Fire Research Note
No.948

THE SURVEY OF FIRES IN BUILDINGS
FIRE SURVEY GROUP. 2ND REPORT - INDUSTRIAL FIRES

by

A. Silcock, C. R. Theobald and W. N. Daxon

October 1972

FIRE
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SUMMARY

The first report[1] of the results of the pilot exercise in fire surveying set out the nature of the information obtainable from such surveys and gave a preliminary analysis of the nineteen house fires surveyed by the date of issue.

This second report presents and discusses an analysis of information from 40 industrial fires.

There are admittedly too few observations of any one feature for firm conclusions to be drawn, but typical of points of interest are observations relating to the downward spread of fire through timber floors, and the marked effect of the direction of air currents around the edge of a timber door on its fire resistance.

KEY WORDS: Building, fire, industrial, survey

DEPARTMENT OF THE ENVIRONMENT AND FIRE OFFICES' COMMITTEE
JOINT FIRE RESEARCH ORGANIZATION

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1. INTRODUCTION

This report first indicates the broad principles upon which information was obtained from the 40 industrial fires surveyed and then presents the results in the form of 3 analysis sheets and 32 tables based upon these sheets with explanatory notes. A short discussion follows the notes in which comments are made upon some aspects of Building Regulations and cost effectiveness of fire protection which arise from the tables.

2. THE BROAD PRINCIPLES UPON WHICH THE INFORMATION WAS OBTAINED AND CAN BE USED

2.1. The basis upon which the information was collected.

A visit to a fire ground can provide a wealth of information on a wide variety of aspects and a long term programme of objectives is essential to avoid the haphazard collection of relatively useless and irrelavent detail. Although the nature of the information can be so varied according to the subject or subjects chosen for study a factor common to all aspects is the need to understand actual fire and building behaviour within the context of the particular building and the circumstances in which the fire acted.

Initially a fire in a building must be confined by some form of walls, floors, ceiling or roof and these confines (which may not necessarily have fire resistance to the standard required by Building Regulations for that building) will affect its behaviour as will also the materials and form of construction, extent of ventilation, fuel disposition and other circumstances. The part of the building which for practical purposes forms this confine or enclosure to the fire can be referred to as the 'fire environment' and this expression includes its size, nature and the general circumstances pertaining to it. One of the aims of the pilot exercise has been to

identify this environment and explain the reasons for fire and building behaviour within it and for spread beyond it if this occurred. The information so obtained can form part of a 'data-bank' which will thus give - for specific types of building and occupancy - details of the nature of fire environments, reasons for fire spread, or failure to spread, the contribution and behaviour of materials and constructions, fire protection measures and other factors affecting performance of fire and the building. Such information alone will provide an important contribution to the appreciation of the behaviour of fires and buildings in actual fire situations but in addition it forms the essential basis upon which survey information obtained for a specific study can be assessed in its proper perspective. Thus in designing a long term programme of fire surveys two purposes must be considered: these are the acquisition of:-

(a) basic information for the data-bank
(b) detailed information related to a specific study or studies

2.2. The use of the information obtained

The information obtained as outlined above has many possibilities for general use and in addition a great variety of specific studies can be undertaken. The broad classifications under which the information can be used are as follows:-

1. The evaluation of the effectiveness of Building Regulations.
2. The evaluation of the effectiveness of Means of Escape provisions.
3. Cost effectiveness studies of fire protection measures.
4. The verification and application of laboratory experimental results.
5. The construction of mathematical models of fires.

The following analysis demonstrates the nature of data bank information available from industrial fires and the discussion (commencing on page 22) considers some of the aspects of use noted above. A fuller discussion of the use of the information is given in a separate report[2].

3. AN ANALYSIS OF 40 INDUSTRIAL FIRES REQUIRING THE USE OF ONE JET OR MORE FOR THEIR EXTINGUISHMENT

3.1. Introductory information

The majority of the fires surveyed were in the Hertfordshire and Buckinghamshire fire brigades areas in which the pilot exercise was mainly operated. Five fires from other areas have also been included: the latter were jet fires which the survey team were specifically invited to inspect and have been included since they fit the general pattern.

The analysis consists of three analyses sheets of information obtained from the fires followed by 32 tables based upon those sheets and upon further information obtained direct from the individual report files of the fires.

3.2. Notes to the tables

Explanatory notes to the tables are given but since some refer to more than one table it has been found convenient to collect all notes to the end of the tables. Each note is referenced to the tables concerned.

3.3. The tables

The information provided in the tables can be broadly classified as follows:-

(1) The Building

Construction and finishes.
Size of building, fire sub-divisions.
Nature of fire environment.
Size of fire environment and extent involved in fire.
Factors which prevented spread or further spread.
Factors which assisted spread.
Factors which, if present, should have prevented spread or further spread.
Structural damage.
Nature of contents - assessments of fire load.

(2) Early stages of the fire

Cause.
Nature of initial burning.
Estimated delay in discovery.
Method of discovery.
Civilian fire fighting and actions.

(3) Fire growth and spread

Fire duration.
Fire size at various stages.
Direction of spread.
Reasons for spread or failure to spread(see also (1)above).

Tables Nos 1-9 give general information related to all fires but it will be apparent that single storey and multi-storey building fires present different problems and the subsequent tables (Nos 10-32) are sub-divided into these categories. This is the major breakdown of the tables but where appropriate sprinklered fires have been isolated and in some tables a further breakdown into 'Factories' and 'Storage' occurs so that comparisons can be made with Building Regulations.

3.4. The limitations of the analysis

An analysis of only 40 fires has limitations when breakdowns into classifications are made and it will be seen that the averages in some of the tables are based upon very few fires indeed and at the moment may not necessarily present a true impression. However, at this stage the purpose in presenting the tables is not to provide comprehensive useable data but to demonstrate the nature of the information which can be obtained from actual fires and indicate some of the relationships which can be shown. Nevertheless the information does form the basis of a data bank for ultimate use.

