Fire Research Note No 1046

COLLECTED SUMMARIES OF FIRE RESEARCH NOTES AND CURRENT PAPERS (FRS) 1975

by

L C Fowler

February 1976

FIRE RESEARCH STATION

Fire Research Station
BOREHAMWOOD
Hertfordshire WD6 2BL

Tel: 01 953 6177

Fire Research Note No 1046
February 1976

COLLECTED SUMMARIES OF FIRE RESEARCH NOTES AND CURRENT PAPERS (FRS) 1975

by

L C Fowler

FEBRUARY 1976

(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 986

GAS EXPLOSIONS IN BUILDINGS PART III
A RAPID, MULTI-CHANNEL, AUTOMATIC CHROMATOGRAPHIC GAS ANALYSIS SYSTEM

by

R N Butlin, S A Ames and C F J Berlemont

A brief general description of the current research programme on gas explosions in buildings was given in the synopsis for FR Note No 984 and in that Note reference was made to the automatic gas sampling and analysis arrangements required for the experiments. The present Note provides a detailed description of the considerations involved and of the rapid gas analysis system which has been developed. Such a system is required for monitoring the gas-air mixtures at different positions in the 1000 ft^3 (28 m^3) explosion chamber both during filling and until actual ignition of the gas mixture.

Of the seven main analysing methods available it was decided to use gas chromatography since this is well developed commercially and has other important advantages. The analysis is based on methane concentration as this gas is a component of both natural and manufactured gas.

Five different lengths of stainless steel tube probes were inserted in various positions projecting down from the explosion chamber roof so that each set was able to provide gas samples from the same depth below the ceiling, thus allowing the formation of gas layers in a horizontal plane to be examined. A device for remotely controlling the height of the probe inlets during an experiment has been designed and will be reported on elsewhere.

The gas samples were taken to a remotely placed analytical unit and its ancilliary equipment so that by means of solenoid controlled valves a sample injection of gas could be analysed about every 20 seconds and the six different channels which were built into the unit could be monitored in about 2 min. The capacity of the system could be extended by incorporating more channels. Further, only minor modifications would be required to enable the apparatus to be used for monitoring manufactured or other similar gases.

The system is fully automatic but with manual override and is remotely controlled. It has operated virtually trouble free for about 12 months. However, the processing and display of the results could be improved and this is under active consideration.

Synopsis of FR Note No 1015

SMOKE AND TOXIC GASES FROM BURNING BUILDING MATERIALS

1. A TEST RIG FOR LARGE SCALE FIRES

by

G W V Stark and P Field

Small scale laboratory tests may measure some aspects of the burning of combustible building materials but they are not always suitable for the assessment of toxic gases and smoke produced by the combustion of organic materials generally, including plastics. It was therefore decided to construct a large scale test rig which could be used to simulate the conditions under which a fire can occur with adequate provision for measuring gas composition and temperatures and smoke production. This Note contains a full description of the test rig and it includes the results of tests carried out using wood cribs.

The rig is constructed of 0.6 m wide aerated concrete panels 2.4 m high supported by an external steel frame and the inner panel surfaces are protected with a rendering of lime, cement and vermiculite, which does not produce toxic gases at high temperature. The rig, which stands on a concrete floor, is in the shape of an L with the short arm as the fire compartment 3 m square and 2.4 m high communicating via a floor to ceiling opening with the long arm of the L which forms a corridor 12.6 m long and 1.3 m wide and 2.4 m high. Both the fire compartment and the corridor are roofed with similar panels.

The test rig is contained in the large Models Laboratory at the Fire Research Station so that the tests are unaffected by the weather; smoke can be extracted from the building through the openable section of the laboratory roof. Ventilation of the test rig can be arranged by removing one or more of the panels but in the present series of tests the sole means of ventilation of the fire compartment was an opening 240 or 700 mm wide (80 mm in one test) from floor to ceiling between the compartment and the corridor through which fire gases and smoke escaped and air entered. The far end of the corridor was left open and unrestricted.

Gas samples were collected from a point at the opening between the fire compartment and the corridor, and near the open end of the corridor, and temperatures at various points were recorded. Smoke censity was measured by the attenuation of light falling on a photocell after passing through the smoke. Measurements were made of the rate of entry of air into the corridor and the rate of evolution of fire gases.

Seven tests were carried out using a wooden crib in the fire compartment, and in two tests there was also a wall lining of wood matching. Except for one test using 1:1 spacing for a slow burning fire, the crib stick spacing was 1:4 and the fire loads 3 and 6 lb/ft^2 (14.5 and 28 kg/m^2). Fires were started by igniting woodwool with a heated electric element. A full report on all the tests is provided in the Note together with a table of results and various graphs.

As a result of these tests it is concluded that the test rig provides a reproducible thermal environment from a fire with a particular amount of ventilation and fire load and, also, that the arrangements for sampling fire gases are effective for measuring the properties of fire gases produced by the fires. Although the amount and density of smoke produced increased with the amount of fuel burnt and with the ventilation, there was a more consistent relationship for smoke quantity than for density. The smoke produced in the tests was sufficiently dense to impede escape.

The moisture content of the wood is important and to ensure free burning should always be less than 12%. More tests are required before any meaningful statistical analysis can be provided as regards the effect of moisture content, fire load and ventilation. A later Note will be presented dealing with further tests including some with additional PVC fuel.

Synopsis of FR Note No 1016

THE EFFECT OF A SPRINKLER ON THE STABILITY OF A SMOKE LAYER BENEATH A CEILING

by

M L Bullen

The hazards of fire and smoke in shopping malls have been investigated at the Fire Research Station and reference should be made to FR Notes No 806, 856, 875 and 954 for which synopses were prepared. Experiments were carried out with 'fires' in the 'shop' of the experimental shopping mall building and in some of the tests sprinklers were fitted in the 'shop' and, in others, a manually operated sprinkler was fitted in the mall itself. The smoke problem mainly concerns the smoke layer in the mall, its collection in ceiling reservoirs and its natural or mechanical extraction. If the smoke layer is hot and buoyant and, perhaps a metre deep, the smoke hazard should not be serious enough to prevent escape and hinder fire fighting but once the smoke is cooled it may well sink lower and smoke-log the mall.

In the light of the experience gained in experimental work, a theoretical investigation has now been made into the effects of a sprinkler spray on the smoke layer under the ceiling of a mall since it is normal practice now to fit automatic sprinklers everywhere, including the mall which may not contain combustible material for which sprinklers would be advantageous anyway.

This Note contains a detailed study of the interaction of sprinkler discharge water drops with a hot smoke layer and of the downward drag force of the water drops on the upward buoyancy force of the smoke ie on the drag-buoyancy effect. It is necessary to make a number of assumptions regarding the drag force and its operation over the whole of the water spray envelope, the shape of the water drops and the uniformity of the gas temperature etc but these variables should not affect the drag-buoyancy equation but only, possibly, the magnitude of the final answer. Experimental data appears to confirm that the theory is viable.

It is concluded that if the smoke layer is hot enough to set off sprinklers then it will be buoyant enough to remain as a layer even with the water spray passing through it. Any lowering of the layer should be delayed until after the occupants have escaped. If the smoke layer is thinner than a metre or so, its buoyancy may not be sufficient to prevent smoke logging at low level but this effect could be counteracted by fitting higher temperature sprinklers, by reducing the water pressure or by increasing the depth of the smoke reservoirs. Alternatively sprinklers could be omitted from circulation areas and escape routes having no fire hazard, but clearly decisions on this must be related to the whole problem and not just one aspect.

Synopsis of FR Note No 1017

THE HAZARD FROM FIRES OF SMALL LOADS OF FLEXIBLE POLYURETHANE FOAM

by

G W V Stark, P Field and Ann Pitt

A series of 13 experimental fires was carried out in the corridor test rig described in FR Note No 1015 using fire loads of flexible polyurethane foam of a size representative of domestic risks. The foams used were of four different types viz: unmodified, flame retardant, high resilience cold cure and a recently introduced improved foam, and small amounts of cellulosic material were added to represent coverings and for ignition. One test was carried out using wood wool for comparative purposes.

The fire loads consisted of cushion squabs 1 ft 6 in square and 3 in thick (450 mm squares 75 mm thick). Two squabs were used for a 'fireside chair' test, a 'bed test' consisted of two simulated steel bed-frames each covered with 'mattresses' of two layers of 8 squabs in cotton sheeting, and 100 squabs were used to simulate a fully furnished room. The squabs were arranged in various ways in the fire chamber at the end of the corridor with which it communicated by an opening 700 mm wide for 10 tests and 1150 mm wide for the other tests.

Measurements were made of the temperatures attained by the gases leaving the fire chamber and of the time of burning. Analyses, by various means, were made of the fire gases consisting of CO, CO_2, nitrogen, oxygen and nitrous gases, hydrogen cyanide and TDI, and the optical density of the smoke issuing from the corridor was calculated. The Note contains tables and graphs giving details of the test results and there is a photograph of the corridor and fire chamber together with plans of the fire load arrangements.

It was found that the rate of burning of the foam was directly dependent on the exposed surface area. The 'fireside chair' fire generated relatively little smoke or toxic gases and should not be difficult to extinguish. However, the 'two single beds' fire indicated that in a freely vented bedroom there could be intolerably high temperatures, smoke and toxic gases in a few minutes and even dilution with fresh air and cooling to a bearable 120°C would not completely remove the toxic and smoke hazards. The amount of smoke evolved was proportional to the weight of flexible polyurethane foam consumed and this was complete except for the very small 'fireside' chair fires using the better foams.

In the larger fires there was little difference in the behaviour of the various foams although the presence of a flame retardant may have had some influence on the combustion products. Generally, the production of toxic gases and smoke was directly dependent on the weight of foam consumed by fire. No measurable amounts of TDI were found, even in the larger fires.

