F.R.Note No. 480
Research Programme
Objective E1/3

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

FIRE HAZARDS OF ELECTRICAL INSTALLATIONS

by

R. E. Lustig

SUMMARY

A special survey of fires associated with electrical equipment was carried out in 1957/58. Of the 9385 reports received from Local Authority Fire Brigades, 6489 referred to electrical appliances; these have been reported on separately. This note deals with the remaining 2896 fires which were reported to be due to wire and cable and equipment forming part of the permanent electrical supply installation, including outdoor fires, but excluding fires in vehicles.

Nearly half the fires occurred in dwellings and 14.3 per cent in commercial premises; 64.5 per cent of the fires were caused by cable or flex.

October, 1961

Fire Research Station,
Boreham Wood,
Herts.

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Introduction

Between September 1, 1957 and August 31, 1958 the Joint Fire Research Organization in co-operation with Local Authority Fire Brigades in Great Britain conducted a survey of all fires associated with electrical equipment to which the Brigades were called, in order to gain more detailed technical data about these fires, which had been increasing steadily in number in recent years. Although this increase seems to be due to fires attributed to electrical appliances, those caused by installation - i.e. wire and cable and equipment forming part of the permanent electrical supply installation - were also included in the survey in view of their large number (an average of 2355 a year for the past ten years), and the concern often expressed about the possible fire danger from ageing wiring. The reverse side of the special questionnaire (Appendix I) was designed in conjunction with the Home Office, H.M. Electrical Inspector of Factories and the Electrical Research Association, to cater for such fires. Some preliminary analyses of the fires associated with appliances have already been dealt with in an earlier paper [1] and this note deals with the installation fires.

The very stability of the number of installation fires, as illustrated in Table 1 by figures of fires caused by wire and cable in buildings, poses a number of queries.

TABLE 1
FIRES ASSOCIATED WITH ELECTRICAL WIRE AND CABLE IN BUILDINGS
GREAT BRITAIN 1947-60

<table>
<tr><th rowspan="2">Year</th><th colspan="3">Number of Fires</th><th rowspan="2">Index 1947 = 100</th></tr>
<tr><th>Lead to apparatus</th><th>Not lead to apparatus</th><th>TOTAL</th></tr>
<tr><td>1947</td><td colspan="2">2556</td><td>2556</td><td>100</td></tr>
<tr><td>1948</td><td colspan="2">2316</td><td>2316</td><td>91</td></tr>
<tr><td>1949</td><td colspan="2">2640</td><td>2640</td><td>103</td></tr>
<tr><td>1950</td><td>288</td><td>1900</td><td>2188</td><td>86</td></tr>
<tr><td>1951</td><td>200</td><td>2456</td><td>2656</td><td>104</td></tr>
<tr><td>1952</td><td>192</td><td>2504</td><td>2696</td><td>105</td></tr>
<tr><td>1953</td><td>255</td><td>2525</td><td>2780</td><td>109</td></tr>
<tr><td>1954</td><td>254</td><td>2344</td><td>2598</td><td>102</td></tr>
<tr><td>1955</td><td>304</td><td>2196</td><td>2500</td><td>98</td></tr>
<tr><td>1956</td><td>248</td><td>2128</td><td>2376</td><td>93</td></tr>
<tr><td>1957</td><td>214</td><td>1810</td><td>2024</td><td>79</td></tr>
<tr><td>1958</td><td>252</td><td>2152</td><td>2404</td><td>94</td></tr>
<tr><td>1959</td><td>192</td><td>2704</td><td>2896</td><td>113</td></tr>
<tr><td>1960</td><td>416</td><td>2732</td><td>2732</td><td>107</td></tr>
</table>

Source:- Statistical Analysis of Reports of Fires [2].

It now seems generally accepted that installation fires are not directly affected by the amount of electricity transmitted and in particular that overloading is a relatively minor cause - this is borne out by this survey and the survey carried out by Gosland[3] and is supported by experimental results [4], but one might expect a connection between the incidence of fires and the extent of installations (i.e. the length of wire and cable energized) and/or the age of installations. If either of these relationships did exist, the number of installation fires might be expected to have increased as installations became more numerous, more extensive and, in aggregate at least, older. This, however, does not appear to have been the case.

Results of Survey

The answers to various parts of the questionnaire are summarized in tabular form in Appendix II, and are largely self explanatory. Items marked with an asterisk were not included on the original self coding questionnaire, but were reported by Brigades under "other than above". They may therefore understate the true position as some Brigades may have coded them under one of the original heads.

Premises

Unlike fires associated with electrical appliances, those attributed to installations show little variation in relative importance in different occupancy groups:-

TABLE 2

FIRES ATTRIBUTED TO ELECTRICAL EQUIPMENT IN BUILDINGS
GREAT BRITAIN 1958

Occupancy	Appliance fires		Wire and cable fires*	
	Number	% of all fires in occupancy	Number	% of all fires in occupancy
Agriculture	60	2.3	108	4.2
Industry	664	10.1	172	2.6
Clubs, hotels, etc.	372	13.4	172	6.2
Dwellings	4108	17.2	1316	5.5
Commerce	1016	23.5	248	5.7
ALL BUILDINGS	6844	13.4	2404	4.7

Source:- Statistical Analysis of Reports of Fires[2].

Dwellings, with 44.1 per cent of the installation fires compared with 57.1 per cent of the appliance fires, were again the largest single group (Appendix IIc).

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*including lead to apparatus

Part of installation failing

As can be seen from Appendix II(d), the majority of the installation fires were caused by failure of cable or flex, accounting for 1867 (64.5 per cent) of the fires. As there were some 16.5 million consumers, this gives an annual rate of 100 fires per million installations. Assuming that each consumer must have also had at least one fuse box and at least one meter, it can be calculated that the 297 fires attributed to the former indicate a rate of (at most) 18 fires per million fuseboxes at risk, and the 29 fires caused by meters show a rate of less than 2 fires per million meters at risk.

There is some considerable difference between the cause pattern for cable and flex on the one hand and other parts of installations on the other:-

TABLE 3

FIRES ASSOCIATED WITH ELECTRICAL INSTALLATIONS
GREAT BRITAIN 1957/8

Part of installation failing / Defect in main conductor	Cable & flex*		Other	
	No.	%	No.	%
Circuit overloaded	113	6.1	120	11.7
Defective contact	73	3.9	227	22.1
Insulation damaged mechanically	494	26.5	62	6.0
Insulation damaged non-mechanically	855	45.8	304	29.5
Other and unknown	332	17.8	316	30.7
TOTAL	1867	100.0	1029	100.0

Source:- Special Report from Local Authority Fire Brigades.

Non-mechanical damage to insulation (e.g. due to moisture, heat, age, chemical action) was the most commonly reported cause of installation fires, accounting for 40.0 per cent. This was the case for both cable and flex (45.8 per cent) and other parts (29.5 per cent). On the other hand, mechanical damage to insulation accounted for 26.5 per cent of the cable and flex fires but only 6.0 per cent of the others, and defective contact which caused 22.1 per cent of the fires in "other" installations caused only 3.9 per cent of the cable and flex ones. Only 6.1 per cent of the cable and flex fires were caused by overloading, despite the great increase in average consumption per installation since most of the installations were first connected(5). This seems practical corroboration of the laboratory experiments carried out by the Joint Fire Research Organization on the extent of overloading required to cause fire (4) in various types of cables. These suggested that a very substantial overloading - at least five times the rated current - was generally required to start a fire, even in cable 36 years old.

