and 0.59 respectively. On the other hand the correlation coefficient between fire incidence and vapour pressure, and between the fire spread index and vapour pressure is -0.51 in the former instance and is not significantly different from zero in the latter. This is summarized in the following table:-

Correlation coefficients obtained from single regressions

	Sunshine	Vapour pressure	Rainfall
Incidence	+0.55	-0.51	-0.49
Spread Index	+0.51	*	-0.48

*not significantly different from zero

The correlation between fire incidence and vapour pressure is indicative of a relationship between vapour pressure and the spread of fire since, to have been included, these fires must have been of sufficient size to warrant calling the brigade. The absence of any relationship between vapour pressure and the fire spread index probably means that beyond a certain size of fire vapour pressure has no effect on further spread.

Significant year and month variations

The frequency of fires has changed significantly over the period 1951 to 1961 inclusive; the fire spread index has also changed significantly over these years; there has, however, been no significant change in the average cost of fire estimate until the data for 1962 are included in the analysis when the change from 1951 to 1962 in the estimate is significant just below the 95% confidence level.

A significant seasonal variation is also apparent in the monthly variation occurring in fire incidence, in the fire spread index and in the weather variables, sunshine, vapour pressure and rainfall. The monthly variation of the average cost of fire estimate (including the 1962 data) is significant at the 90 per cent confidence level. The average monthly variations which occurred over the period 1951 to 1961 in the fire spread index, the fire incidence, and the average cost of fire estimate are depicted in Figs. 3, 4, and 5. Figs. 3 and 4 show that the frequency of fire is higher in the winter than in the summer months but that the fires which occur in winter tend not to spread so far as those which occur in summer, (for example) space heating appliances are more frequently sources of ignition in winter than in summer.

Fig. 5 shows seasonal variation in two measures of fire spread which appear very dissimilar. This apparent independence implies that monetary loss is not necessarily linked directly to the physical size of the fire. It would seem reasonable, however, to expect that such a link might exist. The independence which appears in the Figure is itself dependent upon the accuracy, or otherwise, of the overall cost figures published by the B.I.A.

The method used to determine the effect of weather conditions upon the spread of fire, is not, however, the best method to use to determine whether there are significant year and month variations in the spread of fire index and the average cost of fire estimate, since the respective fire incidence has not been taken into account. The resulting bias has meant that the significance level of the variance ratios testing the between year variations are too low, whereas those testing the between month variations are too high. The analysis presented, however, suffices to show that there is more certainty that the fire spread index has changed with the years and seasons, than that the average cost of fire estimate has changed.

Conclusions

Variations in the amounts of sunshine and rainfall which occurred monthly appear to have had as great an effect on the extent of fire spread as on the frequency of fires, while changes in vapour pressure apparently affected the number of occasions when the brigades were called to a fire, but had no effect on the subsequent spread.

There are marked annual and seasonal variations in the frequency of fire and the fire spread index. The variations in the average cost of fire estimate, however, are only significant when the 1962 data have been included in the analysis.

Reference

(1) Hogg, Jane. M. The relationship between fire incidence and climatological variations 1951-1961 Fire Research Note No. 522, Joint Fire Research Organization, 1963.

Table 1

England and Wales

Estimated Vapour Pressure
Mean millibars per day

	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	Total
Jan.	29.3	26.4	28.7	26.6	27.1	28.5	32.0	28.4	25.6	30.1	28.3	311.0
Feb.	27.9	25.9	29.1	26.6	23.6	21.0	30.8	30.6	29.7	28.5	34.6	308.3
March	28.2	32.3	28.6	31.2	24.1	29.6	39.2	26.4	34.1	31.3	34.1	339.1
April	29.1	36.2	31.5	30.8	35.7	29.1	33.9	31.3	37.1	35.3	41.2	371.2
May	38.2	46.1	44.8	41.2	36.6	40.0	37.0	41.2	42.6	44.2	38.9	450.8
June	47.6	49.7	52.7	49.1	48.9	46.9	47.9	51.3	50.1	53.0	48.6	545.8
July	57.1	56.7	55.6	52.1	59.1	57.3	60.9	57.5	57.2	54.3	52.1	619.9
Aug.	55.0	57.9	57.8	55.7	62.7	51.1	57.5	61.1	60.8	56.2	55.3	631.1
Sept.	54.7	42.4	52.5	48.3	51.9	56.3	49.5	58.9	50.3	51.3	57.8	573.9
Oct.	42.4	48.8	43.8	49.5	39.5	41.9	45.6	46.3	48.0	46.1	45.1	487.0
Nov.	39.6	29.6	39.6	36.2	36.4	33.1	33.9	36.5	36.5	36.7	33.7	391.8
Dec.	32.4	27.7	38.0	34.3	33.2	34.3	30.3	32.2	33.5	29.9	27.5	353.3
Total	481.5	469.7	502.7	481.6	478.8	469.1	498.5	501.7	505.5	496.9	497.2	5 383.2

