Fire Research Note
No. 939

COLLECTED SUMMARIES OF FIRE RESEARCH NOTES 1971

by

L. C. FOWLER

July 1972

FIRE
RESEARCH
STATION

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L. C. Fowler

(These summaries were prepared for the Fire Offices' Committee but it is thought that they may have general interest)

KEY WORDS: Fire research, review

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

Synopsis of F.R. Note No.792

A BRIEF ANALYSIS OF LARGE FIRES DURING 1965 to 1968

by

G. Ramachandran and Patricia Kirsop

This Note contains an analysis of 3464 large fires (costing £10,000 or more) out of a total of 3600 such fires which occurred in the period 1965 to 1968 inclusive) and the research is based on the Fire Brigade reports (K433 and special reports) and details of losses supplied by Insurers through the F.P.A. In all, 368,000 fires in buildings occurred during the period and cost £347m of which £211m was the result of the 1% of large fires.

The author has used statistics provided by the Building Research Station to assess the total value of manufacturing buildings, plant, machinery and stock at £40,000m (excluding distributive trades, commercial, construction, mining, utilities etc) and the losses in these manufacturing risks amount, in the period concerned, to £34m per annum (as compared with about £50m for all large fires). Therefore about 20 pence is lost by fire in these risks every year for every £100 at risk.

In some of these manufacturing risks where the total annual loss is £31m, the gross floor area is estimated at 2370m ft^2 (probably a slight over estimate but on the safe side when assessing the cost benefit of fire protection). This gives a loss of about 3 pence per square foot in large fires.

About 55% of all the large fires occurred in the manufacturing risks and they contributed 64% to the total loss in large fires. The distributive trades, especially departmental stores, accounted for nearly 18% of the large fires. Large cinema fires are becoming more costly and fires in hotels trebled in frequency during the period under review. The probability of a fire becoming large in production and storage areas is about equal but the latter are more costly.

The Note contains numerous tables and some are based on those shown in F.R. Note No.763 for which a synopsis was issued. The tables provide information for each year (and the average for the four years) on the -

(1) frequency distribution of large fires (number and cost of fires in each size range)

(2) hazard in which fires started

(3) place of origin, source of ignition and material first ignited

(4) extent of spread, and number of jets used

(5) time of call, day of week, attendance and control time

(6) fire protection devices.

The conclusions reached by the author are much the same as those reached in Fire Research Technical Paper No.16 (Fires fought with five or more jets) and are summarised as follows:-

(1) the most common known source of ignition is electricity but it does not appear to be inherently more dangerous than other sources of power in its contribution to fire spread

(2) 'smoking' causes fires which have a high probability of causing large fires

(3) malicious and intentional ignition may produce a serious situation (9% of all large fires in 1968 were so caused as against 6% in 1965)

(4) 'oxyacetylene cutting and welding fires' are the most expensive (average cost £110,000)

(5) packaging, cardboard, textiles and liquids are the most hazardous in starting and spreading large fires

(6) older and taller buildings produce more frequent large fires. The average cost in large fires is also higher in taller buildings. However, the age of the building does not appear to influence the average cost if a large fire breaks out

(7) 76% of large fires are confined to the building of origin

(8) 50% of large fires require only 4 jets at most to extinguish

(9) night fires are the most dangerous but there is little difference as between the days of the week

(10) delay in discovery of fire is more important than either delay in calling the brigade or in its arrival

(11) 77% of large fires occurred where there was no fire protection device (or not known) but the average loss in these buildings was only £50,200 as compared with £58,800 for all large fires (including those at premises with protection devices which did not operate)

(12) the average loss in buildings where sprinklers operated was £45,400 as compared with £154,300 in sprinklered buildings where the sprinklers failed to operate (or their performance was unknown)

(13) fires in buildings with operating automatic detectors and with operating fire doors averaged £134,800 and £117,400 each respectively but there were only 23 such large fires in the four years and the number is too small for the purpose of comparison

(14) it appears that fire detectors and fire-fighting activities are coping with the growth of individual fires in the industrial field but not with their frequency.

Note: The statistics do not reveal the benefits of sprinklers and other fire protection devices because they do not include any information regarding the values at risk and the hazards in the protected premises. Both these factors are likely to be much higher than average. The author will endeavour to obtain more information on this aspect of the problem. A copy of the table dealing with the fire protection devices is attached.

It might well be that the average loss for protected premises would be comparatively lower if all fires were considered since a higher than average proportion of fires below £10,000 may well occur in industrial premises with sprinklers and alarms etc. which operate. The statistics for large fires include, of course, the few very large fires in sprinklered premises where the sprinklers operate but fail to prevent fire spread.

FIRE PROTECTION DEVICES

Fire protection device	Performance	1965		1966		1967		1968		For the four year period		
		No.of fires	Total cost (£thousands)	No.of fires	Total cost (£thousands)	No.of fires	Total cost (£thousands)	No.of fires	Total cost (£thousands)	No.of fires	Total cost (£thousands)	Average cost per fire (£thousands)
Sprinklers and drenchers	Did not operate or performance not known	15	1999	4	321	7	1143	6	1476	32	4939	154.3
	Operated	33	1125	28	1068	23	1666	22	950	106	4809	45.4
CO_2, foam steam and nitrogen systems	Did not operate or performance not known	1	51	2	51	1	153	1	93	5	348	69.6
	Operated	6	141	63	3466	108	7523	101	9418	278	20548	73.9
Automatic detectors	Did not operate or performance not known	Included under 'Others'		2	80	1	15	2	375	5	470	94.0
	Operated			2	505	1	80	7	763	10	1348	134.8
Fire doors	Did not operate or performance not known			2	178	1	73	2	146	5	397	79.4
	Operated			8	621	4	405	1	500	13	1526	117.4
Others	Did not operate or performance not known	5	692	4	738	7	822	12	1154	28	3406	121.6
	Operated	5	1543	43	3346	42	3636	60	7063	150	15588	103.9
Combination	Did not operate or performance not known	2	62	5	1421	10	758	15	2423	32	4664	145.7
	Operated	8	1134	33	1696	46	5388	46	3276	133	11494	86.4
	Not installed, unknown or not applicable	566	31192	694	34879	677	34046	730	33927	2667	134044	50.2
	TOTAL	641	37939	890	48370	928	55708	1005	61564	3464	203581	58.8

Synopsis of F.R. Note No. 834

MULTI-STOREY CAR PARKS
A COST COMPARISON : STEEL VERSUS CONCRETE

by

D. V. Maskell

In this Note a comparison is made between the costs of ten concrete built storied car parks and five steel built storied car parks which have already been constructed in various parts of the United Kingdom. The steel built car parks are those for which Part E of the Building Regulations was relaxed so that the structural steelwork is unprotected.

The author has updated all the costs to the 1970 level and the average costs per parking place for the car parks erected is £480 (concrete) and £342 (steel) but, since most of the steel built car parks are not truly multi-storied but are, so far, generally limited to 2 or 3 storeys, a further allowance has been made for this factor and the actual difference in costs on this revised basis shows a saving of about £50 per car parking place by using unprotected steel instead of reinforced concrete.

However, if the steelwork has to be protected then the concrete car park would be cheaper by about £20/£25 per car parking place.

N.B. In the comparison no allowance has been made for any difference in maintenance costs e.g. the painting of steelwork.

Published as: MASKELL, D. V. Multi-storey car parks - A cost comparison. Conrad, 1971, 2 (4) 185-6.

Synopsis of F.R. Note No. 839

FIRE LOSS INDEXES

by

G. Ramachandran

This Note refers to the earlier F.R. Note No. 792 in which an attempt was made to relate the total annual fire loss to the loss per square foot and to £100 of value at risk. In this earlier Note it was calculated that, for all manufacturing risks, the overall loss from large fires only was £34 M (average over the period 1965 to 1968), the total value at risk was £40,000 M and the total floor area involved was 2370 M ft^2.

The present Note contains tables dividing these total figures into those applicable (based on the latest information) to 9 main manufacturing industries. The overall index for floor area was found to be 3^d per square foot and 18 pence (revised from 20 pence) per £100 (excluding the textile industry) both for large fires only. These overall figures are divided as follows:-

Industry	Loss per sq ft (old pence)	loss per £100 at risk (old pence)
Food, drink and tobacco	2.7	13.6
Chemicals and allied industries	3.8	13.0
Metal and engineering (including electrical and marine)	2.0	9.8
Vehicles	2.3	Not available
Textiles	4.6	"
Leather, fur, clothing and footwear	5.8	25.3
Brick, pottery etc	3.8	17.9
Timber, furniture etc	5.4	21.3
Paper, printing and publishing	4.0	24.2
Overall	3.0*	17.5**

* excludes "other manufacturing industries"

** includes "other manufacturing industries"

N.B. This paper refers to pre-decimalization currency.

Large fires account for about 60% of the total fire loss and, therefore, for all fires (large and small) the index for value at risk would be 30 pence per £100 $\left(\frac{18 \times 100}{60}\right)$.

It must be emphasised that the figures quoted have been based only on such statistics as are available to the author. These are necessarily incomplete and the indexes should not, therefore, be used to derive insurance rates.

These indexes could be useful for the purpose of planning fire protection measures. The loss indexes estimated in this Note can be regarded as constants for groups of industries and they take into consideration the possibility of fires becoming large but not the probability of fire originating.

The frequency of fire can be related to the value at risk according to the equation $F = KX^{\alpha}$ where K and α are constants depending on the nature of the risk and X is the value at risk. Probably a similar relationship exists between the size of the loss and the area at risk, according to the equation $L = K^{1} A^{\lambda}$ where K^{1} is a constant related to the conditions causing a fire to become large and λ is a constant related to the fire protection measures, e.g. it appears to be about 0.58 for sprinklered buildings and 0.66 for non-sprinklered buildings. It is hoped to improve the precision of the estimates for λ when sufficient data become available for each industrial group.

