REVIEW OF LATEST DEVELOPMENTS IN FIRE PROTECTION

by

D. J. Rasbash

INTRODUCTION

In this review an attempt will be made to see in perspective the various methods of providing protection against fires and explosions described at this meeting, not only one with another, but also with the fire problem as a whole. This will help pinpoint where there are deficiencies and drawbacks in these methods and where there is room for future development.

The important aim for any interested party is that the total cost of fire per annum should be kept to a minimum. Of course, the individual Factory Manager who is concerned with running his plant at a profit and the Insurance Manager, making a profit on the business of servicing the fire risk cover will see the problem differently from Government, who should be concerned with keeping down the total cost of fire to the nation. However, all these parties require similar information on the cost and effectiveness of various approaches to the fire problem to allow a sound judgment to be formulated.

INTRINSIC VALUE OF FIRE PROTECTION MEASURES

In order to assess the value of fire protection measures it is necessary to compare the cost of the measures with the potential reduction in fire losses that they might bring about. The major part of the cost of fire is due to large fires. It has been estimated[1] that taking a mean value for all buildings in a built-up area the expected loss in large fires per annum per square foot of floor area is well under 0.5d. per annum. The present cost of installing detectors or sprinklers when amortized over a period of twelve years, and including maintenance costs varies from 2d. per square foot per annum upwards. Even if it is assumed that the wholesale installation of these devices would wipe out completely all large fire losses, and even including an ample allowance for losses in small fires and consequential losses, the above figures suggest that such universal installation would not pay for itself at present prices. For this reason it is necessary that protective installations be concentrated in high risk areas, and indeed many, if not most industrial premises may be classified as being high risk areas. Nevertheless, there is wide variation in fire risk in industry, for example, there is a factor of 70 in the probability of the more hazardous industries having a fire compared with the least hazardous industries[2].

To achieve the widespread use of fire protective installations there is little doubt that they need to be considerably cheaper than they are at present. While this is of dominant importance for non-industrial premises, it is likely that certain sections of industry of low fire risk or of fire risk comparable to commercial, office or domestic premises may stand to benefit by the development of such systems. It is relevant, therefore, to give some consideration here to possible ways of reducing the cost of protective installations.

REDUCING THE COST OF PROTECTIVE INSTALLATIONS

To achieve this aim may require certain reductions in the standards of the detection and extinction of fire, but such requirements may well be less onerous in comparatively low hazard premises under consideration. Moreover, a reduction in technical performance to achieve simplicity and cheapness may well be balanced by a reduction in the necessity for maintenance. A reduction in costs may also be obtained by improved standardization and the production of increased numbers, but the contribution in this direction is limited, since the labour costs of installation would not be affected. Here, the main way of reducing costs is to reduce the amount of piping needed in the installation of sprinklers, and the amount of wiring needed for detectors.

As far as sprinklers are concerned normal sprinkler systems operate at a mean flow of about 5-10 kg $m^{-2} min^{-1}$ (0.1 to 0.2 gal $ft^{-2} min^{-1}$) of floor area. The amount of water, however, required to extinguish a square foot of fire in wood is far less than one-tenth of this figure[3], as long as the spray can be made to reach the burning surface. Therefore, any situation where the fire load is not too great and the surfaces at which burning can take place are easily exposed to water from the sprinkler, a cheaper system may be justified. As far as detectors are concerned, wiring may in many cases be reduced or eliminated by using an infra red detector or a light beam such as a laser[4] to monitor a large area or by using a single conducting wire with a number of fusible links at intervals.

Another possible way of reducing costs is for a number of factories to share high cost capital items, e.g. pumps and detector monitoring equipment. These could well form part of a common service on an industrial estate. However, it is important at present to state that before encouragement can be given to the widespread installation of cheaper systems than at present exist, more operational information on the fire risks will be needed than is at present available, to give a clear definition where such systems are likely to be beneficial. Moreover the standards for any cheaper systems must be as rigidly controlled as the standards for more expensive systems.