Table 2

England and Wales

Sunshine
Mean hours per day

	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	Total
Jan.	1.44	2.31	1.28	1.77	1.16	1.77	1.54	1.63	2.58	1.18	1.36	18.02
Feb.	2.29	2.75	2.24	2.03	2.82	2.47	2.73	1.99	2.10	2.73	2.30	26.45
March	3.07	2.89	4.40	3.27	5.04	4.47	3.08	3.57	3.12	2.22	4.85	39.98
April	6.24	5.49	5.72	6.07	5.57	5.47	5.22	5.02	4.92	5.32	3.31	58.35
May	5.31	6.58	6.88	4.99	6.64	7.80	6.70	5.79	7.37	5.91	6.76	70.73
June	7.60	6.41	4.96	4.69	5.43	5.09	9.58	4.69	7.71	8.58	7.30	72.04
July	6.39	5.74	6.05	4.36	8.50	5.06	4.54	5.65	7.68	4.95	5.3	64.22
Aug.	4.89	5.43	6.29	3.99	6.35	4.87	4.65	4.05	6.67	5.20	5.6	57.99
Sept.	3.71	4.03	4.88	5.24	5.15	3.30	3.74	4.14	6.42	4.14	4.3	49.05
Oct.	3.52	3.30	2.89	2.67	3.85	3.59	2.73	3.02	4.42	2.16	3.7	35.85
Nov.	1.95	2.33	1.59	1.93	1.82	1.87	2.10	1.53	1.85	2.15	2.1	21.22
Dec.	1.56	1.68	1.03	1.45	1.41	0.66	1.66	1.01	1.01	1.63	1.8	14.90
Total	47.97	48.94	48.21	42.46	53.74	46.42	48.27	42.09	55.85	46.17	48.68	528.80

Table 3

England and Wales

Rainfall
Inches

	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	Total
Jan.	3.8	3.4	1.4	2.6	3.4	5.1	2.9	3.6	4.1	5.2	4.7	40.2
Feb.	4.7	1.1	2.1	3.4	2.6	1.1	3.9	4.8	0.4	3.2	2.8	30.1
March	4.7	3.1	1.1	3.1	2.2	1.2	2.7	1.9	2.6	2.0	0.6	25.2
April	2.9	2.3	2.9	0.6	1.4	1.6	0.4	1.2	3.1	1.8	3.9	22.1
May	3.2	2.6	2.5	3.0	4.0	0.9	1.9	3.4	1.1	1.8	1.6	26.0
June	1.3	2.1	2.4	3.5	3.5	2.7	1.9	4.5	1.8	2.0	1.5	27.2
July	1.9	1.3	3.8	3.5	1.0	4.0	4.1	3.7	2.7	4.5	2.7	33.2
Aug.	5.2	4.1	3.3	4.6	1.2	6.1	4.1	4.0	1.4	4.5	3.3	41.8
Sept.	3.5	3.8	3.2	3.5	2.0	3.7	5.0	4.8	0.3	4.5	3.2	37.5
Oct.	1.3	4.1	2.9	4.8	3.0	2.3	3.0	3.3	3.4	7.5	4.7	40.3
Nov.	7.2	4.0	2.8	6.6	2.4	1.3	2.5	2.2	4.7	5.9	2.5	42.1
Dec.	4.0	3.6	1.4	3.5	4.2	4.2	3.3	4.2	6.4	4.6	4.0	43.4
Total	43.7	35.5	29.8	42.7	30.9	34.2	35.7	41.6	32.0	47.5	35.5	409.1

Table 5

Cost of fires in U.K. (£ thousands)