The frequency of fires and the expected loss therefore appear to depend on the size of the building and the value at risk (building and contents) but until there is information on the number of buildings at risk, graded according to size and value, any assessment of the economic value of fire protection measures must be inconclusive. Special surveys would be required in order to obtain this fuller information and one has been initiated in respect of the textile trade.

For individual buildings the indexes probably depend more on the value at risk than on the size of the building and it is possible that the size of the building could be a relatively unimportant factor since size and value are related. However, dependence on the value density of a building (and contents) appears to be strong.

Synopsis of F.R. Note No. 841

FIRE AND CAR PARK BUILDINGS

by

E. G. Butcher

In Fire Note No. 10 (Fire and car-park buildings), an HMSO publication dated November 1968, a full report was made on the experimental work carried out by JFRO and the Greater London Council on nine cars under storage conditions simulating an open-sided multi-storey car park. The tests showed that there was little danger of uncontrolled fire spread or of high temperature in the building structure resulting from a fire in one vehicle. In consequence of this work it was suggested that the fire-resistance requirements of such buildings could be very considerably reduced.

During earlier tests at JFRO on the behaviour of structural steel in fires, it was found that at fire loads of 3 to 4 lb/ft^2 with high ventilation, unprotected structural steel did not reach its critical failure temperature.

The present Note contains reports on visits to 20 multi-storey car park buildings in various parts of England. These visits were made to verify the fire loading and other conditions in such buildings. The Author also comments on an examination of fire losses in this class of building during 1966/7/8.

The conclusions reached are that uncontrollable fire spread is unlikely to result from an outbreak of fire within a single parked vehicle in an open-sided above-ground car park building and that the earlier experimental arrangements were representative of normal practice. No fire spread to adjacent cars in any of the fires investigated. No plastics bodied cars were found among the 7000 cars inspected during the visits.

Published as: BUTCHER, E. G. Fire and car park buildings. Conrad, 1971, 2 (4) 181-4.

Synopsis of F.R. Note No. 842

THERMAL EXPLOSION IN RECTANGULAR PARALLELEPIPEDS

by

P. C. Bowes

In predicting the conditions for self-heating and ignition in materials stored in rectangular piles having sides of different lengths (described, geometrically, as rectangular parallelepipeds) it is necessary to evaluate the critical condition parameter for any given dimensions.

The calculations are shown in this Note and the work is of value as a further step in the investigation of this problem in relation to goods stored and in transit.

Synopsis of F.R. Note No. 843

EXETER CHIP PAN SAFETY CAMPAIGN: EFFECT ON FIRE SIZE

by

E. D. Chambers

The effect of the 1966/7 campaign in Exeter was reviewed in F.R. Note No. 801 (see synopsis) and it was then suggested that there might have been some slight reduction in the number of fires as a result of the campaign.

The new Note examines the effect on the average size of the fires and the author concludes, with considerable reserve, that there was an immediate effect of reducing the average fire size by about a half although it returned to the pre-campaign level after a year or so. Therefore, the apparent saving in chip pan fire losses as a result of the campaign was about half-a-year's losses.

Synopsis of F.R. Note No.844

FIRE LOSSES IN DIFFERENT COUNTRIES

by

G. Ramachandran

The author has endeavoured to make some comparisons between the direct fire losses which occurred during the period 1955 to 1968 in a number of different countries, viz: U.K., U.S., Australia, Canada, Austria, Denmark, Norway, Sweden, Switzerland, Japan, France and West Germany. There are various differences in the methods of collecting, classifying and estimating loss data as between one country and another and, therefore, no direct comparison is possible but the relative trends in the different countries are indicated.

The Note contains various tables showing, for each country, the fire losses (in sterling, and both actual and corrected for inflation), the number of fires and the losses related to the Gross National Product, per head of pupulation, and in relation to the fixed assets (buildings, plant and machinery).

The conclusions are summarised as follows:-

(1) inflation was the major factor contributing to the increase in fire losses (from 1955 to 1968)

(2) in countries like U.S., U.K., Australia, Sweden and Norway there was also an increase in the fire frequency, but in Canada it decreased

(3) the average loss per fire did not increase significantly in most of the countries except:-

(4) the average loss per fire steadily decreased in the U.K. after 1964

(5) " " " " " rose rapidly in Canada (this balanced the frequency decrease)

(6) fire loss as a percentage of G.N.P. increased in the U.K.

(7) " " " " " " was stable in the U.S. and Canada

(8) " " " " " " decreased in Japan

(9) fire loss per head of population increased everywhere except in Canada and Japan

(10) fire loss per head of population in U.K. is low compared with the U.S. and Canada (perhaps due to lower living standards in U.K.)

(11) fire loss as percentage of gross fixed assets was stationary or decreased in all countries except Norway (it was similar in U.K. and U.S.).

Synopsis of F.R. Note No.845

EXPERIMENTS ON SMOKE DETECTION
PART 3: FIRES IN EXPANDED POLYSTYRENE,
POLYURETHANE FOAM, AND COMPRESSED CORK

by

E. F. O'Sullivan, B. K. Ghosh and R. L. Sumner

This Note describes further experimental work on the detection of fires by smoke detectors. Parts 1 & 2 of this work were described in F.R. Notes 770 and 780 (experiments carried out in a three compartment building, now demolished), and some experiments on wood cribs were described in F.R. Note 793. Synopses were issued for these three Notes.

For the latest experiments, 3 (commercially available) ionization chamber smoke detectors were installed on the 20 ft high ceiling of the laboratory, and were spaced in a line 15 ft apart. An optical scattering type detector was also tested at the same time. The optical density close to the detectors was measured by using a photocell and a light beam travelling over a distance of one metre.

Fires were lit on the floor under the outer detectors and smouldering combustion was produced by using a hot plate placed under the outer detectors but on a platform only 10 ft below the ceiling since there was insufficient heat to carry the smoke to 20 ft. The materials tested were expanded polystyrene, polyurethane foam and compressed cork. Such materials would be common in cold stores and the first two in dwellings.

Cribs of the materials were used for some fires and other fires were produced by placing sticks of the materials in the flames from a tray of burning methylated spirit (which does not produce smoke) to simulate burning from an external flame. The material was placed on the hot plate (450°C) to produce smouldering combustion.

The main conclusion from the experiments was that the ionization chamber type detectors would detect the smoke produced by all the materials tested apart from polystyrene burning in an external flame (insufficient smoke) and so would the obscuration of light type of detectors, apart from the burning cork.

The light scattering type of detector either worked, or the optical density measurements indicated that it should work, with all these fires (including smouldering) with the exception of cork. Therefore, only an ionization type detector would be suitable for cork fires.

More work is, however, needed on the response of both kinds of smoke detectors to the smokes produced in the present work.

Synopsis of F.R. Note No.847

GAS EXPLOSIONS IN MULTIPLE COMPARTMENTS

by

D. J. Rasbash, K. N. Palmer, Z. W. Rogowski and S. Ames

Comments on the gas explosion hazard in dwellings were made in F.R. Note No.759 following the Ronan Point collapse and, later, full-scale tests were carried out for the Building Development Agency by The British Ceramics Research Association (B.C.R.A.) in conjunction with the Gas Council. These tests confirmed that windows can act as useful explosion reliefs but high pressures (above 3.3 lbf/in^2) and severe turbulence were not experienced and, therefore, the Ministry of Public Building and Works, together with J.F.R.O., B.C.R.A. and the Gas Council carried out further tests to simulate an explosion, in a dwelling, passing from room to room with a possible substantial increase in turbulence.

These tests were carried out in a concrete bunker 18 ft long, 10 ft wide and about 7 ft high, with one open end. The bunker was divided into three compartments by substantial perforated partitions across the bunker. The rear compartment (A) was separated from the centre compartment (B) by a partition with two openings equivalent to the area of one normal doorway and B was separated from C (open ended) by a partition with openings, between it and the side walls, substantially greater than the area of a normal doorway. The open end was the size of a large window and was covered with a polythene sheet.

Experiments were done using both town and natural gas and the gas was introduced into the top of each compartment so that it formed a 3 ft deep layer below the ceiling. The time taken to form this layer varied from 15 to 25 minutes and some difficulty was experienced in injecting the gas so that it formed a layer without some general mixing throughout the air in the bunker. However, generally this was achieved and gas layers were formed of 100% town gas and mixtures of 40, 30, 20 and 15% of town gas with air and of 10% natural gas with air. The most violent explosions were expected with mixtures of 30/20% town gas and 10% natural gas since these are about the same or are slightly richer than the stoichiometric mixtures.

Ignition was by safety fuses fixed along the rear wall of compartment A at about the interface of the mixture layer viz: 3 ft below the ceiling, and ignition took place about a minute after the layer had been formed.

A high speed cine camera (up to 750 frames/second) recorded the view of the open end of the bunker from some distance outside and almost in front. Measurements were made of the flame speed from the back wall to the front opening (the polythene sheet) and of the pressures in the three compartments.

The experiments were designed to estimate the increase in violence, of an explosion, caused by the turbulence that might occur as the explosion passes through doors from one room to another, and not to measure the maximum possible explosion pressure which might occur if the whole volume was filled with the mixture, or the openings were different or there was furniture. Also, there was no "back relief" and a further series of tests would be required, preferably in specially built compartments, to elucidate the effect of these various factors which might arise in dwellings and have an influence on the force of the explosion.

