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THE RELATIONSHIP BETWEEN THE IGNITION OF FIRES IN BUILDINGS IN ENGLAND AND WALES AND CLIMATOLOGICAL VARIATIONS OVER THE PERIOD 1951 TO 1961

by

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May, 1963.

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F.R. Note No. 522

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THE RELATIONSHIP BETWEEN THE IGNITION OF FIRES IN BUILDINGS IN ENGLAND AND WALES AND CLIMATOLOGICAL VARIATIONS OVER THE PERIOD 1951 TO 1961

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Summary

The influence of weather on the occurrence of fire has most frequently been studied in relation to forest and bush areas. This note deals with the effect of weather on the number of fires which occurred in buildings in England and Wales during the years 1951 to 1961. The results obtained do not, in general, agree with results published in earlier studies undertaken in Japan and the United States of America. It is conceivable, however, that fires occurring under different conditions may be affected by different weather effects.

April, 1963.

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AND CLIMATOLOGICAL VARIATIONS OVER THE PERIOD 1951 TO 1961

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Introduction

The influence of weather is acknowledged to be an important factor in the ignition and spread of forest fires(1). Studies undertaken in the 1920s in Japan(2) concluded that relative humidity is a factor influencing the chance of a fire start in a building. An American publication(3) dealing with fires in buildings in certain American cities also drew the conclusion that relative humidity is a factor affecting the chance of ignition, but with the proviso that dew-point temperature has a greater effect than relative humidity in the winter months; while the air temperature also affects the chance of fire in buildings during the winter months.

Interest in the effect of weather on the chance of ignition of fire in buildings in the United Kingdom was aroused at the Joint Fire Research Organization when in 1959 there was a spectacular increase in the annual fire incidence in the United Kingdom, both indoors and outdoors. Fires in buildings increased by over 9,000 and outdoor fires by about 127,000 from 1958 to 1959.

Discussion of the model used to determine the effect of weather upon fire frequencies in buildings

A study of the relationship between one or several weather effects and the chance of occurrence of a fire in buildings will give misleading results if the effects of other influences are not removed. For example, as the air temperature falls more space heating appliances are used in buildings, which increases the chance of a fire occurring in those buildings. The fall in temperature has thus affected the chance of a fire indirectly through its effect upon human behaviour. However, the actual number of fires which will occur within a month may also depend directly upon weather conditions since the chance of a fire may change with weather effects even without any change in human behaviour.

Since human behaviour changes with the seasons, the effect of weather on fire frequencies must be tested within similar periods of the year, for example, months. To do this several observations for the same set of months must be obtained. This was achieved by taking observations over several years. However, the weather effects must also be tested within years since the chance of a fire, irrespective of weather conditions, changes each year.

The following mathematical model summarises the above:

$$Z_{ij} = \mu + Y_i^{*} + M_j^{*} + \sum \beta_k x_{kij} + \varepsilon_{ij} \qquad (1)$$

where Z_{ij} are the number of fires occurring in the i^{th} year and the j^{th} month:

$x_{ij} = X_{ij} - \bar{X}$, where X_{ij} represents the value for a particular weather effect in the i^{th} year and j^{th} month, the subscript k denoting which effect, and $\bar{X}_k$ represents the mean value experienced throughout for that effect.

Y_i^{*} and M_j^{*} are the year and month effects adjusted for the effect of the X's.

μ represents the overall population mean and is estimated by $\bar{Z}$.

β_k represents the average straight line relationship between x_k and the z terms, and $z_{ij} = Z_{ij} - \bar{Z}$. The assumptions are that there is no year-month interaction effect $(YM)^*_{ij}$, and that the ϵ_{ij} are independent normally distributed variables with variance σ^2 for each set of X's.

The ϵ_{ij} represent the error term.

A genuine cause and effect relationship between the weather effects and the frequencies will be provided by model (1) so long as changes in human behaviour remain proportionately constant between months and between years, since there can be only one set of observations for any month in any year (obviously Z_{ij} can only occur once). The model has been checked to ensure that the possible month-year interaction effect is non-existent by separating it into two parts, one for the period 1951 to 1956 and the other for the years 1957 to 1961, and then ascertaining that the same cause and effect relationship held for both periods.

Availability of data

Climatological data are published in monthly form(4) for the daily mean air temperature, inches of rainfall, and sunshine (mean hours per day): additional data had therefore to be specially compiled.