Estimated direct damage - British Insurance Association

	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	Total (1951-1961)	1962
Jan.	1 555	2 543	2 006	3 403	1 855	2 025	1 605	4 234	3 162	3 888	3 469	29 745	3 884
Feb.	1 907	2 762	1 821	2 502	2 191	2 581	3 109	2 473	4 354	6 189	2 142	32 031	3 219
March	1 737	2 715	2 125	2 185	5 166	2 873	1 190	3 167	1 917	7 575	4 070	34 720	6 137
April	1 705	1 251	2 043	1 326	2 144	2 962	3 380	1 457	1 747	2 207	3 656	23 878	3 111
May	2 536	1 391	2 506	1 453	1 605	2 545	3 795	1 951	5 104	3 368	3 619	29 873	7 705
June	1 161	2 095	1 462	2 020	3 373	1 608	3 249	1 106	5 085	3 651	3 463	28 273	6 766
July	1 912	1 474	2 528	1 482	1 386	1 824	1 562	829	1 870	1 316	2 317	18 500	3 320
August	1 217	1 046	2 581	3 959	1 516	1 391	982	2 369	4 145	1 965	3 471	24 642	2 428
Sept.	1 761	3 009	1 335	864	2 874	2 918	2 357	1 781	5 533	2 283	2 062	26 777	4 662
Oct.	3 177	1 404	2 881	2 368	1 374	1 579	1 336	1 530	6 416	4 563	3 803	30 431	5 312
Nov.	2 467	1 205	1 564	1 776	2 659	2 429	1 924	2 036	2 098	2 657	2 444	23 259	4 793
Dec.	2 013	3 335	2 283	2 845	1 552	2 676	1 360	1 212	2 748	4 112	2 954	27 090	4 250
Total	23 148	24 230	25 135	26 183	27 695	27 411	25 849	24 145	44 179	43 774	37 470	329 219	55 587

Table 6

Monthly cost of fires in U.K. divided by the fire incidence in buildings in England and Wales (£)

	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	Total (1951-1961)	1962
Jan.	431	634	506	650	409	503	395	945	585	752	612	6 422	666
Feb.	633	766	504	551	570	432	971	635	983	1 282	479	7 806	550
March	518	778	520	612	1 100	674	370	636	467	1 559	734	7 968	928
April	472	399	595	362	617	759	855	322	453	459	859	6 152	597
May	831	471	771	444	548	649	956	545	1 100	744	695	7 754	1 555
June	397	797	580	849	1 240	551	753	401	1 246	817	707	8 338	1 272
July	688	482	1 023	621	420	682	526	303	458	352	497	6 052	733
Aug.	520	394	1 039	1 749	464	575	325	866	1 058	535	821	8 346	578
Sept.	764	1 033	555	342	964	1 180	828	588	1 208	619	484	8 565	1 064
Oct.	1 026	433	954	821	370	444	397	414	1 331	1 050	747	7 987	1 035
Nov.	868	286	484	530	719	582	452	503	460	582	429	5 895	885
Dec.	572	743	647	757	386	679	292	277	597	808	454	6 212	646
Total	7 720	7 216	8 178	8 288	7 807	7 710	7 120	6 435	9 946	9 559	7 518	87 497	10 509

Table 7

The percentage of fires in buildings extinguished by hose reel jets, power pumps and hydrants in England and Wales

	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961
Jan.	43.6	48.4	43.4	48.3	47.3	49.6	52.4	54.8	52.2	56.2	56.4
Feb.	42.7	48.8	46.3	45.5	50.8	50.1	52.8	54.3	55.9	55.4	61.2
March	49.0	47.0	53.9	51.0	53.5	57.0	55.5	56.9	58.1	59.4	64.4
April	50.7	50.0	60.0	58.8	58.9	58.1	61.8	64.1	60.8	63.9	62.6
May	52.6	52.4	54.9	55.3	59.4	62.8	62.4	63.4	65.9	65.6	67.1
June	53.8	54.5	51.4	54.5	58.4	57.5	64.6	58.1	65.6	67.2	65.6
July	51.6	56.2	52.2	50.8	57.3	54.1	56.5	58.2	65.5	61.3	68.0
August	50.3	52.5	55.5	50.4	59.3	54.7	58.2	57.7	65.0	65.1	68.6
Sept.	51.7	53.4	55.7	54.0	58.3	54.5	58.2	60.5	69.4	62.4	65.2
Oct.	49.9	49.8	49.8	53.4	55.5	58.3	59.9	59.3	66.3	62.0	64.6
Nov.	44.3	45.9	50.9	47.1	52.3	57.6	57.8	59.1	60.9	58.1	59.4
Dec.	44.0	41.8	47.6	48.7	50.8	52.5	54.1	52.3	54.3	55.8	54.8

Appendix

Analyses of variance, covariance and regressions of the fire spread index upon sunshine, vapour pressure and rainfall

Analysis of Variance					
Source of variation	Degrees of freedom	SUM OF SQUARES			
		Sunshine (x_1)	Vapour Pressure (x_2)	Rainfall (x_3)	Fire spread index (z)
Between years	10	13.9535	151.93	28.039	2 935.104
Between months	11	433.4509	14 380.41	59.112	1 539.826
Residual	110	78.2704	1 172.40	184.319	569.031
Total	131	525.6748	15 704.74	271.470	5 043.961

