Fire Research Note
No 1064

COLLECTED SUMMARIES OF FIRE RESEARCH NOTES AND BRE/FRS CURRENT PAPERS - 1976

by

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FIRE RESEARCH NOTE NO 1064

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L C Fowler

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

Department of the Environment and Fire Offices' Committee
Joint Fire Research Organization

Synopsis of FR Note No 988

GAS EXPLOSIONS IN BUILDINGS

PART V THE MEASUREMENT OF SOUND LEVELS AND PRESSURES OUTSIDE A VENTED GAS EXPLOSION CHAMBER

by

R N Butlin and C P Finch

As part of the research programme on the venting of gas explosions in buildings using the 28 m^3 (1000 ft^3) explosion chamber at Cardington (see synopses for FR Notes 984 and 985) it is necessary to measure the pressures developed outside the compartment and to measure the sound levels. The pressure measurements are required to enable predictions to be made of the effect of pressure waves on nearby property and to establish the relevance of pressure differentials on the surfaces of any building in which a vented explosion may occur.

The external pressures are measured by using quartz piezo-electric pressure transducers secured, in a collar of flexible foamed plastic as a vibration damping medium, to a steel bar cast into a substantial concrete base. To avoid any radiation effect the transducers are fixed with the face at right angles to the explosion chamber vent and about 9 m and 18 m therefrom.

The sound produced by an explosion is of short duration (1 to 1000 milliseconds) and can be measured and recorded by using impulse sound level meters and suitable microphones. The microphones are placed about 1 m from the ground at distances of 18.3 m and 36.3 m from the face of the explosion chamber and the meter characteristics are such that the recorded sound is similar to that detected by the human ear.

The transducers and meters were frequently calibrated as described in the Note which includes photographs of the apparatus and examples of oscilloscope records of the pressure and sound levels.

Synopsis of FR Note No 1004

PRODUCTION OF GAS LAYERS FOR LARGE-SCALE GAS EXPLOSION STUDIES PART I. PRELIMINARY INVESTIGATIONS

by

R N Butlin

The research work being carried out by the Fire Research Station into the explosion of layers of flammable gas, which may or may not contain air, has involved experiments on the method of formation and the composition of these layers in the 28 m^3 (1000 ft^3) explosion chamber at Cardington (see synopses for FR Notes 984 and 985).

Various exploratory experiments using buoyant natural gas/air mixture established that, by using two box type diffusers to discharge the gas upwards just below the ceiling of the chamber, an acceptable uniform horizontal layer distribution was obtained. Therefore sampling probes placed centrally down from the top of the chamber could be used to measure the depth of the whole layer below the ceiling. By placing the probes at close vertical intervals a detailed study could be made of the gas/air layer itself and the diffuse nature of the interface between the layer of gas/air mixture and the air below it.

Numerous experiments were then carried out with gas concentrations of about 8, 10 and 12.5 per cent natural gas in air and also with 100 per cent natural gas. It was found that there was a diffuse layer about 0.5 m deep separating the introduced gas/air mixture from the air in the explosion chamber and that this was particularly marked when natural gas alone was used. Such diffusion could be caused by air entrainment and mixing, by convection, or by molecular diffusion, but the first two factors were unlikely to be important in the circumstances of these experiments. The molecular diffusion was therefore examined further and was found to be the most important factor in the production of the diffuse interface. A filling rate of 0.9 m^3/min produced less diffusion than a slower rate of 0.45 m^3/min.

The layers formed by the introduction of flammable gas/air mixtures were found to be reasonably stable for periods of up to 10 min after the gas flow had stopped and attention will be paid to means of improving the separation between the layers in the main explosion programme.

Synopsis of FR Note No 1013

THE ASSESSMENT OF SMOKE PRODUCTION BY BUILDING MATERIALS IN FIRES
PART 4. LARGE SCALE TESTS WITH WALL LINING MATERIALS

by

P R Watts and revised by Barbara M Goldstone

Experimental work at the Fire Research Station appeared to suggest that there might be a real difference between the quantity of smoke produced by burning lining materials on a large scale and that produced in a small scale laboratory test such as on the Fire Propagation test apparatus. Consequently, a series of experiments was arranged in order to investigate the problem.

The lining materials selected for examination were expanded polystyrene, plasterboard, heat resistant laminate and glass reinforced polyester resin which were all classed as 0 under the Fire Propagation Test, and wood fibre insulating board which had been classed 4. When the Fire Propagation Tests were done, all the smoke produced was collected in the laboratory compartment which had a volume of 18.8 m^3. The smoke was mixed uniformly by fans and its optical density was measured.

For the large scale comparative tests, sheets of the lining material were fixed to three sides of an open fronted steel framed compartment (like a telephone box without a door) and the total exposed area of the lining was 8 m^2. The ceiling was of asbestos. Inside the compartment and at the foot of each of the three sides were metal trays containing methylated spirit which produced no smoke and was used for ignition. A fourth tray of spirit was placed on the floor a little way from the compartment and this was burnt in each experiment in order to induce a flow of gases, dilute the smoke and make its measurement easier.

The test box or compartment was placed on the floor to the rear of the brick fire compartment of the large scale "arcade" building described in FR Note No 856 (see synopsis) and the smoke from these tests spread freely into the "arcade" where the optical density measurements were made.

The note contains a full description of the experiments together with tables and graphs of the results.

The range of optical densities measured for the materials tested was very large - GRP produced the most and polystyrene the least smoke. It was found that both the large-scale and the Fire Propagation tests gave broadly similar values for the materials producing most smoke but that there were big differences when only little smoke was produced. This discrepancy could be partly corrected by adjusting the results according to the proportion of material actually burnt and this was less than total in the large-scale tests on the better materials. It is concluded that smoke measurements are easier to make if all the smoke is collected in a given volume rather than by continuously monitoring the smoke in a flowing gas layer.

Subject to confirmation from possible future tests it is suggested that the Fire Propagation test method may be a suitable standard for determining smoke production from interior wall lining materials.

Synopsis of FR Note No 1037

PERFORMANCE OF A TWO ELEMENT CRIMPED RIBBON FLAME ARRESTER

by

Z W Rogowski and Ann I Pitt

The most common form of flame arrester made and used in the UK consists of a straight and a crimped metal ribbon wound around a central core and encased in a suitable metal housing. Only one element is used in each arrester assembly and its performance is dependent on the crimp height and the ribbon width.

In Germany the construction and design of these flame arresters is different and it is customary, for some reason, to use two or more 1 cm thick arrester elements with a universal crimp height of 0.7 mm and with the crimp shallower than in the UK arresters. There are mandatory tests in Germany before arresters can be approved for industrial use and experiments have been carried out at the Fire Research Station on one such approved system, consisting of 2 elements, each 1 cm thick, in order to evaluate the arresters' ability to extinguish moving flames and the resistance to flash-back.

The specimen tested was fitted to the end of a long horizontal 153 mm diameter steel pipe, sealed at the other end, which was filled with a flammable gas mixture. The mixture passed through the arrester and also filled a plastic sleeve fitted over the arrester assembly.

The mixture in the pipe was then ignited to see if the moving flames of the explosion were transmitted through the arrester to the flammable mixture in the plastic sleeve.

For the flash-back tests the arrester elements were fitted to the top of a similar but vertical steel pipe about 1 m long which was then filled with a flammable gas mixture. The gas escaping through the arrester was ignited in order to see if, within 30 min, an explosion occurred within the pipe.

It was found that a double element arrester performed as well as a single element of the same thickness in preventing the moving flames in the horizontal

pipe from reaching the gas in the plastic sleeve. However, in the flash-back tests the performance of a double element arrester was inferior to that of a single element arrester. The reason for the better performance of the single element is not clear and further evidence would be required before any conclusions could be drawn.

The Note contains tables and graphs of the results and some photographs of the test equipment.