Data for dry bulb temperature, wet bulb temperature, dew point temperature, vapour pressure, wind and cloud are recorded at certain climatological stations at three hourly intervals, and were available from the Meteorological Office. A preliminary analysis was therefore undertaken using observations at the towns of Blackpool, Liverpool, Nottingham, Birmingham and Bristol at three hourly intervals, from 0600 hours to 2100 hours inclusive. Averages were obtained for three monthly periods over the three years 1958, 1959 and 1960. As it was conceivable that the cause and effect relationship between weather effects and fire frequencies might vary for different seasons of the year two models were used, one comprising the winter months of January, February and March, the other the summer months, June, July and August. (Appendix I).

The preliminary analysis revealed a relationship between both vapour pressure and dew point temperature and the chance of fire in dwellings in the five towns in both the winter and summer seasons. (Vapour pressure and dew point temperature measure an identical weather phenomenon but use different scales, so that making use of vapour pressure for forecasting the number of fires in dwellings precludes the use of dew point temperature. Vapour pressure data are used, hereafter, since the error terms appear to be more normally randomly distributed about this scale than that of the dew point temperature). None of the other weather effects examined appeared to have any effect on the three hourly average frequencies of fires in dwellings in the towns used in the analysis.

Average monthly values of vapour pressure have been compiled for England and Wales for the period 1951 to 1961 inclusive, and are shown in Table 1, Appendix II. Sunshine and rainfall data are given in Tables 2 and 3, while Table 4 gives the monthly fire incidence in buildings in England and Wales.

The results of the analysis

A multiple regression using the analysis of covariance model (1) showed that variations in the monthly frequency of fires were most highly dependent upon the amount of sunshine occurring in the month, and that the residual variation was more dependent upon the vapour pressure level than upon the amount of rainfall; nevertheless, the amount of rainfall had some effect on the fire frequencies even after the effects of both sunshine and vapour pressure had been taken into account.

The multiple correlation coefficient for all the three weather effects (sunshine, vapour pressure and rainfall) and the occurrence of fires was 0.75. The correlation coefficient for sunshine and fire frequencies was 0.55; the partial correlation coefficient for vapour pressure and fire frequencies, given the amount of sunshine, was 0.49, while the partial correlation coefficient for rainfall and fire frequencies, given the amounts of both sunshine and vapour pressure, was 0.41. The values for these respective correlation coefficients could have occurred individually by chance less than once in a thousand times.

Figure 1 shows both the actual annual fire incidence in buildings in England and Wales over the period 1951 to 1961 inclusive, and the adjusted frequencies calculated by correcting for the differences between the annual mean values and the overall mean values of sunshine, vapour pressure and rainfall, using the estimated regression coefficients. From these curves it appears that the increase in the annual fire incidence observed between 1958 and 1959 was due less to the weather conditions of 1959 than to those pertaining in 1958 which resulted in a lower fire frequency than would normally occur.

Conclusion

The weather effects which had a direct relationship upon the number of fires which occurred in buildings in England and Wales from 1951 to 1961 inclusive were sunshine, vapour pressure and rainfall. Fire frequencies in buildings are correlated most with changes in the amount of sunshine, next with changes in vapour pressure, and least with changes in the amount of rainfall. The increase in the annual frequency of fire observed between 1958 and 1959 was due to weather conditions affecting fire frequencies so that they were well below the number which would have been expected from the trend line in 1958, and slightly above the number expected in 1959. Although it is clear from this analysis that weather conditions play an important role in the occurrence of fire, it is unlikely that it will be possible to predict bad fire spells until longer range weather forecasting can be achieved.

References

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(3) PIRSKO, A. R. and FONS, W. L. Frequency of urban building fires as related to daily weather conditions. U.S. Department of Agriculture, Forest Service, Division of Fire Research. Interim Technical Report AFSWP-866. Berkeley, California, 1956.

(4) Annual Abstract of Statistics.

APPENDIX I

BETWEEN TOWNS, BETWEEN TIMES AND RESIDUAL VARIATIONS AND COVARIATIONS - WINTER

Source of Variation	Degrees of freedom	SUM OF SQUARES							
		Dry Bulb Temperature (x_1)	Relative Humidity (x_2)	Dew Point Temperature (x_3)	Vapour Pressure (x_4)	Wind (x_5)	Wet Bulb Temperature (x_6)	Cloud (x_7)	Fires (y)
Towns	4	21.83328	58.50968	12.48149	114.47149	38.93288	21.09555	0.087759	38,093.867
Times	5	122.71092	522.7815	10.69411	91.74136	17.11379	75.51858	3.941684	4,983.6
Residual	20	2.64902	15.19596	2.30784	16.50971	1.77805	7.16138	0.196518	4,115.733
Total	29	147.19323	596.48714	25.48344	222.72256	57.82473	103.77551	4.225961	47,193.2