Analysis of Covariance							
Source of variation	Degrees of freedom	SUM OF PRODUCTS					
		x_1 and z	x_2 and z	x_3 and z	x_1 and x_2	x_1 and x_3	x_2 and x_3
Between years	10	42.102	400.892	- 7.310	3.8913	- 12.7055	- 0.8968
Between months	11	744.545	3 228.455	- 137.717	1 686.7915	- 93.7625	+ 137.3800
Residual	110	108.024	- 57.868	- 155.075	- 56.6313	- 49.8044	+ 29.0150
Total	131	894.671	3 571.479	- 300.102	1 634.0515	- 156.2724	+ 165.4982

Single regressions				
Source of variation	Degrees of freedom	SUM OF SQUARES		
		z on x_1	z on x_2	z on x_3
Due to regression	1	149.088	2.856	130.471
Residual	109	419.943	566.175	438.560
Total*	110	569.031	569.031	569.031

Double regression		
Source of variation	Degrees of freedom	Sum of Squares
		ž on x_1 and x_3
Regression on x_1 alone	1	149.088
Extra due to x_3	1	48.840
Regression on x_1 and x_3	2	197.928
Residual	108	371.103
Total*	110	569.031

* Residual sum of squares of fire frequencies from above analysis of variance

Comparison of the regressions of the fire spread index and fire incidence upon sunshine and rainfall

Regression of the fire spread index upon sunshine and rainfall

Source of variation	Degrees of freedom	Sum of squares z_1 on x_1 and x_3
Regression on x_1 alone	1	149.088
Extra due to x_3	1	48.840
Regression on x_1 and x_3	2	197.928
Residual	108	371.103
Total	110	569.031

$r_1 = 0.51$
$r_{3.1} = -0.34$
$R_{13} = 0.59$

Regression of fire incidence upon sunshine and rainfall

Source of variation	Degrees of freedom	Sum of squares z_2 on x_1 and x_3
Regression on x_1 alone	1	6,736,325
Extra due to x_3	1	1,881,195
Regression on x_1 and x_3	2	8,617,520
Residual	108	13,846,826
Total	110	22,464,346

$r_1 = 0.55$
$r_{3.1} = -0.35$
$R_{13} = 0.62$

Correlation coefficients obtained from single regressions

	Sunshine	Vapour Pressure	Rainfall
Incidence	0.55	- 0.51	- 0.49
Spread	0.51	*	- 0.48

* not significantly different from zero

Analyses of variance, covariance and regression of the average cost of fire estimate upon sunshine

Source of variation	Degrees of freedom	Sum of squares	Sum of products
		Cost of fire	Cost and sunshine
Between years	10	881 614.9	1 517.265
Between months	11	1 086 846.1	8 170.333
Residual	110	7 493 913.3	- 1 455.363
Total	131	9 462 374.3	8 232.235

Source of variation	Degrees of freedom	Sum of squares	Mean square	Variance Ratio
Due to regression	1	27 061.1	27 061.1	0.4
Residual	109	7 466 852.2	68 503.2	
Total	110	7 493 913.3		

Testing the significance of the between years and between months variations

Source of variation	Degrees of freedom	MEAN SQUARE					
		Fire incidence	Fire spread index	Average cost of fire estimate	Sunshine	Vapour pressure	Rainfall
Between years	10	4 634 110.2	293.510	88 161.5	1.39535	15.193	2. 8039
Between months	11	3 047 150.9	139.984	98 804.2	39.40463	1307.31	5.37382
Residual	110	204 221.3	5.173	68 126.5	0.71155	10.6582	1.67563

Source of variation	Degrees of freedom	VARIANCE RATIO					
		Fire incidence	Fire spread index	Average cost of fire estimate	Sunshine	Vapour pressure	Rainfall
Between years	10	22.7	56.7	1.29	1.96	1.43	1.67
Between months	11	14.9	27.1	1.45	5.54	122.66	3.21

Analysis of Variance
of 'average cost of fire estimate', 1951-1962

Source of variation	Degrees of freedom	Sum of squares	Mean square	Variance ratio
Between years	11	1 380 176.9	125 470.6	1.83
Between months	11	1 343 102.6	122 100.2	1.78
Residual	121	8 309 293.1	68 671.8	
Total	143	11 032 572.6		

