Fire Research Note
No 869

COLLECTED SUMMARIES OF FIRE RESEARCH NOTES 1963 - 1970

by

L. C. FOWLER

May 1971

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

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KEY WORDS: Fire research, review.

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

Synopsis of F.R.Note No. 527

CONTROL OF FIRES IN LARGE SPACES WITH INERT GAS AND FOAM PRODUCED BY A TURBO-JET ENGINE

PART 6 TRIALS IN COLLABORATION WITH THE LONDON FIRE BRIGADE AT DISUSED BASEMENT PREMISES

by

D. J. Rasbash, G.W.V. Stark, G. M. J. Elkins and B. Langford

The experimental turbo-jet engine, used at Boreham Wood, filled the Models Laboratory (250 000 ft^3) with inert gas in 5 to 10 min and extinguished liquid fuel fires, virtually extinguished solid fuel fires, and cleared the smoke within this time. High expansion foam can be produced with a 60 per cent efficiency in converting the gas to foam so this method would take nearly twice as long to fill the same building on the assumption that the foam would spread throughout the building as quickly as inert gas but this is not quite true. Experiments were carried out in a basement at a disused brewery, in collaboration with the London Fire Brigade, in order to investigate the whole problem.

Numerous tests were carried out utilizing inert gases having different oxygen and moisture content, and various high expansion foams were used. Firemen, (suitably protected) were able to work in the atmospheres and sound travelled well in the foam. The gas and foam were injected into the basement through 2 ft 6 in diameter textile sleeves.

The inert gases can be divided into 3 broad classes viz:-

Class 1 - a cool gas (about 90°C) - oxygen 15-16 per cent water 15-17 per cent
Class 2 - a warm gas (about 110°C)- oxygen 14-15 per cent water 18-19 per cent
Class 3 - a hot gas (about 120°C)- oxygen 6-10 per cent water 34-48 per cent

The class of gas can be changed during the injection and whilst all the gases would be capable of controlling a fire those with a lower oxygen content would do so more rapidly and those with more water would produce a misty, humid atmosphere with poor visibility. The time to control a fire decreased as the oxygen content decreased and water content increased but it would appear to be most economical and practical to use a cool gas with high oxygen and low water content so that the atmosphere can be kept clear of water vapour and the flaming controlled, allowing firemen to enter and complete extinction.

The high expansion foam (1000 to 1 expansion) was produced using a Class 2 gas and the foam readily penetrated throughout the basement(s) although there was a high rate of drainage because of the particular foam compound used. Tests at the Fire Research Station have shown that foams with higher stability and lower rate of drainage would make extinction easier and would reduce the rate of breakdown of the foams due to mechanical causes e.g. flowing past obstacles.

Inert gas is lighter than air and a high level fire is best attacked with a Class 3 gas injected as gently as possible. A general contents fire is best dealt with by injecting through an open ended duct a class 2 or 3 gas. A fire at ground level only can be attacked with foam or inert gas. If there is uncontrolled ventilation e.g. the roof has collapsed, then foam should be used.

A foam with a low drainage rate is more likely to extinguish a fire than inert gas which may require firemen to complete the extinction. However, a class 1 inert gas injected after a fire has been controlled with foam, would help to break down the foam and make way for the firemen to deal with any pockets of fire not completely extinguished.

As mentioned earlier the gas and foam in the trials were injected into the building through a 2 ft 6 in diameter textile duct and the problems arising from this method are described in F.R.Note No. 619.

N.B. The prototype gas turbine would produce much cooler Class 1, 2 and 3 gases. A Class 1 gas can be walked through without breathing apparatus.

PRELIMINARY INVESTIGATION OF FIRES FOUGHT WITH 5 OR MORE JETS

by

J. E. Gaunt

This investigation covered the period July 1962 to December 1963 during which 710 fires occurred at which 5 or more fire brigade jets were used. It was assumed that, with a few exceptions, all these fires cost £20 000 or more.

There was no significant difference in the day or month when these fires occurred as compared with fires generally but there was a difference as regards the time of day. The peak for all building fires was between 1500 and 1800 hours but for 5 jet fires it was between 2100 and 2400 hours. The delay of about 6 hours in the detection of the fires allowed them to become larger and these fires, of course, occurred mainly in the high risk categories of occupation.

The statistics showed the number of large fires in the various occupancies but were of little value without details of the total number of premises at risk in each occupancy. Some fires where 5 or more jets were used cost less than £20 000 but in the Paper, Printing & Publishing industry there was quite a number of fires costing more than £20 000 which did not involve 5 jets - this seems to indicate that a substantial loss can be suffered in this industry as a result of a relatively small fire. To a lesser degree these comments apply to the Clothing, Footwear and Textile industries.

The point of origin and cause of ignition could not be determined in a large proportion of these fires for obvious reasons. Where this information was known, about 32 per cent started in the storage area and 21 per cent in the production and maintenance area. The largest single known cause of these fires was smoking materials (63 fires and twice any other known cause) and next came children playing with fire (28 fires) malicious or intentional ignition (25 fires), spontaneous ignition (21 fires) and electric wire and cable (20 fires).

The materials first ignited were not known in more than half of the fires but the largest known group of materials was packing, wrapping, paper and cardboard.

The information about the age of the buildings indicated that there was a greater tendency for older buildings to be involved in these large fires and that changes in occupation, and overcrowding in these buildings, had some adverse effect on the loss experience.

More than half the buildings concerned in these fires were unoccupied at the time of discovery of the fire and, in fact, only about one quarter of all the buildings involved were fully staffed and this meant that there was a delay in the discovery of the fire in these cases. It was also revealed that security patrols were not particularly efficient in detecting fires. Further, in 85 of the 710 fires there were delays in calling the fire brigade, usually due to employees or the Works Fire Brigades trying to extinguish the fires on their own.

Sixty-eight per cent of these fires were confined to the building of origin,

Regarding the effectiveness of the fire protection devices, it was revealed that in 16 out of 55 cases where fire stop doors were fitted, the doors were ineffective mainly because they were left open. In 6 out of 11 sprinklered risks the installation was ineffective because it was shut down or was not in the area affected. However, where there were fire stop doors and walls operating correctly the spread of fire was controlled effectively.

The conclusions to be drawn from these statistics are:-

(1) Had automatic fire alarms been installed, the size of many of the fires would have been greatly reduced.

(2) Compartmentation is effective in reducing spread of fire if fire stop doors are closed when the building is unoccupied.

(3) Sprinklers are effective if installed correctly and fully operative.

N.B. There has been no 'follow-up' to this in the form of an F.R. Note but further study of the figures was incorporated in Fire Research Technical Paper No.16. Further studies of large fire statistics will, of course, be done.

Synopsis of F.R.Note No. 598

THE USE OF NETS AS BARRIERS FOR RETAINING HIGH EXPANSION FOAM

by

D. J. Rasbash and B. Langford

To be effective high expansion foam must fill a compartment within about 10 minutes and this means that, using one foam making appliance, the size of the compartment should not exceed $\frac{1}{2}$ to 1 million ft^3, depending on the output of the generator.

One possible way of dividing a large area into smaller compartments in which foam would be retained is to use net curtains of such materials as nylon, terylene or asbestos. These curtains would normally be held up at roof or truss level, in such a way that they could be released and allowed to fall as a curtain in the event of a fire on which foam was being used. Such curtains would weigh about 1 lb per ft run if 20 ft high and if the holes in the net were 0.1 square inches the foam would build up to 20 ft or even a little more before the input of foam equalled the leakage through the net.

No substantial difference between the various net materials was revealed in the tests which were carried out. The asbestos net was much simpler in construction but not so strong but the strength is not of overriding importance if a non-flammable fabric is required. Another possibility might be to use an ordinary string net which has been treated with a fire retardant.

Published as RASBASH,D.J., and LANGFORD, B. The use of net barriers for retaining high expansion foam. Fire Technol., 1966, 2 (4) 298-302.

Synopsis of F.R.Note No. 606

INERT GAS GENERATORS FOR FIGHTING FIRES

by

D. J. Rasbash

Inert gas can be used to control or extinguish difficult or large fires if produced in sufficient quantities at relatively low temperature and oxygen content. The lower the temperature and oxygen content the quicker will be the effect on the flaming and the clearance of smoke.

Brief details of the various appliances which can be used to produce inert gas are shown in the following table:-

Types of inert gas generators

Type	Flow output ft^3/min	for time min	Comments
1. Liquid nitrogen	2000	75	Available from bulk storage depots in road tankers (by arrangement with the Home Office)
2. Liquid CO_2	2000	50	
3. Generator (traditional combustion)	500-100 (cool gas) (usually 2% oxygen content	Several hours	Available generally for static installations
4. Gas turbine	33000-70000 Depending on temperature and oxygen content (usually a minimum of 5% oxygen content)	30 to 90	Prototype being developed - could be used to produce high expansion foam at 30000 ft^3/min
5. Gas turbine (small)	12000	60	Smaller version of 4.

Liquid nitrogen and carbon dioxide are available in increasing quantities from depots widely distributed throughout the country, and stategically placed in the areas where large fires mainly occur.

The more common method of obtaining inert gas in large quantities is to make it as and where required using a combustion apparatus (Type 3) or, preferably, the more compact gas turbine when this has been developed (Types 4 and 5).

By varying the proportions of fuel burnt and the air used the right temperature and oxygen content can be obtained and cooling of the products of combustion can be effected by passing the gases through a water spray.

With any of the generators (Types 3, 4 and 5) it is possible to provide ancilliary apparatus to convert the gas generated to high expansion foam and generator (Type 4) has been designed to incorporate this facility.

Water is the best extinguishing agent but in conditions where water cannot be used inert gas may be useful especially in the following circumstances:-

(1) deep set and inaccessible fire in packed or stacked goods

(2) site of fire cannot be found because of smoke

(3) large amount of flaming which prevents efficient application of water

Very large quantities of inert gas are required to clear smoke, especially when the premises are not gas tight, but gas generators can make a useful contribution to fires in class (3) by extinguishing the flaming sufficiently to allow firemen to approach near enough to apply water efficiently.

Inert gas from generators can be introduced into the building through collapsible ducts or through permanent duct systems. Permanent delivery duct systems could be used to distribute gas from a gas turbine at a high rate of flow but many full-scale tests will be required before this method can be put into general use.

Both capital and running costs per unit of output are much lower for the high flow rate producers of warm or hot gases (Types 4 and 5) than for low flow rate producers of cold or cool gases. Volume for volume nitrogen is generally less efficient than CO_2 but there is no significant difference in efficiency between the cool, warm or hot gases produced by the generators (Types 3, 4 and 5).

An examination of the records of large fires shows that these occur in buildings of 50,000 to 1 m cubic feet and are brought under control between 45 min and 3 hours. A very high rate of flow of inert gas would be necessary to control such a fire and a significant effect on the fire would have to be made within 15-30 min after putting the appliance into use. A single Type 4 or a group of 3 to 5 Type 5 generators should be sufficient for this purpose.

Synopsis of F.R.Notes Nos.613 and 658

THE PROTECTION OF EQUIPMENT WITH FLAME ARRESTERS

PARTS I and II

by

K. N. Palmer and Z. W. Rogowski

Note: This synopsis relates to Notes which were issued in February, 1966 and April, 1967 respectively. It is, consequently, brief but should provide sufficient background to the work reported upon in the recently issued F.R.Note No. 756 for which a separate synopsis has been prepared.

Fire Research Notes 613 and 658 describe work which was done at the Fire Research Station on a new method for the protection of industrial equipment which is used in flammable atmospheres and which may spark and ignite gas or vapours if they enter the casing containing the equipment. Previously such casings had to be strong enough to resist internal explosions and the machining etc. of the casings had to be accurate enough to prevent flames from burning gases or vapours leaving them. By venting the casings and fitting flame arresters in the vents it is possible to use standard casings and the only extra cost is that of the flame arresters and fittings. The heavier form of construction would probably cost 50 per cent more than the standard lighter casing.

The flame arresters in the outer casing or cover of the equipment cannot prevent flammable gas from entering and being ignited by a spark from the equipment but they relieve any internal explosion pressure and prevent the passage of flame to the atmosphere outside the casing. They have to be strong enough to withstand frequent internal explosions without deterioration.

The tests were carried out using a 4 per cent (by volume) propane-air **explosive** mixture (propane is a typical Group II gas) and four sizes of cubical casings were used having capacities of $\frac{1}{10}$, $\frac{1}{3}$, 1 and 3 cubic feet. Various vents were provided in the top cover of the casings (which were made strong for safety) and these were fitted with flame arresters or were blanked off. Except for the largest casing, all the tests were carried out in a larger box (about 16 ft^3) which had a polythene diaphragm over one open side and the explosive mixture was contained both in the casing and the outer box. The ignition in the casing was caused by a spark and this took place in various positions i.e. near the vent, in the centre of the casing and at the side away from the vent. Three types of arrester were used viz. crimped ribbon, perforated metal sheeting and wire gauze but the last two were found unsatisfactory and failed to contain the explosion when the igniting source was remote from the vent (the most hazardous situation).

The Note contains detailed information on the numerous experiments carried out. Different vent sizes and positions, and numbers and type of crimped ribbon arresters were used. The crimped ribbon was either wound in circular form or was in straight lines. The relationship between the vent area and the cross-sectional area of the casing is known as the K ratio and this value gets larger as the vent area decreases (it would be one if the whole of one side was vented). Experiments were also done with open vents in order to find the effect on the internal pressure of fitting arresters into the vents. The increase in pressure was found to be about 3 times as high when arresters were fitted, for the same K value.

The crimped ribbon arresters were made of cupro-nickel, nickel and 'Incoloy' (a nickel-chromium-iron alloy) and various thicknesses and widths of ribbon were used, and the gaps between the ribbons also varied. In no case, however, when these arresters were used, did flame propagate through the arresters and with empty casings the internal pressure was low, often less than 2 lbf/in^2. However, experiments were also done with obstacles inside the casings and these obstacles consisted of solid or perforated shelves, wire gauze, cubes and bars and they had the effect of increasing the explosion pressure quite substantially although this could largely be remedied by adjusting the positions of the obstacles and the vents. Venting over an area of about 7 to 10 per cent of the area of the largest side of a casing containing a small amount of internal partitioning would probably be sufficient to most cases and the vent area might even be less if it was sub-divided over several sides of the casing.

Flame arresters made from nickel or nickel-chromium-iron alloy were markedly more resistant to oxidation and melting than when cupro-nickel was used. With the latter type it was the damage by heat which was the controlling factor whereas it was the maximum permissible pressure which controlled the use of the former two types.

Experiments were also carried out to test the effect of protective covers over the arresters since these might well be necessary in some situations to prevent the ingress of moisture or dust. Polyethylene sheet diaphragms and magnetically-held covers were tried and it was found that, whilst they were effective, the increase in explosion pressures was directly related to their strength and weight i.e. resistance to bursting or opening.

It is not yet possible to predict the maximum explosion pressure in vessels containing obstables and at present it is still necessary to carry out tests with each individual item of equipment. The data so far obtained relate to cubical vessels but a rectangular vessel with vents on the largest side would, in comparison, have a bigger margin of safety.

Flame arresters allow the passage of gas and may also permit the discharge of hot metal particles should wire or other metal component fuse inside the casing. The extent to which this phenomenon may occur with copper and aluminium wires is being investigated.

Synopsis of F.R. Note No. 619

CONTROL OF FIRES IN LARGE SPACES WITH INERT GAS AND FOAM PRODUCED BY A TURBO-JET ENGINE

PART 8 - FLEXIBLE DUCTING FOR CONVEYING INERT GAS AND FOAM

by

D. J. Rasbash, G. W. V. Stark and G. H. J. Elkins

In the tests described in F.R. Note 527 the inert gas and the foam were conveyed through a flexible textile duct of 2 ft 6" diameter. The maximum temperature of the gas was 120°C and the maximum flow rate was about 45000 ft^3/m. It is estimated that 100 ft of ducting should be sufficient to supply a gas or foam from an appliance to a building on fire.

The ducting must be flexible (up to 180° bend), resistant to hot moist gases, able to withstand pressures of 1-2 lbf/in^2, reasonably unsquashable and with low permeability (for normal purposes). Also, it should stow away easily, have gas tight joints and some means of securing to prevent whipping or sagging and it should be resistant to scuffing on concrete, gravel etc, and to contamination from oil, chemicals etc. Each section of the ducting (probably 25 ft lengths) should be light enough to be manipulated by two firemen at the most.

The prototype gas turbine generator will require ducting of 4 ft 6" diameter and will be capable of delivering 70 000 ft^3/min of inert gas at a maximum temperature of 90°C or foam at 30 000 ft^3/min.

(Note: To convey 45 000 ft^3/m of gas through a 2 ft 6" diameter duct the gas would travel at 150 ft/sec but only at 47 ft/sec through a duct of 4 ft 6" diameter so the friction losses and stresses would be much less with the larger diameter duct.)

Numerous experiments and tests were carried out as opportunities arose during tests of fire extinction. It was found that neoprene coated terylene was the best material to use. A light-weight grade of the material could be unsupported or reinforced with heavy stitching or fabric webbing if any support was found necessary, and two ducts each 100 ft long made in this way would weigh only 100 lb and could be rolled up for stowage. Zip fasteners could be used for any joins. Using the larger diameter duct the foam could be produced at the generator, although in the experiments, using the 2 ft 6" diameter duct, the foam had to be produced in an apparatus attached to the far end of the duct because the high velocity in the duct would have destroyed the foam.

Synopsis of F.R. Note No. 669

HIGH-EXPANSION AIR FOAM
A SURVEY OF ITS PROPERTIES AND USES

by

R. N. Butlin

High expansion foam has been shown to be a practical and useful agent in fighting many types of fires by extinguishing or, at least, controlling fires in combustible materials and flammable liquids. It can fill large spaces quickly and can reach fires in underground ducts and basements.

It was originally developed, around 1956, by the Safety in Mines Research Establishment (S.M.R.E.) for fighting fires in mines. Further development, by commercial interests, took place between 1960 and 1963.

Protein foams have expansions between 5 and 15 but high expansion air foam has expansions up to 1000 or even more. H.E. air foam works by blanketting, cooling (since it contains water) and by the production of steam. It is also extremely effective in slowing down the spread of fire due to radiation.

Numerous foaming agents were tested in order to find the best for all purposes, viz:- expansion, stability, use with water of various degrees of hardness, and storage. These requirements were best met by using ammonium lauryl sulphate with a very small amount of additive to improve the stability of the bubbles.

The foam is made by spraying an aqueous solution of the foaming agent onto a mesh screen through which air is blown by a fan or other device. Various materials were tested for the screen and it was found that nylon nets were best and these are now usually made in the form of a concertina-ed net (a zig-zag) set at right angles to the air flow.

An important factor in the formation of the foam is the air-speed from the blower fan. The blowers for commercially-made foam generators are usually worked by electric motors or petrol engines but the air flow may be induced by water flow. There are various methods of injecting the foaming agent into the water supply to form the spray.

Two important features of the foaming agent, or air-foam liquid, are the 'half-drainage time' and the 'half-life time' or the time for the foam volume to reduce to half its original amount. The half-drainage time should probably be about 10 minutes. A comprehensive list of requirements could be drawn up and these would include in addition to the above-mentioned features, specifications for induction factors, storage temperature, ageing, corrosive and injurious effects, flash point, precipitation, specific gravity and packaging.

Small and large scale testing of the high expansion foam on fires of different nature has been carried out and much information has been gained. Its effective use on Class B (flammable liquid) fires has been demonstrated. There are many practical examples of the successful application of air foam in real fires. High expansion foam can also be used to fill large buildings in order to control or extinguish fires and clear smoke and much successful work of this type has been done in Russia. Damage to stored records and electronic equipment as a result of the use of high expansion foam has been found to be small and this foam has successfully extinguished fires in wood, rubber and clothing.

Two prevalent problems, however, are those of reignition of materials covered in foam and of the continued burning of materials and fuels covered with a layer of foam. Continued or repeated applications of foam will usually control or extinguish the fire. There is also the problem of getting the foam to flow for any great distance from the generator and this can probably be met by injecting the foam at an elevated level. By reducing the expansion to 500 : 1 the foam could be 'thrown' from a generator outside the building without the use of ducting. Foam cannot be seen through and it is possible that there would be some hazard from electrical supplies, although this should be less than with water.

High expansion foam is not necessarily suitable in all situations but may well be of great use in many risks and in combination with other extinguishing agents. The combined use of high expansion air foam and a sprinkler system has already proved effective in extinguishing a deep-seated paper fire. Investigations into the sphere of combined usage would be valuable and other matters worthy of further research include:- 'flow' properties, heat transfer, chemical and physical make-up, and structure, application, electrical hazards, power supply and ability to cover and extinguish fires of various kinds.

Future use of high expansion foam would appear to lie in the following directions:-

(1) combined use with sprinklers, inert gas, etc.

(2) high rate fixed automatic generators

(3) application into basements, ducts etc., and in the open and its use on expensive equipment and machinery.

Synopsis of F.R.Note No. 685

WATER DISTRIBUTION FROM AN ARRAY OF FOUR SPRINKLERS

by

R. A. Young and A. Lange

Experiments were carried out in 1967 in order to examine the distribution of water from an array of four sprinklers set at the corners of an 11.4 ft square (130 ft^2) and installed in accordance with F.O.C.Rules. Five makes of $\frac{1}{2}$ in bore sprinklers were used, of the spray and conventional type, both upright and pendant, and water at 10 lbf/in^2 was discharged for 10 min. The water discharged was collected in 57,11 in square-top plastic buckets placed at nominal distances of 2, 4 and 12 ft below the sprinklers. The buckets were arranged regularly over the 11.4 ft square with 6 buckets along each side making 36 in all which would, therefore, have covered evenly about 50 per cent of the total area but in the central 5 ft square, 21 extra buckets were added so that there was total coverage in this central area of 25 ft^2 where the discharge from the four sprinklers overlapped.

Measurements were made of the water flow and distribution and the mean rates of deposition per unit area, both measured (from the total flow) and estimated (from the discharge into the buckets), were calculated for each make and type of sprinkler. This was done both for the whole area and for the central 25 square feet, and the ratio X of:-

$$\frac{\text{Mean estimated rate for central area}}{\text{Mean estimated rate for total area}}$$ provided an indication of the distribution. For an even distribution the ratio would be unity but if less than 1 then a higher proportion of water would be falling outside the central area and vice versa. A complete record was also made of the percentage of the total area receiving less than selected rates of deposition per unit area.

The mean value of ratio X was calculated for each group of sprinklers, as a guide, as follows:-

Sprinkler Group	Ratio X
Upright spray	0.85
Pendant spray	0.71
+ Upright conventional	0.51
Pendant conventional	0.72

The type marked + provided markedly less uniform distribution than the others at all levels.

The mean density of water distribution was mainly dependent upon the total rate of discharge and at 10 lbf/in^2 this varied from 0.1 to 0.124 gal/ft^2 min.

The distribution of water became more uniform as the distance between the sprinklers and the buckets increased and it was concluded that, for the best results, there should not be less than 4 ft between the sprinkler deflectors and the goods they protect. Generally, the water distribution at 2 ft was very erratic. Some makes of sprinkler gave more uniform distribution than other makes but, in general, the differences were small.

Consideration of a simple method of 100 per cent sampling of the whole area would be probably be profitable, although in respect of the central area it was found that a collecting area of 20 per cent of the total probably provided sufficiently accurate results.

N.B. The 100 per cent sampling facility has now been provided in a test room in the main building of the Fire Research Station.

Synopsis of F.R. Note No. 701

SUMMARY OF WORK IN PROGRESS AT FIRE RESEARCH STATION ON THE GROWTH AND SPREAD OF FIRE IN BUILDINGS

by

P. H. Thomas

There are four inter-related research studies being made, viz:-

(1) small-scale experiments in a compartment 2 m x 1 m x 1 m, investigating the effect of different amounts of fuel, the disposition of fuel, etc., and various sizes and positions of ventilation openings,

(2) the role of flames under ceilings,

(3) work on the application of statistical information to theoretical models,

(4) theoretical work on the effect of compartment insulation.

Research on growth of fire is being done in co-operation with several foreign countries.

With regard to (1) above, it was found that initially fire spread was similar to that expected in the open air but after 21 min in one particular test the fire spread rapidly to the ventilation opening and after 26 min there was a virtual flashover in the compartment.

Initial spread varied with the type of crib(s) used but the later stages of fire spread were not so significantly different as between one form of crib and another. Lining the compartment with hardboard reduced the 21 min mentioned above, to 17 min.

The work under (2) was done in a model corridor 1.2 m wide and 7.3 m long, with shallow side and rear screens and the gas burner 'fire' was at one end. Experiments are proceeding and the main results so far indicate that when flames reach the ceiling and spread along it there is downward radiation from the horizontal flames about four times as great as from the vertical flames. However, some radiation is absorbed by the ceiling and the floor and the thermal properties of the ceiling and floor are important.

Information gained in these experiments can be used to assess the probability of fire spreading from the area of ignition to other combustible material in a compartment. This spread and the flashover time is dependent on rate of heat output and the combustibility and insulation properties of the compartment linings.

The fire brigades' reports are being used to provide information on the spread of fire in compartmented buildings, both single and multi-storeyed, and the spread of fire upwards and sideways is being investigated. Attempts are being made to see if the data can provide distinctive fire spread features for different occupancies.

Insurers should derive some benefit from this research work which will enable assessments to be made of:-

(1) the size of fires in relation to the duration,

(2) the effect of linings on the spread of fire,

(3) the spread of fire expected in particular occupancies.

N.B. Since this paper was presented there have been many more similar experiments both at J.F.R.O. and in overseas laboratories and eventually this further work will be analysed. It seems that there may not be too much difference between an untreated hardboard and the non-combustible lining used when other differences in experimental conditions are taken into account.

Synopsis of F.R. Note No. 710

THE FIRE PROPAGATION TEST AS A MEASURE OF THE FIRE HAZARD OF A CEILING LINING

by

P. L. Hinkley, H. G. H. Wraight and Ann Wadley

The present standard test to assess the hazard of combustible linings is the "Spread of Flame" test of B.S. 476 (Part I) (shortly to be Part 7) but it has been found that the new "Fire Propagation" test (to be Part 6 of B.S. 476) is capable of distinguishing better between the performance of linings, especially those with low fire spread qualities. This latter test is intended to assess the contribution which combustible lining materials made to the growth of a fire when used to line a ceiling or wall. Experiments in a model corridor are referred to in the Synopsis of F.R. Note No. 712 and are of interest in this connection.

The Fire Propagation test apparatus consists of a rectangular box of asbestos wood having a combustion area 191 mm x 191 mm and 90 mm deep and the material to be tested forms one of the larger (removeable) vertical sides of the box. The material is 'backed' with thick asbestos board (see Plate 1 of F.R. Note for photograph of apparatus). The chamber is heated internally by 2 electric elements and a number of small gas flames. There is a chimney, and a ventilation hole in the rear vertical side.

The specimen is first exposed to the gas flames (526 W), which are near the bottom of the chamber, for $2\frac{3}{4}$ min and then the electric elements are also turned on at 1800 W for $2\frac{1}{4}$ min after which they are reduced to 1500 W. The heating is then constant at the lower rate until 20 min after the gas flames were ignited. The chimney (flue) gas temperature is measured.

The apparatus is first calibrated by using a test panel of asbestos wood, a non-combustible material which absorbs and conducts heat readily. A formula incorporating the temperature rise and time produces an index (the lower the better) and this is weighted heavily against materials having an early rise in temperature. This is justified since the greater the initial heat output from the lining material the quicker the spread of fire (ignoring any other burning materials).

The gross rate of heat transfer to the specimen is 0.5 W/cm^2 at the start of the test and increases to 5.0 W/cm^2 after 20 minutes. The "gross" heat transfer comprises heat received by radiation from the electric heater, by convection from flames and hot gases within the combustion chamber and by radiation from the walls of the chamber. It is therefore higher for good insulators since less heat is lost through the chamber walls. Once the specimen has ignited there is a large increase in the gross heat transfer rate.

The rate of heat transfer to the ceiling in the corridor experiments described in F.R. Note No. 712 was 1 W/cm^2 when the flames just licked the ceiling and reached a maximum of 17 W/cm^2 when the flames were increased. In these corridor experiments the intensity of radiation from the ceiling gradually decreased along the corridor away from the "fire" except in the case of stove-enamelled hardboard when there was a constant rate of radiation along the corridor. The burning rate of the stove-enamelled hardboard was above the average for linings generally and there were jets of gas emitted through small pin-holes in the enamel which rapidly mixed with the surrounding air and burnt fiercely. Not all stove-enamelled hardboards behave so badly in the Spread of Flame or Fire Propagation tests and this may be because the panels are vertical in these tests and not horizontal as in the corridor tests.

A comparison between the Fire Propagation test, the Spread of Flame test, the minimum heat to ignite untreated cellulosic materials (Pilot ignition test) and the results of the corridor experiments shows that:-

1) after 5 minutes from the start of the Fire Propagation test the rate of heat transfer exceeds that in the Spread of Flame test allowed as the maximum for Class 1 materials (2.8 W/cm^2)

2) The Fire Propagation test can, in principle, distinguish between the materials in the Spread of Flame Class 1 category.

3) The maximum heat transfer rate in the Fire Propagation test (5.0 W/cm^2) is much greater than the minimum necessary for ignition in the "Pilot" test of untreated board but may not be quite sufficient to ignite, but only decompose impregnated boards.

4) The maximum heat transfer rate in the Fire Propagation test is much below the maximum in the corridor test (17 W/cm^2). Although such a high rate would only occur in severe fires where the additional contribution from the burning boards should be relatively insignificant, some increase in the Fire Propagation test rate at the end of the test may be desirable.