The rate of fire development could be reduced if the room door was closed but with open doors in a typical dwelling of 250^{3}m in volume the toxic gases and smoke would rapidly rise to levels hazardous to life.

The behaviour of other combustibles is being investigated on a similar basis so that comparisons can be made.

Synopsis of FR Note No 1018

THE TRANSMISSION OF EXPLOSION OF FLAMMABLE GAS/AIR MIXTURES THROUGH A FLANGE GAP ON A VENTED VESSEL

by

Z W Rogowski

Previous experimental work had shown that when vessels, which are being used in flammable atmospheres, have explosion relief openings fitted with flame arresters then the maximum experimental safe gaps (MESG) at the join flanges of the vessels may be increased. This work and the 8 litre vertical steel cylinder used in the experiments is described in FR Note No 973 (see Synopsis). The cylinder with separate end plates was held in an hydraulic press, the whole apparatus being enclosed in a polyethylene sleeve or bag, before the flammable mixture was allowed to fill the vessel and the sleeve. The experimental gap was arranged between the top of the cylinder wall and the top end plate by fitting silver shims at intervals around the gap between the cylinder and the end plate.

However, measurements of rates of pressure rise and photographic studies have indicated that relief venting, although reducing the maximum explosion pressure, may increase the rate of pressure rise when the combustion products are flowing through the flange gap and in some explosions the relief has caused acoustic oscillations probably as a result of fluctuating combustion. Further, the transmission through the flange gap does not necessarily occur at a point nearest to the igniting source and in some cases ignition may take place on two locations simultaneously.

A further series of experiments has therefore been carried out in order to investigate the problem further and resolve some apparent contradictions. The same apparatus was used and flammable gases of 6.5 per cent ethylene/air and 28 per cent hydrogen/air mixtures were employed. The flame arresters were of crimped ribbon or 80 grade Retimet and the flange gap was slightly larger than the MESG. Some tests were done with unvented vessels and in many cases the explosion was transmitted through the flange gap. Many direct photographs were taken and also temperature gradient photographs using the Schliesen method with mirrors. The Note contains numerous photographs and graphs of pressures and flame movement.

It was found that the presence of a relief vent does not decrease the MESG but it may increase the rate of pressure rise during the initial stages of an explosion. The rate of rise is not uniform and changes in the rate can be rapid. Further, an explosion may be transmitted through the gap in more than one place.

Synopsis of FR Note No 1019

PRESSURES PRODUCED BY GAS EXPLOSIONS IN A VENTED COMPARTMENT

by

R N Butlin and P S Tonkin

A series of gas explosion tests has now been carried out in the 1000 ft^3 (28 m^3) steel chamber erected at Cardington and described in FR Note No 984. The tests were designed to investigate the effect of different gas layer depths and vent areas on the pressures developed inside and outside the chamber. The 'venting' side of the chamber was partly closed with steel panels to the lower part so that upper vent areas of $\frac{1}{2}$, $\frac{1}{4}$ or $\frac{1}{8}$ of the total side area of 7.2 m^2 were available, and the whole of the side was covered with polyethylene sheet to form the burstable panel. Gas mixtures of 10 per cent natural gas in air were used and the layer depth, below the ceiling, was defined as that level at which there was a minimum 95 per cent concentration of the mixture. Ignition was by a spark at the layer interface. Measurements were made of the internal and external pressures and the sound levels, both the latter at different distances from the chamber.

A full analysis of the test results will be given later. However, as an example, in one test with a 1.83 m deep layer and a $\frac{1}{4}$ vent area (ie 0.6 m deep) the plastic panel burst after 320 ms at a pressure of about 0.7 kN/m^2. At 540 ms after ignition a further pressure peak of 2.1 kN/m^2 occurred closely followed at 600 ms by a sharp rise to 8.3 kN/m^2. This double pressure peak phenomenon is known to occur in gas explosion venting especially with small vents. Numerous tests with different layer depths and vent areas enabled an assumption to be made that with the chamber full of gas the theoretical maximum pressure would be 15, 10 or 7 kN/m^2 respectively for the $\frac{1}{8}$, $\frac{1}{4}$ or $\frac{1}{2}$ vent areas.

Because of possible disruptive effects on neighbouring structures, measurements were made of the pressures and sound at distances from the chamber mainly at right angles to the venting side and 30 ft (9.14 m) and 60 ft distant therefrom. It appears that the pressure drops inversely as the distance (doubling the distance halves the pressure) and it would also seem from a preliminary investigation, that the sound level declines similarly so that doubling the distance gives a reduction of 6 dB in the sound level.

A further point emerging from the experiments is that, as regards explosions in buildings, consideration must be given to the pressure differential between the inside and outside of a given wall or element. The experiments have been of help in assessing the effect of blast waves from chemical plant explosions. A more detailed analysis of the data will be provided later.

Synopsis of FR Note No 1020

IGNITION DUE TO SELF-HEATING IN A PLANE SLAB WITH A CONSTANT HEAT FLUX ON ONE FACE

by

P C Bowes

Slabs or layers of material having one face exposed to a source of heat and the other face to cooler surroundings may ignite due to self-heating. The heated face may be maintained at a constant high temperature or just be exposed to a constant flux of heat; the first situation has already been extensively studied and the second is the main subject of this Note. Practical examples are some types of combustible panels close to a heated flue pipe and sawdust lying on an electric motor.

Various existing theories having a bearing on this problem have been reviewed in considerable scientific detail in this Note and their application to the present problem has been assessed. Given limited heat losses from the cool face of a slab two different practical situations can arise. Firstly, as with sawdust on the electric motor, there may be no heat loss from the heated face since it is continuously heated and in close contact with the casing. Secondly, the combustible panel, whilst being continuously heated by the flue pipe, is not in close contact with it and can lose heat on that side as well as on the cool side. Some calculations for typical cases of wood fibre insulating board, which has self-heating properties and which is receiving heat from a flue pipe, are shown in the Note.

The fibre board panels used in the calculation are 14 and 41 mm thick. The critical data for ignition of horizontal panels above a pipe and at an ambient temperature of 25^{o}C have been computed. The incident flux for ignition was found to be 4.1 kN/m^2 for the thinner panel and 2.3 kW/m^2 for the thicker, with the temperature of the pipe surfaces 424^{o}C and 343^{o}C respectively. It is possible, therefore, to calculate the shortest safe distance between the surface of a flue pipe and a panel and in the light also of experimental observations it was estimated that, for the range of measurements considered, the time to ignition would be of the order of $\frac{1}{2}$ h to several hours. The heat due to the oxidative self-heating is only a small fraction of the incident flux required for ignition.

Synopsis of FR Note No 1021

TOXIC GASES AND SMOKE FROM POLYVINYL CHLORIDE IN FIRES - STATISTICAL ANALYSIS OF TEST RESULTS

by

C Ramachandran and F E Rogers

Fourteen test fires were carried out using the test rig which consists of a fire compartment and corridor and is described in FR Note No 1015. The fire loads consisted of a wood crib to which was added, for some tests, PVC rigid wall sheeting. Although the tests were not designed for statistical analysis it has been possible to carry out an analysis of 10 of the tests in so far as the measurements of fire load, temperature and concentration of oxygen, CO and CO_2 are concerned. The ventilation factor of the doorway between the corridor and the fire chamber (240 or 700 mm wide) was also taken into account.

The test variables were the temperature and gas concentrations and there were maximum readings for the temperature, CO and CO_2 and minimum for the oxygen. These are extreme values and the statistical technique developed is based on the extreme value theory expounded in FR Note No 837. The intention is to compare two levels of one factor at constant levels of all the other factors. For example the maximum temperature at the doorway position for the two ventilation levels of 240 and 700 mm was found not to differ significantly for any fixed level of the other factors of wood and PVC fire load. However, for one particular ventilation opening there were significant effects on the maximum temperature, CO and CO_2 concentrations measured at the opening depending on whether there was wood only or wood and PVC in the fire load when this weighed 241 kg.

Further experimentation is required and it is suggested that, with 24 similar tests in all, some meaningful conclusions on the interactions of the various factors concerned could be drawn.

Synopsis of FR Note No 1022

FLASH POINTS OF MIXTURES OF FLAMMABLE AND NON-FLAMMABLE LIQUIDS

by

P F Thorne

The hazardous nature of a flammable liquid is mainly assessed by finding the flash point using the 'closed' or 'open' test and the Abel or Pensky-Martens 'closed' cup flash point apparatus is that most commonly used. These flash point values are freely available for most pure liquid fuels and a theoretical basis is also well established for the assessment of flash points for liquid mixtures in which all the components are flammable. However, there is considerable interest in the flash points of multi-component liquid mixtures in which some of the components are non-flammable and this problem is the subject of this Note. Examples of such mixtures are the dilution of water miscible fuels with water used either to disperse the fuel or to extinguish a fire and the addition of halogenated hydrocarbons to such fuels during fire extinguishment or to render them non-flammable. Paints and adhesives can also be mixtures of flammable liquids.

Non-flammable components of these mixtures can either have no flame suppressing effect or can suppress flames either through the physical means of dilution or cooling or by a chemical inhibiting mechanism. The suppressing effect is dependent essentially on the partial vapour pressure of the non-flammable component in relation to that of the flammable liquid and on any flame inhibiting effect the additive may have in the vapour phase. The 'closed-cup' flash point can be regarded as the temperature at which the vapour pressure of the fuel results in a concentration of fuel vapour above the liquid surface equal to the lower limit of flammability of the fuel vapour in air although there are some differences in experimental conditions and parameters when determining the flash points and flammability limits. The flammability test, for instance, requires the flame to propagate a substantial distance but the flame propagation is relatively small in the flash point apparatus. Both the lower and upper flash points can be related to the upper and lower flammability limits.

The Note contains a full discussion of the problems and details of the various experimental results, together with typical examples of the constant 'k' which is the measure of the magnitude of the flame suppressing effect of the additive; the higher the 'k' value the less the suppressing effect and visa versa. Data is presented for mixtures of n-hexane, n-heptane and n-octane with carbon tetrachloride, BCF and BCM and for mixtures of methanol, ethanol and acetone with water.

