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JOINT FIRE RESEARCH ORGANIZATION

FIRE RESEARCH IN THE UNITED KINGDOM

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FIRE RESEARCH AND THE NATIONAL STRUCTURE

In making a survey of fire research in the United Kingdom it is necessary to consider first its part in the structure of the nation. The annual direct losses by fire are estimated to amount to some £26 million. When allowance is made for a change in the value of money, there is at present no marked trend with time, though the post-war figures are somewhat lower than the pre-war period. This refers only to the direct losses and takes no account of the disorganization of the industrial pattern following a fire and no doubt if the loss of productivity were considered, the financial loss would be substantially greater. The matter is one that might be studied by economists, particularly bearing in mind the future spread of automation when the value of built-in fire control systems will have to be assessed in terms of the normal control mechanisms required in production.

Fire losses in domestic property account for about £2 million out of the total loss and this could be catered for by a capital investment of the order of £3 per household. This means that if some method of fire prevention or some highly efficient extinguishing system could be developed so that future losses from fires attended by the Brigades could be completely eliminated, it would be worth about £3. As this figure is so low it would suggest that the prevention of domestic fires in existing property would be a matter of changing the habits of the population rather than alterations to construction of or the installation of fire prevention and extinguishing devices. The foregoing remarks, it should be emphasised, refer to existing property; new dwellings are in a different category and it may be possible at the outset to design houses in such a way as to reduce the fire risk.

About 750 persons out of a population of rather more than 50 million die annually by fire and explosions. The saving of human life has an emotional significance to which no material values can be attached. Emotions are swayed largely by tradition and quite involuntarily the toll of 750 deaths per annum has come to be accepted in the United Kingdom. If the figure were to increase significantly or rapidly the public conscience would be stirred as in the time of any disaster, and no doubt legislation would be brought to bear, but any drive to reduce this general figure would depend on the wellbeing of the nation. Legislation to reduce the mortality due to accidents is in fact an improvement in the standard of living, and varies with the fortunes of any country. The majority of deaths are due to personal clothing becoming ignited. Quite apart from these fatalities, such accidents result in some quarter of a million hospital bed days per year being absorbed from the Health Services of Great Britain and this situation is receiving close study from a number of bodies in the United Kingdom at the present time.

Fire research should not only be considered as a means of reducing loss or suffering; in its wider and more positive sense it should advise the public as to the risks associated with any given operation. The largest investment of the nation is in building; this is proceeding at an annual level of £1000 million, and accounts for about one-fifth of the National income and one-half of the capital investment. As yet, the proportion of this expenditure which is conditioned by fire regulations is not determined, but it must be considerable. These fire regulations have come into being largely as the result of disasters and are not at present founded on any systematic study of the problem. New materials and new methods of building construction are constantly being evolved and these need evaluation in terms of the functions they are required to perform.

The importance of Service and Civil Defence requirements in fire research is difficult to estimate. Fortunately, much of the basic information of use in war-time is also necessary in peace-time; of the rest, the needs will obviously vary from country to country. During the first half of this century two of the worst wars that mankind has known have taken place and these have led to the loss of about a million lives in the United Kingdom. During this period, however, about 25,000,000 people have died from causes unconnected with war, so that the effect of wars even of this magnitude, on the trends of the population as a whole, is small. Of course, wars are becoming potentially more destructive, but at the same time, nations are more disposed to try and settle differences by negotiation. With the possibility of exploiting nuclear fusion in the future and the consequent chance of improvements in the standard of living, it is possible that nations will be more pre-occupied with internal development than in the past. Any fire research conditioned largely by war-time requirements alone would be concerned with a situation which, taking the long view, would be comparatively unimportant.

It has not been possible so far to place any monetary value on fire research as a whole. It is doubtful whether indeed the exercise would be worth the trouble. The value of research should be generally apparent without a detailed financial assessment, and when this is called for it may be symptomatic either of a failure to put over results effectively or of the fact that the wrong projects are being tackled. It may be said, however, that the value of any research on fire extinction will be circumscribed by the fire losses of a country, whereas research into the need for fire protection is likely to be economically more important.