In the corridor tests the fire spread over the floor appeared to be controlled initially by the rate of increase in the intensity of radiation downwards and the total distance of spread depended on the maximum intensity of radiation except in the case of the stove enamelled hardboard. The rate of spread, in practice, would be accelerated by 'feed-back' to the ceiling from a fire on the floor (i.e. the contents burning). The initial rate of fire spread over the floor in the corridor tests was calculated and was found to correlate well with the Fire Propagation test Index for the materials investigated, <u>including</u> the stove-enamelled hardboard. The correlation was better than that between the rate of spread and the Spread of Flame classification. The distance of spread did not correlate with either of the other tests but this is not so important since the distance of spread along the corridor would have no meaning for a wide floor (open factory area).

The correlation with other types of lining material such as plastics and wall linings is to be investigated.

The Fire Propagation Index and Spread of Flame classification for the materials tested are as follows:-

Type of building board	Fire Propagation Index	Spread of Flame classification
Hardboard with intumescent paint	16.5	2
Impregnated fibre insulation board	18.7	1
Panel board with plastic paint	23.7	2
Impregnated medium hardboard	29.7	4
Stove-enamelled hardboard	40.6	3
Fibre insulating board with emulsion paint	42.0	4
Fibre insulating board with chlorinated rubber paint	53.5	4
Untreated fibre insulating board	75.3	4

Synopsis of F.R. Note No. 712

THE CONTRIBUTION OF FLAMES UNDER CEILINGS TO FIRE SPREAD IN COMPARTMENTS -

PART I - INCOMBUSTIBLE CEILINGS

by

P. L. Hinkley, etc.

Experiments were carried out in a model of a corridor 7.3 m long x 1.2 m wide and mounted 1.8 m above the laboratory floor. It was made of 1.27 cm thick asbestos wood with screens along the side and rear also of asbestos. The side screens were 120 cm deep at the 'fire' end and 50 cm at the far end. The fuel for the 'flames' at one end of the corridor was town gas which, being of know calorific value, could be used to produce the required heat.

Although the flow of heat was in a line along the corridor and not radially, similar movement of heat would be expected in bays of buildings. The corridor, having no floor, could be used for the experiments without 'feedback' from the floor. The effect of a floor will be dealt with in a later report.

Measurements were made of radiation downwards, ceiling temperatures, heat transferred to the ceiling, and the temperature of the hot gas stream. The velocity of the gases and flames and the oxygen content were also measured.

The heat transfer to the ceiling immediately over the burner, which varied with the gas flow and the distance of the burner beneath the ceiling, determined whether a flammable ceiling lining was likely to ignite and the time taken to ignite it. The maximum possible rate of heat transfer appeared to be about 17 W/cm^2 and this occurred as the transition was made from an air-rich to a fuel-rich mixture. Any further increase in the gas flow rate resulted in a decrease in the heat transfer to the ceiling.

As the vertical flames reach the ceiling they are turned at right angles along the ceiling of the corridor and reach out to a greater distance than they would attain if they continued vertically. The horizontal flames behave as though they have their origin at a point on the ceiling behind the end of the corridor and this point of "virtual origin" is about 2 to 3 times the distance of the gas burner beneath the ceiling. The horizontal flames (measured from this "virtual origin") are about $5\frac{1}{2}$ times greater than the lengths of vertical flames from the same gas burner. Once the flames reach the ceiling they become elongated and their length is probably at least twice what it would be if they continued vertically.

There are two layers of burning along the ceiling. One, nearer the ceiling, is air-rich as a result of the entrainment of air by the vertical portion of the flames. Below this is a fuel-rich layer where the flames are only in the lower part of the layer and the flames are reaching down for more oxygen. There is no well defined transition between the layers. It is likely that with an actual fire in a compartment the air-rich layer would be important during the critical stages in its growth.

The heat loss by radiation into the corridor up to the flame tips is a measure of the proportion of the heat of combustion which is radiated at an intensity sufficient to cause flame spread over materials. There is no evidence of a scale factor and it should be possible to use the results obtained for larger scales although larger scale experiments are obviously desirable. The heat transferred by radiation is up to four times greater from horizontal flames than from vertical ones.

This F.R. Note is essentially a detailed scientific description of the work done and the practical implications will be dealt with later. The work is, of course, concerned with the 'flashover' time which is important in determining the size of a fire on the arrival of the fire brigade. Although these experiments were carried out in a non-combustible model corridor, later experiments will be done in a corridor with combustible linings. However, by using a non-combustible model it was possible to measure, without the added influence of combustible linings, the heat transfer to the ceiling and downwards by radiation. Side effects, such as the heat transfer to the ceiling by convection currents and lack of heat transfer from the floor (there was none), could be studied.

Fig. 26 and Plates 1 and 3 at the back of the F.R. Note provide a picture of the model corridor and of the flames below the ceiling.

N.B. This report is the first of a series on experiments investigating the characteristics of flames beneath various kinds of ceilings. Once the flames from a fire in an enclosed space reach the ceiling they extend horizontally and there is then a dramatic increase in radiation to (unburnt) material well away from the fire. This can lead to fire spread, even under non-combustible ceilings, irrespective of other influences.

The relevance of this research work to the Fire Propagation test is commented upon in the synopsis for F.R. Note No. 710.

Synopsis of F.R. Note No. 713

SOME MEASUREMENTS OF AIR FLOW THROUGH WOOD CRIBS

by

H. Wraight and P. H. Thomas

This note records the result of work done on one aspect viz:- air flow, of the behaviour of wood cribs when used as fuel in experimental fires. (See also F.R. Note No. 728).

The following tentative conclusions may be of interest to Insurers but it should be borne in mind that the research is only related to the 1963 statistics.

1) There are morelong-lasting fires in multi-storeyed than in single-storey buildings.

2) There is little difference in the spread of fire from the room of origin as between storeyed buildings and sheds.

3) In new buildings fires spread sideways more frequently than expected but less frequently upwards - the latter is probably the result.

Synopsis of F.R. Note No. 717

SLURRIES OF SOLID CARBON DIOXIDE AS EXTINGUISHING AGENTS

by

D. J. Rasbash, P. F. Thorne and W. D. Woolley

Slurries are made by mixing a powder with a fluid and this paper describes numerous exploratory tests in a laboratory and also larger scale tests using a slurry of solid powdered CO_2 and a vaporizing liquid such as B.C.F. A slurry using liquid nitrogen to produce a solid CO_2 powder was not found to be satisfactory.

These slurries can be effective on flammable liquid fires as a result of the cooling effect and are more effective than the solid CO_2 or vaporizing liquid if used separately. A characteristic of the extinction by slurries is that the flames are pushed sideways and upwards and they are two to three times as effective in extinguishing petrol and kerosine fires as the vaporizing liquid or solid CO_2 alone. They are more efficient on kerosine than on petrol fires.

Research will be needed to improve the method of application in order to get more even evaporation and cooling and a more rapid spread of the slurry over the surface of the flammable liquid. Slurries may be more effective if tailor made to suit a given fuel. However, useful results might be possible in some circumstances from crude methods of application and dumping of the agent from a helicopter on to an aircraft fire might be effective. It is unlikely that slurries containing solid CO_2 could be used in ordinary extinguishers because of the necessity of keeping the agent at a low temperature.

P.S. Since this note was written research has shown that it may be possible to store B.C.F. and liquid CO_2 in an extinguisher under pressure. By using a special nozzle this mixture would be ejected as a slurry of solid CO_2 and liquid B.C.F.

Synopsis of F.R. Note No. 721

THE APPLICATION OF HIGH-EXPANSION AIR FOAM TO TWO TYPES OF FIRE

by

P. S. Tonkin and D. M. Tucker

A commercially available portable type foam generator (designed to deliver 5000 ft^3 per min) producing H.E. foam was used to test the extinguishing qualities on a flammable liquid fire (petroleum product). The fires were in trays, one on the floor and the other 1 ft 6" below the ceiling (about 8 ft 6" above the floor) of a small brick and concrete building.

The foam was injected at various constant rates of flow through openings in one wall of the building and the expansion was about 1000 to 1. The floor tray fires were allowed to burn for 30 secs before the foam was injected and the ceiling fires for 3 min. Numerous experiments were carried out to determine the rate of flow, the height of foam, the foam breakdown and the possibility of reignition. Temperatures and radiation were measured.

The highest rate of foam application with which extinction was not achieved was:-

Floor tray	0.15 m(ht)/min	(0.5 ft (height)/min)
Ceiling tray	2.0 m(ht)/min	(6.5 ft (height)/min)

There was no rapid breakdown of the foam nor reignition of the fuel with the floor fire once the foam was built up to 1 ft or more above the fuel surface, after extinction.

With a ceiling fire it would be necessary to continue to maintain the foam in contact with the ceiling after extinction in order to prevent reignition. In the experimental ceiling fires the heat from the ceiling continued to break down the foam after the fire was extinguished.

The results of the experiments showed that high-expansion foam was more efficient on floor level liquid fires than with ceiling level fires. Not only did the foam take longer to reach the tray at ceiling level but it was affected by radiated heat from the ceiling.

In both instances, however, once the foam reached the tray it flowed across the surface of the fuel relatively quickly and effected extinction mainly by blanketing. There appeared to be no marked effect in these experiments from the steam produced when the foam broke down nor by cooling, but further research would be necessary to assess their actual contribution to the extinction process.

Research will now be necessary to obtain information regarding the ability of high-expansion foam to extinguish fires in solid materials and liquid fuel burning on hot metal surfaces. The fires used for the liquid fires in trays are reproducible and could be used for assessing the relative efficiencies of HE foaming agents. Fig. 1 in the F.R. Note shows the lay-out of the building for the floor and ceiling fires.

Synopsis of F.R. Note No. 724

THE EXTINCTION OF INDUSTRIAL FIRES BY FOAMS

by

P. Nash and D. M. Fittes

This paper summarises in some detail, the available foams for fire extinction.

There are M.P.B.W. specifications for chemical foam charges and mechanical liquids and J.F.R.O. is preparing a Home Office specification for high expansion foam liquids. Other foams may be assessed by using similar test methods, the most important feature being its stability and resistance to drainage.

The various types of foam are summarized as follows:-

(1) Chemical - an aqueous solution of aluminium sulphate and sodium bicarbonate with a bubble stabilizer. CO_2 fills the bubbles.
It is used for non water-miscible flammable liquids by hand or fixed systems but mechanical foam is better for the latter (i.e. for dip tanks, storage tanks, etc).

(2) Mechanical or air foams - made by aerating an aqueous solution of protein-based foaming liquid (made from waste proteins).
It is used for non water-miscible flammable liquids by hand or fixed systems.

(3) Fortified mechanical foams - a mechanical foam stabilised by the addition of fluoro-carbons.

(4) All-purpose foams - a mechanical foam stabilised for use with water-miscible flammable liquids.

(5) Light-water foams - a mechanical foam made from an aqueous solution of a per-fluorinated surface active agent for use with non water-miscible and some water-miscible flammable liquids.

(6) High-expansion foams - a mechanically produced foam using a synthetic foaming agent with bubbles filled with air or inert gas. The expansion can vary from 100-1 to 1000-1. Foams with expansions up to 500-1 can be used for flammable liquids and above this for filling large areas of buildings.

There is a detailed description of the methods of foam production and some drawings of the apparatus used are included. These are mainly hand-held branchpipes and foam-making pumps and generators.

Application of mechanical or air foam to non water-miscible fuels such as petrols, paraffins, lubricating oils, etc. can either be on the surface or, with fixed storage containers, by application from the base, i.e. below the surface.

Ordinary mechanical foams can also be used for surface application to mixtures of hydrocarbons and water-miscible flammable liquids with some loss of efficiency dependent upon the proportion of water-misible liquid. All-purpose foams with bubble-wall stabilizers can be used on water-miscible fuels and are also of use on petrol fires, whereas ordinary mechanical foams are quite impractical for this latter purpose.

"Light water" foams can be used for surface application to hydrocarbon and water-miscible fuels. However, they have less heat resistance than protein foams and so will not resist "burn-back" so well if a large fire area is re-opened. They will, however, seal small fires more readily. 'Light water' costs some thirty times as much as protein foam when in solution form but it is more economical to use on some fuels and there are incidental savings in respect of the equipment required.

Medium and high expansion foams (bubbles can be filled with air or inert gas) extinguish by a combination of smothering and cooling. Medium expansions (100-1 to 500-1) are suitable for flammable liquids and in the open, but higher expansions can be used for flammable liquids in buildings and for 'contents' fires generally. However, one of the main problems is the distribution over large areas and it may be necessary to arrange dispersed generation points, possibly at ceiling level, operated on demand by heat or smoke from the fire. The air supply for making high-expansion foam should be as uncontaminated by combustion products as possible.

Synopsis of F.R. Note No. 725

FIRE PROTECTION IN THE PROCESS INDUSTRY BUILDING-PLANT AND PLANT STRUCTURES

by

Margaret Law, B.Sc.

The basic way to reduce fire spread is to make fire-tight compartments and any doors in the compartment walls which have to be kept open should be fitted with, say, a fusible link to enable them to close automatically. Openings for services in walls, floors, or ceilings, must be properly 'fire-stopped' and unenclosed trunking should have a damper, also with a fusible control. Doors need not be so well insulated as walls because combustible materials should not be in contact with them.

The hazards of suspended ceilings (including blanketting of sprinklers) and combustible linings are emphasized and mention is made of the benefits of roof venting and roof truss curtains and water screens.

The furnace tests do not simulate real fire conditions but provide a system of grading building elements which has worked satisfactorily up to now. A fresh look is being taken at the present fire grading of buildings following the introduction of new materials.

The protection of structures containing flammable liquids is considered. Fires in these structures behave differently from building fires and the relationship with the furnace tests is less direct. The furnace tests can, however, be used to estimate the behaviour of protective materials. For radiant heating by flames in a separate bund, a flame radiation of 17 W/cm^2 can be assumed and the necessary protection can be calculated accordingly. It will depend on the separation distances, the area of the flames and the shape of the structures. The radiation which can safely be accepted on the face of a building would normally be taken as 1.25 W/cm^2. The temperature rise in a flammable liquid fire is much more rapid than in the furnace test under B.S. 476.

Structural steel will normally fail to support its design load if its temperature exceeds 550°C but a temperature considerably less than this would be necessary to prevent undue tank pressures or ignition of flammable vapours. The structure and the vessel must therefore be kept below hazardous temperatures by protective materials. Any heat which flows through the protective materials will be soaked up by the steel which acts as a heat sink.

The information about thermal conductivity is very sparse although it is known that most insulating materials deteriorate when their temperature rises. However, estimates can be made from the results of furnace tests.

Examples of protective materials are: sprayed asbestos, vermiculite plaster or cement, mineral wool, and concrete. Some of these are damageable and some heavy - none is suitable for all situations. The fixing and re-inforcement is important.

Although structural steel will fail at 550°C, prestressed bars in concrete will normally fail at about 400°C and there must be sufficient concrete over the bars to keep them cool and the concrete should not spall.

The paper contains some examples of the calculations involved and there are numerous references to authoritative documents which deal in more detail with the various topics covered in the F.R. Note. One table shown, which is of some interest, relates to the furnace test temperatures. Under the B.S. 476 test the furnace temperature rises gradually but the equivalent constant furnace temperature has been derived as follows:-

Time hours	Under B.S. 476 Temperature rises to:- °C	Equivalent constant temperature °C
1	927	840
2	1010	930
4	1121	1050
6	1204	1120

Also of interest is the surface temperature of protective material when exposed to radiation (assuming a black vertical surface which represents the most hazardous condition).

Intensity of radiation on surface W/cm^2	Surface temperature °C
0.15	100
1.5	400
6.0	700
15.5	1000

Published at: LAW, MARGARET, Structural fire protection in the process industry. Building Lond., 1969, 217 (6583) 29/86-29/89; (6587) 33/65-33/68.

Synopsis of F.R. Note No. 726

REVIEW OF LATEST DEVELOPMENTS IN FIRE PROTECTION

by

D. J. Rasbash

This F.R. Note consists of a paper given in November 1968 to the Institute of Mechanical Engineers. The author's remarks are in very general terms and review the existing methods of fire protection and point to some possible fire protection systems of the future.

With regard to sprinkler installations it is emphasized that these can only be economic in high risk areas i.e. most industrial premises, and that every endeavour must be made to reduce the cost by improvement on the production and design of the equipment. Similar comments are made regarding alarm installations, where in addition the elimination of false alarms is also important.

Whilst water reigns supreme as an extinguishing agent non-wasteful and effective use must be made of it especially in sprinkler installations; reference is made to the research work on sprinklers in high stacked storage. The provisions of the new Sprinkler Rules have, of course, overtaken many of the author's comments.

Apart from water, attention is drawn to the benefits and disadvantages of HE foam, CO_2, vaporizing liquids and dry powder. The remarks are only of a general nature and are already known to fire insurers. In view of the limitations in the use of extinguishing agents the author suggests that dual protection may provide the answer, and reference is made to the controlled use of roof vents and curtains.

Brief reference is made to built-in fire resistance and explosion vents.

Published as: RASBASH, D. J. Review of the latest developments in fire protection. Instn Fire Engrs Q., 1969, 29 (75) 261-72.

Synopsis of F.R. Note No. 727

FIRES IN OLD AND NEW NON-RESIDENTIAL BUILDINGS

by

P. H. Thomas

This paper contains a review of the 1963 loss data in respect of the duration of a fire (time between arrival of fire brigade and fire 'stop' time) in non-residential single and multi-storeyed buildings having more than one room or compartment. The data are used to establish a comparison between old and new (post 1950) buildings and single and multi-storeyed buildings as regards spread beyond the room of origin. An element of uncertainty must enter into the review as a result of some ambiguity in the meaning of room or compartment as interpreted by the fire brigades.

The 1963 data do not provide information regarding the relationship between duration of fire and financial loss but there may well be some connection between these two quantities for any one occupancy. However, some useful information is provided in respect of the spread of fire sideways and upwards in single and multi-storeyed buildings.

The following tentative conclusions may be of interest to Insurers but it should be borne in mind that the research is only related to the 1963 statistics.

1) There are more long-lasting fires in multi-storeyed than in single storeyed buildings.

2) There is little difference in the spread of fire from the room of origin as between storeyed buildings and sheds.

3) In new buildings fires spread sideways more frequently than expected but less frequently upwards - the latter is probably the result of improved floor construction following the new building regulations.

It is proposed to continue with this form of research in later years to try to assess the economic value of elements of fire resistance and to make comparisons between the various occupancies that are shown in the Building Regulations. The task of evaluating elements of fire resistance is, however, complicated by the introduction of extraneous factors such as the leaving open of doors.

N.B. Statistics for 1967/8 onwards will give fuller information on construction and linings so, eventually annual reviews on the lines established in F.R. Note 727 will produce spread of risk assessments, for various occupancies, which should be of value to Insurers.

<u>Synopsis of F.R. Note No. 728</u>

THE RATE OF BURNING OF CRIBS OF WOOD

by

P. G. Smith and P. H. Thomas

This note records the results of research work on the behaviour of wood cribs when used in experimental fires and is necessary if proper and accurate use is to be made of model fires.

Published as: SMITH, P. G. and THOMAS, P. H. The rate of burning of wood cribs. Fire Technol., 1970, <u>6</u> (1) 29-38.

Synopsis of F.R. Note No. 729

SPREAD OF FIRE IN BUILDINGS - EFFECT OF SOURCE OF IGNITION

by

R. Baldwin and P. H. Thomas

The UK Fire Statistics for 1964, 5 and 6 are used to explore the differences in the spread of fire in compartmented buildings in relation to the source of ignition. Unfortunately many fires in single compartment buildings are excluded since no measure of spread (from the room or compartment of origin) is available.

There is quite an extraordinary consistency from year to year on the probability of spread according to the source of ignition. The three highest values are significantly greater than the overall value for all other sources of ignition, as shown in the following table:-

	Source of ignition	Probability of spread
(1)	Malicious or intentional ignition	0.41
(2)	Rubbish burning	0.41
(3)	Unknown	0.46
(4)	All others	0.14 (in the range 0.10 to 0.26)

Published as: BALDWIN, R. and THOMAS, P. H. Spread of fire in buildings - effect of the source of ignition
Instn Fire Engrs Q., 1969, 29 (74) 183-4.

Although the authors do not say so in so many words it would seem that the reason for the high spread probability for (1) and (2) may be that there is a more substantial source of ignition when these are involved than with heating appliances, smoking materials or even spontaneous ignition. Many of the unknown causes may well be due to (1) or (2) but being large fires all evidence of ignition is destroyed and the same comments may also apply to large fires in non-compartmented buildings.

Published as: BALDWIN, P. and THOMAS, P. H. Spread of fire in buildings - effect of the source of ignition.
Instn Fire Engrs Q., 1969, 29 (74) 183-6.

Synopsis of F.R. Note No. 730

MEASUREMENTS OF COTTON FLY DEPOSITS IN A MILL

by

M. J. O'Dogherty, R. A. Young and A. Lange

Measurements were taken of the amount of cotton fly accumulating on sprinkler heads over a period of 12 months in an opening and beating room 60 ft x 45 ft x 12 ft high. The sprinkler heads had pendent deflector plates 6" below the ceiling.

The collection from heads was planned to provide a representative accumulation over the whole area of the room.

The fly was in the form of a small 'beard' below the deflector plate and there was no fly on the deflector or around the fusible strut.

There was a relatively high rate of accumulation during the first month but after this period the rate of deposition of the accumulated fly diminished. The quantities of fly accumulated were very small and there was an average of 30 mg of fly on a sprinkler over a period of 12 months with a very few heads having more than 100 mg.

These quantities are unlikely to produce any appreciable hazard of premature opening of sprinkler heads should the fly be accidentally ignited.

Synopsis of F.R. Note No. 732

A STATISTICAL ANALYSIS OF SOME RATES OF SPREAD OF FOREST FIRES

by

M. J. Woolliscroft

This paper contains the results of research work into the rate of spread of both wild and controlled fires in forests and heathland. The information is mainly of use in fire-fighting strategy and has no significance to insurance since no discrimination is made in the rate of burning of different species of trees nor is any reference made to peat.

Synopsis of F.R. Note No. 731

THE PERFORMANCE OF WATER-TYPE EXTINGUISHERS ON EXPERIMENTAL CLASS A FIRES

by

M. J. O'Dogherty, R. A. Young and A. Lange

Under the aegis of CEN (Gomite European de Co-ordination des Normes) the standards organisations of France, West Germany and the U.K. held their first meeting in October 1967 and decided to carry out a programme of work in each country to develop suitable fire tests for hand fire extinguishers in relation to Class A (solid materials) fires. Tests were carried out with 1¼ and 2 gal extinguishers to determine the largest test fire which could be extinguished by an efficient operator, the fire having a certain pre-burn (free burning before operating the extinguisher) time and no reignition, after exhausting the extinguisher, within a certain time.

The French test fire consisted of wood sticks in a metal basket and the German fire was a crib with 4 cm square sticks. The former had a pre-burn time of 4 min with no reignition for 5 min and the latter 12 min and 3 min respectively. The French method was complicated and inflexible and was not an adequate test of the extinguisher ability. The German standard specified no time for ignition and the pre-burn time of 12 min was unnecessarily long. Both had a number of other undesirable features and the only advantage appeared to be that the German crib was easy and quick to construct.

An experimental test fire consisting of a crib of constant cross-sectional area was therefore devised so that only its length had to be altered to obtain different fire sizes. The sticks were 2 cm square at 6 cm spacing and the cross section was ½ m x ½ m. The length was altered in "steps" of ¼ m. The pre-burn time was taken as 3 min (including 2 min ignition by petrol contained in a tray equal in area to the base area of the crib).

Each experiment was carried out by operating the extinguisher from 5 m away until the flames were beaten down to the level of the top of the crib after which the operator moved in until the extinguisher was exhausted. Three tests were made for each length of crib. Ordinary water jet type extinguishers were used.

To satisfy the test there should have been no flaming within the crib when the extinguisher was exhausted and no reignition for 5 minutes thereafter.

It was found that the total quantity of water required for extinction was proportional to the crib length and was about 1.1 gallon per metre of crib length. It will be necessary to fix pre-burn and reignition times at such a figure that the test provides an adequate task of extinction and that the probability of reignition is low.

Synopsis of F.R. Note No. 733

ANALYSIS OF FIRE PREVENTION SLOGANS

by

Sheila F. Nash

It was suggested by the competition entries during the "Make Leicester Fire-safe" campaign in 1967, that the public in general lack knowledge of the technical aspects of fire prevention and in any case tend to emphasise the dangers to life and limb rather than to property.

About half the local authority fire brigades in England produce fire prevention handbooks and they devote on average about one third of the available space to fire prevention, such as the maintenance of electrical equipment and wiring and the use of fireguards etc. It is considered that fire brigades could devote more space in their handbooks to the subject of general and technical fire prevention in the home.

Synopsis of F.R. Note No. 734

FIRE DEATHS IN THE FIRST NINE MONTHS OF 1968

by

S. E. Chandler

This is an interim review of deaths in fires attended by fire brigades and so far in the period covered there have been 597 deaths in 467 fires, and in 68 of these incidents there was more than one death. The most serious incidents in the third quarter of the year involved a hotel and a house converted into flats.

The statistics continue to emphasize the dangers of smoking materials and space heating of all kinds.

Synopsis of F.R. Note No. 735

THE SPREAD OF FIRE IN BUILDINGS - THE EFFECT OF THE TYPE OF CONSTRUCTION

by

R. Baldwin and P. H. Thomas

An analysis has been made, on a rather narrow basis, of the 1963 and 1964 loss statistics to see if there is any evidence of the effect of certain structural features of a building on the spread of fire. The investigation refers only to compartmented buildings where there was spread of fire from the room or floor of origin and where there was some effect on the structural integrity of the building. Single compartment shed buildings could not be included.

The chance of fire spread has been assessed under the following 'types':-

		Internal columns		
		None	Unprotected	Protected
Walls	Timber framed	Type 1	Type 2	Type 3
	Loadbearing	Type 4	Type 5	Type 6
	Framed unloaded	Type 7	Type 8	Type 9

and under the following headings:-

Single storey	for both:-	Manufacturing Industries
		and
Multi-storey		Distributive Trades

There are no significant differences in the proportion of fires spreading in the two years. The higher loss figures for 1964, compared with 1963, are due to an increase in the number of fires (or their value) and not to their severity.

Unfortunately the data is not sufficient to produce any significant results and without knowing the sizes of the risks involved and the types of construction (apart from the column details) it is not possible to measure the effectiveness of the various features.

It has long been known, of course, that buildings with timber framed walls are more hazardous than with better types of wall but this analysis does establish that, for 1963/4 losses, the chance of fire spread in such buildings is about twice as great as in other buildings. Also, the analysis indicates clearly that there is a 50% greater chance of fire spread in multi-storey buildings with unprotected columns.

Further study will be needed if any useful conclusions are to be drawn from statistics of this kind.

Synopsis of F.R. Note No. 736

THE CRITICAL DISTANCE FOR IGNITION FROM SOME ITEMS OF FURNITURE

by

C. R. Theobald

Some experiments were carried out at the request of the Home Office to ascertain the minimum separation distances between items of furniture at which fire would not spread from one piece to another following ignition by an atomic flash.

The test compartment (7.7 m x 3.7 m and 3 m high) was preheated to simulate the atomic flash heating and there was no glass in the 'window opening'. These conditions would not usually apply to an ordinary private house fire but, on the other hand, the heating from an atomic flash would be only momentary. The results of the tests would be applicable to ordinary private house fires to some extent.

Whole pieces of furniture were set alight since fire spread was most likely under these conditions. The tests revealed that there were large differences in the maximum distances at which items of furniture would cause ignition (some items could not ignite wood as close as about 6 inches) and the chance was mainly dependent on the way in which the items burnt.

Tests were carried out using kitchen, easy and arm chairs, a bookcase and a wardrobe. The burning time of each item was governed principally by the weight and geometry of the furniture. Further tests would be necessary to confirm that this control applies equally to other items of furniture.

One interesting revelation was that with tall furniture, viz. the wardrobe, the flames extended about 12 feet beneath the ceiling and ignited combustible material about 4 feet away. In a smaller room the flames might well have covered the whole ceiling. Once flames have reached the ceiling and are travelling under it the distance at which material can be affected by heat, or ignited, increases sharply. Flames from the chairs did not reach the ceiling. Those from the bookcase reached the ceiling but did not spread beneath it.

Synopsis of F.R. Note No. 737

FIRES IN HOTELS

by

S. E. Chandler, B.Sc.

This Note contains a detailed study of fires in hotels during 1966 and the research work was prompted by the recent loss of life in fires in hotels, flatlets etc. An analysis was made of 649 fires. A more detailed study was made of 130 of these fires in order to determine the effect of construction on fire spread. 40 fires which were confined to single compartment buildings were not analysed.

There are numerous tables in the Note giving information on:-

(1) Month in which fires occur

(2) Time of call to fires in relation to day of week

(3) Place of origin of fires in relation to the time of day

(4) Causes of fires in hotels and private dwellings (in 1966 - 34251 fires)

(5) Causes of fires in relation to the time of day

(6) Cause of fires in relation to the place of origin

(7) Extent of fires in relation to the time of call

(8) Cause of fires in relation to the extent of fire

(9) Method of extinction of fires in relation to their extent

(10) Effect of fire-fighting before arrival of brigade (for 130 fires)

(11) Date of construction of hotels affected by fire (for 130 fires)

(12) An Appendix giving details of fires which spread beyond the room of origin (for 20 fires out of the 130 fires)

Published as: Fire Research Technical Paper No. 23.