The tests showed that the effect of the partitions was to increase the flame speeds (10–20 times higher) in compartments B and C as compared with compartment A. The maximum pressures measured in the tests were 5 lbf/in^2 for town gas-air mixtures and 3 lbf/in^2 for natural gas-air mixtures, but these high pressures only occurred in a small part, or narrow band, of the total range of conditions that can produce explosive effects. The high pressures resulted from 20% mixtures of town gas and 10% mixtures of natural gas, and richer or weaker mixtures produced much lower pressures. On the other hand, more severe turbulence which might arise in domestic premises could produce pressures substantially higher than 5 lbf/in^2. In the experiment with 20% town gas the explosion was violent and a hut 50 ft away was moved bodily and some damage was done to the front of the bunker when the 10% natural gas mixture was exploded. The tests with 100, 40 and 15% town gas-air mixtures produced negligible pressures.

Published as: RASBASH, D. J. et al. Gas explosions in multiple compartments. Department of the Environment Directorate General of Development. London, 1971.

Synopsis of F.R. Note No. 848

STATISTICAL ANALYSIS OF FIRE SPREAD IN BUILDINGS

by

R. Baldwin and Lynda G. Fardell

The relationship between the chance of a fire becoming large and the chance of fire spreading beyond the room of origin, and the effect of the Fire Brigade risk category on fire spread were reviewed in F.R. Notes 833 and 789 respectively. In the new F.R. Note the authors analyse the 1967 fire statistics in an endeavour to assess the various factors influencing fire spread and the factors chosen are:-

1. Time of discovery (night or day).
2. Multi- or single-storey and age of building (1920 1920/49 and 1950/67).
3. Fire Brigade risk classification (ABC or D) and time of attendance.
4. Purpose group of building (industrial, storage, shops, assembly, offices or residential).

Reference is made to the earlier Note in which it was shown that the chance of a fire becoming large (P_L) approximately equals the cube of the chance of fire spread beyond the room of origin ($P_S{}^3$). The authors also confirm the earlier assumption that the Fire Brigade attendance time has no systematic effect on fire spread, mainly because the Brigade classification already takes account of the hazard and fire spread risk.

The Note includes tables showing the chance of fire spread for the various purpose groups and the conclusions are as follows:-

1. There are significant differences between buildings used for different purposes and between some multi-storey and single-storey buildings.
2. The biggest single factor is the time of discovery of the fire, the chance of a fire becoming large is about 4 times as great at night when there is likely to be a longer delay in discovery.
3. The chance of fire spread is considerably smaller in modern buildings, particularly multi-storey, probably as the result of increased building control and safety consciousness.

More data are required in order to understand fully the implications of this analysis.

Synopsis of F.R. Note No. 850

SMOKE TESTS IN THE PRESSURIZED STAIRS AND LOBBIES
IN A 26-STOREY OFFICE BUILDING

by

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E. G. Butcher and C. Shore of Fire Research Station

Recent research (see F.R. Note No. 704) has shown that pressurization is a practical way of keeping stairs clear of smoke when natural ventilation is not possible and three tests were carried out using smoke candles (cold smoke - about 20°C at candle) on the sixth floor of a 26 storey office building which was nearing completion in Cardiff. The building was 92 ft square with a central core, containing lifts, two stairs, toilets and services, surrounded by a corridor having doors to numerous offices between this corridor and the external walls of the building. There were swing doors, some with rebated centre styles, between the main lifts' lobby and the stairs and the corridor.

Mechanical ventilation fed air into the offices through ducts below each window and this was extracted through ducts in the ceiling of the central corridor. Air was also fed into and extracted from the stairs (4 changes per hour) and was also fed into the main lifts' lobby and extracted via the toilets (10 changes per hour).

Although some external windows were openable, the weather conditions and wind, which was variable, did not affect the tests.

Smoke candles were lit either in the corridor only or in the corridor and lifts' lobby. The designed normal 'emergency' operation following the detection of smoke by a detector head was:

1. All extraction to continue except from the toilets
2. Supply of air to offices to cease
3. " " " " stairs to be quadrupled (both stairs 1 & 2)
4. " " " " lifts' lobby to continue unaltered.

Therefore, the pressure on the stairs was in excess of that in the spaces on to which they opened.

In test 1, extraction from stairs 1 was also stopped and in test 3 all fans were initially switched off but, after 5 min the normal 'emergency' operation was put into effect.

Final adjustments to the ventilation system had not been made at the time of the tests and the pressures developed were somewhat lower than designed but, even so, the pressurization system prevented smoke penetration into the protected spaces and effectively cleared the smoke even after the severe smoke logging in test 3 when the fans were off. Even with doors to the corridor open the smoke penetration was minimal.

The closing of the extract grilles on stairs 1 in test 1 was inconclusive and, although extraction has a part to play in a pressurized system, especially if the building is virtually sealed, the tests showed that pressurization will clear smoke even without the help of extraction.

The test results were so good that, although only cold smoke was used, the authors were convinced that the system would be effective even under real fire conditions, especially when the greater pressures are available.

Published as: BUTCHER, E. G., COTTLE, T. H. and BAILEY, T. A. Pearl Assurance Building Cardiff. Part 2. Some tests on the pressurized stairs and lobbies of a 26-storey office building. Build. Serv. Engr., 1971, 39 (December) 206 - 10.

Synopsis of F.R. Note No. 851

THE THERMAL DECOMPOSITION PRODUCTS OF PHENOL-FORMALDEHYDE LAMINATES

PART 1. THE PRODUCTION OF PHENOL AND RELATED MATERIALS

by

W. D. Woolley and Ann I. Wadley

This Note describes in considerable scientific detail laboratory and full-scale fire tests designed to determine, by gas chromatography and mass spectrometry, the extent of phenolic products resulting from the thermal decomposition of phenol-formaldehyde laminates in the temperature range 300 to 550°C. Phenol-formaldehyde resins are now widely used as adhesives for numerous building boards but this experimental work was concerned only with the possible hazards of the phenol products in respect of five different commercial laminates.

Tests were done in the small laboratory tube furnace described in F.R. Note No. 769 and, in addition, three fire tests were done in a fire chamber (4.5 m x 4.5 m x 2.5 m high) lined with the laminates. A wood crib was used as the main fuel in these field tests. The ventilation was controlled in the field tests and, in the laboratory tests, both air and nitrogen were used.

The concentrations of the phenol products, viz phenol, cresols and xylenols were measured. The toxicology of these three vapours appears similar but, unfortunately, there is very little information available on the toxic inhalation hazards of these phenolic compounds. Much depends, of course, on the time of exposure to the vapours.

The five phenolic laminates tested were similar in chemical structure and composition, and the maximum yield of phenolic products occurred in the inert (nitrogen) atmosphere at 460°C. The presence of air, as shown particularly in the field tests, greatly reduced the yield of phenols and the concentrations in these fires were much lower than expected and were certainly not hazardous in comparison with carbon monoxide. Further large-scale tests are required to study the production of phenols, using different fuel loadings and ventilation.

Synopsis of F.R. Note No. 852

THE THERMAL DECOMPOSITION PRODUCTS OF PHENOL-FORMALDEHYDE LAMINATES

PART 2. THE PRODUCTION OF FORMALDEHYDE, CARBON MONOXIDE AND CARBON DIOXIDE

by

W. D. Woolley and Ann I. Wadley

Following the investigation into the release of phenol products, as described in F.R. Note No. 851, further similar tests were carried out on the laminates to determine the extent of the release of formaldehyde and CO and CO_2 from the thernal decomposition of this material between 200 and 550°C in both air and nitrogen. The laminates contained cellulosic additives in the resin and after the thin decorative surfaces were removed the body of the material was broken up and 1 gram samples were used in the small laboratory tube furnace. Formaldehyde was detected only between 400 and 500°C but CO and CO_2 was monitored between 250 and 550°C.

Formaldehyde is known to be a toxic gas but it was shown that the toxic hazard was small in comparison with that of carbon monoxide and the phenolic products. In full-scale fires, flames may have a significant effect and this report should be regarded only as indicating the types of products which should be monitored in future model and full-scale fires which would be designed to determine if the phenol and related compounds present a hazard in relation to that of carbon monoxide in actual fires.

Synopsis of F.R. Note No. 853

A VERSATILE CHROMATOGRAPH FOR COMBUSTION GAS ANALYSIS

by

W. D. Woolley

This Note describes in detailed technical terms how a conventional organic research gas chromatograph (which is available on the Station) can be used to analyse both permanent gases and organic materials from fire and similar tests. The analysis is facilitated by the use of an automatic electronic desk computer. Use is made of a special gas inlet (injection) system into the chromatograph and this modification does not interfere with the normal operation of the instrument although both tasks cannot be undertaken at the same time.

The system enables the percentages of the permanent gases in the decomposition products (oxygen, nitrogen, carbon monoxide and carbon dioxide) to be determined easily and quickly. Speed and ease of analysis are more important than a high degree of accuracy in this type of work but with care and by introducing certain experimental modifications the general accuracy could, if necessary, be improved.

Synopsis of F.R. Note No.854

SMOKE TRAVEL IN SHOPPING MALLS
EXPERIMENTS IN CO-OPERATION WITH GLASGOW FIRE BRIGADE – PART 2

by

A. J. M. Heselden

A preliminary report was made on smoke tests carried out in a disused Glasgow railway tunnel in F.R. Note No.832. In the present Note optical density and gas temperature measurements are analysed. Temperatures were measured at four positions along the tunnel (at 0.7 ft, 1.6 ft, 3.3 ft, 5.3 ft and 7.5 ft below the apex of the ceiling in each position) and the optical densities were measured at two positions by photocell smoke meters (at 1.5 ft and 8.5 ft below the apex of the ceiling in each position).

The smoke meters were fixed 150 ft on each side of the fire (trays of kerosine) in tests 1, 2 and 3. When only one tray was used there was negligible smoke at the lower meter but with 4 trays burning the density at the lower meter was about half that at the higher meter long before the fire burnt out.