Synopsis of FR Note No 1042

THE DEVELOPMENT OF AN IMPROVED DRY POWDER - FIELD TRIALS

by

P F Thorne and D M Tucker

Previous research had indicated that any improvement in existing dry powder compositions could only be achieved by modifying the particle size distribution of the powder unless a new chemical could be devised. Subsequent laboratory experiments suggested that mono-ammonium phosphate with a particular particle size could be more effective and this Note contains a report on fire tests on Class A and Class B fires using such a powder in a standard 25 lb (11 kg) extinguisher.

Two forms of experimental powder were used. One, called graded experimental powder, was prepared by size classification of a standard mono-ammonium phosphate and contained a siliconised silica flow additive and the other was prepared by a milling process, the powder subsequently undergoing a surface silicone treatment.

The draft European Standard was used for the Class A fires and the standard circular CENTRI fire with AVGAS fuel for the Class B fires. A commercially available ABC powder was also used for comparison with the Class A fires, and previous experience with standard dry powders on Class B fires was available for comparison.

The Note contains tables and graphs of the results. It was found that the experimental powders were more effective on Class B test fires than an exceptionally fine standard sodium bicarbonate dry powder and that it was comparable to a typical available general purpose ABC powder for the extinction of Class A test fires.

Synopsis of FR Note No 1043

DRAG REDUCTION IN FIRE HOSE
TRIALS AT FIRE SERVICE TECHNICAL COLLEGE 1974

PART 2 ANALYSIS AND APPLICATION OF RESULTS

by

P F Thorne C R Theobald and P Mahendran

The reduction in friction losses in fire hose by the use of the drag reducing additive polyethylene oxide (PEO) in slurry form (known as Rapid Water Additive) has been investigated in numerous trials which have been described and discussed in FR Notes Nos 1033 and 1036 and in Current Paper 70/75 for which summaries have been issued. The practical applications of drag reduction in fire fighting operations are discussed in detail in this Note.

The slurry can be injected into the suction inlet of the pump but the present commercial injection system has certain disadvantages in that it will deliver the slurry only at one of a number of pre-selectable rates so that the additive concentration does not vary directly with the flow rate. Injection equipment providing a constant concentration of additive even at the lowest flow rates would be necessary before realistic assessments could be made with hose-reel hose of 19 mm bore which is frequently used by the Fire Brigades in the UK for small fires. Hose of 44.5 mm ($1\frac{3}{4}$ in), 70 mm ($2\frac{3}{4}$ in) and 89 mm ($3\frac{1}{2}$ in) is also used and the particular problems related to each size of hose and nozzle outlet are discussed in detail and equations have been derived for the calculation of pressure losses.

The problem in the UK where 70 mm hose and nozzles of 15 mm to 22 mm are used are different from,for instance, those in the USA where, generally, 44.5 mm hose is used with 25 mm nozzles.

Various claims are made for Drag Reducing systems regarding reduction in pressure losses, flow rate increases and pump pressure reductions, increase in hose length and smaller bore hose for a given flow rate but, in general, only the claim that the hose length can be doubled and the flow rate maintained is generally true and this is an important factor in the USA. Other claims are only true under certain specific conditions.

In the UK some benefit from the use of PEO with 70 mm and 89 mm (relaying) hose might be gained but improvement in the nozzle design might be just as important. However, it is possible that 70 mm hose could be used instead of 89 mm hose for relaying since the use of the Drag Reducing additive could enable a flow rate to be achieved, in the smaller hose, equivalent to 96 per cent of that in the larger hose with plain water. On the other hand the pressure losses resulting from the use of the present standard instantaneous couplings, with their smaller bore, are considerable and if pressure losses due to the couplings could be substantially reduced the beneficial effect might be greater than that obtained by the use of the DRA, especially with 89 mm hose.

The Note contains various graphs of the test results showing friction factor against flow rate. One graph shows the height and throw from a 25 mm jet with both treated and plain water. The increased jet range with treated water might be equivalent to 'three storeys of a building' with a more coherent jet but, on the other hand, just as valuable an improvement might result from the use of modified nozzle profiles.

Synopsis of FR Note No 1044

THE EVALUATION OF AN IMPROVED METHOD OF GAS-FREEING AN AVIATION FUEL STORAGE TANK

by

P J Fardell and B W Houghton

Large storage tanks for aviation fuel, such as JP-4, have to be emptied for maintenance purposes at about yearly intervals if they are not epoxy-lined but less frequently if they are epoxy-lined. The traditional procedure for purging a tank of an explosive gas mixture, when it has been emptied as far as possible, is expensive and lengthy and is hazardous for an unpredictable time. An improved method has been sought and an experiment was carried out on an 'empty' tank, of 1 M imp gallon capacity, in the shape of a horizontal disc 32 m in diameter and 5.6 m high covered with concrete and earth. The tank was lap welded and the bottom undulated so that, although 'emptied', pockets of fuel still remained in low spots. The tank had very limited access through three openings in the top and gas freeing was therefore very difficult.

The whole operation started on a Tuesday and ended on the following Monday. During the day-time two compressed-air operated venturi-type air movers were installed in each of two openings, one blowing air in and one drawing it out at 35 m^3/min (1200 ft^3/min). A compressed-air operated portable pump removed most of the residual fuel although the suction pipe had to be fitted with a fish-tail scoop to remove the last puddles of fuel. At night time and at the weekend canvas wind sails were used in the openings, one as a scoop to deflect air into the tank and the other as an eductor tube.

Frequent tests were made for flammable gas in the atmosphere in the tank using three types of portable detectors and, also, samples of the atmosphere were taken away for laboratory analysis using a gas chromatograph. It was found that the gas concentrations within the tank were brought down to below 25% LEL (lower explosible limit) within 2 days and the atmosphere in the tank was between the lower and upper explosible limits for a much shorter time than when using the traditional procedure. Further, the pumps could remove most of the residual fuel before the operators entered the tank for final clearing of the puddles of fuel.

The experiment showed that it was easy to reduce the gas concentration to 4% of the LEL although 25% LEL is adopted by various authorities as the maximum before anyone can enter a tank. The decreasing gas concentration could be readily monitored but instrumental errors in the portable detectors should be previously calculated and allowed for.

Previously water has often been used to 'float out' the residual fuel and the new system avoids the resultant problem of disposal of the contaminated water. The new technique requires adequate pre-planning and operation by trained staff but it is much quicker and more controlled than the traditional method of gas-freeing.

Synopsis of FR Note No 1045

A 50 LITRE PER MINUTE STANDARD FOAM BRANCHPIPE

by

S P Benson and J G Corrie

It is the intention eventually to design a 200 l/min foam branchpipe suitable for the fire service but as an interim step a 50 l/min foam branchpipe has been constructed and the design is a development from the 5 l/min branchpipe described in Fire Research Note No 970 (see synopsis). This medium sized branchpipe could be used for experimental fires and also for the discharge nozzle attached to a 19 mm ($\frac{3}{4}$ in) dia hose reel should foam be required from a fire appliance hose reel.

This 50 l/min foam branchpipe has an overall length of about 0.6 m (without valve and coupling) and consists of an aluminium alloy tube 5.7 cm dia and nearly 50 cm long with two half round baffle plates fitted towards the discharge end of the tube. At the valve (induction) end of the tube there is a filter disc with 29 holes and then an orifice plate with 3 holes of about 4 mm dia producing three converging jets. At this point there are 8 air holes in the tube so that air is induced into the foam liquid stream before it travels up the tube, past the baffle plates, and is discharged at the nozzle end. At the nozzle there is a cone shaped dispenser fixed co-axially in the centre of the outlet. The design of the branchpipe is easily defined and the apparatus is simple to reproduce. Variations could be made in the components to suit particular circumstances if the branchpipe was brought into active service.

Performance tests were carried out with a prototype branchpipe and some 9 different protein, fluoroprotein, fluoro-chemical and synthetic foams were used and comparisons made with the performance using the 5 l/min branchpipe as regards foam expansion, shear stress and 25 per cent drainage time. The configuration and dispersal of the foam jet was found to be satisfactory when the branchpipe was used at a 15° elevation. Mainly, a 4 per cent protein A1 solution at 7 or 8 bar discharge pressure was used for assessing the performances and for providing an example of a suitable specification. The branchpipe could serve as a defined standard for conducting experimental fires of about 10-17 m^2 size which would be representative of many spillage fires.

