U N I V E R S I T Y O F E D I N B U R G H

DEPARTMENT OF FIRE SAFETY ENGINEERING

"NEW VARIATION ON AN OLD THEME"

Inaugural Lecture Presented by

Professor D J Rasbash

on 14 November 1974 at

The Appleton Tower, Edinburgh

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Dean of the Faculty of Science, Ladies and Gentlemen: I don't think I had been in the University for more than a few days before I had an officially worded communication indicating that it was expected of new professors that they should give an Inaugural Lecture. So many of you might well be asking - "Why has this man been skulking away for eighteen months before coming up with the goods?"

What is Fire Engineering?

Well, my Department is called the Department of Fire Engineering*. It is a very rare department indeed in a University. Nowhere else in Europe is there a similar animal. There are a few close relatives in North America but, you might say, many exotic flowers blossom there. Perhaps I imagined a tendency to turn with a sympathetic but questioning eye, asking - "What is this peculiar specimen cast up on the beautiful beach that comprises the academic world of this ancient university?" As Trincolo exclaimed in The Tempest when he stumbled across Caliban on the beach, "Is it man or fish? Methinks it has a very ancient and fish-like smell!"

I had not been here a month or two before I had the greatest of provileges of being introduced by our illustrious previous Principal to the Chancellor himself, no less, as the New Professor of Fire Engineering. "What!" said he with incredulity, "A professor of fire engines?" Well, undoubtedly, whatever happens, fire engines will occupy an honoured place in my Department as they must surely occupy an honoured place in the hearts of everyone here. But I must share the Chancellor's incredulity if he thought that the Department would be devoted entirely to fire engines, inspite, let me hasten to say, of many intriguing possibilities.

But this does raise the question - what is fire engineering? I expect the task that my lecture would need to be an inaugural lecture for the subject, who knows, possibly something more, acted as something of a deterrent, particularly when I was not sure of the answer myself. The Chair owes its existence to the combined contribution of quite a number of organisations, mainly from Industry and Commerce, and the tireless enthusiasm of Frank Rushbrook, the former Firemaster for South East Scotland; and to these I express deep gratitude. I am certain that each contributor had a clear idea of what Fire Engineering was. I have a feeling from my discussions around and about that these ideas are not necessarily identical. To these ideas I add my own but I sincerely hope the thoughts that I am about to express will not stray too far from what the founders had in mind.

First, it does seem to me that a great deal of what my Department is really about lies in a missing word which, if brought to the light of day, will stem confusion, and the word is "safety". My Department is concerned with Fire Safety Engineering.

Up till quite recently the word "fire" tended to be used reasonably impartially for both the friendly tame fire under control and the unfriendly wild fire out of control. It may be with the disappearance of/

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* Changed in May 1975 to the "Department of Fire Safety Engineering".

of the honest toilers on the old steam locomotives and the flickering flames from many hearths, there has been a move for "fire" to denote the wild fire variety. Firemen are now only those who are concerned in saving people and property from fire. Fire authorities are those concerned with keeping the community safe rather than providing the community with a basic form of energy as might easily have been the case in cold barren celtic lands in days gone by. Tame fire, that is the thing that is kept in boxes and on burners and behaves itself, is now fairly universally called "combustion", particularly when it appears in a university department. The four letter word has become more and more associated with the thing that comes out and hits you, Anyway, my Department bags the word "Fire",

Fire Experience

What lies behind the threat of this small word? The duet between mankind and fire goes back some half a million years. Indeed, one might claim that after recent American research on the use of sign language by chimpanzees, the characteristic of playing around with fire is the one thing left that distinguishes mankind from the other species that crawl between earth and heaven. Hazard and safety, value and threat, are of course interpretations which man himself puts on his environment. Prior to his appearance fire was a force which helped shape our planet and the characteristics of its vegetation. I have heard our Professor of Forestry and Natural Resources speak of forest species that need fires for their regeneration: a thought that has occurred to me is that natural synthesis has tended to result in materials being produced, which have gone just so far but not much further towards becoming hydro-carbons, since available rainfall would not then have been sufficient to extinguish fire or prevent its spread. So perhaps it is right to say that vegetation has been playing games with fire since they came together. Undoubtedly there was fire in the environment for man to use when he was ready and for the scene to be set for the love/hate relationship that has since developed.

There must be surely little need for us to remind ourselves of the bitter side of this relationship. Fire has ravaged cities through the ages, almost with the same regularity as they ravaged forests before and since there were cities. It has not discriminated between nations. Rome's fire was of course infamous but it was really Nero's misfortune that it happened in his time; from the way the city was built it was perhaps only to be expected. Tokyo had the misfortune of being subject to earthquakes as well, which required them to build with light combustible materials, and has been extensively burned on many occasions. The 1923 earthquake was followed by a disastrous fire in Tokyo which killed 90 thousand people.

In its short history, the United States has suffered more than its share of severe fires. In addition to the Great Fire, London burned many times. In previous days such a fire might have provoked a spectacular artist's canvas (as did this fire in the Custom House in 1814)*. I am afraid I knew of no theory which would account for flames of such apparent formidable dimensions, but it is indeed a veritable column of fire by night. These days of instant photography there is less need for spectacular pictures to be painted. (Here are just a few of recent devastating fires*:-

1. Livonia - Car Assembly Plant
2. Car storage premises, UK.
3. Rubber materials factory - by night.
4. High rise office - tragic life loss,

5/6 Desperate methods of escape - high buildings.

