Fire Research Note No. 882

THE SURVEY OF FIRES IN BUILDINGS
FIRE SURVEY GROUP. FIRST REPORT OCTOBER 1971

by

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October 1971

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SUMMARY

Fire is still a comparatively young science and over the past years the main aim of the Fire Research Station has been to establish a basic theory of fire behaviour: the work on 'Ignition and Growth' and 'Fires in Compartments' are examples of what has been achieved in this direction. The task for the future is to apply the basic theory to the practical problems of fire protection related to the sophisticated planning, constructional techniques, services and contents of our present day buildings. The achievement of this aim will require considerable effort in experimental research. However, the limitations of laboratory experiments are such that it will be necessary to reinforce this work by observation of the behaviour of actual fires in buildings and effects of fires upon buildings. Only in this way can the value of existing and proposed building regulations and means of escape requirements be properly assessed and rationalised.

In April 1970 the Fire Research Station set up a Fire Survey Group and commenced a pilot exercise in surveying actual fires to investigate the possibilities of obtaining the required information. This report gives an account of the organisation of the group, the nature of the information obtained from the pilot exercise and analyses some of the first results.

KEY WORDS: Fire, survey, building

DEPARTMENT OF THE ENVIRONMENT AND FIRE OFFICES' COMMITTEE

JOINT FIRE RESEARCH ORGANIZATION

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1. INTRODUCTION

The main source of our information regarding actual fires is the K433 form upon which the United Kingdom Fire and Loss Statistics are based, but despite the obvious value of this form there is still no compendium of detailed technical information designed to relate fire behaviour to the environment in which the fire acts or to evaluate the effectiveness of modern fire protection practice. As a first step in overcoming this deficiency the Fire Research Station has undertaken a pilot exercise in surveying building fires on a regular basis. The purpose of the exercise, which still continues, is to test the possibilities of the scheme, consider the nature and extent of the information obtainable from fires and the purposes for which such information could be used.

It is intended that the results of the exercise will be published as a series of Fire Research Notes and this, the first, introduces the scheme, gives details of its scope, method of operation, and analyses some of the first results.

2. STAFF COMPLEMENT

The Fire Survey Group consists of an architect and an experimental officer operating from the Fire Research Station. In addition, the Building Regulations Division of the Department of the Environment provides a surveyor who attends on one day per week to assist in the work and to co-ordinate the Building Regulations interest. A clerical officer assists telephonic liaison with the two fire brigades involved.

3. SCOPE OF THE EXERCISE

With the limited staff available there is an obvious advantage in working locally and, by prior agreement with the respective Chief Fire Officers, the exercise which began in April 1970 is confined to the areas covered by the Buckinghamshire and Hertfordshire Fire Brigades.

In order to test fully the possibilities of the scheme in a comparatively short time a broad spread of information is desirable and this is best obtained from fires which have either become large or at least have exhibited some growth. Such fires usually warrant the use of jets rather than hose reels and it was agreed with the two brigades that the survey group should be notified of all fires in which one jet or more were used. However, at the initial meetings with the brigade officers the latter pointed out that the dividing line between the use of hose reels or jets is not clear cut; thus many fires of particular interest would be excluded - perhaps by reason of the brigade's efficiency in coping by means of a hose reel only! It was, therefore, agreed that the team should be notified in addition of any other fires which in the officer's opinion exhibited points of special interest.

Apart from the regular programme of fire surveys described above, the team have also visited fires in various parts of England and Scotland as part of the normal work of the Station and in each case these fires have been fully documented and reported as a separate section of the same exercise. Currently a total of nearly 100 fires have been fully reported. In order to cover the very wide range of expertise required and to complete a visit to a fire within one day the staff work as a team.

4. FIRE REPORTS

Each fire visited has been the subject of an individual report file (Plate 1) consisting of:

(a) a short summary of the fire giving salient features, an appreciation of the scientific and Building Regulations interest and any conclusions drawn

(b) small scale plans and sections sufficient to illustrate the building and the fire - particularly fire extent, spread and damage caused

(c) a completed questionnaire

(d) annotated colour photographs illustrating the general nature of the incident and important features

(e) a copy of the K433 form.

5. METHOD OF OPERATION

The operational procedure is as follows:

1. Each morning and evening telephone calls are made to fire brigade divisional headquarters for a list of any fires which fall in the agreed categories together with the name of the brigade officer to contact in the event of a visit.

2. A rendezvous is arranged by telephone with the contact officer.

3. The fire is then surveyed - normally within a few hours of being extinguished (i.e. a fire during the night would be visited the following morning) and the visit completed in one day.

4. Following the survey the report is prepared complete with drawings, questionnaire, photographic record and summary of the incident. The latter involves consultation with specialist staff so that the implications of the burning pattern in its environment is fully understood - or at least commented upon - the scientific and building regulations interest noted and any conclusions drawn.

6. THE PART OF THE FIRE BRIGADE OFFICER

The survey team is accompanied at the fire ground by a fire brigade officer who either fought the fire in question or represents the Fire Prevention Branch. In either case he will be aware of most, if not all, the details of the incident and the fire fighting process. In addition, he may well have a close knowledge of the building, its services, and much of interest to say regarding the practical difficulties of fighting fires in it. In fact, for the particular fire in question, he becomes a member of the team and the importance of his role cannot be over-emphasized.