The Note contains drawings of the branchpipe, some photographs and graphs of the performances in the various tests.

Synopsis of FR Note No 1048

THE INHALATION TOXICITY OF POLY-VINYL CHLORIDE PYROLYSIS PRODUCTS

by

P C Bowes J A G Edgington and R D Lynch

Investigations into the hazards of smoke and toxic gases from burning building materials has now been extended to include a limited study of the toxic effects on animals of hydrogen chloride gas produced from the pyrolysis of poly-vinyl chloride (PVC) in the presence of carbon monoxide which is generated when wood burns. Large scale laboratory tests have previously been carried out in the special test rig in the Models Laboratory at FRS using wooden cribs only (FR Note No 1015) and wood and PVC (FR Note No 1030). Following these earlier tests, experiments were carried out at Porton Down on rats and guinea pigs to determine the toxicity of carbon monoxide, in particular, produced from the combustion of plywood (FR Note No 1040).

These experiments at FRS and Porton Down showed that carbon monixide was the only hazardous gas released, in significant amounts, from the burning of plywood but that the presence of about 100 kg of rigid PVC in a wooden crib or a PVC lining to the corridor of the test rig produced enough hydrogen chloride to be a hazard to life.

In the present FR Note there is a report on a series of experiments, also using rats and guinea pigs, to determine the toxic effect of a mixture of carbon monoxide (CO) and hydrogen chloride gases (HCl) or of HCl alone. The same equipment involving a modified Fire Propagation Test apparatus and a 10 m^3 chamber as described in FR Note No 1040, was used and the material under test was hardboard faced with rigid PVC. It was clear, however, that for some reason, much of the available HCl in the PVC was being lost and, therefore, HCl gas was introduced into the chamber from a cylinder to restore the HCl concentration to levels which had been observed in the large scale fire tests.

After each specimen had been burnt the oxygen concentration was restored to 21%, to remove the effect of oxygen deficiency, and the temperature of the chamber was allowed to fall to near ambient before the animals were introduced for 30 min periods. Those animals which did not die were studied for a further period after that.

The effect of each gas or a gas mixture on rats was somewhat different from that on guinea pigs but high concentrations of HCl caused damage to tissues of both. Apart from this the most significant result from these trials was that the presence of HCl can increase the death rate due to the CO but that this is important mainly at concentrations of HCl which are likely to be lethal when present alone. This effect was most marked with guinea pigs which survived exposure to CO alone.

Broadly speaking it seems that, in practice, fire gases containing both HCl and CO at the concentrations experienced will be highly aggressive and probably more lethal than when HCl is absent.

Further, the presence of the highly irritant HCl gas may prevent some people from reaching escape routes in the early stages of a fire when there would otherwise be relatively harmless fire gases and smoke. Also, survivors may suffer long term or even permanent injury from high concentrations of HCl gas and this aspect of the problem requires further study as does the variation in the concentration of the gases as the fire develops.

Synopsis of FR Note No 1049

AN EVALUATION OF HAND PORTABLE FOAM TYPE FIRE EXTINGUISHERS

by

J C Pusey and D Prater (Department of the Environment)
and J G Corrie (FRS)

A series of over 200 fire tests was carried out at Cardington in order to investigate the relative efficiencies between Defence Standard type 9 litre extinguishers containing chemical foam, and those containing mechanical foam consisting of portein, fluoroprotein or fluorochemical foam liquids. European CEN Standard (CENTRI 2-2) 313 E tray fires were used ranging from size 21B (0.66 m^2) to 144B (4.5 m^2) and the flammable liquids were Avgas (petrol), Avtur (kerosine), White Spirit and Diesel fuel. Control and extinction times were recorded and these are shown in tabular and graph form in the Note. Tests were duplicated and the same operator was employed for every test. The time taken to discharge each extinguisher was 76 s for the chemical type and 52-54 s for the mechanical type.

It was found that the petrol was the most difficult fuel to extinguish, and diesel and white spirit the easiest. The tests showed that the mechanical foams had control and extinction times superior to those of the chemical foam, which conformed to Defence Standard 42 and consisted of sodium hydrogen carbonate and aluminium sulphate. Of the different foam liquids used fluorochemical was the most effective, followed by fluoroprotein, with protein the least effective. However, a specially designed nozzle might have improved the performance of the less effective foam liquids.

The comparisons revealed by these test data should be useful when considering the type of portable foam extinguisher to use in a particular situation.

Synopsis of FR Note No 1051

A COMBINED OVERALL AND SURFACE ENERGY BALANCE FOR FULLY-DEVELOPED VENTILATION-CONTROLLED LIQUID FUEL FIRES IN COMPARTMENTS

by

M L Bullen

Extensive research efforts into fully developed compartment fires, based on compartments of various shapes with different window openings, have mainly assumed that the burning rate is proportional to the air in-flow or ventilation. This is an overall trend in the results of large numbers of experiments using wood cribs as the "fire" source, and much of the scientific information so far obtained has been related to this cellulosic type of fuel.

Plastics materials are now becoming increasingly important in fully-developed fire situations and since these materials have a much wider range of properties than wood there is a need to relate the behaviour of a fully developed fire to the fundamental properties of the fuel. As part of this research work this note presents an outline of a theoretical energy balance for a liquid fuel fire in a compartment, and a computer program for simulating this type of fire is described and analysed.

Two of the fundamental combustion properties of a fuel are its heat of combustion (per unit mass of air for a ventilation controlled fire) and the latent heat of evaporation or volatilisation (including heat required to raise the fuel to the volatilisation temperature). This note describes a theoretical heat balance for a compartment fire with a simple liquid fuel tray fire and it discusses, in considerable scientific detail, all the problems involved including (1) the effect of these fuel properties on burning rate and compartment temperature, (2) the relative importance of each of the compartment material constants(walls, fuel bed and ventilation opening), and (3) the effect of compartment shape and scale, on fire behaviour. The burning rate of a range of hypothetical fuels is compared by considering the energy or heat balance of a 3 m x 3 m x 3 m compartment with a single window in one wall.

The heat balance is also evaluated for compartment shapes and scales as used in the CIB research programme (see FR Note 923) so that comparisons can be made. In the CIB experiments wood cribs occupying about 70 per cent of the floor area were used.

With a liquid fuel area of 25 per cent of the floor area agreement with the CIB data is quite good, with a few exceptions, indicating that the energy balance can reasonably predict the behaviour of ventilation controlled fires. It is therefore possible to investigate the effect of different non-cellulosic fuels on the behaviour of compartment fires. The affects of shape and scale on the burning rate can also be predicted moderately well.

Synopsis of FR Note No 1052

GAS EXPLOSIONS IN BUILDINGS, PART VI. REMOTELY CONTROLLED GAS SAMPLING PROBE AND CLOSURE VALVES FOR A GAS EXPLOSION CHAMBER

by

I G Buckland, R N Butlin and D J Annable

This Note describes a new gas sampling probe system which has been designed and constructed at the Fire Research Station for use with the 28 m^3 (1000 ft^3) experimental explosion chamber at Cardington. The experimental work and some of the equipment involved has already been reported upon in FR Notes Nos 984, 985, 986 and 987 (see synopses).

The probe consists essentially of a hollow stainless steel cylinder of 57 mm diameter and 1.66 m in length, fitted vertically above the centre of the chamber and supported by a mast structure. Inside the cylinder are six stainless steel gas sampling tubes which are spaced radially and at 300 mm vertical intervals. The whole assembly can be lowered into the chamber to the required level, through a gland in the chamber roof, by a combined pneumatic/hydraulic system. The hydraulic (oil) part of the system actually moves the probe so that the pneumatic oscillations do not affect the probe which is withdrawn before each explosion in case it causes turbulence and distorts the explosion pressures.

The movement of the probe is remotely controlled and its position is monitored, and the pneumatic power now available at the chamber is also used to operate the gas valves which were previously operated manually.

Various photographs and diagrams of the gas sampling system and the valves are included in the Note.