The following are summaries of the salient features revealed in the tables:-

(1) No significant difference from month to month

(2) Time of occurrence appears directly related to periods of activity

(3) Over 20% of fires occur in kitchens and nearly 17% in bedrooms (many of these during the day)

(4) Over 20% of fires caused by 'smoking materials' (about 9% for dwellings) but only 0.6% caused by 'children with fire' (5.5% for dwellings)

(5) 34% of fires caused by 'smoking materials' occur between midnight and 6 a.m.

(6) 30% of fires in bedrooms are caused by electric heating or electric appliances

(7) About 75% of fires are confined to the room of origin. Over 40% of fires which involve the whole of a multi-storey hotel occur between midnight and 6 a.m.

(8) 28% of fires caused by 'smoking materials' spread beyond the room of origin

(9) 25% of fires were extinguished before the arrival of the Fire Brigade. 50% of the fires dealt with by the Fire Brigade were extinguished by using hose reel jets and the water in the tank only

(10) Some obvious advantage results from the use of extinguishing appliances before the arrival of the Fire Brigade

(11) At least 50% of the fires occurred in hotels built before 1900 (total number of hotels at risk is not known)

(12) An open door assisted fire spread in 11 of the 20 fires investigated. Fire spread through a wall or partition in 6 fires and through the ceiling or floor in 10 fires and up the staircase in 4 fires.

The recommendations made in the Note are:-

(1) Adequate provision of ash trays

(2) Escape routes to be clearly marked and left unobstructed

(3) Staff should be trained in fire prevention including training in the use of extinguishers

(4) More use of central heating and the exclusion of additional space heating and portable appliances.

Synopsis of F.R. Note No. 738

THE DARKENING OF IRRADIATED WOOD SURFACES

by

S. J. Melinek

Thermal radiation can be accurately measured with a radiometer but these instruments are expensive and means have been devised for making less accurate measurements more cheaply by using small blocks of wood which are usually fixed to poles and placed in various positions and at different distances from an experimental fire.

High intensity radiation which is sufficient to char wood can be calculated by measuring the depth of char but this method is of no use for low intensity radiation which is insufficient to burn the wood.

However, small amounts of thermal radiation can be estimated by observing the degree of darkening on the surface of the wood blocks and it is often preferable to make numerous rough measurements in this way rather than only a few highly accurate ones with radiometers.

If the degree of darkening and the time of exposure are known then the radiation in watts per square cm (W/cm^2) can be assessed. The rate of darkening depends on the rate of heating and once the reflectivity of the darkened surface is known there is an equation (on page 3 of the Note) which can be used to find the intensity of radiation.

The reflectivity of the darkened surface is found by shining a source of light onto it and using a photo-electric cell to measure the amount of light reflected.

Synopsis of F.R. Note No. 739

THE FIRE PROPAGATION TEST - ITS DEVELOPMENT AND APPLICATION

by

Barbara F. W. Rogowski

Note: The general research work in connection with the development of the Fire Propagation Test and details of the apparatus and test procedures are described in F.R. Notes No. 710, 712 and 743 for which synopses were prepared. They should be read in conjunction with this synopsis.

Any control on the use of linings has largely depended on the Surface Spread of Flame test (B.S. 476 : Part 7) which, being an 'open' type test does not make allowance for any significant contribution by the heat evolved from the material during its combustion, as is likely to occur in an actual fire; nor is it able to test some plastics since these just melt and fall away from the furnace.

The properties of linings, both to walls and ceilings, which influence their performance in fire are the thermal properties, the ease of ignition, the rate of flame spread and the amount of heat released during combustion. The Fire Propagation Test was designed to assess these hazards mainly for use in the Building Regulations, especially to replace the Class A and 0 linings, the specification for which was felt to be unduly restrictive towards the further development of good lining materials which have a homogeneous mixture and are not just layers of material of particular type and thickness.

After a number of full-scale and small-scale tests it was found that there was good correlation in regard to the 'flashover' time as between full and small-scale tests. Further, in the scale model tests it was found that there was good correlation between the 'flashover' time and the grading of the materials whether they were applied to the walls, or to the ceiling (the other surfaces being non-combustible). There was only a coarse measure of agreement between the 'flashover' times and the Surface Spread of Flame rating, especially for materials likely to be used in 'safety' areas.

The Fire Propagation test was therefore developed using a non-combustible enclosure in preference to the 'open' type test (other countries are also adopting this type of test). This enclosed apparatus overcame the difficulties experienced in testing some plastics in the Surface Spread of Flame test.

Before a test is carried out the apparatus must be calibrated by testing a sample of asbestos wood similar to that used for the walls of the apparatus. When this has been done a sample of the material to be tested (up to 2" thick) is inserted in the specimen holder and the temperature rise of the flue gases is again recorded throughout the 20 min test. The mean of three tests is obtained. Having obtained the temperature difference between the calibration and the actual test, various methods were considered for producing a resultant index which would grade the materials in an order of merit similar to their observed performance in fires, making due allowance for ease of ignition and the subsequent pattern of heat release. Eventually it was decided that, by taking readings at $\frac{1}{2}$ min intervals during the first 3 min, at 1 min intervals from 4-10 min and at 2 min intervals from 12-20 min a total index was obtained which matched this order of merit. The index, therefore, provides a comparative measure of the contribution a material will make to the heat build-up and, thus, to the fire spread within a compartment. The index numbers range from 0 to about 100, the latter being roughly that of expanded foam rubber.

It is emphasized that the tests must be carried out on the material as a whole i.e. including any substrate, adhesive or surface finish etc.

The range of indices for materials to be allowed in various situations is under discussion and data on large numbers of materials are being accumulated.

Published as Fire Research Technical Paper No. 25.

Table

Performance indices for typical materials

Material	Thickness mm	Thickness in	I	i_1	i_2	i_3
Polyether foam	51	2	88.5 X*	68.4	18.0	2.1
Fibre insulating board	13	½	66.4 P≁	41.0	22.0	3.4
Softwood	16	⅝	46.6 P	20.2	21.6	4.8
Plywood	6	¼	41.1 P	19.5	19.2	2.5
Hardboard	5	3/16	30.1 P	10.5	16.8	2.8
Polyurethane foam (flame retardant)	13	½	28.6 P	23.4	5.1	0.1
Glass fibre reinforced polyester	3	⅛	26.4 P	10.4	12.5	3.5
Decorative plastics laminate (phenol-formaldehyde base)	3	⅛	18.4 P	5.4	11.8	1.2
Softwood with intumescent fire-retardant coating	19	¾	15.1 P	5.8	4.6	4.7
Plastics coated steel	Coating 390 g/m^2	Weight 11.5 oz/yd^2	12.0 P	4.0	7.6	0.4
Plasterboard	9	⅜	9.7 P	5.4	3.6	0.7
Mineral fibreboard acoustic tile	13	½	7.7 P	4.0	2.8	0.9
P.V.C. coated steel	< 0.8 (coating)	$< 1/32$	5.5 P	2.2	3.0	0.3

* X denotes failed preliminary ignitability test of B.S. 476 : Part 5 : 1968 ref. 3.

≁ P denotes passed preliminary ignitability test of B.S. 476 : Part 5 : 1968.

N.B. The Note contains a graph which shows the relationship between the delay in time to flashover obtained in fires in small-scale rooms, lined with different materials (11 different types) and the Fire Propagation test index. This curve indicates the following:-

Index	Time to flashover (min)
over 30	5
15 - 30	5 - 10
5 - 15	10 - 18

The results of all the 11 materials tested fall closely on the curve.

Synopsis of F.R. Notes Nos 740 and 744

NOTES ON FOREST FIRE FIELDWORK
NEW FOREST - MARCH 1967 AND MARCH 1968

by

M. J. Woolliscroft

A party from the Fire Research Station attended controlled burnings carried out by the Forestry Commission in the New Forest in the Spring of 1967 and in 1968. Measurements were made of the rate of fire spread, radiation and temperature. The fires were mainly 'head' fires involving gorse, grass, heather and bracken.

It was found that the flames contribute appreciably to the rate of fire spread but it is not certain that this is the only factor other than radiation from the fuel bed. The field work data did not correlate with earlier laboratory research work but the reasons for the discrepancy are not known.

With 'head' fires, when there is an appreciable quantity of dry grass the spread of fire is as fast as it would be if only grass was present.

Synopsis of F.R. Note No. 741.

FIRE RESISTANCE OF STRUCTURAL CONCRETE BEAMS

by

H. L. Malhotra

Although some limited tests had previously been carried out on reinforced concrete beams and tests, in more detail, on prestressed concrete beams, no work had been done on steel beams with concrete encasement and it was decided to examine all three types under similar conditions and expose them to the heating conditions specified in B.S. 476 : Part 1. The tests were also to include a proposed revision to the B.S. that the maximum deflection should not exceed 1/30 where 1 is the clear span.

The Building Research Station designed and made 24 beams in accordance with the appropriate Codes of Practice - 7 were of prestressed concrete, 14 of reinforced concrete and 3 of concrete encased steel beams. The beams were 25 ft long except for 5 which were 37 ft long (2 each of prestressed concrete and reinforced concrete and 1 of encased steel) and various types of concrete and steel were used. The unsupported span in the furnace was 24 ft. All but three beams were of rectangular section; the three mentioned were I section prestressed concrete beams, and all were provided with a cast slab on top (e.g. as part of a floor) to form a T-beam. Some of the specimens were provided with supplementary reinforcement and all but 6 were designed to have a fire resistance of at least 4 hours.

The beams were stored for up to 3 years before testing in the Fire Research Station's floor furnace under a load provided by hydraulic jacks applying pressure at four points along the beam. The long beams extended beyond the furnace and the cantilevered (overhanging) portions were weighted with iron weights. A brick pier was provided below the centre of the beams to prevent complete collapse although it allowed substantial deflection.

The Note contains Tables showing details of the construction of each beam, the ageing period, the design load and fire resistance, and the temperatures, deflection and time to reach the critical deflection of $^{1}/30$ in the furnace test. An Appendix provides numerous comments on the 24 tests but in view of the great variety in the forms of construction and performance there is no clear picture readily apparent. The furnace heating was stopped in most cases before complete collapse on to the brick pier but 3 beams did fall on to the pier before the heating could be turned off. Some thermocouples did not work correctly but the times for the critical deflection of $^{1}/30$ in respect of beams which did not actually collapse were computed so that a common basis could be provided for a comparison of the performance of all beams.

The main revelation from the tests was the rapid spalling of the concrete protection from the soffit and sides when gravel aggregate was used without supplementary reinforcement or insulation. In fact, spalling of this type of concrete started within $\frac{1}{2}$ hour and the beams failed in $1\frac{1}{2}$ hours as a result of the exposure of the steel reinforcement. This substantial spalling did not, however, occur with the rectangular section beams using gravel aggregate concrete with supplementary reinforcement.

The exact mechanism of spalling is complex and not fully understood. It occurs with gravel aggregate concrete and depends on the distance from the exposed face to the steel reinforcement; if this is less than 1.6" then only the arrisses spall but if the distance is greater the concrete cannot support itself and large portions fall away and expose the bars, wires or cables. Therefore, when silicious aggregates are used, either supplementary reinforcement or further insulating encasement is required. Supplementary reinforcement can also prevent collapse of the thin section concrete joining the thicker parts as with the webs of the I Section beams. The supplementary reinforcement can consist of steel wire fabric having a mesh of not more than 6" or a system of steel wire links at 6" centres. Expanded metal lath might prove satisfactory if the concrete cover is 1.6" or less. Encasement with, say $\frac{1}{2}$" of vermiculite/ gypsum plaster would be equally effective in the prevention of spalling by providing additional insulation.

Lightweight concrete (expanded clay or foamed slag) is free from the phenomenon of spalling and even if $2\frac{1}{2}$" thick it needs no supplementary reinforcement nor insulation and both the beams tested with this protection lasted for 6 hours. The use of lightweight concrete resulted in a 38% longer time for the steel to reach 550°C; in other words the thickness of the concrete cover could be reduced by about 20% and still meet the design fire resistance. With concrete encased steel beams with supplementary reinforcement a reduction of 20% in the thickness of the concrete cover might also seem reasonable i.e. 2" instead of $2\frac{1}{2}$" for 4 hour fire resistance.

There was found to be less than 10% difference in performance between mild steel, cold worked twisted steel and hot rolled alloy steel but further tests would be needed if more precise comparisons are required.

There was little difference between the performance of the longer beams with cantilevered ends having no restraint on the expansion of the beam and those of only 25 ft with no overhang.

Synopsis of F.R. Note No. 742

THE IGNITION OF MOTOR TYRE SAMPLES

by

H. Wraight

Experiments were carried out to determine the lowest intensity of radiation at which motor tyres would ignite as a result of exposure from a nearby fire. There was no information available on the subject and, since large stocks of motor tyres would present a fire hazard unless adequately separated from sources of ignition examination of the behaviour of this type of material was of value for deciding on separation distances.

60 mm square sections of the tread and sidewall of used tubeless motor tyres were used and were tested for both spontaneous and pilot ignition. The results were compared with those of similar tests on European Whitewood and the minimum intensities were found to be:-

	Minimum intensity - W/cm^2	
Type of ignition	Tyre rubber	European whitewood
Spontaneous	4.0	5.2
Pilot	1.65	1.6

A small vertical gas fired radiant panel was used and the pilot ignition was obtained by providing a small downward pointing gas jet just above and in front of the specimen, in a position to ignite the stream of decomposition gases rising from the specimen.

It was found that:-

(1) There was little difference between tyre rubber and the wood especially for pilot ignition although the tyres took rather longer to ignite owing to their greater conductivity.

(2) There was no tendency for the rubber to melt at least before ignition occurred.

(3) The behaviour of the tyre rubber would be considerably influenced by the quantity of carbon black incorporated in the tyre and the carbon would probably retard or prevent melting of the rubber.

N.B. It would seem therefore that stacks of motor tyres should be separated from one another by a distance similar to that required for stacks of soft wood, and full scale tests on stacks of these materials should provide information regarding the radiation relative to stack height.

Synopsis of F.R. Note No. 743

THE CONTRIBUTION OF FLAMES UNDER CEILINGS TO FIRE SPREAD IN COMPARTMENTS

PART II COMBUSTIBLE CEILING LININGS

by

P. L. Hinkley and H. Wraight

Note: Reference should be made to the Synopsis for F.R. Note No. 712 for details of the research work on incombustible ceilings (Part I) and to the Synopsis for F.R. Note No. 710 for comparisons between the "corridor" tests, the Fire Propagation Index and the Spread of Flame classification for ceiling linings.

The model corridor used in the experiments described in this Note was that referred to in F.R. Note No. 712 but underneath the non-combustible ceiling, linings of cellulose-based building boards were fixed. A table showing the Fire Propagation Index and Spread of Flame classification of the boards involved was included in the Synopsis for F.R. Note No. 710. The linings, which were fixed to the underside of the non-combustible ceiling, extended a distance of 4.4 metres from the rear or 'fire' end of the corridor, thus leaving 2.9 metres of non-combustible ceiling at the non-'fire' end of the corridor which was 7.3 m long in all. The linings were nailed to battens (as recommended by manufacturers) which in turn were bolted to the non-combustible ceiling.

Measurements were made of the downwards radiation, the heat transfer to the ceiling, the temperature of the gases at various distances from the 'fire' and depths from the ceiling, and of the burning rate of a small section of the lining at the non-'fire' end by weighing during each experiment.

The flow of gas to the burner or 'fire' was such that the heat transfer over the burner to a non-combustible ceiling was 10 W/cm^2 (i.e. sufficient to ignite all the linings).

The times taken for the linings to ignite are shown in the consolidated table*. After ignition of the lining the flame length increased to a maximum (greater than length of lining). Generally there

*at end.

were only small differences in the maximum flame lengths except for stove-enamelled hardboard, the flames from which extended 3 m out of the end of the corridor and even beneath the side screens. The times for the flames to reach maximum length varied from 1 to 5 minutes and were longest for materials with good ratings in the Fire Propagation Test. The flame length generally remained near the maximum for 3 or 4 minutes and then decreased but tended to advance a second time as the lining burnt away. However, with hardboard treated with intumescent paint and stove-enamelled hardboard the flames did not decrease until the lining was nearly burnt away.

After a few minutes pieces of lining started to fall to the floor where they generally continued to burn.

The maximum temperature at 2 m from the 'fire' was about 750 - 800°C at a level about 10 cm below the ceiling (compared with 600°C for a non-combustible ceiling). Generally the depth of the layer of hot gases was changed little by lining the ceiling with combustible material and this confirmed that the mass of fuel gases emitted by the burning lining was small compared with the mass of hot gases and air resulting from the 'fire' at the rear of the corridor.

The distance from the rear end of the corridor over which the intensity of downwards radiation exceeded 1.0 W/cm^2 is also shown in the consolidated table. There was remarkably little difference between the types of material except for stove-enamelled hardboard for which a radiation of about 4 W/cm^2 was recorded over its whole length during the period of intense flaming. For the other materials the increase in flame length due to the lining was roughly what would have been produced by doubling the rate of burning of the 'fire'. However, it is evident that the effects of lining the ceiling with combustible board cannot be considered simply as equivalent to an increase in size of the 'fire' and the effect can be trebled (rather than doubled) when the 'fire' is small. The anomalous behaviour of stove-enamelled hardboard may have been due to an increase in the mixing of the gases below the lining, possibly by gases being emitted through pin holes in the enamel coating. Hardboard coated with intumescent paint also produced jets of flame but these were much smaller. Increased mixing of the gas layers caused by pieces of lining hanging downwards may also have been responsible for the increase in downward radiation.

Calculations were made, using the experimental data, to find the rate of spread of fire along a wooden strip on the floor. The rate of spread in the early stages depends on the rate of rise of intensity of radiation because the initial rise in temperature of the floor due to the increase in radiation occurs more rapidly than the increase of radiation itself. The ultimate distance of spread was related to the maximum intensity of radiation except for stove-enamelled hardboard and the rate of rise of intensity of radiation and rate of spread can be correlated with the Fire Propagation test index.

The Note contains a graph relating the initial rate of spread in m/min to the Fire Propagation Index and the following are four sample measurements:-

Fire Propagation Index	Initial rate of spread in m/min
20	0.75
40	1.5
60	3.0
70	4.0

These calculations assumed no 'feedback' from the floor fire to the ceiling. Where 'feedback' from a floor fire can occur an accelerating rate of spread of fire would result until other factors such as a shortage of air, intervene. In these circumstances the initial rate of spread would assume an even greater importance since the accelerating spread would in effect be an accumulation of successive initial rates of spread rather in the same way as spread itself is a succession of ignitions.

<u>Consolidated table</u>

	Fire Propagation Index	Spread of flame classification	(Mean) ignition time -s	Max flame length -m	Time to reach 80% of max flame length -m	Distance on "floor" over which intensity of radiation exceeded 1 W/cm^2 -m
Hardboard with intumescent paint	16.5	2	110	7.3	4	5.0
Impregnated fibre insulating board	18.7	1	50	7.3	5	4.4
Panel board with plastics paint	23.7	2	52.5	7.3	3	4.7
Impregnated medium hardboard	29.7	4	16	7.3	2	4.3
Stove enamelled hardboard	40.6	3	32.5	7.3+	1	≫7.3
Fibre insulating board with emulsion paint	42.0	4	17.5	5.5	1	4.2
Fibre insulating board with rubber paint	53.5	4	30	5.5	1	4.1
Untreated fibre insulating board	75.3	4	10	7.3+	1	4.7

Synopsis of F.R. Note No. 745

THE CHANCE OF AN OUTBREAK OF FIRE AND THE LIKELIHOOD OF LARGE FIRES IN VARIOUS OCCUPANCIES

by

R. Baldwin

This paper reviews the available statistics for 1962/6 (inclusive) in order to assess the chance of an out break of fire and of an outbreak becoming large, in various occupancies and the tables in the Note are summarized in the following consolidated table.

The main sources of information are the annual UK Fire Statistics and the FPA Journals (for details of large fires) but the Inland Revenue rating information and the Ministry of Labour employment figures are also used to provide information for 1962 regarding the numbers of buildings and establishments at risk.

There are many factors which can affect the chance of an outbreak of fire and its size, such as the size of the building, the type of contents and the processes carried on but an examination of all these factors is outside the scope of this investigation.

The conclusions reached are as follows:-

(1) In the manufacturing industries there is a sharp increase in the annual number of fires from 1962 to 1966 but the chance of a fire becoming large has remained constant.

(2) In the distributive trades the annual number of fires has remained fairly constant but the chance of a fire becoming large has increased considerably.

Although the number of premises at risk is not known (apart from an assessment for 1962) "Conclusion (1)" implies that, in the manufacturing industries, the principal cause of increasing fire losses is the increasing number of fires and in the distributive trades it is the increasing size of individual fires. This indicates that fire protection remains effective with the former but not with the latter, and, vice versa, fire prevention remains effective with the distributive trades but not in the manufacturing industries. However, the increase in the percentage of fires which become large in the distributive trades is probably the result of increasing concentration of value in warehouses and shops such as Supermarkets.

Column A: Number of fires
Column B: Chance of fire exceeding £10000 (% age)
Column C: Chance of fire per establishment (% age)

Occupancy	1962			1963			1964			1965			1966		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Manufacturing Industries:-															
Food, drink, tobacco	512	5.1	9.7	518	6.4	Not available	500	6.2	Not available	495	8.5	Not available	573	5.1	Not available
Chemicals & Allied Industries	496	8.1	20.2	640	6.9	Not available	570	7.5	Not available	653	6.1	Not available	765	5.6	Not available
Metal, Metal Goods, Engineering & Electrical	1762	3.6	9.9	1920	4.4	Not available	2284	5.6	Not available	2445	3.6	Not available	2511	4.9	Not available
Shipbuilding & Marine	82	2.4	10.9	72	1.4	Not available	92	6.5	Not available	87	3.4	Not available	83	4.8	Not available
Vehicles	280	6.8	14.5	318	3.1	Not available	300	3.7	Not available	345	7.2	Not available	383	3.1	Not available
Textiles	729	8.0	13.0	790	6.3	Not available	998	6.0	Not available	964	5.7	Not available	1050	5.6	Not available
Leather, leather goods & fur	68	14.7	4.2	84	7.1	Not available	66	21.2	Not available	90	5.6	Not available	106	6.6	Not available
Clothing & footwear	232	7.7		248	8.5	Not available	284	10.2	Not available	251	14.1	Not available	254	11.0	Not available
Bricks, pottery & glass	266	4.5	10.1	268	4.5	Not available	324	6.2	Not available	373	2.4	Not available	415	3.9	Not available
Paper, printing & publishing	346	7.5	6.6	394	8.6	Not available	462	7.1	Not available	420	7.1	Not available	466	8.6	Not available
Other (incldg. timber & furniture	1242	3.8	19.9	1268	3.5	Not available	1458	4.4	Not available	1396	6.0	Not available	1280	5.7	Not available
Totals	6015			6520			7338			7519			7886		
Distributive trades:-															
Retail	3644	1.1		3632	1.0		3810	1.9		3544	1.7		3625	1.6	
Wholesale		–		442	5.9		458	10.7		520	8.7		499	13.2	
Other	1420	–		848	1.9		906	1.7		950	3.0		937	4.8	
Totals	5064			4922			5174			5014			5061		
Residential houses	24274	0.03		28182	0.05		25782	0.08		24970	0.05		24466	0.05	
Probability of a fire per building (based on Inland Revenue rating information):-	% age														
Industry	7.1			Not available											
Distributive trades:-															
Retail	0.63			Not available											
Wholesale	0.55			Not available											
Offices	0.16			Not available											
Residential houses	0.20			Not available											
Chance of fire becoming large:-	% age			% age			% age			% age			% age		
Manufacturing industries	5.4			5.2			5.9			5.5			5.5		
Distributive trades	1.7			1.6			2.6			2.7			3.4		

Synopsis of F.R. Note No. 746

VIBRATION TESTING OF FIRE DETECTORS

by

M. J. O'Dogherty

The proposed revised B.S. 3116 : 1959 contains a vibration test designed to assess the ability of a detector, including its elements, to withstand the effects of vibration, within certain limits of strength and frequency. The Note discusses the problem and also the similar test proposed by the Aachen Institute (West German) - I.E.N.T.

Since an alarm detector is usually fixed to the structure of a building the vibration features of a building are also investigated. Vibration of an alarm detector may cause false alarms, and failure by fatigue or loosening or detachment of components may result in its inability to operate in the event of a fire.

A number of units have been suggested for defining the intensity of vibration (most of German origin) and this Note is only concerned with those vibrations known to occur in buildings.

One useful unit of 'power of vibration' is the 'Vibrar' which is related to strength and frequency. There is also the Zeller (Z) in cm^2/s^3 and a comparison of these Units is shown in the following table:-

Vibrar	Z	Z rating	Classification of vibration	Assessment of damage	Physiological effect
10–20	2–10	2–3	Light	Very light	Just perceptible
40–50	5000	7	Heavy	Severe	Unpleasant
50–60	20000	8	Very heavy	Destruction	Painful

The general inference from these criteria is that serious damage will occur to a building structure from vibrations in excess of 47 vibrars or a Z value of 5000 and this is the datum proposed for the I.E.N.T. test method.

The revised B.S. 3116 : 1959 test is now in two parts:-

(1) Search for false alarms

(2) Search for resonance and endurance test.

No false alarm nor component failure should occur during the tests.

The proposed B.S. tests and the I.E.N.T. tests both cover the same range of frequencies of vibrations viz: 5-60 Hz but differ in the details of the tests. These differences can be summarized as follows:-

	Test detail	B.S.	I.E.N.T.
(1)	Vibration intensity for false alarm test	Strong but not destructive to building	Would result in severe damage to building
(2)	Resonance	High peak intensity	Peak intensity not so high
(3)	Endurance	Tested	Not tested
(4)	Sensitivity after test	Tested	Not tested

The I.E.N.T. test is more severe under (1) but the B.S. test is better under (2) (3) and (4) and its purpose is to subject the detector to severe stresses in order to reveal design weaknesses. The B.S. test under (1) is intended to search for false alarm possibilities from strong vibrations but at a level below the intensity at which building damage would occur.

Synopsis of F.R. Note No. 747

FURTHER EXPERIMENTS WITH WOOD BLOCK RADIOMETERS INCLUDING THE RESPONSE TO A SKEWED PULSE OF RADIATION

by

A. J. M. Heselden and Lynda G. Griffiths

(Note:- The use of wood blocks as radiometers was referred to in the synopsis for F.R. Note 738 and this paper deals with another aspect of the same problem)

In the large Flambeau fire test in 1967, wood blocks were used as radiometers to measure, with reasonable accuracy and cheaply, the thermal conditions within the whole fire area.

Previous experiments have translated the effect on the wood blocks used in the Flambeau fire test into the 'equivalent constant intensity' which, if applied for 20 min would produce the same effect on the wood blocks.

The radiation from a real fire increases steeply as the fire develops until, quite quickly, it reaches a peak after which the radiation reduces, first quite quickly, and then more slowly. This is termed in this F.R. Note 'skewed pulse of radiation'.

The 'curve' of radiation viz. a quick rise and then a more gradual fall can be converted into 'steps' which closely follow the experimentally measured curve. By utilizing these 'steps' of radiation in experiments it was possible to produce an effect on a wood block, by charring or darkening, similar to that which would have been produced by the 'skewed pulse of radiation'. Curves of different peak heights, or maximum radiation, were used.

The F.R. Note contains graphs which relate the peak pulse radiation to the effect (either charring or darkening) on the wood block and they provide a relationship between the equivalent constant intensity and the peak radiation of the 'skewed pulse of radiation'.

This research work is of value in that it enables wood blocks, which are cheap and exceedingly simple to deal with in the field, to be used in large numbers. Systematic variations in radiation can then be distinguished from random variations which are inevitable in large-scale tests.

Synopsis of F.R. Note No. 748

THE DETECTION OF FIRES BY SMOKE
PART 1: RESEARCH PROGRAMME AND DEVELOPMENT OF
STANDARD TEST METHODS

by

M. J. O'Dogherty

A draft standard test for smoke detectors is at present under consideration in the revision of B.S. 3116 (part 3) and experiments have been carried out in order to determine a basis for tests in a specially designed apparatus. This apparatus will probably take the form of an oval shaped re-circulating tunnel in which smoke is generated in a controlled manner and under controlled conditions.

The revised B.S. 3116 refers to 'point' or 'spot' heat-sensitive detectors and includes tests for building vibrations, corrosion, impact, shock and low ambient temperatures and these will form the basis of tests for smoke detectors which may also include tests for high ambient temperatures, dust and high air velocities.

Ambient conditions in factories are being measured so that realistic standards can be set for smoke detectors to ensure maximum sensitivity consistent with minimum liability to false alarms.

This F.R. Note describes the research work carried out, the purpose of which is to provide designers and installers of smoke detection systems with the necessary data as well as to provide a basis for the specification of suitable test procedures. Crib fires were used in the experiments and ceiling heights varied from 8 to 23 ft and distances from the 'fire' from 0 to 32 ft. A petrol fire was also used and the detailed results of all these experiments and those on rubber and plastics fires will be described in subsequent parts of the report.

Optical density and air temperature rise were measured, together with the response time to give warning of fire and the Note contains some graphs which relate optical density change in voltage across ionization chambers, ceiling height, distance, size of fire and rate of burning to time of detection. The time of detection of a fire is largely accounted for by the time the smoke takes to reach the detector but also by the time taken by the smoke concentration in the detector to build up sufficiently to produce the alarm signal. A typical graph clearly indicates the very rapid response of an ionization chamber to the freshly formed smoke immediately above a fire and the slower response at a distance from the fire.

The experimental work and work on the proposed standard test continues.