In spite of differences between the flash point and flammability limit tests it is shown that experimental evidence does support the validity of a theory which enables flash points of liquid mixtures to be predicted from a knowledge of the flammability data. Further, lower flammability limits can be determined from flash point measurements. Flash point tests are relatively simple to carry out and the results therefore provide a convenient method for constructing the flammability picture in the light of the knowledge regarding the liquid vapour pressures. Upper flash points and upper flammability limits were not studied in detail and research on this problem would be of great interest.

Synopsis of FR Note No 1023

IGNITION OF FLAMMABLE VAPOURS, GASES AND SHEET MATERIALS BY CATALYTIC HEATERS

by

Z W Rogowski and Ann Pitt

Portable butane catalytic space heaters, for which a draft test specification has been prepared (see synopsis for FR Note No 1006) could be used in areas, particularly on industrial premises, where flammable gases are present. A French report indicated that hydrogen and ethyl ether could be readily ignited by such heaters but it was inconclusive regarding other gases and liquids. This Note describes work carried out at the Fire Research Station for the purpose of assessing the ignition hazard from flammable gases and liquids and from combustible sheet material such as textile fabrics and paper.

The tests were done with two new heaters of 2.8 kW and 3.5 kW maximum output respectively and one 2.5 kW heater which had been previously used for experiments. All the tests were done at maximum output, at which setting the highest catalytic bed temperature was about 520°C. With each heater the hottest part was near the bottom.

The liquids tested were decane, hexane, ethyl ether, petroleum ether and leaded petrol; the gases were hydrogen, ethylene and propane and the sheet material was cotton, nylon and cellulose acetate fabrics, newsprint and tissue paper. The liquids were squirted from a syringe with or without a hypodermic needle and gases were ejected from a small nozzle so as to ensure that the jet penetrated to the hot part of the catalytic bed. The sheet material was in 200 mm wide strips from top to bottom and in contact with the catalytic bed surface for up to 7 min or on the guard of the heater for up to 90 min. The Note contains a full description of the various tests and the results in tabular form together with some photographs of the gases and liquids being ejected onto the catalytic beds and of the formation of hot spots where combustion was taking place after penetration of the bed by the jet of liquid or gas.

With ragard to the sheet materials, only those made from cotton and wood pulp ignited when placed on the hot catalytic bed. Cellulose acetate and nylon fabrics melted and charred but did not initiate flame. None of the materials ignited when placed on the guard and then only the cellulose materials scorched.

With liquids only ethyl ether ignited when projected onto the bed.

The mechanism of ignition for the gases is somewhat complex and is dependent on the velocity of the jet, eg gases must have a velocity greater than 0.75 m/s to ignite ethylene and greater than 1.5 m/s to ignite propane, these being the lowest velocities at which the gases can penetrate the bed. When liquids are projected onto the bed they must be vaporised before flaming combustion can occur. It was found possible to ignite all the gases and vapours, except petrol, if projected at a sufficiently high velocity but with liquids the heat necessary to vaporise the liquid cooled the bed and the vapours rose by convection so that, with the exception of ethyl ether, there was no ignition; this latter liquid has a very low ignition temperature. The ignition of the gases was assumed when there was a stable flame on the surface of the bed (flash) or when the liquid gases flashed to and stabilised on the jet nozzle (flame). There were some differences between the three heaters, eg propane did not ignite on the second and third heater.

The surface temperature of the catalytic bed, above 500°C, exceeds the temperature for auto-ignition of most flammable vapours and gases and industrial catalytic heaters are not likely to be different from the domestic types tested. It is concluded, therefore, that these catalytic heaters should not be used when there can be accidental splashes or leaks of volatile flammable fluids.

Synopsis of FR Note No 1025

CASUALTIES ATTRIBUTED TO TOXIC GAS AND SMOKE.
A SURVEY OF STATISTICS

by

P C Bowes

The UK Fire Statistics for the years 1955–72 have been analysed, together with other relevant statistics, in order to investigate the problem of fatal and non-fatal casualties attributable to toxic gas and smoke. Over the period of years considered the proportion of casualties suffering from gas and smoke trebled and, currently, about half of the casualties resulting from all causes, per annum, are, in fact, caused by gas or smoke.

During the period investigated there was some reclassification on the Fire Brigade returns regarding burns asphyxiation, gas and smoke but this does not appear to have affected the conclusions significantly. About 85% of all casualties occur in buildings and the majority of these (75%) are in dwellings. The Note contains a table showing the annual numbers of casualties for the years involved divided between 'burns and scalds', 'overcome by gas and smoke' and 'other and undefined', both as regards fatal and non-fatal casualties. In 1972 there were, in all, 1078 fatal and 6330 non-fatal casualties.

It is not possible from the statistics available to analyse the detailed causes of death or injury under 'overcome by gas or smoke'. It is well known that carbon monoxide is a major toxic component of fire gases but other toxic products in fire gases may well result from the introduction of plastics into buildings. These other products could be more lethal than carbon monoxide and might produce more long term damage in non-fatal casualties. However, there is no significant trend in the proportion of non-fatal casualties from gas or smoke and this indicates that there has been no particular change in the toxicity of fire gases. Future studies of toxic gas hazards should embrace a study of fire casualties. Although the available statistics do not permit any casual relationship to be established an increase in the amounts or irritancy of gas and smoke generated could result in more persons being trapped.

There has been an increase in multiple-death fires associated with multi-occupancy dwellings and with hospitals such as Shelton and Coldharbour and this may, to a minor extent, be associated with the increase in casualties overcome by gas or smoke. An earlier analysis did show that these fatal casualties were higher than average expecially among casualties remote from the seat of the fire.

Synopsis of FR Note No 1026

A REVIEW OF INFORMATION ON EXPERIMENTS CONCERNING THE VENTING OF GAS EXPLOSIONS IN BUILDINGS

by

R N Butlin

The various factors which have a bearing on the problem of gas explosions in buildings are, briefly. the physical features of the building and the venting, the nature of the gas and the control and distribution within the building or compartment, the nature and number of ignition sources, the flame speed, turbulence, pressures, and the noise. So far as laboratory experiments are concerned the effect of scaling is important.

A certain amount of research work having a bearing on the problems has already been carried out and these studies are reviewed in some detail, and the data is set out in tabular form. The work includes that by Cubbage and Simmonds on drying ovens, Harris' investigation using a cylindrical vessel containing pentane/ air mixture, work in Sweden in 1957 in a building of 200 m^3 using meteorological balloons filled with explosive gas mixtures, and three separate programmes of work done in 1970 and 1972 at Potters Marston in which the Fire Research Station was involved. Work has also been done in Holland using two large scale adjacent compartments separated by a doorway in a wall but only pressure measurements were recorded.

The work at Potters Marston involved interconnecting compartments and both town and natural gas - air mixtures were used. Considerable data was obtained from these experiments and recorded maximum pressures were 21 kN/m^2 (3 psi) for natural gas/air and 35 kN/m^2 (5 psi) for twon gas/air mixtures. Both flame speeds and pressures were higher in the compartment(s) beyond that in which the ignition took place, this is sometimes referred to as the 'cascade' effect.

The experimental material reviewed has been used to provide an overall picture of the current knowledge of the venting of gas explosions mainly for the purpose of deciding where the emphasis of future work should be. It is clear from the review that there are many unresolved problems and the Fire Research Station has initiated a programme of research involving the production of reproducible layers of gas/air mixtures and the measurements of pressures generated inside and outside a single vented compartment of 28 m^3 volume. The instrumentation has had to be developed and proved. Further work will be done on the effect of different forms of pressure relief venting in a single compartment and after that experiments will be done with a multi-compartment explosion chamber with variable geometry. The main emphasis with this work will be on determining the effect of turbulence on the pressures generated, especially as regards two communicating compartments.

Synopsis of FR Note No 1028

MAXIMUM PERMISSIBLE OXYGEN CONCENTRATION TO PREVENT DUST EXPLOSIONS IN A LARGE SCALE VERTICAL EXPLOSION TUBE

by

P S Tonkin

Recent new processes in industry and the wide use of materials in dust form have brought into question the validity of the laboratory scale standard furnace test as the criterion for determining the safe maximum permissible oxygen content in atmospheres supporting dust clouds. It was felt that this small scale test, by heating the dust cloud above ambient temperatures and by providing a large source of ignition, had resulted in excessively low oxygen concentrations being required. A comparison was also desirable with the small scale vertical tube laboratory apparatus (see synopsis for FR Note No 928).

A series of tests was therefore arranged using the large scale vertical tube apparatus (10 in dia and 17 ft high) at the Fire Research Station. This apparatus employs a jet of burning propane/air mixture injected into the dust cloud as the ignition source. The Note contains a full description and a drawing of the equipment together with details of the atmosphere supply, flow and sampling systems and graphs of the results.

The materials tested were phenol-formaldehyde resin and diphenylol propane which are industrial powders. Nitrogen or carbon dioxide were used to dilute the atmosphere in the tube to the required oxygen content which was continually monitored. Carbon dioxide only was used for the former dust. When the tube was full of an atmosphere containing the selected oxygen content the dust held in a hopper at the top of the tube was allowed to fall down to form a dust cloud in the tube and at the appropriate moment the igniting flame was introduced near the bottom of the tube. After each test the tube was purged and several tests were done for each oxygen content mixture chosen using various dust concentrations.

The results were graded according to whether the flame propgagated less than 2 ft, more than 2 ft but less than the full length of the tube and those propagating throughout the length of the tube.

The results in this large scale vertical tube apparatus were in line with those obtained using the small vertical tube apparatus and were safer and more reliable than those obtained when using the Bureau of Mines spark tube apparatus. Results from the large scale tube apparatus have previously been shown to be applicable to large sized industrial plant and, consequently the small scale tube apparatus test results can also be applied to large scale plant.