Synopsis of FR Note No 1054

ESTIMATION OF MAXIMUM EXPLOSION PRESSURE FROM DAMAGE TO SURROUNDING BUILDINGS EXPLOSION AT MERSEY HOUSE, BOOTLE - 28 AUGUST 1975

by

R N Butlin

In August 1975 an explosion occurred in a ground floor flat in the NW corner of a 16 storey block of flats in Bootle called Mersey House and it caused extensive damage to windows in other blocks of flats, one 50 m to the SW and another 60 m to the west of Mersey House. Some window damage was also caused to private property more than 100 m to the NW of Mersey House. The Fire Research Station examined the damage to the surrounding property with the object of assessing the maximum explosion pressures in the damaged flat, and, hence, the quantity of natural gas involved in the explosion. This Note contains brief details of the damage, discusses the problems involved and makes certain assessments of the explosion pressures involved.

In assessing the maximum pressures produced by the explosion in the Mersey House flat, which was completely wrecked, use is made of the knowledge gained so far from the research work on the 28 m^3 single chamber explosion compartment at Cardington, from theoretical work already available and from other recent experiments at the Fire Research Station and elsewhere using window glass similar to that in the damaged flats.

A basic assumption is that, with a vented gas explosion, if the pressure at a threshold distance of, say, 9 m is known, then the pressure in the compartment can be calculated. Beyond this threshold distance the pressures reduce linearly ie. doubling the distance will halve the pressure. In the 28 m^3 compartment tests the maximum pressure of 11 kN/m^2 in the compartment is about three times that at 9 m.

It is oncluded that the maximum pressure in the flat, estimated from the damage to surrounding property, was between 46 and 82 kN/m^2 (6.5 to 11.5 lbf/in^2) or, based on the best available equation (C Yao), was 21 kN/m^2. Damaged structural parts of the flat itself might have provided a more accurate basis of assessment. The natural gas leaked out in the kitchen of the flat and spread to the lounge and elsewhere, forming a layer under the ceiling under which the occupant could have moved about until some source of ignition caused the explosion. The violence of the explosion and speed of flame propagation would depend very largely on the turbulence caused by doorways and other obstructions in the flat and on the speed of any explosion relief such as a breaking window. This relief would have to operate within, say, 300 m sec of ignition.

The effect of turbulence is most important since a maximum pressure in an empty single compartment might be only 10–20 kN/m^2 compared with the above mentioned values estimated for this incident and a programme has been commissioned by FRS for a test rig with obstacles and restrictions in order to ascertain the contribution which turbulence makes to explosion pressures.

The Note contains photographs of the flats and of the damage to the flat and the floor above.

Synopsis of FR Note No 1055

MEASURING THE SHEAR STRESS OF FIRE-FIGHTING FOAMS

by

J G Corrie

The fluidity of fire-fighting foams having an expansion of from 4 to 14 to 1 affects the rate at which a foam will spread over a fuel surface and extinguish a flammable liquid fuel fire. For many years torsional vane viscometers have been used to measure the shear stress of this foam in accordance with the UK Defence Standard 42-3 and this measurement has been used to assess the fluidity of the foams. After prolonged use the instruments required replacement and the opportunity was taken to consider possible modifications in the design in order to improve the mechanical operation and their ability to assess the shear stress of new foams with lower shear stresses, and to provide a more fundamentally correct measurement. With foams containing complex molecules the shear stress is not directly proportional to the rate of shear as it is with liquids such as water and it cannot be used, therefore, to determine the viscosity. The instrument does, however, act as a shear stress meter which can provide a comparative measurement for different foams.

The Note contains a very detailed description of the three main types of viscometer arrangements and of the many experiments carried out to determine the performance of each and the advantages and disadvantages of variations in the design and operation. The basic principle is that a vane or solid cylinder suspended, in a sample pot of foam, at the end of a torsional wire is slightly rotated out of its neutral position by the relative rotation of the foam. Either the vane or the pot of foam can be rotated and the amount of twist in the wire provides a measurement of the shear stress characteristic of the foam although not of any fundamental property of the foam since the instrument's own characteristics also affect the measurements.

The conclusions reached are that a modified viscometer similar to that which has been in use until now is still the most suitable but that the sample pot should be rotated, and not the wire, so that the continuous shear can be read from a stationary pointer and scale at the front of the instrument. A separate FR Note No 1059 provides details of the construction and operation of this improved viscometer which can be referred to as the 'Fire Research Station Foam Viscometer'.

Synopsis of FR Note No 1056

A 200 LITRE PER MINUTE STANDARD FOAM BRANCHPIPE

by

J G Corrie

Foam branchpipes of 5 and 50 l/min have been described in FR Notes No 970 and 1045 respectively (see synopses) and, as forecast in the latter Note, a 200 l/min branchpipe, based on the earlier studies, has now been developed and is described in this Note. This larger size is suitable for use as a precisely defined standard for experimental fires and could be modified for general use by the fire service.

The prototype of the 200 l/min version was constructed by scaling-up the 50 l/min model and could be modified in various ways in order to assess the effect of changing the orifices, the length and configuration of the 76 mm dia foam making section, the diameter and configuration of the outlet nozzle, the type of baffles and the size of the air inlet holes. The Note has a photograph of the various baffles, cones etc tested and also full details and drawings of the final version. This version consists of a hose coupling and ball valve leading to a tube about 52 mm in dia and about 250 mm long containing two orifice plates and 6, 19 mm dia air inlet holes. This tube is attached to the 76 mm dia foam making section which is 450 mm long with a nozzle 50 mm in diameter and 82 mm long. The prototype was made in brass but production models could be made of light alloy.

The branchpipe was fully tested with various types of foam liquid and comparisons were made with six commercially available branchpipes, and most tests were done at a pressure of 7 bar. Tables and graphs show comparative details of the tests. The branchpipe is simple to construct and it produces foam with physical properties superior to the foam from branchpipes in general use, although further improvements are possible, especially in making the foam quality independent of the operating pressure and in making the foam dispersion conform to any preferred characteristics determined by practical experience. The apparatus could also be adapted to discharge at 150 l/min and so extend the range of application rates for experimental fires.

Summary of Current Paper No 95/75

EVACUATION OF BUILDINGS - SOME EFFECTS OF CHANGES IN PERFORMANCE STANDARDS

by

S J Melinek and R Baldwin

Present Building Regulations dealing with the evacuation of people from a fire compartment or the 'fire' floor and floor above assume an evacuation time of $2\frac{1}{2}$ min. An important factor in providing the necessary facilities is the width of the staircase(s). The problem is mainly relevant to multi-storey buildings with high population densities such as shops and offices. A mathematical equation has been derived to enable the staircase width to be calculated so that the staircase can provide an adequate safe area for evacuation purposes. The calculations are based on the present data available on crowd movement.

Based on the $2\frac{1}{2}$ min evacuation time from two floors the cost of the exits is about $1\frac{1}{2}$ per cent of the rentable value of the building or about £6 pa per person. If enough standing space could be provided on the staircase(s) for all the occupants the costs would be 2.5 per cent of the rentable value or £10 pa per person. On the other hand with an evacuation time of 5 min for the evacuation of one floor only the figures would be 1 per cent and £3-4 respectively.

Fire statistics indicate that there have been only 50 fatalities in three years in buildings of 6 or more storeys but there could, of course, be a catastrophe at any time and any possible relaxations in the evacuation provisions will have to be dependent on the result of further research including an extensive study of the behaviour of people in buildings. This study is being carried out at the Fire Research Station.

Summary of Current Paper No 96/75

AN ANALYSIS OF EVACUATION TIMES AND THE MOVEMENT OF CROWDS IN BUILDINGS

by

S J Melinek and S Booth

Reference was made in CP No 95/75 to data available on crowd movement. In the present paper the crowd movement data is reviewed and particular reference is made to an exhaustive study carried out by K Togawa in Japan in 1955.

Crowd movement in buildings mainly concerns the movement along corridors, up and down staircases and through doorways, and the chance of panic can be reduced by the avoidance of bottle-necks, and the provision of safe areas, good communications and emergency lighting. Details are given of current information, and equations are provided for calculating rates of flow of people and the time taken to pass through an opening. It is concluded that the normal capacities per unit (metre) width of corridors and stairs are about 1.5 and 1.1 persons per metre per second respectively.