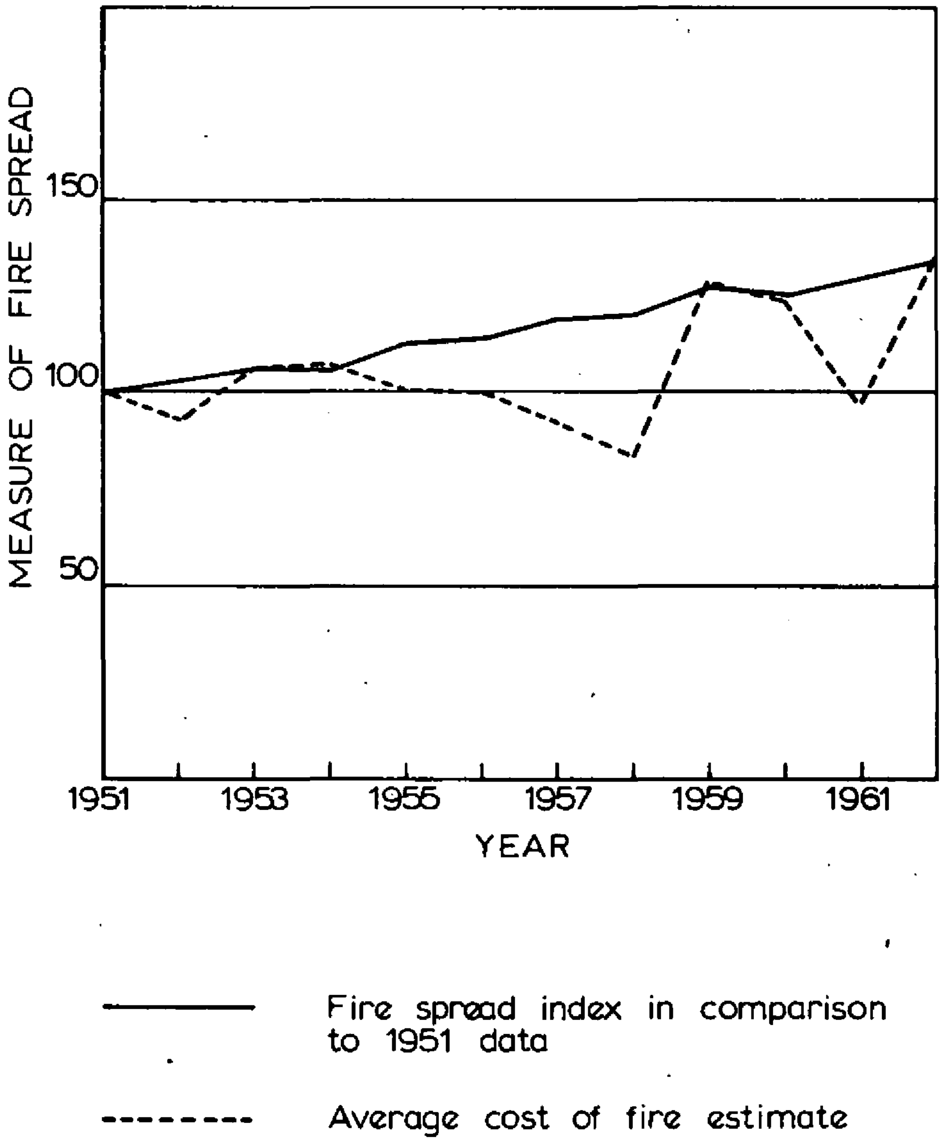

FIG. 1. FIRE SPREAD 1951-1962
COMPARISON OF YEARLY DATA RELATED TO 1951 (=100) BETWEEN TWO MEASURES OF AVERAGE SIZE OF FIRE IN BUILDINGS IN ENGLAND AND WALES