7. THE NATURE OF THE INFORMATION OBTAINED

The reports have been designed to give a comprehensive picture of the incident from the scientific and building regulations points of view. Their purpose is to enable quick retrieval of information mainly covered by the following sub-headings:

(a) The nature of the building

- (i) It size, fire sub-divisions, estimated standard of fire resistance and nature of means of escape provisions.
- (ii) Installed fire-fighting equipment and alarm systems.

(b) Civilian action and behaviour

- (i) Nature of action and effectiveness.

(c) Basic fire information

- (i) Fire times - scale, cause, discovery, alarms, call to brigade.

(d) Location of fire

- (i) Room and floor of origin.
- (ii) Environment in which the fire started and to which fire spread.

(e) Fire spread

- (i) Directions of spread.
- (ii) Cause of spread.
- (iii) Factors preventing further spread.
- (iv) Ventilation conditions.

(f) Extent of fire

- (i) Size of area involved in fire.
- (ii) Size of area involved in smoke.

(g) Behaviour of the building and its components in fire

- (i) Fire resistance of constructions and components.
- (ii) Extent of structural and superficial damage.
- (iii) Contributions of compartmentation.
- (iv) Contribution of combustible linings.
- (v) Contribution of installed fire-fighting equipment.
- (vi) Contribution of building services.
- (vii) Contribution of doors.

(h) Damage

(i) To building and contents due to fire.

(ii) To building and contents due to smoke.

(i) Personal hazard

(i) Type and effectiveness of escape routes.

(ii) The effectiveness of doors as fire and smoke stops under varying conditions.

(iii) Smoke movement and other hazards on escape routes.

(iv) Casualty details.

Some of the above items are covered by the K433 form but are included in the reports in order that the latter may stand as documents complete in themselves and also because in some cases further detail has been added.

8. THE RETRIEVAL OF INFORMATION

The provisional questionnaire used for the pilot exercise was designed as a self-coding form but the coding was not completed - since it was judged better to consider first the nature of the information and its use before embarking upon an elaborate coding system. The design of such a system must be based upon the immediate and long term needs of scientific and building regulations interests and in the first instance may be too sophisticated for the amount of information available but a firm basis for expansion must be provided.

It is proposed that coding should be by the standard 80 column punch cards as in use for the K433 form (more than one will be required for each fire) but eventually transferred to magnetic tape for use with a computer. A card sorting machine is available at the Fire Research Station.

9. THE USE OF THE INFORMATION

The individual report files are designed to permit:-

(a) a comprehensive reconstruction of each fire incident

(b) the production of analytical tables, and

(c) the study in depth of problems related to the behaviour of fires in buildings and the effects of fires upon buildings.

With regard to (c) above the following is a list of some major fire subjects to which the results are applicable. The list does not exhaust all the possibilities.

1. Fire duration

(a) Estimated time from ignition to discovery.

2. Fire growth

(a) The reasons why some fires spread while others do not.

(b) The relative importance of factors influencing growth in initially smouldering fires and initially flaming fires.

(c) The effect of methods of storage and disposition of fuel.

(d) The size of fires and characteristics of fires on discovery.

3. Fire spread

(a) The direction and extent of spread and its relationship to fire resistance, compartment size, building services, escape routes and fire damage.

(b) Environmental factors which assist or retard spread.

(c) The effect of roof construction and materials on spread in single storey shed type buildings.

4. Fire resistance

(a) The relationship between fire resistance achieved in the furnace tests and in actual fires.

(b) The comparison between the severity of actual and experimental fires.

(c) The influence of the quality of workmanship on standards of fire resistance.

5. Escape routes

(a) Smoke movement in buildings and the influencing factors.

(b) The effectiveness of doors - circumstances in which failure to withstand smoke is likely.

(c) The effectiveness of escape routes.

6. Cost studies

(a) Fire damage - costs of structural and superficial damage and repairability.

(b) Smoke damage.

(c) Cost/effectiveness of building regulations.

10. THE ANALYSIS OF THE RESULTS

The main purpose of the pilot exercise is to examine the nature of the information available from fires, its method of presentation and the uses to which it can be put. In furtherance of these objectives a series of initial analyses with comments are being prepared on the basis of the results obtained so far. The first of these analyses on house fires forms part of this Research Note. The next note in the series will give similar analyses dealing with fires in other occupancy groups; further notes will demonstrate the application of the results to the study of specific subjects. The general uses of the information were considered in Section 9 above and in the following section the practical application is demonstrated.

4. AN ANALYSIS OF NINETEEN HOUSE FIRES

Table 1 lists all the fires surveyed. Tables 2-7 analyse the results from nineteen house fires and are in the form of column headings each indicating a particular feature. An "X" in a column shows that in the fire concerned the relevant feature was present. The purpose of the tables and the accompanying comments is to illustrate the possibilities of using the information obtained from actual fires but obviously not all the information obtainable from the reports appears in the tables or is commented upon.

Although some interesting tendencies are already observable no firm conclusions regarding fire behaviour or the behaviour of buildings in fires can be drawn from an analysis of only nineteen fires. The following tables and comments should be considered in this light.