FORTY FIRES IN INDUSTRIAL BUILDINGS

ANALYSIS SHEET 1 - BUILDING DETAILS

File No.	Purpose group	Type of industry or storage	Fire load	Date of construction	No. of storeys	Construction							Total floor area (m^2)	Sprinklered building
						Method of construction	Walls	Floors	Partitions	Roof structure	Roof finish	Roof lining		
H11	Storage	Chipboard	High	1955	1	Timber	Corr. Iron	Concrete	Corr. Iron	Timber	Corr. Iron	-	426	-
H14	Storage	Wood pulp	High	Pre	2	Unprot. st. fr.	Brick	Concrete	Corr. Asb/bk	Steel	Corr. Asb	-	2,700	X
H24	Storage	Wood pulley	Medium	Pre	2	L.B. Brick	Brick	Timber	Brick	Timber	Slate	-	600	-
H32	Factory	Gear box afrs.	Low	1956	1	Unprot. st. fr.	Brick	Concrete	-	Steel	Felt on wood wool slab	-	30,000	X
H47	Factory	Furniture afrs.	Medium	1965	1	Unprot. st. fr.	Steel	Steel	-	Steel	Steel	-	30	-
H49	Storage	Bedding	Low	Pre	1	L.B. Brick	Brick	Concrete	Brick	Steel	Felt on timber	-	150,000	-
H53A	Storage	Furniture	Medium/high	1966	2	R.C. fr.	Brick	Concrete	Brick	R. Concrete	Felt	-	640	-
H53B	Storage	Furniture	Medium/high	1950	1	R.C. Portal fr.	Corr. Asb/ brick	Concrete	-	P.C. Portal	Corr. Asb	-	180	-
H66	Storage	Jute and flax	High	1968	1	Unprot. st. fr.	Corr. Iron	Concrete	-	Steel	Corr. Asb	-	250	X
H69	Storage	Foam plastic	High	1965	1	R.C. Portal fr.	Con. block	Concrete	-	R.C. Portal	Corr. Asb	-	780	X
H84	Factory	Cellulose paint	Low/medium	1965	1	R.C. Portal fr.	Brick	Concrete	Brick	R.C. Portal	Corr. Asb	Pl. bd	600	X
H85	Factory	Sheet metal	Low	1959	1	R.C. Portal fr.	Brick	Concrete	Timber	R.C. Portal	Corr. Asb	F.I.B. (treated)	2,560	-
H134	Factory	Light Engrg	Medium	1964	1	L.B. Brick	Concrete	Concrete	Strawboard	Unprot. st.	Corr. Asb	F.I.B.	136	-
H144	Factory	Food processing	Medium	Pre	1	L.B. Brick/Unprot. st. fr.	Brick	Concrete	Brick	Steel/Al.	Corr. Asb	Fibre bd. (treated)	4,000	X
H156	Storage	Packing Mat.	Medium	Pre	1	R. Concrete	Concrete	Concrete	-	Steel	Asphalt	-	2,840	-
H172	Storage	Chemicals	High	1955	1-2	L.B. Brick	Corr. Iron /Asb.	Concrete	Tim/Stramit	Timber	Timber/felt	Asb. wood	1,940	-
H2	Factory	Furniture	High	Pre	1,2-3	L.B. Brick	Brick	Con/Timber	Brick	St/Timber	Corr. Asb/slate	-	9,370	-
H9	Factory	Joinery	High	Pre	1	L.B. Brick	Brick	Concrete	-	Steel	Felt on timber	-	450	-
H10	Factory	Light Eng.	Low	Pre	1	L.B. Brick	Brick	Concrete	Brick	Steel	Corr. Asb	-	400	-
H19	Factory	Plastic Assocs	Medium	Pre	2	L.B. Brick	Brick	Timber	Brick	Timber	Slate	-	1,090	-
H22A	Factory	Furniture	High	Pre	2	Timber/Brick	Tim/Brick	Timber	Brick	Timber	Tiles	Tim/bdg.	950	-
H22B	Factory	Furniture	High	Pre	2	Timber/Brick	Tim/Brick	Timber	Tim/Brick	Timber	Tiles	Tim/bdg.	800	-
H23	Storage	Plastics	Low	1963	1-2	Unprot. st. Portal fr.	Brick	Chip. bd/con	F.I.B. stud.	Unprot. st. Portal	Corr. Asb	Fibre bd.	600	-
H26	Factory	Garage	Medium	Pre	1	L.B. Brick	Brick	Concrete	Brick	Timber	Corr. Iron	-	350	-
H30	Factory	Adhesives	High	1965	1	R.C. Portal fr.	Brick	Concrete	-	R.C. Portal	Corr. Asb	-	1,400	X
H39	Factory	Timber Bldgs	Low	1950	1	L.B. Brick	Brick	Concrete	-	Steel	Corr. Asb	-	1,120	-
H41	Factory	Furniture	High	1965	2	R.C. fr.	Brick	Concrete	Pl. bd. stud	P.C. Concrete	Felt	-	5,000	X
H48	Factory	Saw Mill	Medium	Pre	1	Timber fr.	Timber	Concrete	-	Timber	Corr. Asb	-	200	-
H52	Storage	Food stuffs	Medium	Pre	2	L.B. Brick	Brick	Timber	Fibre bd stud & brick	Timber	Asphalt	Fibre bd.	192	-
H75	Factory	Light Engrg	Low	Pre	1	L.B. Brick	Brick	Concrete	Steel	Timber	Bitn. on Tim.	Timber	1,460	-
H77	Storage	Furniture	High	1960	1	Unprot. st. fr.	Timber	Concrete	Corr. Asb	Steel	Corr. Iron	-	1,530	X
H92	Storage	Furniture	High	1965	1	Unprot. st. fr.	Corr. Asb	Concrete	-	Steel	Corr. Asb	-	1,350	X
H93	Factory	Electrical goods	High	1960	1	Unprot. st. fr.	Corr. Asb	Concrete	-	Steel	Corr. Asb	Pl. bd	4,800	-
H98	Factory	Furniture	High	Pre	2-3	L.B. Brick/Unprot. st. fr.	Brick	Timber	Brick	Timber	D/skin Asb/slate	-	2,000	-
H151	Factory	Light Engrg	Medium	Pre	1	L.B. Brick	Brick	Concrete	Bk/Timber	Tim/slate	Slate	Felt on T & G Bdg	2,250	-
S1A	Storage	Cardboard boxes	High	1963	1	Unprot. st. fr.	Corr. Asb	Concrete	-	Steel	Corr. Asb	-	4,100	-
S1B	Storage	Paper reels, crdb	High	Pre	4	L.B. Brick/st/C.I. fr.	Brick	Brick	Brick	Unknown	Unknown	-	12,000	-
S4	Storage	Chemicals	Low	1970	5	R.C. fr.	Brick	Concrete	Brick	Concrete	Asphalt	-	2,400	-
S8	Storage	Consumer goods	High	Pre	1-2	L.B. Brick/st/C.I. fr.	Brick	Concrete	Brick	Steel Beams	Slate	T & G Bdg	29,720	X
S15	Factory	Upholstery	High	Pre	4	L.B. Brick	Brick	Timber	Hardboard	Timber	Slate	-	3,840	-