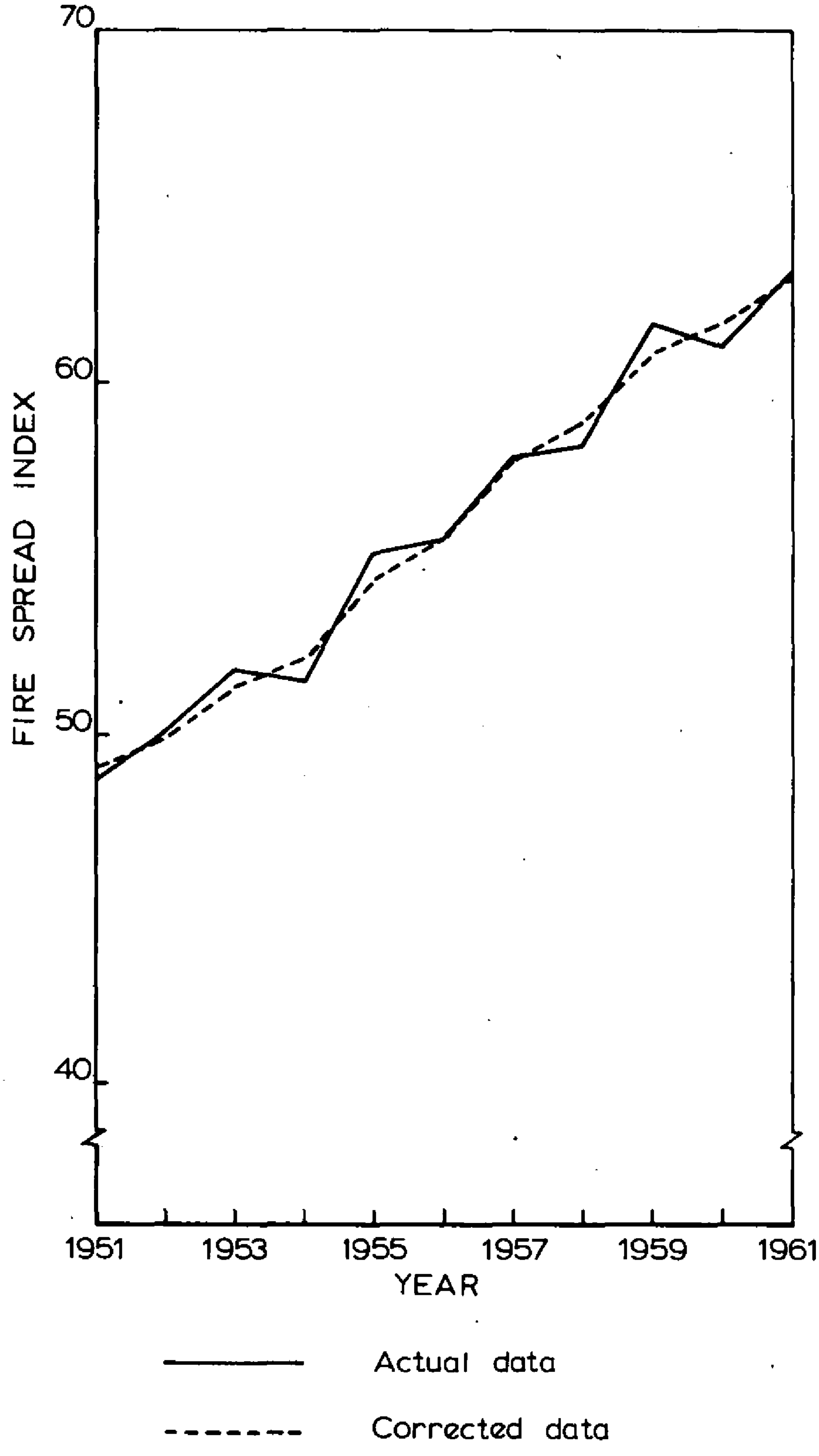

FIG. 2. FIRE SPREAD INDEX COMPARED WITH FREQUENCIES OBTAINED BY CORRECTING FOR WEATHER VARIATIONS (1951–1961)