TABLE 1. FIRES NOTIFIED AND SURVEYED APRIL 1970 - JUNE 1971

Occupancy type	Number notified[1]	Number surveyed[1]
Houses	45	22 (1)[2]
Flats	4	6
Offices	3	4
Shops	7	8 (3)
Factories	27	23 (2)
Public Houses etc	7	2
Warehouses	3	10
Farm building	36	2
Schools	7	3
Hospitals	1	2 (1)
Hotels	1	2 (1)
Miscellaneous	53	1 (1)
TOTAL	194	85

1. The fires in the "number notified" column are classified by the use of the whole site whereas in the "number surveyed" column the fires are classified according to the actual use of the building on fire.

2. The figures in brackets are fires in other parts of the country visited during the period and included in the total.

COMMENTS ON TABLE 1

Introduction. The table lists the eighty five fires surveyed in the period April 1970 - June 1971 and compares this to the total number of fires notified to the Survey Group.

One jet or more fires. The criterion of 'one jet or more' is easily identified by fire brigades and has provided the type of fire from which much information is available. (See Section 3 above). Therefore for the purpose of fire surveys it is convenient to sub-divide fires as follows:-

(i) 'One or more jet' fires.

(ii) Fires requiring less than one jet to extinguish.

The nature of the information obtainable from each type will vary. The following comments on Tables 2 - 7 illustrate the information available from (i) but as yet no survey has been carried out of fires in (ii). The guiding principles upon which survey information could be collected from each type of fire may be expressed as follows:-

fires in (i) What are the factors which enable fires to grow and spread?

What effects do buildings and their contents have on fires?

What effects do fires have upon buildings and their contents?

What are the cost benefits of fire protection?

fires in (ii) What are the factors which prevent small fires from becoming large?

Locality of future samples. The interpretation of a fire incident on the lines indicated above requires trained staff with highly specialised knowledge backed up by the scientific resources of the Research Station. The Station is well situated North West of London to permit travel to fires in any direction over a large area without undue expenditure of time in travelling.

The nature of the sample. Samples of fire may include all types of buildings in a particular area and all types of fires (see (i) and (ii) above) or be confined to fires in a particular type of building. The precise nature of the sample selected will depend upon:-

(a) The assessment of the final results of the pilot exercise.

(b) The needs of current research programmes.

(c) Staff available.

(d) Location of the sample.

HOUSES TABLE 2 BASIC INFORMATION - DISCOVERY - CIVILIAN FIRE FIGHTING

File No.	BASIC INFORMATION					DISCOVERY				Civilian fire fighting	
	Age	Construction	Occ	Casualties	Cause	Call	Method of discovery	Estimat[d] delay	State of fire on discovery	Positive action	effect
B7	P	Bk/Tile	X	1 (K)	Smoking	01.55	Dog barking	2 hours	Large rapidly Grow[g]		
15	45-50	St.frame	X		Oil htr	14.25	Ignition seen	Nil	" " "		
17	A	Tim/Bk.	X		Spark	12.31	" "	Nil	Small	X	Partly
34	P	Bk/Tile	X	1 (K)	Elect[l]	03.23	Sound	1 hour	Large		
45	60-65	"	X		"	13.55	"	½ "	Small rapidly Grow[g]		
58	P	"	X	2(INJ)	Explosion	22.19	"	Nil	Small		
60	P	"			Smoking	01.32	Chance	3 hours	Small rapidly grow[g]		
97	P	"	X	1 (K)	Elect[l]	22.48	"	2 "	Small		
H4	P	"			Smoking	14.12	"	4 "	Large rapidly grow[g]		
6	P	"			Elect[l]	05.51	Sound	2 "	Small " "		
22	P	"	X		"	08.38	Chance	3 "	Large " "		
33	P	"	X		"	07.38	"	5 "	" " "		
35	45-50	"	X		Cooking	23.59	"	½ "	Small	X	Partly
43	P	St.Frame	X		Matches	11.20	Ignition seen	Nil	Small rapidly grow[g]		
44	P	Bk/Tile	X		Unknown	10.31	Sound	1 hour	Large " "		
54	A	"	X		Smoking	14.46	"	½ "	Small	X	ineffective
72	P	""	X		Blowlamp	14.07	Ignition seen	Nil	"	X	Partly
86	P	"	X		Candle	19.17	Sound	½	Small		
S3	P	"	X	7 (K)	Matches	15.05	Chance	1 hour	"		

COMMENTS ON TABLE 2

Introduction. This table gives some basic information related to the building, the fire, its cause, civilian casualties and action; and then clarifies the early stages of the fire about which so little is generally known.

Fire duration and discovery. Estimates have been made of the time elapsing between actual ignition and discovery. The assessment is based upon the known movements of the household before the fire was discovered and the scientific possibilities and probabilities derived from evidence of the fire. Obviously specific accuracy cannot be guaranteed but it is possible to obtain the orders of magnitude of delay in discovery. The results will be far reaching: since the size and condition of the fire on discovery are also given this data can be applied to statistical models of the early stages of fires in terms of times for actual ignition related to delay in discovery and the resulting effects on life hazard, the cost of repairs and the role of detection devices.

State of fire on discovery. In this context the term 'large' indicates that an area representing at least most of one room of a house is involved. Any other fire is classed as 'small'.

Method of discovery. 'Chance' is defined as the discovery of a fire without any warning or prior indication that anything is amiss, ie a person walking along a road may observe smoke because he happens to be looking in that direction; or a person casually entering a room may come upon a fire unexpectedly.