In addition to the defects in main conductors, defects in the protective system were reported in just under a quarter of the fires.

*not including lead to apparatus

Of these the majority - 408 - were earth continuity conductors touching gas pipes. Excessive fuzing was reported in only 25 instances, but as this was not a defect specified on the questionnaire, this may be an understatement (Appendix IIm).

Age of installation

As can be seen from figure 1, considerable peaking occurs in the age distribution at five year intervals. This is a well known feature of investigation involving estimates of time intervals and results from the vagaries of human memory. It is possible to reduce the effect of this by taking a five year moving average. The castellated appearance of the moving average curve in figure 1 at the upper end of the age scale is probably due to a coarser approximation to ten year intervals at that stage.

No direct information seems to be available on the age distribution of existing installations, but some estimates can be made from figures published by the Ministry of Power (5) of the number of consumers at the end of each year back to 1920. The net increase during each year may be regarded as an approximation to the number of new installations and hence as an indication of the number of installations of that date now at risk. This procedure has two major disadvantages, both stemming from the fact that no allowance can be made for installations disconnected or rewired. On the one hand this results in an overestimate of the number of older installations since an unknown, though presumably substantial proportion is no longer in existance. On the other hand it leads to an underestimate of the new installations in any year in which old installations went out of use; this will presumably be more important in recent post-war years when slum clearance assumed considerable proportions, and when electricity authorities may have insisted on re-wiring on change of tenancy.

However, bearing these limitations in mind, it is possible to calculate a fire incidence rate for installations of different ages. The need to use moving averages makes the incidence rate a rather blunt statistical tool, but the results of this national survey appear similar to those arrived at in Gosland's regionalized sample (3). Post-war installations in general seem to have a higher incidence rate than pre-war ones (Appendix III Fig.C), probably due, at least in part, to different installation methods, particularly in prefabricated houses (3) and there are indications, (in the same figure) albeit inconclusive, of a higher incidence rate for older pre-war installations, though published data on the number of consumers do not go back far enough to permit an adequate measure of this increase. As far as they go, they tend to corroborate Gosland's findings that there is a relationship between age and fire incidence for pre-war installations, but this in itself does not justify the next assumption sometimes taken - that ageing is a major factor causing fires. As the survey covered only one year, it is impossible to differentiate between the effect of age and the effect of year of installation. Consequently the same sort of apparent relationship could have arisen from a gradual introduction of improved installation methods or equipment during the pre-war period.

Similarly, the higher proportion of fires due to non-mechanical damage to insulation amongst older installations (Table 4) may be due either to progressive deterioration due to ageing, or to a gradual introduction of improved wiring which is less prone to non-mechanical damage to insulation.

TABLE 4

FIRES ASSOCIATED WITH ELECTRICAL INSTALLATIONS
GREAT BRITAIN 1957/58

DEFECT IN MAIN CONDUCTOR AS PERCENTAGE OF FIRES IN EACH AGE GROUP

Defect / Age of installation	Circuit over-loaded	Defective contact	Broken conductor	Insulation damaged mechanically	Insulation damaged non-mechanically	Other & unknown	TOTAL
0-2	9.5	11.9	2.7	28.9	23.1	24.2	100.0
3-7	5.7	15.0	3.0	22.2	31.2	22.5	100.0
8-12	8.4	15.6	2.7	16.8	39.6	17.7	100.0
13-17	7.1	10.8	3.6	16.9	43.4	18.1	100.0
18-22	8.9	11.6	2.6	18.5	43.2	15.5	100.0
23-27	4.8	9.7	4.8	14.5	49.3	16.7	100.0
28-32	9.0	7.9	2.3	10.7	55.4	14.7	100.0
33-37	6.0	-	-	21.0	57.0	12.0	100.0
38-42	13.3	8.9	-	22.2	37.8	17.7	100.0
43+	2.4	9.8	2.4	12.2	63.4	9.8	100.0
Unknown	8.1	8.1	1.7	19.2	40.6	22.5	100.0
TOTAL	8.0	10.4	2.4	19.2	40.0	20.3	100.0

Source:- Special reports from Fire Brigades.

Some support for the latter may be found in the fact that prior to the 1930's the rubber compounds used for insulation did not contain anti-oxidants and were therefore more liable to perish (discussion on Gosland's paper).

If it were accepted that ageing is a factor affecting fire incidence, and in particular, if Gosland's conclusions were accepted that the relationship is a linear one - 7 fires per million installations at risk per year of age - a new problem would be posed. Namely, why has there not been a marked increase in the number of installation fires in recent years. At the beginning of the last war there were over 10.5 million consumers; assuming that only 10 million of these installations are still at risk one would expect an annual increase of 70 fires, even ignoring the net increase of over 6 million installations by 1958. As has already been seen (Table 1), this has not happened. Gosland's conclusions could only be reconciled with actual fire records in recent years under conditions of very heavy scrapping of old installations - so heavy, that the aggregate age of installations remained stable.

Time related variations

Although no long term trend can be ascertained, there are signs of marked seasonal and hourly variations, as yet unexplained. As can be seen from figure 2, there is a similarity between seasonal variations in the frequency distributions for electrical fires and for electricity generation, except that whereas the latter is at a minimum in July/August, electrical fires (both installation and appliance ones) seem to reach a second peak in this period. It has so far not been possible to explain this summer peak. One possible factor that has been investigated is that of outdoor fires, but both indoor and outdoor fires have a similar peaked distribution.

There also seems to be some relationship between installation fires and electricity consumption on an hourly basis - at least peak fire periods seem to coincide with known peak consumption periods at lunch time and early evening. Unfortunately, no other information on hourly power consumption seems to be available. Moreover, there is a marked similarity between the distribution pattern for installation and appliance fires; in fact, only between 9 a.m. and 11 a.m. is there any significant difference. It is probably fair to assume the frequency distribution for electrical appliance fires is a reasonable approximation to the consumption pattern (if only because appliances are more likely to cause a fire when "on"). If this assumption is correct, it would suggest a fairly close relationship between power consumption and installation fires.

The apparent relationship between installation fires and power consumption on an hourly, and possibly on a seasonal basis, is a little difficult to understand in view of the apparent lack of relationship between these variables on a long term basis. The relationship could be more apparent than real, and if not entirely coincidental, at least indirect and due to a common third factor. One such factor could arise if installation were more prone to start fires when actually passing current rather than when only energized, without current passing. If this were the case, most fires would tend to occur when the largest number (or longest extent) of installations were passing current, which, for obvious reasons would tend to coincide with the periods of maximum consumption. However, laboratory experiments would be required to confirm this hypothesis.

Labour used for installation

Of all the fires 6.4 per cent were reported to have occurred in parts of installations attributed to amateur labour (Appendix II(f)). Although no information is available on the relative incidence of amateur and professional installations it seems that the proportion of fires amongst amateur installations is rather high.

The age distribution of amateur installations in which fires occurred suggests that these tend to be newer than their professionally installed counterparts (Table 5). This, indeed, might be expected as the do-it-yourself vogue, particularly in relation to electricity, is a comparatively recent innovation. This age disparity may in part explain the higher proportion of fires caused by mechanically damaged insulation among the amateur installations, (Table 6) as it has been shown in Table 4 that newer installations tend to have a higher proportion of fires caused by mechanical damage to insulation.