Pre - Pre 1950

ANALYSIS SHEET NO.2 - EARLY STAGES AND FIRE SIZE

File number	Occupation		Cause of fire	Initial burning	Method of discovery	Time intervals					Time of maximum fire spread	Time taken to reach maximum fire spread	Fire sizes		
	Site	Building				Estimated maximum delay in discovery (min)	Time of discovery	Time of fire brigade arrival	Time of main fire out	Fire duration (min)		(min)	Fire size on discovery (m^2)	Fire size on brigade arrival (m^2)	Final fire size (m^2)
H11	Occ	Unoc	Smoking materials	Smouldering	Smoke seen	30	20.29	20.34	21.10	41	20.40	11	5	128	426
H14	Occ	Occ	Smoking materials	Smouldering	Flame seen	Unknown	00.45	01.02	01.02	17	01.00	15	Unknown	20	20
H24	Occ	Unoc	Unknown	Flaming	Smoke seen	15	13.12	13.19	13.58	46	13.20	8	90	140	310
H32	-	Occ	Furnace blowback	Flaming	Flame seen	nil	04.36	04.42	04.48	12	04.36	-	10	10	10
H47	Occ	Unoc	Mechanical spark in ducting	Smouldering	Smoke seen	15	11.14	11.22	11.30	16	11.22	8	Unknown	Unknown	3
H49	Unoc	Unoc	Electrical	Smouldering	Smoke seen	Unknown	07.38	07.45	08.10	32	07.55	17	Unknown	24	24
H53[A]	Unoc	Unoc	Arson	Flaming	Flame seen	60	21.29	21.36	22.12	43	21.38	9	Unknown	5	5
H53[B]	Unoc	Unoc	Radiated heat	Flaming	Flame seen	60	21.29	21.36	22.12	43	21.38	9	7	7	7
H66	Occ	Unoc	Smoking materials	Smouldering	*Auto alarms	Unknown	18.06	18.15	18.35	29	18.06	-	40	40	40
H69	Occ	Occ	Unknown	Smouldering	Noise heard	Unknown	21.21	21.27	21.46	25	21.23	2	Unknown	30	30
H84	Occ	Occ	Mechanical	Flaming	Flame seen	nil	14.04	14.07	14.20	16	14.05	1	2	2	6
H85	-	Occ	Unknown	Unknown	Flame seen	13	22.32	22.41	22.50	18	22.32	-	14	14	14
H134	Unoc	Occ	Mechanical	Flaming	Flame seen	2	21.10	21.15	21.30	20	21.15	5	7	47	50
H144	Occ	Occ	Oven (gas)	Flaming	Flame seen	nil	07.45	08.06	08.20	25	07.45	-	2	2	2
H156	Occ	Unoc	Unknown	Smouldering	Smoke seen	30	17.06	17.10	17.45	39	17.15	9	50	60	60
H172	Unoc	Unoc	Unknown	Flaming	Flame seen	56	05.30	05.34	06.52	82	05.40	10	1,000	1,000	1,055
B2	Unoc	Unoc	Unknown	Unknown	Smoke seen	Unknown	18.30	18.36	21.00	150	20.30	120	1,960	3,500	9,370
B9	Unoc	Unoc	Unknown	Unknown	Smoke seen	180	20.51	21.01	22.00	69	21.00	9	Unknown	354	354
B10	Unoc	Unoc	Oil fired heater	Smouldering	Smoke seen	Unknown	18.45	18.50	18.50	5	18.47	2	Unknown	1	1
B19	Unoc	Unoc	Unknown	Smouldering	Explosion	60	22.35	22.49	00.30	115	23.00	25	Unknown	500	550
B22[A]	Occ	Occ	Arson	Unknown	Smoke seen	Unknown	12.14	12.24	13.20	66	12.36	16	90	820	820
B22[B]	Occ	Occ	Radiated heat	Flaming	Flame seen	nil	12.20	12.24	13.20	60	12.45	25	Unknown	250	500
B23	Occ	Occ	Electrical	Smouldering	Smoke seen	Unknown	08.28	08.34	09.30	62	08.40	12	1	50	75
B26	Occ	Occ	Welding equipment	Flaming	Flame seen	nil	17.06	17.12	17.25	19	17.08	2	20	80	80
B30	Occ	Occ	Explosion	Flaming	Explosion	nil	14.06	14.12	14.40	34	14.06	-	160	160	160
B39	Occ	Unoc	Unknown	Unknown	Smoke seen	240	20.16	20.27	20.45	29	20.27	11	Unknown	30	30
B41	Occ	Occ	Smoking materials	Smouldering	Sprinkler alarm	170	19.58	20.07	20.10	12	20.03	5	Unknown	1	1
B48	Unoc	Unoc	Mechanical fault	Unknown	Smoke seen	60	12.42	12.51	13.20	35	12.57	15	Unknown	35	35
B52	-	Unoc	Smoking materials	Smouldering	Smoke seen	360	02.21	02.25	03.10	49	02.52	31	Unknown	100	100
B75	-	Unoc	Unknown	Unknown	Smoke seen	360	23.12	23.18	01.00	108	23.19	7	Unknown	1,000	1,200
B77	Occ	Unoc	Smoking materials	Smouldering	Sprinkler alarm	Unknown	10.00	10.09	10.45	45	10.15	15	Unknown	130	130
B92	Occ	Occ	Arson	Smouldering	Burning smelt	Unknown	17.31	17.39	18.03	32	17.34	3	Unknown	28	28
B93	Occ	Unoc	Unknown	Unknown	Smoke seen	Unknown	05.06	05.11	06.32	86	05.13	7	Unknown	1,850	1,850
B98	Occ	Occ	Smoking materials	Unknown	Flame seen	nil	12.38	12.46	13.50	72	13.24	46	3	1,425	1,425
B151	Unoc	Unoc	Malicious	Flaming	Smoke seen	30	04.09	04.12	04.35	26	04.22	13	Unknown	166	166
S1[A]	Unoc	Unoc	Unknown	Flaming	Noise heard	120	18.41	18.44	02.00	439	18.50	9	Unknown	4,100	4,100
S1[B]	Unoc	Unoc	Radiated heat	Flaming	Flame seen	nil	18.41	18.44	02.00	439	18.50	9	Unknown	300	12,000
S4	Occ	Occ	Elec. fault in A/C	Smouldering	Smoke seen	Unknown	18.40	18.54	19.00	20	18.50	10	Unknown	2	2
S8	Occ	Occ	Unknown	Flaming	Flame seen	nil	15.50	16.06	19.39	229	16.20	30	1	940	10,600
S15	Unoc	Unoc	Unknown	Flaming	Flame seen	Unknown	20.20	20.23	21.50	90	20.50	30	Unknown	Unknown	3,840