There is, therefore, a need for the reappraisal of the standard test procedures for determining realistic values for permissible oxygen concentrations in industrial plant containing explosible dusts and the large or small scale tube apparatus or, even, the furnace may be appropriate in particular circumstances.

Synopsis of FR Note No 1029

THE EARLY STAGES OF FIRE GROWTH IN A COMPARTMENT
A COOPERATIVE RESEARCH PROGRAMME OF THE CONSEIL INTERNATIONAL DU BÂTIMENT (COMMISSION W14)
FIRST PHASE

by

A J M Heselden and S J Melinek

The rate of early fire growth in a compartment of a building affects safety, fire fighting and the eventual fire size. In order to investigate these problems on a laboratory scale the Fire Research Station designed a programme of experiments for the Fire Commission (W14) of the CIB to be carried out at eight international laboratories (also an extra 'scaling' test in the USA). The main factors to be considered were the compartment shape, ventilation, and lining to walls and ceiling, area and position of ignition source, and height and stick and crib spacing of the wooden cribs.

The compartments used were of two shapes viz: 121 & 211 to the metre scale - the numbers being width, depth and height of 1 or 2 metres as shown - and the ventilation opening in one side was the full height of the compartment and either $\frac{1}{4}$ or the full width of that side. One large or 21 small cribs were used, any lining was of hardboard and the area of the alcohol ignition source was 16 or 144 cm^2 either in a corner away from the opening or in the centre.

Each test was done twice and, in all, 256 tests were carried out with measurements taken up to 'flashover' conditions, times being recorded for flames to reach the ceiling, at development from slow to fast growth, and for flaming across the tops of all the cribs. The Note contains a full report and comments on the experiments and there are tables and graphs.

After analysing the test results the following summarised conclusions are reached regarding the time for flaming over the top of the whole of the fuel:

1. It was not significantly dependent on the compartment shape, ventilation or fuel continuity but was materially affected by the position and size of the ignition source, fuel height and stick spacing, and the lining but the latter was not the most important.

2. It was most sensitive to changes in lining material with corner ignition and large ventilation opening and there is possibly a correlation with the thermal inertia and flame spread or fire propagation index of the material.

3. It is fairly constant as regards 'scale' if the fuel height is increased in proportion to any increase in the compartment height.

It is suggested that the data be analysed further and the influence of lining and ventilation be explored in more detail.

Synopsis of FR Note No 1030

TOXIC GASES AND SMOKE FROM POLYVINYL CHLORIDE IN FIRES IN THE FRS FULL SCALE TEST RIG

by

G W V Stark and P Field

A series of tests was carried out in the 'Compartment and Corridor' full scale rig in the Models Laboratory at the Fire Research Station in order to investigate the effect of PVC wall linings when present with a cellulose fire such as a wood crib fire. Previous tests in the rig, when wood cribs and wood linings were used, were described in FR Note No 1015 (see synopsis) and the results of these tests were used for comparison. The present Note contains a very full description and the results of 14 tests carried out with a wood crib in the compartment and with PVC wall linings either in the compartment or in the corridor. The linings tested were of rigid unplasticised PVC sheet 3 mm thick or PVC coated decorative wall-cloth or wall-paper. The sheet was nailed to the walls and the thin linings were stuck on with water-based cellulosic adhesive. The wood crib fire loads were of 3 or 6 lb/ft^2 to represent a dwelling fire. The opening between the compartment and the corridor, which was the full height of the rig, was either 240 mm or 700 mm wide.

Measurements were made of the temperature in the compartment and along the corridor, and the fire gases produced, in particular the toxic gas CO and hydrogen chloride, were sampled. The speed of air into and of fire gases out of the corridor was recorded and the smoke quantity and density was measured and observed. A statistical analysis, as recorded in FR Note No 1021 (see synopsis) was made of the results using the extreme value theory so that a comparison could be made with the earlier 'wood only' fires.

As a result of these tests it was found that full flaming took a few minutes only and $300^{\circ}C$ was reached within a minute of the flaming, causing a high rate of flow of fire gases. Smoke was produced shortly after ignition whether or not PVC was included in the fire load and within 8 mins the visibility was less than adequate for escape even if the gas temperatures were not too high. In a ventilated fire at temperatures which could be borne the CO concentration would have been a hazard to life.

The presence of about 100 kg of rigid PVC sheet in the compartment produced enough hydrogen chloride to be a hazard to life and 3 mm PVC sheet lining in the corridor presented a still greater hazard even at bearable temperatures. However, the cloth and wall-paper in the compartment did not add significantly to the hazard of the crib fires but such linings in the corridor might produce a highly irritant atmosphere.

These tests indicate that it should be possible to predict any hydrogen chloride concentrations in fires involving thick sections of rigid PVC provided the fire gas temperatures can be estimated, but further information would be required before any CO concentration could be predicted.

Synopsis of FR Note No 1032

GAS VELOCITY MEASUREMENT IN FIRES BY THE CROSS-CORRELATION OF RANDOM THERMAL FLUCTUATIONS

by

G Cox

This Note contains a description of a new, improved and economic technique for measuring the velocity of hot and turbulent gases from a fire. For such relatively slow moving gases the present methods involving CO_2 measurement, the use of a pitot tube or vane anemometer and a camera or TV record have their limitations and the proposed system which uses cheap and easily replaceable thermocouple probes has many advantages.

Although the equipment placed in the gases is relatively simple, the statistical concept, the data recording and the analyses of the temperature measurements are far from simple but are explained in scientific terms in the Note.

The equipment in the fire compartment consists of two insulated thermocouple wires, passing through a steel tube fitted in the fire compartment wall or ceiling, and splayed out so that the thermocouples themselves are in the fire gases and 38 mm apart. The flames and turbulent hot gases from the fire flow past the thermocouples which are in line with the direction of travel of the gases (and can be turned round 180°) so that one part of the flames or gases affects one thermocouple first and then, almost immediately, the other thermocouple. It is by cross correlating the temperature fluctuations from the two thermocouples, after allowing for the time 'shift', that it is possible with the recording and analysing equipment used, to identify or 'fingerprint' particular parts of the turbulent flames or gases so that one particular portion can be established as passing both the first and second thermocouple. The time for this portion to travel the 38 mm provides the velocity of the flames or gases. By rotating the thermocouples 180° any differences due to corrosion or soot etc can be averaged out.

Eight tests were done in the Models Laboratory using about half the full length of the corridor rig (see synopsis for FR Note 1015) viz: 2.5 m high, 1.3 m wide and 6.35 m long. The 'fire' was placed near the closed end of the corridor and the twin thermocouple probe was placed through the ceiling so that it was in the path of the flames and gases passing along the ceiling towards the open end of the corridor. Methylated spirit 'fires' were used to simulate a fire with constant thermal output and a wood crib for a fire of changing output.

The new technique has been proved efficient for measuring flame and smoke movement although improvements could be made in the sensor design and the 180^{o} reversal of the probe could be mechanised. A probe with four sensors could 'vector' the velocities where direction of flame or gas movement was not clear.

Synopsis of FR Note No 1033

DRAG REDUCTION IN FIRE HOSE
TRIALS AT FIRE SERVICE TECHNICAL COLLEGE 1974
PART I EXPERIMENTS AND RESULTS

by

P F Thorne, C R Theobald, P Mahendran.

The use of 'drag reducing additives' which can be long chain high molecular weight water soluble polymers, has been developed in the USA by The Union Carbide Corporation and preliminary information on their application to UK fire fighting operations was provided in FR Note No 959. One of the most effective polymers is Polyethylene Oxide (PEO) and the present Note describes the results of experiments to determine the friction factors of UK fire hoses under a wide range of operating conditions using PEO. The system used is commercially available and the trials were carried out at the Fire Service Technical College at Moreton-in-Marsh by the Fire Research Station and the Home Office Fire Department.

The original system involved the use of a premixed solution of PEO in water which was injected downstream of the pump and which provided a final concentration of 0.003 to 0.005 per cent. This was known as 'Slippery Water' and had disadvantages as it could only be effective if injected downstream of the pump. A more recent development is the use of a slurry of powdered PEO which can be injected into the suction inlet of the pump and this is known as 'Rapid Water' and was used in various arrangements including repumping in the recent trials at Moreton-in-Marsh.

Fire hoses in common use were laid out in a more or less straight line and were up to 3600 ft in length. Static pressures were measured at various points along the hose together with the water flow rates. New 'Duraline' hose of $1\frac{3}{4}$ in, $2\frac{3}{4}$ in and $3\frac{1}{2}$ in were utilised and also a BTR $\frac{3}{4}$ in hose reel. Various Fire Brigade pumps were used and water was drawn by suction from a large static tank at 10^{o}C. The general arrangements of the layouts are shown in diagrams in the Note together with tabulated results of the nineteen groups of tests carried out.

The overall results for friction factor plotted against Reynolds number and flow rate are shown in graph form and comparison is made with that for a hydraulically 'smooth' pipe. There was some variation of friction factor with flow rate and this will be discussed in a future publication.

For the $1\frac{3}{4}$ in and $2\frac{3}{4}$ in hoses the amount of Drag Reduction was of the order of 50 per cent but only 20 per cent for the $3\frac{1}{2}$ in hose. Using the $\frac{3}{4}$ in hose reel the reduction was about 70 per cent. Injection of the additive into the suction inlet of the pump resulted in a reduction of the effect by about 5 per cent and if the treated water was passed through a second relay pump the Drag Reduction was reduced by about one quarter.

Synopsis of FR Note No 1035

ON THE NON-EXISTENCE OF SYNERGISM BETWEEN INHALED HYDROGEN CYANIDE AND CARBON MONOXIDE

by

R D Lynch

The combustion of wood and some plastic building materials can produce carbon monoxide and hydrogen cyanide which are both toxic. It was not clear, however, whether the toxicity of the two gases mixed together could be greater than would be expected from the sum of the calculated individual toxicities. At the instigation of the Fire Research Station a study of the problem was carried out at Porton Down and this involved subjecting rats to gas mixtures of various proportions and observing the mortality rate.