TABLE 5

FIRES ASSOCIATED WITH ELECTRICAL INSTALLATIONS
GREAT BRITAIN 1957/8

AGE OF AMATEUR INSTALLATIONS CAUSING FIRE

Age	Number of fires		Amateur as proportion of total %
	Amateur Installation	All installations	
0-5	52	534	9.7
6-10	21	334	6.3
11-20	26	427	6.1
21+	13	575	2.2

Source:- Special reports from Fire Brigades.

TABLE 6

FIRES ASSOCIATED WITH ELECTRICAL INSTALLATIONS
GREAT BRITAIN 1957/58

LABOUR USED IN INSTALLATION AND CAUSE OF FIRE

Defect / Labour used	Professional	Amateur	Both	Unknown	TOTAL
Circuit overloaded	180	15	2	30	227
Defective contact	268	19	1	18	306
Broken conductor	60	4	-	6	70
Insulation damaged mechanically	446	59	1	50	556
Insulation damaged non-mechanically	1005	67	6	81	1159
Other and unknown	490	20	3	65	578
TOTAL	2449	184	13	250	2896

Source:- Special reports from Fire Brigades.

Conclusions

Overloading, particularly overloading of cable and flex has again been shown to be a relatively minor cause of fire. Damage to insulation, especially non-mechanical damage, emerged as the most important single cause, being attributed with nearly three quarters of the cable and flex fires.

Some correlation appears to exist between the incidence rate of fires and the age of installations, but it has not been established as a cause and effect relationship. The fact that non-mechanical damage was proportionately more frequent among the older installations, tends to lend some support to this belief, though by no means conclusive support.

There appears to be no long term relationship between electricity consumption and installation fires. Despite the rapid increase in the former, fires have remained at a fairly steady level. On the other hand, there are indications that installation fires and electricity consumption have hourly frequency distributions.

Amateur installations were reported to have caused 6.4 per cent of the fires. Although no data are available to indicate the relative extent of professional and amateur wiring, the proportion of installation fires caused by the latter does seem rather high. Amateur installations reported in the survey tended to be newer than professional ones, which might be expected, and a significantly high proportion occurred as a result of mechanical damage to insulation, which seems rather surprising.

Acknowledgement

Acknowledgement is due to members of the Fire Brigades who undertook the additional task of completing questionnaires on which this survey is based.

Thanks are also due to Miss M.Weston, formerly of the Statistics Unit of the Joint Fire Research Organization who carried out most of the tabulation work, and to other members of the unit who prepared the data for analysis.

References.

1. LUSTIG, R. E. Fire Hazards of Electrical Apparatus. I. Some preliminary analyses. Joint Fire Research Organization F.R.Note. No. 454

2. Statistical Analysis of Report of Fires Attended by Fire Brigades in the United Kingdom. Joint Fire Research Organization Annual.

3. GOSLAND, L. Age and the Incidence of Fires in Electrical Installations. Institution of Electrical Engineers Proceedings Vol. 103, Part A, No.9 June 1956

4. LAWSON, D. I. and McGUIRE, J. H. Fires due to Electrical Cables. Joint Fire Research Organization F.R.Note. No. 55/1953.