*Sprinkler and smoke detector alarms acting simultaneously

ANALYSIS SHEET NO.3 - FIRE LOCATION, ENVIRONMENT, SPREAD AND DAMAGE

File number	Fire location		Fire environment							Structural damage to building (per cent)
	Floor of origin	Location of fire	Area of origin	Size of area of origin (m^2)	Additional areas within environment	Size of additional areas (m^2)	Division of building formed by environment	Total size of environment (m^2)	Environment involved in fire (per cent)	
H11	Ground	Stacked cardboard	Room	96	Room	320	Building	426	100	100
H14	Ground	Waste paper store	Room	2,160	Room	540	Building	2,700	1	Nil
H24	First	Storage area	Room	200	Rooms	280	Compartment	480	65	50
H32	Ground	Production area	Room	30,000	-	-	Building	30,000	1	Nil
H47	Ground	Plant room	Room	30	-	-	Building	30	10	Nil
H49	Ground	Mattress store	Room	24	Rooms	164	Compartment	188	12	Nil
H53[A]	External	External hazard	Room	270	-	-	Compartment	270	2	2
H53[B]	External	External hazard	Room	180	-	-	Building	180	4	5
H66	Ground	Jute store	Room	250	-	-	Building	250	16	Nil
H69	Ground	Polyurethane store	Room	780	-	-	Building	780	4	Nil
H84	Ground	Production area	Room	88	Corridor/room	180	Compartment	268	2	Nil
H85	Ground	Office	Room	12	Room	2,388	Compartment	2,400	1	1
H134	Ground	Spray booth	Room	136	-	-	Building	136	37	5
H144	Ground	Production area	Room	1,280	-	-	Compartment	1,280	1	Nil
H156	Ground	Packing department	Room	320	-	-	Compartment	320	20	Nil
H172	Ground	Processing area	Room	750	Room	50	Compartment	800	88	20
B2	Ground	Storage	Room	80	Rooms	9,290	Building	9,370	100	100
B9	Ground	Production area	Room	326	Room	28	Compartment	354	100	95
B10	First	Heating appliance	Flue pipe	2	-	-	Compartment	216	1	Nil
B19	Ground	Storage area	Room	130	Rooms	960	Building	1,090	50	50
B22[A]	Ground	Storage area	Open room	180	Rooms	540	Compartment	720	90	80
B22[B]	Ground	Production area	Room	400	Rooms	400	Building	800	63	63
B23	Ground	Service duct	Ducting	2	Rooms	598	Building	600	12	2
B26	Ground	Spray shop	Room	350	-	-	Building	350	23	2
B30	Ground	Production area	Room	720	-	-	Compartment	720	22	10
B39	Ground	Production area	Room	1,120	-	-	Building	1,120	3	1
B41	First	Production area	Room	280	-	-	Compartment	280	1	Nil
B48	Ground	Production area	Room	200	-	-	Building	200	18	20
B52	Ground	Common service area	Cupboard	2	Rooms	190	Building	192	52	25
B75	Ground	Production area	Spray booth	10	Rooms	1,450	Building	1,460	86	33
B77	Ground	Storage area	Open room	180	Room	180	Compartment	360	36	3
B92	Ground	Production area	Room	180	-	-	Compartment	180	15	Nil
B93	Ground	Production area	Room	2,000	-	-	Compartment	2,000	92	40
B98	First	Plastic foam store	Room	72	Room	1,928	Building	2,000	74	80
B151	Ground	Storage area	Room	48	Rooms	652	Compartment	700	22	1
S1[A]	Ground	Storage area	Room	4,100	-	-	Building	4,100	100	100
S1[B]	Ground	Storage area	Room	3,000	-	-	Compartment	3,000	100	100
S4	Fourth	Ventilation ducting	Ducting	4	-	-	Compartment	66	2	Nil
S8	Ground	Storage area	Room	400	Rooms	1,200	Compartment	11,200	95	40
S15	Ground	Production area	Room	200	Rooms	2,880	Building	3,840	100	100