It was found that within the limitation of the experimental conditions, there was no added toxicity beyond that expected from adding the toxicities of the two gases together.

Synopsis of FR Note No 1036

PRESSURE LOSSES IN UK FIRE HOSE

by

P F Thorne, C R Theobald and P Mahendran

A large number of tests has recently been carried out for the purpose of investigating the pressure losses which occur during the flow of water through a fire hose. This is a problem of practical interest to firemen and one which was of concern in connection with the recent experiments on drag reduction and the use of PEO as a friction reducing agent - see Synopses for FR Notes 959 and 1033.

The hoses tested were three makes of low pressure and one of high pressure 19 mm ($\frac{3}{4}$ in) hose-reel hose, four makes of 44.5 mm ($1\frac{3}{4}$ in) and one each of 70 mm ($2\frac{3}{4}$ in) and 89 mm ($3\frac{1}{2}$ in) relaying hose. Any couplings used to connect lengths of hose were of the hermaphrodite or instantaneous type and because the internal diameter of these is less than that of the hose they can affect the water flow and pressure drop. Other factors affecting the pressure drop are the internal surface roughness of the hose, seams and stretching under pressure.

The Note contains tables of the test results and a graph of the friction factors for the hoses tested and a smooth pipe, as a function of the water flow rate. It was found that the friction factor of 0.005 quoted, for all non-percolating hose, in the Manual of Firemanship was a good guide although there were some notable exceptions as follows:

(1.) The friction factor varied widely for the 19 mm hose-reel hose probably due to different wall construction, internal roughness and stretching and the worst hose had a factor 76 per cent higher than the best.

(2) The friction factor for the worst 44.5 mm hose was 70 per cent higher than for the best.

(3) The couplings were probably the main cause of the high friction factor for both the 70 mm and the 89 mm (relaying) hose.

The coupling constriction causes sudden contraction and expansion of the water and could behave as a simple orifice or as a venturi, which is better. Further detailed measurements of hose coupling losses are desirable and it would be profitable to explore better internal profiles so that couplings behave more like a venturi.

Synopsis of FR Note No 1038

FIRE BEHAVIOUR OF BEDS AND BEDDING MATERIALS

by

W D Woolley, S A Ames, A I Pitt and J V Murrell

In order to study the burning characteristics of beds using common bedding materials a series of 18 full-scale tests was carried out in the 'compartment corridor' rig in the Model Laboratory at the Fire Research Station (see FR Note No 1015). The bed consisted of a single size metal frame with spring base and headboard of chipboard covered with a surface laminate and it was placed in the fire compartment of the rig. Apart from the mattress, each bed was made up with cotton sheets, cotton cellular or wool blanket and cotton bedspread together with cotton covered pillows. The mattresses used were of various types of polyurethane foam, animal hair spring interior and one of foamed rubber. Mattress covers were of cotton or nylon, some treated, and a hair or glass fibre interlining was placed between the mattress and the cover in a few tests.

Apart from two initial tests with underbed ignition, the ignition source was crumpled newsprint placed on top of the middle of the bed after the top covers had been 'turned-down'. Ignition of the newsprint was by an electric element.

Measurements were made of the temperatures, smoke production, radiation and air input velocity, and the opening between the compartment and the corridor was 700 mm wide and the full height of the rig. The Note contains a full description of the tests together with tables, graphs and some photographs.

Underbed ignition may have preheated the bed to give a serious although delayed fire but top ignition on the 'unmade' part of the bed tended to produce a more rapid and realistic fire and was used for most of the tests.

The conclusions are set out in considerable detail and these are of course, numerous variations resulting from the different combinations of materials used. The main conclusions are summarised as follows:

(1) The standard polyurethane foam mattress with cotton cover produced a severe fire in 7 min but a fire retardant (FR) cotton cover delayed the full fire development to 16 min although a double FR cover gave little further 'added' protection. A proofed nylon cover produced the severest fire but with a fibre cloth interlining the full fire development was delayed to almost 30 min.

(2) The modified and cured foams were a little better than the standard foam and here again there was improvement with FR covers and interlining.

(3) A new flame retarded polyurethane foam delayed the fire development substantially but after an accelerated ageing process there was a marked deterioration in performance. Flame retardant paints on foam also gave a better fire performance but no ageing tests were done on the paint.

(4) The air mattress and spring interior mattress produced maximum temperatures of only 65°C and 130°C respectively throughout these tests.

(5) The foamed rubber mattress with FR cover produced a lot of smoke and a temperature of 220°C after 15 min.

(6) Radiation was greatest with the polyurethane mattress with proofed nylon cover and it may have been sufficient to ignite a nearby bed. Substantial smoke was also produced in the early stages of this fire.

Substantial improvement in fire behaviour can be achieved by using an FR cover on the mattress and, in some cases, by the use of a protective interlining between the mattress and its cover.

Synopsis of FR Note No 1039

THE THERMAL DECOMPOSITION PRODUCTS OF RIGID POLYURETHANE FOAMS UNDER LABORATORY CONDITIONS

by

W D Woolley. P J Fardell and I G Buckland

Numerous full scale fire and laboratory pyrolysis tests have already been carried out on flexible polyurethane foams, which are used for furniture and bedding, in order to establish the general decomposition mechanisms and temperatures and to investigate the production of hazardous gases such as hydrogen cyanide and other low molecular weight nitrogen products at high temperatures (700° to 1000°C). The fire tests were described in FR Note No 1017.

There has recently been concern about the release of toxic gases from the rigid polyurethane foams employed in the construction industry where the material is used for such purposes as ceiling and wall boards, and insulation. It is proposed to carry out a series of full scale fire tests at the Fire Research Station, similar to those for flexible foams, in order to study the release of toxic products when rigid polyurethane foams are involved in real fire situations.

For the effective design of full scale tests it is necessary to carry out laboratory pyrolysis experiments first, as was done for flexible foams, and this Note contains a full description of the tests done and the results using the silica furnace tube and chromatographic analysis of the decomposition products. Preliminary research on these rigid foams was described in FR Note No 880.

The four types of rigid polyurethane foams used are typical of commercially available materials, based on MDI, both with and without organophosphorus flame retardants. The tests showed that the general decomposition mechanisms were similar for all four types but quite different from that observed with flexible polyester and polyether foams. Firstly, there was a release of some of the polyol content followed by a uniform fragmentation of the residue as yellow smoke at temperatures up to 600°C. This smoke then decomposed above 700°C to produce the nitrogen containing products such as hydrogen cyanide, acetonitrile, acrylonitrile, pyridine and benzonitrile. At 1000°C the yields of hydrogen cyanide represented 28 to 42 per cent of the theoretically available nitrogen and the yields of hydrogen cyanide were directly proportional to the nitrogen content.

Phosphorus from the flame retardant foams was readily lost at low temperatures although a proportion was still in the residue at 700°C but the additive did not appear to alter substantially the general decomposition mechanism.

Synopsis of FR Note No 1040

THE ACUTE INHALATION TOXICITY OF CARBON MONOXIDE FROM BURNING WOOD

by

J A G Edginton and R D Lynch (of Porton Down, Wiltshire)
(Fire Research Station liaison - P C Bowes)

As part of a study of the toxicity of combustion products, in particular carbon monoxide (CO), from wood and plastics, a series of experiments, using rats and guinea pigs, was carried out at Porton Down on the combustion of 12 mm Finnish birch plywood both with and without a flame retardant treatment of mono-ammonium phosphate. The combustion took place in a Fire Propagation Test box (BS 476 - Part 6) modified to allow less ventilation and with more heating and a longer burn time than under the standard test. The apparatus was placed in a 10 m^3 chamber which was also used for comparison tests with pure CO. Measurements were made of the CO and CO_2 concentrations in the chamber using infra-red gas analysis.

All the animal deaths were due to carbon monoxide intoxication and the report concludes that this is the only hazardous gas released, in significant amounts, from the burning of the plywood samples with or without the flame retardant treatment. There was a very slight increase in the toxicity from burning plywood as compared with pure CO and this may have been due to some irritant products of the pyrolysis of the wood although this was not proved.

Synopsis of FR Note No 1041

A PHOTOGRAPHIC TECHNIQUE FOR THE STUDY OF WATER JETS

by

C R Theobald

The jet of water from a fire fighting hose nozzle may be improved by altering the nozzle design and by the use of PEO as a drag reducing agent. The nozzle design has not been studied in great detail since 1889 but the use of drag reducing additives has recently been reported upon - in particular see synopsis for FR Note No 959. If the nozzle design can be improved to produce a more compact jet of increased 'throw' this could more easily be directed through restricted openings and could be beneficial even though the quantity of water leaving the nozzle was, as a consequence, slightly decreased.

The conventional nozzle has an internal profile convex to the water eg a venturi type profile, and, although it passes a high flow of water, there is an early break-up of the jet and production of spray which can result in little of that water reaching the target. In considering the nozzle design it is thought that significant features may be any abrupt changes in direction or relatively long tapering sections in the nozzle's internal profile as well as the relationship between the length of the final parallel section to the outlet diameter.

As a first step in this research it has been necessary to develop a photographic technique for the close study of water jets moving at from 18 to 32 metres per second and this Note describes in detail, with diagrams, the system which has been devised and there are sample photographs of water jets. Briefly, the apparatus consists of a stroboscopic light, behind a semi-translucent plastic screen, shining through a horizontal jet of water on to a camera film also travelling horizontally and at the same speed as the image of the jet. After some modification the system has been found satisfactory and it may prove useful in work on foam discharged from branchpipes.