Source of Variation	Degrees of freedom	SUM OF PRODUCTS						
		yx_1	yx_2	yx_3	yx_4	yx_5	yx_6	yx_7
Towns	4	93.18561	-687.9277	-128.80185	-443.9534	392.16101	-170.71808	16.98782
Times	5	700.45461	-1,427.7616	210.56974	612.2782	252.85535	569.29004	46.23911
Residual	20	-38.39299	-28.2863	-49.1214	-134.6355	7.23014	22.93137	-10.45793
Total	29	755.24723	-2,143.9756	32.64649	33.6893	652.24649	421.50332	52.76900

Effects due to	x_1	x_2	x_3	x_4	x_5	x_6	x_7
Regression coefficient b_1	-14.49328	-1.86144	-21.28458	-8.15493	4.06633	3.20209	-53.21614
Regression sum of squares	556.440	52.653	1,045.528	1,097.943	29.4	73.428	556.531
Variance Ratio ($F_{1,19}$)	2.97	-	6.47	6.91	-	-	2.97
Significance level	15%	-	2.5%	2.5%	-	-	15%
Correlation coefficient r_{iy}	-0.37	-0.11	-0.5	-0.52	0.08	0.13	-0.37

APPENDIX I

BETWEEN TOWNS, BETWEEN TIMES AND RESIDUAL VARIATIONS AND COVARIATIONS - SUMMER

Source of Variation	Degrees of freedom	SUM OF SQUARES							
		Dry Bulb Temperature (x_1)	Relative Humidity (x_2)	Dew Point Temperature (x_3)	Vapour Pressure (x_4)	Wind (x_5)	Wet Bulb Temperature (x_6)	Cloud (x_7)	Fires (y)
Towns	4	6.24005	207.65867	45.98072	1,068.0335	47.73729	15.5703	0.824169	7,648.867
Times	5	371.53745	2,016.48869	3.60276	110.86958	44.78743	88.5009	1.208367	2,382.267
Residual	20	11.22884	74.6005	3.84281	90.61484	3.90374	2.83277	0.857789	1,090.733
Total	29	389.00634	2,298.74786	53.42629	1,269.51792	96.42846	106.90398	2.890325	11,121.867

Source of Variation	Degrees of freedom	SUM OF PRODUCTS						
		yx_1	yx_2	yx_3	yx_4	yx_5	yx_6	yx_7
Towns	4	22.80882	-988.37935	-358.21159	-1,719.10882	85.56159	-158.07017	-17.912319
Times	5	918.33889	-2,133.84638	67.08986	407.32729	316.36159	447.66787	6.963525
Residual	20	-8.60519	-52.20616	-35.72754	-168.33393	15.33406	-20.19505	0.776812
Total	29	932.54251	-3,174.43188	-326.84928	-1,480.11546	417.25725	269.40266	-10.171982

Effects due to	x_1	x_2	x_3	x_4	x_5	x_6	x_7
Regression coefficient b_i	-0.76635	-0.69981	-9.29724	-1.85769	3.92804	-7.12908	0.9056
Regression Sum of Squares	6.594	36.534	332.168	312.712	60.233	143.972	0.703
Variance Ratio ($F_{1,19}$)	-	-	9.15	7.64	-	2.89	-
Significance level	-	-	0.1%	2.5%	-	15%	-
Correlation coefficient r_{iy}	-0.08	-0.18	-0.55	-0.54	+0.23	-0.36	+0.03

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 4

Monthly fire incidence in England and Wales

In buildings

	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	Total
Jan.	3 610	4 008	3 965	5 236	4 536	4 024	4 061	4 480	5 404	5 168	5 664	50 156
Feb.	3 014	3 608	3 610	4 544	3 844	5 976	3 201	3 892	4 428	4 828	4 468	45 413
March	3 356	3 488	4 090	3 572	4 696	4 264	3 219	4 976	4 104	4 860	5 544	46 169
April	3 614	3 136	3 435	3 662	3 476	3 904	3 953	4 520	3 860	4 808	4 256	42 624
May	3 050	2 956	3 250	3 270	2 928	3 924	3 971	3 580	4 640	4 524	5 208	41 301
June	2 928	2 628	2 520	2 378	2 720	2 920	4 317	2 756	4 080	4 468	4 896	36 611
July	2 778	3 060	2 470	2 388	3 300	2 676	2 967	2 736	4 084	3 736	4 666	34 861
Aug.	2 342	2 652	2 485	2 264	3 264	2 420	3 019	2 736	3 916	3 676	4 228	33 002
Sept.	2 304	2 912	2 405	2 524	2 980	2 472	2 845	3 028	4 580	3 688	4 262	34 000
Oct.	3 096	3 240	3 020	2 886	3 716	3 556	3 366	3 692	4 820	4 344	5 090	40 826
Nov.	2 842	4 212	3 230	3 348	3 700	4 176	4 253	4 044	4 564	4 564	5 700	44 633
Dec.	3 522	4 488	3 530	3 756	4 016	3 940	4 651	4 376	4 604	5 088	6 504	48 475
Total	36 456	40 388	38 010	39 828	43 176	44 252	43 823	44 816	53 084	53 752	60 486	498 071

