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JOINT FIRE RESEARCH ORGANIZATION

FIRE RESEARCH IN THE UNITED KINGDOM

by

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Summary

This paper outlines the growth of fire research in the United Kingdom up to the present day and deals in particular with the growth of fire in buildings. The value of the use of model techniques is stressed and an account is given of the more recent developments.

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EXTINCTION TRIALS WITH A MIXTURE OF DIFLUOROCHLOROBROMOMETHANE AND DIFLUORODIBROMOMETHANE

by

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Introduction

The effects of pure difluorochlorobromomethane (CF_2ClBr) and of a mixture with 25 per cent of difluorodibromomethane (CF_2Br_2) on the flammable limits of n-hexane have been reported (1). In order to evaluate the mixture as an extinguishing agent its effectiveness has been compared with that of chlorobromomethane in extinction trials on petrol fires.

The properties of chlorobromomethane and of the constituents of the mixture are given in Table 1. Except for its peak value, no information was available for the mixture.

Table 1

The properties of chlorobromomethane, difluorochlorobromomethane, and difluorodibromomethane

	Chlorobromomethane CH_2ClBr (2)	Difluorochlorobromomethane CF_2ClBr (2)	Difluorodibromomethane CF_2Br_2 (2)
Boiling point °C	68.7	-4	24.5
Vapour pressure mm.Hg/15°C	11.5	1550	5.43
Density (liq) gm/cc	1.93	1.83	2.28
Peak value with n-hexane per cent vol.	6.4 (1)	5.2 (1)	3.55 (1)
Peak value with n-hexane per cent vol. of mixture		3.8 (1)	

Experimental

The fire was two litres of petrol burning in a steel tray 46 cm. diameter and was given 15 seconds preburn before applying the agent.

The agents were applied through a manually operated applicator carrying a pair of No. 1 Bray gas burners arranged to produce a semicircular flat spray. The vessel containing the liquid was pressurized to 20 lb/in^2 with nitrogen. This gave a nozzle pressure of 8 lb/in^2 with chlorobromomethane and 10 lb/in^2 with difluorochlorobromomethane mixture. Because of its low boiling point the mixture was cooled to -10°C and the pressure vessel was stood in a freezing mixture so that the agent was discharged as a liquid.

The manual application was adopted after preliminary trials with nozzles fixed round the fire had shown that experiments to design suitable apparatus to give reproducible results would require more agent than was available. The results of the trials are given in Table 2.

Table 2

	Chlorobromomethane			Difluorochlorobromomethane		
Nozzle pressure lb/in^2	8			10		
Delivery rate ml/sec	12.8			7.5		
gm/sec	24.8			13.8		
Test No.	Extinction time sec.	Amount used Wt. gm.	Amount used Vol ml.	Extinction time sec.	Amount used Wt. gm.	Amount used Vol ml.
1	9.5	236	122	22.5*	310*	169*
2	7.0	173	90	10.5	145	79
3	4.5	112	58	8.6	118	65
4	5.5	136	71	5.8	80	44

* Fire not extinguished.

When either of the agents was applied, the fire was swept quickly from the surface of the tray but flames persisted beyond it, and, until the technique of application had been acquired, attempts to extinguish these allowed the flames to flash back to the tray. There is thus a minimum time of extinction, and this has been noticed in other trials of this nature.

The minimum time of extinction depends upon the size of the fire, the ease with which the applicator can be handled, and wind conditions. The results with chlorobromomethane indicate that the technique was being acquired during tests 1 and 2, and that tests 3 and 4 represent the best times obtainable. This appears to be approximately 5 seconds. Because the physical properties of the two agents are different, the techniques required were different and test 4 with difluorochlorobromomethane mixture is considered to approximate to the minimum time with that agent.

Therefore, comparing the best results, the extinction times are similar although extinction required less difluorochlorobromomethane than chlorobromomethane.

The quantity of material available was not sufficient for a series of tests comprehensive enough for a complete evaluation, but the results show that the difluorochlorobromomethane mixture is a promising extinguishing agent and that it is probably more efficient than chlorobromomethane.

References

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2. Kinetic Technical Bulletin B - 4. Du Pont Nemours & Co. (Inc.) Wilmington, Delaware.