GENERAL TABLES (ALL FIRES)

Table 1. Purpose Group

Group	Number of Buildings		
	Multi-storey	Single storey	Total
Factories	7	15	22
Storage	9	9	18
Total	16	24	40

Table 2. Fire Causes

Cause of Fire	Number of fires
Smoking Materials	7
Malicious	4
Radiated Heat	3
Mechanical -	
Fault in Equipment	3
Fault in Ducting	1
Electrical -	
Fault in Equipment	2
Fault in A/C System	1
Gas oven (Industrial)	1
Oil Fired Heater (Industrial)	1
Oil Fired Boiler	1
Explosion	1
Welding Equipment (Oxy-acetylene)	1
Unknown	14

Table 3. Nature of Initial Burning

Nature of burning	Number of fires	Percentage of Total
Flaming	16	40
Smouldering	15	38
Unknown	9	23
Total	40	

GENERAL TABLES (ALL FIRES)

Table 4. Average Estimated Delay in Discovery

Type of Building	No. of Buildings	Estimated Delay Ignition – Discovery (mins)
Unsprinklered	29	77
Sprinklered	11	–
All Buildings	40	69

Table 5. Methods of Discovery – Occupation and Average Estimated Delay in Discovery

Method of Discovery	Occupied Buildings	Delay (mins)	Unoccupied Buildings	Delay (mins)	Total Buildings	Delay (mins)
Smoke seen	3	unknown	14	132	17	132
Flame seen	10	2	5	44	15	15
Noise heard	2	nil	2	90	4	60
Klaxon heard	–	–	1	unknown	1	unknown
Sprinkler alarm	1	170	1	unknown	2	170
Smell	1	unknown	–	–	1	unknown

Table 6. Fires Fought by Civilians

Civilian Action	Multi-storey Buildings			Single-storey Buildings		
	No.of Incidents	Effect on fire		No.of Incidents	Effect on fire	
		Nil	Controlled		Nil	Controlled
Fought Fire	3	2	1	2	1	1
Failed to fight fire	13	–	–	22	–	–

GENERAL TABLES (ALL FIRES)

Table 7. Reasons why Civilians did not fight fires

Multi-storey Buildings		Single-Storey Buildings	
Reason	No. of Incidents	Reason	No. of Incidents
Fire beyond control on discovery	6	Building unoccupied	9
Building unoccupied	6	Hampered by smoke	6
Left to sprinklers	1	Left to sprinklers	5
		Beyond control on discovery	2

Table 8. Average Fire Duration (Discovery - Main Fire Out)

Building	All Buildings (mins)	Factories (mins)	Storage (mins)
Unsprinklered Buildings			
Multi-storey	109	92	121
Single-storey	64	39	119
All Buildings	85	57	111
Sprinklered Buildings			
All Buildings	25	20	30

Table 9. Average Sizes of Fires in Sprinklered and Unsprinklered Buildings

Time	Factories (m^2)	Storage (m^2)
Unsprinklered Buildings		
At Discovery	349	164
At Fire Brigade Arrival	672	527
Maximum Spread	1193	2212
Sprinklered Buildings		
Maximum Spread	35	50

MULTI-STOREY BUILDINGS

(TABLES 10 - 21)

Table 10. Construction and Age

Form of Construction	No. of Buildings		
	Pre 1950	Post 1950	Total
Load bearing brickwork	7	2	9
Reinforced concrete frame	-	3	3
Load bearing brick/timber frame	2	-	2
Portal Frame - Unprotected steel	1	-	1
Unprotected Steel Frame	1	-	1

Table 11. Size of Buildings

Size Group (m^2)	No.of buildings in Group	No.of Storeys				Average Floor Area (m^2)	Average Volume of Buildings (m^3)
		2	3	4	5		
0- 3 000	11	9	1	-	1	1 265	4 759
3 000- 1 200	4	1	1	2	-	7 553	23 805
12 000-30 000	1	1	-	-	-	29 720	176 305

Table 12. Fire Environments

Nature of Environment			Number of Buildings
Area of Origin	Additional Areas Within Environment	Division of Building Formed by Environment	
Room	Room (s)	Building	8
Room	Room (s)	Compartment	4
Room	-	Compartment	4

MULTI-STOREY BUILDINGS

Table 13. Size of Fire Environments

Size Group (m^2)	No.of Buildings in Group	Average size (m^2)	Average size (m^3)	No of building in which Environment involved was more than one storey	Percentage of whole building, forming environment 0-50%	50-75%	75-100%
0 - 2 000	11	432	2 285	8	4	-	7
2 000-10 000	4	2.354	17 833	3	1	-	3
10 000-12 000	1	11 200	66 440	1	1	-	-

Table 14. Extent of the Environment Involved in Fire

Extent of Fire Spread	No.of Fires	Percentage of the Environment involved (in each category)	Percentage of the Environment involved (categories combined)
Fires confined to the Environment of Fire Origin	10	36	60
Fires spreading beyond the Environment of Fire Origin	6	90	

Table 15. Rate of Growth and Fire Size

Rate of Growth		Fire size at stated times	
Interval Groups	Average time intervals (mins)	Stated times	Fire size (m^2)
Ignition-Discovery	61	Discovery	450(275)
Discovery - F.B.arrival	8	F.B. arrival	695
F.B.arrival - Max.fire size	20	Maximum growth	2900
Fire duration	109		

MULTI-STOREY BUILDINGS

Table 16. Direction in which fires spread within & without the Environment of Fire Origin

Direction of Fire Spread	No. of fires
Upwards	9
Sideways (to a substantial extent)	9
Downwards (by burning through a floor)	4

Table 17. Reasons for Fire Spread Beyond the Environment of Fire Origin

Reasons for Fire Spread	No. of Fires
Unprotected Opening	2
Failure of a Door in Fire Resistance	1
Door left open	1
Failure of structure in Fire Resistance	1
Unknown	1

Table 18. Factors which if present might have prevented Fire Spread or further Spread