THE ORGANIZATION OF FIRE RESEARCH IN THE UNITED KINGDOM

During 1936 a Government enquiry was made into the working of the Fire Brigades in the United Kingdom and one of its recommendations was that research should be carried out into fire protection and extinction. As the war drew to a close consideration was given within the Department of Scientific and Industrial Research to the intention already expressed of resuming research into the peace-time aspects of fire protection. When it became known that the Insurance Companies also intended to embark on fire research it was decided after discussion to establish a single Joint Fire Research Organization, the cost of which would be shared equally by both bodies. Its function was to make recommendations for research on the prevention and extinction of fires, on the safety of life in fires, and on the mitigation of damage.

The Department of Scientific and Industrial Research has fourteen Stations covering the basic industrial needs of the country, and the Fire Research Station is one of the newer and smaller of these. In addition to these, the Department gives financial assistance on co-operative research ventures with industry. Thus there are forty-six Research Associations covering a wide range of interests from lace to iron and steel. The Department also sponsors research in Universities so that the whole forms a well-knit scientific structure inside which good liaison is maintained. The Senior Officer in the Department of Scientific and Industrial Research is the Secretary to the Research Council which is composed of eminent scientists and industrialists and which, through the Lord President, advises the Government on the deployment of the scientific resources of the country.

The Director of each Research Station of the Department of Scientific and Industrial Research is advised by a Research Board of specialists in his particular field. The Fire Research Board, for example, comprises a total of twelve scientists, industrialists, and members of the Insurance Companies. It meets at four month intervals and one meeting is devoted to a discussion of the annual report, another to the research programme, and a third to an inspection of the work of the Station. The Board Meetings are also attended by twenty-one Assessors who are responsible for maintaining liaison with the Government Departments they represent. From time to time committees of specialists are formed to advise the Board on the particular research fields in which the Station is interested.

The Research Station, which is situated about 12 miles north of London, is organised into five sections :

1. Operational Research and Publications
2. Chemistry and Chemical Engineering.
3. Physics.
4. Building Materials and Structures.
5. Fire Extinction and Equipment.

The buildings at present occupied by the Station were originally laid down in 1935 by the Fire Offices' Committee, and during the year it is hoped to add a Burning Building complete with wind-producing apparatus in which fire tests can be carried out under controlled conditions. Within the next three years, a permanent Station will be built at a total cost of about £400,000. The present staff totals 100 of which about half have professional qualifications.

In addition to the research programme actually carried out at the Research Station, certain projects, notably those involving basic studies of combustion, have been placed with Universities and it is 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.

THE DEVELOPMENT OF FIRE RESEARCH

The systematic study of fire protection and fire extinction is comparatively new. Up to twenty years ago in Great Britain, the only information available had been built up by the Insurance Companies, by the Fire Brigades and by ad hoc tests. The immediate need when the Fire Testing Station was opened in 1935 by the Fire Offices' Committee was to evolve a series of tests which would grade building structures and fire-extinguishing equipment by subjecting them to conditions representing as closely as possible those encountered in practice and to fix standards of performance based on experience in the field where this was available. In this way, standard tests for fire-resistance, spread of flame, and sprinkler and extinguisher performance were evolved, and these are paralleled in the United States. While work of this kind is not scientifically profound it has an important industrial and administrative significance. It enables commercial development to take place on an agreed basis and it allows codes to be drafted without reference only to materials which have proved satisfactory in the past. Such information was the inheritance of the Joint Fire Research Organization when it came into being in 1946.

While this is a valuable first step, its weakness is that it is based on tradition. Such a procedure is not always applicable to new structures and materials; quite frequently, adequate field information is lacking for common forms of construction and in these cases the tendency of drawing up codes is to play for safety. Thus it came about that the next step in fire research was to see whether materials, structures and equipment were adequate for the function they had to perform. This involves a change in outlook: the function of fire research is no longer to advise the legislature on what to prohibit, but rather to advise on what new structures can be safely accepted.

In the developments discussed so far, the scientist working on fire problems has been dealing with situations and structures presented to him, and has in the first instance devised tests and fixed pass limits based on experience where possible; as a second stage he has examined the requirements in terms of the functions to be performed. Although it is possible at this second stage for the scientist to make a real saving in the budgeting on fire, he has so far not ventured into design and it is only when he is able to exercise control over the field in which he works that his subject can be said to become a science in its own right. In order to do this he has to be informed on the laws governing the growth of fire both in enclosed spaces and in the open, on time-scales varying from that of growth at smouldering rate to explosive violence. He must also understand the extinction of fire which is the mirror image of growth. All this is the next stage in the development of fire research. It is scarcely necessary to say that the three phases of development discussed so far do not run sequentially; they coexist. As development takes place there is a gradual changing in emphasis from one to the other.