The existing standards for means of escape are also summarised, and an equation is provided for the calculation of the maximum number of people which can be evacuated to a staircase in a permitted time of 2½ min, depending on the staircase width and the number of storeys. A further equation is given for calculating the minimum time for total evacuation of a multi-storied building and some calculated times are compared with observed evacuation times for 11 office buildings. It appears that the actual times are likely to be about 2 min longer than the predicted values which ranged from 1.8 min for a 7 storey to 9.9 min for a 26 storey building and this is probably the result of people's delay in responding initially to an emergency alarm.

Summary of Current Paper No 98/75

THE PERFORMANCE OF A FOAM-SPRINKLER INSTALLATION ON SIMULATED OIL RIG FIRES

by

R A Young and J G Corrie

A series of 10 experiments was carried out in the Sprinkler Test Building at the Fire Research Station in order to investigate the effectiveness of a foam installation against a typical oil-spillage fire which might occur on a North Sea oil platform. An array of 6 foam sprinklers was arranged 7.1 m above floor level and each head was designed to discharge about 90 l/min (20 gal/min) of foam solution at a pressure of 7 bar (100 lbf/in^2). Both fluoroprotein and fluorochemical foam liquids were used in a 6 per cent solution and preliminary tests were done to determine the foam properties and distribution.

Two experiments were carried out using only trays of kerosine and the pre-burn time for all the experiments was from 30 to 60 s. In the other experiments obstructions were erected above the trays to simulate pipework and these consisted of steel drums threaded onto horizontal scaffold poles placed one above another, and staggered in some tests, the lowest line of drums being about 1 m above the trays on the floor and the top line about 2-3 m above the floor. For some experiments a fuel pipe line was arranged to discharge kerosine above the drums so that it cascaded over the drums and simulated a running fire from a fuel leak.

The paper contains numerous diagrams of the pipe arrays, tables of the results and some photographs.

It was found that both types of foams extinguished the tray fires, without obstructions, in a similar time but that fluorochemical foam extinguished the tray fire more rapidly when the trays were obstructed by the pipework array. Neither foam extinguished the running fire but dry powder extinguishers effectively extinguished this fire even whilst the foam was still being discharged.

All the experimental fires were extinguished quickly even when the building doors were left open to allow a draught but, of course, in practice higher wind speeds and more volatile fuels might be encountered. However, the test installation appeared to have a considerable reserve to offset more difficult fire conditions.

Further experimental work would be of value in order to assess the effect of wind, of different foam liquids on other fuels, and of foams produced from normal water sprinklers. The compatibility of water, dry powder, halon 1211 or 1301 in a dual agent system requires investigation as this might be available on an oil rig.

Summary of Current Paper No 4/76

FIRES IN SCHOOLS : AN INVESTIGATION OF ACTUAL FIRE DEVELOPMENT AND BUILDING PERFORMANCE

by

A Silcock and D M Tucker

Between 1965 and 1975 there have been about 28,000 schools in England and Wales and the number of major fires each year has progressively increased from 12 to nearly 70 so that now a large fire occurs each year in one of every 400 schools and the annual fire loss is nearly £7 M. The increase in the number of fires was mainly due to malicious ignition but the reasons for the size of the fires, especially in modern schools which number slightly less than a quarter of the total, was not so obvious although ceiling voids were clearly a major cause. The Fire Research Station, therefore, decided to carry out an investigation by visiting, as soon as possible after a fire, a number of large school fires.

Most of the 22 fires so far investigated related to local authority schools designed by a consortia of architects and 14 of these fires, at least 11 of which were malicious, are described in detail in this paper. There are tables showing the routes of fire and smoke spread for each fire and another showing brief details of the constructions. These tables are followed by a detailed description of the fire events and damage at each school, including a scale plan of the school. Apart from an examination of the fire damage, information was obtained from the fire brigades, eye witnesses, architects and the press and others.

The major single factor affecting fire spread was the presence of undivided ceiling voids but other means of fire spread were also important in most cases. The ceiling construction and behaviour in the fire were most significant and the ceilings were either of flaxboard or mineral or wood fibreboard. It is pointed out that a suspended ceiling does not have a fire rating under BS.476 : Part 8 in its own right but only as part of a roof or floor construction. It is emphasised however, that the method of fixing the suspended ceiling panels by means of a metal grid is important since the ceiling should remain in place as long as possible in order to protect the steel lattice beams, tops of steel columns or other floor or roof construction above. The methods of fixing the suspension grids and the arrangements for expansion joints are discussed in considerable detail. The unsatisfactory performance, where it occurred, of the suspended ceilings, which were in all but one of the 14 schools, was found to be associated with the following:

1. Grid exposed and not concealed within the panels
2. Restraint to the expansion of the grid by partition walls
3. Inadequate fixing of the ceiling panels to the grid
4. Ignition of material in the ceiling void
5. Uneven heating, grid distortion and malfunction of the expansion devices and fixing of light fittings to the grid
6. Badly designed panel layout and omission of panels in some places such as above a cupboard.

Limitation of the spread of fire and smoke could be achieved by sub-dividing the ceiling voids with barriers.

There is a full discussion of all the other relevant factors including the fire performance of the roofs, floors, partitions and doors. All the schools were roofed with bituminous felt or asphalt flat roofs with decks of plywood, wood, steel, woodwool or flaxboard. It was found that asphalt did not add significantly to a fire but that any bitumen added considerably to the fire although only after the room below was already well alight. In one case fire spread to adjoining rooms because the bitumen on the roof dripped down after the polystyrene insulation melted.

A closed door, unless the fire started near to it, was surprisingly effective as a fire stop even when it was of light construction.

The importance of early fire detection is emphasised and it is stressed that general site planning and layout could be improved, as could the general understanding of the fire hazards involved with modern forms of construction. There is a detailed discussion on the sub-division of ceiling voids, the protection of vertical cavities and ducts, fire venting to reduce lateral fire spread, and on the need for proper maintenance by qualified staff who should also be conversant with the fire hazards of non-traditional construction and materials.

The paper contains numerous photographs which illustrate the various problems discussed.

Summary of Current Paper No 11/76

THE BEHAVIOUR OF PEOPLE IN FIRE SITUATIONS: POSSIBILITIES FOR RESEARCH

by

D Canter and Rowan Matthews

This paper contains a very detailed review of the various factors affecting the behaviour of people in fire situations and has been prepared by two members of the Department of Psychology at the University of Surrey under an extra-mural contract. In order to plan future research it has been necessary to review the current knowledge of such behaviour and the assumptions already used in existing regulations, and to suggest ways in which the problem could be approached in the light of modern psychological research.

There are many variables which can have a bearing on the behaviour of individuals and these include the general attitude to fire, the degree of preparedness and the readiness to recognise the presence of fire, the subsequent actions and the width and other physical features of the escape route. The type of building and its occupancy can also affect people's attitudes and reactions.

The lines to be followed in future research could include examinations of actual fires, simulations, and field and laboratory experiments, interviews with firemen and information from people generally regarding their attitudes and experiences. It is emphasised that there should be a continuous review of all ongoing research activities and frequent consultations between researchers.

Summary of Current Paper No 13/76

THE MOVEMENT AND CONTROL OF SMOKE ON ESCAPE ROUTES IN BUILDINGS

by

A J M Heselden and R Baldwin

The provision of relatively smoke free staircases and escape routes is very important both for safety of life and for the fire brigade and the problem is particularly relevant to multi-storied buildings. The research work and investigations so far carried out are summarised and discussed in this Paper and reference is made, in particular, to FR Notes Nos 850, 889 and 958 (see synopses). Conventional smoke extraction systems for escape routes have short-comings and one solution to the problem lies in raising the pressure in the stairways slightly above that in the rest of the building from which the stairs should be separated by doors and lobbies.