Factor	No. of Fires to which Factor Applies
Separation of Risks	8
Sprinklers	4
Better Fire Resistance of Floors (from attack above)	4
Adequate Space Separation	4
Earlier Detection(Excluding Sprinklered Buildings)	3
Early Roof Ventilation	3
Non-combustible Wall & Ceiling Linings	2
Closed Fire Doors	1
Adequate Fire Protection to Duct	1
Smoke Detector in A/C Plant	1

MULTI-STOREY BUILDINGS

Table 19. Factors which prevented spread or Further Spread

Factor	No. of Fires to which Factor Applies
Sprinklers	2
Works Fire Brigade Action	1
Quick Fire Brigade Action	1
Early Detection	1
Compartment Wall	1
Fire Doors	1

Table 20. The Age of Buildings and Structural Damage, Fire Loads and Fire Duration

Age of Buildings	Percentage of the whole Buildings Structurally Damaged	Assessed Fire Loads (No. of Incidents)				Fire Duration (mins)
		Low	Med	Med/High	High	
Pre 1950	63%	-	3	-	8	121
Post 1950	Negligible except for one incident with 20% damage to a single storey area.	2	-	1	2	44

Table 21. Extent of Structural Damage, Fire Loads and Nature of Environments

Extent of Damage	No. of Buildings	Fire loads (No. of Incidents)				Nature of Environment		Buildings occupied at time of fire
		Low	Med	Med/H	High	Compartment of Building	Whole Building	
Building Totally beyond repair	8	-	2	-	6	3	5	3
Building partly beyond repair	2	-	-	-	2	1	1	1
Building slightly damaged	3	1	1	1	-	2	1	1
Building not damaged	33	1	-	-	2	2	1	3

SINGLE STOREY BUILDINGS

(TABLES 22-32)

Table 22. Construction

Form of Construction	Number of Buildings		
	Pre 1950	Post 1950	Total
Unprotected Steel Frame	1	7	8
Load bearing brickwork	6	2	8
Reinforced contrete Portal Frame	5	–	5
Reinforced Concrete Frame	1	–	1
Timber frame	1	1	2
Total	14	10	24

Table 23. Size of Buildings

Size Group (m^2)	No. of Buildings in Group	Average floor Area (m^2)	Average volume (m^3)
0 – 3 000	19	963	4 150
3 000 – 7 000	3	4 300	29 716
30 000	1	30 000	178 470
150 000	1	150 000	679 886

Table 24. Fire Environments

Nature of Environment			Number of Buildings
Area of Origin	Additional Areas Within Environment	Division of building formed by Environment	
Room	–	Building	10
Room	–	Compartment	6
Room	Rooms	Compartment	6
Room	Rooms	Building	2

SINGLE STOREY BUILDINGS

Table 25. Size of Fire Environments

Size Group (m^2)	No. of Buildings in Group	Average size (m^2)	Average size (m^3)	Percentage of whole building forming environment		
				0-50%	50-75%	75-100%
0-1 000	13	325	1 421	6	3	9
1 000-4 100	5	2 072	15 266	1	1	3
30 000	1	30 000	178 470	-	-	1

Table 26. Extent of Environment involved in Fire

Extent of Fire spread	No. of fires	Average percentage of envoronment involved
Fires confined to environment of origin	21	29
Fires spreading beyond the environment of origin	3	42

SINGLE STOREY BUILDINGS

Table 27. Fire Size

Size Group of Fires (m^2)	No. of Fires	Average Fire size (m^2)
Unsprinklered Buildings		
- 166	11	43
354-4100	5	1586
Sprinklered Buildings		
160	8	51

Table 28. Direction in which Fires Spread within and beyond the Environment

Direction of Fire Spread	No. of fires
Upwards (Igniting combustible roof)	3
Sideways (To a substantial extent)	9

Table 29. Reasons for Fire Spread beyond the Environment of Fire Origin

Reason for Spread	No. of fires
Fire Door left open	1
No fire stopping at junction Wall/roof	2

SINGLE STOREY BUILDINGS

Table 30. Factors which if present should have prevented fire spread or further spread

Factor	No. of fires to which factor applies
Earlier detection	5
Roof ventilation	4
Isolation of risks	2
Sprinklers	2
Non combustible roof lining	2
Better fire resistance of wall	1
Fire stopping	1
Closed fire door	1
Better housekeeping	1
Non combustible roof	1

Table 31. Factors which prevented Spread or further spread

Factor	No. of fires to which factor applies
Good fuel disposition	7
Sprinklers	6
Early discovery	4
F.B.action	4
Early ventilation via roof	3
Good general ventilation	2
Good housekeeping	1
Civilian action	1
Smoke stop doors	1

Table 32. Structural damage

Age group of buildings	No. of buildings	No. of buildings sustaining structural damage	Average percentage damage where damage occurred	Assessed fire loads No. of incidents					Fire duration (mins)
				L	L/M	M	M/H	H	
Pre 1950	9	5	30	3	–	5	–	1	40
Post 1950	15*	9	30*	3	1	2	1	8	59

*Only one sprinklered building suffered damage (10%))
*Eight buildings sprinklered.

4. NOTES TO THE ANALYSIS TABLES.

GENERAL TABLES Nos. 1 - 9

4.1. Sprinklered Buildings (Various tables)

Sprinklers were installed in three multi-storey and eight single-storey buildings and operated successfully in all incidents except one: in the latter case (concerning a multi-storey building) the system was inadequate and ineffecient. Since it had no discernible effect upon the fire this incident has been grouped with the unsprinklered buildings as far as fire size and fire duration are concerned. (Tables 8 and 9).

4.2. The early stages of the fire (Tables 3, 4 and 5)

The main characteristic of burning (smouldering or flaming) during the early stage of the fire and the time elapsing between ignition and discovery have been deduced from a technical appreciation of the fire situation, the evidence of the fire, reports of fire brigade officers and civilians and the time when the building was last known to be safe. In the last respect some of the times will be the maximum reasonable delay.