The temperature measurements indicated that the fall in temperature of the smoke layer as it travelled along the tunnel was largely due to a heat loss by radiation and convection into the tunnel walls and ceiling and not to any mixing of cold air into the layer. The temperature measurements supported the visual measurements of the layer depth and the predictions of layer thickness with size of fire. There appears, therefore, to be little mixing of air into the smoke layer.

The measurements made showed that there could be no great precision in applying the data to other situations.

As mentioned in the earlier Note a further test was carried out under a station canopy which extended across the track (from the platform) to a wall on the far side of the track. One 4 ft square tray of kerosine on the track was burnt and there was a 7 ft/s wind blowing along the track at the time. It was not easy to draw conclusions from a single test of this kind but the experiment did demonstrate that the path of smoke-laden gases from a fire depends very much on wind conditions and smoke does not have to be completely confined in order to give smoke-logging at a low level.

Synopsis of F.R. Note No.855

AN INVESTIGATION INTO THE FIRE RESISTANCE OF TIMBER DOORS

by

W. A. Morris

Eighteen timber doors and frames, supplied by the British Woodwork Manufacturers Association, were tested in accordance with B.S. 476 : Part 1 : 1953, for stability and integrity. All but two of the doors were designed to provide fire protection for ½ hour and the other two for 1 hour. Doors satisfying both requirements for the appropriate period are classified "fire-resisting" but only "fire-check" if they satisfy the integrity condition for only 20 or 45 minutes respectively. The integrity failure usually occurs as a result of orifices or openings forming along the edges of the door. During the tests a particular study was made of the effect of the depth of rebate, the fit between the door and frame, the use of intumescent strip at the door edge, the thickness of the door, and of any glazing, and the effect of positive furnace pressure.

Most of the doors had 1½ pairs of hinges (3 hinges), some opened towards the furnace and some away, and swing doors were also tested. Although any glazing was of Georgian wired glass, various methods of fixing were employed viz:- wooden beads (planted and integral) and metal beading. The doors were 6 ft 6 in x 2 ft 6 in and of the type normally found in residential and commercial buildings.

The following is a summary of the conclusions:-

1. a ½ in rebate will not be adequate for fire check purposes unless the fit is perfect

2. a 1 in rebate will reach the ½ hour fire check standard with a less good fit but additional precautions would be required for ½ hour fire resistance standard

3. swing doors would have a low fire-resistance standard

4. the fit of the door is more important than the size of the rebate and the use of intumescent strip to seal the edges enhances the performance, including that of swing doors, and might provide 1 hour fire resistance even without the impregnation of the door frame with flame-retardant chemicals

5. intumescent strips do not, however, provide an efficient smoke barrier if the door is ill-fitting

6. a 1½ in thick door can meet the requirements of a ½ hour fire check door and a further ¼ in will provide ½ hour fire resistance if the rebates and sealing are good and, subject to these requirements, a 2¼ in thick door will achieve 1 hour fire resistance grading

7. the furniture for the door must not be of low melting point material

8. glazing up to 10 ft^2 in area will not affect the $\frac{1}{2}$ hour rating if the glazing beads are of timber, $\frac{1}{2}$ inch in depth, although for $\frac{1}{2}$ hour fire resistance grading the timber should be treated with intumescent paint or be covered with a non-combustible trim or capping. The beads should, if possible, not be planted but be cut from the frame. Aluminium and PVC beading is not satisfactory.

9. glazing panels can be used for 1 hour doors if the glass is retained in a suitably designed non-combustible frame.

10. intermediate glazing bars can be a source of weakness

11. doors tending to deform when tested will fail earlier when opening towards the furnace and fire attack on the hinges and latch plate assist this tendency.

B.S. 476 does not specify the precise procedure for integrity failure but, in these tests, failure was construed as the appearance of flaming on the unexposed face persisting for 15 seconds or more, or the development of a gap greater than about $\frac{1}{4}$ in wide with charring or glowing near the gap. The intumescing material available is in the form of a strip $\frac{1}{8}$ in x $\frac{1}{2}$ in which is let into the door edge or frame and it only swells sufficiently to close the gap after direct fire attack for 10 to 15 minutes and during this time smoke could pass through the gap.

This investigation was designed to resolve some of the problems arising from the use of doors made entirely of wood, as compared with the hollow core construction specified under B.S. 459 : Part 3 : 1951, introduced at a time when timber was scarce.

Synopsis of F.R. Note No. 856

FIRE PROBLEMS OF PEDESTRIAN PRECINCTS
PART 1. THE SMOKE PRODUCTION OF VARIOUS MATERIALS

by

A. J. M. Heselden

This report describes the initial research work on fire spread and smoke production in pedestrian precincts utilising the full scale mock-up building described in F.R. Note No. 806. This building is of corrugated steel, 78 ft long 30 ft wide and 25 ft high erected between two existing brick buildings and the mock-up pedestrian mall is an area, enclosed with wood-wool slabs, 60 ft long, 20 ft wide and 10 ft high erected inside the corrugated steel building. The mall is closed at one end and open at the other and to one side at the closed end is the ground floor of one of the brick buildings which forms the fire compartment, representing a shop. This fire compartment freely communicates with the mall through an opening 10 ft wide and 8 ft high and contains a weighing platform, on which the fuel is burnt, and sprinkler heads.

Measurements were made at various points in the mall of the temperatures, radiation, air (or gas) flow and optical density. The smoke meters used measured the absorption by the smoke of a beam of light and the results were expressed as a 'standard optical density' taken as the optical density for a 1 metre light path length after burning 1 gram of the material in a stirred volume of 1 m^3. The recorded measurements were converted in this way so that the data could be used in relation to other situations.

All the experimental fires were lit so as to get the fuel flaming quickly and, being in an open-fronted compartment, they were well ventilated fires. No tests were done for smoke production from fires with restricted ventilation. The fuels tested were:-

1) Kerosine (5 gal on cool water in a tray) - for one fire there was a 'spreader' placed about 2 ft above the tray as in the Glasgow tunnel tests (see F.R. Notes 832 and 854)

2) Wood crib

3) Polyurethane foam cushions

4) Expanded polystyrene pieces

5) Foam rubber offcuts

Synopsis of F.R. Note No. 856 cont'd

Only very small quantities of the materials need to be burnt to produce a high level of smoke-logging. The smoke measurements were made at a point where the smoke had cooled substantially, though not completely. The worst materials for smoke production gave optical densities 7-9 times that of the best materials. Although no high precision can be claimed for the smoke measurements they are probably accurate enough for the intended purpose of simulating real fires in pedestrian precincts. However, the results for expanded polystyrene were considerably higher than those obtained in standard tests such as the Fire Propagation test but the differences could be due to the different mode of combustion. Wood in the form of an open crib produced the least smoke so it is not the best material to use for smoke production experiments. Kerosine was a bad but by no means the worst smoke producer; both foam rubber and expanded polystyrene were worse. Polyurethane foam was placed between wood and the kerosine.

The main purpose of these experiments was to measure the smoke production of various materials under realistic conditions and to correlate the results with those from small-scale testing. Apart from expanded polystyrene there was reasonable correlation but the tests did emphasise the considerable difficulties which arise in setting up meaningful tests for smoke production of some lining materials.

Synopsis of F.R. Note No. 857

THE EXTINCTION OF FIRES IN STORAGES OF RACKED GOODS USING HIGH EXPANSION FOAM

by

P. Nash, N. W. Bridge and R. A. Young

Experiments were carried out in the Models Laboratory at JFRO to investigate the effectiveness of H.E. foam in controlling fires in palletized storage racks, 24 ft high, consisting of two rows of back-to-back pallets at four levels. Each row was 4 pallets long and there were, therefore, 32 pallet compartments in all and the pallets were of wood.

The fire load consisted of corrugated cardboard boxes filled with wood wool and each pallet was stacked to a height of 5 ft (except top layer - to 4 ft) and the racking was of tubular steel.

The area containing the racking was at one end of the laboratory and was partitioned off from the remainder of the building with a polythene curtain fixed right across the full width of the laboratory and 30 ft from the end of the building. The racking was centrally placed within this area.

Four Walter Kidde foam generators were used, each designed to deliver 5000 ft^3 of 1000:1 H.E. foam and they were positioned 32 ft from the ground on scaffolding outside the building (except for the first experiment). They ejected foam through openings in the external wall. The units were driven by petrol motors and the tests showed that these must operate in clean air.

Three detectors were installed above the racking - Walter Kidde Fire-saver Fyr-index and Fire-alert types - and also a fusible link detector consisting of a glass bulb rated at 68°C. The temperatures at various positions were recorded. Ignition was achieved by lighting a torn cardboard box in the bottom layer of boxes between the two central pallets and 1 ft from the front face of the stack.

Foam was introduced either after a predetermined interval (30 s to allow escape of personnel) following the operation of the first alarm (smoke detector) or when the flames reached a predetermined height. There was usually a slow early development of the fire followed by a rapid increase in flame height. In one test the flames were "intercepted" by the foam, that is, the foam level came sufficiently close to the flame tips to quell the fire before it increased to the top of the stack and this is, clearly the best situation in order to achieve control and to prevent damage to the upper layers of the goods and to the ceiling. The tests showed that the growing fire was controlled by the application of the H.E. foam to the area in which the racks were situated.

Both the timing of the foam application and the rate of fill were important factors and an early application mitigated, to some extent, a slow rate of fill and a relationship could be established between these two factors according to the conditions.

It was found that it might be necessary to keep the racked goods covered with foam for some considerable time in order to ensure that all smouldering material was cooled below its ignition temperature, and periodic topping up was necessary. The use of foam tended to produce a clean-burning fire with little smoke production, although there were high temperatures and severe flame damage.

After immersion in the foam for the duration of the test, the outer surface of the unburnt cartons at all levels, appeared to be thoroughly wetted. However, the printing on the side of the cartons was not affected by the foam and the cartons dried out without distortion in about 12 hours. Cartons in the interior of the pallet/loads were unaffected by water draining from the foam and were found to be completely unmarked.