Some tests have been carried out using experimental nozzles. One such test involved a 12.5 mm nozzle with an internal profile concave relative to the direction of water flow and with a sharp edged orifice chamfered outwards at 45°. Preliminary tests indicated that such a nozzle could produce a water jet carrying 25 per cent further than that from a conventional nozzle for equal nozzle exit velocities and there was a significant absence of ripples and spray in the jet.

The research work is continuing.

Summary of Current Paper No 3/75

FIRE HAZARDS OF PLASTICS IN FURNITURE AND FURNISHINGS: CHARACTERISTICS OF THE BURNING

by

K N Palmer, W Taylor and K T Paul

This Paper contains a very full description of the second year's work on a three year contract on Fire Hazards of Plastics in Furniture and Furnishings being carried out by the Rubber and Plastics Research Association. The first year's work was described in Current Paper No 18/74 and concerned the ignition behaviour. The present Paper deals with the characteristics of burning once ignition has been achieved and experiments were carried out on upholstered chairs, curtains, carpets and beds etc with ignition sources ranging from cigarettes to wood cribs. The Paper contains numerous tables giving details of the experiments and also some photographs.

This is a progress report and although certain behaviour patterns are emerging further work still needs to be done, particularly involving full-scale room fires. The extent to which the behaviour of furniture and furnishings in real fires can be predicted from small-scale experiments has still to be measured. One of the main purposes of the research is to compare the behaviour in fires of modern materials, involving plastics, with that of traditional materials.

Summary of Current Paper No 25/75

PROBLEMS WITH THE USE OF FIRE-FIGHTING FOAMS

by

J G Corrie

The use of foams for extinguishing flammable liquid fires involves a number of problems such as the foam decay drainage and burn-back resistance properties, the design and performance of foam branchpipes, the rate of foam application and the design of, and measurement facilities for model fires for the purpose of predicting large-scale results.

This Paper contains a lecture, given at the International Fire and Security Exhibition and Conference in London in 1974, in which one further problem is explained and discussed, namely why the quantity of foam required to extinguish a fire increases progressively as the foam application rate is increased. For example if a fire is extinguished in 55 s by foam applied at 2 l/m^2 min then at double this rate (4 l/m^2 min) it will take 33 s and not 27.5 s.

Possible reasons for the paradox are considered in some detail. The explanation could be related to the foam forming period or surface turbulence and cooling but these are readily discounted and only mechanical distribution of the foam and the foam spreading characteristics are reviewed and reference is made to earlier research work including FR Note No 762 (see synopsis). It is shown that the foam distribution and spreading features examined in earlier tests were not always present when the paradox occurred and they are, therefore, also discounted, at least as the main factors. A different explanation has therefore been sought.

It is known that foams have different physical properties when in motion from those at rest and this difference is very marked with protein foams. Assume that a layer of foam whilst in motion presents no great resistance to the escape of vapour from the fuel surface but that while at rest it will act as a sealing blanket, then, if the time of transition from fluid to static state is, say, 20 s there is an answer to the paradox. This 'setting' time hypothesis has been demonstrated in research work in a different field but could be relevant to the foam problem. It is suggested that after a foam layer has been spread to a certain minimum thickness over a flammable fuel fire, the foam 'setting' period must elapse before the fire is extinguished. If, then, it is assumed that the foam is destroyed at a constant rate which is the critical application

rate then:

$$\text{Control time (or extinguishment time)} = \frac{\text{Minimum thickness required}}{\text{Application rate} - \text{critical rate}} + \text{foam setting time}$$

This formula is applied to and compared with actual experimental conditions and results and the control times calculated in this way are in close agreement with those obtained in the tests.

Although there is clearly a delay in the extinction process, and the foam setting period may be the cause, it is still desirable for further research work to be carried out on other changes in the foam which may occur during the first 30 s or so of its existence as a static layer.

Summary of Current Paper No 29/75

THE PERFORMANCE OF THE SPRINKLER IN DETECTING FIRE

by

P Nash and R A Young

This Paper contains a concise and clearly expressed description of a glass bulb or soldered strut sprinkler head and its operation as a 'constant temperature' device and of the various factors which affect its opening. There are general comments on the way in which hot gases from a fire heat a sprinkler head and on how the height, shape and nature of a ceiling or roof and the positioning of the head can affect its operation. It is emphasized that the sprinkler head is far less responsive to radiant than convective heating.

Brief comments are made on suspended ceilings and the effect of roof venting, and in respect of the latter it is made clear that not enough is yet known of the problem of whether the vent or the head should open first. It is suggested that investigation could be made into the provision of a centrally placed detector which could actuate a group of sprinkler heads and open the vents above a fire at the same time.

Architects and other designers of buildings should find this Paper of value when considering the installation of sprinklers.

Summary of Current Paper No 31/75

A SIMULATION METHOD FOR ESTIMATING THE DISTRIBUTION OF FIRE SEVERITIES IN OFFICE ROOMS

by

Sara K D Coward

Previous work (see synopsis for FR Note No 877) on fires in compartments demonstrated that the fire resistance time (t_f) equals $K \frac{L}{\sqrt{A_W A_T}}$ where L is the fire load, A_W is the window area and A_T is the sum of the wall and ceiling areas excluding A_W and K is a 'constant' which, experimentally, has been shown to vary from 0.7 to 1.5. The work described in this Current Paper concerns the estimation of the statistical distribution of t_f for rooms used as offices and for this purpose K is assumed to be 1. Reference is made to the results of two surveys on conditions and floor loadings in office buildings.

This statistical analysis shows that about 7 per cent of office rooms would require a standard fire resistance of more than one hour but it is emphasised that there are many variables and further assessment of the various factors is required. However, the results obtained in this preliminary study are said to be encouraging and indicate that this particular approach to the problem may provide a feasible technique for use in this field of research.

Summary of Current Paper No 32/75

THE BEHAVIOUR OF AUTOMATIC FIRE DETECTION SYSTEMS

by

J F Fry and Christine Eveleigh

This Paper contains a reprint of Fire Research Note No 810 for which a synopsis was prepared and which is contained in the collected summaries in Fire Research Note No 869. The report on false alarms is based on information available from the Fire Brigades in 1968.

The conclusions of the analysis were:

(1) The ratio of false alarms to genuine fire calls by automatic systems of all types was about 11:1 and of the false alarms:

$\frac{1}{4}$ were attributed to ambient conditions
$\frac{1}{2}$ " " " mechanical and electrical problems
17% " " " the communication system

(2) About 68% of calls to genuine fires were made by automatic systems when these were installed and the remainder by other means when the automatic system did not operate on about 53% of the occasions.

(3) In about 73% of the 'failure to operate' cases there was insufficient heat or smoke.

Summary of Current Paper No 36/75

THE EXPLOSION RISK OF STORED FOAMED RUBBER

by

W D Woolley and S A Ames

An explosion and fire occurred in November 1974 at Chatham Dockyard in a store containing 178 foamed rubber mattresses, mainly uncovered, and two people died and four were injured. Following an investigation of the incident the Fire Research Station carried out some experimental work in order to examine the problem which was broadly that a severe explosion, but not sufficient to damage the main structure of the building, happened before any real fire had developed and after the building had been filled with cool dense smoke.

The main experiments in the laboratory were carried out with 'new' foamed rubber (density 65 kg/m^3) similar to that in the fire incident where any salvage foam had been wetted and was unsuitable for tests. Lighted matches actually ignited the foamed rubber, over which flames then spread rapidly, but a lighted cigarette only caused smouldering and the evolution of grey smoke, the decomposition products being flammable. The lighted cigarette caused a hemispherical cavity to form in the rubber and this grew with time. At 48 min after the start of the test the rubber ignited. Similar smouldering experiments were also done in a steel explosion chamber having a polyethylene sheet vent. After 32 min a small flame was introduced into the chamber which was then full of smoke and an explosion occurred having a yellow flame and this ignited the residual foamed rubber.

It is estimated that with smouldering combustion it would have taken about two hours for the mattress store (176 m^3) to be filled with an explosive atmosphere. There was a high load of foamed rubber in the store and experience to date does not indicate that a similar situation would arise in a domestic risk.

Summary of Current Paper No 37/75

FIRE RESISTANCE - PRESENT AND FUTURE

by

H L Malhotra

This Current Paper contains a lecture given by Mr Malhotra at the International Fire and Security Exhibition and Conference in London in 1974. It gives a resumé of the development of standards for fire resistance in GB and the USA and of the present international collaboration as regards uniform procedures for assessing fire resistance.

Reference is made to the establishment of the British Standard 476 in 1932 and to the relationship between the standard time/temperature curve and the fire load. Brief details are given of the existing fire resistance test arrangements and the reload requirements in the British Standard. Attention is drawn to some of the shortcomings such as the inability to test the boundary conditions of test specimens so as to reflect the use of the tested material in an actual building and the absence in the present test furnaces of facilities to exert end restraint on beams. Wall and column loading methods and furnace heat transfer characteristics and combustion conditions do not necessarily reflect the effect of real fires. The environmental conditions of actual fires cannot be reproduced in laboratory tests but on the other hand it may be possible to carry out tests on particular parts of a building element and assess its performance, although the behaviour of joints and junctions is largely unpredictable.

Future developments both nationally and internally through the various interested bodies should include:

(1) Improved realism of tests particularly in regard to boundary conditions, and facilities for testing composite structures.

(2) Reproducibility and exchange of data between the various laboratories.

(3) Development of computer programmes for the design of structures taking account of the occupation and the computation of fire resistance to be incorporated in building codes.

(4) Data on the effect of high temperature on the thermal and structural properties of materials.

Summary of Current Paper No 38/75

CURRENT RESEARCH ON FIRE DETECTION AT THE FIRE RESEARCH STATION

by

P E Burry

This Paper contains a lecture, given at the International Fire and Security Exhibition and Conference in 1974, which outlines at considerable length but in general terms the work done at the Fire Research Station in the field of fire detection, this work being principally aimed at the introduction or revision of British or International Standards for testing heat and smoke detectors. Reference is made to the basic principles of a detector and to the necessity to avoid false alarms (see synopsis for FR Note No 810), and also to Papers delivered at the Fire Research Symposium No 6 in 1974. Mention is made of the problem of inter-laboratory comparisons and it cites the ceiling for smoke detector testing which has had to be moved from the Models Laboratory to the Sprinkler Test building so that the ceiling height can be adjusted from 2.5 m to 8 m high to be in line with other laboratories' facilities.