5. Statistical Digest Annual. Ministry of Power. London, H.M.Stationery Office.

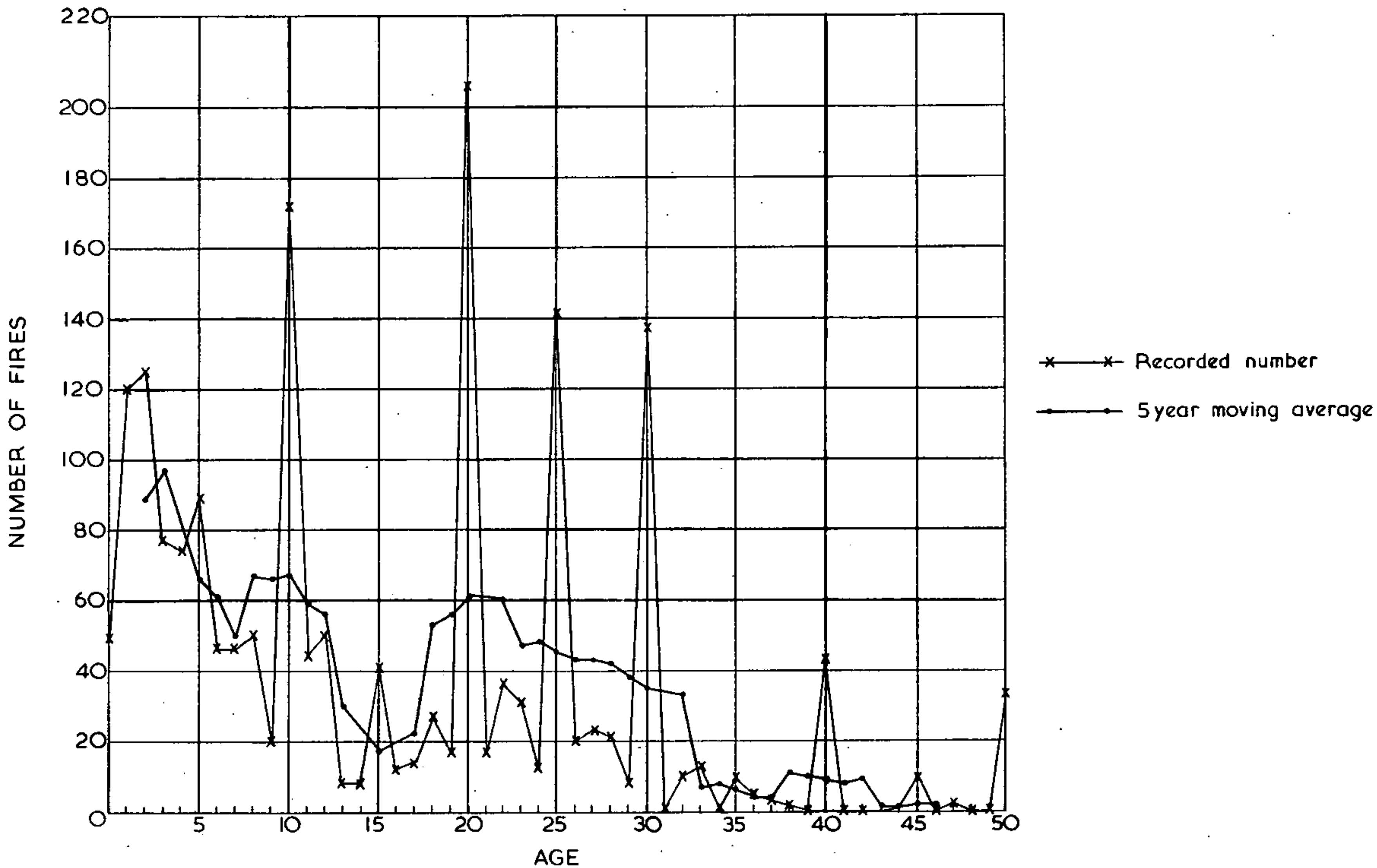

FIG. 1. FIRES ASSOCIATED WITH ELECTRICAL INSTALLATION – AGE OF INSTALLATION GREAT BRITAIN 1957 – 1958

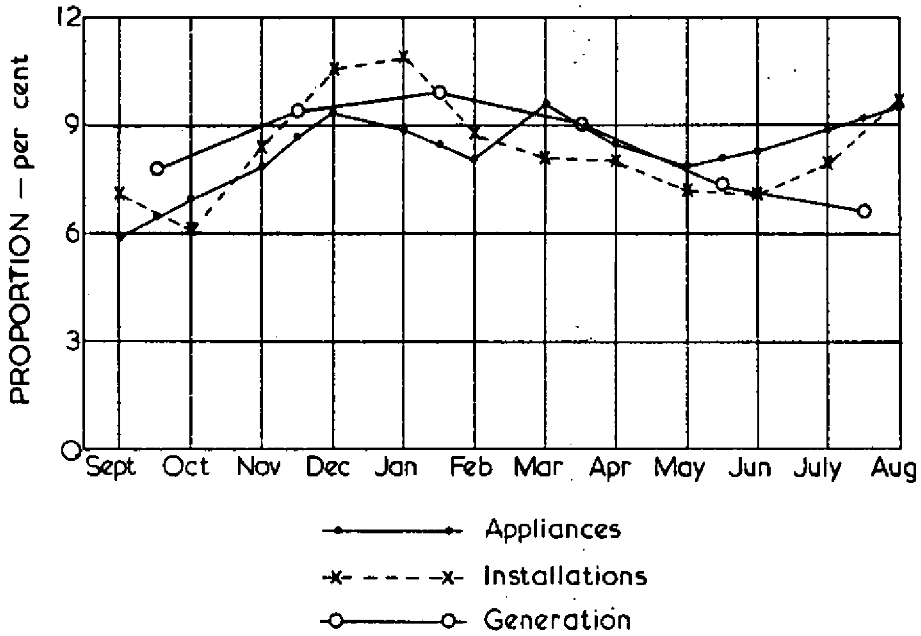

FIG. 2. FIRES ASSOCIATED WITH ELECTRICAL EQUIPMENT GREAT BRITAIN 1957 - 1958 - MONTH OF OCCURRANCE

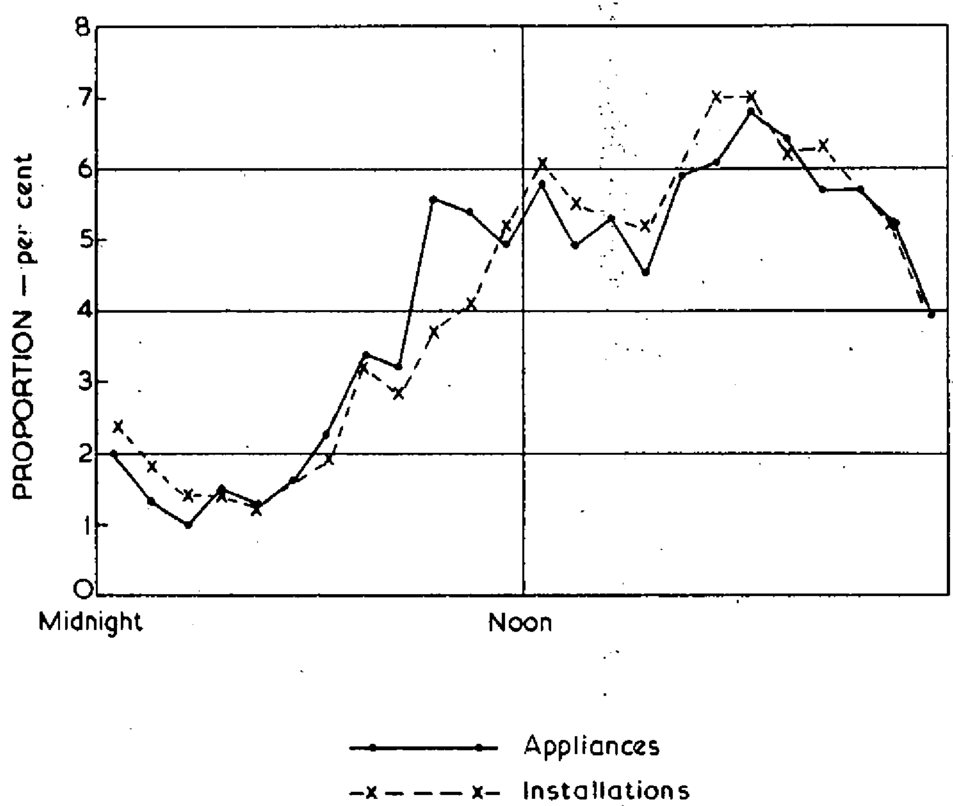

FIG. 3. FIRES ASSOCIATED WITH ELECTRICAL EQUIPMENT GREAT BRITAIN 1957 - 1958 - HOUR OF OCCURRANCE

F.R. 480

1/4341

APPENDIX I

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

19 Cornwall Terrace,
London, N.W.1

REPORT OF ELECTRICAL FIRE

This side of form to be used for reporting fires due to wire and cable and equipment forming part of permanent electrical supply installation, including outdoor fires but excluding fires in vehicles

Code	ITEM	Cols.
	Fire Brigade........	1-3
	K.433 No........	4-7
	Date	8-13
	Day of week........	14
	Time of discovery........	15-16
	PREMISES	17-18
00	House	
01	Flat built as flat	
02	Flat in converted house	
03	Club, hotel, restaurant, etc.	
04	Office	
05	Shop or showroom	
06	Warehouses, wholesale dealers	
07	School, college	
08	Hospital, home, institution	
09	Factory, workshop, other industrial premises	
	Other than above........	
	LOCATION OF FAILURE	19
0	Indoor	
1	Outdoor	
	PART OF INSTALLATION FAILING	20-21
00	Cable or flex	
01	Ceiling rose	
02	Circuit breaker	
03	Fusebox (metal)	
04	Fusebox (bakelite, plastic)	
05	Fusebox (other than above)	
06	Joint box (compound filled)	
07	Joint box (not filled)	
08	Plain socket	
09	Switch socket	
10	Switch	
11	Distribution board	
	Other than above........	
	AGE OF INSTALLATION	22-23
	Age in years........	
99	Unknown	
	TYPE OF LABOUR USED FOR INSTALLATION	24
0	Professional	
1	Amateur	
2	Unknown	
	TYPE OF FUSE	25
0	Enclosed	
1	Open	
2	Cartridge	
3	Miniature circuit breaker	
4	Enclosed fuse with earth-leakage circuit breaker	
5	Open fuse with earth-leakage circuit breaker	
6	Cartridge fuse with earth-leakage circuit breaker	
7	Miniature circuit breaker with earth-leakage circuit breaker	
	Other than above........	
	SIZE OF FUSE OR RATING OF CIRCUIT BREAKER	26-27
	Amps........	
99	Unknown	

Code	ITEM	Cols.
	TYPE OF WIRING CAUSING FIRE	28
0	V.R. lead covered	
1	V.R. other than lead covered	
2	T.R.S.	
3	P.V.C. or other plastic covered	
4	Flexible cable (flex)	
5	Temporary wiring	
	Other than above........	
	PROTECTION OF CABLE	29
0	Unprotected	
1	Casing and capping	
2	Steel conduit	
3	Plastic conduit	
4	Ducting	
	Other than above........	
	SIZE OF CONDUCTOR — Size / Current Rating	30-31
00	1/.044 — 6.1 amps	
01	3/.029 — 7.8 ,,	
02	3/.036 — 12.0 ,,	
03	7/.029 — 18.2 ,,	
04	7/.036 — 24.0 ,,	
05	7/.044 — 31.0 ,,	
06	7/.052 — 36.8 ,,	
07	Other cables with 7 strands or less	
08	Cables with more than 7 strands	
99	Unknown	
	DEFECT IN MAIN CONDUCTORS	32-33
00	Circuit overloaded	
01	Defective contact	
02	Broken conductor	
03	Insulation damaged mechanically e.g. by chafing and piercing	
04	Insulation damaged from other causes e.g. moisture, heat, age, chemical action	
	Other than above........	
99	Unknown	
	DEFECT IN PROTECTIVE SYSTEM	34-35
00	Defective contact in earthing circuit	
01	Earth continuity conductor touching gas pipe	
02	Earth fault not associated with gas pipe	
	Other than above........	
99	None	
	SEAT OF GENERATION OF HEAT CAUSING FIRE	36
1	Any defect in main conductors	
2	Any defect in protective system	
	EXTINCTION OF FIRE	37
1	Fire died out	
2	Fire extinguished before arrival of Fire Brigade	
3	Fire tackled before arrival of Fire Brigade, extinguished by Brigade	
4	Fire not tackled before arrival of Fire Brigade, extinguished by Brigade	

REPORT OF ELECTRICAL FIRE

This side of form to be used for reporting fires due to electrical apparatus, including outdoor fires but excluding fires in vehicles.