It would possibly be an advantage to use a combined system in which the rising foam level is aided by a low density water spray from above, or, possibly, by the application of H.E. foam over the top of the goods. This type of development should be considered.

Synopsis of F.R. Note No. 859

INTUMESCENT MATRICES AS FIRE RESISTANT PARTITIONS

by

D. I. Lawson

Honeycombs made of paper or aluminium and coated with intumescent paint (U K Patent Application No. 43423/70) have been tested (in the 3 ft square furnace) and the indications are that a 1 in thick (or wide) paper honeycomb coated with 0.0011 in of intumescent paint will give a fire-resistance rating of about 40 minutes. On this basis a $1\frac{1}{4}$ in wide honeycomb should give 1 hour fire resistance.

The honeycomb matrix could be triangular, square or hexagonal and, although the latter shape has the smallest surface area (of the three) for the paint, these matrices are commercially available.

The intumescent paint froths up into a friable meringue-like mass when heated and, in the furnace tests, it closed the honeycomb in about 1 minute and was held in place by the matrix (hexagonal paper honeycomb).

Matrices of this type could be used in place of dampers in ventilating ducts, as the core between the surfaces of a partition or door, or for suspended ceilings since the open honeycomb would permit the passage of light or air.

The use of intumescent-coated honeycombs may lead to the production of lightweight partitions, doors and ceilings at a highly competitive price.

Synopsis of F.R. Note No. 860

NOTES ON DIBROMOTETRAFLUOROETHANE (DBE)

by

P. F. Thorne and T. B. Chitty

DBE (dibromotetrafluoroethane) is a halogenated hydrocarbon (also known as Healon 2402 or Freon $114B_2$) available from major chemical manufacturers. Extinguishing agents of this type have usually been BTM or BCF but a recent reassessment has been made of DBE although the tests so far carried out have not been comparable. The toxicity hazard from the use of DBE appears to be low enough to justify its use both in portable fire extinguishers and for total flooding systems (subject to certain safeguards).

The most interesting use of DBE seems to be in conjunction with water-based extinguishing agents and a fuller assessment of DBE should include the following:

1) Fire tests on a range of standard flammable liquids (Class B) fires e.g. CENTRI-2 test fires using appropriately designed discharge nozzles.

2) Methods for incorporating DBE into foam liquids and solutions.

3) Fire testing of foams treated with DBE.

Synopsis of F.R. Note No. 862

PRESSURE TESTS FOR FIRE EXTINGUISHERS

by

P. F. Thorne

A CENTRI 2 sub-committee has been set up to study the problems associated with the European standards for portable fire extinguishers. In this Note the author examines one of these problems, viz: - the strength of extinguisher bodies necessary to support their working pressures safely under all likely conditions and to avoid damage by impact etc.

The 'nominal' working pressure can be affected by the ambient temperature by obstructions in the discharge pipework, and, especially those not filled in a factory, by variations in the quantity of extinguishing agent or pressurising gas. Extinguishers re-chargeable by the user normally incorporate a CO_2 cartridge, the charge contained therein also being variable.

An extinguisher can fail or burst as a result of the failure of the material used for the body or of the components. Various levels of pressure have to be considered. If the working or 'design' pressure is taken as 1 then the test (or proof) pressure will probably be about 1.5, the 'yield' pressure 2 and the burst pressure 3. The test pressure must be sufficient to cover all possible working pressures but not so high that it will enter the 'yield' range and, thereby, weaken the extinguisher body or components. Variations in the quantity of extinguishing agent and propellant or a blocked nozzle can affect the working pressure to the extent of ± 30 per cent. However, more data on this problem would need to be available before a proper statistical analysis could be made.

Consideration is given to the appropriate ambient temperature for the standard and it is thought that 60 or 65°C might be suitable for all extinguishers other than "chemical" for which temperatures of 45 to 50°C might be appropriate.

Apart from satisfying the pressure requirements, an extinguisher should be robust enough to withstand rough handling and misuse.

After considering all the available evidence the author recommends that the test pressure should be $1\frac{1}{2}$ times the working pressure or 350 lbf/in^2, whichever is the greater, and that the burst pressure should be twice this or 700 lbf/in^2 whichever is the greater. The burst pressure would, therefore, be three times the working pressure and the test pressure, at $1\frac{1}{2}$ times the working pressure, would be sufficient to cover the aforementioned $\pm$ 30 per cent variation likely to be encountered in practice in the working pressures.

To be published in the I.F.E. Quarterly.

Synopsis of F.R. Note No.863

A STIRRED JAR FOR PRODUCTION OF STANDARD FOAM IN THE LABORATORY

by

J. G. Corrie

Mechanical foam used for fire-fighting can be produced in many ways and the control of the production is dependent on the concentration of the foaming agent and the energy used, eg the air flow from a fan. In the examination of the foaming processes in a laboratory it is desirable to have some means of producing small batches of uniform foam of a chosen expansion and this Note describes an apparatus which has been designed for use in a laboratory and in which the foam is produced by an agitator. In this way the foam stiffness is determined by the agitator speed and the geometry of the apparatus and is independent of the concentration of the foaming agent (above a minimum value). A subsequent Note will describe an apparatus, designed to produce batches of foam, in which the stiffness of the foam is dependent on the concentration of the foaming agent and not on the energy application.

The apparatus consists essentially of a perspex jar about 4 in diameter and 5 in long placed horizontally with an axially mounted stirrer. The stirrer consists of a brass shaft with 9 stirrer blades formed from brass rods fixed at right angles to the shaft; rather like a small BBC 2 television aerial. The shaft is placed along the central axis of the jar, ie horizontally and is rotated by a 60 (or 100) watt electric motor. There are means for filling and emptying the jar by removing it from the apparatus and taking off the screw cap whilst the jar is held vertically. A small drain hole allows liquid, but not foam, to drain away when the foam is being made, and a standard stirring time of 6 minutes was adopted for the tests.

Tests were done using various proprietary foam liquids and numerous graphs in the Note record the 25 per cent drainage time, shear stress, concentration, stirring time, stirring speed and expansion and their inter-relationship. With other variables kept constant it was found that the time for a foam to commence drainage was directly related to the expansion and this indicates that there is a critical bubble wall thickness below which drainage does not occur as the foam collapses because the liquid from the collapsing bubble wall film is absorbed into the surviving film thus increasing the thickness of that film.

Foams can be classified into fully-foamed or partially-foamed liquids according to whether the bubble wall thickness is below or above the critical value.

It was found that the 25 per cent drainage times had little meaning for partially-foamed liquids, and for fully-foamed liquids this time should be independent of the depth of foam since this is only a few centimetres in the laboratory apparatus used.

The stirred jar enables knowledge of some of the properties of a foam liquid to be obtained with minimum effort and minimum quantities of foam liquid. By comparing the shear stress of a branchpipe foam with that of the same type of foam produced in the stirred jar, the efficiency of the branchpipe can be assessed and this is one way in which the knowledge can be used.

Synopsis of F.R. Note No.864

SMOKE TRAVEL IN SHOPPING MALLS
MODEL STUDIES - PART I : RATES OF LATERAL SPREAD

by

A. M. Phillips

Early work on the smoke problem in shopping malls or arcades and the preliminary tests using the 80 ft x 20 ft experimental building at JFRO were described in F.R. Notes 806 and 807 in which reference was made to the use of a model mall or arcade constructed to investigate the movement of smoke along a greater scale distance than was possible in the experimental building. Early indications were that smoke could travel from a fire at a rate of 100 m in $\frac{1}{2}$ min and 200 m in $2\frac{1}{2}$ min.

The present Note describes the model equipment and the general test procedures. Detailed analyses of the results will be reported upon in a later Note but it can now be stated that the smoke speeds measured in the model arcade can be successfully related to the theory expounded in F.R. Note 807 and to the observations in the Glasgow railway tunnel experiments (F.R. Notes 832 and 854).

The model arcade consists of a rectangular duct (0.56 m wide and 0.46 m high) made up of 6 sections (or modules) each 2.44 m long so that although only, say, 2 or 4 modules were used on some tests, the full length can be almost 15 m. The ducts are made of hardboard on wood framing and have windows for viewing, and the rear wall is hinged so as to open as a flap for clearing the smoke. The ducts are lighted with fluorescent tubes and the wood is painted black. At one end is a "fire compartment" containing 3 - 750 W electric heaters (2 used only in most experiments) and also a smoke-producing plant (smouldering fibre insulating board) to inject a visible aerosol into the hot air stream. Exhaust and inlet shutters to the "fire compartment" are operated in such a way that the flow of hot air and 'smoke' is suddenly injected into the mall when the test is started. The heaters simulate sufficiently well the convection output of a real fire. The other end of the duct can be open or closed.

Two types of flow "regime" may be distinguished in the model arcade after the smoke flow has been suddenly released from the "fire compartment". The first or 'transient' period occurs until the smoke reaches the open (or closed) end of the arcade and the 'steady state' develops slowly after that time.

At the start of the transient period the smoke mass issuing from the "fire compartment" soon assumes a curved nose as it travels along just below the ceiling.

The lower 'trailing' edge of the nose breaks up raggedly into a turbulent mass of vortices and eddies moving more slowly than the nose. After a short time these 'trails' of smoke below the rolling roof layer form an easily distinguishable intermediate layer between the top layer and the clearer air layer near the floor. This intermediate layer is often smoothly striated with a streamline appearance. Above the top layer is a shallow jet or current of smoke flowing along the roof into the nose at a greater speed than the nose which is thus continually fed with smoke. None of these flow properties change much when the arcade length is altered and the phenomena are generally the same for both open and closed ends up to the moment the smoke reaches the end.