<u>Synopsis of F.R. Note No. 749</u>

THE ASSESSMENT OF SMOKE PRODUCTION BY BUILDING MATERIALS IN FIRES
2. TEST METHOD BASED ON SMOKE ACCUMULATION IN A COMPARTMENT

by

P. C. Bowes and P. Field

This paper reviews the possibilities of measuring the smoke produced when testing materials in the Fire Propagation Test apparatus for the purpose of providing a 'smoke index' for each material. It is suggested that the acceptable level of smoke production by a given building material would depend on its position in the building and its possible time of involvement in relation to a developing fire e.g. flooring material might be permitted a higher level of smoke production than wall or ceiling linings. Where significant involvement would depend on the existence of an already large fire in other materials (i.e. contents) the level of smoke production could be correspondingly high.

As a result of the research work described in this note it is concluded that the Fire Propagation Test apparatus could be used, under certain agreed conditions, to provide an acceptable index of smoke production. Assessments were made on the maximum optical density and not on the rate of smoke production and a more detailed study would be required if the feasibility of a rate index is accepted. The index of smoke production could be simply the maximum optical density of the smoke produced by a particular material under certain test conditions. It is possible to convert the optical density into distance of visibility.

The apparatus would be used in a reasonably smoke-tight room (probably 1200 ft^3) in which there would be sufficient oxygen for combustion to be complete. There would be fans to stir the air and dilute the smoke and also facilities for clearing the smoke from the room after every test.

Tests were carried out in accordance with B.S. 476 : Part 6 although the test period was extended for 5 min beyond the 20 min of the standard test so that the maximum smoke obscuration could be obtained. In addition to this, non-standard tests were carried out by using the electrical heaters only at low power so that smouldering combustion or merely pyrolysis was obtained without ignition and this necessitated a test time of about 45 min to obtain maximum smoke obscuration.

The building materials tested were:-

1. Paper-filled phenol/formaldehyde board (¼" thick)
2. Wood-fibre insulating board (½" thick)

The maximum optical densities (average) and visibilities for these materials were:-

		Maximum optical density per metres	Visibility metres
1.	Flaming combustion (standard test)	1.22	1.2
	Smouldering "	0.019*	28
2.	Flaming combustion (standard test)	0.041	17
	Smouldering "	0.46	2.5

These results show that there can be a large difference between the smoke production under the two methods of testing.

A number of other building boards were also tested in order to explore the capabilities of the test and the range of smoke densities likely to be encountered. The range of visibilities in these tests lay between 1 and 5 m (other than plasterboard and wood fibre insulating board undergoing flaming combustion). Except for PVC faced hardboard and rigid PVC smoke production was greatest under the smouldering test.

Building materials may be expected to contribute smoke as a result of simple pyrolysis, smouldering combustion or flaming combustion, at different stages during the growth of a fire and for these reasons it is desirable that the smoke rating should include their behaviour under, at least, smouldering and flaming combustion. Reproducibility between different laboratories using the Fire Propagation Test apparatus in accordance with the proposed procedure is likely to be good but would require checking. The effects of heating and humidity in the test chamber would also require further investigation.

N.B. This research work was carried out at the request of a British Standards Committee which is to consider the adoption of a 'smoke index' test.

*Conditions for this test were not necessarily the optimum for this material.

Synopsis of F.R. Note No. 750

FIRE DEATHS IN 1968

by

S. E. Chandler B.Sc.

The Fire Brigade reports received by the 10th February, 1968 show that there were 809 deaths in 628 fires during 1968 and in 89 of these fires there were multiple deaths.

Although the total of deaths was slightly less than the previous highest total, in 1963, the final figures may well be more than 818 when all reports are received. In 1963 there was severe winter weather.

The most serious fires involving deaths were in an hotel in Brighton, a furniture warehouse in Glasgow, a mental hospital at Shelton and the Ronan Point flats (explosion).

Nearly one third of the fatal fires occurred, for certain, in terraced houses or houses converted into flats and, in fact, probably 40% of the fires were in this type of property. Over a quarter of the fires having known causes were due to 'smoking materials', and space heating accounted for a large proportion of these fatal fires.

Synopsis of F.R. Note No. 751

FIRES IN POST-WAR MULTI-STOREY FLATS IN LONDON, 1966

by

J. F. Fry

This report is on similar lines to the reports on fires in this type of building in 1962 and 1965 (F.R. Notes 543 and 674) but also includes information on fires in "common service areas" and those which spread beyond the floor of origin.

The Note includes tables which provide information on:-

(1) Rates of incidence of fires according to height of building

(2) Sources of ignition

(3) Location of fires

(4) Spread of fire

(5) Method of extinction

(6) Appendices - 1(a) Common service areas

(b) Fires which spread beyond room of origin

2. Casualties.

The main conclusions can be summarized as follows:-

The overall rate of incidence of fire in these buildings of three or more storeys is 29.6 per 10 000 dwellings as compared with 19/20 per 10 000 dwellings of all kinds but when fires in rubbish chutes are discounted the incidence for the multi-storey flats is reduced to 16.5 per 10 000 dwellings.

Almost half of the fires start in dust chutes and refuse rooms and 21 per cent start in kitchens. The fires which start in common service areas (staircases, landings, lifts, etc) are frequently associated with accumulations of rubbish. The proportion of fires caused by gas appliances, children with fire, and smoking materials is much higher than for dwellings as a whole.

The incidence rate in high rise flats (of nine or more storeys) is lower than for less high flats and this may be attributed to the absence of fires caused by space heating equipment. There are very few fires caused by solid fuel appliances in all the flats concerned.

Most of the fires which spread beyond the room of origin are confined to the flat or maisonette in which they start and it is unusual for more than one floor to become involved.

Over 25 per cent of the fires are extinguished before the arrival of the fire brigade and most of those dealt with by the brigade are extinguished by hose reel jets using the tank water only. Only 7 out of 356 fires extinguished by the brigade require the use of pumps or hydrants.

Most of the casualties in the flats are at or near the point of origin of the fire and there is no evidence that occupants of the flats are more likely to be trapped than those in other dwellings.

Published as: FRY, J. F. Fires in flats and maisonettes. Munc. Public Services J., 1970, 78 (30) 1669-71.

Synopsis of F.R. Note No. 752

TOXIC GASES FROM RIGID POLY (VINYL CHLORIDE) IN FIRES

by

G.W.V. Stark, Wendy Evans and P. Field

Experiments were carried out in a compartment about 3 ft cube erected in the Models Laboratory (about 260,000 ft^3) and constructed of asbestos millboard with the front moveable to provide a ventilation gap, at the top of the front of the compartment, which could be 2, 4 or 6 in deep extending right across the front. The walls of the compartment were lined with unplasticized poly (vinyl chloride) (UPVC) in thickness of 0.001, 0.02, 1/16, 1/8 and 1/4 in and the fire load was a crib of (square section) wood fibre insulating board (W.F.I.B.) of two sizes viz:- 14 or 28 lb with a space of about 5 in between the crib and the walls of the compartment. Some tests were done without lining the walls but with the equivalent quantity of UPVC as strips incorporated in the upper layers of the crib.

The tests were carried out mainly to assess the emission of carbon monoxide and hydrogen chloride gases and the consequent hazards of these toxic gases, although the Note contains some comments on the extent of hydrogen chloride gas emission, its quantity and the timing, which could have a bearing on the corrosion hazard. Gas samples were taken during the tests and thermocouples were fitted so that the temperature of the combustion gases and the concentration and total quantity of CO and HCl gases could be recorded.

In some of the experimental fires there was flaming combustion and in others only smouldering, depending on the size of the ventilation gap. The results were distorted to some extent by the behaviour, during the 'fires', of the wall lining which in some tests fell across the crib, curled up or collapsed to the floor of the compartment and this was dependent largely on the thickness of the UPVC, the method of fixing and the substrate, if any. The presence in some of the cribs used of UPVC strips on top of the WFIB strips affected the results of those tests because the upper layers of the crib became cemented together into a matrix which disturbed the combustion and gas distribution.

It was found that, with the smallest ventilation gap, CO was given off quickly and in the greatest quantity, but HCl was only produced in significant quantities after the crib had been burning for about 90 mins. When the largest ventilation gap was used both CO and HCl were given off quite soon after ignition.

The maximum CO concentration occurred at about the same time as the temperature peak but the maximum HCl concentration depended very largely on the mechanical behaviour of the UPVC lining, e.g. falling onto the crib etc.

The Note contains tables and graphs which would help in calculating the timing and extent of contamination of the atmosphere in a building and the escape of toxic gases from a burning compartment onto the escape routes. It is not possible at this stage, however, to present results in a way that permits extrapolation to buildings of various sizes and layouts. In general terms, however, when the ventilation/fire load ratio is small the risk due to CO far outweighs the risk due to HCl but the reverse can apply when the ventilation/fire load ratio is larger. In the latter case the amount of HCl evolved would depend on the amount of PVC in the compartment. With high ventilation it can be assumed that all the chlorine content of the PVC present would be released as HCl during a fire and the total quantity released would be a proportion of the plastics content of the materials.

The rate of emission of HCl was less in the compartment tests than in some laboratory tests which were also carried out, mainly because in the former only the exposed surface of the UPVC burnt initially in a rising temperature whereas, in the latter, PVC granules were ignited by a flame of constant temperature in a furnace.

Further tests are to be done to examine the effect of size on the combustion processes and to find out if the rate of emission of HCl is related to the temperature of the exposed surface of the PVC within the compartment.

Note

A condensed version of this F.R. Note No. 752 has been included in the publication "Rubber & Plastics Age" of April 1969.

Also, the full F.R. Note was incorporated in a paper prepared by the author for the symposium SKYDD 69 at Stockholm on April 24th 1969. This symposium dealt with corrosion risks in connection with fire in plastics and the paper included some comments on the corrosion risk, in addition to those in the F.R. Note No. 752. It was pointed out that the risk of corrosion of machinery and equipment remote from the fire will exist if the products of combustion can reach them and will be severe if moisture in the atmosphere can condense with the HCl to form aqueous acid. It is desirable to maintain the atmosphere in the building at the highest permissible temperature and the lowest humidity to reduce condensation because any hydrochloric acid in a humid atmosphere will raise its dew point and the combustion of most organic materials will release about 15-20% of their weight as water.

Further research work is therefore required on the problems of the relative humidity and rates of ventilation necessary to safeguard materials from corrosion. There will be small-scale laboratory tests and also tests in a three-compartment building about 10 m x 2.5 m x 2.5 m high which is now being designed. PVC will be burnt in "wet" and in "dry" conditions and the action of the gases, from the fires, on the building materials will be examined.

Synopsis of F.R. Note No. 753

A CRITICAL LOOK AT SOME CURRENT PROBLEMS OF ESCAPE ROUTE PLANNING AND A GLIMPSE OF THE FUTURE
(The Background to the Symposium)

by

A. Silcock, A.R.I.B.A.

This paper was prepared for a Symposium on "smoke movement on escape routes" and deals, in some detail, with the safety of life problem on the escape from buildings. In 1966 there were 266 deaths in buildings (other than 2 storey dwellings which is a separate problem). Few people are actually burnt to death; the majority are overcome by smoke and hot gases but only very few deaths can be attributed in any way to faulty escape routes.

Although the escape problem is of no direct interest to fire insurers, the matter of ventilation and doors is of some concern. The majority of casualties may well be in old buildings which are not up to modern standards of fire protection but even the present Codes of Practice on Means of Escape are rather inflexible and some of the requirements at least questionable in the light of modern building techniques, design and size. The codes are becoming more difficult to apply especially to very tall buildings and to the new central area development complexes.

The dominant factor in most escape planning is the distance to travel to the staircase or safe area. Normally staircases are ventilated but these together with the escape routes can be mechanically pressurized. The weakest link in any escape route is almost invariably the self-closing fire check door which may be jammed open or shut etc and the failure of the door to function properly is responsible for nearly half of the total of those killed, injured or in danger. The absence of a door of any kind is responsible for nearly all the other half of those killed, injured or in danger. Fire check doors which function properly have proved to be of the greatest value.

Ideas on escape and the need for escape are changing and the concept of partial evacuation or evacuation to safe areas within a building is being developed. It is suggested that less reliance be placed on the human element and more reliance on automatically operating mechanical systems including detectors, door closing and air handling devices especially in large buildings and building complexes.

When the relationship between all the various factors is more clearly understood it should be possible to tailormake the fire protection to the requirements of a particular project, in other words adapt the fire protection to suit the design rather than the design to suit the fire protection as so often happens today.

Published as: SILCOCK, A. A critical look at some current problems of escape route planning and a glimpse of the future. Paper 1 of Movement of smoke on escape routes in buildings. Department of Trade and Industry and Fire Offices' Committee Symposium No. 4 London, 1970. H.M. Stationery Office.

Synopsis of F.R. Note No. 754

THE PREDICTION OF THE BEHAVIOUR OF SMOKE IN A BUILDING USING COMPUTER TECHNIQUES

by

E. G. Butcher and P. J. Fardell, J.F.R.O.

and

P. J. Jackmann, M.V.R.A.

This paper describes a new approach to the problem of assessing the effectiveness of the means of escape particularly in new buildings at an early design stage by using a digital computer to calculate the potential movement and density of smoke. The calculations can take account of natural or mechanical ventilation, wind conditions, effect of doors and windows and of fire conditions.

The building is divided into zones which are identified by 'nodes' which represent the pressure value resulting from certain conditions in the building at which an air flow balance at each of the 'nodes' is achieved. The computer can then calculate the change in the air flow path resulting from any change in the conditions in the building such as an open door or window or a fire. This enables the movement and density of smoke from a fire to be determined and the escape routes to be planned.

Published as: BUTCHER, E.G. and FARDELL, P.J. Prediction of the behaviour of smoke in a building using a computer. Paper 9 of Movement of smoke on escape routes in buildings. Department of Trade and Industry and Fire Offices' Committee Symposium No. 4 London, 1970. H.M. Stationery Office.

Synopsis of F.R. Note No. 756

THE PROTECTION OF EQUIPMENT WITH FLAME ARRESTERS
PART III. PERFORMANCE OF ARRESTERS WITH ETHYLENE-AIR FLAMMABLE MIXTURE

by

K. N. Palmer and Z. W. Rogowski

Note: Parts I and II of this research work are described in the synopsis for F.R. Notes Nos. 613 and 658 to which reference should be made for the background to Part III.

A further series of experiments was carried out using the same $\frac{1}{3}$, 1 and 3 ft^3 vessels (casings) employed in the earlier tests but this time the flammable gas was a 6.5 per cent (by volume) ethylene-air mixture. Ethylene is a typical Group III gas (B.S.229) such as would be found in the chemical and petroleum industry and is relatively fast burning.

The arresters used were of nickel ribbon 1 in wide, about 0.006 in thick and the crimp height (i.e. distance between layers) was 0.02 in. The alternate layers of crimped and flat ribbons were packed in square metal cases which were fitted over circular vents, in the casings, of 4.3 in, 2.25 in and 1.15 in, diameter.

In some tests obstacles were placed in the casings and these consisted of metal plates and shelves fixed in various positions. However, in other tests no obstacles were inserted and, in these experiments, it was found that the explosion pressures, when arresters were fitted to the vents, were twice those with the vents open. Using the large casing, for a given K value (fraction of cross-sectional area of casing over vent area), the maximum pressure was twice that obtained with the smaller casings, both with vents covered by flame arresters and open. This was not entirely surprising because other work with larger containers produced higher values caused, probably, by the turbulence within the flame zone and a higher combustion rate.

When obstacles were used, the maximum explosion pressures depended very much on the area, but not the position of the obstacles, and the position of the ignition source in relation to the obstacles. In general, the obstacles resulted in a pressure up to three times greater than that for an empty casing.

No structural damage was suffered by any arrester and the heat damage was similar to that found when using the propane-air mixture.

By using the combustion rate and the venting rate it was possible to predict that the maximum pressure, for a given K value, will increase in proportion to the square of the flame speed between the igniting source and the vent if there are no obstacles. By this method it can be shown that the pressure, using ethylene-air mixture, is 2.5 - 4 times that for propane-air and this was confirmed in the experiments. The results of the experiments widen the scope of the existing design data. They indicate the maximum pressures that will be produced by some of the Group III gases but, whilst they are accurate for small empty casings, they only provide guidance for casings containing obstacles and such equipment would have to be specially tested.

Synopsis of F.R. Note No. 758

PRELIMINARY ANALYSIS OF FIRE REPORTS FROM FIRE BRIGADES IN THE UNITED KINGDOM, 1968.

by

S. E. Chandler

The Fire Brigade reports which were received up to 7 March 1969 are analysed to show the total number of fires attended by the various Brigades throughout the U.K., the number of fatal and non-fatal casualties, and the number rescued.

The total number of fires attended by the Brigades throughout the U.K. (other than those confined to grass and heathland) was 171 686, an increase of 8% over the 1967 figure.

Mass evacuation or rescue was necessary or advisable in 11 incidents (2 hospitals, 2 hotels, a school, 3 buses, one train, a football ground and a departmental store). In all there were 821 fatal casualties as compared with 739 in 1967.

Synopsis of F.R. Note No. 759

THE RELIEF OF GAS AND VAPOUR EXPLOSIONS IN DOMESTIC STRUCTURES

by

D. J. Rasbash

Following the publication of the Ronan Point Enquiry, information was sought regarding the explosion pressures likely to be encountered in domestic structures under various conditions and this Note contains a detailed summary of the relevant information available at the Fire Research Station and an indication of the data which would require checking if the extrapolations included in the Note are to be confirmed.

The severity of any explosion depends on the type of gas, the concentration of the mixture of gas and air, the likely turbulence and the effectiveness of any explosion relief. The figures quoted in the Note relate mainly to propane (common solvents and liquid fuels would be similar); ethylene, town gas or acetylene would produce substantially higher pressures but natural gas somewhat lower pressures.

The author reviews in some detail the effectiveness of windows and doors (internal and external) in relieving pressures, depending on the particular room in which the explosion occurs, and it is emphasized that gases being forced through doorways can increase turbulence and, consequently, the force of the explosion. The conclusion is that it should be possible to design domestic premises so that fuels such as L.P.G. will not produce explosive pressures of more than 5 lbf/in^2 by providing windows, of reasonably generous proportions, made to burst or fly open at the lowest practicable pressure, bearing in mind the possible wind suction forces.

Some form of explosion relief away from the internal doors should also be provided (known as 'back' relief) and this could take the form of doors leading to verandas or to large open corridors, which should open at rather lower pressures than those associated with gale force winds. Where 'back' relief cannot be provided a self-closing door to each room or mechanical ventilation might prevent turbulent explosions being transmitted to the rest of the dwelling.

If sufficient explosion relief cannot be provided it might be necessary to bridge over loadbearing walls (to the major rooms) and this, in any case, would be a useful precaution to take since excessive pressures might be reached.

However, windows, even double glazed, which burst at about 1 lbf/in^2 and other explosion reliefs would usually restrict the explosion pressure in a dwelling to less than 5 lbf/in^2.

Further information would be required on the pressures at which windows and doors blow out, the pressure build-up in various parts of a furnished dwelling which is provided with general and 'back' relief, and the ability of structural elements to resist internal pressures (present experience relates to external explosions).

Published as: RASBASH, D.J. The relief of gas and vapour explosions in domestic structures. Struct. Engr., 1969, 47 (10) 403-8; J. Instn Heat Vent Engrs, 1969, 37 (October) 141-5.

Synopsis of F.R. Note No. 760

USE OF MECHANICAL VENTILATION TO REDUCE EXPLOSION HAZARDS IN HIGH FLATS

by

K. N. Palmer

Note:- Reference to mechanical ventilation in addition to explosion reliefs was made in F.R. Note 759.

Mechanical ventilation was provided only in the bathroom/toilets of the Ronan Point flats and this paper reviews in some detail the possible use of ventilation in preventing or reducing the force of explosions arising from gas or vapour mixtures with air resulting from leakage or spillage of town or North Sea gas, L.P.G., aerosols, petrol or solvents in any room of a dwelling. Although explosion reliefs would still be required, mechanical ventilation, in addition, might enable economies to be made in the provision of explosion reliefs. For high flats, continuously run individual or common duct systems, venting to the external air, would be essential, but the degree of air movement should not be sufficient to cause discomfort to the occupants.

It is possible that some limitation could be imposed on the volume of flammable liquid permitted in a single container in high flats but some mechanical extract ventilation in the principal rooms should give substantial protection against the formation of explosive gas or vapour mixtures capable of causing severe structural damage even in the worst conditions. Some tests on gas flow patterns in furnished rooms with different heating systems would be useful in predicting more accurately the likelihood of hazardous conditions arising.

Town and North Sea gases are lighter than air but the other vapours mentioned above are heavier and, where both types can be present, ceiling and floor ventilation may be necessary. In general terms, 2 air changes per hour would be required for living and bed rooms and 4 changes for kitchens, whilst 6 changes are already customary in bathroom/toilets. The extraction should be divided between the floor and the ceiling levels if there is a supply of town gas. A hood may well be suitable for the extraction of gas from the area above a gas appliance and this should be capable of dealing with at least 10 times the possible maximum escape rate of gas.

If the extraction rate is such that there are several changes of air per hour then an inlet grille may be necessary, preferably placed diagonally opposite the extraction vent. The inlet rate should be about 25 per cent less than the extraction rate.

The Note goes into some detail regarding the ventilation of the various rooms involved in the Ronan Point flats and the conclusion is that the mechanical ventilation would need to be increased five-fold in order to provide adequate protection throughout the flats.

Synopsis of F.R. Note No. 762

THE USE OF 'LIGHT WATER' FOR MAJOR AIRCRAFT FIRES

by

D. W. Fittes, D. J. Griffiths and P. Nash

Experimental work was carried out last year at the Fire Service Central Training Establishment at Manston, Kent, on three realistic scale aircraft crash fires using 'light water', protein and 'fortified' protein foams. The 'fortified' protein foam contains fluoro-carbon additive. A cylindrical steel tube (largest one was 10 ft in diameter) and steel drums represented the aircraft fuelage and wings and these were placed in three separate low-walled bunds (875, 2240 and 3500 ft^2 in area) containing brick rubble in water on which was floated AVTUR (J.P.1.) or AVTAG (J.P.4.) fuels. The foam was projected mainly from the Fire Research Station's gas turbine operated generator (TURFOGEN) but Mk 6 and Mk 7 fire crash tenders of the R.A.F. were also used, mainly to give a comparison between jet and spray application. The pre-burn time was 1 minute for most tests.

Virtual control of the fires was assumed when the radiation was reduced to 1/10 of the initial radiation (i.e. 9/10 control) - since at that stage rescue could take place, and a record was also made of the 'burn-back' or reignition times after the foam application had ceased.

The results of the experiments were variable, as might be expected with large-scale outdoor fires, but it was possible to reach certain conclusions, as follows:-

(1) radiation was reduced almost immediately after starting the application of 'light-water' foam but there was a delay of a few seconds with protein foam.

(2) only half the weight of fire-fighting solution was required for 'light water' (as compared with protein foam) to control a fire of the same size.

(3) 'fortified' protein foam was 25 per cent more effective than ordinary protein foam.

(4) no obvious difference in the times of extinction between protein and 'light water' foams, and there was little difference between jet and spray application.

(5) the resistance to 'burn-back' of 'light water' foam was only a third that of protein foam (this would be important if there was no 'backing-up' equipment available to deal with a re-established fire).

(6) there was no difference in the performance of the foams as between Avtur and Avtag fuels nor was there any significant difference when the 'pre-burn' time was increased from 1 minute to 3 minutes.

(7) increasing the foaming solution strength from 6 to 12 per cent did not improve the performance of the protein foam.

(8) the critical rate of application was about 0.02 gal/ft^2 min but efficient application was achieved at about 0.06 gal/ft^2 min, especially on the larger fires.

The more rapid fire control and superior re-sealing effect of 'light-water' foam (as compared with protein foam) was probably due mainly to its greater fluidity and ability to flow over fuel surfaces. The 'light-water' foam formed a layer $\frac{1}{2}$ to 1 in thick whereas 1 to 2 in was formed with protein foam in sealing off the flammable vapours.

The cost of the 'light-water' agent is about 20 times that of the protein foam liquid and using a 6 per cent concentration as compared with a 4 per cent protein foam solution, the cost factor is 30 : 1. However, the two-fold increase in effectiveness of 'light-water' (see (2) above) means that the cost factor is 15 : 1 or 10 : 1 if a 6 per cent solution of protein foam is used.

'Fortified' protein foam is about 25 per cent better than ordinary protein foam but its cost is 4 times as much so that the cost factor for these two foams is 3 : 1 in favour of ordinary protein foam.

If 'light-water' foam fire fighting is developed then costs may decrease with the increase in the quantity produced but it is not necessarily sound advice to suggest halving the foam producing equipment just because 'light-water' is twice as effective, especially at a time when very large passenger aircraft are about to be introduced. A preliminary assessment of the overall costs has been made by the Service departments and, taking account of reasonable savings in appliances and man-power resulting from the use of 'light-water' instead of protein foam, the eventual increase in present costs has been assessed at seven times for the same overall level of protection. It has to be borne in mind, however, that extra costs may be justified if more lives will be saved by using 'light-water' foam.

Published as: FITTES, D.W., GRIFFITHS, D.J. and NASH, P. The use of 'light-water' for major aircraft fires. Fire Technol., 1969, 5 (4) 284-9.

FITTES, D.W. and NASH, P. Extinction of experimental aircraft fires with 'light-water'. Fire, 1969, 62 (773) 315-6.

Synopsis of F.R. Note No. 763

PRELIMINARY ANALYSIS OF LARGE FIRES DURING 1968

by

G. Ramachandran and Patricia Kirsop

This Note has been prepared mainly for the benefit of the F.P.A. who will probably be analysing the statistics further on their Journal of July 1969.

During 1968 there were 1005 fires in the U.K. costing £10 000 or more each and, in all, these caused damage amounting to £61.6M out of a total annual fire wastage of £100M. The average loss per large fire has increased from £52 600 in 1962 to £61 300 in 1968 but, taking account of the 25 per cent increase in the index of retail prices during this period, the average cost per fire, in terms of real money, decreased. An accurate comparison between 1962 and 1968 is not possible without lengthy research because an adjustment should be made either to include or exclude fires around the £10 000 mark which because of the change in the value of money should either be in or out of the figures for 1962 or 1968 but, in fact, were not. However, making a reasonable assessment (not shown in the Note) the number of large fires in 1968 (actually 1005) would, at 1962 values be 835, compared with 537 large fires in 1962. The estimated increase in the number of large fires in theperiod from 1962 to 1968 would therefore be about 55 per cent.

The Note contains numerous statistical tables divided into two main classes - (1) those in buildings, numbering 967 and (2) those outdoor but possibly spreading to buildings, numbering 38.

The tables provide details of the number of fires and the cost in respect of the following:-

(1) Size range in varying steps above £10 000
(2) Occupancies involved in outdoor fires
(3) Sources of ignition
(4) Point of area of ignition
(5) Extent of spread
(6) Number of jets employed
(7) Year of construction
(8) Time of call and the day and month
(9) Breakdown of losses in the manufacturing industries and distributive trades

It is not easy to read anything very constructive into figures, especially since 1 year only is involved. The FPA, who are probably consolidating the years 1965/8 inclusive, will be able to provide a full analysis but the following points on the 1968 figures may be of interest to insurers:-

(1) There was a logical decrease in the number of fires as the size range increased.

(2) A third of the 38 'outdoor' fires were in chemical plants and outdoor storage and the largest fires were in an electrical sub-station £100 000 and a manufacturer of paper and board (£355 000).

(3) Unknown sources of ignition were more numerous than known, which is only to be expected with large fires, but of the known causes, malicious or intentional ignition and smoking materials were predominant both in number and size.

Rubbish burning accounted for a third of the cost of all 'outdoor' fires.

(4) About 25 per cent of all fires started in 'store, stockrooms and warehouse'.

(5) 742 out of 967 fires in buildings were confined at least to the building of origin.

(6) 2 to 5 jets were used in 50 per cent of all the building fires.

(7) The number of buildings of different ages at risk is not known but the tables indicate that there was little, if any, difference according to age.

(8) More and bigger fires occurred in buildings between 11 pm and 1 am but most fires in 'outdoor' risks occurred in the middle of the day (only 1 occurred between 11 pm and 1 am). Nothing of significance was revealed regarding the month or day of week.

(9) The trades having the highest average fire loss were (in order)

(1)	'Other manufacturing industries'	(average £146 000)
(2)	Engineering and electrical goods	(average £118 000)
(3)	Food, drink and tobacco	(average £107 000)

The largest fires occurred in these trades - 7 fires over £½M costing in all £9½M.

Textiles (average £97 000) had no fire over £½M but 7 out of 28 fires in the range of £¼ to £½M were in textile risks and, in all, there were 61 large fires in this trade.

87 large fires (the highest for any class) occurred in the retail distributive trade with an average of £47 000 per fire.

Synopsis of F.R. Note No. 764

BREAKDOWN OF HIGH EXPANSION FOAM USING ANTIFOAMING AGENTS

by

P. S. Tonkin and C. F. J. Berlemont

At the instigation of the London Salvage Corps experiments were carried out to find a means of dispersing H.E. foam quickly and efficiently. Small and large scale tests were made with commercially available non-toxic anti-foaming agents consisting of a solution (technically - a suspension) of the liquid in water using readily obtainable garden spray equipment (slightly modified) costing about £6 at most.

As a result of the tests it was found that a 5 per cent solution of N71D5 (made by Nalfloc Ltd of Northwich, Cheshire) or NXZ and DNH-1 (both made by Nopco Hess Ltd of Leeds) was the most satisfactory and cost about 30/- per gallon, sufficient to produce 20 gallons of solution. This quantity would be enough to collapse about 50,000 ft^3 of foam and it would cost substantially less than the foam itself and would only add 6 to 7 per cent of water to that present in the foam. One operator broke down 1000 ft^3 of foam in 3 minutes.