7. Our own tragedies - Summerland Leisure Complex.
8. Flixborough - chemical plant.

* slides shown.

The destruction of man's habitations and livelihood by fire is an old theme indeed: how has he dealt with this? There's certainly a questioning of the inherent nature of fire that goes back to antiquity but it is very doubtful if this conscious questioning really produced anything of great value to the control of fire, until about 200 years ago when Lavoisier, in a corner stone of Chemistry, established the quantitative aspects of the chemical reaction between fuel and air. This did not mean of course that the essential information needed for the control, prevention and extinction of fire was not available until the light dawned on the scientific age: far from it. In times of emergency every man was his own fire fighter.

Inherited Knowledge of Fire

The fundamental facts of fire and the treacheries and conundrums which it poses are enshrined in the instincts of mankind. They have always added brightness as well as fear to the written and spoken word. Indeed, one can look back on some of these embellishments to find that a great deal about fire was known long before science was thought of. Perhaps, with your indulgence, I might mention just a few. "FOR BEHOLD HOW GREAT A MATTER A LITTLE FIRE KINDLETH" and how "THOSE THAT WITH HASTE WILL MAKE A MIGHTY FIRE, BEGIN IT WITH WEAK STRAWS". Clear lessons in Fire Prevention. Then there is the inevitable upward motion of the flames acted upon by buoyant convective forces in a gravitational field. "FOR WAS NOT MAN BORN TO TROUBLE AS THE SPARKS FLY UPWARDS?" And the problems and the practicalities of extinction as well. "THE MORE FIRE IS COVERED UP, THE MORE IT BURNS". This is a deep one indeed. I am wondering if Ovid observed the lengthening of flames under a cover and the effects of downward radiation in acceleration to flashover. If so, one of the most significant recent contributions of the Fire Research Station will have been predated by 2000 years. Perhaps more straightforward is our "Will", with the favourite quotation of all sprinkler manufacturers - "A LITTLE FIRE IS QUICKLY TRODDEN OUT, WHICH BEING SUFFERED RIVERS CANNOT QUENCH". But I still wonder what he meant by rivers. Water of Leith? - not much there. Sweet Avon? - a bit more. What will not an Amazon my raging fire quench? The answer - yes probably, if you can get the engineering right! Of course, not all was simple. Wind was ever a problem, "SO THAT BY WIND WAS FIRE FOSTERED AND BY WIND EXTINGUISHED". "SMALL LIGHTS ARE SOON BLOWN OUT: HUGE FIRES ABIDE AND WITH A WIND IN GREATER FURY SET". Actually, it is only in the last twenty years or so that we have sorted this out and I am sorry to say the incentive for the knowledge has come not from the need to fight fire but to stop the flames of jet engines from blowing out. And even when you think the fire is out - use your hook and your hose, for even in our ashes live our wonted fires".

Traditional Regulations

Such quotations as I have used give only a glimpse of the wealth of traditional knowledge that lies behind man's close relationship with fire. After many painful lessons, much of practical utility has been handed down to us in fire safety, particularly in the way we build our cities. My knowledge of Roman architecture is nil, alack, but on the authority of the Encyclopedia Britannica I have it that after the fire of Rome, Nero rebuilt the city - which had been a maze of narrow streets before the fire - with great care, with low stone buildings and wide streets. The Colossium built shortly afterwards of stone and concrete is there to this day: an object lesson in fire safety engineering.*

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* slide shown

People have known how to plan against city fires for quite a long time, yet the fire regulation history of London is punctuated with fire safety requirements which just were not met or enforced. In the beginning of the 17th century, well before the Fire of London, earlier requirements and decrees which would have made the fire most unlikely, were being circumvented. In this, London, I should imagine, was not unique. It tempts one to ask if there is any reason, apart from the cost of fire regulations and perhaps their inconvenience, that makes people persist in ignoring lessons from fire until a real disaster hits them. Indeed, this could well be an interesting subject for research for a historian with a special eye to social attitudes and a smattering of engineering. Under what conditions do the lessons of fire tragedies that have plagued us through the ages ultimately become adopted; how long does the new mood last before old ways creep in again, and why?

Anyway, until the Fire, London maintained its medieval character (looking something like this - The Shambles at York*) with projecting timbers and overhanging floors and narrow streets. (Here is an artist's impression of what London looked like before the fire*). Well, I must admit that as a Fire Safety Engineer, it might depress me, but as a human being, I find I like it. Don't we need the intimacy and the bustle which goes with these narrow crooked places where the human dimension dominates? Don't we also need the warmth that goes with the materials used, rather than everywhere the cold, cold stone. Anyway, I find these mazes the most interesting part of European cities - where one can get both lost and found.

Then came the Great Fire and after the fire the previous proclamations were reconstituted and severely enforced (with this result, and buildings like it throughout the country.*) In general appearance certainly also attractive, and with it goes an air of dignity and a potential for grandeur not in the previous picture. But has not an air of coldness, remoteness, also crept in? Here are some at Bath with the straight facade*; the elimination of timber, windows that are recessed from the face, but it is interesting to note some of the additions that provide warmth and colour that might not appeal to a conscientious fire prevention officer. When fire forces our hand, it is well to be fully conscious of what we are doing.