4.3. Estimated delay in discovery (Table 4)

No average delay in discovery is given for the sprinklered fires. In fact in five of these fires the delay was 'unknown'; in a further five fires the delay was nil (i.e. the fire was not 'discovered' by sprinkler operation); and in one fire the delay was 170 minutes due to a long period of smouldering. In only three cases did sprinkler action discover the fire.

4.4. Fire duration (Table 8)

Since the time from ignition to discovery is still imprecise (see 'Early stages of fire' above) fire duration is based upon the time of discovery to the point when the main area of flaming was considered subdued. Time to extinguish isolated pockets of flame, picking over and damping down is not included in the estimate.

4.5. Fire sizes (Tables 9, 14,15, 26 and 27)

For many Building Regulations, means of escape and cost/effectiveness purposes a convenient way of measuring fire size and extent of spread is by plan area of the parts of the building subjected to actual flaming. Values are shown for fire size at discovery, fire brigade arrival and final fire size (max.spread). Few values were obtained for fire size on discovery (see Analysis Sheet No.2) since an obvious difficulty arises with fires in unoccupied buildings discovered by passers by outside. However, even for these fires some deductions can be made from the available evidence but a survey of small fires (i.e less than one jet) should provide valuable

information to assist clarification of this aspect.

NOTES TO TABLES Nos 10 - 21 MULTI-STOREY BUILDINGS

4.6. The size of buildings (Table 11)

For greater clarity the buildings have been placed into the size groups given in the table. 'Average Floor Area' is based upon the total floor area of all floors of the multi-storey buildings (see also note to table 13).

4.7. Fire environments (Table 13)

A dictionary definition of 'environment' is 'the conditions or influences under which any person or thing lives or develops' and the term 'fire environment' has been taken to mean the general surroundings which confine or affect the fire. These surroundings are the largely unperforated walls, floors and ceilings which would impede the free movement of fire and smoke but the standard of fire resistance they provide might be below the general standard required by Building Regulations for such a building.

In its simplest form a 'fire environment' may consist of a single room with a closed door; but if two rooms are connected by an open door or other substantial unprotected opening at the time of the fire then the two rooms - if together forming a resisting boundary - would constitute the fire environment.

In this analysis an attempt has been made to define fire environments by a three part phrase. (See Analysis Sheet No.3). The first part defines the immediate room or area of fire origin; the second part defines other areas connected to the first at the time of the fire by virtue of substantial unprotected openings or construction which has virtually no fire resisting meaning in the contect of that particular building. Thus the first two parts of the phrase define the boundaries which in practical terms surround the fire and constitute the fire environment: the third part of the phrase expresses the sub-division - if any - of the whole building which this environment forms. Any detailed study needs to take account of additional environmental factors such as shape, ventilation, numbers of openings, materials used for finishes and construction and possible significant changes in the environment as the fire proceeds.

It will be appreciated that the fire compartment of the Building Regulations is a different concept to the fire environment outlined above. The former is a fire sub-division of the building to specific standards

designed to permit the reduction of the area at risk to suit various purposes. Further sub-divisions of the compartment to lesser standards are not recognized by the Regulations but since such sub-divisions form a barrier to the free progress of a fire - or at least affect its development - they must be included in detailed studies of the behaviour of fires in buildings and the behaviour of buildings and their component parts and contents in fires. Such studies will take account of the interaction of factors and assess the relative importance of those which assist, retard or prevent fire growth and spread in differing circumstances.

4.8. The size of fire environments (Table 13)

As with building sizes (Table 11) the environments have been placed into size groups. The Average Size (m^2) is based upon the floor area of the largest floor of the environment so that a direct comparison can be made with the sizes given in Building Regulations for compartment floors (Table A Regulation E5).

4.9. The extent of the environment involved in fire (Table 14)

The percentage of the environment involved in fire is given where the fire was confined to the environment of fire origin. A further value is also given for the percentage of the environment of fire origin involved in fire where the fires spread beyond that environment.

4.10. Rate of fire growth (Table 15)

It was only possible to estimate the size of fire on discovery in six incidents involving unsprinklered buildings (See Analysis Sheet No.2). These six incidents give an average fire size on discovery of 450 m^2 but this figure is thought to be very high due to the smallness of the sample. If approximate values are given to the 'unknowns' on the basis of the possibilities, then the average reduces to the order of 275 m^2. This figure is given in brackets in the Table.

4.11. Direction of Fire Spread (Table 16)

An indication of the direction in which fires spread has been given. Obviously some fires spread in more than one direction. Sideways spread does not necessarily indicate that an intervening partition had been penetrated since a substantial degree of spread can occur in a very large area or room.

4.12. Factors which if present should have prevented fire spread or further spread (Table 18)

An assessment was made of the factors which could reasonably be expected to be present in any well thought out scheme of fire protection for each particular building and its use, and which, had such factors been present, should have prevented fire spread or further spread. The emphasis is upon 'reasonable' and impossibly high standards were not expected.

4.13. Factors which prevented spread or further spread (Table 19)

This table lists the factors which did in fact prevent spread or further spread. Although the factors were effective in preventing spread in one direction spread might still be occurring in another and this too has been noted.

4.14. The age of buildings and structural damage, fire loads and fire duration (Table 20)

As yet there is no clearly defined line between structural and superficial damage. In this analysis structural damage is taken to be more serious than broken glass or plaster off walls (although it is appreciated that the plaster may form part of the fire protection).

The fire loadings refer to the contents only and the assessment was on the following basis.

Low - Low/Medium - Medium - Medium/High - High

Fire duration is on the basis explained in the note to Table 8.

NOTES TO TABLES NOS. 22-32. SINGLE STOREY BUILDINGS

In principle the notes to the multi-storey buildings apply to the single storey buildings but an additional note has been added for Table 27.

4.15. Size of Unsprinklered building fires (Table 27)

Because of the wide range of fire sizes in single-storey buildings the fires have been sub-divided into two size groups. Fires in sprinklered buildings have been shown separately in the table.