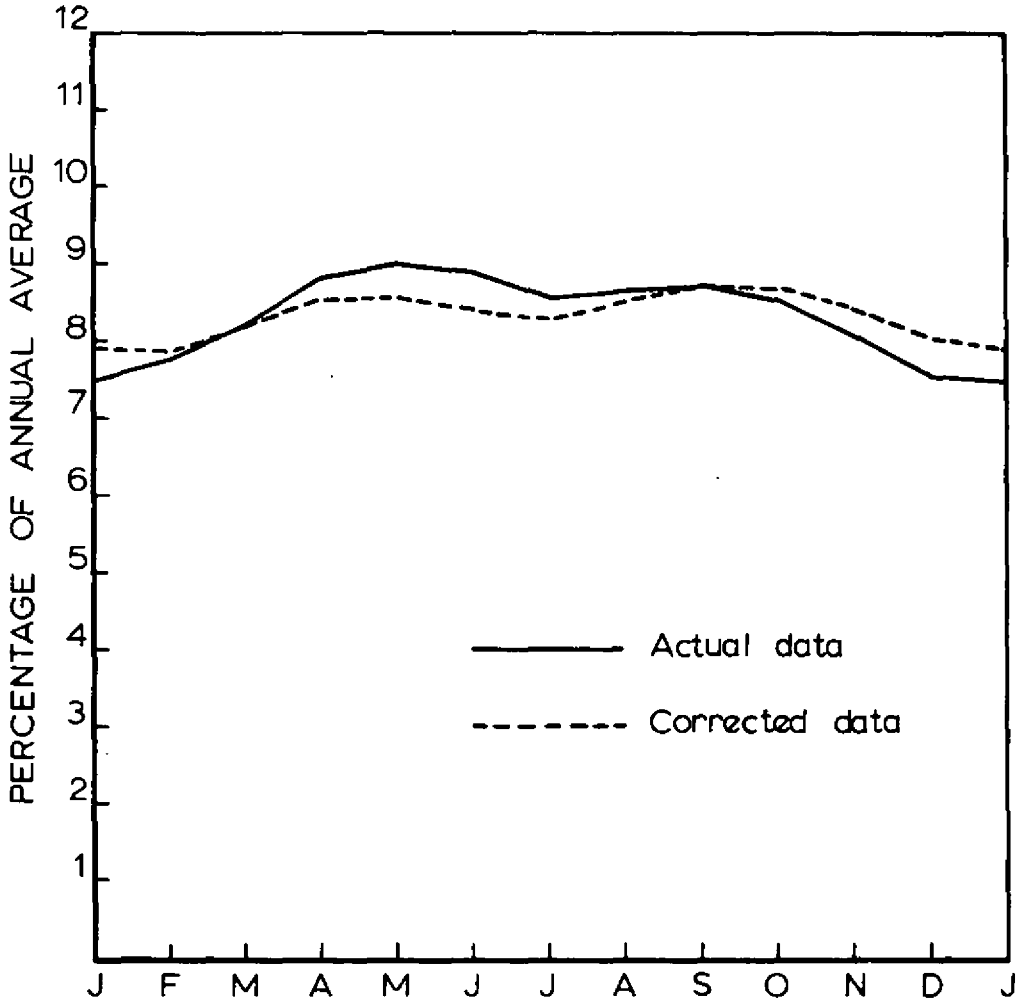

FIG. 3. FIRE SPREAD INDEX COMPARED WITH FREQUENCIES OBTAINED BY CORRECTING FOR WEATHER VARIATIONS BY MONTHS (1951–1961)

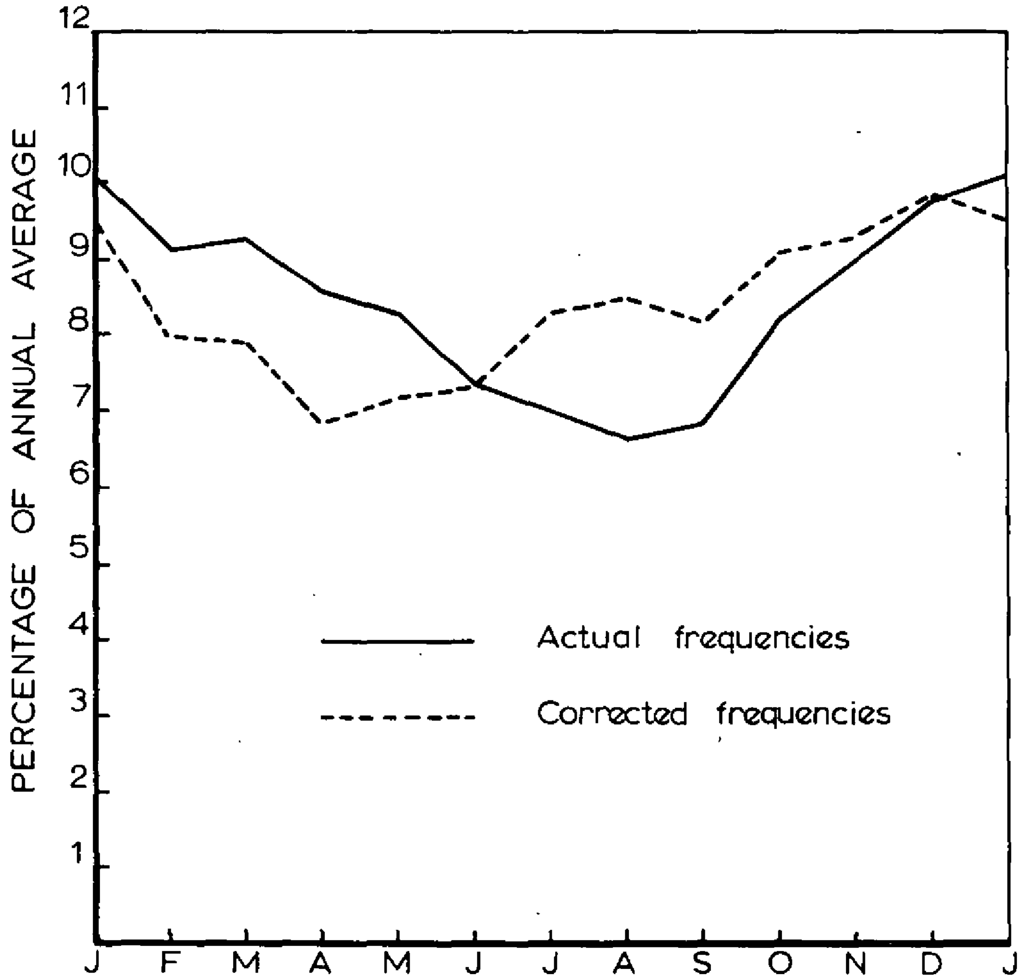

FIG. 4. MONTHLY FIRE INCIDENCE IN BUILDINGS IN ENGLAND AND WALES COMPARED WITH FREQUENCIES OBTAINED BY CORRECTING FOR WEATHER VARIATIONS (1951–1961)