FIRE RESEARCH IN THE UNITED KINGDOM

by

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INTRODUCTION

When I was asked to speak about fire research in the United Kingdom, there seemed to be little point in trying to give a detailed picture of current work, rather it would be more useful to describe the development of fire research and to try to forecast the direction that should be taken in the future.

There are gathered here today a great number of people connected in one way or another with the building industry and it is appropriate, therefore, that most of what is said should concern fires in relation to buildings. Indeed, as buildings account for about half of our capital investment and one-fifth of the national income, a study of fires in buildings must be an important factor in any fire research programme.

GROWTH OF FIRE RESEARCH IN THE UNITED KINGDOM

The first systematic enquiry into fire protection in the United Kingdom took place about sixty years ago following a particularly disastrous fire during 1897, in Cripplegate, a district of London. At that time Edwin O. Sachs, an architect of only 27 years of age, gathered together a number of influential people to study how to protect life and property from fire and formed the British Fire Prevention Committee. A fire testing station, a reading room and a reference library were started and six years later with Sachs as its Chairman, the Committee convened the First International Fire Congress which was attended by over 800 members. During the first seven years of its existence, the British Fire Prevention Committee conducted 79 fire-resistance tests and tests on fire equipment and issued 57 publications of test results and 22 other publications dealing with fire prevention and visits to fires. In 1919 at the age of only 49, this remarkable man, Edwin Sachs, died and after his death the British Fire Prevention Committee on which he had spent so much of his energy and private fortune, lapsed! By that time they had issued over 200 publications or "Red Books" as they came to be known, dealing with fire prevention and after the Committee had disbanded a further 46 books in this series were published from public funds.

The Insurance Companies had of course always been interested in reducing fire loss and in fact at one time operated the Fire Brigades. Nearly one hundred years ago, in 1868, an association of Insurance Companies was constituted as the Fire Offices' Committee for the purpose of transacting business and fixing insurance rates appropriate to risks. As time went on, the assessment of risks naturally involved a certain amount of technical investigation and therefore a Station was opened in Manchester in 1905 for the purpose of testing sprinklers and other extinguishing apparatus and later the Fire Offices' Committee erected a furnace for testing fire-resisting doors and shutters. As the work increased during the following quarter of a century, a new Testing Station had to be built. This was opened in 1935 at Boreham Wood, some 14 miles north of London and contained three large furnaces in use at the present day, for testing walls, columns and floors in addition to laboratories where sprinklers and other extinguishing apparatus could be examined. While the Fire Offices' Committee's own staff were responsible for tests on sprinklers and fire alarms, the new furnace equipment was operated by the staff of the Department of Scientific

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and Industrial Research Building Research Station working to a programme devised jointly by the Department of Scientific and Industrial Research and the Fire Offices' Committee.

In 1936, a Government Committee was set up under the Chairmanship of Lord Riverdale to enquire into the working of the Fire Services in the United Kingdom and one of its recommendations was that the Government should carry out research on fire protection. This recommendation was due to be implemented on the 1st September, 1939, two days before war on Germany was declared and so the question of starting a Fire Research Station had to be shelved for the time being.

During the war it became rapidly apparent that the damage by fire was many times that due to high explosives and very soon fire research programmes were started under the Ministry of Home Security at the Building Research Station, the Forest Products Research Laboratory and the Road Research Laboratory and also in Universities to discover how the new problems of fire spread and the extinction of fires could be solved.

As the war drew to a close, discussions again took place on the establishment of a Station to carry out research into fire protection. By this time the Fire Offices' Committee were themselves also considering the starting of a Fire Research, as distinct from a Fire Testing, Station and it was finally agreed that both they and the Department of Scientific and Industrial Research should join together in an equal partnership. So in 1946, the Joint Fire Research Organization was formed with Mr. S. H. Clarke appointed as its first Director in 1947.

The majority of the buildings at present occupied by the Organization were originally laid down in 1935 by the Fire Offices' Committee. During the present year a new Models Laboratory, 150 ft x 50 ft x 40 ft, has been added for the study of the growth and extinction of fire under controlled conditions and next year this Laboratory will be equipped with fans producing wind velocities up to 30 m.p.h. over a section 15 ft x 10 ft x 10 ft. Within the next two years a permanent Station will be built bringing the total cost of the permanent buildings to about £500,000. The present staff totals 120 and nearly half of them have professional qualifications.