Extensive studies of this system have been made in other countries such as France, Germany, Canada, Australia and the USA and in the UK pressurization systems have been built into or are planned for 37 buildings. A British Standard Code of Practice is being prepared. Not all the existing systems are satisfactory mainly on account of the inadequacies of the ventilating system and ducts and ill-fitting doors but suitable design factors have now been established together with practical over pressures and these are outlined in FR Note No 958.

The main mechanisms affecting smoke movement are the temperatures, stack effect, wind and mechanical ventilation and a computer program has been devised to provide answers to the air flow problems according to the various parameters which can interact with one another. As a result of this study it is hoped that it will be possible to assess the effectiveness of smoke control and to identify those parameters whose variability can be safely ignored and those which must be treated statistically. Further, it should be possible to indicate where future research should be concentrated.

Summary of Current Paper No 21/76

FIRE HAZARDS OF PLASTICS IN FURNITURE AND FURNISHINGS:
FIRES IN FURNISHED ROOMS

by

K N Palmer, W Taylor and K T Paul

The third and final year's work carried out by the Rubber and Plastics Research Association, and financed by the Home Office, for the purpose of comparing the fire behaviour of modern and traditional furniture and furnishings is described in this Paper. The two previous years' work was described in CP 18/74 and CP 3/75. This Paper contains a description of the fire compartment/corridor test building and of the arrangements for the various full scale fires and the results of the tests. There were eight simulated sitting/dining room experiments and ten tests on a variety of traditional and modern type suites of settee and armchairs. Four exploratory tests were carried out on simulated furnished bedrooms and a further five main tests after the best layout of bedding and furniture had been determined. There was also one experiment with a simulated modern hotel bar and two on an office, one being furnished traditionally and the other with modern equipment.

Various sources of ignition were used but generally there was a large ignition source such as a crib of fibreboard.

The Paper contains tables giving brief details of the fire experiments and the results including some information on the toxic gas concentrations. There are also over 90 photographs.

The conclusions are set out in some detail and these are summarised as follows:

1. Traditional sitting/dining room furniture was relatively difficult to ignite and when burning produced less smoke than furniture containing rubber or polyether foams and in nc tests did flashover occur whatever the ventilation.
2. Modern type furniture, in any price range, containing foam, generally ignited readily and burnt rapidly producing considerable smoke and enough heat to ignite cther furniture.
3. Modern furniture was improved considerably by the use of less flammable filling and covering material and by the provision of a flame-retardant interlining so that it behaved much like traditional furniture. The design could also affect the fire behaviour.

4. Traditional interior-sprung mattress beds smouldered and then burnt for some time but did not spread the fire and the highest rate of fire growth occurred when the blankets and sheets were heaped together but other furniture had to be close to become ignited.
5. Modern mattresses burnt relatively fast and any benefit from a less flammable foam was reduced if a flammable blanket was present, although a woollen blanket did improve the fire performance of a polyether mattress.
6. A modern style bedsitting room produced a severe fire and considerable smoke, and the large amount of furniture in the room was destroyed.
7. A modern style hotel bar fire resulted in the complete destruction of the closely arranged furniture and there was a similar result with a modern office suite. In a tradition style office, the fire was much less severe and not all the furniture became involved.
8. A match or something more severe, rather than a cigarette, was required to ignite a modern chair but when burning there was considerable smoke and a more rapid fire than with traditional chairs.
9. Polyether foam cushions with polypropylene covers could be ignited by a match and then burnt rapidly, and the cover could even melt and expose the foam.

Summary of Current Paper No 22/76

TOXIC PRODUCTS OF COMBUSTION OF PLASTICS

by

W D Woolley and M Raftery

This Current Paper contains a reprint of an article, published in 1975, which summarises briefly the research work undertaken at the Fire Research Station and elsewhere to study the problems of the toxicity of combustion products resulting from the pyrolysis and burning of plastics materials now being used increasingly in building structures and in their furnishings such as linings.

The toxicity hazards are summarised and reference is made to studies of the production and identification of toxic gases in laboratory-scale thermal degradation experiments, large-scale fire tests in the compartment/corridor test rig (FR Note 1015) and extra-mural research to assess the toxicity on animals (FR Notes 1035, 1040 and 1048).

A range of structural and furnishing materials has been examined, including PVC (FR Note 1030), PF laminate (FR Notes 851 and 852), and flexible PU foams (FR Note 1017) and an assessment has been made of the chief toxic products in addition to carbon monoxide.

Research on toxic gas production from plastics has required a considerable amount of fundamental work to evaluate the basic decomposition processes but this, together with the data from large fire tests, is beginning to provide information about additional toxic hazards of fire atmospheres resulting from the use of plastics in buildings. This information is needed by designers of buildings and furniture and by authorities who must assess the hazard in relation to traditional materials and, if necessary, control their use.

At present there is no legislation in this country which requires materials used in buildings, or their contents, to be controlled on account of their combustion toxicity. It will be necessary to develop agreed standard methods of tests and these are being considered by Standards Organisations in the UK and internationally. Test procedures are vital if control of materials is to be implemented and the present method of assessing materials will need to be

simplified by using small and medium scale tests with physical and chemical analysis supported, perhaps, by animal experiments.

Present day control of smoke movement by venting, extraction or pressurisation may also restrict the dispersal of toxic gases. These methods are not generally suitable for private dwellings but they may be of value in high rise buildings, shopping arcades or institutional buildings.

Summary of Current Paper No 39/76

PLASTICS IN BUILDINGS - FIRE PROBLEMS AND CONTROL

by

Barbara F W Rogowski

This Paper reviews the situation which has developed in recent times as a result of the introduction of polymeric materials into the construction and equipment of modern buildings. To a large extent these materials replace timber and other cellulosic materials, the fire performance of which varies much less widely and is more easily predicted than that of the wide range of plastics products now available as freely supported sheets and films, as composites with other materials and as individual components. Whilst many plastics materials produce more smoke and a greater variety of decomposition products than cellulosic materials, this is not true of all. By careful selection and use, and with some control through the Building Regulations, plastics materials may be used with safety and can contribute to the range of building products available.

Assessment of the fire performance of plastics products is based on standard fire tests such as BS 476, BS 2782, BS 3119 and BS 3210 but, of course, no scale tests can predict fully the performance of a material when incorporated in a structure. The Paper contains five tables which summarize the current knowledge on the various plastics materials and components now on the market.

Table 1 lists the uses of plastics for such purposes as windows, lights, roofing, ceilings, partitions and cladding, and against each are shown details of the polymers available, the technically appropriate tests and the extent of any legislative building control. Brief details are also given for complete buildings such as pleasure domes and air-supported structures.

Table 3 sets out the uses of composite plastics materials for surface application, as core or infill materials, and as homogeneous or distributed mixes with inert additives such as glass fibre or as aggregate in concrete, together with details of any appropriate tests and building control. Table 4 summarizes details of polymers available for use as pipes, ducts, frames (door or window), beams and fitted furniture etc, together with information regarding any appropriate tests and building control.

Table 2a lists the rigid plastics materials available in sheet form or as foam, together with details, where known, of the fire performance of each under BS 2782, BS 476 (Part 7 - Surface Spread of Flame and Part 6 - Fire Propagation). Table 2b lists the flexible plastics films and shows the results of flammability tests under BS 3119 and BS 3120 and under BS 2782.

It is emphasised that, in view of the wide range of plastics available, strict attention must be paid to the fire performance when specifying their use as part of a building fabric and fire tests may have to be carried out on the complete product exactly in the form in which it would be used. The fire performance of materials and, in particular, of plastics products in real fires may not follow the performance suggested by the laboratory tests and the Executive Board of BSI established, in 1974, a Co-ordinating Committee on Fire Tests to investigate the issues involved for the purpose of avoiding misunderstandings of fire test data which could lead to disastrous fires.

A general review of the major uses of polymeric materials in buildings was provided in CP 91/74 . The available tests and hazards were outlined and comments were made on the development of tests and on outstanding research problems.