NECESSITY FOR MORE ADVANCE PROTECTION SYSTEMS

While it is possible that for a number of applications it may be desirable to cheapen fire protection systems with a possible acceptable reduction in performance in order to bring about the optimum use of these systems, there is, on the other hand, an increasing requirement for installations which need to manifest the fullest degree of technical sophistication. The whole tendency of modern technology is to cheapen production and handling processes by the use of expensive automatic equipment, operating in one single concentration of capital goods. The traditional principle of compartmentation is resisted as it interferes with the efficiency of the process. Once fire gets out of control in a situation of this kind - and particularly when highly flammable materials are involved - the losses can run into several million pounds. One tends not to have just large fires, but small fires and enormous fires, and the margin between the two is dangerously reduced. Over the last few years, there have been very large fires in petroleum and chemical processes and in high-stacked extensive storage warehouses, which bear out this point. In this type of fire too, the consequential losses may be even more painful to bear than the direct fire losses. In these instances an even larger proportion of the burden in preventing these high losses must fall upon the efficiency of the protective equipment than in traditional risks, and it is worth investing a great deal to ensure that protective equipment is rapid in action and very effective. The problem is difficult, since often in this field the experience gained over the years in protective installations is of limited value; one is not dealing with old problems writ large, but with new problems. Great care is needed in extrapolating empirical information from past experience, particularly when the basic understanding of the laws which govern the operation of the system, is only sketchily comprehended. Perhaps in this context it is relevant to look at some of the criteria by which the effectiveness of protective installations may be judged.

CRITICAL FACTORS IN PROTECTIVE INSTALLATIONS

To protect a plant or a building against fire or explosion, an installation must either

(1) detect a fire at an early stage and follow the detection by some action, which either directly or indirectly brings the fire under control before getting out of hand, e.g. informs the fire brigade, brings in an extinguishing agent automatically, instructs computer to divert flammable material in an automatic process up a flare stack, or,

(2) be an inbuilt part of the plant or building which limits the damage caused by a fire or explosion, e.g. fire-resistance between compartments, separation between buildings and storage tanks, flame arresters between items of plant, explosion relief on items of plant.

DETECTION OF FIRE

There is no difficulty about the detection of fire in its very early stages. Current smoke detectors and infra-red methods are very sensitive, and even these do not represent the limits of sensitivity that are technically possible. The scientific background on fire detection is also reasonably well understood, although more information is needed on the movement and composition of smoke, particularly of the limiting conditions when the buoyancy forces resulting from a small fire are too small to counteract extraneous influences due to draught etc. There is a definite tendency at present for the fire detection systems to give false alarms, which can be a very undesirable feature, particularly when the detector is harnessed automatically to an extinguishing system. This drawback should be capable of removal with careful design of the system and definition of ambient levels of the parameter that is being detected.

The large majority of automatic installations used indoors, and particularly almost all sprinkler systems, are operated by detecting the smoke and hot gases rising and spreading under the ceiling. For any complete flooding system, for example carbon dioxide or high-expansion foam, there is no reason why this type of detection should not be made as sensitive as possible, subject of course to obtaining no false alarm. However, with a localised system such as sprinklers, while their rapid operation near the fire is an advantage, their operation remote from the fire by the spread of hot gases under the ceiling is not, not only because of the possibility of unwanted water damage, but the disastrous effects it might have on the efficiency of the system. These factors have, over the years, resulted in a development of relatively insensitive detectors for sprinklers and the trend now is to make them even less sensitive still by uprating the sprinklers[5]. As a result, a gap is tending to build up between the time when a fire can be reliably detected and the time when sprinklers operate, so that the fire can be of a large size even before sprinklers operate. This difficulty can be overcome to some extent by having a sensitive fire detector system in addition to sprinklers. On the other hand, there is reason to develop a fire detector system which is not operated by the hot gases at the ceiling, but rather by real flame in the area covered by the extinguishing devices which the detector actuates. It is quite feasible that infra-red systems can be made to fulfil this purpose. A positive detector of this kind could not only, for example, bring in the appropriate local extinguishing system at the earliest practicable moment in a fire, but could also prevent a remote part of the system being actuated superfluously, in the absence of a local fire, merely by the presence of the smoke and hot gases.