Civilian action. The problem of human behaviour in a fire situation is being studied by Loughborough University and is largely beyond the scope of this exercise. However the individual report files contain much information regarding human actions in addition to the effect of civilian fire fighting included in this table. Cooperation with the University study is indicated.

Age. 'P' indicates pre 1939 and 'A' indicates an ancient building. The age of post war buildings is given to the nearest 5 years period unless the actual date is known.

Occupied. At time of fire.

Casualties. (K) indicates a death. (inj) indicates injured.

Cause. The cause stated is what - in the opinion of the team - is the certain or most likely cause and is based upon an assessment of the known facts and consultation with specialist scientific staff as required.

Call. The time of call to the fire brigade control room.

HOUSES TABLE 3 FIRE VENTILATION

File No	Fire duration	Initial burning	Flash-over	Initially oxygen starved	Window(s) broken during growth	Effect of broken window on fire growth	Free burning on fire brigade arrival	Main source of oxygen associated with free growth
B7	0.35	Smouldering		X	X	Slight	X	Floorboards burnt through
15	0.20	Flaming	X		X	"	X	Fierce fire on ignition.Air in house
17	0.19	Smouldering			NA		X	N A
34	0.17	"	X	X	X	Moderate	X	Door opened then air in house
45	0.20	"					X	Air in house
58	0.21	Flaming			X	Slight	X	Explosion blew roof off
60	0.04	Smouldering		X			X	Floorboards burnt through
97	0.12	Flaming		X				No growth beyond smouldering but floorboards nearly burnt through
H4	0.09	Smouldering		X	X	Asst Growth	X	Broken window
6	0.22	"					X	Floorboards burnt through
22	0.16	"	X		NA		X	Air in loft
33	0.34	"	X		X	Slight	X	Open window
35	0.27	Flaming					X	Air in house and loft
43	0.18	"	X		X	Slight	X	Fierce fire at ignition. Air in house
44	0.44	Unknown	X		NA		X	Air in loft
54	0.08	Smouldering			X	Moderate	X	No spread beyond article of origin probably due to fuel disposition
72	0.31	Flaming			NA			N A
86	0.19	Smouldering					X	Air in house
S3	0.07	"		X				Floorboards burnt through.

COMMENTS ON TABLE 3

Introduction. The table is mainly concerned with fire growth and some of the factors associated with growth.

Fire growth and the influencing factors. It is important to ascertain why it is that some fires grow while others do not and considerable research has been carried out into the theory of fire growth. However, the relative importance of the influencing factors upon growth of actual fires is still unknown. Obviously the nature of the initial burning must be one such factor. Twelve out of the nineteen fires smouldered initially and the influences which can convert smouldering and slow burning fires into a free burning state are being studied. It will be seen that six out of fifteen fires (if the four loft and roof fires are ignored) became starved fires and the main cause of the eventual increase in burning rate was the burning through of the floorboards which allowed air from the ventilated sub-floor space to reach the fire. In a seventh case (B.97) it is thought that but for the timely arrival of the brigade - the same thing would have occurred very shortly. On the other hand in eight of the same fifteen fires the windows were broken during the fire growth period but in only one case was fire growth greatly influenced. To some extent a broken window must affect ventilation conditions and consequently fire behaviour but the precise extent is not always easy to determine scientifically. Nevertheless it is often possible to make a reasoned assessment and the classifications of 'moderate' or 'slight' were made after due consideration of the facts and reflect the opinion that the fires would have grown for reasons other than window ventilation. The relative importance of these 'other' factors is being studied.

Initial burning. This column assumes that the major characteristic of the early stages of a fire will be either smouldering or flaming and that this characteristic will have continued for some minutes at least. The fact that a smouldering fire may have been originally ignited by a flame is ignored, ie a lighted match thrown onto some waste material which then smoulders for some time before finally bursting into flame is considered to be a smouldering fire as far as 'Initial Burning' is concerned.

Fire duration. Fire duration is taken to be from call to brigade to a point when the main flaming area has been subdued. Time for damping down and extinguishing small isolated pockets is not included.

The question of fire duration in terms of time from actual ignition has already been discussed under Table 2. However since calculations up to now have always been based upon time of call to brigade it will be helpful to include a fire duration upon this basis for comparative purposes.

HOUSES TABLE 4 FIRE ENVIRONMENT - SPREAD

File No	FIRE ENVIRONMENT			COMBUSTIBLE LININGS			FIRE CONFINED TO		FIRE SPREAD				
	Room of origin	Door position	environment	None present	No.signt contrib^{n}	Signt contrib^{n}	Room	Envir^{t}	On floor of origin	To floor above	To floor below	To loft	Down from loft
B 7	Bedroom	Open	Bed/landing	X							X	X	X
B15	Liv.room	Open	Living/hall			X			X	X			
B17	Roof	NA	Roof	NA				NA					
B34	Liv.room	Open	Living/hall						X	X		X	
45	Lin.cupd	Shut	Cupd/landing	X					X			X	
58	Liv.room	"	Living room	X					X	X		X	
60	" "	Open	Living/hall	X			X	X					
97	" "	"	Living/kit^{n}	X				X					
H 4	Bedroom	"	Bed/corridor	X			X	X					
6	Liv.room	"	Living/hall	X			X	X					
22	Loft	NA	Loft	X									X
33	Bedroom	Shut	Bedroom	X					X			X	
35	Kitchen	"	Kitchen		X							X	X
43	Liv.room	Open	Liv/kit/Hall			X			X	X		X	
44	Loft	NA	Loft	X									X
54	Kitchen	Shut	Kitchen	X			X	X					
72	Roof	NA	Roof	NA				NA					
86	Landing	Shut	Landing	X								X	
S.3	Liv.room	"	Living room	X			X	X					

COMMENTS ON TABLE 4

Introduction. This table identifies the environment in which the fire occurred and indicates the limits of spread in terms of direction. The influence of combustible linings is also recorded.