Of course, there have been forms of protection other than city planning that have developed throughout the ages, particularly in the last few hundred years. The Fire of London was unique perhaps since it also gave rise to fire insurance which has made its own contribution in alleviating the hurt of fires. After the Edinburgh fire in 1824, the first municipal Fire Brigade was formed. The practical engineering which has flourished in the last 200 years has also found industrious and extensive application. If one wished to highlight one point here - the use of the sprinkler now 100 years old, has been a tremendous boon in keeping fires down.

<u>Status of fire knowledge</u>

But what of our understanding of fire? Lavoisier's was a great step 200 years ago. Since then combustion science has taken strides, but alas, with few exceptions - such as some understanding of explosion - small word "fire" science really only began to move into reasonable gear within this generation. When one takes into account that fires produce smoke and noxious gases which trap people and kill them, as well as heat, then fire science only really began to move in the last few years. It is interesting to reflect that the major part of such advances in fire safety engineering that we have seen in the last 200 years needed little more/

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* slides shown

more knowledge of fire itself than that which was available to the ancients. Of course,there has been much drawing upon science and engineering in other fields. There has been extensive experimentation of what might or might not burn; of what might or might not put fires out. Modern technology has produced manythings to try and the principle of 'suck it and see' has been by far the most used principle, and this has indeed resulted in many valuable advances, but the understanding of the laws which lie behind the initiating of fire, its growth and development, the way materials behave, hasbeen very meagre.

Why a University Department?

Even so, it seems as if we have managed reasonably well in the past - we have managed to get by. There has even been difficulty in applying the obvious lessons that we know. Do we now need a new variation on the fire theme in the form of a University Department to help improve and spread the message on fire safety, particularly if in these days of inflation and against a background of cutback of funds available to Universities, it is going to cost a minimum of £30,000 per annum? There is a burgeoning of technical empirical information relevant to fire safety, becoming available in guides and codes, to deal with more and more complicated risks, but do we need a University Department to dispense and apply this? Well maybe. But the argument is not entirely c onvincing.

Surely, however, our mounting fire losses is a sign that all is not well. £200 million of annual direct loss at least, double this at least to bring in consequential loss and a toll of 1,000 dead per annum. In Scotland alone 158 people died last year because of fire - a record upon a record. And this should be set against a background of a National Cost of something like £500 million per annum in our efforts in one way or another, to cope with the fire problem. Why should this be? Well, it is clear to my mind that we have just lost control, or perhaps never had it, and this forms the central reason for the establishment of a new department, and indeed a new method in dealing with fire.

The basic reason of this lack of control in the present time is the proliferation of fire risks of different kinds that we see all about us. For better or for worse we live in a technological age and we are going to continue to do so. We have changed the chemistry of our environment and will change it further. Materials which are a novelty in one decade become used in everyday articles in the next in a context which aggravates the fire risk. We give ourselves the fire safety headaches of making these new materials and transporting the necessary raw and finished components around the globe, sometimes through the middle of our cities. We raise buildings of non-traditional and complicated design and we move ourselves furiously around at supersonic speeds with new and precarious forms of energy.

All right, we all know this, but what we are finding increasingly in this situation is that we cannot continue to rely on the time honoured method of the past in dealing with fire safety, i.e. to rely on experience painfully built up and the passage of decades, if not millennia, for lessons to be learned, sink in and acted upon. Direct experience is becomming too painful a teacher and we must marshall our forces to avoid it, if only because of the extensive investments and commitments that might be involved before a tell-tale incident occurs and is recognised, and the trauma of putting things right afterwards. To take just two examples in the aftermath of which I have been concerned: three million drip-feed radiant paraffin heaters were sold and used for a/

a number of years before, through a multiple death fire, an intrinsic fire danger in the design was recognised. Two hundred high rise blocks of flats of a particular design were put up before it was realised by a terrible accident that they could collapse if there was a gas explosion in one flat. And there are other examples, perhaps even more poignant, whose pain we are living through now and will live through yet. We need a discipline which makes us visualise how we affect fire - and indeed other aspects of safety, and plan effectively for these when we introduce changes into our ways of life. In fact we must learn to reverse nature and be wise before the event. This I think is a task which is as demanding as any you can find in a university; it is to my mind a task which society must demand that universities undertake and make the means available.

Shaping of a new "Fire Safety" Discipline

Just how are we to set about shaping this discipline? Well here again we have the three words: 'Fire', 'Safety' and 'Engineering'.

First, Fire. It is with a sense of deep privilege and anticipation that I have taken my place within the Faculty of which you, Sir, are Dean - the Faculty of Science. Fire Safety Engineering just cannot be pursued as I envisage it without a much deeper knowledge of fire than we have now, and the pursuit and acquisition of this knowledge rests firmly with Science, wherein it crosses the boundaries of many traditional disciplines, particularly physics, chemistry and engineering. It might be appropriate here if I could elaborate a little on one or two ways in which I think science has helped and could help further.

Some recent developments in fire science

One of the most daunting aspects of the current fire situation is the multiplicity of materials that are being widely used that can burn or even react by themselves to give out heat, and the variety of situations in which they may be found. The aptitude of chemists to produce such materials - often as an attempt to answer fire hazard - is almost without limit. The same questions are being continually asked of them - "Under what conditions will they become ignited and give out their heat dangerously, not forgetting that the presence of a fire in other materials is also a condition" - and added to this - "how much smoke and poisonous and corrosive gases will they produce as well?" Clearly what we need first are some generalisations which would allow us to predict the behaviour of different materials in different environments. These have in the past eluded us, inspite of extensive experimental work. But there are signs that they are now beginning to surface.