APPENDIX 2

BETWEEN YEARS, BETWEEN MONTHS AND RESIDUAL VARIATIONS AND COVARIATIONS

Analysis of Variance

Source of Variation	Degrees of freedom	SUM OF SQUARES			
		Sunshine (x_1)	Vapour pressure (x_2)	Rainfall (x_3)	Fire frequencies (z)
Between years	10	13.9535	151.93	28.039	46,341,102
Between months	11	433.4509	14,380.41	59.112	33,518,660
Residual	110	78.2704	1,172.40	184.319	22,464,346
Total	131	525.6748	15,704.74	271.470	102,324,108

Analysis of Covariance

Source of Covariation	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	+6,028.18	+36,992.7	+1,007.1	+3.8913	-12.7055	-0.8968
Between months	11	-90,769.03	-664,582.8	+1,658.8	+1,686.7915	-93.7625	+137.3800
Residual	110	+22,962.03	-82,635.7	-31,555.8	-56.6313	-49.8044	+29.0150
Total	131	-61,778.82	-710,225.8	-28,889.9	+1,634.0515	-156.2724	+165.4982

Single regressions of z on x_1, x_2 and x_3

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	6,736,325	5,824,513	5,402,413
Residual	109	15,728,021	16,639,833	17,061,933
Total*	110	22,464,346	22,464,346	22,464,346

Double regressions of z on x_1 and x_2 and z on x_1 and x_3

Source of variation	Degrees of freedom	SUM OF SQUARES	
		z on x_1 and x_2	z on x_1 and x_3
Due to regression	2	10,588,909	8,617,520
Residual	108	11,875,437	13,846,826
Total*	110	22,464,346	22,464,346

Source of variation	Degrees of freedom	Sum of squares
Regression on x_1 alone	1	6,736,325
Extra due to x_2	1	3,852,584
Regression on x_1 and x_2	2	10,588,909
Extra due to x_3	1	1,973,822
Regression on x_1, x_2 and x_3	3	12,562,731
Residual	107	9,901,615
Total*	110	22,464,346

Total* = residual sum of squares of fire frequencies from above analysis of variance

APPENDIX 2

CALCULATIONS FOR ADJUSTED FREQUENCIES IN FIG. 1.

$Z_{ij} = \mu + Y_i^* + M_j^* + \Sigma\beta_k x_{kij} + \mathcal{E}_{ij}$ where β_k is estimates by b_k

and $b_1 = +178.265$
$b_2 = -59.0586$
$b_3 = -113.7368$

		1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	Overall
Sunshine	Annual mean	3.997	4.078	4.017	3.538	4.478	3.868	4.022	3.507	4.654	3.847	4.057	4.006
	Difference from overall mean	-0.009	+0.072	+0.011	-0.468	+0.472	-0.138	+0.016	-0.499	+0.648	-0.159	+0.051	
	Resultant additional fire frequencies	+1.604	-12.835	-1.961	+83.428	-84.141	+24.601	-2.852	+88.954	-115.516	+28.344	-9.092	
Vapour pressure	Annual mean	40.12	39.14	41.89	40.13	39.90	39.09	41.54	41.81	42.12	41.41	41.43	40.78
	Difference from overall mean	-0.66	-1.64	+1.11	-0.65	-0.88	-1.69	+0.76	+1.03	+1.34	+0.63	+0.65	
	Resultant additional fire frequencies	-38.979	-96.856	+65.555	-38.388	-51.972	-99.809	+44.885	+60.830	+79.139	+37.207	+38.388	
Rainfall	Annual mean	3.64	2.96	2.48	3.56	2.57	2.85	2.97	3.47	2.67	3.96	2.96	3.10
	Difference from overall mean	+0.54	-0.14	-0.62	+0.46	-0.53	-0.25	-0.13	+0.37	-0.43	+0.86	-0.14	
	Resultant additional fire frequencies	+61.418	-15.923	-70.517	+52.319	-60.281	-28.434	-14.786	+42.083	-48.907	+97.814	-15.923	
All three weather variables	Resultant addition of fire frequencies for 12 months	+289	-1 507	-63	+1 168	-2 357	-1 244	+327	+2 302	-1 023	+1 960	+160	
Fire frequencies obtained from regression		36 745	38 881	37 927	40 996	40 819	43 008	44 150	47 118	52 061	55 712	60 646	