Code	ITEM	Cols.
	Fire Brigade........................	1-3
	K.433 No........................	4-7
	Date	8-13
	Day of week........................	14
	Time of discovery........................	15-16
	PREMISES	17-18
00	House	
01	Flat built as flat	
02	Flat in converted house	
03	Club, hotel, restaurant, etc.	
04	Office	
05	Shop or showroom	
06	Warehouses, wholesale dealers	
07	School, college	
08	Hospital, home, institution	
09	Factory, workshop, other industrial premises	
	Other than above........................	
	....	
	LOCATION OF FAILURE	19
0	Indoor	
1	Outdoor	
	APPARATUS PRIMARILY INVOLVED	20-21
00	Boiling ring	
01	Cooker, oven (domestic)	
02	Drier (other than oven)	
03	Hot-plate	
04	Kettle	
05	Oven (industrial)	
06	Fire (guarded)	
07	Fire (unguarded)	
08	Heater (convection)	
09	Heater (off peak storage type)	
10	Radiator or tubular heater	
11	Lamp (portable)	
12	Light or light fitting (fixed)	
13	Fluorescent lighting (or choke)	
14	Immersion heater	
15	Water heater (other than immersion)	
16	Radio or radiogram	
17	Television	
18	Accumulator	
19	Blanket or bed-warmer	
20	Iron	
21	Motor	
22	Motor controller	
23	Plug, adaptor or connector	
24	Projector	
25	Refrigerator (compressor type)	
26	Refrigerator (heater type)	
27	Thermostat or thermal relay	
28	Transformer	
29	Washing machine	
30	Welding apparatus	
31	Wire or cable (lead to apparatus)	
	Other than above........................	
	....	
	....	
	INDICATOR LAMP	22
0	Pilot lamp fitted	
1	No pilot lamp	

Code	ITEM	Cols.
	THERMOSTATIC CONTROLS	23
0	Thermostat fitted	
1	No thermostat	
	POWER TAKEN BY APPARATUS	
	(a) Watts........................	24-27
	or (b) Horse power........................	28-30
	FUSE IN CIRCUIT FEEDING APPARATUS	31-32
	Size of fuse amps........................	
99	Unknown	
	MAKE OF APPARATUS	33-34
	Maker's name........................	
	....	
99	Unknown	
	AGE OF APPARATUS	35-36
	Age in years........................	
99	Unknown	
	ALLOCATION OF FAULT	37
0	Fault in equipment	
1	Fault in installing or connecting equipment	
2	Improper or careless use	
	Other causes........................	
	....	
99	Unknown	
	CAUSE OF FIRE	38-39
00	Heating due to bad contact	
01	Heating due to defective insulation	
02	Overheating other than by overloading	
03	Overloading	
04	Short circuit by mechanical defect or external agency	
05	Earth fault leading to generation of heat elsewhere	
06	Direct contact with combustible material	
07	Ignition of combustible material without direct contact	
	Other causes........................	
	....	
	....	
99	Unknown	
	SPREAD OF FIRE	40
1	Fire confined to apparatus of origin	
	Fire spread beyond apparatus of origin	
2	damaging-structure only	
3	-contents only	
4	-structure and contents	
	EXTINCTION OF FIRE	41
1	Fire died out	
2	Fire extinguished before arrival of Fire Brigade	
3	Fire tackled before arrival of Fire Brigade, extinguished by Brigade	
4	Fire not tackled before arrival of Fire Brigade, extinguished by Brigade	

(2170) Wt.54990/6 5M. 12/57 M.P.Ltd. Gp. 722.

APPENDIX II

FIRES ASSOCIATED WITH ELECTRICAL INSTALLATIONS GREAT BRITAIN 1957/8

SUMMARY OF QUESTIONNAIRE REPLIES

(a) Month when fire occurred

		England and Wales	Scotland	TOTAL	
				No.	%
1957	September	189	18	207	7.1
	October	157	21	178	6.1
	November	215	28	243	8.4
	December	276	30	306	10.6
1958	January	281	36	317	10.9
	February	222	32	254	8.8
	March	208	26	234	8.1
	April	213	18	231	8.0
	May	190	19	209	7.2
	June	186	19	205	7.1
	July	204	28	232	8.0
	August	262	18	280	9.7
	TOTAL	2603	293	2896	100.0

(b) Time of discovery

	England and Wales	Scotland	TOTAL	
			No.	%
Midnight to 12.59 a.m.	49	10	59	2.0
1.00 to 1.59 a.m.	31	7	38	1.3
2.00 to 2.59 a.m.	25	4	29	1.0
3.00 to 3.59 a.m.	38	5	43	1.5
4.00 to 4.59 a.m.	33	4	37	1.3
5.00 to 5.59 a.m.	37	8	45	1.6
6.00 to 6.59 a.m.	56	11	67	2.3
7.00 to 7.59 a.m.	95	4	99	3.4
8.00 to 8.59 a.m.	84	8	92	3.2
9.00 to 9.59 a.m.	152	10	162	5.6
10.00 to 10.59 a.m.	140	17	157	5.4
11.00 to 11.59 a.m.	136	7	143	4.9
Noon to 12.59 a.m.	150	18	168	5.8
1.00 to 1.59 p.m.	130	11	141	4.9
2.00 to 2.59 p.m.	135	18	153	5.3
3.00 to 3.59 p.m.	116	15	131	4.5
4.00 to 4.59 p.m.	153	19	172	5.9
5.00 to 5.59 p.m.	157	21	178	6.1
6.00 to 6.59 p.m.	180	17	197	6.8
7.00 to 7.59 p.m.	170	16	186	6.4
8.00 to 8.59 p.m.	151	14	165	5.7
9.00 to 9.59 p.m.	146	20	166	5.7
10.00 to 10.59 p.m.	134	17	151	5.2
11.00 to 11.59 p.m.	102	12	114	3.9
Unstated	3	–	3	0.1
TOTAL	2603	293	2896	100.0