It is pointed out that there are no agreed standards for smoke measurement and attention is drawn to the problems of monitoring ambient conditions in actual commercial premises and the lack of satisfactory measuring instruments.

There are general comments on the two types of smoke detector, optical and ionisation, and on the development of a tunnel for test purposes. Some details are given of the initial work being done on a separated ionisation chamber in which the air is first ionised and mixed thoroughly before being passed to the measuring chamber. This is a new theory which is now being studied.

After making these general references to some of the detection work being done at the Fire Research Station the author lists other topics on which work is being done, viz:

Radiation and flame flicker and the relationship between smoke and heat outputs from a fire, and thermal currents caused by fire

Reliability of detector control equipment and cost-benefit analyses

Detectors in particular risks

Work on other projects is being considered but staff shortage is restricting this development.

Summary of Current Paper No 42/75

FIRE PROTECTION OF FLAMMABLE LIQUID STORAGES BY WATER SPRAY AND FOAM

by

P Nash

This Current Paper reproduces two articles, published in Fire Prevention Science and Technology in 1973 and 1974, describing the fire protection of flammable liquids by fire fighting foams and water sprays respectively. Both papers summarise the then current knowledge on the performance of these extinguishing media in a clear and concise manner and indicate the problems requiring further research.

The protection afforded by foam makes it unique where large areas of flammable liquids are involved such as in aircraft fires, fuel storage tanks and large spillage fires. It is non-toxic, does not induce large volumes of air to the fire nor obstruct the view of the fire zone but its action can be slow and its weight relatively high for a given effectiveness. Details are shown of the six main types of foam which are generally used at a concentration up to 6% and at a low expansion of up to 12:1. The drainage and critical shear stress characteristics are explained and indications are given of the foam properties required for particular applications. Water should, of course, not drain away from the bubbles too rapidly and reignition should be prevented for a considerable time after the foam application. High shear foam is stiff and will not readily flow whilst low shear foam will flow easily but may not retain its water adequately. Foam must be selected according to the type of fuel to be protected and the fuel can be water miscible or non-water miscible and the boiling points can vary. This paper deals mainly with non-water miscible liquids and with the practical fire-fighting considerations.

The way in which the foam effects extinction and the particular properties and effectiveness of the various protein, fluoroprotein, fluro-chemical and synthetic foams are described. Details are given of the laboratory tests designed to assess the properties and reference can be made to the Synopses for FR Notes 863,918,925, 970, 971, 972, 975, 976, 980 and 993 which deal with various aspects of the tests and other foam problems. There is a general description of the protection of large fuel storage tanks and it is suggested that existing foams could be more efficiently used. Such development would be preferable to the introduction of expensive new foam materials.

In the second section of the Current Paper there is a description of the control and extinction of flammable liquid fires by water sprays including the protection of such liquids in tanks with pipework when hot metal can cause re-ignition of the liquids after a fire has been once extinguished. Information is provided regarding the rate of application of the water and the drop size necessary to cool the liquid and surrounding metal and penetrate to any hot zones in the liquid and also for the protection of adjacent tanks. Attention is drawn to the dangers of water on flammable metals.

Spray systems for low fire point liquids, whether miscible or immiscible with water utilise medium velocity spray nozzles of the open or closed type and actuation is usually automatic. Comments are made on the protection of oil-filled equipment, such as transformers, by high velocity sprays and on the protection and siting of adjacent equipment and storage tanks. The design of tank farm installations may require further study.

Summary of Current Paper No 45/75

ECONOMICS OF STRUCTURAL FIRE PROTECTION

by

R Baldwin

This paper is based on two lectures given by the author during 1974, which reviewed earlier work done on the problems of the effective cost of structural fire protection and the provision of fire resistance. A mathematical model is formulated in order to evaluate the optimum level of fire resistance. Reference is made to previous Fire Research Notes and, in particular, to Notes 808, 877, 901, 934 and 963.

The relationship between the costs of fire protection and the expected fire losses is in the form of a U-shaped curve; with no costs, losses may be large but with high costs losses should be small and from an economic point of view the best level of fire resistance is that which minimises the total costs ie the lowest point on the U-curve. Some part of any fire resistance may be sacrificed in exchange for a sprinkler installation.

The economical approach is based on previous research work done on laboratory compartment fires and on surveys done on floor fire loadings in office buildings. Fire severity is related to time and the fire resistance rating of building materials in the furnace tests. It is pointed out that the probability of a fire occurring can be estimated from fire statistics for different building types once the number of buildings at risk is known.

With regard to office buildings for which fire load data are available the structural fire protection costs are related to possible losses following the failure of any fire resistance provisions and it is suggested that for any fire resistance to be justified $\frac{D}{I}$ must be greater than 4 where D is the expected loss, given that failure occurs, and I is the initial building cost. Where $\frac{D}{I}$ is about 10, a 30 min fire resistance would be suitable as compared with none when $\frac{D}{I}$ is 4 or less. Further, it is suggested that if the expected losses following failure of fire resistance are, say, 100 times larger than the initial building cost then the present requirements of 1 hours fire resistance for office buildings is justified economically.

It is shown that there is a limit to the amount of fire resistance that can be economically provided and if the mean fire severity is too large it may be more economical to have no protection. A mathematical expression is derived for the reduction of fire resistance which would be justified when sprinklers are installed.

Summary of Current Paper No 48/75

SMOKE HAZARDS IN COVERED, MULTI-LEVEL SHOPPING MALLS: AN EXPERIMENTALLY BASED THEORY FOR SMOKE PRODUCTION

by

H P Morgan and N R Marshall

Extensive research work has been done on smoke spread and control in single storey shopping malls and it is reported upon in FR Notes Nos 807, 875, 954, 977 and 1001 for which synopses have been prepared. However, many shopping complexes are of two levels or more and may have balconies projecting from the upper level shops to some way across the covered mall. The 'ceiling reservoir' would then be formed under the roof above the mall and the smoke and hot gases would be extracted from there. The worst situation arises when the fire is in a shop at the lowest level.

The Note contains a detailed theoretical analysis of the problems involved and reports on supporting experiments carried out in a model of a two level shopping complex constructed to $^{1}/10$ full scale with the 'fire compartment' representing a full size gound floor shop either 14 or 7 m wide and 5 m deep. A controllable methylated spirit 'fire' was used and this developed up to 16 kW which approximates to a full size fire of 5 MW. Numerous temperature measurements were taken of the rising plume of hot gases.

It is shown that the wider shop fronts lead to greater entrainment and more smoke in the plume but, whatever the shop width, it is necessary to use channelling curtains beneath the balconies and extending from the shop front to the balcony edge, in order to restrict lateral spread of the smoky gases. These gases will then rise around the balcony edge in front of the shop and up to the reservoir below the roof. The experimental results show that the extraction rates then required are much larger than had previously been supposed and, consequently, the recommendations for single level malls must be assumed to be quite inadequate. Calculations, however, indicate that extraction rates could be greatly reduced by extracting smoke from the shop itself.

It is also suggested that suitably deep curtains suspended from and parallel to the balcony edge might enable each level to be treated as a single level mall if it had its own extraction system. Further work is being done on this idea.

Summary of Current Paper No 67/75

THE PERFORMANCE OF THE SPRINKLER IN THE EXTINCTION OF FIRE

by

P Nash and R A Young

The basic principles of a sprinkler installation and the operation of a sprinkler head as a fire detector were described in Current Paper No 29/75 (see summary) and the present Paper, which is complementary to the earlier publication, discusses the factors affecting the extinction of a fire by sprinklers. It was published in the Fire Surveyor Vol 3 No 3 in 1974.

There is a detailed description of the water distribution from a sprinkler head or array of heads and of the range of experimental wooden crib fires carried out by the Fire Research Station in order to determine the appropriate water discharge rates for fires of various sizes. As a result of this work and from experience gained in real fires and through other organizations, it was possible to assess the appropriate densities of water distribution required to control and extinguish fires in light, ordinary and some high hazard occupancies. These rates varied from 2.25 to 14.5 mm/min (1 mm/min is equivalent to 0.020 gal/ft^2/min). The Paper contains numerous tables and graphs and explains the bases adopted in arriving at the main requirements of the FOC Rules (29th Edition) for Sprinkler Installations and these are being followed through to the International Organisation for Standardisation.

The special problems of extra hazard occupancies and of high-stacked storage are also discussed in general terms and details are given of the higher rates of water application necessary to deal with such risks. The maximum rate could rise to as high as 32 mm/min for a 25 ft high stack of high-hazard material. There are also general comments on the need for ceiling wetting and on the relationship between sprinklers and venting. Possible methods of linking automatic detection systems, sprinkler installations and venting arrangements will be discussed in a future publication.

Summary of Current Paper No 70/75

DRAG REDUCTION IN FIRE-FIGHTING

by

P F Thorne

This Paper is based on one presented at an International Conference on Drag Reduction in Cambridge in 1974 and the information on drag reduction given in Part I of the paper has now been published in FR Note No 1033 for which a synopsis has been prepared. In addition to the technical details given of the use of PEO (polyethylene oxide) to produce 'slippery water', and of powdered PEO as a slurry which results in 'rapid water', the paper also makes a comparison between the use of this drag reducing agent in the UK and the USA. In the UK the fire brigade hoses are mainly 70 mm ($2\frac{3}{4}$ in) internal diameter and it is pointed out that in the USA it has been possible, for example, to reduce their standard 64 mm hose to 44.5 mm still with their standard 25 mm nozzle, and even so continue to deliver water at 900 l/min as a result of using PEO. The weight of the smaller 44.5 mm USA hose is half that of the 64 mm hose when full of water.