5. DISCUSSION

SOME ASPECTS OF BUILDING REGULATIONS, COST/EFFECTIVENESS AND MEANS OF ESCAPE PROVISIONS INFERRED FROM THE PRESENT ANALYSIS

It will be apparent that the range of industrial buildings covered by the pilot exercise was too broad to permit any firm conclusions or practical application of the results for the purposes set out on page 2. A full discussion of the use of information obtained from fire surveys is the subject of a separate report[2], but here, it is pertinent to make some tentative observations regarding this analysis and some aspects of Means of escape, Building Regulations and associated cost/effectiveness inplications.

Multi-storey buildings - It will be seen from Table 11 that the multi-storey buildings have been placed in three size groups. Ten of the eleven buildings in the smallest size group were not considered sub-divided into fire compartments to the standards required by the Regulations*. Both factory and storage buildings appear in this group and the nearest comparable requirement under the Regulations would be for 1 hour fire resistance to the structures with ½ hour fire resistance for non-compartment floors. In the event, seven of the buildings had non-compartment floors below this standard: six failed during the fires (four in a downward direction from a fire above the floor in question) causing considerable fire spread in five cases and resulting in some 50% severe damage to the building structures. Nevertheless seven of the buildings were considered repairable. The poor fire resistance of the floors did not seriously affect the life hazard in any of the occupied buildings nor is it thought likely that this factor would have proved a serious hazard in the unoccupied buildings had these been occupied: this is explained by the means of escape provisions which, with certain exceptions were generally good since account had been taken of the poor circumstances. In one incident where conditions were more questionable the occupants had previously agreed to evacuate immediately an alarm was given.

From the evidence so far available it appears that the reduction in the standard for non-compartment floors to ½ hour fire resistance in purpose groups VI and VIII of the Regulations is not detrimental to life safety: but it remains to be shown (by surveys in post Regulations buildings) what improvements in the extent of damage result where the full ½ hour standard applies and what effect the full standard has upon means of escape provisions. The answers will affect cost/effectiveness exercises as well as Building Regulations considerations.

Single storey buildings - In none of the single storey buildings was there evidence that collapse of unprotected structure would occur during the normal escape period.

Compartmentation - Of the five modern multi-storey buildings included in the survey four contained areas of differing purpose group which would require compartmentation under E4(3) (c) of the Building Regulations. In fact, in

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*It is a debatable point whether or not such floors - although substandard - should be considered to be one confine forming the fire environment (see page 20). Fire environments can be "typed" but are also complex and further evidence and scientific consideration is required to resolve this point.

all these buildings compartmentation was provided but in three of them failures occurred at the compartment walls due respectively to lack of fire resisting wired glass, inadequate fire resistance and failure to provide a damper to a duct. In the fourth case (where failure did not occur) an unprotected opening in a compartment wall was observed but was not involved in the particular fire. The ages of the buildings ranged from 1955 to 1970 and although only one was constructed under the Regulations (one of the failures) the need to pay attention to detail in otherwise good construction was obvious. In each of the three failures some fire spread occurred to the next compartment but due to fire brigade action this was not serious. In a larger survey it should be possible to indicate the average time at which failure is likely to occur.

Size of fires and environments in single and multi-storey buildings - Both the average building size and fire environment size were slightly greater for the multi-storey buildings than for those of one storey: however, the average fire size for the former buildings greatly exceeded the latter. It is obvious that fires will tend to spread upwards and in seven of the multi-storey buildings timber floors provided additional fuel at a convenient position to facilitate spread. A survey of fires in buildings where the full half hour standard has been applied to the floor would indicate the effect of such a floor on both fire spread and damage and the importance of neglected openings through the construction. The question of downward spread through a timber floor appears to have some importance.

Apart from indicating the effectiveness of the Building Regulations information of the nature obtained could form the basis of cost effectiveness exercises in which the benefits to be derived by improving the standard of existing buildings could be shown for individual cases: but these exercises would need to take account of other influencing factors such as method of ventilation, the provision and use of portable fire fighting equipment and so forth. Surveys would make this information available.

Means of escape provisions - In at least four buildings serious trappings could have resulted had fires occurred at other specific points and in one building the occupants were so alive to the dangers that immediate voluntary evacuation had been agreed following any raising of the alarm. Nevertheless in all the occupied industrial buildings surveyed only one person was trapped (subsequently rescued unharmed); and with this exception means of escape provisions proved adequate in these particular fires despite some sub-standard non-compartment floors and other forms of protection. However this should not be taken as an overall justification for such standards. In many buildings

the margin of safety was obviously small - depending upon early discovery - while some buildings representing a considerable hazard were particularly well served by alternative escape routes. The previously suggested survey of fires in post Building Regulations buildings would permit an assessment of the value to means of escape of the full $\frac{1}{2}$ hour fire resistance standard required for non-compartment floors.

The rapid worsening of smoke conditions due to sprinkler action was confirmed by one incident in which an employee encountered considerable smoke towards the end of a 26 metre open escape route across a storage building having commenced to escape immediately on discovery of the fire (by observing flames) and before the sprinklers operated.

The survey confirms the need for regular inspection and maintenance of escape routes by a responsible executive to ensure that routes are not blocked by storage, consideration is given to escape problems if storage patterns or the nature of storage are changed, and that the implications to escape routes are considered when building alterations are undertaken.

The Fire resistance of doors - Evidence in the individual files suggests that the most important factor affecting the fire resistance of timber doors is the direction of the air currents around the edges of the door - these being the resultant of natural currents and those induced by the fire. Some doors of very inferior construction and/or fit (which would certainly have failed the B.S. furnace test) provided complete protection from very severe fires for considerable periods. Two examples might be quoted: a pair of normal double swing corridor doors with open butt joint at the meeting stiles and a ledged and braced (1 in timber) door with a 'Norfolk' latch. Evidence from fires surveyed in other purpose groups during the pilot exercise confirms the importance of air currents in the resistance of a door to both fire and smoke penetration.

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