If the arcade end is closed, the smoke moves down the end wall, touches the floor and rises again slightly as it begins to flow back towards the "fire compartment". It then forms a somewhat turbulent layer with diffuse leading edge overriding a shallow residual layer of clear air near the floor. This sub-layer gradually disappears as the smoke continues to move. The time required to establish the steady state is about ten times that taken for the smoke to travel to the end of the mall. When the end is open the lower layer contains fewer streamers of smoke in the steady state than in the transient since those previously formed in the intermediate layer, by the break-up of vortices shed from the nose, have already drifted back to the fire compartment. Especially with the hotter 'fires' the interfaces between the layers appear like an elastic membrane with a series of waves passing along it, but with little mixing of the layers. Severe smoke-logging is more apparent when the arcade end is closed.

Smoke cooling on the ceiling and walls flows slightly down the walls as it moves along the arcade and the smoke layers therefore have a somewhat arched section and this makes the depth measurement of the smoke layers rather difficult when viewed through the windows.

The smoke travel times and calculated velocities will be analysed in a later Note and possible applications will then be discussed.

Synopsis of F.R. Note No.867

APPLICATION OF THE THEORY OF THERMAL EXPLOSION TO THE SELF-HEATING AND IGNITION OF ORGANIC MATERIALS

by

P. C. Bowes

This Note consists of a paper delivered by the author at the "International Symposium on self-heating of organic materials" held at Delft in February 1971 during the session on chemical self-heating at which the author was Chairman.

The paper summarises the work done at the Fire Research Station on the procedures for determining the conditions for the safe storage and transit of materials liable to spontaneous combustion. The materials considered are cellulosic, activated carbon, and mixtures of vegetable oils and sawdust which are intended to simulate commodities such as oilseed meals, oiled textiles and fishmeal.

The author indicates, in scientific terms, the ways in which practical answers can be obtained for the safe storage and transit of these materials and subsequent papers will deal, in more detail, with the application of the theories to particular materials such as activated carbon and oil-bearing materials.

Further synopses will be prepared in due course when the subsequent papers are issued.

Synopsis of F.R. Note No.870

COUPLED GAS CHROMATOGRAPHY - MASS SPECTROMETRY AND ITS APPLICATION TO THE THERMAL DECOMPOSITION PRODUCTS OF CELLULOSE

by

W. D. Woolley and F. N. Wrist

A study has been made in a laboratory of the thermal decomposition products of cellulose in nitrogen and in air using an analytical system consisting of a gas chromatograph - mass spectrometer unit linked to a small tube furnace as described in F.R. Notes 769, 776, 851 and 852 when the decomposition of plastics was investigated. Samples of flame-retarded cellulose, using mono-ammonium phosphate, were also tested. Samples of cellulose (15 mg) in the form of filter paper were decomposed at temperatures between 250 and 500°C in a flow of air or nitrogen. The flame-retardant samples were prepared by coating the filter paper with a sufficient volume of aqueous mono-ammonium phosphate (M.A.P.) to give, after drying a 10 per cent increase in weight.

The Note contains tables showing the numerous decomposition products of cellulose, both in air and nitrogen, evolved during the 15-minute test period. Tests on the flame-retarded cellulose were carried out only at between 250 and 400°C in nitrogen and between 200 and 300°C in air.

About 30 components were detected during the decomposition of ordinary cellulose in nitrogen and 19 were identified, and 10 components were identified using air, both at 500°C. In general, the products in both cases were aldehydes, acids, ketones, alcohols and heterocycle compounds.

The decomposition of flame-retarded cellulose produced only 4 main components although at lower temperatures (250°C) there was a distinct increase in the quantities of flammable vapour so that the 'retarded' material was more prone to decomposition than normal cellulose. At higher temperatures (up to 350°C) there was an increase in the quantity of volatiles from normal cellulose but about the same quantity from 'retarded' cellulose and this tendency increased as the temperature rose and, further, at 400°C the 'retarded' cellulose produced only 2 main components.

During the work some interesting features about the action of flame retardants became clear but the report is not designed to present a detailed account of the decomposition of cellulose nor to investigate the action of flame retardants. The work does show, however, that the analytical unit is a very powerful and versatile tool for the study of the decomposition products of organic building materials.

Synopsis of F.R. Note No. 871

THE COMPACTION OF POWDERS BY VIBRATIONS - PRELIMINARY RESULTS

by

P. F. Thorne

One of the features being studied by the Tripartite Sub-Committee (CENTRI-2) in regard to an international standard for portable fire extinguishers is the compaction of the powder in dry powder fire extinguishers. These extinguishers are often kept in buildings, vehicles or ships which are subject to vibrations and they can also be impacted on a floor or other hard surface by being set down heavily during normal handling or maintenance. The effect of these movements can be to 'pack' the powder so that the operation of the extinguisher is adversely effected.

Experiments have been carried out to determine the conditions of vibration or impaction under which the maximum compaction occurs for particular powders. Three commercially-available powders were used - sodium bicarbonate and two others, one based on potassium bicarbonate and the other on ammonium phosphates. A transparent Perspex tube was used (63 mm inside diameter and 220 mm high) and a given weight of powder was poured in and gently tapped to a predetermined level. The container was then sealed and placed on an electromagnetic vibrating table for from 5 to 20 minutes until a constant 'compacted' level was established. The vibrations varied from 10 to 100 Hz.

Impaction tests were also carried out by dropping the container (in a vertical position) on to a rigid steel plate from a height of 1.5 cm at frequencies up to 1 Hz (1 c/s).

The degree of compaction is expressed as the ratio R which is -

$$\frac{\text{bulk density after vibration}}{\text{bulk density before vibration}}$$

"Fluidization" of the powder appears to occur at certain frequencies (notably 40 Hz) and this is probably due to a resonance phenomenon which separates the particles temporarily thus reducing the inter-particle friction and allowing the powder to pack more closely. The deceleration forces in the impaction test have a similar effect and also, by forcing particles past each other, the packing is even closer. The finest powders are compacted the most by both vibrations and impactions.

Since higher levels of compaction were achieved by dropping the container than by vibrating it, further work should be done on the impacting method as this is relatively simple and just as effective as vibration for compacting powders.

Synopsis of F.R. Note No. 872

MAINTENANCE OF STRUCTURAL STEEL MULTI-STOREY CAR PARKS

by

D. V. Maskell

Under certain conditions the Department of the Environment permits the use of unprotected steelwork for the construction of multi-storey car parks. However, although this form of construction may be cheaper by about £50–£55 per car parking place than concrete construction (see F.R. Note No. 834 for which a synopsis was issued) there is a draw-back in that steel needs continuing protection against corrosion, normally by painting.

The author has obtained useful information on this problem from Local Authorities and six examples are analysed in some detail. The extra cost of steel protection is related both to the initial costs and to the continuing running and general maintenance bills of both steel and concrete car parks.

The analysis indicates that the 'present day' worth of future steel redecoration is about £9 per car parking place, based on a life of 40 years and an investment interest rate of 7%. The above mentioned advantage of steel over concrete is therefore reduced to about £44 (drop of 17%). The cost of the steel redecoration (based on a 4 year maintenance cycle) is, however, only about 7½% of the overall maintenance bill (including wages) of a multi-storey car park. The type and situation of a particular car park will, of course, greatly influence the relative costs and savings and the above mentioned figures only provide general guidance.

Synopsis of F.R. Note No. 874

THERMAL MEASUREMENTS ON UNPROTECTED STEEL COLUMNS
EXPOSED TO WOOD AND PETROL FIRES

by

A. J. M. Heselden, C. R. Theobald and G. K. Bedford

The proposal to use unprotected steel work in multi-storey car parks was based, to some extent, on experimental fires sponsored by the B.I.S.F. in which wood cribs representing a fire load density of 7.5 kg/m^2 ($1\frac{1}{2}$ lb/ft^2) produced temperatures of not more than 360°C in unprotected steel columns in a compartment.

Part, at least, of the fire load in a car park may be made up of petrol and, to supplement the earlier experiments, a further series of 8 experimental fires was carried out at the Fire Research Station on a vertical I-Section mild steel column 8 in x 6 in and 7 ft long. In 5 tests wood cribs (of different stick size and spacings) were placed round or to one side of the base of the column and each test represented the same $1\frac{1}{2}$ lb/ft^2 fire load.

Three petrol tests involved different depths of petrol floating on water in steel trays placed around the base of the column and these produced either the same fuel weight or the same generated heat as the wood cribs, but one test represented a fire of very short duration.

Temperatures were recorded at intervals up the column and calculations were made of the heat transfer to the column and loss of heat by radiation.

The petrol fires gave higher temperatures than the wood fires (even those producing flames of similar thickness) because of the higher emissivity and increased height of the petrol flames.

It was found that the fuel arrangement made substantial differences to the flame height and heating and it was concluded that some fuel arrangements, albeit corresponding to a low fire load, could produce temperatures at the column base in excess of 500°C which is usually taken as safe for a loaded column. If the column had been in an enclosure even higher temperatures might have been reached as a result of re-radiation from the walls.

To be published in Fire Prevention Science and Technology.

Synopsis of F.R. Note No. 875

SOME NOTES ON THE CONTROL OF SMOKE IN ENCLOSED SHOPPING CENTRES

by

P. L. Hinkley

This Note summarizes the results so far obtained from investigations by JFRO into the smoke problem in covered shopping centres and also the results of experience with roof venting of single-storey buildings. The recommendations made will be revised, if necessary, in the light of future experience.

Previous F.R. Notes dealing with the basic principles of this problem are Nos. 806/7, 832, 854, 856 and 864.