It is important always to study scientific problems in the correct terms; an engineer does not design a bridge from a consideration of the interatomic forces in the structure. It would be wrong generally to try to develop fire research by the detailed study of chemistry and physics, as it is not possible to account in these terms even for the burning of a match. Fire research must be in the main a science of heat and mass transfer and, therefore, of dimensionless groups. Such a science must lean heavily on model techniques, for full-scale fires are prohibitive both on the score of cost and time, particularly in a complicated subject in which experiments will have to be designed statistically. The word model is used in the sense that one system will be a model of another system if it is governed by a similar set of differential equations. It does not follow that it will always be a scaled replica of the original. The understanding of such models and their application to fire research is undoubtedly the key to future progress.

An exception to the general rule of studying systems macrocosmically must be made in dealing with inhibition of combustion and the strength of materials in fire. The molecular processes involved in inhibition are not well understood. Some chemical groups appear to be very effective, though how this comes about must wait for further developments in spectroscopy and radio-chemistry. The fuller understanding of these processes would no doubt yield more satisfactory inhibitors and might be a problem that universities and industrial chemists could undertake.

As far as is known, little attention has been paid to the chemistry of concrete at high temperatures. A study of the changes that occur in this most important building material might result ultimately in the development of better fire-resistant structures.

Mention has been made of the importance of fitting performance limits to the needs of society, and some examples of the present work of the Station will show how this is being done.

Textiles being flexible hang vertically and it is in this position that flame is most readily propagated. In assessing the danger of any fabric it will be necessary to determine the speed with which flame is propagated vertically over it and a simple robust apparatus is now available for making this measurement. This quantity is important as it is a measure of the time available for either extinguishing the flames or discarding the burning fabric. The vertical flame speeds over fabrics which have been involved in burning accidents is being examined to find out how this affects the incidence of burns and its relation to the severity of the burns received. It is too early to predict the final results of this work, but it seems clear at this stage that the most flammable fabrics cause only a small fraction of the total casualties and that any legislation aimed at prohibiting their use would have a negligible effect on the number of burning accidents. This is no doubt due to the non-uniform distribution of fabrics of varying degrees of flammability throughout the population, and it is certain that legislation would be impracticable since to be effective it would have to prohibit most of the fabrics in common use. The statistical picture is clarified by the fact that burns casualties occur in the main among females up to 16 years and over 65 years of age, and it may be possible to induce those responsible for these people to adopt flame-retardent treated fabrics for outer garments. It has been suggested that the reduction in the load on the Health Services by the introduction of such a measure might be used to offset a subsidy on these fabrics. This could only be decided after the necessary statistical information has been assembled.

Regulations have been enforced for some types of building covering the kind of wall-linings which may be used. Measurements which have been made in recent years show that the main dangers to human life occur at the instant when the room is about to become fully involved in flame; this is often referred to as flashover. At this time the carbon monoxide level, not only in the room on fire but in adjacent rooms also, rises rapidly and visibility falls due to smoke and distillation products. This is also important in that it marks the point after which it is unlikely that the fire will be able to be controlled without the assistance of the Fire Brigades. This might be especially important in wartime when much will depend on the ability of the civilian population to control incipient outbreaks. A striking example of the importance of flashover on the incidence and spread of fire is provided by the statistics of one type of post-war house. As built, these houses were lined completely with fibre insulating board and had a flashover time of about 5 minutes. In 1949, the rate of fires attended by the Fire Brigades amounted to 43.8 fires per 10,000 houses of this type and in more than half of these the fire had spread beyond the room of origin. By 1955, the interior surfaces of all these houses had been covered with an incombustible lining and they had a flashover time of nearly 20 minutes. The annual rate had then shrunk to 0.8 fires per 10,000 houses (2 percent of its former value) and in no case had the fire spread beyond the room of origin.

A test has now been developed to grade materials according to the time of flashover in a full-scale fire. This is in effect the measurement of the rapidity with which burning materials liberate heat. In many instances, non-combustible linings are required in buildings; this requirement can now be re-examined and it is likely that other constructions will be allowed in future without any loss of safety. Non-combustible constructions may be confined to locations such as hearths and flues, where heating takes place continuously by design rather than by the chance heating from an accidental fire. This relaxation would give greater freedom in building design.