The antifoaming agents were not flammable and there was no evidence of corrosion. When mixed, the solution should be used within about 2 hours or stirred up before use, if left standing for longer.

The spray equipment is self contained and portable (with shoulder straps) so that the operator has a free hand and can disperse the foam in front of him as he walks into a building filled with foam. The foam was more readily dispersed after it has been standing for a time with consequent bubble drainage; at that time it was stiffer and did not flow towards the operator.

Published as: PALMER, K.N. and TONKIN, P.S. Breakdown of high expansion foam using antifoaming agents. Fire Int., 1971, 3 (31) 84-92.

Foam can be washed away with a plain water spray or jet but the bubbles are not collapsed as they are with the antifoaming agents and almost as much water is required to effect dispersal as is in the foam itself. Also it takes a substantially longer time to do the job when applied at the same rate. If the foam is still fluid it is possible to suck it away but this system does not work well when the foam has become stiff.

The antifoaming agents tested were all effective on all types of H.E. foam Any new foam or antifoaming solutions could be similarly tested.

Synopsis of F.R. Note No. 766

NOTES ON THE USE OF HIGH EXPANSION AIR FOAM IN FIRE FIGHTING

by

P. F. Thorne, D. M. Tucker and D. J. Rasbash

There is increasing use of foam in the Fire Services and this Note contains general comments on the use of high expansion air foam in the extinction of fires in various fuels and situations. High expansion air foam can have expansions of from 50 to 1200 and, up to 500, is normally generated in self-aspirating equipment but above this figure a power driven fan is required. The higher the expansion the greater the volume produced, the lighter the foam and the shorter the 'throw'. Foam with an expansion of 150 can be 'thrown' about 6 ft. High expansion air foam expanded 1000 times can be pushed forward as a solid plug but cannot be 'thrown' and, therefore, operators may require protective clothing to enable them to get near the fire although flexible ducting can be used. Foam with an expansion of about 150 is usually termed medium expansion foam.

Uncontaminated air should be used since contaminants may be detrimental to the foam and to operators working in the foam. Men can work, without breathing apparatus, in foam if they move about and the foam is not more than a few feet above their heads. Life lines or 'intercom' should be used. Although high expansion air foam is a weak electrical conductor, floors may be wet as a result of bubble drainage and the precautions taken should be similar to those for extinction with ordinary water.

The flow rates for foam application are expressed as the gross rate of increase in the height of the foam layer over the whole protected area and the following table indicates some typical recommended minimum rates, extinction times and foam making capacities required, assuming all fuel in the compartment is involved.

Type of fire or situation	Recommended minimum rate of application ft/min	Expected extinction time mins	Foam making capacity for 1000 ft^2 area
Liquid hydrocarbon fuel fire at ground level	3.0	2-3	3000 ft^3/min
Solid fuel fire (including rubber and plastics) at ground level	1.0 for each 1.0 lb/ft^2 fire load	20-30	1000 ft^3/min for each 1.0 lb/ft^2 fire load
Ceiling fire (e.g. at top of high stacked goods)	8.0	2-3	8000 ft^3/min
Filling compartments not involved in fire (to prevent spread of fire)	1.0		1000 ft^3/min

Note: (i) Foam can either cover the area on fire or fill the compartment which contains a fire. There is not sufficient information available as yet to provide similar details for fires involving alcohol, acetone and other water miscible liquids nor those in rooms which have reached the 'flashover' stage.

(ii) The foam making capacity shown in the last column would be sufficient for a compartment of 10 000 ft^3 if the ceiling height was 10 ft.

Although high expansion air foam (H.E.A.F.) can quickly subdue flaming combustion, prolonged application may be necessary to extinguish smouldering combustion and to maintain the level of foam, especially with fires where a hot ceiling breaks down the foam from above. Some openings have to be provided, away from the point of entry of the foam, to enable the displaced air and products of combustion to escape, but all other openings should be closed.

It is unlikely that the whole of the fuel available for combustion in a large compartment will be involved at any one time and, further, compartments can be sub-divided with nets (see Synopsis for F.R. Note No. 598). Practical experience in the field would be very valuable in judging the flow rates required for various full scale situations. On a small scale it has been shown that, using M.E.A.F. (medium expansion air foam), a fire in a pile of 15 motor car tyres in the open, preburning for 5 min, can be extinguished without the use of protective clothing, in 10 seconds.

Research work is being carried out on the quick dispersal of foam, as required by the Salvage Corps, and the prevention of rust on steel etc which has been immersed in foam, and details of this work will be published separately.

Foam liquid can cause corrosion and should be stored in plastic containers (above + $5^{o}C$ if possible) and kept away from the skin.

Synopsis of F.R. Note No. 767

INVESTIGATION INTO THE PROCESSES GOVERNING THE OPERATION AND DISCHARGE OF FIRE EXTINGUISHERS

by

J. A. Gordon and H. C. Prince

In order to assess the design, performance and safety of hand operated Fire Extinguishing Appliances which are submitted for approval, tests were carried out on seven common types of extinguisher to determine the pressures (normal and peak) with blocked nozzle and whilst discharging, and the time and rate of discharge. A pressure transducer and a recording oscilloscope were used and these enabled sudden high pressures to be recorded - the normal 'approving' procedures do not provide all this information.

The extinguishers tested were:-

Reference	Type (all 2 gallons except for No. 7 which was 20 lbs)	Maximum pressure during discharge lbf/in^2	Time of discharge in seconds
1	Soda acid (turnover type). Sulphuric acid spills into sodium bicarbonate/water solution on inversion.	80	120
2	Soda acid (plunger type). Sulphuric acid is in sealed glass bottle until this is broken - otherwise same as 1.	70	150
3	Foam chemical (turnover type). Acid salt solution spills into sodium bicarbonate solution containing liquorice etc on inversion.	30	60
4	Foam (gas pressure type) CO_2 cartridge punctured and gas expels a hydrolised protein solution.	208	50
5	Water (gas pressure) similar in operation to 4.	150	80
6	Water (gas pressure with <u>metered</u> gas discharge) similar to 4 but gas release is more controlled and slower.	150	50

Cont.

7	Dry powder (gas cartridge type). Similar in operation to 4 but release of powder controlled by valve which can be shut or opened during operation.	248	21 (including pressure build-up)

N.B. The average rate of discharge is proportional to the time of discharge, e.g. type 4 discharges 3 times as fast as type 2.

General Comments

With regard to the safety aspect it was found that, although pressures rose and fell during operation, at no time did excessive transient high pressures develop. In type 7, the normal gas pressure developed fully in 5 seconds and one second after this time the valve was opened to discharge the powder.

The pressures with the nozzle closed, (and, consequently, the most dangerous situation) were higher with the gas pressure types than with the chemical types since, with the latter, there was only a slow generation of pressure. If the acid 'charges' are carefully checked in the design stage there should be no dangerous build up of pressure even with a blocked nozzle. There is a cushioning effect with the dry powder type due to the slow diffusion of the gas through the powder and this is probably the safest type to use. In fact, the maximum pressure using type 7 with a closed nozzle was 230 lbf/in^2, slightly less than that developed when discharging. With all other types the maximum pressure with blocked nozzle was higher than that during discharge but in no case was 250 lbf/in^2 exceeded.

Particular comments

Type reference

1. The acid is close to the nozzle and it could be expelled, before mixing with the solution, by a sudden early surge of pressure.

2. There is little risk of acid discharge with this type.

3. There appears to be inefficient mixing of the solutions and an improved inner container might cure this trouble and produce better quality foam.

4. There is an efficient and even rate of discharge.

5. There is a rapid initial increase in pressure until 80 lbf/in^2 is reached (in the blocked nozzle test) in 50 milliseconds.

6. In spite of the metering (ejection of gas through a small fixed-size orifice) the gas pressure fully develops in 2 seconds.

7. It takes only 21 seconds to discharge the powder (including the 6 seconds for pressure build-up).

Synopsis of F.R. Note No. 769

A STUDY AND TOXIC EVALUATION OF THE PRODUCTS FROM THE THERMAL DECOMPOSITION OF PVC IN AIR AND NITROGEN

by

W. D. Woolley

PVC may be subjected, in actual fires, to temperatures in excess of 1000°C and it may be burning in atmospheres with only a little oxygen, in consequence of which toxic gases and materials may be produced. The burning process is extremely complex and this Note describes, in detailed scientific language, the results of a series of experiments using gas chromatography and mass spectrometry to detect the products of the decomposition of PVC at temperatures between 300 and 500°C.

The experiments were carried out in a small tube furnace using mainly small samples, in cube form, of a commercially available rigid PVC sheet containing certain additives, but relatively pure PVC polymer specimens were also used to see if there were any striking differences between the decomposition products of the pure and commercial materials. The commercial PVC was essentially an emulsion polymer containing about 10 per cent of organic and inorganic additives with an overall chlorine content of 49 per cent.

The experiments were done in the furnace in a stream of both air and nitrogen in order to find the effect of oxygen on the decomposition process.

During the first or primary stage of decomposition there was a rapid release of all the chlorine in the PVC as hydrogen chloride together with some minor products such as benzene which was released throughout the heating range of 300 to 500°C, and other products such as toluene, xylene and naphthalene which were mainly produced at about 425°C, both in air and in nitrogen.

After all the hydrogen chloride had been given off, and at about 450°C, carbon monoxide and dioxide and water (steam) were produced in the secondary stage of decomposition in air but not, of course, in nitrogen.

The main toxic hazards in the decomposition products were hydrogen chloride and carbon monoxide. The release of carbon monoxide and dioxide was not studied in these experiments since this problem was investigated at the Fire Research Station earlier and was reported in F.R. Note No. 752 for which a Synopsis was prepared.

The possible production of phosgene during decomposition has been studied separately and will be recorded in a future publication.

Hydrogen chloride is an irritating acid gas and a concentration of, say, 1500 parts per million (p.p.m.) can be directly hazardous to life within a short period. However, because of its acrid nature relatively low concentrations (100 p.p.m.) can be difficult to breathe and present an indirect hazard to personnel trapped in a fire. The contribution of the other component products of decomposition (apart from CO) was small in relation to that from hydrogen chloride which was produced in the experiments in concentrations of 338* p.p.m. for commercial PVC and 390* p.p.m. for pure PVC.

This Note does not comment on the corrosive effects of hydrogen chloride on materials as a result of the decomposition of PVC in fires.

* These figures are not necessarily applicable in all cases and relate only to these particular experiments.

Published as: WOOLLEY, W.D. The decomposition products of PVC Bt. J. Appl. Chem.

Synopsis of F.R. Note No. 770

EXPERIMENTS ON SMOKE DETECTION
PART I - FLAMMABLE LIQUID FIRES

by

M. J. O'Dogherty and R. N. Panday

Note: Reference should be made to the Synopsis of F.R. Note No. 748 for comments on the research programme regarding the framing of standard test procedures for smoke detectors.

As a first step to obtaining background information on the detection of smoke, experiments were carried out in a room about 29 ft x 26 ft and 8 ft high with a ceiling divided into three bays, the detectors being placed centrally in the middle bay. The smoke was produced by burning mixtures of industrial spirit and benzene in a circular tray of 4 inch diameter. Four fuel mixtures were used - 5, 10, 15 and 20 per cent of benzene and the smoke emitted increased with the increase in benzene content. Very little smoke, although easily visible, was emitted from 'fires' with only 5 per cent benzene in the fuel.

The detectors used were:-

'A', an ionization chamber type and

'B', a light scattering type. The optical density was measured continuously by a light source and photocell fitted close to the detectors. The air temperature close to the detectors was also recorded.

Although the smoke emission was conveniently varied by altering the benzene content of the fuel, this did not materially alter the convective heat output of the 'fires'. The 'fires' were burnt on the floor directly under the detectors and at 5, 10 and 20 ft along the centre line of the middle bay from the point immediately below the detectors.

In all the experiments the air temperature rise (a few degrees only) would have been insufficient to operate a heat sensitive detector although the fires lasted for 30 mins and more.

The optical density of the smoke increased steadily with time although in some experiments there was no further increase after 20 to 25 min. The smoke density decreased up to a distance of about 10 ft from the 'fire' but beyond that it remained fairly constant and this applied for all rates of smoke emission and at all times during the experiments.

The results of the 32 experimental 'fires' are summarized as follows:-

Detector A (ionization chamber)

No operation for 5 per cent benzene mixture at any distance and even over the 'fire'.

Over the fire - operation within about 11 s for 10, 15 and 20% mixtures.
From 5 - 20 ft - " " " 20 min for 10% mixture.
" " - " " " 4 min for 15% mixture.
" " - " " " 1 min for 20% mixture.

There was a marked increase in the time of operation for mixtures having less than 15 per cent benzene (except for fires with more than 5 per cent benzene immediately under the detectors) but the indications were that the time of operation would not have been reduced below about 1 min even if the mixture had contained more than 20 per cent benzene.

In general, the operating time increased slightly with distance beyond 5 ft but there was a 'flattening out' of the time curve beyond 10 ft. As the rate of smoke emission increased, the operating time decreased rapidly. The effect of distance was similar for Detector A as for the optical density detector.

Detector B (light-scattering)

Only operated in 8 of the 32 experimental fires and even then the time of operation was much longer than for Detector A (except that Type B did operate slowly once with a 5 per cent benzene mixture).

The optical density measuring equipment could be used as a detecting device and could be 'set' at the appropriate operating optical density. The times taken to reach that setting would be the 'correct' operating time for a detector. If set too high it would not operate if insufficient smoke was emitted, even continuously. If set too low and, therefore, too sensitive there would be too many false alarms.

The various graphs included in the Note show that, for relatively high smoke densities, Detector A would be quicker to respond that the optical density type but as the smoke density was reduced the performance of the optical density detector would become better than Detector A.

Detector B was found to be relatively insensitive to this type of fire,

Future work will cover a variety of fires including cellulosic material, rubber, plastics foams and petrol and diesel oil. Also, experiments will be carried out in larger compartments to find out, in particular, the effect of ceiling height on the time of operation.

Synopsis of F.R. Note No. 771

LANCASHIRE COUNTY FIRE BRIGADE
DOMESTIC FIRE HAZARDS REMOVED AFTER ADVICE FROM FIREMEN

by

W. N. Daxon

This Note describes the results of a campaign carried out by the Lancs. County Fire Brigade to assess the value of house-to-house visits. Visits were made to 2736 households of various types and in various localities; about 1500 were found satisfactory and about 1060 required a second visit to check that a hazard had been dealt with. Only in 39 cases was entry refused for no apparent reason.

It was found that electrical appliances and wiring accounted for most of the hazards in old dwellings. About half of the households requiring fire guards had obtained them when the second visit was made. There are detailed Tables in the Note regarding all the various hazards encountered.

There was generally good co-operation from the public and, since the firemen and the vehicles were presumably 'on call' at all times, the actual cost of the campaign was probably low. Consequently it is possible that the saving in life, injury, fire-fighting and fire damage costs would outweigh the cost of this particular Fire Prevention activity.

Published as: DAXON, W.N. Firemen's visits cut fire hazards in the home. Munic. Public. Services J., 1970, 78 (2) 61.

Synopsis of F.R. Note No. 772

NOTES ON THE USE OF SMOKE EXTRACTORS FOR FIRE FIGHTING

by

D. J. Rasbash

This is a brief review, at the request of the Home Office Joint Committee of Design and Development, of the smoke extraction problem. Smoke can either be extracted from, or air injected into a building in order to remove smoke and both these operations can be done with a fan, including that contained in a HE Foam generator (if care is taken not to damage it by heat or smoke).

There must, of course, be openings or gaps around windows and doors etc. where replacement air can enter or smoke can escape but any air blown, or sucked in must do so at a relatively low speed if the smoke layer is not to be disturbed thus making the whole building smoke logged. However, if the smoke is sufficiently diluted with air there may be reasonable visibility even when the building is smoke logged but there would have to be very large amounts of air to dilute the smoke produced by some materials e.g. 15000 ft^3/min for flame retardant polyester, as compared with only 1000 ft^3/min for fibre insulating board, in order to increase the visibility to 16 ft when 54 ft^2 of the materials surface is flaming.

Air should normally be introduced at a low level, possibly through a collapsible duct, and smoke extracted at a high level so that the smoke and air layers are maintained.

Pressurization can be used to hinder the movement of smoke along or into a corridor but there must be somewhere for the smoke to escape. For this purpose air would probably have to be injected at about 10 ft/s but, generally, when blowing air into a building the speed should not exceed 5 ft/s if turbulent mixing of air and smoke is to be avoided. This can be achieved by using a large porous bag at the delivery point. Care must be taken not to inject too much air since this might increase the combustion rate.

Synopsis of F.R. Note No. 773

WORCESTER CITY AND COUNTY: EFFECT OF FIREMEN'S ADVICE SCHEME ON DWELLING FIRE FREQUENCY

by

E. D. Chambers

Over a period of ten years the Worcester City & County Fire Brigade carried out house-to-house canvasses by crews whilst on duty and within call. Most householders were visited twice in this time and about a quarter of them showed some positive interest in fire prevention advice. During the period covered there was a gradual reduction in the frequency of dwelling fires so that eventually the number of fires in the area was a third less than it had been at the start of the campaign, and the national average.

Various factors such as the size of fires and the introduction of central heating on a larger than average scale may have had some influence on the outcome but the fact remains that, possibly, a £$\frac{1}{4}$ M may have been saved by the campaign at very little cost.

Synopsis of F.R.Note No. 775

THE ASSESSMENT OF SMOKE PRODUCTION BY BUILDING MATERIALS IN FIRES

PART 3 THE EFFECT OF RELATIVE HUMIDITY ON MEASUREMENTS OF SMOKE DENSITY

by

P. C. Bowes, P. Field and G. Ramachandran

The problem of smoke production by building materials in fires was initially described in F.R.Note No. 660/1967 and the preliminary work on actual tests using the Fire Propagation Test apparatus was described in F.R.Note No. 749 for which a synopsis was issued. The work then carried out was related to a proposed Standard Smoke Test and the relative humidities experienced during those tests did not vary widely. The new Research Note describes the experimental investigations into the possible effect of relative humidity on the optical density of the smoke produced in the standard test.

Tests were carried out using wood-fibre insulating board and chipboard (12.7 mm thick), as in the previous tests, and they were done with an ambient relative humidity of about 28 per cent, and a humidity of about 86 per cent (obtained by hanging up wet hessian sacks in the test chamber). As a result of the combustion during the tests the relative humidity was probably increased by about 4 per cent.

A systematic testing programme was adopted in order to deal with, and make allowance for the changing ambient humidity over the period of the tests and both flaming and smouldering combustion was used as in the previous series of tests.

An analysis of the test results showed that the effect of relative humidity on the optical density of the smoke could be highly significant. The effect of relative humidity depended both on the nature of the material burned and on the mode of combustion. So far as the two materials tested were concerned the optical densities increased by amounts up to 34 per cent on increasing the relative humidity from about 30 per cent to 90 per cent. The increase might well be greater for other materials. Some control of the ambiemt relative humidity is therefore, necessary for any Standard test. A reasonably accurate density measurement might be possible if the relative humidity is kept within the range 55-65 per cent as is at present required for the conditioning of materials for the Fire Propagation Test.

Synopsis of F.R.Note No. 776

STUDIES OF PHOSGENE PRODUCTION DURING THE THERMAL DECOMPOSITION OF PVC IN AIR

by

W. D. Woolley and Ann I. Wadley

Note: Experiments carried out in a small tube furnace were described in the Synopsis for F.R.Note No. 769. That Note commented on the release of hydrogen chloride etc. from burning PVC but the possible production of phosgene was to be the subject of a further note.

Both commercial PVC and relatively pure PVC emulsion polymer powder were used in the experiments and this paper describes in scientific detail the problems of detecting the presence of phosgene in the products of decomposition of PVC. Phosgene is a difficult material to handle and analyse since it seems to disappear whilst the gases of combustion are being collected and transferred from the furnace for analysis. Steps were taken to introduce known amounts of phosgene into the furnace section so that the detection level could be determined.

Phosgene was not detected in these experiments, by gas chromatography, during the decomposition in air of either the commercial PVC or the pure PVC polymer, at temperatures between 250° and 500°C. Even if very small amounts were present but undetected the toxic hazard would be much less than that from the hydrogen chloride. Any such small amounts could, possibly, be removed by including certain additives in the commercial PVC (generally the additives amount to about 10 per cent by weight).

Published as WOOLEY, W.D. The decomposition products of PVC. But.J.Appl.Chem

Synopsis of F.R.Note No. 777

MAKE LEICESTER FIRE-SAFE CAMPAIGN
FALSE ALARM STATISTICS

by

E. D. Chambers

Following a four weeks' intensive generalized fire prevention campaign in Leicester in 1967 it was found that there was no discernably large effect on the tendency of people falsely to call the Brigade, either maliciously or with good intent. Although false alarms from automatic detection systems decreased slightly for a while after the campaign this was thought to be a coincidence.

Published as: CHAMBERS, E.D. Leicester Campaign suggests control optimism Instr. Fire Engrs Q.

Synopsis of F.R.Note No. 778

THE EFFECT OF A COMMERCIAL AEROSOL ON THE RATE OF RECOVERY OF WETTED ELECTRIC MOTORS

by

S. A. Ames

At the suggestion of the London Salvage Corps tests were carried out on 8 electric motors of various types (I and III phase, $\frac{1}{4}$ to $\frac{1}{2}$ hp and totally enclosed or ventilated) in order to find the effect of clean water on the windings terminals, and operating ability and of an English aerosol designed to 'displace and seal out water in motors and windings'.

The insulation resistance of the motors was recorded both before and after wetting which was done very thoroughly using tap water and steam with the motor being turned by hand during the process to ensure complete wetting.

The tests indicated that after tipping and shaking the motors it was possible to run them not under load but at full voltage as little as 10 minutes after wetting without apparent detriment. Although the insulation resistance was reduced to about 20 KΩ by the water it increased rapidly, after being run without load for about $1\frac{1}{2}$ hours, to about 80 per cent of its full resistance and returned to a full resistance of 100 MΩ in 3 or 4 days, without further running. The use of the aerosol did not provide any marked increase in the rate of recovery of the insulation resistance nor did the use of a hot air blower on the junction box and terminals.

Synopsis of F.R.Note No.779

FIRE DEATHS IN THE SECOND QUARTER OF 1969

by

S. E. Chandler

This note contains little information of interest to fire insurers apart from emphasising the continuing hazards of oil heaters which caused the deaths of four children in two fires. Children playing with fire resulted in the deaths of five people in another fire.

In all, 151 people died in 124 fires in England, Wales and Scotland in the second quarter of 1969.

Synopsis of F.R.Note No. 780

EXPERIMENTS ON SMOKE DETECTION

PART 2: FIRES IN WOOD CRIBS, RUBBER CRIBS,
POLYVINYL CHLORIDE POWDER AND PETROL

by

M. J. O'Dogherty, R. A. Young and A. Lange

Experiments were carried out in the same room as, and in a similar manner to that described in the Synopsis of F.R.Note No.770, but, instead of mixtures of spirit and benzene, the following 'fires' were used:-

(1) Wood crib, 1 ft x 1 ft and 6 in high-ignited by methylated spirit.

(2) Rubber crib, 6 in x 6 in x 1½ in high (1 lb of rubber), ignited by methylated spirit.

(3) P.V.C. powder, filling a tray 1 ft x 3 in x ⅝ in deep, ignited by electric element.

(4) Petrol in a 6 in diameter tray.

Optical density measurements were made at ceiling level over ½ metre distance with the followihg results:-

(1) Wood crib - smoke was produced in "puffs" with some delay before there was any appreciable measure of smoke viz - 1 min over the 'fire' to 4 mins at 20 ft from the 'fire. Smoke then increased, first gradually and then rapidly, especially at the 20 ft mark.

(2) Rubber crib - there was measurable smoke after about 2½ min when there was a rapid increase in the smoke until the maximum was reached at from 5 to 9 min. Maximum percentage of obscuration was about 50 per cent.

(3) P.V.C. powder - there was measurable smoke after about 3 mins when there was a rapid increase in the smoke until the maximum was reached at from 5 to 9 min. Maximum percentage of obscuration was about 20 per cent (30 per cent over 'fire), which is low.

(4) Petrol - smoke development was similar to spirit/benzene fires i.e. initial rapid increase, then gradual increase up to the maximum per centage of obscuration optical density of about 45 per cent (70 per cent over 'fire') after about 25 min.

Except for the wood fires (1) which produced random 'puffs' of smoke, there was a gradual decrease in smoke up to about 10 ft from the fires (2), (3) and (4) but a fairly even distribution of smoke from 10 to 20 ft.

Detectors A (an ionisation chamber type) and B (a light scattering type) were tested for time of operation and the following results were obtained from the various fires:-

(1) Wood crib - both detectors operated over the fire at about 2 min (A was slightly quicker) gradually increasing to about 6 min for both at the 20 ft position.

(2) Rubber crib - detector A operated in under 1 min over the fire and at about 3 min from 5 ft to 20 ft away, Detector B operated at just over 4 min over the fire and at 5 min when 20 ft away.

(3) P.V.C. powder - detector A operated at about 5 min over the fire but there was no response at any distance from the fire. Detector B operated at about $4\frac{1}{2}$ min over the fire and at about 7 min when 20 ft away.

(4) Petrol - detector A operated in under 50 s in all positions up to 20 ft from the fire, Detector B operated in about 2 min over the fire and at about 15 min when 20 ft ($12\frac{1}{2}$ min at 5 ft).

The rise in air temperature at the time of smoke detection for all fires was below $5^{\circ}C$ even over the fire.

Detector A operated much more rapidly than detector B for both rubber and petrol fires (although the difference was less great at 5 ft or more from the rubber fires) and slightly quicker for wood fires but it only operated (at about the same time) when sited immediately over the P.V.C. powder fire whereas detector B continued to operate up to 20 ft away from the P.V.C. fire. Both the detectors operated over the P.V.C. fire at approximately equal optical densities, which were relatively large in comparison with most of the other results.

Both detectors had good sensitivity for both wood and rubber fires; detector A was very sensitive to the petrol fires and operated at a relatively low optical density but detector B was slow to respond. Detector B responded to the P.V.C. powder fires in a similar way to other solid fuel fires.

In F.R.Note No.770 it was reported that detector A responded to all spirit/benzene fires with 10 per cent or more benzene but that there was a poor response from detector B for all these fires.

The following is a summary of response times at a distance of 10 ft for all the fires tested so far.

		Average response time in mins	
Type of fire		Detector A	Detector B
Wood		4	4
Rubber		4	4
P.V.C. Powder		No response	6
Petrol		1	14
Benzene/Spirit	5% benzene	No response	No response
	10% benzene	18	more than 20 min when it did operate
	15% benzene	4	
	20% benzene	1	

Synopsis of F.R. Note No. 782

AN EXPERIMENT IN ESTIMATING FIRE LOSSES

by

E. D. Chambers

Most Fire Brigade reports do not contain an estimate of the fire damage and consequently the Fire Research Station does not then have the loss amounts if they are less than £10 000. The author, therefore, asked two people on the Station (one experienced but the other new to fire research) to estimate the damage from the Fire Brigade reports (K433 forms) for 100 fires for which Brigade estimates had been provided but were concealed.

The examination showed that two people placed the loss in the same range as the Brigade in about 75 per cent of the cases and were only slightly out in the remainder and it would seem therefore that when Brigades do not provide estimates of damage, reasonably useful indications can be provided simply from reading the Fire Brigade reports.

The Fire Research Note may encourage Brigades to provide loss estimates if they do not do so already.

Synopsis of F.R. Note No. 783

FLAME ARRESTERS AS BARRIERS AGAINST HOT METAL PARTICLES

by

Z. W. Rogowski

In the last paragraph of the synopsis for F.R. Notes Nos. 613 and 658 reference was made to the problem of hot metal particles being discharged through flame arresters and that synopsis provides the background to the research work reported upon in F.R. Note No. 783.

Experiments were carried out using the $\frac{1}{3}$ ft^3 casing employed in the previous tests and this was, as before, placed in the 16 ft^3 box which had polyethylene sheeting over the 'open' side.

Arresters of nickel or nickel-chromium-iron alloy were fitted to the vents and both the propane and ethylene air mixtures, as utilized in the previous experiments, were used together with, for some experiments, a 3.4 per cent diethyl ether-air mixture. In some tests obstacles were placed in the casing in front of the arrester(s).

Tinned copper fuse wire of from 22 to 36 S.W.G. was stretched across the inside face of the arrester(s) at a distance of $\frac{1}{2}$ in. from it. The wire was fused with an electric current and this varied from 330 to 1200 A at 240 V D.C. depending on the gauge of the wire. The current used was that which would have flowed through the wire if it had had no resistance (called the prospective current).

The maximum explosion pressure, obtained with ignition by the fuse wire, increased with an increase in the wire diameter but decreased with an increase in the prospective current. The maximum pressures, however, did not differ greatly from those obtained with an inductive spark as used in the earlier series of experiments. Incandescent metal particles were shot through the arrester apertures and they were free to travel the 15 in until they hit the roof of the 16 ft^3 box. No particles produced by fusing any of the wires ignited the propane-air mixture in the outer box after penetrating the arrester(s) but when using the thicker wires and a prospective current of 1200 A particles did ignite the ethylene-air and the diethyl-ether air mixtures in the outer box.

Also, if particles of the copper hit and ignited any aluminium alloy within the casing then portions of this ignited aluminium alloy might penetrate the arrester(s) and ignite the propane-air mixture in the outer box.