Fire Environment. Fire behaviour will vary according to the environment within which it acts and it is desirable to identify that environment. A definition of the term "environment" might be an area enclosing the fire and within which air can freely circulate! In its simplest form an environment is a room with a closed door. However, if a door to an adjoining room or to a hall is open then the environment becomes 'room/room' or 'room/hall' respectively. Further clarification beyond this stage is not easy because the exact positions (open or shut) of all other doors are not usually known (particularly in the latter example); and if some are known to have been open then the whole concept may become too complex to be meaningful. A further complication arises if the fire grows - since in this case the environment may change. In this analysis the environment has been identified at the point considered most relevant to fire growth - usually at or soon after discovery.

The concept of the fire environment as outlined above has an application far beyond house fires. Up to now studies of fire growth have been based upon the fire occurring in a simple rectangular room and there is little recorded data available on the fire and smoke spread patterns which may occur in all types of buildings when the door of the room of fire origin is open or part of the enclosure to that room collapses. In forthcoming analyses it is proposed to analyse the extent of fire and smoke spread beyond the room of origin and its relationship to Means of Escape, fire compartment sizes and standards of fire resistance as laid down by Building Regulations. These studies will be linked to those on Fire Growth considered under comments to table 3 above and Fire Spread considered later.

Door position. The door concerned in the table is to the room of fire origin. The determination of door position (open or shut) is made after due consideration of fire brigades and civilian statements and observation of the burning pattern and other evidence. If the evidence is overwhelmingly in one direction a definite statement has been made. However there will be occasions when a conclusion cannot be reached (ie if human memory is at fault or the evidence is destroyed), and in these cases the term 'unknown' will be used in this column.

Fire Spread. This section indicates whether or not the fire was confined to the room or environment of fire origin and, if not, indicates to what other areas it spreads in terms of direction. For the purpose of defining fire spread the extent of flaming was immaterial and a fire was considered to have spread if any flaming occurred within the areas indicated. The reasons for fire spread are dealt with under Table 7.

Hall	-	the ground floor circulation space of a house
Landing	-	the 1st floor circulation space of a house
Corridor	-	the circulation space of a flat
Loft	-	the space enclosed by the external roof finish and the ceiling
Roof	-	the external cladding (thatch in the two fires quoted).

TABLE 5. SPREAD TO ADJOINING BUILDINGS - FIRE EXTENT AND DAMAGE - EFFECTIVENESS OF DOORS

File No.	Fire Spread via Separating Wall			Fire Extent		Fire Damage			Effectiveness of Doors			
	Wall Involved	Spread to adjoining property		Fire Area (m^2)	Smoke Area (m^2)	Structl	Finishes & Components	Contents	Fire		Smoke	
		Fire	smoke						Resisted	Failed	Resisted	Failed
B 7				80	120	33%	33%	33%			X	
B15	X		X	68		80	80	80				
B17				15	NA		10					
B34	X			40	35	10	75	75		X		
B45	X		X	5	28		10	10		X		X
B58	X		X	1		80	50	15				
B60				5	25	5	5	30				X
B97				3	28		5	10			X	
H 4				10	50		15	50		X		
H 6				45	100		10	10			X	
H22				70		15	1					
H33	X	X	X	42		10	20	30		X		
H35				6			5					
H43	X	X	X	70		100	100	100		X		
H44	X	X		60	60	20	15	5				
H54				1	40		20	1			X	
H72				24	NA		10					
H86	X	X	X	5	3		5	5		X	X	
S 3				0.5	15		10	10			X	

COMMENTS ON TABLE 5

Introduction. This table records fire spread to adjoining buildings and gives an indication of fire size and extent of damage. Details of door behaviour are also recorded.

Fire spread to adjoining property. All four cases of fire spread to adjoining property occurred within the loft and in three of the cases was due to flames and hot gases penetrating the joint between the separating wall and the roof tiles: the fourth case was due to flame passing through a large hole left above a roof purlin at its seating on the wall. Fire brigade actions prevented serious damage to the adjoining lofts in each case. A total of six adjoining lofts were considerably affected by smoke.

Extent of fires and the nature of damage caused. Up to now little data has been available regarding the extent of fires and the damage sustained - yet this information has many uses for comparative analysis of the effects of fires upon buildings: the assessment of the fire resistance of actual structures, studies of the effectiveness of Building Regulations and the quantitative evaluation of active and passive fire protection methods are examples. The information given in the table illustrates the application in principle but the precise details regarding both fire extent and nature of the damage can be varied to suit particular studies.

Extent of fire. Fire size is given in terms of plan area (m^2). Similar plan areas involved in considerable quantities of smoke are also shown but smoke areas are exclusive of fire areas.