EXTINGUISHING AGENTS

Turning now to actual materials used for extinguishing purposes, there are certain basic requirements by which their performance may be judged. These may be summarized as follows:

1. High extinguishing power per unit weight, cost or availability.

2. Capability of use under a wide range of fire conditions so that multiplicity in the number of agents used is avoided.

3. Capability of being delivered in a very short time, onto the fire and its immediate vicinity.

4. No undesirable extraneous effects, such as toxicity or extra damage.

Water

There is no doubt that, per unit cost and availability and probably per unit weight as well, water reigns supreme as an extinguishing agent. Its drawback is that in order to manifest its full extinguishing power it must be distributed sufficiently evenly onto surfaces which are actually burning, so that it can be vaporized[6]. Under these conditions a little water can go a very long way indeed. However, when water is not vaporised at a burning surface, there is a triple penalisation. Firstly, the latent heat of vaporization is not used to reduce the burning rate of fuel. Secondly, the vapour which might have been evolved is not available to extinguish the flames, and thirdly, the water that runs away may well cause water damage. There is a compensation, however, in that the wetting down of the material in the vicinity of the fire, allows the rate of spread to be reduced and even stopped; the fire is thus isolated and burns out. Indeed [illegible] controlling fires. Here again, as far as [illegible] concerned, very little water is needed to prevent the [illegible] spread of fire. Although information on precisely how much water is required and how it depends on the size of the fuel and the size of the fire is very scanty indeed; experiments carried out by O'Dogherty[1] have shown that for wood cribs this flow rate is of the order of 0.06 $kg\ m^{-2}\ min^{-1}$ (the area referred to is the actual area of the fuel surfaces). This figure may be compared with the flow rate used for normal sprinkler systems per unit floor area, which is about 5–10 $kg\ m^{-2}\ min^{-1}$. Indeed, one tolerates water in many protective installations because it is so cheap and generally harmless that one can afford to waste the bulk of the agent even when applied for long periods provided just enough remains on all the surfaces of the [illegible] near the fire to prevent its spread. If one could be certain of complete extinction in the first minute of application, there would be a substantial argument for using a much more expensive agent even for cellulosic materials. For a fuel like a light hydrocarbon, in which the surface of the burning material has a low temperature, then water cannot be vaporised at the fuel under the best conditions and it becomes a poor extinguishing agent. However, under the right conditions, it is still effective as a method of reducing fire spread, particularly by cooling metal surfaces in the fire.

Again, with high-stacked storage, and with water application from sprinklers at the top of the store, the sheer inaccessibility of fire in the lower part of the store prevents water reaching uniformly all channels through which fire may spread horizontally, and providing them with the necessary degree of wetting needed to stop the lateral progress of the fire. Moreover, the upward draught of the flames which can develop in an uninterrupted canyon between stacked goods, can push the water from the sprinklers completely aside and prevent water getting near the actual source of fire. These difficulties can be overcome to some extent by the installation of sprinklers at intermediate levels. Great care is needed in the siting of such sprinklers, since they are generally responsive only to the direct impact of flame, and powerful fires may develop in a neighbouring canyon or vertical chimney, in or between stacked goods without being detected. Moreover, the obstruction effect of the packed goods round the sprinkler head may prevent the adequate wetting of all the horizontal channels within the region nominally covered by the sprinkler head.

High-expansion foam

Some of the problems outlined above [illegible] of water can be overcome by using high-expansion foam. This is a versatile agent which extinguishes petrol fires as well as being able to flow into the larger channels between stacks of goods and prevents access of air to the smaller channels. However, this agent suffers from the disadvantage that it cannot be directed onto the seat of the fire. The foam needs to flow through a whole compartment which happens to include the region where there is fire. This takes time during which the fire might spread well beyond the place where it began. Although residual damage caused by high-expansion foam is substantially less than that caused by water, it is still not known to what extent it is acceptable, particularly where food is stored. These limitations tend to make high-expansion foam less acceptable for very large compartments. There are also certain development problems outstanding with this agent, particularly reliability in cold weather.