Tests were carried out using a sleeve over the copper fuse wire. The sleeves were made of PVC coated glass fibre and of terylene, and epoxy resin was used to seal the ends of the sleeves. Wires having the former sleeves did not ignite the surrounding gas but with the latter type the outside gas was ignited in one test out of eight because the sleeve fractured.

Without any sleeve it seems that the copper particles lose heat at a very high rate and emerge from the arrester at a temperature insufficient to ignite the propane-air mixture but still capable of igniting the two other mixtures. The direct current which was used was expected to produce arcs at least equal to if not greater than those resulting from an alternating current of the same capacity. If a heavy electrical discharge is likely to occur in the casing near the arrester(s) then it would be necessary to cover the wires with a strong insulating sleeve with sealed ends in order to prevent hot metal particles penetrating the arrester(s). If desired, this eleeve could be in addition to the standard insulation.

Electric arcs may be caused by the parting of two components carrying an electric current, e.g. displacement of a lead, and it may be desirable to compare the effects of this type of arc with that of fusing copper wire as described in this Note.

Synopsis of F.R. Note No. 784

THE PROTECTION OF EQUIPMENT WITH FLAME ARRESTERS
EFFECT OF VARIATION OF GAS COMPOSITION AND CONTENTS

by

K. N. Palmer and Z. W. Rogowski

This paper summarises the results of the research work reported upon in more detail in F.R. Notes Nos 613, 658 and 756 for which synopses have been prepared.

Synopsis of F.R. Note No. 785

STRESS-STRAIN CURVES OF CONCRETE AT HIGH TEMPERATURE - A REVIEW

by

R. Baldwin and M. A. North

This paper reviews some data on the effect of temperatures (up to 700°C) on the relationship between stress and strain for concrete under compression.

The physical properties of concrete depend to a very large extent on the aggregate and age of the concrete, and the existing data on the elastic properties of concrete under compression at high temperature are applicable only to the particular specimens tested.

In the previous tests cylindrical specimens of concrete were tested under pressure in a furnace and it was found that when the pressure (stress) was released during a test the specimens did not return to the original length but remained compressed, and when the test was continued and the pressure was reimposed the strength continued to decrease as from the point previously reached.

The compressive strength was found to remain nearly constant until the temperature reached 300° - 400°C when there was a dramatic decrease in strength.

One result of this research work is a simplification of the stress-strain calculations since these can now be derived entirely from the stress-strain figures at room temperature provided the maximum stress-strain (the compressive strength of the material) at high temperature is determined (e.g. at 700°C).

This work is part of a computer program designed to calculate the effect of heating on concrete beams without the need for an actual furnace test and it is related to the research work being done at Imperial College.

Synopsis of F.R. Note No. 786

FIELD TRIALS TO ASSESS THE BLOCKAGE OF ARRESTERS BY ATMOSPHERIC POLLUTION

by

Z. W. Rogowski

A box containing, on its underside, six nickel crimped ribbon flame arresters was placed in the open on the outskirts of Boreham Wood in order to evaluate the possible blockage that might result from the use of arresters on petroleum tanks and electrical and other equipment operating in the open.

An electric blower sucked air at a very high rate through the arresters and the pressure drop across the arresters was measured according to a set time table and operating programme over a period of 14 months. It was, therefore, possible to calculate the degree of blockage at any time during this period. Over the whole period there was a blockage equivalent to a 35 per cent reduction of the arrester area.

Blockage could be caused by ice, pollution, seeds etc., and although the test conditions were more severe than those likely to be experienced in practice they did confirm that there is a need for some protection and periodical cleaning of arresters. The efficacy of protective covers also needs investigating.

Synopsis of F.R. Note No. 787

FIRE PROTECTION ENGINEERING WITH PARTICULAR REFERENCE TO CHEMICAL ENGINEERING

by

D. J. Rasbash

This paper contains a resumé of four lectures given by the author at the Chemical Engineering Dept., University College, Swansea, on the 6-7th November, 1969.

The first part of the paper outlines the cost and cause of fires and the general principles of extinction. This part is mainly technical and of no unusual interest to fire insurers. The latter paragraphs refer to the protection against fire and explosion (including the economic aspects) and the following extracts may be of interest in view of the nature of the audience (Chemical Engineers).

"A basic tenet of fire (and explosion) protection is that it should be considered at the design stage of a process or a building".

"Fires which are discovered in the small hours of the night are about five times more likely to become large fires than fires discovered during the day because of the delay in detecting the fires".

"Smoke detectors used at present are several times more sensitive than heat detectors but are more expensive. Within most urban areas of this country fire brigades can attend within five minutes. For most ordinary risks, therefore, an automatic fire detection system with a direct line to the brigade is a powerful form of defence. However, in a situation where a fire may spread rapidly ..... an automatic extinguishing system is required. The most important type of system is water sprinklers. Other systems employ agents such as tonnage CO_2, vaporizing liquids, dry powder, foam and H.E. foam; these are used in general only in special cases."

"The total cost of fire protection is probably substantially greater than the total financial cost of fire damage. It is, therefore, important in designing the fire protection to obtain a balanced approach rather than an indiscriminate use of every measure that could have some effect. [As regards costs] a straight forward approach would be to leave these aspects to the accountant working on the premium reductions allowed by insurance, and investment grants and taxation reductions".

The Note includes Tables relating to the 1966 statistics showing the hazard in which fire started and the source of ignition. These U.K. statistics have been available to insurers but the following figures may be of particular interest.

Out of 77000 fires not in buildings 26214 started in 'Refuse'

Out of 88000 fires in buildings 15219 were started by 'children with fire e.g. matches' and 4168 by 'rubbish burning' (as compared with 8026 by 'smoking materials').

Published as: RASBASH, D.J. Fire protection engineering with particular reference to chemical engineering. Chem. Engr. Lond., 1970, (243) CE385-CE390.

Synopsis of F.R. Note No. 788

THE THERMAL EXPLOSION OF SOLID UNSTABLE SUBSTANCES

by

P. C. Bowes

This paper contains a detailed scientific study of the decomposition and explosion hazards, by spontaneous heating, of some solid organic peroxides. It also looks at the available concepts, regarding these problems, for the purpose of predicting the safe conditions for the storage and transport of substances which are, generally, chemically unstable at normal temperatures.

It is concluded that by carrying out experiments to find the critical (ambient) temperature required to cause an explosion in a small sample of the substance (of given shape and size) it should be possible to predict the large-scale behaviour in regard to the storage and transport of the unstable substance. Such prediction should be accompanied by an elementary examination of the decomposition of the material in order to see if there are any exceptional factors which would influence the extrapolation from small to large scale.

The conclusions reached regarding the solid materials have some relevance to liquids but the explosion hazard of these, by spontaneous heating, has not been studied sufficiently widely for the available concepts to be applied with confidence.

N.B. This paper was specially prepared for a meeting of experts on fire and explosion hazards of unstable substances, under the sponsorship of O.E.C.D.

Synopsis of F.R. Note No. 789

THE SPREAD OF FIRE IN BUILDINGS - THE EFFECT OF VARYING STANDARDS OF FIRE COVER

by

R. Baldwin and P. H. Thomas

The fire cover provided by the Fire Brigades is pre-determined by them according to type of risk or area and the required time of attendance, and the number of appliances is arranged on the following basis:-

Risk category	First attendance (pumps) (Number)	Attendance time (min) 1st Appliance	2nd Appliance	3rd Appliance
Special or high	individual	assessment		
A (highest)	3	5	5	8
B	2	5	8	
C	1	8–10		
D (lowest)	1	20		

The statistics for 1963 have been reviewed in respect of fires where there was more than one compartment and a risk of spread of fire from the room or compartment of origin to see if the 'fire cover' arrangements had any bearing on the actual spread of fire. The Fire Brigade times relate to the interval between call and arrival but the analysis considers the interval between discovery and arrival which is more realistic. For the analysis the time intervals were divided into 3 categories viz:- 0 - 5 min, 6 and 7 min and 8 min + and this resulted in about $\frac{1}{3}$ of the fires falling in each category.

The Note includes Tables showing the number of fires in each category and the chance of fire spreading beyond the room of origin, subdivided into single and multi-storey buildings for both the manufacturing and distributive trades separately, and also houses of more than one storey.

The results of the analysis show that there was no measurable or significant effect of the attendance time on the chance of fires spreading except in the following cases where the spread risk was significantly higher, especially in respect of (i) :-

(i) Multi-storey high risk manufacturing industries.

(ii) Single and multi-storey manufacturing industries in the D category.

These cases may require further examination but apart from these it appears possible that the attendance time has been so adjusted by the Fire Brigades that potentially hazardous fires have the same chance of confinement as less hazardous fires. However, this absence of any measurable effect of the attendance time may be due to other factors such as the time interval between ignition and discovery, and ambiguities regarding 'room of origin' which could have a bearing on the size of fire on arrival of the Brigade and at present there is no means of assessing the effect of these factors.

Synopsis of F.R. Note No. 790

THE DEVELOPMENT OF A FOIL HEAT FLUX METER

by

H. Wraight

The Fire Research Station has designed and developed a robust and simple heat flux meter, or radiometer, capable of measuring the heat received from a radiation source or convection currents, in the range of 0-10 W/cm^2. Although this range would cover the heat transfer rates most commonly encountered in fire research, it is proposed to design a higher range version which could record up to 25 W/cm^2, an intensity higher than any yet found in building fires. The development of this latter model will have to await the provision of a new high intensity radiant source before it can be calibrated. Although it is less sensitive than the field radiometer already in use, this new Gardon type heat flux meter can record with adequate accuracy if data-logging equipment is employed for continuous measurements.

The new apparatus has a water cooling jacket consisting of a brass cylinder 2 in in diameter and 2 in long with a $\frac{3}{8}$ in open-ended brass tube along its central axis. Two tubes at the rear of the water jacket provide for water circulation and the sensing element of this heat flux meter is inserted in the central brass tube so that its front end is roughly in the same plane as the front face of the water jacket. The sensing unit consists of a $3\frac{1}{2}$ in long copper tube (having a sliding fit in the $\frac{3}{8}$ in brass tube previously mentioned) with a constantan disc soft soldered to the (front) end. A copper wire is hard soldered to the centre of the constantan disc and passed down the centre of the copper tube to an electrical terminal at the other (rear) end. A very small electric current passes between the centre of the disc and the circumference when the disc receives heat since the centre is then hotter than the circumference which is cooled by the water jacket. It is this current which is measured and provides the W/cm^2 readings.

The sensing unit can be withdrawn for storage. Also, it can be pushed along the $\frac{3}{8}$ in brass tube so that the disc at the front end is in the same plane as the front face of the water jacket or is inset a short distance so that it receives heat from a narrower angle than the normal 180°.

An infra-red transmission window can be fitted over the front of the constantan disc. The meter is then not affected by convection currents. Calcium fluoride is a suitable material for this window. By using one meter with a window and one without, side by side, it is possible to determine separately the heat received from a radiation and a convection source.

The meter is insensitive to draughts and wind and to changes in the cooling water flow. The sensitivity is sufficient to enable a change in heat flux of 0.1 W/cm^2 to be detected and the meter can be used out of doors in reasonable weather, and it can be momentarily immersed in flame without permanent damage.

Synopsis of F.R. Note No. 791

THE PREVENTION OF FIRE SPREAD IN BUILDINGS BY ROOF VENTS AND WATER CURTAINS. PART I. FIRE EXPERIMENTS

by

A.J.M. Heselden and C. R. Theobald

Five experimental fires were carried out in a brick built shed building $51\frac{1}{2}$ ft x 15 ft, as shown on Figs. 1 and 2, the centre section of the building being $16\frac{1}{2}$ ft high with a pitched asbestos roof and the end sections 8 ft high with flat concrete roofs. There were some wall openings and a roof vent in the centre section (which could be opened or closed) and a roof screen of plaster on metal lathing extending down to within 11 ft of the floor, all as indicated on the sketch.

The fires consisted of a wood crib 10 ft x 6 ft and 1 ft high and, to test for fire spread, additional narrow 1 ft high cribs were erected from the main crib into the end compartments (the one in the south compartment was used for tests 1 and 2 only and that in the north compartment was omitted for test 2.) The water curtain pipe was erected in position X for test 2 and in Y for tests 3, 4 and 5 and consisted of Lechler flat jet nozzles, 1 ft apart, producing 'fan shaped' sprays at an angle of 20° to the pipe to prevent one spray impinging on the next. The water application was just larger than 0.1 gal/ft^2 min.

Various temperature and radiation measurements were made and the object of the tests was to assess the effect of venting and water curtains on the size and spread of fire. Numerous fibre insulating board, paper and cardboard specimens were distributed around the compartments to give indications of fire spread.

Preliminary tests were made with a gas fired radiation panel to find what effect a water curtain had on the transmission of radiation through it. A water flow of 1.6 gallons per foot run of pipe per min resulted in about a 50 per cent reduction in radiation but, at the flow rate used in the experimental fires, a reduction of only about 10 per cent would have resulted.

In test 1 no water curtain or roof vent was used and, as the pipe in position X was too effective, in test 2 it was moved to position Y for tests 3, 4 and 5. The following is a summary of the test conditions:-

Summary of test conditions

Test	Position of curtain	Roof vent ($49\ ft^2$)	Time from ignition when water turned on
1	None	closed	-
2	X	closed	3 m
3	Y*	closed	2 m 30 s
4	Y*	open	5 m 40 s
5	Y*	open	2 m 15 s

*This position made the task of the water curtain more difficult.

In test 1 flames reached the ceiling in 1 min, filling the main compartment roof space with flames in $1\frac{1}{2}$ min and filling the whole building with smoke (to within 4 ft of the floor) in $2\frac{1}{2}$ min. The fire was virtually finished in $12\frac{1}{2}$ min and the average rate of spread along the narrow cribs was 1 ft/min, which indicated that the spread was substantially assisted by radiation from the ceiling flames and the heated building generally. All the specimens were burned away and a temperature of 600°C was reached in the end compartments after the main crib fire had subsided. Smoke hindered the radiation from the flames although it radiated heat itself but to a lesser extent than the flames albeit from a larger area.

Brief details of the other tests are as follows:-

Test 2

The water curtain (in position X) was turned on when the 'fire' reached a point on the narrow crib beneath the pipe and the 'wetting' extinguished the flames and prevented any further spread of fire but there was some scorching beyond the wetted section which indicated a high level of radiation through the water curtain. High temperatures were reached in the south compartment beyond the water curtain for about 7 min but after that they dropped because the fire did not spread along the narrow crib.

Test 3

The water curtain was in position Y and, although this prevented fire spread along the narrow crib, 'specimens' at higher level beyond the curtain were burned or damaged. It seems therefore that, even in an unvented building, the water curtain can prevent fire spread at a low level beyond the wetted section of the crib and also slightly reduce radiation, but combustible material at higher level might be ignited.

Test 4

The roof was vented and the main fire burned briskly but took twice as long to involve the main crib completely and to reach the point beneath the water pipe. Most of the building remained substantially smoke-free. Maximum temperatures were lower than in Test 3 but some hot gases obviously 'spilled over' beyond the roof curtain. The temperatures generally beyond the water curtain were lower, indicating that the gases penetrating the curtain were much cooler than in the previous tests.

Test 5

The fire spread speed was similar to Test 4 but the water was turned on earlier, and before the fire reached the point beneath the pipe. The temperatures beyond the curtain were appreciably lower than in Test 4. The readings taken, in the north compartment, of the flame intensity above the main crib were high, and this was due to the lack of smoke which would have restricted the readings. However, the radiation received in this end compartment was low because the compartment itself was cool and this applied to Test 4 also.

Conclusions

(1) Very little radiation is absorbed by the water curtain and its use is to wet down the fuel for a sufficient width to prevent fire spread.

(2) The water density used in the tests was sufficient for the 1 ft high crib. Other 'materials' might require more water and the flow rate would be that appropriate to arrest fire spread in the material if burned in the 'open'.

(3) If the fire is not vented, hot gases can penetrate the curtain and cause ignition beyond it.

(4) Fire spread is not prevented by venting alone if there is combustible material to spread the fire.

(5) The water curtain/roof venting combination is successful but further experiments would be required to assess the performance in other conditions, especially in high piled storage.

(6) The water curtain would require substantially less water per unit area than sprinklers although, because it must be applied over the perimeter of a burning area, the total rate of water application might not be less.

(7) A water 'curtain' is a misnomer - it is virtually a 'wetting-down' spray.

(8) A comparison, on economic grounds, between the combined use of water and vents (as an alternative to compartmentation) and the use of sprinklers is not straightforward and needs further study.

The possibility of the water curtain spray being drawn towards the fire was investigated and the work will be described in Part 2 of the Note.

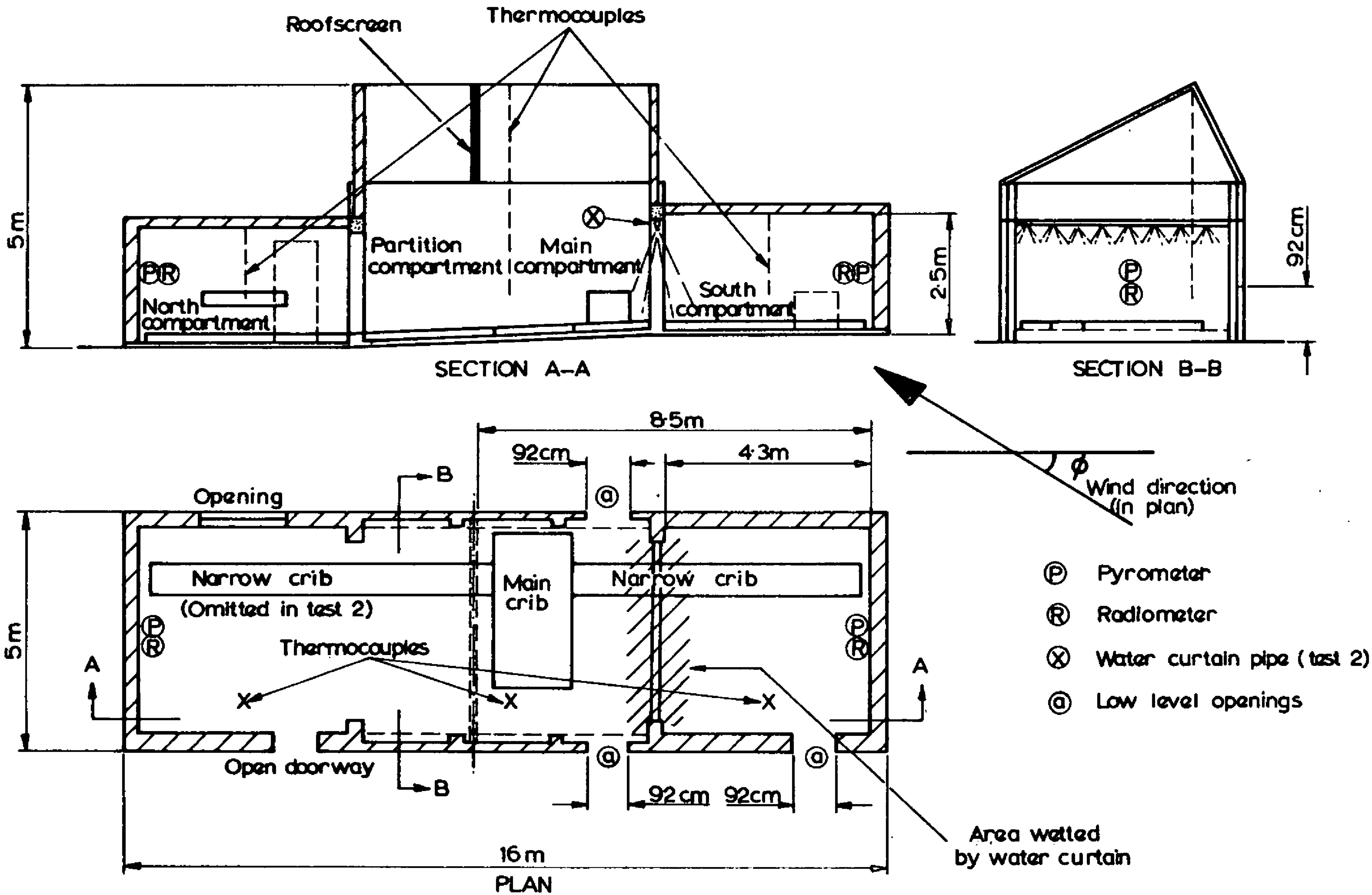

FIG.1. EXPERIMENTAL ARRANGEMENT FOR TESTS 1 AND 2

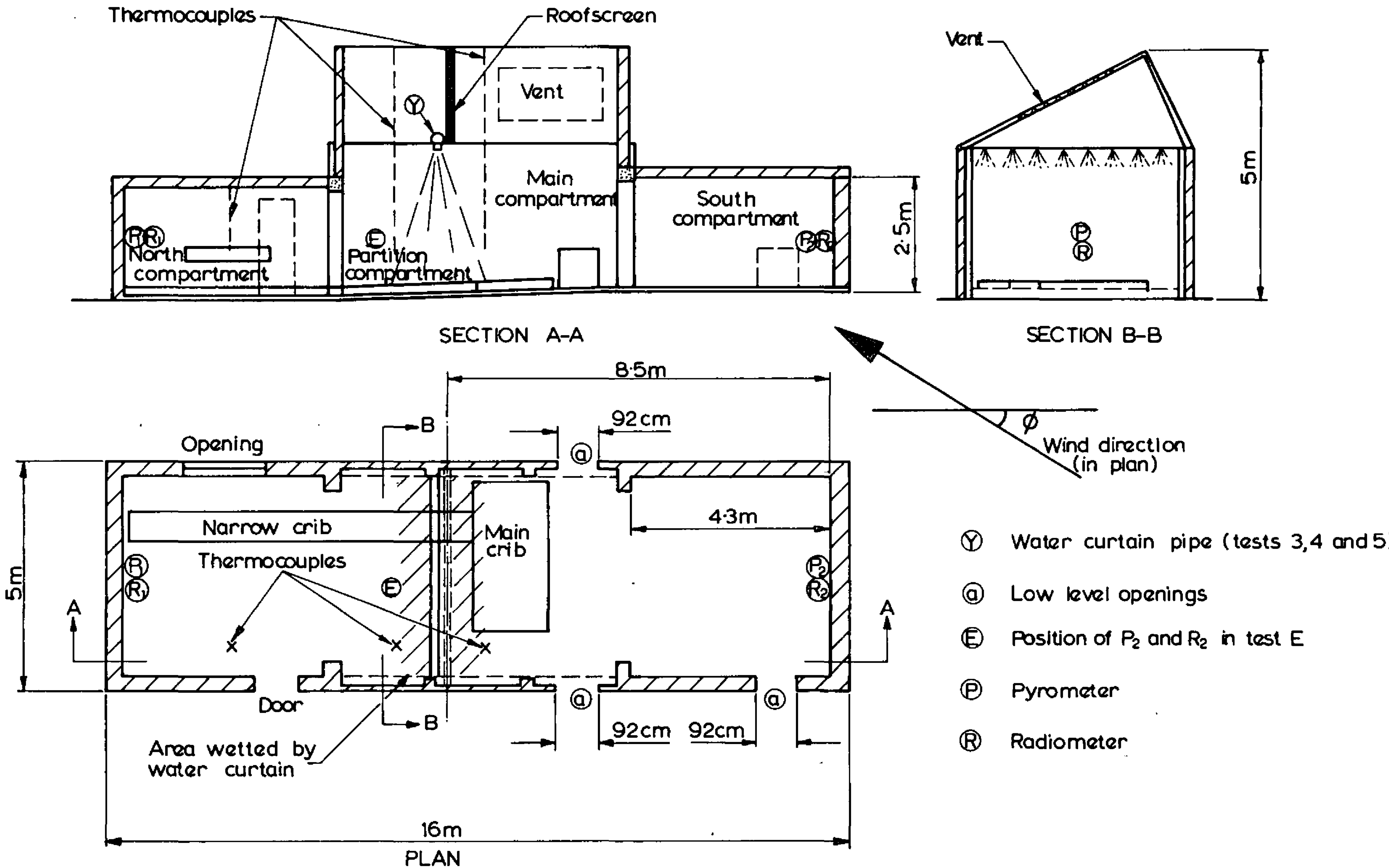

FIG. 2. EXPERIMENTAL ARRANGEMENT FOR TESTS 3,4 AND 5

Synopsis of F.R. Note No. 793

THE DETECTION OF FIRES BY SMOKE:
PART 2 SLOWLY DEVELOPING WOOD CRIB FIRES

by

M.J. O'Dogherty

Note:

Part I of this work, which relates to the development of standard test methods, was described in general terms in F.R. Note No. 748 and this new Note gives more detail regarding the study of the detection of small slowly developing wood fires.

Experimental work on the smoke detection of flammable liquid fires and fires in wood and rubber cribs, P.V.C. powder, and petrol is described in F.R. Notes No. 770 and 780 which are not concerned, however, with the standard test methods.

Experiments were carried out using a small 9 in cube wood crib in a laboratory with a ceiling height of 23 ft. The detectors fixed to the ceiling were - Type A (ionization chamber) and Type B (optical scattering) and the fire was directly underneath the detectors, and at 16 ft and 32 ft horizontally from the fire. Ceiling heights of 16 ft and 8 ft (in addition to 23 ft) were obtained by lifting the wood crib off the floor. Measurements were made of the optical density at ceiling level, the change in potential across the open chamber of Type A detector, and the output signal of Type B detector. The response times of some proprietary detectors, the ceiling level temperatures and the rate of burning of the cribs were also recorded. The crib fire developed slowly and produced smoke at an early stage with relatively little flaming.

It was found that, on average, the smoke rose vertically at 20 ft/min and spread horizontally at 7 ft/min. Once the smoke reached the detector there was a delay of say, $\frac{3}{4}$ min before the detector operated and this depended on the design and the setting of the instrument and the control equipment.

The total time to detection was directly proportional to the ceiling height and horizontal distance from the fire, in addition to the time delay of the detector (a constant factor). The optical density of the smoke decreased proportionally with height, and progressively with distance but at a decreasing rate, in other words once having reached the ceiling the smoke spread sideways and its density decreased at a slower rate than the distance increased.

Each crib fire was weighed continuously in order to find the rate of burning at the time of detection. In Part I of this work it was said that 75 per cent of the heat of combustion was convected upwards. There was found to be good correlation between the smoke density over the fire and the rate of burning. The rates of burning which gave an optical density reading and operated a detector were very small.

It was found that ionisation chamber detectors operated at lower optical densities than Type B when over the fire, but at 16 ft or more away the two types of detector were comparable. Approximate operating times, in minutes, for the ionisation type detector were:-

Ceiling height	Above fire	16 ft distant	32 ft distant
8 ft	$\frac{3}{4}$	3	6
16 ft	1	4	$6\frac{1}{4}$
23 ft	$1\frac{1}{2}$	5	$6\frac{1}{2}$

In order to establish a realistic test procedure it is necessary to determine the smoke concentrations which are likely to result from actual fires and further work is required to establish whether the *tunnel test alone is likely to give an adequate assessment of detector sensitivity under fire conditions. Further work is also required to find smoke conditions at a ceiling height of 40 ft and it may be necessary artificially to age the smoke used in the tunnel test in order to simulate practical fire conditions.

*for comments on this see Synopsis for FR Note No 748.

Synopsis of F.R. Note No. 795

EXPERIMENTAL AND THEORETICAL STUDIES OF THE DEHYDROCHLORINATION OF PVC IN AIR AND NITROGEN

by

W. D. Woolley and Ann I. Wadley

Note:- A study of the products of the decomposition of PVC at temperatures between 300°C and 500°C was contained in F.R. Note No. 769 for which a synopsis was issued and it was mentioned in that report that during the first or primary stage of decomposition there was a rapid release of all the chlorine, in the PVC, as hydrogen chloride. The new note No. 795 describes the production of hydrogen chloride from the commercial rigid PVC in the lower temperature range of 200°C to 300°C.

The apparatus, a small tube furnace, used for the experiments was that described in the earlier Note and also, as before, the decomposition was carried out in streams of both air and nitrogen. The PVC contained about 10 per cent by weight of organic and inorganic additives and the theoretical HCl content was 50.6 per cent. The PVC sheet was made into small cubes for the experiments.

The Note describes in detail the results of the various experiments which were carried out in the furnace under controlled temperature conditions between 200°C and 300°C. In actual fires PVC materials are subjected to conditions where the temperature increases are not uniform and factors such as ventilation, fuel load and the position of the PVC relative to the fire will have an influence. However, the release of HCl under these conditions may be calculated with some degree of approximation by considering the complete temperature rise in the experiments as a series of short time intervals with a mean temperature throughout each interval.

Ventilation and fuel loading will affect the supply of oxygen and this can vary from, say, 20 per cent to a few per cent but, by considering the experimental results using both the air and the nitrogen atmospheres, it is possible to estimate the HCl production under the various practical conditions.

Flaming and combustion are not required for the HCl to be released from the PVC undergoing thermal decomposition and the work described in the Note should be of value in estimating the HCl production in problems such as the overheating of electrical equipment as in computers, telephone equipment and cable ducting. Also, the information is relevant for studies of toxicity and corrosion.

It was found that 75 per cent of the theoretical HCl content of the PVC was released, at 270°C, in about 13 min both in air and in nitrogen but only in about 1 min at 300°C. At temperatures below 200°C the release of HCl is very slow.

The report shows that the release of HCl can be estimated solely from temperature and time measurements.

Synopsis of F.R. Note No. 797

AN ESTIMATE OF THE RISK OF DEATH BY FIRE WHEN STAYING IN AN HOTEL

by

J.F. Fry

Note:- Information on fires in hotels (in particular the causes, extent and means of extinguishing regarding the 1966 statistics) was given in F.R. Note No. 737 (eventually produced as Fire Research Technical Paper No. 23.