A recent promising advance is the prediction of spontaneous ignition of solid materials that can undergo an exothermic reaction. The inspiration for this work came from the theories of thermal ignition for gases, developed in the Soviet Union by Semenov and Frank Kamenetsky. This has been applied particularly at the Fire Research Station by Phillip Thomas and Phillip Bowes to the practical problem of predicting when a deep seated reaction within a solid causes them to become ignited. The theory allows simple experiments to be carried out in the laboratory, for example, finding the temperature in an oven that will ignite spheres or cubes of different size (Fig.1) and requires their representation in a way (Fig.2) which can pinpoint two factors A and B that sufficiently describe the exothermic reaction, broadly associated with the energy of activation on the one hand and the product of heat of reaction and frequency factor on the other. The mathematics also allows the calculation of a certain critical paramater δc which depends intrinsically upon the geometry and/

and the environment and which can be used to apply these factors predictively over a wide range of conditions. We are therefore now well on the way to being able to predict when materials which can manifest this property ignite in a variety of situations. These include, for example, when combustible dusts are deposited on a hot surface, or become lodged in a spray drier, or when lagging becomes contaminated with an oil leak, or when bulk materials are conveyed through the tropics in the hold of a ship. (Fig. 3).

Unfortunately, the situation is less clear when we move to the question of ignition of volatiles given off by materials under conditions of heat stress exerted by igniting sources and fire, and when ignited, how much heat, smoke and toxic gases do they produce, and much remains to be done here (Fig. 4). As far as ignition is concerned, the easy thing to say is- let us put a match to the material and see, and little tests have proliferated with materials presented to match-like ignition sources in different ways (Fig.5). These tests have often misled us. The call has gone out to keep faith in tests and simulate real practical conditions. So we have tests that expose parts of walls and floors to high radiant heat, bits of ceiling to high convective heat, tests where we build room corners and ignite them, or shut the materials in a box and give it a heating punishment such as we think it might encounter in a fire. But the rider of the interpretation of such tests is always there. Perhaps I am over-stating it if I say - "If your practical situation departs from the conditions of the tests by one jot, you are lost - and don't blame the test". And of course each nation has its own practical fire tests, just as they have a national anthem and a national airline; such agreement as there might be between the results of the tests is more by good fortune than design.

It seems to me that we need an A and B etc about such materials that can be measured without too much difficulty in the laboratory and which will allow us to predict first how they behave in tests, and from this the way we might expect them to behave in real fire situations.

My own instinct here is to follow the line I took many years ago to account for the extinction of fire by cooling the fuel, which is the reverse side of pilot ignition of fires by heat stress. Put, I hope, simply, this thinking suggests that there are four such properties of material in relation to the volatiles it produces, to which one could attach labels - A, B, C and D - and which might well allow prediction of fire behaviour, as follows:-

A The amount of volatiles the materials give off.

B The heat of combustion of the volatiles.

C The heat required to pull the volatiles out of the material. This may sound simple, and it is for a pure liquid, but for a thick solid which decomposes, chars, loses heat from the surface and might already have been preheated, it can become highly complicated. But it is measurable in the laboratory nevertheless, and such measurements as are made in the laboratory may also be broadened by calculation if conditions are known and understood.

D A criterion for the presence of continuous flaming at the surface. This again is complex. It is governed by the chemical kinetics in the flame and includes such factors as the temperature and oxygen concentration of the atmosphere and the presence of inhibitors in the volatiles and even perhaps the nature of the surface. But the indications are that it can be represented either by a critical heat loss from the flame to the surface or a critical flow rate of volatiles into the flame, both of which are measurable in the laboratory.

Knowing/

Knowing these factors, it is possible, using relationships enunciated by Professor Spalding of Imperial College, for heat and mass transfer in the boundary layer of burning materials, to connect them with the geometry and heating conditions of the environment in a manner that could enable us to decide under what conditions a material will contribute the combustion of its volatiles to a fire situation, and how much will the contribution be. Of course, let us not be euphoric too soon; in fires, the geometry (Fig.6), the oxygen concentration and the heating environment change, so the above suggestions are really only a start but we have available plenty of computer power once we are confident of the way fire is structured. I should add that these thoughts are not just mine alone. I was pleased to see Dr Roberts of the Safety in Mines Research Establishment put forward last year ideas of a similar kind, although expressed rather differently. The Factory Mutual Corporation in the United States have also produced some powerful papers that show considerable overlap of ideas, particularly in regard to the importance of C. I might add that I found the above approach useful albeit in its simplest form, earlier this year in estimating independently of tests, the fire properties of materials used at Summerland.

Then we have the problem of how materials, once they have become involved, contribute to a fire in an enclosure, and vice versa, and how such a fire can affect the building as a whole (Fig.7). In this matter, thank goodness, we have had the good fortune of being blessed with a few highly simplifying facts, for the clarification of which we owe a great deal to the Japanese workers - Dr Yokoi and Professor Kawagoe, and to my recent colleages at the Fire Research Station.

(a) The worst fire in a room is controlled by the amount of air that flows in rather than the amount of fuel that is given off.

(b) The amount of air that flows in over a wide range of fire situations depends on the size and shape of the openings through which the air is entering, and the hot gases leaving, and not on the temperature in the room.