Summary of Current Paper No 45/76

SMOKE HAZARDS IN COVERED MULTI-LEVEL SHOPPING MALLS: SOME STUDIES USING A MODEL 2-STOREY MALL

by

H P Morgan, N R Marshall and Mrs B M Goldstone

The problems of smoke extraction from multi-level shopping malls have been further investigated with the use of a 1/10 th. full scale model, made mainly of hard board and perspex, being a modified version of the model referred to in the initial report on this research work contained in CP No 48/75 (see Summary). This model is based on a composite of two similar shopping malls with two floors and a smoke reservoir above the upper floor, there being two large voids in the floor between the two levels. The 'fire' compartment to one side of and communicating with the lower floor contains three 1 kW convector heaters with provision for the introduction into the compartment of smoke from a generator. The 'fire' conditions in the 'fire' compartment, representing a shop, correspond to a full-scale 1 MW cool (ie sprinklered) fire.

Numerous experiments were carried out using the model and these are fully described and the results are discussed in this Paper. There are numerous graphs and diagrams, together with tables of the temperatures, smoke densities, extraction and air inlet rates and other relevant measurements. The scale of 1/10 th. has been chosen because scaling relationships are available to convert and extrapolate the results to full scale.

It is concluded that to maintain a head-height smoke free region beneath the smoke reservoir, in a mall having the geometry of this model, it is necessary to have a large vent area of more than, say, 40 m^2 for each reservoir, where the distance from the upper deck to the vent is about 10 m. For a full scale 5 MW fire an extraction rate of about 100 kg/s would seem to be necessary. Air should have free access to the mall through inlet areas twice the size of the minimum vent area. The inlet and vent areas could be varied in approximately inverse proportion according to a formula. About half of the air inlet area should open on to the upper level of the mall where the air should be allowed to reduce in velocity before reaching the smoke. This can be achieved by positioning a shelf or curtain with its inner edge set back about 3 m from the inlet(s) and 3 m above the floor.

Smoke spread beneath the upper floor should be restricted by curtains projecting down from the ground floor ceiling so that all smoke from the 'shop' is directed to one floor void, the perimeter of which should be, at most, about 30 m so as to minimise the perimeter of the rising smoke plume.

Smoke free conditions cannot be achieved with these arrangements particularly because air is entrained in the smoke plume rising through the floor void and this cools the deep smoke layer in the reservoir. This trouble might be cured if smoke could be ducted from the lower level to the reservoir and be prevented from passing through the void by hanging curtains from the void edges. Each mall level would then behave as a single-storey mall and research work on this idea has begun. Work on channelling the smoke directly from the 'shop' to the void edge will also be carried out on a modified model. Large-scale tests of all the systems would be desirable.

Summary of Current Paper No 50/76

THE USE OF AUTOMATIC SPRINKLERS AS FIRE SENSORS IN CHEMICAL PLANT

by

P Nash and C R Theobald

This Paper contains the text of a lecture given at a Symposium on "The technical lessons of Flixborough" at Nottingham University in December 1975. It describes simply the usual method of operation of a sprinkler as a result of convection currents ascending to and spreading under a roof or ceiling, or by flames from, say, an oil fire playing directly on the sprinkler or 'sensor'. This sprinkler-type sensor will operate within a few minutes when immersed in heated gases or in rapidly developing flames. However, when its operation has to depend on thermal radiation alone there may be a long delay and experiments have been carried out at the Fire Research Station to investigate the problem.

Both the glass bulb, favoured in the UK, and the fusible link type, favoured in the USA, were tested centrally in front of a 0.3 m square (1 ft x 1 ft) vertical radiant panel. The sprinklers were mounted vertically on a water pipe with the sensitive element on the horizontal axis of the panel at various distances so that the radiant intensities could be varied up to 12 W/cm^2. Some sprinklers were tested with one side of the yoke facing the panel and others with the yoke parallel to the panel. A graph shows the results of the tests.

It was shown that the soldered strut type of sprinkler was generally less responsive to radiant heat than the glass-bulb type but the position of the yoke arms, which tended to shield the sensor, did not affect the former type so markedly as the glass-bulb type. At an intensity of 1 W/cm^2 the operating times varied from 2 to 9.5 min but were only 0.7 to 1.7 min at 3 W/cm^2. At intensities lower than 1 W/cm^2 the time was much longer and at 0.48 W/cm^2 the glass bulb type with one side of the yoke facing the panel took over 47 min to operate. These points should be borne in mind when siting sensors in chemical plants.

Summary of Current Paper No 52/76

SPRINKLER SYSTEMS FOR SPECIAL RISKS

by

P Nash and R A Young

Sprinkler systems for special risks which are not covered by the requirements of the Fire Offices' Committee and other rules and codes are discussed in this Paper which was first printed in the Fire Surveyor in 1975. The risks which are considered to need some kind of special treatment are aircraft hangars, computer suites, cold storages, paper and carpet warehouses and off-shore drilling platforms. The protection for these and other similar special risks should be dealt with at the design stage and it is not sufficient to adapt an existing "standard" system.

The fire protection for the Concorde Hangar at Filton, Technical Block B and the British Airways '02' Hangar at London Airport is briefly described and reference is made to "under-wing" protection with floor mounted "pop-up" foam sprinklers, to deluge systems and fixed or auto-swing foam monitors, and to triggering detection devices. Reference is made to European practice and, in particular, to the HI Hangar at Charles de Gaulle Airport. Comments are made on the American NFPA Code and on the requirements of the FOC Rules for Extra High Hazard occupancies such as aircraft hangars.

The protection of computer suites by sprinklers, CO_2 or BCF, and detection devices is also reviewed and it is emphasised that different forms of protection are needed for the computer itself and for the areas containing data and records.

Problems related to the sprinkler systems in cold storages where special means have to be devised to deal with the low temperatures are discussed briefly as are the special hazards of paper storage which can be stacked vertically or horizontally. Carpet storage is also mentioned as requiring special treatment, in particular when deep shelving is used and this is a problem still being studied.

Brief comments are made on the protection of off-shore drilling platforms and reference is made to experiments recently carried out at the Fire Research Station using foam sprinklers to extinguish a floor fire below typical pipework from which flammable liquid was leaking and on fire. This work was described in CP No 98/75 (see summary).

Summary of Current Paper No 53/76

THE EXTINCTION OF AIRCRAFT CRASH FIRES

by

P Nash

This Paper contains a general review of the problems of aircraft crash fires and their extinguishment and it was first published in 'Fire Prevention' in 1976. About 70 per cent of aircraft crashes involving fire occur on an airfield and therefore can be dealt with by the airfield equipment. There are still many crashes outside an airfield although about 90 per cent of all crashes do occur within 6-4 km from an airfield. If all these crashes are to be dealt with by land-borne appliances the "survival time" of occupants before fire fighting can begin will have to be increased to at least 8 min for rescue to be effective. This time increase could best be achieved by the use of safer fuels although other measures would also help.

At greater distances from an airfield, airborne appliances are likely to be effective and a model of a proposed helicopter containing a foam making appliance is shown in sectional form in the Paper. Even so, for such an appliance to be effective up to, say, 24 km, the "survival time" would have to be increased to at least ten minutes.

The Paper discusses the properties and merits of the various low expansion foams (up to 30 - 1) available for use with fuels such as Avtur, Avtag, and Avgas and there are diagrams showing the comparative performances of protein, fluoro-protein, synthetic and fluorochemical foams as regards control time (to reach 1/10 th of the initial radiation), extinction time and resistance to burn-back. It is pointed out that much small and large scale research has been carried out at the Fire Research Station, in Europe and in the United States, and that the large scale work generally supports the findings of the small-scale research.

Medium expansion foams up to 200-1 have their uses but these are mainly confined to fires inside cabins and other enclosures and in situations where the foam can be poured onto the fire from close range. The discharge of such a foam from a helicopter is not likely to be successful but its use in this way may be worthy of trial to find out its possibilities and limitations. Brief comments are also

made on the use of dry powders, and inerting or inhibiting gases but since these are "transient" agents, that is, they are only effective whilst they are being applied, they are likely to be of most value in a supporting role. High expansion foam is really too light to be of any real value in such fires.