The Joint Fire Research Organization is at present divided into five sections:

(1) Operational Research and Intelligence

This Section received reports in a standard form of every fire in the United Kingdom which is attended by the Fire Brigades. The number of these fires amounts to approximately 120,000 per annum and is about equally divided between fires in buildings and fires in the open. These statistics form the background of all our knowledge of fires in practice and enable research to be planned with the public needs in mind. The statistics obtained in this way are not usually detailed enough to indicate remedial measures and for this purpose it is usually necessary to carry out special surveys with the co-operation of sections of the Fire Service.

Current surveys of this kind are aimed at reducing fires from electrical causes, estimating the optimum fire cover, and evaluating the more general use of sprinklers and fire alarms in relation to fire loss.

(2) Ignition and Growth of Fire

The ignition of materials is common to all fire problems and a good deal of attention has been devoted to the study in recent years. It is now possible to predict under what circumstances ignition will occur when the ignition period is short. When the heating is slow, as for example in stored materials, the equations governing the process are intractable except for some simple configurations.

This Section is responsible for the investigation into the growth of fire which will be dealt with in more detail later.

(3) Building Materials and Structures

The work of this Section concerns the testing of structures under fire conditions. During the twelve years since the formation of the Joint Fire Research Organization, the testing work which is paid for by industry, has increased by a factor of 12, and there is as yet no sign of a levelling off. Work has been undertaken to measure the strength of concrete at high temperatures with a view to designing structures from first principles which will be able to perform their normal function for a given period in a fire.

This Section in conjunction with the Ignition and Growth of Fire Section is studying the fire spread over the facade of multi-storey buildings, and how it is affected by the size of window openings, balconies, curtain walls and combustible claddings on the exteriors of the buildings.

(4) Chemistry and Chemical Engineering

The work here is mainly directed towards studying the fire problems associated with industrial processes. Many industries are concerned with solvent removal and it is therefore necessary to transmit flammable vapours to recovery plant and methods have to be found to do this with safety which involves the study of devices for flame suppression and explosion reliefs. Similar problems occur in the case of the dusts produced in cutting, milling and in spray drying and these are also being investigated.

(5) Extinguishing Materials and Equipment

Water is the most important fire-fighting agent and most of the work of this Section is therefore concerned with its use in the form of sprays, jets and foam. Work is also being carried out on the evaluation of more specialized extinguishing agents, such as dry powder and the halogenated hydrocarbons. Recently measurements have been made of the movements of hot gases during the early period of building fires with a view to obtaining some idea of the spacing pattern necessary for fire detectors and automatic sprinkler heads.

In addition to the research programmes actually carried out at the Fire Research Station certain projects, notably those involving basic studies of combustion, have been placed with Universities and it will be the intention, in the future, to extend this co-operation on the more basic problems of fire research. It has also been found expedient to place research contracts with other Government Departments; thus some of the large-scale work on industrial explosions and explosion venting is being dealt with by the Safety in Mines Research Establishment because of the unique facilities they possess.

FIRES IN BUILDINGS

FIRE REGULATIONS AND TESTING

Having outlined the growth of fire research in the United Kingdom up to the present, I should like to deal now more specifically with its application to buildings. Nearly everyone is familiar with the Great Fire of London but there were many disastrous fires prior to this and each one brought its own quota of building regulations. The present requirements for fire-resistance in buildings in the United Kingdom, and indeed in many other countries, are based on the floor area of the building and on the weight of combustible material per unit area. The fire-resistance tests in all countries simulate, in a qualitative way, the fire conditions in buildings. The tests relating the contribution of wall linings to the growth of fire in buildings in general, require materials to be subjected to heating by radiation and the acceptance limits are based on experience.

It is of course important that there should be standards for the performance of building materials and structures in fire, for it is only in this way that codes can be drafted without reference to materials and structures which have proved satisfactory in the past.

While the setting up of even arbitrary tests is a valuable first step, it has obvious limitations, for any procedure based on tradition is not usually the best when new materials and changing conditions are involved. Where information is lacking, the tendency is to fix conservative limits and this is wasteful particularly in buildings in which over £1,000 m. is invested annually. Clearly it is necessary to know something of the development of a fire and this depends on a number of factors: size and shape of building; degree of ventilation; amount, nature and dispersal of fuel; and of course the wind velocity.