Carbon dioxide and vaporizing liquids

Carbon dioxide is also mainly used for filling a whole space and has limited directional effects; its use is also limited by its toxicity. The efficiency of liquid carbon dioxide is hindered by the fact that when it is discharged as a jet into the atmosphere, more than 50 per cent of the agent immediately flashes into a gas, the remainder changing into a fine solid. The gas stream then entrains air into itself, bringing about some evaporation of the fine solid. A great deal of the cooling effect which the agent could have on a burning surface, is therefore eliminated. Vaporizing liquid agents such as halogenated methanes do not suffer from this disadvantage, but their inherent cooling capacity is relatively low compared with that of liquid carbon dioxide or water[8]. In recent months some work has been carried out at the Fire Research Station on the use of liquid nitrogen and also slurries of solid carbon dioxide in vaporizing liquids[9]. These slurries can extract a significant amount of heat from surfaces in and in the immediate vicinity of the fire and in the course of vaporization produce a useful inerting gas. It may be that such agents can achieve some of the desirable properties of water, particularly its ability to be projected directly onto a burning surface and cool it as well as those of carbon dioxide and bromochlorodifluoromethane, i.e. ability not to cause water damage and to surround the burning material with an extinguishing vapour in the event of the agent not scoring a direct hit on the fire. Such slurries would also be effective agents against liquid fires as they appear to be capable of flowing and vaporizing smoothly over the surface of burning liquids. However, halogenated agents when involved in an intense fire might produce gases which bring about corrosion effects under unfavourable conditions.

Dry powder

Dry powder, owing to its greater fineness has perhaps a greater ability than water spray to penetrate flame zones behind obstacles. However, the powder which falls outside the fire zone is generally wasted. It is, therefore, essential that dry powder is accurately projected to where the flame and the burning material is going to be. This restriction limits its widespread use. A very promising variant of dry powder is the production of a highly active powder that owes its effectiveness to the fact that it decrepitates and thus becomes very fine in the flame[10]. Another variant is the use of micro-encapsulated materials as extinguishing agents[11]. In this way some harmful or noxious materials may be made acceptable since they manifest their properties only when the encapsulation is destroyed by fire.

DUAL PROTECTION

The above comments indicate that for some applications there are certain disadvantages in most types of protective installation. However there are ways of providing two-pronged protection where the two individual prongs are not only compatible, but might reinforce each other to such an extent as to provide a complete answer to a risk, for which either one or the other would not be very effective. The combination of sensitive detectors with insensitive sprinklers has already been mentioned. Sprinklers which control fire from the top of a building downwards could also be used in conjunction with high-expansion foam which controls fire from the floor upwards. The use of roof vents is compatible with the use of high-expansion foam and will tend to reduce the spread of flame under the ceiling in the time taken to fill the compartment. They are not quite so compatible with sprinklers, as the latter tend to push smoke downwards into the room where there is fire, whereas roof vents rely on the buoyancy effect of smoke and hot gases taking them through the vent in the roof. However, the use of roof vents in this context is still likely to be advantageous.

Another possibility is the stratified introduction of a light inert gas, e.g. produced by a jet engine near the upper part of a building, combined with a stratified introduction of heavy gas, e.g. carbon dioxide or high-expansion foam in the lower part of the building. The light inert gas can contribute by extinguishing the flame under the ceiling which is the mechanism of fire spread in buildings and also the major influence tending to cause ceilings to collapse.

Methods for sub-dividing a large building in the event of fire, by using curtains, could also be used in conjunction with high-expansion foam [2]. However doubling the system in the above manner will, in general, increase the [illegible] installation, and one must be certain that there is a real improvement in [illegible] to warrant the extra cost.

CONTROL OF AUTOMATIC PROCESSES

Very little experience is available on the detection and control of fire that may involve automatic processes. In this situation the computer which controls the process must have special consideration. Although the computer itself may be a comparatively low fire risk, its failure to operate because of fire may bring a whole process to a halt and may even cause hazard in the process itself. For this type of risk, therefore, a computer would merit a protective installation in its own right.

A more complicated problem is the way in which a computer may instruct emergency procedure to a process in a situation when fire may occur, or in which it has actually occurred. Decisions need to be made as to whether the process should be shut down and if it is to be shut down, the sequence in which the shut down should take place. If a fire has occurred, it may be necessary to decide whether an automatic extinguishing agent should be brought in, (e.g. when there is a spillage of liquid fuel) or whether it is best to deflect the fuel from the fire, (as in the case of fire in a gas leak which, if extinguished, may lead to explosion). These problems are in their infancy, but it is likely that in the next few years we shall see a great many more of them.