If you add to these points that the heat of combustion of air - unlike fuels - is pretty constant (in fact about 3000 J/g) you have the basis of calculating a heat balance for the fire in a room, no matter what the fuel is inside. Such heat balances have been industriously and rewardingly pursued by schools in a number of countries, particularly Sweden and Canada, to calculate fire resistance requirements for buildings, but there is one thing that seems to have slipped by, although perhaps not quite unnoticed. The volatiles that are produced depend on how much surface area there is exposed and the factor C, mentioned above. Sometimes a lot more volatiles are produced than can burn in the room, so they burn outside and this has been shown in tests. Sometimes they bypass the normal floor level compartmentation in a building by spreading through the outside windows. This mechanism is thought to have contributed to the recent terrible South American fires in high rise buildings.

Quantitative approach to Safety

There is indeed a great deal more about fire and its science with which we could occupy ourselves, but perhaps we should move now to the understanding of the word "Safety". Here we need to venture from Physical Science and move afield. Firstly, there is a great deal we need to know about the way in which the various agencies that fire produces, i.e. pressure, heat, smoke and noxious gases, affect people - and of course property as well - and this involves us heavily in medical matters/

matters. Nor should we forget in this context the immediate psychological and social effects of fire when they occur. Thus, one of the findings of the Summerland tragedy was that separate members of a family would attempt to get together and greatly prejudice their safety in escape by so doing.

However, the point I wish to dwell on for the moment is - what do we mean by safety? Particularly in a situation where it is impossible to eliminate all risks and a great deal of the danger comes from the actions of people, including you and me, with our due quota of frailty, carelessness, mental instability and sometimes downright maliciousness. How much safety can we ask for in our design procedures, and is it right that we should ask for more safety in one area than another? Some guidance on the former had undoubtedly come from decisions in case law, but judging from the comments in the Robens Report, this can give a distorted view of what is sensible because of the necessary dominance of the word of the law itself. I feel on firmer ground in obtaining as good a measure we can of the safety we actually have. I regard the rigorous planning, collection and analysis of statistics both on fires and on the failures that can lead to fires as the best tool to give us this measure. In this we must concern ourselves with what people do, rather than what they say they do, or we think they do. But by these means we can form estimates of basic factors that affect fire safety, including the influence of various activities - that includes doing nothing - on fire safety. They also give us an approach to defining the level of risk which has been traditionally acceptable in our specific field of danger, and allow us to put it alongside the risk we accept in other fields. This might help us to decide how much safety we want; and safety costs money, so it is most important to decide how much we want.

Knowledge of fire and the human and general environment allows us to proceed to define fire risk. We need imagination for this exercise, an imagination which has been often lacking in the past. While we might encourage the thinking of possible terrible happenings, it is essential not to leave one's dire thoughts hanging in the air; even less to frighten everybody out of their wits by proclaiming them. It is necessary to quantify the risks to the best of our professional ability; otherwise we have no disciplined way of marshalling our engineering resources to produce the safety we desire or on deciding the level of precautions that are really called for. Activities of this kind are only just beginning to be formulated as far as Fire Safety is concerned. It is my intention that they shall become a focal point in the development of my Department.

Engineering

The contribution which all forms of engineering can make, including Mechanical, Electrical, Chemical and Civil, to improving safety from fire to an acceptable level, is great indeed; this is the traditional core of my subject and it would need another lecture to elaborate them. There have been encouraging advances in recent years and I am sure there are many yet to be made, particularly in the ways we can detect and extinguish fires at an early stage. But there is a major gap in the information concerning fire protection methods which we must fill and I hope this will not prove an uphill task. The gap concerns both installations and built in requirements and may be expressed as the likelihood - or, if you prefer it - the unlikelihood - that the protection will not operate as designed when called upon to do so. What is the use of an automatic installation if the current or the valves are turned off? What is the use of a protected stairway if the fire doors are open? I think/

think it most desirable that information on possible failure should be part of the design data on safety equipment and methods. Reliability technology particularly of the kind pioneered by the Systems Reliability Service of the Atomic Energy Authority, will be of great value in this context but both manufacturers and authorities that require the installation of protection systems have a large part to play here.

In engineering we must include also the management tasks and social engineering; these extend to the political and administrative action that requires the right standard for safety in our legislation and codes, and the right level of education. The latter is relevant for training our professional people who deal with fire safety, as well as educating the public who inadvertently, or otherwise, are major influences in fire occurrence. There are those who say that we must constantly belabour the public to a continual awareness of the hazards that surround them, through shock tactics if necessary. My own feeling is that there is a limit to what the average human being can stand before he just turns off. There are also so many hazards which surround him in this age that we must be careful that such limited educational action as we can profitably undertake is rationed out amongst them. I think the better approach is the professional one of getting the right degree of safety inherently in our systems and it is essential in this to take due cogniscance of the hyman factor. Hopefully my Department will contribute to providing this professional approach.

<u>Epilogue</u>

Well this declaration could be a suitable point for me to stop, but there are just one or two more points I would like to make - an epilogue, if you can bear with me. I have made a list of some of the different subjects touched upon in this talk and here they are:-

Chemistry	History	Medicine	Chemical Engineering
Physics	Art	Law	Mechanical "
Aerodynamics	Literature	Social Science	Electrical "
Heat & Mass-Transfer	Anthropology	Psychology	Civil "
Botany		Economics	Building Science
Meteorology		Social-Administration	Architecture
Mathematics		Business-Management	
Statistics			

I know there is a vogue these days for "interdisciplinarianism" but, as Groucho Marx would say, "This is ridiculous!" There may be some among you that rejoice at this list, but I can well imagine well justified reservations from any "single-disciplinarianists".