The author of the present F.R. Note No. 797 compares the risk to persons in hotels with that to persons in domestic dwellings. The figures are based on the 1961 census and on information regarding hotel accommodation provided by the British Travel Association.

The conclusions are:-

(1) once involved in a fire the chance that a hotel guest will die is similar to that for a person in a dwelling.

but

(2) the change of a hotel guest being involved in a fire is some ten times as large as that of a person in his home.

Published as: FRY, J.F. An estimate of the risk of death by fire when staying in an hotel. Fire, 1970 62 (776), 466; Fire Prot Rev., 1970, 33 (353) 116; Inst Fire Engrs., 1970, 30 (77) 69 - 70.

Synopsis of FR Note 798

STREET NUMBERS OF HOUSES WHERE FIRES OCCUR

by

E.D. Chambers

Any direct approach to householders regarding fire prevention matters would have to be carried out on a sampling basis and the author suggests that this could be done by selecting houses in an area with certain street numbers. He indicates how a graph could be prepared showing the fires which have occurred, in an area, at houses having numbers in a particular range of numbers so that any subsequent deviation from the previous experience regarding these houses would be apparent and the effect of the approach would be revealed.

Synopsis of F.R. Note No. 799

FIRE DEATHS IN THE FOURTH QUARTER OF 1969

by

S.E. Chandler

After revising the estimates for the first three quarters, the Note shows that 789 people died in fires in England, Wales and Scotland during 1969, although the final figure may well approach the record high figure for 1968 of 865. 11 people died in the 4th quarter at the Saffron Walden hotel and 2 firemen lost their lives during the period.

The Note includes the usual tables regarding hazards, time of calls, sources of ignition, age of buildings, age and sex and causes of death and the casualties in each brigade area but there seems to be no unusual information revealed which would be of particular interest to fire insurers.

Synopsis of F.R. Note No. 801

EXETER CHIP PAN SAFETY CAMPAIGN: EFFECT ON FIRE FREQUENCY

by

E.D. Chambers

This Note reviews the effect of the campaign held in Exeter during the period October, 1966 to January, 1967 when leaflets on the safe use of chip pans were distributed to about 30,000 households in the city.

After making the necessary adjustments for a proper comparison, the experience in Exeter in regard to chip pan fires is related to the figures for the United Kingdom in respect of such fires.

It is not possible to estimate the number of fires prevented by the campaign but, on statistical evidence, it is likely that there were some saved and only one prevented fire could have paid for the quite modest campaign. The maximum effect probably occurred about eighteen months after the end of the campaign.

Synopsis of F.R. Note No. 802

MAKE LEICESTER FIRE-SAFE CAMPAIGN:
STATISTICS OF FIRES IN DWELLINGS

by

E.D. Chambers

This "Make Leicester Fire-Safe Campaign" took place on the initiative of the Home Office during the 4 weeks after 25th September 1967 and the F.P.A. and Home Office provided publicity material. It was intended as a pilot exercise for planning national campaigns.

Only dwelling house fires were considered and the experience in Leicester was compared with that in Nottingham (both cities with a population of about 300,000) where there was no particular campaign. Surveys were made immediately before the campaign, immediately after and a year later.

The size of fires and the numbers were considered and, for this purpose, fires which were out when the Brigade arrived were called "small", and the others "large" for which a "weighting" ratio of 5 was applied in order to give an arbitrary "magnitude" effect.

The average size of fires before the campaign was smaller in Leicester than in Nottingham and there was a short term decrease in the size of the Leicester fires after the campaign (greatest at about one month) until, after a few more months, the sizes in both cities became about equal. The fire frequency also reduced in Leicester for a time but the greatest effect was not attained until about 4 months after the campaign. There could, however, have been other factors contributing to this decrease.

The cost of the campaign was difficult to assess and it seems likely that measurable decreases in fire losses could only be associated with measurable expenditure on propaganda, education or legislation for a much more specialized and, possibly, larger campaign. Improved knowledge and behaviour of the public would probably provide a better indication of the effect of such a campaign although, for a few months, both the frequency and size of fires in dwellings may be reduced by about a third. The long term effect is not easy to assess.

Synopsis of F.R. Note No. 803

THE USE OF WATER IN THE EXTINCTION OF FIRES BY BRIGADES

by

R. Baldwin

The author reviews the data available regarding the use of water, the most common extinguishing agent, and the time taken and the rate of water application necessary to bring a fire under control (but not to achieve extinction).

An American survey regarding a variety of 134 fires was recently published and this is compared with British and experimental data. Although there are differences in the methods by which the two sources of data are produced, the results are very similar.

The note contains equations and graphs relating the size of fire to the time and the rate of water application, both as regards actual fires and experimental fires and it is concluded that in real fires the rate of application of water is between 3 and 4 times as great as that in experimental fires. It seems, therefore, that the important practical problem is an operational one of getting the water on to the fire efficiently and this is an aspect of fire fighting which would repay study.

Published as: BALDWIN, R. Use of water in the extinction of fires by brigades. Instn Fire Engrs Q.

Synopsis of F.R. Note No. 804

FIRES IN TELEVISION SETS

by

S.E. Chandler

Prompted by a fire in the hotel at Saffron Walden, which was said to have originated in a television set, the author has reviewed the fires due to television sets in the period 1960 - 1968 inclusive.

His conclusions are:-

1. The number of fires per annum increased in the period from 528 to 1244 although the licences only increased from $10\frac{1}{2}$ m to 15 m so that the fires per million licences rose from 50.4 to 82.4 during this time, and the major part of this increase was after 1965.
2. About 85% of the fires occurred between 15.00 hours and midnight, although 5% happened outside normal viewing hours.
3. About 50% of the fires were confined to the sets and only 6% spread beyond the room of origin.
4. In most cases the sets had been left plugged in even when switched off at the set during "non-viewing" hours.
5. No conclusion was reached regarding colour sets as compared with black and white.

Published as: CHANDLER, S.E. Fires in television sets. Fire, 1970, 63 (783) 193 - 4.

Synopsis of F.R. Note No. 805

SOME STATISTICS OF DAMAGE TO BUILDINGS IN FIRES

by

R. BALDWIN and G. ALLEN

In this pilot survey, the 840 fires in industrial and storage buildings occurring in Hertfordshire during 1965/8 inclusive were studied in the light of the Fire Brigade reports and the comments therein regarding the area, location, nature and seriousness of the structural building damage sustained.

It was found that in 715 fires there was no structural damage to the building. Of the remaining 125 fires, 121 suffered some damage (in 13 the extent was unknown) and in 4 it was known that there was some collapse (3 walls and 1 roof). In about 60 per cent of these fires the damage was to the roof or ceiling only.

The main conclusions are:-

(1) The chance of structural damage was 14 per cent

(2) The chance of structural failure was $\frac{1}{2}$ per cent

(3) In about half the fires the damaged area was less than 10 m^2

(4) In about three-quarters the damaged area was less than 100 m^2

(5) The extent of damage in a class of fires is associated with the size of the fire as represented by the probability of spread beyond the room of origin.

Synopsis of F.R. Note No. 806

A PRELIMINARY NOTE ON THE MOVEMENT OF SMOKE IN AN ENCLOSED SHOPPING MALL

by

P.L. Hinkley

A preliminary investigation has been carried out into the movement of smoke in a shopping mall prior to tests being done in an experimental building of corrugated iron on steel (80 ft x 20 ft) simulating a shopping mall and joining two brick and concrete 2 storey (existing) experimental buildings at the Fire Research Station, which will be used to simulate shops fronting onto the mall.

Spread of smoke experiments were carried out in an underground car park in Japan in 1966 and use has been made of the results of those tests. The Note discusses the practical implications of a tentative theory which will be explained in another Note and it is concerned with the flow of hot gases and smoke in two directions only i.e. along the mall, and not radially as with a fire in the centre of a shop.

In a mall 6 m wide and 4 m high it is estimated that, with a small fire such as could arise in a sprinklered shop, escape exits 70 m from the fire, in both directions, would be difficult to use in 2½ min and, should the fire 'flashover', the mall would be heavily smoke logged for 200 m in both directions in about the same time. Experimental work will be carried out to verify these tentative conclusions. The effect of roof venting, draughts and forced ventilation will also be investigated. A small scale model will probably be used to find the effect of greater distance from the fire, especially in respect of the cooling and flow pattern of gases in a mall.

Synopsis of F.R. Note No. 807

THE FLOW OF HOT GASES ALONG AN ENCLOSED SHOPPING MALL
A TENTATIVE THEORY

by

P.L. Hinkley

The author of this Note considers the theory regarding the rate of travel of smoke along an enclosed shopping mall, the hazards of which were described in F.R. Note No. 806. Reference is made to a number of scientific works and theories and, in particular, to the theory of "gravity currents" investigated by T.B. Benjàmin in 1968 and to formulae for calculating the rate of spread of a layer of hot gases beneath a ceiling, and the depth of the layer.

The depth of a spreading layer of hot gases cannot exceed half the height of the mall but smoke in the layer can mix with the cold air flowing towards the fire and so deepen the depth of smoke. As the "nose" of the layer of hot gases advances along the mall it displaces cold air and the rate of advance, which depends only slightly on the rate of entrainment of air by the fire (i.e. the area of the fire), is roughly proportional to the cube root of the heat output from the fire and inversely proportional to the cube root of the width of the mall.

The depth of the layer in a mall of given height is roughly dependent on the area of the fire and inversely proportional to the rate of advance multiplied by the width of the mall.

When the fire has grown to a critical size so that the hot gas layer fills half the height of the mall, the flow becomes unstable and turbulent, and smoke logging can quickly occur down to ground level. There may well be some mixing of the hot and cold layers even with a smaller fire, and especially in the vicinity of the "nose". Draughts from windows or doors can also cause local mixing of the layers.

It will be realized, therefore, that both the depth and speed of advance of the smoke layer can be estimated for a fire of a particular size in a particular shopping mall. However, more experimental work is required to test further the validity of the theories. If the theories are found to be correct it will clearly be necessary to install a ventilation system if occupants of a mall are to be given time to escape since, without forced ventilation, smoke could spread to 100 m from a fire within half a minute or to 200 m in $2\frac{1}{2}$ minutes.

Synopsis of F.R. Note No. 808

SURVEY OF FIRE-LOADS ON MODERN OFFICE BUILDINGS - SOME PRELIMINARY RESULTS

by

R. Baldwin, Margaret Law, G. Allen and Lynda G. Griffiths

A survey was carried out of two modern office buildings in London containing, in all, 93 rooms, one 5 storeys and the other 6 storeys, in order to investigate the fire load density and the fire-load per unit window area, for the purpose of predicting the possible fire severity (i.e. temperature and duration).

It was found that, in these buildings, the average fire-load per unit floor area was 4.1 lb/ft^2 (20 kg/m^2) and the mean fire-load per unit window area was 11 lb/ft^2 (55 kg/m^2). In regard to the rooms themselves (as distinct from the whole building) the fire load density was less than 12 lb/ft^2 and the fire-load per unit window area was less than 30 lb/ft^2, in 95 per cent of the rooms. In these circumstances a fire in any of the (95 per cent of) rooms would be controlled by the amount and characteristics of the fuel and not by the limiting size of the windows, and, at 12 lb/ft^2 maximum fire-load in the rooms, the buildings would be placed in the low fire load category (Fire Grading of Buildings).

Fair assessments were made of the amount of fuel contained in the furniture and equipment and it was found that, on average, 27 per cent of the floor area was covered by furnishings. The fire load density of a room was not related to the room size and, by implication, the fire-load density in a fire compartment (i.e. one floor or more) was not related to the way in which it was sub-divided.

A more extensive analysis will be made of the available information and this will be the subject of a further paper. Internal partitions, even if their fire resistance is small, will have some influence on the course of a fire and their existence is relevant to any analysis. The size and shape of the rooms is also relevant. The rooms were generally shallow and similar to those which were used in the recent experiments on the behaviour of structural steel in fire.

Synopsis of F.R. Note No. 809

PERFORMANCE OF METALLIC FOAM AS A FLAME ARRESTER

by

S.A. Ames, J.P. Davies (Dunlops) and Z.W. Rogowski

A new metallic sponge-like material called "Retimet" has been developed by Dunlop Co. Ltd. It can be manufactured from various metals and alloys and the size of the pores can be varied. One use of the material was thought to be as a flame arrester in place of the usual crimped ribbon or wire gauze etc. arresters. The material can be readily cut and mounted in a frame. Tests were therefore carried out to determine the effectiveness of "Retimet".

Most of the experiments were done with a 6.5% ethylene-air mixture and the majority of the arresters tested were of nickel chrome with porosities varying from 10 to 80 pores/in. A long perspex explosion tube was used, the arrester being fixed near the centre of the tube and ignition was initiated with an electric spark.

It was found that "Retimet" with porosities above 20 performed well as a flame arrester and was no worse than crimped ribbon of similar aperture. Arresters of "Retimet" with a porosity of 10 would not be safe and those of 20 pores/in would only have a limited application.

(Mr. Davies of Dunlop Co. Ltd. worked at J.F.R.O. on this research programme and the material "Retimet" was featured in the TV programme "Tomorrows World.")

Synopsis of F.R. Note No. 810

THE BEHAVIOUR OF AUTOMATIC FIRE DETECTION SYSTEMS

by

J.F. Fry and Christine Eveleigh

During 1968 the Fire Brigades completed special report forms for all fire calls to premises, equipped with an automatic fire detection system, at which there was, in fact, no fire. The reports, therefore, covered all false alarms but did not include cases where a fault signal was correctly given by the equipment. The brigades also completed the forms for actual fires at premises so protected, whether the call was made by the alarm or by other means.

In the year covered there were 6218 calls to premises so equipped but 5441 were false - a ratio of 11 : 1 - and of the 777 genuine fire calls 288 were made to the brigade by means other than the alarm system, so that the alarms worked properly and unaided in only 489 instances.

The false alarm ratio varied from 4½ : 1 for manual types (i.e. having only a manually operated connection from the premises to the Brigade or alarm station) to 23 : 1 for "heat and smoke" systems, regarding which there was no detailed information. Heat type installations produced a false alarm ratio of 11 : 1, the smoke type 14 : 1, the sprinkler alarm connection 10½ : 1 and the mixed and unspecified types about 8 : 1.

The reasons for the false alarms were grouped under three main headings:-

(a)	ambient conditions	25.9%
(b)	mechanical and electrical	46.1%
(c)	communication	16.6%
(d)	unspecified and unknown	11.5%

Extraneous heat and smoke was the most important cause under (a) and this could have arisen from carelessness, bad siting or unforeseen circumstances. Under (b) defective wiring and heads predominated and, in regard to alarms connected to sprinkler installations, over 50 per cent of the false alarms under this heading were caused by "surge in mains". The troubles under (c) appeared to result mainly from testing or maintenance work without previous notification to the brigade.

Regarding the type of connection to the brigade, in 80 per cent of the cases involving false alarms there were individual direct lines or 999 diallers - the former were operating in nearly 4000 of the 5441 false alarm calls.

As previously mentioned, 288 calls were made for fires at protected premises by means other than the alarm and in 154 of these cases the alarm failed to work, mainly through insufficient heat and smoke, and in 134 instances the alarm operated only after the Brigade had been notified by other means, but the reasons for this delay were not generally known.

The failure to detect fires mainly resulted from insufficient heat or smoke and this would be expected if the fires were quickly detected by work people and it is surprising, therefore, to find that proportionally more failures occurred for this reason at night than during the day.

Where there were genuine fires at protected premises the alarm system operated correctly in 68 per cent of the cases and, therefore, proved their value apart from the problem of false alarms which is a universal experience and not confined to this country. Details of the makes of the alarm installations and the age and condition were not generally known.

The troubles could be largely alleviated by setting the sensitivity at the right level, by better inspection and maintenance, and by proper notification to the brigade of all communication testing activities. However, the selection of the sensitivity level is largely a matter of economics in balancing the costs against the losses and this is a problem beyond the scope of this Note.

Synopsis of F.R. Note No. 812

THE PREVENTION OF FIRE SPREAD IN BUILDINGS
BY ROOF VENTS AND WATER CURTAINS

by

A.J.M. Heselden and C. R. Theobald

Note: F.R. Note No. 791 (for which a synopsis was issued) contained details of 'fire' experiments in a roof-vented building using a water curtain (or "wetting-down" spray) to prevent fire spread. The possibility of the water curtain spray being drawn towards the fire was also investigated and this work (Part 2) is described in this additional Note.

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A water curtain was produced from a 10 ft long pipe in the same way as in the 'fire' experiments, and the wind tunnel in the Models Laboratory at the Fire Research Station was used to produce the movement of air across the line of the spray. Three nozzle sizes were used with water pressures of 10 and 25 lbf/in^2 (giving flow rates per nozzle varying from 0.82 to 5.15 gal/min.). The wind speeds employed were 10 and 25 ft/sec.

The wind had the effect not only of moving the centre line of the spray downwind but of broadening the wetted area as a result of the differing wind action on the various-sized water droplets. Consequently, the distribution of water per unit floor area decreased. The deflection of the spray was roughly proportional to the wind speed.

For a given water pressure, decreasing the nozzle size (and, hence the water flow) gave a larger deflection because of a decrease in the momentum of the spray from the pipe, but for a given nozzle size the effect of a change in the water pressure was small, presumably because the change in speed of ejection was balanced by a change in droplet size (smaller droplets are more affected by the wind).

The deflection of the spray under actual fire conditions would depend on the size and shape of the compartment and on the position of the spray pipes and the site of the fire. The deflection would be insignificant if the spray surrounded a well vented fire supplied with air from all sides, but if the spray pipe was across a narrow building with a fire at one end the deflection could be substantial. In cases of extreme deflection and broadening of the wetted area, satisfactory wetting down action may only be achieved by using high water flow rates. A water flow of 2.2 gallons per foot run per min ($0.5 \ l \ m^{-1} s^{-1}$) should give a sufficient width of wetted fuel $16\frac{1}{2}$ ft (5 m) below

the nozzles to prevent fire spread with draughts up to 4 ft/sec (1.2 m/sec) and from experimental data now available it is possible to calculate the requirements for water curtains with pipes at various heights. A water flow of 2.2 gal/ft/min would require nozzles larger than 4 mm in diameter at a pressure of 25 lbf/in^2.

Deflection of the curtain spray might be particularly undesirable in situations involving high piled stock since surfaces facing the fire might then not receive sufficient water to prevent ignition. Water from the curtain carried into the fire would not be effectively used since too little would be available for extinction purposes.

Synopsis of F.R. Note No. 813

TOWN GAS EXPLOSIONS IN DWELLINGS

by

J. F. Fry

A preliminary analysis was made of these explosions immediately following the collapse of the Ronan Point Flats but a more detailed examination has now been made of the fire brigade reports for the period 1957 to 1968 inclusive.

In this period there were 1007 such explosions in the United Kingdom of which 488 caused some structural damage which was severe (as described by the brigade and excluding plaster damage only) in 184 instances (i.e. in 38 per cent of the incidents involving some damage).

Although the average annual frequency of gas explosions over the 12 years involved was 84, the incidents were increasing towards the end of the period. However, when the number of incidents is compared with the amount of gas sold for domestic use it is found that the frequency level is fairly constant over the period at about 5.0 per 100 m therms. (In 1968 there were 152 explosions in Great Britain and 2762 m therms were sold.)

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Published as: FRY, J. F. Gas explosions attended by fire brigades in dwellings. J. Inst. Fuel.

Synopsis of F.R. Note No. 814

FIRE TESTS WITH SPRINKLERS ON HIGH PILED STOCK

by

R. A. Young

Four tests were carried out in the Models Laboratory of the Fire Research Station on simulated palletised storage using tubular steel racking, 16 ft long, 8 ft 2 in deep and 18½ ft high, containing cartons filled with wooden blocks etc, books, aerosols, plastics goods etc. on ordinary wooden pallets placed on top of flat wooden boards. There was storage space for 32 pallet loads of goods, placed back-to-back at each level of the racking.

Infra-red and smoke detectors were tested incidentally to the main sprinkler test and the laboratory's opening roof provided venting between 3 and 10 per cent of the floor area. Thermocouples were placed near each sprinkler head, and elsewhere, and the radiation was measured.

Sprinklers were mounted within the racking and on the ceiling (underside of the roof). The tests were designed to follow but not to check the new Sprinkler Rules. Assuming category 1 goods were used, there was a higher concentration of sprinklers than required by the Rules for 3 tests and lower for the fourth test. Two tests had upright and two pendant heads although the deflector plates were in the same relative position each time. The racking sprinklers had 155°F and the ceiling 286°F heads and in 3 tests 135°F heads were fixed, but not connected, near the 155°F heads.

The water delivery from each head was 22 gal/min in 2 tests and 9 gal/min in the other two tests - the latter being equivalent to a density of 7.5 mm/min for the area covered. There was no obvious difference in the distribution between the pendant and upright heads. In the first 3 tests the heads were placed in the centre of the racking at each level (each head covering 4 pallet spaces) but in the 4th test only at alternate levels (2nd and 4th level).

In all tests the fire was ignited in the aisle but the main flame spread was inside the stacks where, once the flames reached the "chimneys" up the middle of the stack, the upward spread through the centre of the stacking was rapid.

The tests indicated that smoke logging can be serious, especially with a high discharge of sprinkler water and no roof venting. The early opening of the "vents" prevented a deep smoke layer becoming established and the lower water discharge had a smaller cooling effect on the smoke.

The amount of fire damage done in the tests depended on the type of goods and the particular sprinkler arrangements. Plastics goods and cardboard boxes filled with wood wool burnt with considerable intensity. The former were easily extinguished with sprinkler water but the latter were not so easily extinguished and smouldered for some time. Cases of lard burnt very reluctantly.

The radiation across an aisle 5 ft wide would have been sufficient to ignite adjacent cardboard boxes were it not for the operation of the sprinklers which reduced the radiation to á 1/10th of that necessary for ignition.

If sprinklers are effective, only the outer surface of the cartons will burn but should the fire develop for any reason then the nature of the goods in the cartons will be important. An efficient detection/extinction system should aim at complete control, and preferably extinction, in not more than 10 minutes. The heads should be installed at each level of racking with at least one per four pallet positions and each level should be staggered with some protection over the lower heads to prevent water from above cooling them. It seems that, in these conditions, the sprinklers are just as effective at 9 gal/min per head as at 22 gal/min. There is about a 30 second delay with 155°F heads as compared with 135°F heads.

The infra-red and smoke detectors operated, on average, 5 minutes ahead of the sprinklers.

Synopsis of F.R. Note No. 815

PRELIMINARY ANALYSIS OF FIRE REPORTS FROM FIRE BRIGADES IN THE UNITED KINGDOM, 1969

by

S. E. Chandler

The Fire Brigade reports which were received up to the 6th March 1970 are analysed to show the total number of fires attended by the various Brigades throughout the U.K., the number of fatal and non-fatal casualties, and the number rescued.

The total number of fires attended by the Brigades throughout the U.K. (other than those confined to grass and heathland) was 197,825; an increase of 15 per cent over the 1968 figure.

Mass evacuation or rescue was necessary or advisable in 13 incidents (3 hospitals, 6 hotels, 2 schools, 1 bus and a children's hostel). In all there were 830 fatal casualties (including 9 firemen) as compared with 821 in 1968.

Synopsis of F.R. Note No. 816

THE THERMAL MOVEMENT OF CONCRETE FLOOR UNITS UNDER FIRE CONDITIONS

by

F. C. Adams and T. V. Day

Two precast reinforced concrete floor slabs (15 ft x $5\frac{1}{4}$ ft and 8 in thick) each supported at their ends on (steel mesh) reinforced concrete wall units were tested in the floor furnace in order to examine the effect of heating on the junctions between the floor slabs and the wall units. One floor slab was tied into the walls and the other was simply supported (using a hardboard bearing pad) on the walls (Constructions 1 and 2 respectively) and each construction was entirely independent of the other. Three of the wall units were tied to the furnace wall so that they could not move but one wall of Construction 1 was not restrained. Measurements were made of the movements at three floor and wall junctions and also of the vertical deflection at the centre of each floor slab.

All the units were constructed of gravel aggregate and the jointing, of similar concrete, between the floor slabs and the wall units was done in situ, there being reinforcement in the two joints for Construction 1 but none for Construction 2. The floor slab for the latter was, therefore, free to expand across the top of the wall units but was restrained in Construction 1. The junction fillings were made up to the full thickness of the floor slabs and were carried out in accordance with standard industrial practice and the main bearing for the floor slabs on the walls was through ribs built into the ends of the precast slabs.

Both floor slabs were loaded with cast iron weights to provide a uniformly distributed load of 90 lb/ft^2 and the undersides of the slabs and inner surfaces of the wall units were heated in the furnace in accordance with B.S. 476. Both floor slabs were about to collapse after $2\frac{1}{4}$ hours when the test was stopped. There was cracking or spalling on almost all the heated surfaces.

The central vertical deflection (after 2 hours) of the floor slab in Construction 1 was 4.9 in and 6.3 in for Construction 2. The difference in the horizontal expansion of the two slabs was however small ($\frac{1}{4}$ in), being 1.57 in. and 1.31 in for Constructions 1 and 2 respectively, and had the walls been pushed out (and not been restrained) the angular movement of the walls would have been less than 1° at the top of a single storey supporting wall in both cases. This would be unlikely to lead to structural instability. The deflection would probably occur in an external wall since this would be less restrained than an internal wall.

The test showed, however, that there was movement between the tied-in junctions in Construction 1, at both ends, and that both Constructions behaved in a somewhat similar way. It also showed that the method of providing structural ties between the floor edge and the wall (standard industrial practice) was not adequate. The steel links of the reinforcement pulled out of the wall unit but there was no evidence of the steel having yielded.

The investigation did not explore the stresses that might be set up in adjacent floor slabs if restraint was provided to horizontal expansion at both ends.

Synopsis of F.R. Note No. 817

FIRE RISK IN DWELLINGS IN MULTIPLE OCCUPATION

by

W.N. Daxon

Five local authorities (Birmingham, Bradford, Coventry, Nottingham and Wolverhampton) made reports on fires in multiple and single occupancy dwellings during two periods, one during the summer of 1967 and the second during the winter of 1967 - 1968.

The Note contains numerous tables giving details of the 807 fires which occurred during this time showing - cause of fire, date of construction, extent of damage, rate of incidence and numbers of people at risk, and the casualties.

The number of fires in both types of risk is, as expected, greater during the winter than the summer and oil space heating caused 23% of fires in multiple tenure dwellings but 7% only in single occupancy dwellings.

The tables show that the risk of fire in multi-tenure dwellings is 5 times that in single occupancies and the chance of becoming a casualty is twice as great. The chance of being trapped is seven times as great. Oil heating appliances are the main single cause of fires in multiple occupancies and cause a high proportion of the fires which spread beyond the room of origin and the type and age of these dwellings are possibly main factors contributing to the increased risk.

Synopsis of F.R. Note No. 818

COMPUTER PROGRAMS FOR PRODUCING THE UNITED KINGDOM FIRE STATISTICS

by

S.E. Chandler

The United Kingdom Fire Statistics (1967 has just been issued) are now and will, in future, be produced from magnetic tapes prepared from the fire reports received from the Fire Brigades. The reports are classified under three main headings

Fires in buildings
Fires not in buildings
Fires confined to grassland, stubble etc.

Use is made of the computer at the Building Research Station and the program should enable the Statistics to be issued more promptly than in previous years.

The Note deals with the technicalities of the computer program and is primarily an "internal" record for the Fire Research Station.

Synopsis of F.R. Note No. 821

THE EFFECT OF REACTANT CONSUMPTION ON SUBSTANTIALLY SUB-CRITICAL SELF-HEATING

by

P.C. Bowes

In F.R. Note No. 788 (for which a synopsis was issued) the author shows that it should be possible to predict the large-scale self-heating and explosion behaviour of unstable substances if small scale laboratory experiments are done to determine the critical (ambient) temperature for self-ignition.

Laboratory experiments which measure the temperature rise of small samples at temperatures far below the critical ignition temperature can also be used to predict the large scale behaviour and this new F.R. Note deals with an aspect of the theory required for this purpose.

The theory which assumes that the amount of reactant consumed in the self-heating process can be ignored, is confirmed in this Note and the effect of the investigation is to make it possible in suitable cases, to use a relatively small number of laboratory experiments at lower temperatures to predict the large scale behaviour. In other words, instead of having to do numerous experiments at around the critical (self-ignition) temperature for various sizes of the substance, it is sometimes possible to calculate the safe maximum size of the substance by measuring the temperature rise in a few small samples at a temperature well below the critical temperature.

Although this theory may not apply to oxidising processes involving oil (this is the subject of a further Note) it has enabled JFRO to advise on the largest quantity of a substance, such as activated carbon,* which may be stored or transported, when unpacked and exposed to the air, without risk of self-ignition.

* at present confidential but report will be issued.

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Published as: THOMAS, P.H. and BOWES, P.C. Reactant consumption and the application of simple thermal ignition models. New Zeal Sci J.

Synopsis of F.R. Note No. 823

EXPERIMENTS ON THE USE OF A LASER BEAM FOR FIRE DETECTION

PART I - HEAT DETECTION

by

E.F. O'Sullivan, B.K. Ghosh and J. Turner

A general account of the installation and operation of a laser beam fire detection system was given by Mr. D.I. Lawson in F.R. Note No. 824 for which a synopsis was issued and to which reference should be made for the basic facts of the system described in this new Note which deals with the heat but not smoke detection experiments.

The experiments were carried out in the Models Laboratory at the Fire Research Station (135 ft x 50 ft and 40 ft high). Tests were done under ambient conditions which included the operation of space heaters (10 turbo wall heaters) and under simulated fire conditions using trays of burning methylated spirit placed in various positions in the laboratory.