In enclosed shopping centres most combustible materials will be in the shops (or stores) and this is where fires are likely to occur. Consideration is given to the spread of hot gases and smoke from a fire, 3 m x 3 m in area, in a shop. Most of the figures quoted relate to this size of fire because even a fire from a small source of ignition may grow to this size in a minute or two and at that stage would probably only be controllable by sprinklers. A fire developing beyond that stage would produce smoke much faster than any practical ventilation system could deal with and the mall would soon become untenable because of heat. Unless the shop is separated from the mall by fire-resisting construction sprinklers would be essential.

Escape beyond the smoke-logged area must be accomplished during the very early stages of fire development and the main task is to confine the smoke from the developing fire, even if controlled by sprinklers, to as small an area as possible and to remove it from the premises quickly. Ideally, smoke should be confined to the shop of origin by a fire-resisting shop front (with self-closing doors). Even so some smoke may penetrate into the mall. It is not practical to dilute the smoke sufficiently to produce a visibility of, say, 8 metres. Due to the mixing of smoke and cool air, extraction should normally be at twice the rate of smoke production but further work is being done on this aspect. Fans extracting hot gases must withstand high temperatures.

The main problem is to extract the smoke, and complete and prompt extraction is unlikely to be possible from open-fronted shops since the ventilation system would have to extract gases at many times the normal number of air changes per hour. Smoke in these circumstances is therefore bound to spread into the mall. The basic principle for smoke control is the provision of smoke reservoirs of about 1000 m^2 beneath the ceiling of the mall by fitting screens extending from the ceiling towards the floor. These should be at least 1 m, or one-third of the height of the mall, in depth and not more than 60 m apart. A screen or fascia board at the shop front would help to restrict the smoke to the shop area if the shop is otherwise open-fronted.

Consideration is given to the effects of false ceilings, natural and forced ventilation, both inlet and extraction, and to ducts, chimneys, flues and roof vents. There is no material difference in the smoke-logging conditions as a result of the mall being closed or open-ended although there can be some wind effects on all or any of the openings to the shopping centre especially if there are nearby tall buildings.

Smoke control and removal systems such as pressurization or extraction should be automatically controlled and initiated by a smoke detector. Incoming air to replace the extracted smoke should be introduced so as not to disturb the boundary between the hot gases and cool air.

It is essential to consider the smoke control measures at an early stage in the design of a shopping centre. The Note contains numerous sectional outline drawings of malls with shops adjoining (and the smoke movement) together with Appendices showing the method of calculating the various relevant factors.

Synopsis of F.R. Note No.876

THE FIRE PROPAGATION TEST AS A MEASURE OF FIRE SPREAD
CORRELATION WITH FULL SCALE FIRES IN CORRIDORS

by

H. L. Malhotra, W. A. Morris and J. S. Hopkinson

A series of six experiments on fire spread along a corridor with ceiling and walls lined with (1) plasterboard (2) polystyrene tiles and (3) hardboard was carried out in the Models Laboratory at the Fire Research Station in order to assess the relative fire behaviour of these linings, especially in relation to their Fire Propagation Test Index (B.S.476 Part 6). The corridor, of aerated concrete, was 13 m long, 1.2 m wide and 2.5 m high, open at one end and communicating by a doorway with a fire compartment at the other end. A wooden crib, representing a fire load density of 15 kg/m^2, was burnt in the fire compartment and temperatures and flame spread along the corridor were recorded.

The following is a consolidated table of the results:-

System	Surface material	Thick ness mm	Substrate and adhesive	Fire prop. index Index I	Fire prop. index Index i_1	Observations
1	Plasterboard	9	Nailed to concrete	9.7	5.7	Some board damaged near fire compartment door but no flame spread.
2	Expanded polystyrene std. grade	9	Asbestos/ cement wallboard (6 mm) with PVA continuous adhesive film	7.9	5.5	Ceiling and upper wall lining damaged but no flame spread on lining. (2 tests)
3	"	9	Asbestos/ cellulose board (3 mm) with latex continuous adhesive film	19.4	10.3	Igniton of lining opposite fire compartment door at 8 min and slow flame spread to 6 m in next 6 min. Lower parts of walls undamaged.
4	Hardboard (untreated)	3	Nailed to concrete	35.6	15.6	Within 1 min of flames emerging from fire compartment door flames had spread the full length of the corridor, with flames from floor to ceiling. (2 tests)

Peak temperatures from the crib fire (ignoring linings) were about 900°C at doorway and 500°C half way along the corridor.

In all the tests heavy black smoke developed in from about 4 to 6 min and flames emerged from the fire compartment in from about 6 to 10 min.

The tests successfully correlated the Fire Propagation Test Index of 12/6 (or under) with the safety standards associated with the current Class 0 (Class A in Scotland) specification under the Building Regulations and they demonstrated that the Index places these different materials in their correct order of performance under actual fire conditions.

The tests were not designed to show the superiority or otherwise of plastics over cellulose products nor do they infer that linings of expanded polystyrene would be acceptable on escape routes. The latter problem was reported upon in F.R. Note No.827 for which a synopsis was issued.

The associated smoke problem needs to be investigated further.

To be published in Fire Prevention Science and Technology.

Synopsis of F.R. Note No.877

A RELATIONSHIP BETWEEN FIRE GRADING AND BUILDING DESIGN AND CONTENTS

by

Margaret Law

Research into the behaviour of fully-developed fires is aimed mainly at estimating the temperatures attained by building elements under various fire conditions, so that possible structural or insulation failure can be forecast. Substantial data on fire behaviour have recently become available as a result of an international research programme undertaken by members of the Fire Research Working Party of the Conseil International du Bâtiment (CIB). The experiments undertaken were on fully-developed fires in single compartments ½ m, 1 m and 1½ m high of various shapes, with various areas of window openings and quantities and dispersal of fuel. A preliminary examination has been undertaken of these CIB data and comparisons have been made with the results obtained from various other experimental programmes in this and other countries.

In the CIB experiments compartments of various shapes were used and these were indicated by a code, e.g. 141 being width 1, depth 4 and height 1, and ¼, ½, ¾ and full-ventilation conditions were employed, the ventilation, or window opening, being the full height in one side of the compartment (½ ventilation being an opening ½ the length of the side). The fuel consisted of wooden cribs with various stick sizes and spacings to provide different fire loads. The results of the CIB experiments are summarised in this Note and comparisons are made between the results of those experiments and the effects of the Standard Fire Resistance Test, in particular in regard to a protected steel column which would normally have a failure temperature of 550°C for the usual design loads.

It is shown that the equivalent fire-reistance times (t_f) for the CIB experiments have a powerful correlation with $\frac{L}{\sqrt{A_W A_T}}$ where L is the total weight of fire load, A_W is the area of the ventilation opening and A_T is the area of the compartment wall, ceiling and floor area (other than the ventilation area). In these experiments scale and stick thickness have negligible effect although closer stick spacing gives greater fire resistance due mainly to longer fire duration. There is also a similar correlation in other and larger-scale experiments and it can be said that, in general, $t_f = K \frac{L}{\sqrt{A_W A_T}}$ and that the value of the 'constant' will vary slightly according to fuel spacing, size of experiments and whether or not there is a wind or forced ventilation. The best value of the constant (K) is 0.95 min m^2/kg for those experiments whose records permit its evaluation.

Further large-scale experimental work would be more valuable if carried out in deep compartments, and the heat flow in structural elements other than protected steel columns needs to be examined. Adjustments to the calculations will be needed to allow for the variation in heat transfer according to the type of furnace involved in the standard test in order to arrive at the correct t_f for the structural element to reach the critical temperature in the standard fire-resistance test. This is mainly due to the furnace having non-luminous flames as compared with radiant flames in a real fire.

Reference is made to the report on the fire loading of 2 modern office buildings (see synopsis for F.R. Note No.808) and it is suggested that some of the theoretical variations mentioned above caused by fuel spacing, scale, etc may not be significant compared with the variations in the value of $\frac{L}{\sqrt{A_W A_T}}$ in respect of these office blocks due, to a large extent, to the variation of fire load from room to room. Another difficulty is deciding what constitutes a fire compartment which may well be the whole of one floor of a building if a room separation has little or no fire resistance.

Synopsis of F.R. Note No.878

FIRE AT WULFRUN SHOPPING CENTRE, WOLVERHAMPTON, 24.12.70.

by

A. Silcock and P. L. Hinkley

A fire having a bearing on the problem of shopping arcade hazards occurred on Christmas Eve 1970 at the Wulfrun Shopping Centre in Wolverhampton. The arcade was built in about 1965 of reinforced concrete with brick or concrete separating walls between shops. It is mainly of one storey with car parking on the roofs. The arcade is about 7½ m wide with shops on both sides and, at about 27 m from the Carpet Shop where the fire started, the arcade bridges a street to join up with similar premises called the Mander Centre. The bridge (about 20 m long) is covered and has glazed sides, and the first shop on the Mander Centre side is a sprinklered department store having sprinkler heads in the arcade in front of the store. In the other direction along the arcade from the Carpet Shop the pedestrian way ceases to be roofed-over and, at a distance of about 1½ m from the Carpet Shop, there are only canopies in front of the shops so that this end of the arcade is virtually open-ended. This open part is called a 'mall'.

The fire occurred in the Carpet Shop at about 6 a.m. and the shop, with glazed front to the arcade, was burnt out. The glazing probably broke about half an hour after the fire started (cause - probably goods in contact with spotlamp or storage heater) and the fire brigade arrived soon after the fire in the Carpet Shop reached its maximum. Once the shop windows broke the rush of hot gases must have reached the end of the arcade in the Mander Centre in about one minute. Although the department store is about 47 m from the Carpet Shop, the five sprinkler heads in the arcade and three more inside the store opened.

There were some decorative wood joists to the ceiling of the Wulfrun Centre part of the arcade but although these added some fuel to the fire they are not thought to have influenced the fire spread materially. The other shops fronting on to the arcade were glazed with deep non-combustible fascias above and all the glass fronts, although cracked, remained in position and consequently restricted fire spread by radiation although considerable smoke penetrated into the shops.