In spite of my present comfortable billet within the Science Faculty, and even in the School of the Built Environment, it could certainly justify snide remarks about whether I was man or fish, or what else. And where does this leave us?

One thing is certain. I cannot, nor would I, deny the nature of my spots. Yet I do recoil from the dilettante snares and the danger of dispersion of effort that could come by having a foot in so many camps.

I have gained some hope of redemption following some recent thoughts that I have had in defining what the fire problem really is and I find that like so many things that begin to be tractable, it can be divided into three parts. One deals with fires starting; the other with the way fires behave;/

behave; and the other with the mess they leave after them. Associated with these parts there is extensive human safety activity which we may call prevention, protection and accommodation respectively. But the interesting thing is that the same simple model can apply to any hazards or risks that threaten us, whether they are natural or man-made; epidemic or environmental hazards. The intrinsic differences are in the distribution of action within the three fields. With fire it tends to be concentrated rather more in the middle sector, i.e. protection, than in the others, with the social emphasis now moving strongly in the direction of prevention of fire, which could well be a r eflection of a determination to get to grips with the hazard at long last. With a catastrophe like meteorites falling upon us, we are just left with such accommodation as we can muster after it has happened. It is interesting to conjecture where ice age calamities fit into this picture. In the past ice age or two, fire itself will have undoubtedly provided some protection but perhaps we can move to prevention before the next ice age arrives.

Is there a new unity coming to light here?

Could it be that my subject is neither man nor fish but a gawky representative of a new species? This species could have as its discipline the understanding and thence the bringing of a modicum of control to the hitherto intractable quality called "Safety", a word whose aura must surely extend beyond ourselves to our fellows, to those that follow us and even to mankind. And in the shadow of Safety there is always Risk which comes strongly into the light when the emphasis of our studies turns to the adventurous journey of mankind through time, space and such as might lie between. In pursuit of gaining the measure of Safety and Risk we could well find ourselves ranging unashamedly from Physics to History, why even beyond. For will we not be concerned with bringing what has been called "Acts of God", amongst which Fire has had such a terrible ranking, into the regime under man's control? What impudence, but if true, it would be New Variation on an Old Theme indeed!

Dean of the Faculty of Science, Ladies and Gentlemen, thank you for your kind attention.

[illegible] and [illegible] with [illegible], [illegible] have [illegible] them. [illegible] with these [illegible] the [illegible] human safety [illegible] which [illegible] the world [illegible], protection and [illegible] respectively. But the interesting thing is that the [illegible] would [illegible] to any hazards or risks that threaten [illegible], [illegible] they are natural or man-made; [illegible] or environmental hazards. The [illegible] differences are in the distribution of [illegible] within the three fields. With fire it tends to concentrated rather more in the middle sector, i.e. protection, [illegible] in the future, with the social emphasis now moving strongly in the direction of prevention of fire, which could well be a reflection of a determination to get to grips with the hazard at long last. With catastrophic like [illegible] falling upon us, we are [illegible] left with such accommodation as we can muster after it has happened. It is interesting to conjecture where the age calamities fit into this picture. In the past Ice Age or two, fire itself will have undoubtedly provided some protection but perhaps we can move to prevention before the next Ice Age arrives.

Is there a new unity coming to light now?

Could it be that my subject is neither man nor fish but a [illegible] representative of a new species? This species could have as its discipline the understanding and therefore the bringing of a modicum of control to the hitherto intractable quality called "Safety", a word whose [illegible] must surely extend beyond ourselves to our fellows, to those that follow us and even to mankind. And in the shadow of Safety there is always Risk, which comes strongly into the light when the emphasis of our studies [illegible] on the adventurous journey of mankind through time, space and such as might lie [illegible]. In pursuit of gaining the measure of Safety and Risk we could well find ourselves ranging unashamedly from [illegible] to [illegible], [illegible]. [illegible] will we not be concerned with [illegible] what [illegible] call [illegible], amongst which Fire has had such a [illegible] position, into the [illegible] under man's control? What [illegible], but if true, [illegible] an old flame indeed!

Dean of the Faculty of [illegible], Ladies and Gentlemen, thank you for your kind attention.

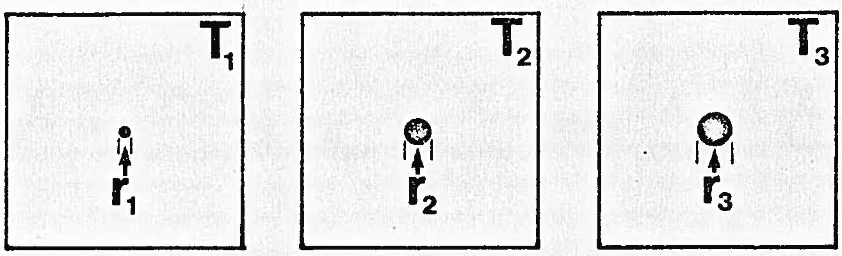

Fig. 1: Thermal Ignition Theory - Ignition of samples of different size in an oven of different temperatures.