The 0.5 mW (low power) helium-neon gas laser beam was focused to travel just below the 2 ft deep ceiling joists, travelling from the laser to a corner-cube mirror at the far end of the building and back, close to the position of the laser, where it fell onto a selenium photocell which had a filter to exclude extraneous light. The area of the photocell was just large enough to contain the unperturbed laser spot so that any disturbance of the beam resulted in a change in the amplified output of the photocell. The convective heat output of the 'fires' ranged from 50 to 250 kw and it was, of course, the thermal air currents which agitated the laser beam.

The "fire to ambient" signal ratio (F/A) is important, since this must be sufficiently large (or a wide enough margin) to prevent false alarms. The most effective part of the photocell's output was found to be in the frequency range of 40 - 80 H_z.

21 experiments were carried out on 5 different days. If an F/A ratio of at least 4 is required for good discrimination between fire and ambient conditions then a 140 kw fire (about a 2 ft dia. tray) anywhere in the laboratory could be detected, or if an F/A of 2.5 is acceptable then any 70 kw fire could be detected and the time to detect any of these fires would be in the range, 25 to 45 secs including a 15 sec delay to obviate false alarms which might be caused by the movement of the laser itself. This performance is, generally, better than that of the most sensitive practical heat detector and the sensitivity, using the laser,

decreases less* with height than it would with a heat detector. In addition, the laser beam system can be readily adapted to act simultaneously as a smoke detector.

A circuit for an experimental laser beam fire detection system is being designed, based on the results of these tests.

* per F.R. Note 824 and being verified

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Published as:- O'SULLIVAN, E.F., GHOSH, B.K. and TURNER, J. Experiments on the use of laser beam detection. Instn Fire Engrs Q., 1971.

Fire Technol., 1971,

Synopsis of F.R. Note No. 824

A LASER BEAM FIRE DETECTION SYSTEM

by

D.I. Lawson, MSc, CEng, FIEE, FInstP, MIFire E

The refractive index of air varies very slightly at different temperatures (visible as a heat haze above, say, a hot road surface in summer) and this feature can be used to interfere with a beam of light passing through the heated air or gases. For accurate and delicate responses it is necessary to use a very narrow beam of light such as that produced by a laser.

One system of detection would be to split the laser beam in two and then detect the very small transit time difference of the two beams caused by the "heat-haze" interference and record changes in illumination by a photocell and amplifier (to give the alarm). However, it was decided to use a single laser beam and detect the movement of the beam and the change in illumination caused by the "heat-haze" and also by smoke.

Under normal conditions a laser beam can be focused to produce a spot of light at 100 m distance not more than 5 mm in diameter. Once a fire is lit under or to one side of a beam traversing the length of a building just below the ceiling, a turbulent plume of gas and warm air will, within a few seconds, rise and impinge on the ceiling and spread out. This turbulence, or heat-haze containing areas of gas or air with different refractive indices, will deflect the beam in a random manner. If the fire develops, the space just below the ceiling will fill with hot gases which will deflect the beam more steadily and in a less random manner and the turbulent area will be at a lower level.

In order to get a quick response the initial turbulence and random movement and not the subsequent steadier deflection must be used for detection. The time to detection increases with height and for a similar response at double the height a fire twice as large would be required. However this is an improvement on the performance of other types of detectors and, for a doubling in height, the point and line type detectors would require fires 5 times and 3 times as large respectively, to give a similar response.

If the laser is at one end of the building and the photocell at the other, the beam will be more sensitive to fires near the laser since the beam will then be 'bent' (by the varying refractive indices) for a longer distance than if the fire was at the photocell end. It is necessary, therefore, to use a mirror to reflect the beam back from the far end of the building to a photocell placed near the laser. An ordinary plane mirror, fixed to the building, might move, and deflect the beam, with any slight distortion of the building but, by using a corner-cube mirror it is possible to reflect the beam back towards the laser on an exactly parallel line irrespective of any movement of the mirror. A corner-cube mirror consists of 3 mirrors at right angles to one another and the light beam is reflected via all three mirror surfaces.

The laser itself could move slightly with any building movement but this would be relatively slow and the effect can be distinguished from the rapid agitation of the light spot which is used to detect fires. Further, a checker-board mask with holes in front of the photocell could be used to distinguish between a slow and a fast moving spot of light. The holes in the checker-board mask would be about the same diameter as the light spot and any slow drift from one hole to another would not operate the alarm. By increasing the thickness of the mask and the length of the holes it could be used to exclude extraneous light.

Fluctuation of the beam caused by ordinary temperature changes in the protected area would be at a lower frequency than those caused by fires and would not cause false alarms.

The system could be made sensitive to smoke as well as heat by making the checker-board mask into a photocell with a further continuous photocell behind it so that the light intensity would be measured, as well as the agitation, and by comparing this with the intensity of the original beam an alarm could be given if the intensity difference caused by the smoke was sufficient.

The laser beam could be reflected by mirrors to floor level and if suitably arranged could provide an intruder detection system since it is virtually invisible.

The cost of the equipment is likely to be about 8d per sq. ft, i.e. less than existing systems, and maintenance should be much easier than with individual detector heads. One laser could be used to protect a building, say 135 ft x 50 ft and 40 ft high. If the system was marketed commercially costs should be substantially reduced.

Published as:- LAWSON, D.I. A laser beam fire detection system. Instn Fire Engrs Q., 1970, 30 (79) 284 - 300; Fire Technol., 1970, 6 (4) 305 - 11; Antincendio, 1970, 22 (9) 502 - 8.

Synopsis of F.R. Note No. 826

GAS EXPLOSIONS IN DWELLINGS, 1969: MATERIAL DAMAGE AND INJURIES

by

E.D. Chambers

The fire brigade reports for 1969 were examined and further information was obtained when a town or natural gas explosion in a dwelling was reported. There were 139 town gas and 17 natural gas explosions reported in Great Britain and it was found that both types of explosion caused, on average, a similar amount of damage, although only 17 natural gas explosions was insufficient for this to be conclusive. The average number of injuries (other than first aid) was 0.4 per incident.

Synopsis of F.R. Note No. 827

FIRE HAZARD OF EXPANDED POLYSTYRENE LININGS

by

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

Following reports of fires, mainly in private dwellings, where expanded polystyrene had been thought to spread fire, a series of tests, both on a model and full scale, was carried out on 9.5 mm ($\frac{3}{8}$ in) and 12.5 mm ($\frac{1}{2}$ in) thick tiles and on 5 mm ($^3/16$ in) wall linings of expanded polystyrene. Possibly 5/600,000 houses are treated in some way with these tiles each year, largely by "do-it-yourself" householders and the tiles are used mainly on the ceilings (of bathrooms and kitchens) being stuck on with 5 dabs of adhesive, usually PVA based, to each tile or with the adhesive spread overall. The wall lining is not used extensively nor are the tiles often fixed to timber battens, either with adhesive or nails.

The tiles may be left untreated or they may be painted with emulsion paint and with gloss paint in addition, and this is frequently done when the tiles become dirty. The tiles are produced in a standard and in a self-extinguishing grade and both have a low melting point. If a flame is applied to the standard grade tile the polystyrene will melt and burn and, whilst moving away from the flame, it will continue to burn if the flame is kept in contact with the unmelted portion of the tile. The self-extinguishing grade tile will recede from the flame before ignition can take place.

Expanded polystyrene is either formed by fusing pre-expanded beads or is extruded (which produces a more regular cell structure) and the manufacture is controlled by BS 3837 and 3932.

Experiments were carried out in three stages:-
Stages I and II used chambers constructed of asbestos wall board; both had cross-sections of 900 mm x 900 mm and the former was 900 mm long with two open sides and the latter 1200 mm long with one open side. Stage III utilised full size rooms. Tests were also carried out on the Ignitability and the Fire Propagation test apparatus (BS 476). Various methods of fixing, surface finishes and sources of ignition were used and, in all, 76 tests were performed, mostly using wooden cribs.

It was found that on thicknesses up to 12.5 mm there was no significant difference in fire hazard between the standard and the self-extinguishing grades when they were attached to a substrate (a ceiling or wall), and, provided this latter was of a Class 1 standard (or non-combustible) and the tiles were stuck on with overall adhesive (not dabs), the polystyrene shrunk back to the substrate, was difficult to ignite and did not spread flame.

Application by dab adhesive did permit the tiles to burn and fall away from the ceiling, especially when attached in this way to battens.

The presence of any surface finish helped ignition and the burning of the tiles. A flame retardant paint made only a marginal difference and a matt emulsion paint led to localised flaming but without any danger of rapid flame spread. A coating of gloss paint, even on top of emulsion paint, did, however, result in very rapid flame spread and produced burning strips capable of igniting combustible material on the floor at a distance from the fire. The reason for this was that the paint film came away from the substrate thus facilitating its ignition as well as that of the polystyrene. Over-painting with flame retardant paint did not improve the hazard to an acceptable level.

No appreciable smoke was produced in any of the tests and what there was appeared to be associated with large size carbon particles.

As a result of the experiments it was considered advisable:-

(1) to apply the tiles to a non-combustible or Class 1 substrate

(2) to use overall and not dab adhesive

(3) not to use a paint finish but if essential to use only a flame retardant paint or, possibly, a matt-finish emulsion paint

(4) never use a gloss paint finish and remove any tiles so painted.

Tiles stuck to a non-combustible substrate with an overall adhesive have a better Fire Propagation index than the same tiles if unstuck but, either way, the Fire Propagation test does place the various methods of fixing and finishes in their correct order of hazard as indicated by the experiments.

The attached table shows the results of the fire propagation tests.

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Published as:- MALHOTRA, H.L. Expanded polystyrene linings for domestic buildings <u>Fire Note</u> No. 12

Table 6. Results of the fire propagation tests

Surface finish	Grade	Adhesive	Index	I_1
None	SE	Overall	8.9	5.9
Intumescent F.R. Paint	Standard	"	9.1	5.8
None	"	"	9.2	6.1
None (12.5 mm)	SE	None	10.1	7.1
Intumescent F.R. Paint	"	Overall	10.6	7.3
None (12.5 mm)	Standard	None	12.2	8.7
2 coats emulsion	"	Overall	13.6	10.0
1 coat emulsion	"	"	14.4	8.4
None	SE	None	14.9	9.8
1 coat emulsion	"	Overall	14.9	10.1
2 coats emulsion	"	"	18.8	13.9
None	Standard	None	18.9	13.0
1 coat emulsion	"	Dab	24.0	15.7
"	SE	"	24.6	15.4
None	Standard	" *	33.5	21.7
1 coat emulsion	SE	None	34.8	29.0
"	Standard	"	35.0	28.5
Emulsion & gloss	"	Overall	37.5	33.5
"	SE	"	45.0	36.2

Note: All tiles 9.5 mm thick except where indicated

*Sample fixed to battens

Synopsis of F.R. Note No. 828

AN ENQUIRY INTO THE FREQUENCY OF SPRINKLERED PREMISES

by

G. Ramachandran

For the purpose of assessing the economic value of sprinklers, the fire brigades provided information on the numbers of sprinklered premises in each occupancy which they obtained during the visits they made in 1965 in the course of their normal inspection work. In all, 37115 buildings were visited of which 4391 were shops and departmental stores, 8831 were factory buildings and 590 were storage buildings.

The Note includes tables showing, apart from the numbers of buildings visited, the frequency of sprinklered buildings in 8 main occupancy classes, and, in respect of nine brigades only, the frequency of sprinklered buildings in 8 industrial occupancies.

Practically no sprinklers were found in dwellings, institutional and school buildings and, although some were found in offices these, generally, only provided partial protection.

The following consolidated table, based on the fire brigade returns for 1965, regarding industrial premises may be of interest.

Occupancy	Number of establishments employing 11 or more persons (Annual Abstract of Statistics HMSO	Percentage with sprinklers	Number of sprinklered establishments (est)
Food drink and tobacco	5274	16	840
Chemical and allied trades	2451	5	120
Metal manufacturing, engineering and electrical goods	17885	7	1250
Textiles	5559	38	2110
Clothes, footwear leather and fur	7195	29	2090
Paper, printing	5215	33	1720
Furniture, timber and allied trades)	11582	12)	1270
Others)		10)	
All industries	55161	15	9400

It was estimated that 27 shops and departmental stores per 1000 visited were sprinklered.

Apart from offices, more than 95 per cent of the sprinkler systems were considered to be effectively installed.

Synopsis of F.R. Note No. 829

LARGE FIRES DURING 1969

by

G. Ramachandran, Patricia Kirsop and Christine Eveleigh

During 1969 there were 1118 (1005 in 1968) large fires (£10,000 or more) in the UK causing direct material damage amounting to £78.2M (65.2 per cent of the total fire wastage of £120M). At 1968 values the loss per large fire would have been £72,000 as compared with £61,000 in 1968, so there were more numerous and more extensive large fires in 1969 than in 1968.

Out of the 1118 large fires, 60 started in outdoor hazards but spread to buildings (38 such fires in 1968).

The Note contains tables showing:-

(1) Occupancy or hazard involved.

(2) Source of ignition and place of origin.

(3) Extent of the spread and number of jets used.

(4) Date of construction.

(5) Time of call, control time, month and day of week.

Without knowing the total number of premises at risk it is not possible to draw any conclusions from (1) and (4) above and much of the other information on its own seems of little value to insurers since only one year is involved. However, the table relating to the behaviour of fire protection devices may be of some interest and is shown below.

Behaviour of fire protection devices on large fires

Fire protection devices installed		No. of fires	Total direct loss (£000)	Average direct loss per fire (£000)
Total		1118	78212	70.0
Sprinklers and drenchers	operated	18	749	41.6
	did not operate	3	511	170.3
CO_2, foam steam and nitrogen system	operated	102	6598	64.7
	did not operate	-	-	-
Automatic detectors	operate	1	37	37.0
	did not operate	4	994	248.5
Fire doors	operate	5	407	81.4
	did not operate	2	305	152.5
Others	operate	85	13127	154.4
	did not operate	11	680	61.8
Combination of above	operated	83	11303	136.2
	did not operate	2	103	51.5
Roof vents	operated	2	65	32.5
	did not operate	-	-	-
Not installed, unknown or not applicable.		800	43333	54.1

N.B. Did not operate includes incidents where the performance was not known.

Synopsis of F.R. Note No. 830

DUST EXPLOSION VENTING - A REASSESSMENT OF THE DATA

by

K. N. Palmer

Venting is a relatively cheap method of obtaining protection of plant handling explosible dusts but unfortunately there is as yet no agreed method of calculating the venting requirements such as there is for gas and vapour explosions. The author has therefore endeavoured to collect together in this Note all the available relevant information on dust explosions and has reformulated the problems of venting dust explosions. Discussion and further experimentation will be necessary to debate and analyse the assumptions he has made from this existing data.

The Note refers to the earlier Research Technical Paper No. 21 which reports on the laboratory scale standard test procedures for the measurement of explosion pressures and to earlier experimental work covering the most severe conditions of test, since these conditions are of particular interest in practice. When considering dust explosions vented to the atmosphere, different relationships are obtained between vent area and maximum explosion pressure for pressures greater or less than the critical value of 12 lbf/in^2. The Note contains comments and equations relating to the various conditions which can arise in a vented dust explosion. These are based on the information already available in regard to various dusts, shapes and sizes of vessels, and sizes and types of vents.

So far, the correlation between the experimental data and the calculated pressures gives support to the assumptions made in the derivation of the equations and evidence has been provided for a link between the small scale tests and the explosion venting data in experiments up to full industrial scale, provided these explosions are severe. These data are limited to volumes up to 700 ft^3 and there might be discrepancies for larger volumes and, for instance, for dusts flowing along ducts. Experiments on the venting of a cyclone are in progress at the Fire Research Station.

The majority of plants which require venting are relatively weak but are capable of withstanding pressures up to 2 lbf/in^2 which is the maximum pressure which correct venting should ensure. The present ad hoc procedure for specifying vent ratio appears to be reasonable, but further experimentation is necessary to analyse the assumptions more vigorously and to provide additional explosion data, in particular for a wider range of dusts, larger plants and differing dust suspensions and sources of ignition. Only unrestricted vents have been considered and analysis should be made of the effect of vent closures on explosion pressures.

Synopsis of F.R. Note No. 831

FIRES IN HOSPITALS

by

S. E. Chandler

This report, which is based on a 1 in 4 sample of the 1968 fires, shows that fires in hospitals have increased from 590 in 1963 to 684 in 1968, a rise which is similar to that for all buildings. During this period there were 62 fatal casualties in 38 fires and 24 of these casualties occurred in the Shelton Mental Hospital fire. The Note includes tables showing the place, time and source of ignition, and material first ignited; the extent of fire and the method of extinction.

Mental hospitals do not appear to be more fire-prone than other hospitals but the fires in the former are more frequent in wards and less frequent in kitchens and are more often attributed to smoking materials and malicious ignition than in the latter.

Most fires occur between 9 a.m. and 9 p.m. and are most frequent in wards (144), stores (80) and kitchens (76) so far as 1968 is concerned. Only 6½ per cent of fires spread beyond the room of origin, compared with 28 per cent for all other buildings, due, no doubt, to prompt detection and fire-fighting activity.

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Published as: CHANDLER, S. E. Fires in hospitals. Fire Research Technical Paper No. 27. London, 1971. H.M. Stationery Office.

Synopsis of F.R. Note No. 832

SMOKE TRAVEL IN SHOPPING MALLS
EXPERIMENTS IN COOPERATION WITH GLASGOW FIRE BRIGADE - PART I

by

A.J.M. Heselden and P. L. Hinkley

This is a preliminary report on tests which were carried out in a disused railway tunnel in Glasgow and which provided an opportunity to compare realistic full scale experiments with the theory and initial test work already done at Boreham Wood and described in F.R. Notes No. 806 and 807. The tunnel was about 2000 ft long, running almost level and in a straight line, NW - SE, with a mainly covered-in station at the SE end. A ventilation shaft in the tunnel was 624 ft from the NW end and 1416 ft from the SE end where there was another ventilation shaft at the tunnel-mouth end of the station. The tunnel was 17 ft high and 25 ft wide.

The Glasgow Fire Brigade provided observers (suitably protected) and the Glasgow Salvage Corps also assisted. Measurements were taken of the smoke travel and layer depth, gas temperature, optical density and CO_2 production etc. and some of these results will be further analysed in a later report (Part 2). Also, a further test simulating a fire producing smoke under a canopy projecting from the side of a building will be reported upon in a later Note.

The experimental fires were produced by burning 10 gal. of kerosine in a 4 ft square metal tray and this was equivalent to an 8 ft square wood crib. A metal sheet "spreader" plate placed above the tray increased the area but not the burning rate of the fire and protected the tunnel roof. The fires burnt for about $8\frac{1}{2}$ min and each tray gave a heat output of about 2 MW.

Five tests were carried out in the tunnel, as follows:-

Test No.	Details
1	1 tray in centre of the 1416 ft long section with both tunnel ends open
2	2 trays ———— " ————
3	4 trays ———— " ————
4	1 tray 180 ft from SE (Station) end with this end closed with tarpaulin sheets
5	2 trays just SE of the central ventilation shaft with both tunnel ends open

Slight wind through the tunnel may have had some effect on the smoke movement but the mean of the smoke velocities, both NW and SE, were taken to counterbalance this effect.

The conclusions reached are summarized as follows:-

(1) a relatively small fire can, under unfavourable conditions, produce substantial smoke logging

(2) the dense smoke moved along at about 3 ft/s (confirming F.R. Note No. 807)

(3) the speed of advance of the smoke front increased only slightly as the size of the fire increased but the larger the fire the deeper and denser was the smoke layer.

(4) thinner smoke formed under the dense smoke layer (reaching to the floor at times) and, as the initially well stratified layer of dense smoke spread along the tunnel, it increased a little in thickness

(5) when the dense smoke layer reached an open end a plug of smoke formed (by cross mixing with air at the opening) and this plug was drawn back into the tunnel by the air drawn towards the fire

(6) an inadequate or poorly vented roof will have little, if any, beneficial effect on smoke logging and could cause more smoke mixing near the floor. (NB. roof venting will be the subject of future experiments at J.F.R.O.)

(7) at the closed end of the tunnel, dense smoke dropped to within 5 ft of the floor and moved back towards the fire.

(8) conditions within an unvented mall closed at both ends would, generally, be even worse after a time than one completely open at both ends but open ends would not reduce the hazard to an acceptable level.

Synopsis of F.R. Note No. 833

THE RELATIONSHIP BETWEEN THE CHANCE OF A FIRE BECOMING LARGE AND THE CHANCE OF FIRE SPREADING BEYOND THE ROOM OF ORIGIN

by

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

The authors have studied the published analyses of the Fire Brigade reports for fires, in 1963, involving multi-compartment buildings (other than dwellings and those involving only common service areas and exterior components) and also for fires in the distributive trades over the years 1963-68, in which there was a spread of fire beyond the item first ignited. They have also extracted information, in respect of these fires, regarding fires spreading beyond the room of origin and those which were fought with five or more jets (these being equivalent to large fires of £10,000 or more). The information on large fires in the distributive trades was taken from F.R. Note No. 792 but the other details were extracted from the UK Fire Statistics and Fire Research Technical Paper No. 16(Fires fought with five or more jets).

The theory adopted by the authors is that a building can be represented by an infinite array of cells with the possibility of fire spreading from one to another at random before it is extinguished or the building burnt out. All the various possibilities are considered mathematically in some detail.

From the information available it was possible to assess the chance of all fires (both large and small) spreading beyond the room of origin (P_S) and the chance of the fires becoming large (P_L). The Note shows that these two chances are approximately related in the proportion $P_L = P_S^3$. It is also shown that large fires, on average, correspond to fires involving four or more rooms. With this relationship established, it is possible to benefit from a study of the factors influencing fire growth in all fires in order to find the reasons for fires becoming large. This is a more rewarding exercise than studying only reports on large fires which are relatively few and are usually devoid of detailed information in view of the substantial destruction; and yet these large fires contribute such a large proportion to the total fire wastage. About 15 per cent of all fires spread beyond the room of origin and yet only about 1 per cent become large. It was assumed that most large fires occurred in multi-compartment buildings.

The authors conclude that the probability of a fire becoming large (P_L) increases rapidly with the probability of fire spreading beyond the room of origin (P_S). Consequently, quite small reductions in the chance of fire spreading beyond the room of origin, such as by compartmentation, sprinklers, detectors etc., can result in relatively large reductions in the chance of a large fire. These problems will be studied further but, as an example, it can be shown that since 40 per cent of all fires started by malicious ignition or by rubbish burning spread beyond the room of origin, all fires so caused have a very high chance of becoming large.

Synopsis of F.R. Note No. 835

FIRE TESTS IN TWO CARAVANS

by

E. G. Butcher and G. K. Bedford

Two 25 ft long timber and hardboard built caravans with mineral wool mat in the wall cavity and with the outer skin of the roof of aluminium, and with normal items of furniture inside, were the subject of fire tests, at the request of the Home Office, to determine the time occupants would have for escape.

During the tests measurements were made of temperatures, external radiation and gas concentrations. Smoke detectors were installed and in one caravan there were 2 sprinkler heads supplied with 2 gallons of water at 100 lbf/in^2. The fires were started by switching on an electric fire element in a cupboard near the centre of the caravan.

The tests showed that toxic gases would make escape within 4 min essential and even less time might be available due to the combined effects of temperature, smoke and toxic gases. Smoke detectors operated at about 30 s after the start of the tests as against $1\frac{1}{2}$ mins which would have been required for heat detectors to operate and the former would provide the most effective warning device. The radiation measurements indicated that a 20 ft separation between caravans would be required to prevent spread in windy conditions. The sprinklers did retard the development of the fire to some extent but not sufficiently to make much difference to the escape time.

The fires developed quickly and were allowed to destroy the caravans.

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Synopsis of F.R. Note No. 836

FIRES IN ROAD VEHICLES - 1968

by

S.E. Chandler

The author reviews, in this Note, information obtained from the Fire Brigade reports regarding fires in road vehicles (not in buildings) during 1968 and he makes some comparison with earlier years, in particular, 1963. Most of the available information has been extracted and various tables and graphs give details of:-

(1) number of fires, separately, for cars, motor cycles (and scooters) lorries, vans, tankers, buses etc. and some comparison is made with the number of licences and the kilometres travelled.

(2) location of fires, age of cars, time of call, source of ignition, material first ignited, extent of fires and method of extinction.

(3) casualties.

The last detailed analysis was made in 1953 and, although the number of fires increased from 10716 in 1963 to 15188 in 1968, the situation is better than at the time of the earlier survey when the fires are related to the number of licences issued, the position in 1968 being:-

	Fires per thousand licences	Remarks
Cars	0.64	0.55 in 1963
Motor cycles	1.02	0.95 in 1963
Coaches and buses	5.27	2.86 in 1963
Goods vehicles	3.16	Goods vehicles are estimated as 50% of 'vans' and 'lorries'

N.B. A complete comparison is not possible since the classification used by the Fire Brigades differs from that used in the Annual Abstract of Statistics.

There is no evidence that the age of the vehicle is an important factor.

Fires in tankers and buses, although small in number, approximately doubled from 1964 to 1968 and although this coincides with the greater use of rear-engined vehicles there is apparently no connection between these two factors. Incidents in which liquids, other than the fuel, was ignited doubled between 1963 and 1968 and this rise could be partly due to an increase in the amount of flammable liquids transported by road.

The most important sources of ignition were:-

	Cars	Buses	Lorries	Tankers
Wire and cable	38.9%	37.5%	19.2%	13.6%
Engine	28.7%	30.8%	18.6%	25.8%
Mechanical heat & sparks) Tyre friction)	1.5%	22.1%	18.2%	nearly 40%

Fires caused by malicious ignition increased from 68 (1963) to 452 (1968). There were 132 tanker fires in 1963 and 264 in 1968 but the number of licences is not known and it is difficult to pin-point the reason for the increase.

Only 1.7% of the vehicle fires spread beyond the vehicle of origin. Nearly 27% of the fires were extinguished before the brigade arrived, mostly with extinguishers.

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Synopsis of F.R. Note No. 837

SOME POSSIBLE APPLICATIONS OF THE THEORY OF EXTREME VALUES FOR THE ANALYSIS OF FIRE LOSS DATA

by

G. Ramachandran

This paper is highly technical but, since the author is trying to establish a theory, the practical application of which might help insurers to anticipate loss trends and assess the importance of contributing factors, some comments on the general concept of the problem may be of value.

The problem would not arise if loss figures over the whole range, and not only for £10,000 and more, were available. Difficulties arise when considering only the large losses because their pattern is far from normal. They do, however, account for about 60% in amount of the total fire wastage (material damage). If the validity of the extreme value theory in this connection is established then the resulting information on large fire losses will be projected backwards to cover small losses. A regression analysis of the factors affecting large losses should show the effect of various fire spread parameters when applied to existing loss data.

The idea is to produce something similar to a life mortality table based on the experience for lives over, say, 45 years of age only. Knowing the influence of good and bad health factors on these lives the life expectancy can be predicted at any age above 45 but the extreme value theory should enable the life expectancy for years of age below 45 to be predicted also. The author refers to the theory when applied to flood but, in this context, only a catastrophe is considered (such as the bursting of a dam) whereas, with fire losses, a less extreme situation is more realistic, although the possibility of a catastrophe such as the complete destruction of a city centre must not be overlooked.

For the theory to work the actual experience over a number of years must be known and there must be a reasonable number of losses in each year. The author has taken the textile trade as an example and has used the figures for 1947 - 67 (21 years - 'N') taking the losses for year ('n') and correcting them for inflation.

The losses ('n' in number) in £x (building and contents but not consequential loss) vary from £10,000 upwards and the 'operational' variable is taken as $\log_e$ (called Z) since the logarithm is exponential. The maximum loss is the value of the building and contents plus an infinite amount to take account of fire spread beyond the building. In the early stages of a fire there is a great tendency for it to spread until 'Z' is reached but then, for large values of Z, the 'failure to spread' rate increases due to fire fighting and the exhaustion of natural forces contributing to fire spread. The parameter a_n is the value of the intensity function at the characteristic largest loss value b_n. The cumulative distribution function, F(Z), denotes the probability that the loss is less than or equal to Z.

The author has estimated that the largest fire in the textile industry (at 1947 prices) will be £1 M within the next 5 years (before 1973). Only drastic changes in fire protection or fire fighting could alter this. Also, a fire of £1.5 M (at 1947 prices) will not occur within 59 years, so any protection envisaged on this basis would suffice for the next 38 years (59 minus 21). These figures are, of course, only applicable to buildings where the values at risk are at least as high as the figures quoted.

The actual period of planning would depend upon the expected life of the building and of the protection. The life of an industrial building has been estimated to be about 40 years.

The cost of protection on this scale would be enormous so protection against losses less than the largest must be considered as practical, thus leaving, as it were, the extremely large losses to continue to arise but at less frequent intervals. Planning fire protection measures on the basis of the largest values may not be economically feasible and, therefore, something less extreme (unlike the flood analogy) has to be considered such as, say, a maximum loss of say £0.5 M. Extremes are not distributed normally, nor are the statistics derived therefrom but research in this direction is likely to yield practical and useful results.

If the parameters a_n and b_n could be found for each group of buildings with similar fire hazards, they would serve as indices of fire risks for planning protection and fire fighting on a national scale, and in forecasting the expected total loss in a particular area. It would also be possible to predict the length of time that fire protection measures in any one building would be expected to guard against a loss above a certain amount. The author hopes also to be able to show the effect of protective measures, such as sprinklers, in reducing the size of fire losses.

AUTHOR INDEX

(The numbers in the index refer to the numbers of the F.R. Notes)

SUBJECT INDEX

(The numbers in the index refer to the numbers of the F.R. Notes)