Structural damage. This includes damage to the structure itself to the extent that renewal or extensive repairs to that part will be required. It does not include superficial damage such as plaster off walls or other damage which leaves the structure intact.

Finishes and components. This includes all damage to the building fabric and its components other than structural damage and includes plaster off walls, ceiling damage, damage to doors and other woodwork and fittings.

Contents. This includes the damage by fire, smoke and heat to the contents of the building to the extent that thorough cleaning or replacement would be required.

The accuracy of the damage percentages. The percentages given in the three columns on fire damage are not based upon precise measurement or calculation. They derive from visual inspection only and are given solely to illustrate the order of magnitude of damage in the three categories and to indicate the possibilities. The information in the individual files would allow more accurate assessments.

The effectiveness of doors in fire protection

(a) Against smoke travel. Although doors can be an effective means of preventing smoke travel it is well known that this is not invariably the case. It is obvious that a closed door must delay smoke penetration even if it does not prevent it indefinitely. The main factors affecting door performance are thought to be the pressure exerted by the fire, fire ventilation conditions, the natural air currents acting in and around the building and warping caused by heat. For life safety it will be necessary to establish the standard of performance to be expected from doors placed in certain positions relating to the plan and section of common types of building bearing in mind the presence of other influencing factors (mentioned above): an analysis of door performance based upon all the fires surveyed so far together with future fire surveys will enable this to be accomplished.

In this analysis two cases of definite failure to withstand smoke were established. In both cases the fires were burning freely at the time of failure but were will not vented to the open air. In one case the fire could not have been burning for more than a few minutes and was classed as 'small' on discovery. In the second case the fire may have been burning for some considerable time before failure occurred.

(b) In fire resistance. In no case was a door attacked by fire for as long as thirty minutes and therefore there is a nil return in the first column of this part of the table. However in six cases definite failure in fire resistance occurred and in four of these cases the failure time (from actual attack by fire to flame penetration on the far side) was established as five minutes in each case.

The 'pay off' in financial benefit if doors are kept closed is indicated in the analysis: the average size of fires in which the door of the room or origin was open was nearly five times greater than those in which the door was closed. The relationship between closure of doors and fire spread to other areas is not yet apparent.

HOUSES TABLE 6 FAILURES IN FIRE RESISTANCE								
File No	Separating walls	Stud Partitions	Timber joist floor with plaster ceiling	Ceiling from fire above	Ceiling from fire below	Duct enclosures	Cavity wall construction	doors
B 7			XX	X				
15						XX		
17								
34					X			X
45					XX			XX
58								
60								
97								
H 4								X
6								
22				X				
33	XX				X			XX
35				X	X			
43	XX	X			X		XX	X
44	XX			X				
54								
72								
86	XX	X			XX			X
S 3								

COMMENTS ON TABLE 6

Introduction. This table indicates where failures in fire resistance could be reasonably established. 'XX' indicates that failure assisted fire spread. The criterion for failure used in the exercise is that the construction or component was judged to have failed one of the three requirements of the B.S. 476 test (collapse, passage of flame and insulation) by virtue of attack by fire on any part of one side only for less than half an hour.

The assessment of fire resistance. It is comparatively easy to decide that a structure or construction has failed under fire attack - the evidence is there to be seen - but the assessment of the conditions under which the attack took place and the severity of the fire at that point requires considerable judgement. In most cases such judgements can be made. Before a construction can be said to have withstood a fire successfully the severity of the fire at that point and its duration must be established.

The evidence suggests that the effect of poor workmanship in construction should be studied.

TABLE 7. Comments on spread or lack of spread and further spread prevention

File No.	Reasons for spread or lack of spread	Further spread prevention
B. 7	Smouldering fire burnt through floor boards. Draught from sub floor caused rapid spread in floor space and to roof timbers	F.B. action
" 15	Fierce initial oil fire spread rapidly due to failure of duct enclosure, combustible internal linings and doors left open	House gutted
" 17	Spread of external roof fire prevented by quick F.B. action	F.B. action
" 34	Door opened by occupant caused rapid increase in burning of smouldering fire to eventual flashover	F.B. action
" 45	Failure of doors in fire resistance was causing spread to rooms on F.B. arrival	F.B. action
" 58	Gas explosion. Resulting well ventilated small fire did not spread before F.B. arrival	F.B. action
" 60	Burning rate of initially starved fire increased on collapse of floorboards allowing sub floor ventilation to fire	F.B. action
" 97	Starved fire. Burning rate would have increased if burning through of floorboards had been completed	F.B. action
H. 4	Growing fire vented when window glass shattered. Heat and flame out of window delayed otherwise rapid spread of fire to remainder of flat	F.B. action
H. 6	Starved fire initially. Burning rate rapidly increasing on F.B. arrival due to collapse of floorboards allowing sub floor ventilation	F.B. action
" 22	Rapid spread of fire to first floor from fully involved loft taking place on F.B. arrival	F.B. action