The Fire Research Station is developing a series of branch-pipes capable of producing well-developed low expansion foam with a good 'throw' and dispersion pattern. Aircraft crash fire appliances are now being greatly improved and a recent UK appliance has a roof mounted monitor capable of delivering over 60,000 l/min at say a 10–1 expansion over a range of 90 m with up to four side-lines delivering 9000 l/min. The foam application can last about 2 min and, by dispersing the foam efficiently a "maximum" size fire in a Boeing 747 (area involved is about 4220 m^2) could be controlled and extinguished. Low expansion foam of 10–1 is self-aspirating so that all the power in the water supply can be used to make good foam and project it to a satisfactory distance.

Summary of Current Paper No 62/76

FIRES IN RESIDENTIAL PERSONAL SOCIAL SERVICES BUILDINGS

by

S E Chandler

Data obtained from the reports of fire brigades during the years 1969–73 on fires in personal social services (PSS) buildings have been analysed in order to identify the circumstances leading to these fires and to estimate the probability of these fires involving life risk ie casualties, rescues, escapes and evacuations. These buildings are occupied by people needing special care such as old people, disabled, handicapped and children but they do not include remand centres and hospitals.

The Paper contains numerous tables relating numbers of fires involving life-risk to other factors. Tabulations show relations between factors such as place of origin, fire spread, time of day, source of ignition and the date of construction of the building. Details are also given of the method of extinction both before and after the arrival of the fire brigade. The 'life-risk' fires are related to the time of call and the place of origin, source of ignition, extent of fire and type of PSS building.

Fires in old people's homes rose from 62 in 1962 to 194 in 1973, during which time fires in all residential PSS buildings rose from 246 to 374. During this period there was an increase in the number of PSS buildings at risk. The analysis is discussed and some conclusions are reached. Since the buildings are staffed, some fire fighting action can be taken before the arrival of the brigade and it is suggested that smothering and buckets appear to be more successful than extinguishers. One half of the fires were out before the arrival of the brigade but more staff training might be beneficial. Possibly the installation of detectors in bedrooms would be worthwhile since more fires start there than in any other room and the risk to life there is greater.

Property damage in 1973 in all residential PSS buildings was about £730,000 and so, after allowing £50,000 for each death, an expenditure averaging about £1M annually could be justified in order to eliminate all these fires.

Summary of Current Paper No 66/76

SOME TRENDS IN FURNITURE FIRES IN DOMESTIC PREMISES

by

S E Chandler

This Paper contains a study of fires starting in furniture in dwellings during the years 1962-73 inclusive, with a detailed analysis for the years 1962, 1967, 1970 and 1972. The main purpose of the study is to assess the trends in numbers of fires, deaths and injuries, fire spread, sources of ignition, time of occurrence and estimated costs. The available information is displayed in graph and tabular form. The data are based on reports from the fire brigades.

The majority of these fires involved upholstery and bedding, and over 90 per cent were attributed to smokers' materials, electric appliances (mainly blankets and television sets), space heating or the activities of children or suspected arsonists. There has been a marked increase in the number of fires involving children and arson and also in the number of fatalities attributed to the effect of smoke and toxic fumes. Some of these increases may be partially due to more detailed reporting of fires. In general, clothing fires have decreased, probably as a result of flame proofing legislation and reduced open fire heating. Furniture and upholstery fires are now more likely to lead to deaths in both day and night time fires although furniture fires are not becoming relatively more frequent in dwellings. Also, upholstery fires are more likely to spread beyond the room of origin than fires involving bedding.

To assess the costs of these fires values of £1000 and £50,000 have been assigned to non-fatal and fatal casualties respectively. The material damage costs of furniture fires have been assumed to be £50 if the fires was confined to the item ignited, £300 if confined to the room of origin and £2000 if it spread beyond the room of origin. Using these values the total cost of the 11280 furniture fires in 1972 was £6.1M for material damage and £15.5M for the casualties, thus producing an average cost per fire of £1918 as compared with £1500 in 1962. There has been a slight reduction in the cost of non-furniture fires (eg clothing) since 1962 but the costs of all domestic fires have increased from £45M to £70M in the period 1962-72. Therefore, although the amounts involved for each dwelling are small there is an increasing trend. The amounts represent the money which could justifiably be spent on fire precautions and prevention in order to eliminate furniture fires.

Summary of Current Paper No 73/76

FIRE BEHAVIOUR OF FOAMED PLASTICS CEILINGS USED IN DWELLINGS

by

W A Morris and J S Hopkinson

In private dwellings of any height the ceiling below the roof is generally not required to have any fire resistance although there may be flame spread requirements as applicable to the exposed surfaces of rooms and the performance is assessed in accordance with BS 476 : Part 7. In the past, most ceilings have been of lath and plaster, fibre insulating board, plaster board or, perhaps, plywood but recently light weight insulating boards of polyurethane or polyisocyanurate, generally sandwiched between two layers of paper, have been used. The Fire Brigades have been greatly concerned about the amount of smoke produced in fires at premises containing these plastics boards and particular attention was focussed on the problem as a result of a fire in Andover in 1972.

As a result of this concern, and following preliminary smoke tests, DOE and the GLC, with the help of the London Fire Brigade, arranged for full scale tests to be carried out in the Models Laboratory at the Fire Research Station in order to investigate the smoke problem more fully and to determine the possibility of a fire in one room spreading to the roof space and then to an adjoining room via the roof space. One half of an existing laboratory rig was modified to provide a concrete block one storey building as a lean-to against a 4 m high block wall, the building being divided into two rooms each 2.75 m x 2.67 m and separated from each other by a block wall to eaves level. One room was the 'fire chamber' and a door led from this room to a hall space in the other half of the existing rig. The rooms each had a window and other ventilating control openings, and the lean-to roof was constructed of timber and steel with timber sarking and corrugated iron cladding which had gaps at joins to provide simulated roof leakage. The gable ends were closed with removable asbestos boards. Ventilation gaps in the roof construction which were not required were filled with mineral wool but there was a free opening between the roof spaces above each room.

For each of the six main experiments the type of ceiling being tested was the same in each room. The ceiling boards were all 12.5 mm thick and in the first two experiments bedroom type furniture providing a fire load of about 4 lb/ft^2 was used. In the other four tests a timber crib giving a fire load of about 3.5 lb/ft^2 provided the 'fire'. In the first two 'furniture' tests, one ceiling was plasterboard with 50 mm fibre-glass quilt above and the other was of polyisocyanurate foam with no extra insulation. In the other four tests, with wooden cribs, another plasterboard ceiling was used and also ceilings of fibre insulating board, polyurethane foam and polyisocyanurate foam. All the ceilings were finished with an underside plastics based plaster coating applied by brush (PCF).

The Paper contains a full description of all the tests and instrumentation together with details, graphs and summaries of the results. There are some photographs of the rig and the fires.

In all the main experiments the fire penetrated the ceiling of the 'fire chamber' in times varying from 6½ to 30 min and after doing so it quickly involved the combustible materials in the roof space. The fire then penetrated downwards into the adjoining room in all cases except where plasterboard was used and this ceiling prevented penetration for the full 60 min test period. The fibre insulating board ceiling was not penetrated downwards until after 30 min. The foamed plastics ceilings allowed fire to penetrate into the adjoining room in times varying from 8½ to 16 min after the test started. The polyurethane ceiling was worse than the polyisocyanurate foam ceiling.

There was smoke penetration into the adjoining room in all tests and this was particularly serious with the foamed plastics ceilings. The smoke and CO hazard in the hall adjoining the fire chamber was bad in some tests and it depended on the pressure difference across the door which was protected with asbestos and had 3 mm gaps at the edges. Even a 'normal' door would not, however, have burnt through before the plastics foamed ceiling had been penetrated.

Following these full-scale tests a number of experiments in a similar structure half that scale have been carried out in order to study the effectiveness of any remedial measures. As a result of this further work it is considered that effective upgrading of existing ceilings of polyurethane board can be achieved either by covering the soffit with 12 mm plasterboard or the upper surface with a wire reinforced mineral wool quilt 50 mm thick. In both cases it is essential that there is good workmanship and that the plastics board is completely shielded.

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