The fire was fought from the open (mall) end of the arcade but this would not have been possible had the fire occurred in a shop further into the covered arcade. Severe fire damage was restricted to the carpet shop but extensive smoke damage was done elsewhere and the concrete roof slabs (possibly 2 hours rating under B.S.476) suffered considerable damage and spalling, and cracks in walls occurred at some distance from the fire due to expansion of the structure. The windows in the sides of the arcade bridge were not even cracked although sprinkler heads on the far side of the bridge were opened. The breakage of glass cannot, it seems, be relied upon to provide venting.

It is clear that the fire brigade arrived only just in time to prevent all the shops facing the arcade in the Wulfrun Centre being involved in the fire since at the time of their arrival the arcade was 'a tunnel of flame', and all the shop windows would have fallen out at any minute. The Brigade was alarmed by a passer-by at about the same time as the A.F.A. connection from the sprinkler installation operated. The fire is estimated to have lasted about $1\frac{1}{2}$ hours from ignition to extinction.

The Note contains a plan and other drawings of the shopping centre.

Synopsis of F.R. Note No.879

FLAMMABLE LIQUID FUELS FOR CLASS B FIRE TESTS FOR PORTABLE FIRE EXTINGUISHERS

by

P. F. Thorne

The problems of European Standards for portable fire extinguishers have been considered by a Tripartite Sub-Committee (CENTRI-2) set up by the Comité Européen de Normalisation.

Particulars are given in this Note of the present fuels used by Britain, France and Germany for Class B fires. There are considerable variations especially in regard to motor gasolines where these are used, and the 'Essenee-F' used by the French Testing Authority is not a normal gasoline like those used by the other two countries.

After due consideration the Committee agreed that 100/130 octane aviation gasoline should be chosen as the standard fuel for Class B fires for testing hand fire extinguishers. This fuel is readily available.

Synopsis of F.R. Note No.883

THE IGNITION OF PLASTICS MATERIALS IN DWELLINGS

by

S. E. Chandler

An analysis was made of half the 396 fires occurring in dwellings during 1969 in which plastics materials (other than woven fabrics) were ignited first. Although there is a toxic hazard from burning plastics, spreading fires involving plastics cannot be identified but this analysis does draw attention to the inception hazard of plastics articles.

A variety of plastics articles was involved, from toys to furniture, but buckets, bowls, and containers were most frequently ignited first. Many of the fires (43 per cent of the incidents) occurred in kitchens and a third of these involved the ignition of buckets, bowls, waste bins and similar containers, mainly by cooking appliances. Thirty-six incidents ($9\frac{1}{2}$ per cent of the total) involved furniture and furnishings, $7\frac{1}{2}$ per cent concerned toys and games and 3 per cent only involved wall and ceiling linings.

The fire hazard often arose through the article and the source of ignition being carelessly placed too close together and the most frequent sources of ignition were cooking appliances (25 per cent), space heating appliances (20 per cent), wire and cable (ten per cent) and smoking materials (9 per cent).

Synopsis of F.R. Note No.884

FIRE SPREAD IN BUILDINGS - THE EARLY STAGES OF GROWTH

by

R. Baldwin, S. J. Melinek and P. H. Thomas

Fire brigade reports for 1961-69 were examined in an endeavour to investigate the chance of fire spreading from the item first ignited (p_a) and its relationship with the chance of fire spreading beyond the room of origin (p_s). Different coding practices over the years caused some difficulties, especially when there were ambiguities in the definition of the item first ignited, and only fires in buildings where spread beyond the room of origin could occur (not single compartment buildings) were included in the investigation. The influence of various factors such as occupancy, source of ignition, times of call, attendance and control were explored, both as regards p_a and p_s, separately and together.

Since fires which had developed only sufficiently for attendance by the fire brigade were investigated p_a was high (about 80%) and this seriously restricted the examination. Further, it was found that coding procedures could seriously distort the yearly trend in p_a. In consequence of this a different approach to the problem was examined.

It was thought that a more practical approach would be to consider the early stages in the spread of fire on a physical basis, taking into account statistical variations in the various parameters such as the separation distances of the fuel, the possibilities of spread by radiation, both direct and from flames spreading across the ceiling, the area and periphery of the fire (S_A), the time of brigade arrival (T_A), and of control by the brigade (T_C). A number of tentative equations have been established for determining the size of a fire in relation to the various parameters, in particular the rate of spread and time of control and these are based on the simplest possible assumptions consistent with the available data. It is hoped that this approach will provide a starting point for the future and more complex study of the factors influencing fire spread.

Synopsis of F.R. Note No.886

THE NUMBER OF SPRINKLER HEADS OPENING IN FIRES

by

R. Baldwin and M. A. North

Data regarding the number of sprinkler heads opening during a fire have been examined, since this information is important in the design of a sprinkler system. The statistics have been drawn from the UK fire brigade reports (689 fires during 1967-8) and the US National Fire Protection Association (73,667 fires in the US from 1925 to 1964).

Although none of the installations was designed to the new 29th Edition of the FOC Rules for Automatic Sprinkler Installations, the examination has been carried out in the light of these Rules and their requirements regarding the density of water discharge, the assumed area of operation and the maximum coverage area per sprinkler head for the various hazard categories under which the maximum number of heads expected to operate can be calculated. The design maximum number of heads operating was, of course, used in the drafting of the new Rules.

The age of the installations was not known but this was assumed to be the same as the age of the building which was known in respect of the UK fires, as also was the occupation of the premises.

The statistics from the US provided information regarding wet and dry sprinkler installations and this was also examined.

The proportion $q(N)$ of fires in which a certain number (N) of heads or more operated (provided the installation worked) was calculated and it was found that the US and UK data were not significantly different. In the UK about 90% of these fires were controlled or extinguished by the sprinklers and the following table summarises some of the information available from the UK fires (619 fires during 1967-8) based on a reasonable assessment of the hazard involved.

Sprinkler performance by hazard groups

Hazard		No. of fires	Design maximum number of heads operating (N_m)	Percentage of fires in which N_m was exceeded	Percentage of fires controlled by sprinklers
Extra light	(XLH)	30	4	23	90
Ordinary	(OH1)	8	6	17	88
	(OH2)	91	12	9	93
	(OH3)	476	18	6	95
Extra high	(XHH)	14	29	3	79

These statistics are in good agreement with the design probabilities assumed under the new FOC Rules. The smaller proportion of controlled fires under the XHH group is not considered statistically significant.

The control probability in relation to the age of the building (and assumed age of installation) was:-

pre-1900 98% 1900-29 92% 1930-67 91%

The reasons for these differences were not apparent, nor was the reason why fewer heads operated in older buildings.

The information regarding wet and dry installations (US data) showed that a higher proportion of fires in buildings protected by a dry system will attain any given size than in buildings with a wet system. This occurs probably because it takes time to exhaust the air from the system and during this time the fire spreads. The fire, being larger when the water is discharged, causes more heads to open in a dry than in a wet system, in fact, on average twice as many heads open in dry than in wet systems and this means that there is more fire and water damage with the former system. There is probably a delay of 50% more in the time taken for dry installations to discharge water and it might well be more economical to heat the premises and have a wet system, or to trigger the system with a smoke detector.

The calculations and assumptions made indicate that a fire doubles its size every 4 min and this is a reasonable result. The calculations are necessarily somewhat speculative but even with the present crude assumptions it seems clear that they can be used to provide a means of estimating some important features of fires in sprinklered risks.

Synopsis of F.R. Note No.887

THE APPLICATION OF HIGH EXPANSION FOAMS TO WOOD CRIB FIRES

by

P. F. Thorne and R. A. Young

A short series of four exploratory experiments was carried out in an enclosure (20 ft x 24 ft) of 9 ft high movable asbestos screens in the Models Laboratory at the Fire Research Station in order to examine the performance of high expansion foam on wood crib fires. The cribs were placed just above the floor and were of the same size as those being developed for the standard fire test for fire extinguishers. One crib only was used in three tests but 4 cribs were placed in the enclosure for the last test. A standard Walter Kidde P 500 foam generator designed to produce 5000 ft^3 of foam per min at an expansion of 1000 : 1 was used. In each test there was a crib pre-burn time of 7 or 8 min before the foam was injected and this was done at different rates and expansions for each test varying from a rate of 0.1 to 0.3 m/min and expansions of from 260 : 1 to 850 : 1. The variation in output from the foam generator was achieved by adjusting the fan speed. In F.R. Note No.766 (see synopsis) a minimum application rate of 0.06 m/min for each 1 kg/m^2 fire load was recommended for these solid fuel fires. Each crib provided an overall fire load in the enclosure of 1.05 kg/m^2 (the 4 crib test provided 4.2 kg/m^2) and the following table shows details of the experimental fires:-

Experiment	Cribs	Mean rate of foam application m/min	Recommended rate m/min	Expansion
1	1	0.3	0.063	850 : 1
2	1	0.1	0.063	260 : 1
3	1	0.24	0.063	600 : 1
4	4	0.24	0.25	700 : 1

Except in experiment 2, flaming combustion was extinguished in about 5 min whilst smouldering combustion was not always completely extinguished. Smouldering was only controlled in some cribs and in two cases only by topping up with fresh foam. Where smouldering was only controlled, re-ignition occurred on removal of the foam. The presence of 4 cribs did not affect the results. In experiment 2, although the rate of application was above the recommended minimum, the expansion was low and the foam was continually destroyed by radiation from the burning crib which was consequently not covered with foam. Further, in this test, the rate of application and the expansion were too low for a sufficient "head" of foam to be built up to enable the foam to flow along the ground effectively.

Although smouldering can continue under the foam this can be limited if there is a sufficient depth of foam.

The results of these tests have been confirmed by further larger scale tests on high-stacked storage - see F.R. Note No.857.

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