File No.	Reasons for spread or lack of spread	Further spread prevention
H.33	Initially smouldering fire vented by open window finally fully involved whole room. Failure of door in fire resistance spread fire to landing. Loft also involved	F.B. action
H.35	Initial cooking fat fire quickly extinguished but small fire in plaster faced fibreboard ceiling above kept in check for some time by elderly occupant	F.B. action
" 43	Paper ignited by child caused rapid spread to fibreboard wall linings. Unfirestopped cavity constructed partitions and open doors assisted rapid spread to whole house	House gutted
" 44	Spread of fire to first floor from fully involved loft just started at F.B. arrival	F.B. action
" 54	Fire in sink unit cupboards vented when window glass shattered causing increase in burning rate. Rest of room not involved. Door kept shut by occupants	F.B. action
" 72	Boarding beneath thatch delayed fire penetration downwards to rooms. No spread	F.B. action
" 86	Poor fire resistance of ceiling led to spread to loft but this caused dissipation of heat and delayed fire spread to bedrooms	F.B. action
S. 3	Smouldering fire in enclosed room commencing to flame on F.B. arrival due to sub floor ventilation	F.B. action

COMMENTS ON TABLE 7

Introduction. This table condenses into one or two short sentences the salient factors regarding the fire - particularly as far as fire growth and spread are concerned. The purpose is to assist appreciation of the foregoing tables.

The reasons for spread of fire. It should be appreciated that fire growth and spread are not necessarily the same thing. The reasons for fire growth (ie why a small fire becomes larger) were considered in the comments to Table 3 but having grown initially in one area spread may then occur to other areas or fire compartments. The pattern of this spread and the influencing factors are of importance since a main aim of legislative fire protection is to control fire spread. The reasons for growth and spread are often complex and may overlap but the final results of an assessment of the relative importance of the factors in individual fires will permit an evaluation of the effectiveness of building regulations.

Further spread prevention. Apart from two houses gutted by fire and the possible exception of a house so badly damaged by explosion that the fire was exceptionally well ventilated it is reasonable to say that only fire brigade action saved the houses from further serious spread.

12. CONCLUSIONS

Some of the main points of interest which arise from the foregoing analysis of house fires can be summarized as follows:-

1. The average estimated time from ignition to discovery was approximately $1\frac{1}{4}$ hours. On discovery seven of the fires had involved an area representing at least most of one room and ten of the fires were growing rapidly.

2. In four cases civilians attempted fire fighting but in only one case was the effort even partly successful. The remainder of the fires were not fought by civilians at all due to:-

incapacity of occupant	3 cases
fierce and uncontrollable fire from ignition	2 "
fire beyond civilian control on discovery	6 "
house unoccupied	2 "
injury to occupants due to explosion	1 case
ill advised action by occupant	1 "

In four cases foolish or ill advised action by civilians followed discovery of the fires.

3. Eight fires were discovered purely by chance, seven were heard and in four cases ignition was seen. No fires were discovered by smell.

4. Twelve of the nineteen fires had a mainly smouldering characteristic in the early stages and six out of the fifteen fires occurring within general accommodation areas (ie excluding roof and loft fires) were at one stage starved of oxygen so that growth was inhibited: the main cause for the eventual increase in burning rate was the burning through of the floor boards allowing sub-floor ventilation air access to the fire. This happened in four cases and undoubtedly would have happened in a fifth case but for fire brigade action.

5. In eight of the fires windows broke during the growth period of the fire but in only one case did this radically accelerate fire growth.

6. The advantage of the door of the room of fire origin being closed is indicated by the following table which gives comparisons of the percentage of the whole building and contents damaged in relation to the door position. The size of areas involved in fire and smoke are also shown.

Position of door to room of origin	Damage			Area involved in fire	Additional area involved in smoke
	Structural	Finishings and components	Contents		
Open	28%	40%	48%	40 m^2	45 m^2
Closed	13%	17%	10%	8 m^2	12 m^2

7. In no case was a door attacked by a fire for as long as 30 minutes but in six fires doors failed within five minutes of being attacked by fire. All the doors concerned were normal types commonly found in houses and none were up to the $\frac{1}{2}$ hour fire check standard. In two cases the failure of the door significantly assisted fire spread.

8. In six of the fires it was established that doors effectively resisted smoke penetration and the average duration of the six fires from time of call to main fire out was nineteen minutes. In two further fires definite failures to resist smoke were also established. In both the latter cases the fires were flaming in a largely unventilated environment when failure occurred. One fire could not have burnt for many minutes while in the second case burning could have occurred for some considerable time before failure occurred.

9. The most common area to which fires spread was to the loft space (on eight occasions). This was due to the poor fire resistance of the first floor ceilings. However, in general, fire spread on first floors would have been greater had the ceilings not failed fairly quickly and thus vented the fires to the loft spaces and thence to the open air via gaps between tiles.

10. Sideways spread beyond the room of origin occurred in six fires. In three cases the door to the room of origin was open and in three cases closed. Failure of the door in fire resistance led to spread in two of the latter cases.

11. In four cases fires did not spread beyond the room of origin although the door to that room was open. In these cases the average fire duration was less than twelve minutes.

12. Fibreboard linings to walls and ceilings were present at two fires and in both cases very rapid fire growth ensued. In a third case the fibreboard lining was applied to the ceiling only and was protected by a skim coat of plaster. In this case fire spread was not rapid and the fire was kept in partial check by civilian effort.

13. In eight cases the separating wall between houses was directly attacked by fire and fire spread to the adjoining property in four of these cases - all within the loft space. On three occasions failure was due to the weak joint between the top of the wall and the tiles and in the fourth case a hole had been left in the wall at a purlin seating.