For many years there has been a need in the United Kingdom for a test for roof constructions. A roof is required to protect the contents of a building from ignition by any external fire. As it would be unreasonable to expect the roof to give greater protection to the contents of a building than does the facade with its window openings, the roof is evaluated in terms of the radiation which, entering through the windows, would lead to the ignition of the contents of the building. This permits of a more rational grading of roof structures, giving an estimate of the performance of combustible roof structures as compared with the more traditional types.

There is no doubt that during the next few years more emphasis will have to be placed on basic work if any real progress is to be made. Mention has already been made of the use of models in building fires; it will be necessary to find out how the growth of fire is affected by the rate at which heat is released and also the part played by the shape and dimensions of compartments. Building codes are at present related to the floor area and to the quantity of combustibles irrespective of their nature and degree of dispersion.

Preliminary experiments suggest, as might be expected, that the aeration of a fire is as important as the amount of combustibles. The interplay of all these factors will have to be considered in the revision of building laws. This is a problem which will be dealt with early in the programme of scale experiments by building models of various sizes and comparing the records of fires in these, and it is hoped that these experiments will give some idea of the quantities involved in sealing such fires.

The present building codes require external walls for industrial and public buildings to be incombustible and to have a fire-resistance of not less than two hours. This excludes the use of many types of curtain wall. Architects would like more freedom in the use of combustible claddings, and also in the area of glazing allowable on the exteriors of buildings. These factors affect the fire spread throughout a building, and as large window openings also increase the chance of ignition of a building from a neighbouring fire, a degree of glazing would therefore affect the necessary distance of separation between buildings. The present state of our knowledge is such that the answers to these questions can only be obtained by erecting full scale buildings, but these experiments will be repeated with models to try to find the scale-factors involved.

The approach using models is the only one likely to give any information on the conditions necessary for conflagrations to develop in cities. In these cases it would probably be important ultimately to model the salient features of large conflagrations which have occurred in the past, though the preliminary part of such work would be concerned with the heat transfer from simple systems involving single fires and groups of fires.

The use of models is equally important in studying fire extinction, as it may be used for evaluating different media, and also when the science of modelling is more fully understood it might give information on the logistics of fire-fighting.

Another field which is largely untouched at present is the fundamentals of the design of structures to withstand fires. A body of information has been built up from the results of a number of costly tests in which the elements of full-scale structures were subjected to fire. The resistance of a structure to fire is determined partly by the thermal transmission and partly by its mechanical performance. Where it is certain that the limiting criterion will be thermal transmission, it is possible to predict the fire-performance of structures using analogue machines, an example of model techniques already in use. In cases likely to involve mechanical failure, the predictions are confined to the ambit of the test data. Undoubtedly the big obstacle to the design of structural elements to withstand fire is the lack of information on the effect of heat on concrete, and a programme on these lines has been started in the United Kingdom.

So far, work on the fire performance of structures has been concerned with single elements such as walls, columns and floors; this, of course, is unreal for in a building the various structural elements act together. Certainly the composite action of beams and columns will merit a close study in the future.

The characteristics of explosions in tubes are being studied for the Factory Department with a view to giving information on explosion vents. An attempt will be made to investigate the scale factors in explosion chambers of various sizes and shapes. Very little appears to be known about the action of flame-traps which are used to prevent the propagation of flame in ducts. An experimental programme has been started by which it is hoped to explain the action of these devices.

In any complex study such as fire research the field of information is diverse and scattered. The fire reports in any one incident may be imprecise for, after all, the Fire Brigades' first duty is to fight the fire. The information from incident to incident is reported by different observers so that an overall picture can be obtained only by collecting a mass of information in some standard way.

One of the few benefits of the Second World War was the centralization of the Fire Services in the United Kingdom, and this facilitated the introduction of a standard reporting system for fire incidents. The reports which amount to 90,000 per annum are coded and statistically analysed by the Joint Fire Research Organization. The immediate value of this is that it gives information on the items to which research should be directed. One of the noticeable changes during the first ten years of the existence of the Joint Fire Research Organization has been the study integration of the work of the Statistical Section with the Station as a whole. In the first instance the work was passive, it was concerned with the collection of statistics and with the noting of trends; now it is taking on a more aggressive role, and it is significant that the name of the section has just been changed to that of "Operational Research".