(c) Premises

	England and Wales	Scotland	TOTAL No	TOTAL %
DWELLINGS				
Flat built as flat	64	69	133	4.6
Flat in converted house	92	7	99	3.4
House	929	100	1029	35.5
*Private Garage	16	1	17	0.6
TOTAL	1101	177	1278	44.1
COMMERCIAL				
Office	62	4	66	2.3
Shop or showroom	266	38	304	10.5
Warehouse, wholesaler	40	3	43	1.5
TOTAL	368	45	413	14.3
INDUSTRIAL				
TOTAL	221	9	230	7.9
PUBLIC BUILDINGS				
Club, Hotel Restaurant	114	16	130	4.5
*Cinema, Theatre etc	15	2	17	0.6
*Municipal Buildings	7	-	7	0.2
*Place of worship	25	2	27	0.9
TOTAL	161	20	181	6.2
AGRICULTURE				
TOTAL	61	3	64	2.2
HOSPITAL, HOME, INSTITUTION				
TOTAL	34	1	35	1.2
TRANSPORT				
*Transport and Communication	29	1	30	1.0
*Petrol Pump	-	-	-	
*Ship	10	1	11	0.4
*Mobile apparatus outdoors	1	-	1	0.0
*Railway power cables	10	1	11	0.4
*Trolley's tram cables	16	-	16	0.6
TOTAL	66	3	69	2.4
SCHOOL, COLLEGE				
TOTAL	24	1	25	0.9
PUBLIC UTILITIES				
*Electricity sub-station	105	3	108	3.7
*Gas, water, sewage	3	-	3	0.1
*Junction box in street	45	-	45	1.6
*Mains cable (overhead)	69	1	70	2.4
*Mains cable (in road)	100	8	108	3.7
*Power station	3	-	3	0.1
*Street distribution box	37	5	42	
TOTAL	362	17	379	13.1

(c) Premises (continued)

	England and Wales	Scotland	TOTAL No	TOTAL %
MISCELLANEOUS				
*Fire and Service premises	15	2	17	1.5
*Premises being built or demolished	7	-	7	0.6
*Doctor, dentist, etc	2	1	3	0.1
*Shed, hut, glass house	19	3	22	0.8
*Street lamp standard	79	5	81	2.9
*Other outdoor hazard	80	6	86	3.0
*Other Buildings	2	-	2	0.1
TOTAL	204	17	221	7.6
UNKNOWN	1	-	1	0.0
GRAND TOTAL	2603	293	2896	100.0

(d) Part of installation failing

	England and Wales	Scotland	TOTAL No	TOTAL %
CABLE FLEX				
TOTAL	1656	211	1867	64.5
FUSEBOX CIRCUIT BREAKER				
Circuit breaker	58	-	58	2.0
Fusebox (metal)	125	18	143	4.9
Fusebox (plastic)	83	5	88	3.0
Fusebox (other)	60	6	66	2.3
TOTAL	326	29	355	12.3
JUNCTIONS, ETC				
Joint box (compound filled)	94	7	101	3.5
Joint box (not filled)	33	7	40	1.4
*Joint block	15	-	15	0.5
Distribution board	109	9	118	4.1
TOTAL	251	23	274	9.5
SWITCHES, SOCKETS				
Plain socket	30	2	32	1.1
Switch socket	30	8	38	1.3
Switch	107	12	119	4.1
TOTAL	167	22	189	6.5
TRANSFORMER RECTIFIER				
*TOTAL	61	1	62	2.1
METER				
*TOTAL	28	1	29	1.0
SUNDRY				
Ceiling rose	17	-	17	0.6
*Gauge absorber	4	-	4	0.1
*Insulator	7	1	8	0.3
*Relay	2	-	2	0.1
*Cutout isolator	13	-	13	0.4
Other	39	1	40	1.4
TOTAL	82	2	84	2.9
UNKNOWN	32	4	36	1.2
GRAND TOTAL	2603	293	2896	100.0

(e) Age of Installation

	England and Wales	Scotland	TOTAL No	TOTAL %
less than 1 year	46	3	49	1.7
1 year - less than 2 years	110	10	120	4.1
2 years- less than 3 years	123	2	125	4.3
3 years- less than 4 years	72	5	77	2.7
4 years- less than 5 years	69	5	74	2.6
5 years- less than 6 years	81	8	89	3.1
6 years- less than 7 years	39	7	46	1.6
7 years- less than 8 years	39	7	46	1.6
8 years- less than 9 years	44	6	50	1.7
9 years- less than 10 years	18	2	20	0.7
10 years- less than 11 years	154	18	172	5.9
11 years- less than 21 years	381	46	427	14.7
21 years- less than 31 years	404	42	446	15.4
31 years- less than 41 years	84	4	92	3.2
41 years- less than 51 years	30	-	30	1.0
51 years- less than 61 years	11	-	11	0.4
Unknown age	898	128	1026	35.4
TOTAL	2603	293	2896	100.0

(f) Type of Labour used for installation

	England and Wales	Scotland	TOTAL No	TOTAL %
Professional	2211	238	2449	84.6
Amateur	172	13	185	6.4
Unknown	208	41	249	8.6
*Both professional & amateur	12	1	13	0.4
TOTAL	2603	293	2896	100.0

(g) Type of Fuse

	England and Wales	Scotland	TOTAL No	TOTAL %
Enclosed	1130	168	1298	44.8
Open	646	67	713	24.6
Cartridge	331	25	356	12.3
Miniature circuit breaker	16	6	22	0.8
Enclosed with earth-leakage circuit breaker	34	1	35	1.2
Open with earth-leakage circuit breaker	13	-	13	0.4
Cartridge with earth-leakage circuit breaker	20	1	21	0.7
Miniature circuit breaker	10	2	12	0.4
*Other circuit breaker	116	3	119	4.1
*Relay	5	-	5	0.2
*Solid Fuse	8	1	9	0.3
*C.T.C.	2	-	2	0.1
*Fusible link	2	-	2	0.1
*Fuse isolator	1	-	1	0.0
*More than one type	5	-	5	0.2
*Other & unknown	264	19	283	9.8
TOTAL	2603	293	2896	100.0

(h) Size of Fuse or Rating of circuit breaker

	England and Wales	Scotland	TOTAL No	TOTAL %
less than 3 amps	26	2	28	1.0
3 amps - less than 8 amps	384	47	431	14.9
8 amps - less than 13 amps	180	19	199	6.9
13 amps - less than 18 amps	593	106	699	24.1
18 amps - less than 23 amps	59	3	62	2.1
23 amps - less than 28 amps	27	4	31	1.1
28 amps - less than 33 amps	246	30	276	9.5
33 amps - less than 38 amps	5	1	6	0.2
38 amps - less than 43 amps	17	2	19	0.7
43 amps - less than 48 amps	11	2	13	0.4
48 amps - less than 53 amps	14	1	15	0.5
53 amps - less than 58 amps	3	-	3	0.1
58 amps - less than 63 amps	178	14	192	6.6
63 amps - less than 150 amps	72	8	80	2.8
150 amps - less than 250 amps	71	5	76	2.6
250 amps - less than 350 amps	76	4	80	2.8
350 amps - less than 450 amps	48	2	50	1.7
450 amps - less than 1000 amps	36	2	38	1.3
1000 amps - above	40	2	42	1.5
Unknown	517	39	556	19.2
TOTAL	2603	293	2896	100.0