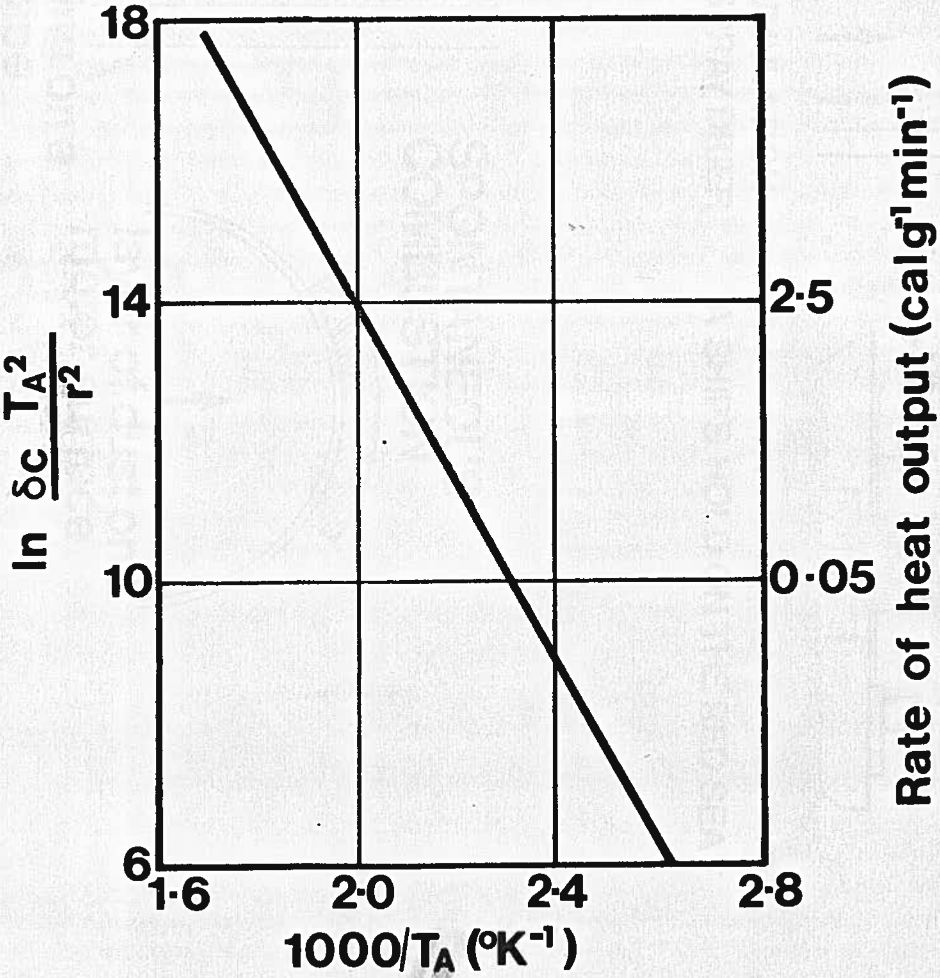

Fig 2: Thermal Ignition Theory - Method of plotting of ignition data to obtain a slope A/B.

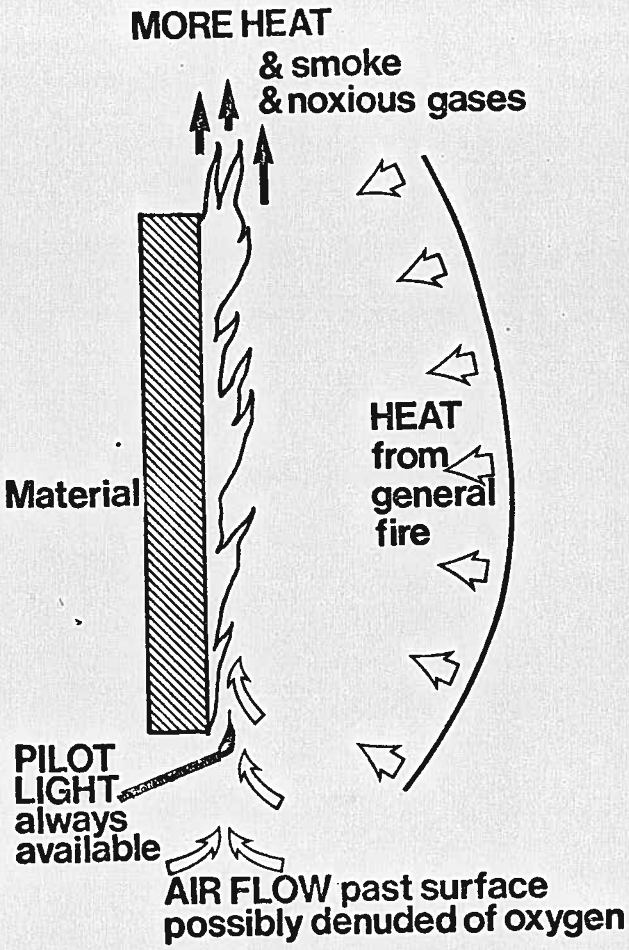

Fig 4: Some factors affecting fire properties of materials.