A little thought will show that the scientist working in this field is up against some rather formidable problems. First of all, to say that no two fires are exactly alike savours of the kind of understatement of which the British are reputedly so fond. The scientist usually meets a challenge of this kind by carrying out a large number of experiments and resorting to statistical methods. Experiments involving fires in full-scale buildings cost money, and by the time all the variables have been explored the cost of the cure may well be more than that of the ill.

What of the 50,000 or so fires occurring annually in buildings, these of course, occur sporadically and so the scientist has no hope of taking measurements and although a number stay overnight at fire stations, their chance of seeing many fires of importance is still very small. The scientist is mainly dependent on the reports from the Fire Brigades for his knowledge of fires in practice. These reports form the basis of all our statistical knowledge about fire and are the starting point of many valuable operational surveys. Taken alone, however, they are not suitable for a scientific enquiry into fire problems. The reports are made by firemen whose first duty is to extinguish the fire, often working under conditions of some personal risk. They have been written after the fire and there is a different reporter for each fire depending on the locality in which it occurred. Too many variables, no measurements at real fires, reports from observers otherwise occupied, obviously some additional approach must be found.

USE OF MODELS

The ideal solution, of course, is to bring the fires into the laboratory, control the conditions as far as possible, and study the variables one by one. The results of the laboratory work may then be compared with the practical experience of the Fire Brigades to check that no significant factors have been overlooked in the laboratory experiments. In order to do this it is necessary to devise a valid model technique.

In a well organized subject it is possible to write down the differential equations and boundary conditions governing any process and from these, at least in theory, to construct a model. Whether or not it will be a model of practical utility will depend on the compromises that have to be made for a reduction in scale. A fire is such a complex happening that a solution which is scientifically tidy is quite impracticable. It is only possible to construct a graded series of simple small-scale replicas and to carry out experiments measuring the rate of burning. It is necessary then to account for the heat loss in terms of radiation, conduction and convection, choosing the transfer mechanism which appears to most important in determining the heat balance. In this rather untidy way, which is a mixture of empiricism and theoretical opportunism, some progress may be made.

Stages in Growth of Fire

Some years ago a number of experiments were made at the Fire Research Station by Hird and Simms, on fires in a graded series of model rooms having a square floor plan with different amounts of combustible material uniformly distributed and different degrees of ventilation.

The results of the experiments showed that in addition to the amount of combustible per unit area the degree of ventilation was also important; this is a factor neglected by fire regulations. It appeared from the time-temperature curves of these fires that the course of the fire could be divided into three periods: a period of growth in which the temperature rose steadily until the enclosure was fully enveloped in fire; a second period in which the temperature rose at a lower rate until a maximum was attained; and a period of decay during which the temperature steadily fell back to the ambient temperature again.

The first period, which extended up to the point where the compartment was fully enveloped in flame, is important from the point of view of escape and is moreover the rate of development which governs the size of fire facing the Brigade when it arrives. The development in this period will also affect the amount of fire damage to stored materials. The second and third periods largely control the damage to the structure.

These experiments were not able to show the factors which controlled the first period, but it seems reasonable to suppose that the specific surface of the combustible would be the most important factor: the amount of combustible per unit area should not affect the development of the fire as this would not have become a limiting factor in this period. The ventilation within fairly wide limits would also be unimportant as it was only necessary to fill the enclosure with a flammable mixture of gases for the room to be involved completely in flame. The other factor likely to affect the results would be the mode of ignition, that is whether the fire was started at one, two or a number of points and this would require careful standardization in any investigation.

The second period appeared to be controlled by both the amount of combustible per unit area (fire load) and the ventilation. This period was roughly proportional to the fire load and inversely proportional to the ventilation (expressed as a fraction of the wall area). For any ventilation above 25 per cent (one wall removed) the effect of ventilation for any given fire load was comparatively unimportant and the combustion was controlled by the supply of fuel. On the other hand, for a low ventilation (less than about 5 per cent) the combustion seemed to be controlled by the air supply rather than by the supply of fuel.