(i) Type of wiring causing fire

	England and Wales	Scotland	TOTAL	
			No	%
V.R. lead covered	352	105	457	15.8
V.R. not lead covered	724	83	807	27.9
T.R.S.	542	42	584	20.2
P.V.C. or other plastic cover	122	16	138	4.8
Flexible cable	209	13	222	7.7
Temporary wiring	33	2	35	1.2
*Steel tape armoured	150	12	162	5.6
*Bitumen covered	35	-	35	1.2
*Cotton covered	5	-	5	0.2
*Asbestos covered	8	1	9	0.3
*Enamelled	1	-	1	0.0
*Glass covered	1	-	1	0.0
*Jute covered	4	-	4	0.1
*Copper sheathed	4	-	4	0.1
*Pyrotenex	3	-	3	0.1
*Marconite	3	-	3	0.1
*Whethertex	2	-	2	0.1
*Bus-bar	11	2	13	0.4
*Uncovered	25	-	25	0.9
*More than one type	43	3	46	1.6
*Unknown or not applicable	326	14	340	11.7
TOTAL	2603	293	2896	100.0

(j) Protection of Cable

	England and Wales	Scotland	TOTAL	
			No	%
Unprotected	1688	203	1891	65.3
Casing and capping	67	3	70	2.4
Steel conduit	441	65	506	17.5
Plastic conduit	10	2	12	0.4
Ducting	133	11	144	5.0
*Earthenware pipes	8	-	8	0.3
*Cast iron pipes or ducting	5	-	5	0.2
*Bitumen troughing	19	-	19	0.7
*Glazed porcelain	3	-	3	0.1
*Rubber sleeving	3	-	3	0.9
*More than one type	19	3	22	0.8
Unknown or not applicable	207	6	213	7.4
TOTAL	2603	293	2896	100.0

(k) Size of Conductor

Size	Current rating	England and Wales	Scotland	TOTAL No.	TOTAL %
1/.044	6.1 amps	188	6	194	6.7
3/.029	7.8 amps	407	56	463	16.0
3/.036	12.0 amps	113	61	174	6.0
7/.029	18.2 amps	330	44	374	12.9
7/.036	24.0 amps	101	22	123	4.2
7/.044	31.0 amps	153	9	162	5.6
7/.052	36.8 amps	38	6	44	1.5
Other cables with 7 strands or less		236	22	258	8.9
Cables with more than 7 strands		436	27	463	16.0
*Two or more conductors		96	8	104	3.6
Unknown		505	32	537	18.5
TOTAL		2603	293	2896	100.0

(l) Defect in Main Conductor

Defect	England and Wales	Scotland	TOTAL No.	TOTAL %
Circuit overloaded	202	31	233	8.0
Defective contact	274	26	300	10.4
Broken conductor	63	7	70	2.4
Insulation damaged - mechanically	497	59	556	19.2
Insulation damaged -non "	1046	113	1159	40.0
*Faulty fusing	4	-	4	0.1
*Short circuit	40	7	47	1.6
*Defective temporary wiring	2	-	2	0.1
*Overloading due to fuse failure	2	-	2	0.1
*Overheating	14	-	14	0.5
*Lighting	41	-	41	1.4
*Accident	9	-	9	0.3
*Voltage surge	2	-	2	0.1
Unknown or not applicable	407	50	457	15.8
TOTAL	2603	293	2896	100.0

(m) Defect in Protective system

Defect	England and Wales	Scotland	TOTAL No.	TOTAL %
Defective contact in earth circuit	126	11	137	4.7
Earth Continuity conductor touching gas pipe	308	100	408	14.1
Earth fault not associated with gas pipe	110	13	123	4.2
*Excessive fusing	19	6	25	0.9
*No earth	3	-	3	0.1
*Fuse failure at power station	1	-	1	0.0
Other	4	-	4	0.1
None	2032	163	2195	75.8
TOTAL	2603	293	2896	100.0

(n) Extinction of fire

Method of extinction	England and Wales	Scotland	TOTAL No.	TOTAL %
Fire died out	488	24	512	17.7
Fire extinguished before arrival of Fire Brigade	393	39	432	14.9
Fire tackled before - extinguished by the Fire Brigade	492	56	548	18.9
Fire not tackled before - extinguished by Fire Brigade	1230	174	1404	48.5
TOTAL	2603	293	2896	100.0

APPENDIX III

CALCULATION OF FIRE INCIDENCE RATE

(a) Age of installation involved in fire

The age as reported by the Fire Brigade showed a distinct tendency to congregate at five and ten year intervals. This was taken to be the result of approximating ages only vaguely remembered to the nearest five or ten years, and has been countered by the use of five year moving averages, which smooth out the regular undulations in the age distribution curve, and provides a less biased estimate of the age of installations.

(b) Number of installations at risk

No figures are published on the age distribution of installations at risk at any one time, but the Ministry of Power published the number of consumers (estimated prior to 1927) at the end of each year back to 1920, and the net increase in any one year has been accepted as an estimate of the number of new consumers in that year. As a five year average is necessary for the age distribution, it must also be adopted for the number at risk.

(c) Incidence rate

At this stage, the two distributions are non-comparable, as an installation of a given age (in whole years) at some unspecified point in the survey may have been installed in one of three calendar years. For instance, an installation reported as one year old may have been installed as long ago as September 1955 - α on Fig.A (if the fire occurred on the first day of the survey and the installation was one day short of its second birthday) or as recently as August 1957 - β on Fig.A (if the fire occurred on the last day of the survey which was also the installation's first anniversary). Conversely, an installation put in in 1955 may have been only one year old if the fire occurred at the beginning of the survey, and the date of the installation was the end of 1955, or it may have been as old as three years if the fire started at the end of the survey and the equipment had been installed at the beginning of 1955.

From the crude data available from an analysis of the age of installations it is only possible to estimate the date of installation within the broad band of the shaded area in figure A, but if information were available on the exact age (say to the nearest day), a straight line relationship between age and date of installation could be plotted for each day of the survey. Thus line AA represents the age/date relationship for the first day of the survey and line BB represents the age/date relationship for the last day; consequently, the double shaded area between the two lines represent the age/date relationship for the whole period of the survey.

From this it is possible to calculate the probability of an installation of a given age being installed in a given year (See figure B)

Year		
1958- n	Pk_n	= .22
1958-(n+1)	Pk_n	= .72
1958-(n+2)	Pk_n	= .06

where n denotes the age (in years) and Pk_n the probability that an installation n years old was installed in a given year. The probability for all other years is, of course, zero (assuming accurate reporting of ages).

Conversely it is also possible to calculate the probability that an installation installed in a given year was of a given age during the survey:-

Age			
1958 - k	Pn_k	=	.22
1958 -(k+1)	Pn_k	=	.72
1958 -(k+2)	Pn_k	=	.06

where k denotes the year of installation and Pn_k the probability that equipment installed in year k was a given age during the survey. Again the probability for other ages must be zero.

The above calculations are based on the assumptions that

(a) installations were commissioned at a steady rate within each year, and
(b) that fires occurred at a steady rate during the survey.

In fact (b) does not obtain, as the monthly incidence was low in the first part of the survey and consequently the probability that the equipment was installed in the first of the three years is slightly lower:-

Year			Age
1958 - n	Px_n = .22 = Px_k		1958 - k
1958 -(n+1)	Px_n = .73 = Px_k		1958 - (k+1)
1958 -(n+2)	Px_n = .05 = Px_k		1958 - (k+2)

Assumption (a) may also be inaccurate, but no information is available.

Having these probability ratios, it is possible to apportion installations in each age group to one of three years or conversely, those installed in each year to one of three age groups. Both methods have been tried and the results are illustrated in Fig.C.