In Part 2 of the paper details are given of the standard UK fire brigade hose nozzle of 19 mm or less diameter. The use of PEO improves the coherence of the water jet and reduces turbulence but not sufficiently to justify the use of PEO specifically for this purpose. The maximum jet 'throw' at a given nozzle pressure is not significantly increased by the use of PEO. However a redesigned internal profile of the nozzle could physically improve the water jet. Different nozzle profiles are now being studied at the Fire Research Station.

Summary of Current Paper No 77/75

THE TESTING OF SPRINKLER INSTALLATIONS

by

R A Young and P Nash

An article printed in Vol 4 No 4 of the 'Fire Surveyor' in 1975 is reproduced in this Current Paper. It describes the testing of sprinkler system components to the requirements of the Fire Offices' Committee and there are a few drawings and photographs of sprinkler valves and a pressure switch. After detailing the test procedure necessary for the approval of all the system's components, it outlines the requirements for the actual installation of a system which, in the UK, must be carried out by installers approved by the Fire Offices' Committee.

The importance of maintaining an installation is emphasised and it is pointed out that 44 per cent of all 'failures to operate' can be directly attributed to inadequate maintenance. A table gives a list of the weekly and other periodic checks required. It is stressed that a sprinkler installation should be able to function efficiently in a fire situation up to at least 25 years after installation and that it is management alone that can keep the fire protection adequate in extent and in good operating condition at all times. Brief details are given of emergency procedures necessary whenever, for any reason, a sprinkler system has to be shut down.

Summary of Current Paper No 78/75

THE TESTING OF SPRINKLERS

by

P Nash and R A Young

This Current Paper reproduces an article which was printed in the 'Fire Surveyor' 1975 Vol 4 No 2 and it provides a comprehensive study of the test procedures for sprinklers used in the UK and European Countries and some comparisons are made with USA procedures. Reference is made to the Approval, Annual and Follow-up tests and to the Fire Offices' Committee's Rules and Standards, and the tests described are those based largely on JFRO procedures and the draft CEA standard. Brief details are given of the initial examination of sprinkler heads and the pressure, functional, thermal, strength, fatigue and corrosion tests. The water flow and distribution tests for conventional, spray and sidewall sprinklers are described and reference is made to tests for drenchers, medium and high velocity spray nozzles and to the sensitivity of sprinklers to radiation.

The paper concludes that there are comprehensive procedures in Europe and the USA, and that whilst these are broadly similar there are differences in approach to the testing problems. Since sprinkler systems are being installed world-wide it is logical that there should be a universal standard and it is hoped that developments through the International Standards Organisation will lead to a suitable appraisal and standards which would do much to simplify testing and so eliminate barriers to international trading.

Summary of Current Paper No 79/75

THE ESSENTIALS OF SPRINKLER AND OTHER WATER SPRAY FIRE PROTECTION SYSTEMS

by

P Nash

This Current Paper contains a reprint of an article,which appeared in 'Fire Prevention' No 108, dealing with sprinkler, water spray and deluge systems designed to extinguish or control, by water, solid-fuel or flammable-liquid fires or a mixture of the two.

The general design features of a sprinkler system are described and reference is made to the three main classes of extra low, ordinary and extra high hazard as described in the 29th Edition of the Fire Offices' Committee Rules (1968). Brief information is given regarding the layout of a sprinkler system and the various types of sprinkler heads and it lists and describes briefly the five main types of sprinkler installations viz: wet, dry, alternate, pre-action and re-setting. There are photographs of some heads and drawings of valves and equipment.

The spacing and layout arrangements of sprinkler heads are summarised and basic information is given in regard to water supplies and pumps.

Water supply systems designed mainly for the extinction of flammable liquid fires are described and typical examples are given of deluge systems.

The Paper provides a useful introduction to the essentials of the equipment and performance of these systems.

Summary of Current Paper No 81/75

THE STRENGTH OF FIRE EXTINGUISHERS

by

P F Thorne

This paper reproduces an article, published in the scientific press recently, dealing with the strength of portable fire extinguisher bodies and the possible European standard requirements now being drafted by the Comité Européen de Coordination des Normes (CEN). The article examines the available evidence on which suitable strength criteria could be decided.

Reference is made to the working, test, yield and burst pressures which could be in the proportion of about 1.0, 1.5, 2.5 and more than 3. The test pressure should be more than the working pressure but less than the yield pressure so that weakening of the extinguisher body does not result from routine test procedures.

The article deals in some detail with the factors affecting working pressure such as temperature, quantity and type of contents and possible discharge blockage, variations in working and burst pressures and in mechanical properties. The calculation of the cylinder wall thickness is shown in detail and two graphs indicate the various requirements under the CEN proposals of 1971 and 1974 respectively.

The current proposal is that the minimum wall thickness should equal $1.3\frac{Dm}{R}$ where Dm is the mean diameter and R is the yield stress; the 1.3 factor means that the yield pressure is not less than 1.3 times the test pressure. Typical examples of wall thickness are indicated on the basis of R = 200 N/mm^2 (20 bar) or 500 N/mm^2 (50 bar) for 'welded' or 'deep drawn' steel bodies extinguishers respectively.

A suggested arrangement for arbitrary minima wall thicknesses expressed as a function of the cylinder diameter in a series of 'steps' is criticised as over-riding the technical equations and ignoring the basic parameters.

Summary of Current Paper No 82/75

SOME DESIGN ASPECTS OF FIRE EXTINGUISHERS

by

P Nash

A Paper on the problems regarding the design and suitability of portable fire extinguishers which was printed in 'Fire Prevention and Technology' 1972 No 12 is reproduced in this Current Paper. It points out that these extinguishers must be capable of being used by men, women and adolescents without previous practical experience of the method of operation or the type of fire for which each type is suitable. There are general comments on the weight of the extinguisher, the way in which it is discharged and the identifying colour or other markings and instructions.

The assessment of extinguisher performance is now being entirely changed in a new series of fire test procedures being devised under the auspices of the Comité Européen de Coordination des Normes (CEN) (Working Group WG/70). There will be four classes of extinguisher viz: A for solid combustibles such as wood, B for flammable liquids such as petroleum, C for gases burning as a jet and D for combustible metals such as magnesium. For Class A and B fires an extinguisher will be rated according to the size of test fire it can extinguish in terms of the Fibonacci series, 1, 1, 2, 3, 5, 8, 13, 21 etc (each is sum of two preceding terms). The Fire Offices' Committee is drafting new rules for dealing with the new 'performance rating' and with the future scale of provision of extinguishers in terms of total rating.

There are general comments on the construction of extinguisher bodies and the minimum acceptable bursting pressure and it is hoped that the future basis of assessment will be related both to the material used and the diameter. It is pointed out that in recent years there has been a great improvement in the performance of both foam and dry powder extinguishers. The vaporising liquid or halogenated hydrocarbon extinguishers have also been developed and are now less toxic.

The author points out that in the last 20 years there has been much progress towards the provision of light, efficient and reliable extinguishers and towards their assessment on grounds of 'operational requirements' rather than by rigid detailed standards. He expects that before long extinguishers will be defined in terms of size, operational requirement, toxicity and life, and that there will continue to be newer and better devices. In the future he predicts that an extinguisher will need replacement every 7-10 years and that this should be encouraged by discounting the cost of the replacement.

The FPA has added a Note to the effect that a Class C test fire may not be needed since a gas jet fire should normally be extinguished by stopping the flow of gas and cooling with water in order to avoid the risk of explosion.

Summary of Current Paper No 83/75

WORK BY THE FIRE RESEARCH STATION ON THE CONTROL OF SMOKE IN COVERED SHOPPING CENTRES

by

P L Hinkley

This Current Paper summarises in some detail the research work which has been carried out at the Fire Research Station on the control of smoke in shopping centres with covered malls and there are a number of photographs, drawings, graphs and tables. An article based on this Paper appeared in the Architects' Journal in 1973. The work on the problem in covered malls, shops and pedestrian precincts has already been described in Fire Research Notes and reference should be made, in particular, to Notes Nos 806, 807, 856, 864, 875, 878, 954, 969, 977 and 1001 and to Notes Nos 832 and 854 for details of experiments on smoke movement carried out in a railway tunnel in Glasgow.

It is emphasised that a fire in a shop in a covered shopping centre can result in people being trapped by smoke and that a glass shop front may be no barrier to the flow of smoke since it can break early in a fire. In single storey or horizontally compartmented shops or malls it is necessary to take remedial measures as follows:

(1) Install sprinkers in shops (and malls if they contain combustibles)

(2) Sub-divide the ceiling into smoke reservoirs either by screens or similar ceiling features

(3) Extract smoke from these reservoirs by natural or mechanical means (details are given of the vent spacing and sizes) and guard against adverse wind effects

(4) Arrange for air to enter the shop or mall at low level in order to replace the extracted hot smoky gases.

Multi-level malls with balconies present a more serious problem and these are at present being considered on an ad hoc basis.

A Home Office Working Party has produced an HMSO publication 'Home Office and Scottish Home and Health Department Fire Prevention Guide 1' - London - 1972, and the Department of the Environment has issued a circular - Ref 19/73 entitled 'The Building Regulations 1972 Town Centres and Shopping Precincts' both of which are essential to a consideration of the problems described in this Paper.

It is stressed that these smoke control measures should be considered at an early stage in the design of a building complex of this nature and it is made clear that there is no reason why sprinklers should not be installed throughout the complex especially when it is possible for combustibles to be placed in the malls.

AUTHOR INDEX

(The numbers in the index refer to the numbers of FR Notes and Current Papers (FRS))

SUBJECT INDEX

(Numbers without a prefix refer to FR Notes: numbers preceded by CP refer to Current Papers)

Printed in England for Her Majesty's Stationery Office By Studio Trade Plates Ltd., Watford, Herts..