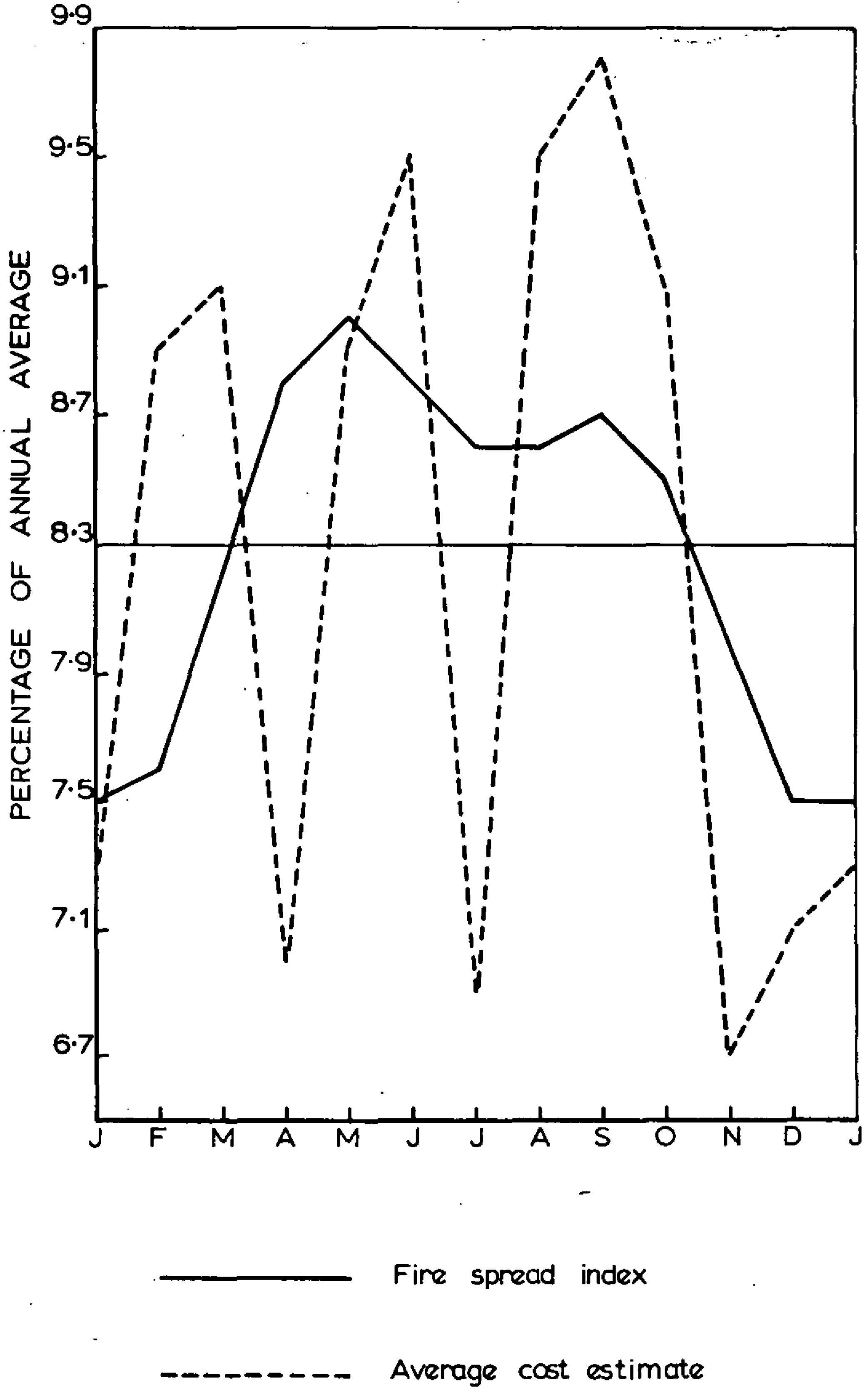

FIG. 5. COMPARISON OF MONTHLY VARIATIONS IN FIRE SPREAD INDEX AND AVERAGE COST ESTIMATE (TOTAL FOR ALL MONTHS = 100)