It seems reasonable to claim that the analysis tables on house fires, the accompanying comments and the above summary demonstrate that much information can be obtained during a comparatively short visit to fires by teams of two representing the architectural and scientific disciplines: furthermore the information obtained has a very wide application. On the completion of the present series of analyses covering all the fires surveyed it will be necessary to assess the overall results and consider the range of the information to be collected and the nature of a meaningful sample of fires to make the greatest impact on current research.

Our present day buildings with their highly sophisticated planning, services and contents present many problems of fire protection. Such is the complexity and interaction of the factors involved that laboratory experiments alone cannot provide solutions. As a means of assessing the relative importance of the factors influencing actual fires and the effects of fires upon buildings "Fire Survey" has much to offer.

13. APPRECIATION

The Research Station is greatly indebted to the respective Chief Officers of the Buckinghamshire and Hertfordshire Fire Brigades for their agreement that the pilot exercise could be carried out in their brigade areas; and the author would like to express his personal thanks to the many officers of both brigades who took part in the exercise and who - without exception - gave such valuable assistance during the surveys. Their friendly cooperation was very much appreciated.

The author would like to express his appreciation to his colleague, Mr. Clive Theobald, for his part in the surveys and scientific assessment of the fires and in addition for his assistance in preparing the analysis tables on house fires.

Thanks are also expressed to Messrs. Hinkley, Baldwin and Bowes and other members of the Research Station staff who advised on specific problems and also to Mr. P. Willcocks of the Building Regulations Division who assisted with the work on a part time basis and who provided liaison with his division.

All credit is due to Mrs. W. N. Daxon for the liaison with the fire brigade control rooms and the smoothness of the visiting arrangements.

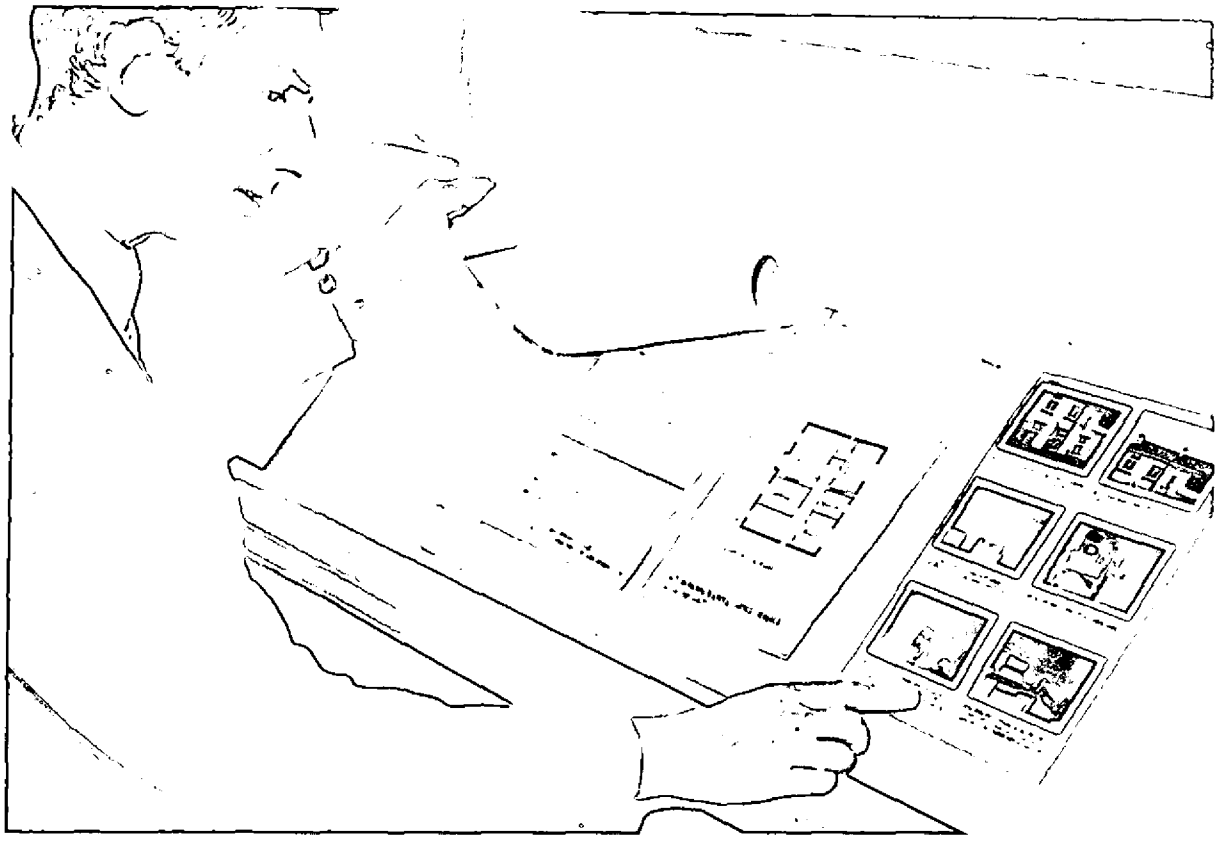

PLATE 1. THE INDIVIDUAL REPORT FILE

The opened out file shows, from the left:
A short summary of the incident.
The self coding form.
A plan of the building.
Colour photographs.