RESISTANCE TO FIRE AND EXPLOSION

The above comments have dealt mainly with protective installations in which fire and explosions are detected and positive action engendered. A different form of protection is to have resistance to fire and explosion actually built in. The object of this protection is to minimise the damage which occurs even if a fire or explosion were to develop to a very serious proportion. Protection of this kind for fire usually takes the form of thermal resistance, and for explosions of explosion relief. In both cases these may be designed to protect either a plant or a building. In both cases there is also a dearth of information which would allow proper design for the large (linear) scale application that is coming into use. This is particularly so for the design of explosion relief, since the onset of turbulence and the transition to detonation are factors which increase the tendency for explosions to become more violent as the scale is increased.

Here a point of cross reference exists with protective installations. Undoubtedly a great deal more can be done in using water to help provide what is the equivalent of fire-resistance. Indeed, wherever fire protection difficulties are envisaged in the protection of metalwork in fire, then the spraying or the passage of water over or through the metalwork could be a feasible method of protection. This principle, of course, is used extensively for protection of tanks containing flammable liquids. There is no real reason why this should not be extended at least to shutter doors, possibly to structural steelwork, and even to temporary metal compartment walls. The reason is that provided the water is sufficiently well distributed over the surface concerned (which could be an interior surface for certain forms of structural steelwork), then it is difficult for the structure to exceed substantially a temperature of 100°C without making use of the considerable cooling capacity of the water. One can use this, therefore, as a simple basic design concept, combined with the fact that if the maximum area of metalwork which must not exceed a certain critical temperature is known, the extent to which non-uniformity of wetting may be tolerated can also be estimated.

CONCLUSIONS

The expected loss due to fires in different risks varies very greatly, and to this extent the degree of protection which is prudent also varies. High hazard industries such as capital intensive process industries handling highly flammable material and those involving flammable materials of almost any kind in high-stacked storage of flammable goods merit a very high degree indeed in sophistication in their fire protection engineering, but a number of practical scaling problems in these fields still remain to be solved. On the other hand, there may be scope in certain instances for simplifying protective installations in order to cheapen them and encourage their more widespread use. Some possible new developments to improve fire protection are suggested. These include the possibilities of double method installations (e.g. the combined use of high expansion foam and inert gas); sprinkler installations which become active more rapidly and yet which do not operate away from the seat of the fire; the use of cold slurries of solid carbon dioxide in a vaporising liquid as an extinguishing fluid; the possibility of using micro-encapsulation to reduce the noxious and damaging properties of extinguishing materials; and the more widespread use of water cooling as an alternative to fire-resistance.

REFERENCES

(1) DUNN, JENNIFER, E. and FRY, J. F. Fires fought with five or more jets. Fire Research Technical Paper No.16. London, 1966. H.M. Stationery Office.

(2) HOGG, JANE, M. and FRY, J. F. The relative fire frequency of different industries. Fire Note No.7. London, 1966.

(3) RASBASH, D. J. The extinction of fires by water sprays. Fire Res. Abstr. & Rev., 1962, 4 (1 & 2) 28-53.

(4) LAWSON, D. I. Fire detection using laser beams - methods and likely costs. Fire, 1968, 61 (757) 78-9, 92.

(5) BRAY, G. Automatic water sprinkler fire systems. Fire Protection Association Third National Fire Conference 1968 (to be published).

(6) RASBASH, D. J. Liquefied gases as fire-fighting agents. Chem. Engr, 1968, (217) CE89-CE93.

(7) O'DOGHERTY, M. J., NASH, P. and YOUNG, R. A. A study of the performance of automatic sprinkler systems. Fire Research Technical Paper No.17. London, 1966. H.M. Stationery Office.

(8) RASBASH, D. J. The contribution of cooling to the effectiveness of vaporizing extinguishing agents. Joint Fire Research Organization Fire Research Note No.705/1968.

(9) RASBASH, D. J., THORNE, P. F., and WOOLLEY, W. D. Slurries of solid carbon dioxide as extinguishing agents. Joint Fire Research Organization Fire Research Note No.717/1968.

(10) Fire extinguishing compositions. Imperial Chemical Industries Ltd. British Patent No.1 118 215. 5th July, 1966.

(11) Fire Research 1967. Ministry of Technology and Fire Offices' Committee Joint Fire Research Organization. London, 1968. H.M. Stationery Office p.

(12) RASBASH, D. J. and LANGFORD, B. The use of nets as barriers for retaining high expansion foam. Fire Tech., 1966, 2 (4) 298-302.