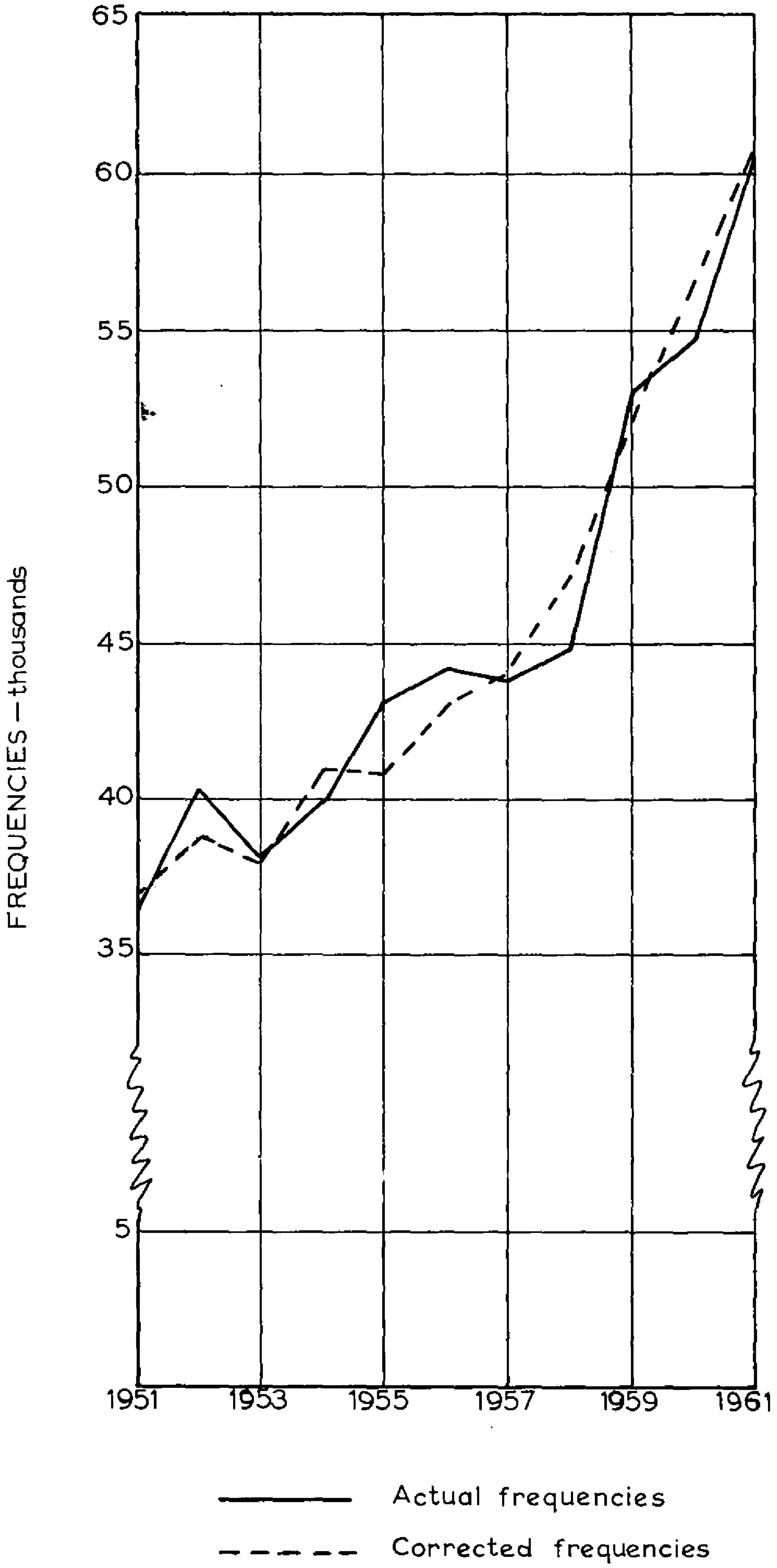

FIG.1. ANNUAL FIRE FREQUENCIES IN BUILDINGS IN ENGLAND AND WALES COMPARED WITH THE CORRECTED FREQUENCIES CALCULATED USING THE ESTIMATED REGRESSION COEFFICIENTS AND THE OVERALL MEAN VALUES FOR SUNSHINE, VAPOUR PRESSURE AND RAINFALL