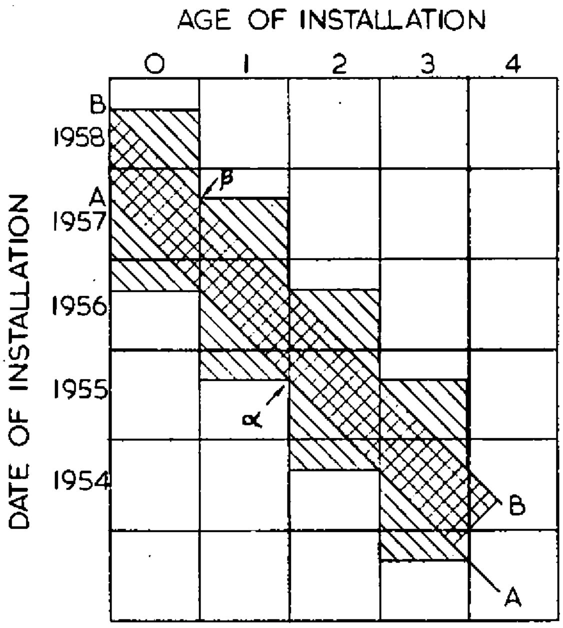

FIG. A. APPENDIX III. AGE & DATE OF INSTALLATION

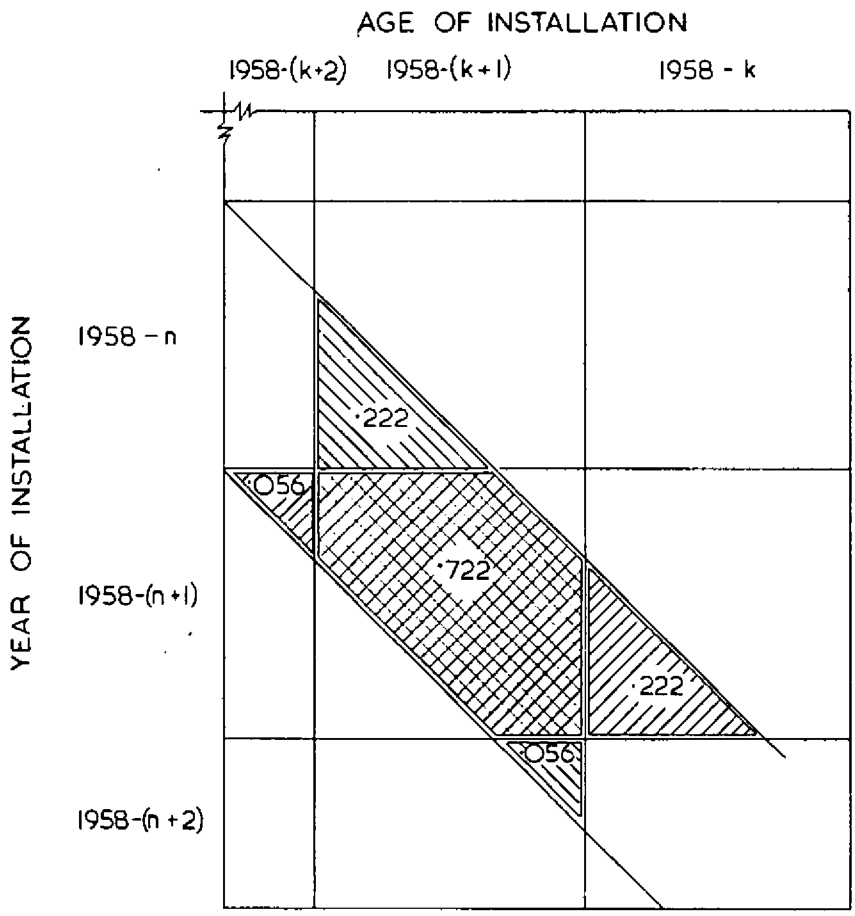

FIG. B. APPENDIX III. AGE & PROBABLE YEAR OF INSTALLATION

F.R. 480

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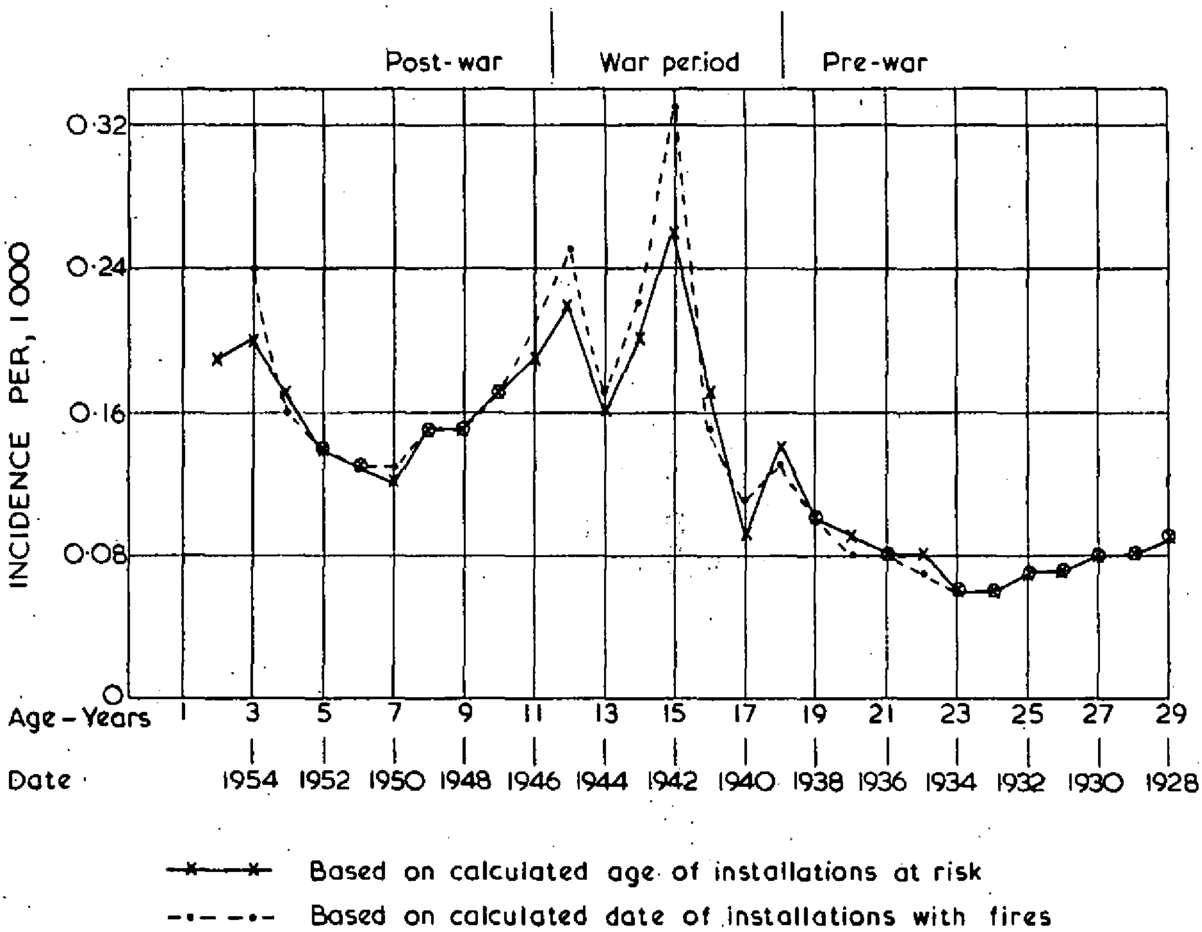

FIG. C. FIRES ASSOCIATED WITH ELECTRICAL INSTALLATIONS INCIDENCE RATES GREAT BRITAIN 1957–1958