The United Kingdom, in common with most countries is expanding industrially. The dwindling coal resources and the development of nuclear fuels will mean that electricity must inevitably play an important part in this development. It may be shown on theoretical grounds, and is supported by the statistical evidence so far obtained, that fires increase proportionately with the quantity of electrical energy transmitted, amounting to one fire for every 10 million units of electrical energy. With the present electrical expansion envisaged during the next 20 years, this would mean a threefold increase in the number of electrical fires and remedial measures will have to be found to curb this increase. A survey is now being started to find how these fires are caused, whether it is due to the use of electrical apparatus or to defects in the apparatus itself. The results of this survey will point to the direction in which action should be taken.

A wider and more difficult problem in operational research is the assessment of the value of fire protection as compared with fire extinction, with a view to advising the Fire Brigades as to how their efforts should be most effectively directed. The answers to this problem will vary depending whether a peace-time or a war-time situation is being considered, for it is almost certain that the economic expenditure in war-time would be more biased towards fire protection than in peace-time.

Another question which is being considered is the effect of coverage by the Fire Brigades. Most cities have sections which are more conducive than others to the rapid growth of fire. The extent of the damage is being estimated in terms of the appliances generally in use in various industrial areas. The degree of fire cover will also affect the time lag between call and arrival at the fire and this is being compared with the damage and casualties involved. It is hoped that the work will assist the Fire Services in arriving at the optimum deployment of Fire Brigades.

One interesting topic which has already received attention concerns the use of water. This is the most important fire extinguishing agent as it is plentiful and absorbs a large amount of heat on evaporation. It is necessary, however, to exercise economy in its use to avoid unnecessary damage. By studying fire reports it is possible to estimate the volume of water used by Fire Brigades, and as might be expected, it is found to be roughly proportional to the fire area and amounts to about $\frac{1}{4}$ million gallons per acre. The rate of usage of water is, however, proportional to the square foot of the area suggesting that most fires are fought from the periphery, the rate of delivery being about 100 gal/min. every 30 feet.

Much has been written on the efficiency of water sprays as compared with water jets in fire extinction. Experiments with water sprays in buildings suggest that they have the greatest advantage over jets when used by untrained people, a factor which might be important in war-time when Fire Services may have to be expanded rapidly. After a little practice with any particular fire it is possible to extinguish it with about the same quantity of water using a jet. The extinction efficiency of sprays appears to be rather uncritical with respect to drop size, and on this score there seems to be little to recommend the use of high pressures. The pistol grip control in use on high pressure appliances, however, is a useful feature which might be incorporated in lower pressure applicators. The work on water sprays is not yet complete and further experiments are scheduled during the next year.

THE FUTURE OF FIRE RESEARCH

It is always tempting to look into the future, not only to the distant horizon but to speculate what lies beyond it. It seems fairly certain that for many years fire research will be concerned with making life more foolproof, and where this is not possible, with counteracting the effect of man's folly.

It is estimated statistically that about two-thirds of all fires are attributable to carelessness. This is really analogous to the situation already discussed in which the scientist is having to take the world as he finds it and adopt suitable paliatives. The psychological sciences have not advanced so far that carelessness is amenable to control; it has not reached the stage of design.

It may be that mass psychology will become a more exact science in the next decade or two, that it may be possible to implant ideas and develop conditioned reflexes that will be permanent. Crude experiments of this kind have already been carried out in the past in some countries, and no doubt the techniques will be refined in the future.

One of the difficulties of propaganda is that the subject, particularly if adult, is resistant to didactic instructions. It might be that one way of overcoming this would be to apply the propaganda subconsciously. Indeed, considerable success has been reported in the United States with a form of advertising in which a single frame carrying advertising matter is inserted into a film sequence. Similar experiments are being carried out in the United Kingdom in which the information is presented continuously at a level below the normal threshold of vision, and no doubt the sense of hearing could be exploited in the same way. Such experiments may have a profound significance in the world of the future.

All this, of course, raises fundamental problems of individual liberty. Would it be right for the State to interfere with the liberty of the citizen to this extent even for his own security ? And if this course were held to be justifiable, where would it stop ? The purchase of National Savings Certificates or blood donation, or a host of other things, are worthy objects. The cure may well be much worse than the illness, but that will be for another generation to decide against a different social background.