The rate of cooling in the third period appeared to ~~increase~~ decrease uniformly with the fire load and seemed to be affected to a less extent by the degree of ventilation.

The temperature inside the enclosure appeared to vary with the degree of ventilation of the fire and as might be expected, the temperature was lower both for small and large ventilations than for intermediate ventilations of from 10 - 20 per cent. The temperature was also influenced by the size of compartment and varied according to some power lower than the square root of the linear dimensions. The effect of scale became less apparent as the degree of ventilation was increased.

The preceding results illustrate in a rather qualitative way the kind of factors likely to be important in controlling combustion in a particular kind of enclosure.

Use of Cribs

Quite recently a further series of experiments on burning cribs have been carried out by Thomas and Webster, this time in cubical enclosures with one side removed. These have been designed to investigate the rate of burning and how it is affected by such factors as the linear dimensions of the box, and the size, amount and packing of fuel.

In this series of experiments three sizes of cube have been considered: 1, 3 and 9 ft, with fuel sections of 1, $\frac{1}{2}$ and $\frac{1}{4}$ in., fuel spacings of 1 : 1, 1 : 2 and 1 : 4 and fire loads of $2\frac{1}{2}$, 5 and 10 lb/ft^2.

Measurements have been made of the rates of combustion by weighing the box continuously during the burning, of the height of the flames outside the box and their duration, and of the temperature inside the box. The results of these experiments are still being analyzed but a few facts already seem to emerge:

1. The rate of burning is proportional to the free burning surface of the wood in the cribs irrespective of the size of the box.

2. The flame height outside the box is proportional to the rate of burning and therefore to the free burning surface of the wood.

3. The duration of the fire appears to be independent of the fire load for any given size of fuel. This would be a necessary consequence of the rate of burning being proportional to the free burning surface. In the same way the duration of the fire would be expected to be inversely proportional to the linear dimensions of the fuel.

4. The closeness of the packing of the fuel does not appear to affect the rate of burning provided that the stick/space ratio is greater than about one-third.

Of course these experiments are only a beginning, but they have the merit that the structure is simple and should give the best chance of making theoretical guesses as to which are the predominant factors affecting the growth of fire. A large number of blocks of experiments must yet be carried out to determine the effect of ventilation and of the shape of the burning structure in addition to the factors already mentioned.

It will be seen that the task of estimating the part played by the factors responsible for development of a fire is formidable. This is not so much because the problem is likely to be difficult as that it is complicated and therefore a large amount of experimental work will be required. The problem of using models for studying fires is common to all countries, for once the fire conditions that structures have to endure can be specified with some assurance, it will be possible for all countries to make an economic examination of their present legislative requirements. A further development of the work would be to examine the extinction of fires using models. This, besides permitting an evaluation of extinguishing agents, would enable the strategy of fire-fighting to be investigated.

INTERNATIONAL CO-OPERATION

I started this talk by saying something about the development of fire research in the United Kingdom, and how it began by the provision of standard tests based on experience. The next step will come when the research worker is able to play a part in design, when he is not having to take the world as he finds it, but is able to shape it to take advantage of the discoveries he has made. This implies a knowledge of the fundamental principles of the field and will involve much work in such a varied subject as fire research.

The commercial gain from fire research for any country will be small when compared with the gain from other scientific and engineering pursuits which must be followed. Our strength. of course, lies in the very absence of commercial rivalry between countries. There is no real obstacle to our working together and sharing results as soon as they are produced.

During recent years there has been a growing interchange of information on fire research at regular international meetings. It is difficult to escape the feeling that the time is now ripe to take another step forward internationally and integrate some areas of our research programmes which aim at uncovering some of the fundamentals of the subject in which we work.

The work involving the use of models to study fires in a single compartment seems to be a particularly good example for it is one of interest to all countries and divides readily into a number of easily related programmes of work. We, in the United Kingdom, would be very ready to join forces with other laboratories interested in this most important topic. Much of the small-scale work can be undertaken with modest facilities, and where necessary we should be prepared to offer accommodation to workers from other countries for their larger-scale experiments in our own new Models Laboratory.

Fire research has now reached a point at which we must enquire more closely into its fundamental processes and no one country with its limited resources will, by itself, be able to cover much of the field of this complex subject. Only by acting in concert and by making a planned attack on these problems shall we solve them quickly.