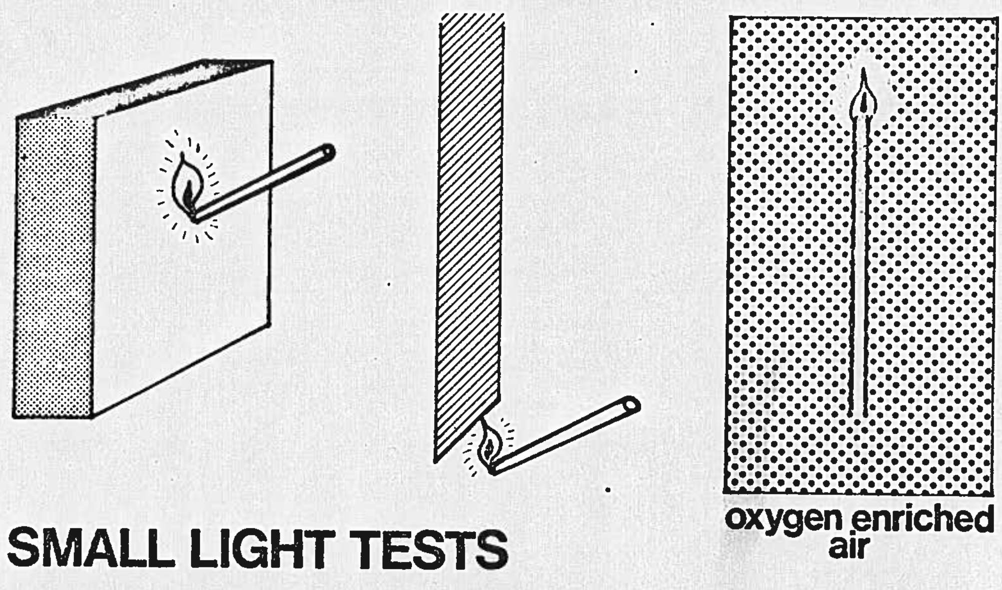

Fig. 5 Diagrams of a few small scale tests.

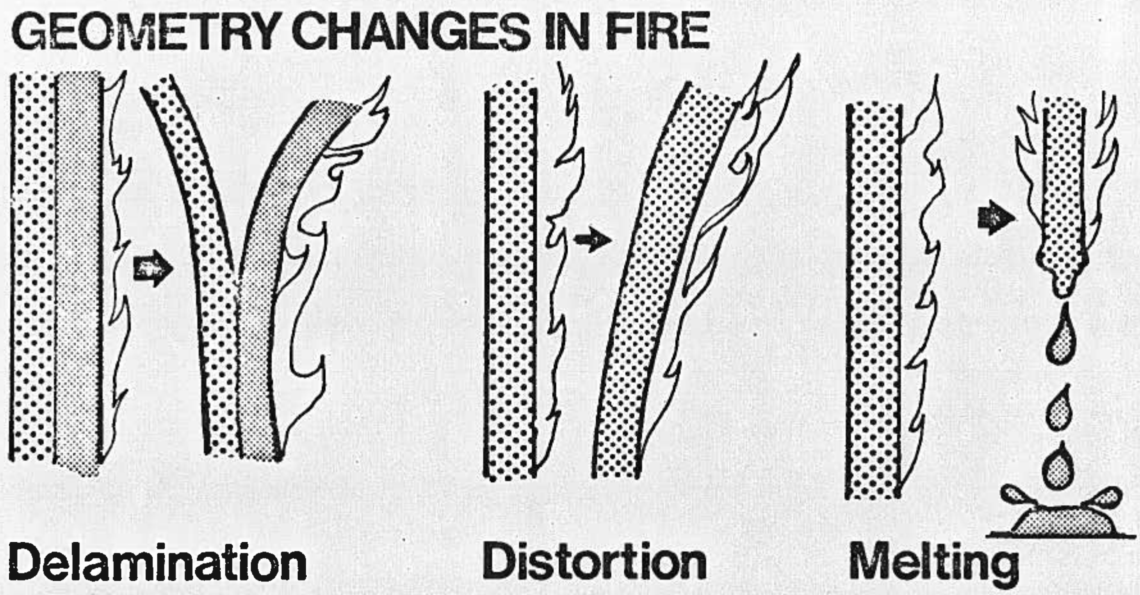
GEOMETRY CHANGES IN FIRE
Delamination
Distortion
Melting

Fig. 6

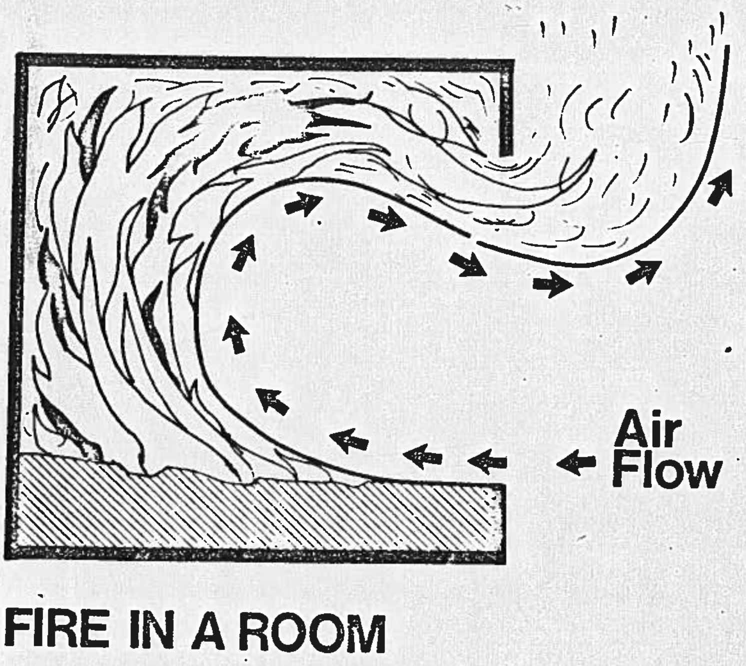
Air
Flow
FIRE IN A ROOM

Fig. 7