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DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH AND FIRE OFFICES' COMMITTEE
JOINT FIRE RESEARCH ORGANIZATION

SOME FACTORS IN THE DEVELOPMENT OF FIRE-FIGHTING EQUIPMENT

by

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Abstract

The author discusses some of the implications of recent discoveries in the use of fire-fighting materials, and indicates how they may affect the design and use of equipment.

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One of the most promising features of the fire extinction industry to-day, is the great interest and activity being displayed in the development of new methods of applying both new and traditional fire-fighting materials. No small part is being played, in this activity, by the people whose responsibility it is to extinguish fires, and who are in the best possible position to assess the operational factors involved. This co-operation of the operational fire-fighter and the research and development teams of the manufacturers and research institutes in an essential feature if the fullest use is to be made of existing and future knowledge. It stems from the fact that the performance of a fire-fighting material when applied to a fire, is a compounding of the intrinsic qualities of the material, the virtues of its method of application, and the characteristics of the type of fire being attacked.

It is possible to take all these factors into consideration in reaching an "overall" assessment of the performance of a material by determining the "critical rate curve", a procedure described in a paper read before the Institution of Fire Engineers in September 1955 (1). This curve shows the time, and quantity of material, necessary to extinguish the fire at various rates of application of the material. It is currently being applied, at the Fire Research Organization and elsewhere, in the solution of some of the outstanding fire-fighting problems of today.

The economical use of water in building fires is to-day engaging much attention, and two questions appear to be uppermost in enquirers' minds. These are whether water sprays are more useful than jets, and whether there are advantages in the use of much higher pressures than the normal values of up to 100 Lb./sq.in. It is likely that there is no universal answer to either of these questions, which can only be considered in relation to the size and type of fire, having regard both to the operational aspect and to the possibility of one method having intrinsic advantages.

There are on the market two or three types of pump capable of developing pressures of 500-700 Lb./sq.in., at discharge rates of from 30 to 50 gallons per minute. These pumps are usually used in conjunction with one or two $\frac{3}{4}$ in. first-aid lines, fitted with one or other of the proprietary types of trigger-operated spray gun having a variable orifice which provides either a wide-angle spray or a very narrow angle spray with a throw of some 30 - 40 feet. Users of such equipment claim that it is very suitable for dealing with small outbreaks of fire, particularly at inaccessible places at some height above the ground. They claim also that trigger operation not only permits the branchman to save water in traversing from one small fire to another but gives him a better control of the use of the nozzle than he would have with a continuously-flowing stream. This results in other incidental advantages such as the saving of the manpower carried to the fire - an important factor in country districts relying on retained personnel. These claims are largely operational, and there is no suggestion of any intrinsic advantage in the high-pressure spray, due, for example, to its reduced water droplet size, other than the fact that the higher pressures are necessary at these limited flow rates to obtain the throws required, or to give penetration of, perhaps, a heap of burning rubbish. It is important to remember that a pressure difference of some 200 lb./sq.in. is necessary between the ends of 240 feet of $\frac{3}{4}$ inch hose, to produce a flow of about 20 gallons per minute. This pressure difference is dependent upon the inverse of the hose diameter, raised to the fifth power, so that any increase in hose diameter is extremely valuable in reducing the pressure necessary at the pump for a given nozzle pressure.

The next larger stage in fires in building comprises those fires in which a room has become wholly involved. In such an application, provided the fireman has access to a window or door, the throw of his spray is not generally a limiting factor, as some 15 - 20 feet is sufficient to reach the far wall of the room. Experiments made by City of Birmingham Fire Service in co-operation with Fire Research Organization have shown that such fires may be extinguished by spray or by jet, operating at 100 lb./sq.in. nozzle pressure, using some 8 gallons of water per 1,000 cubic feet of room volume. The mechanism of extinction appeared to be largely one of smothering the fire by steam, which displaced the oxygen from the room. Sprays seem to require rather less experience to handle than jets in this application, since they disperse their water about the room to give ready formation of steam, without the need for "scanning" the nozzle. Nevertheless, the experienced fireman could produce comparable results with either appliance. An examination of all other available data on the extinction of fully-developed fires in rooms shows no emphatic evidence of any large advantage of high-pressure sprays over low pressure sprays, although nozzle pressures range from 50 to 600 Lb./sq.in. in rooms up to 2,000 cubic feet volume. It is only fair to add that the diverse conditions under which these tests were carried out, by many different experimenters, make it desirable that a carefully-controlled series of experiments be made, not only to give a valid comparison in the use of high and low nozzle pressures, but also to show how the amount of water required to extinguish such a fire varies with rate of application. It is felt that such experiments should be made, as it is only by this means that a firm basis on which to design the first-aid appliance of the future can be attained. This should be an appliance with all the convenience of the trigger-operated hose-reel gun, capable of giving both adequate throw at low rates of flow, and sufficient flow to enable one or two branchmen working reasonably within their "reaction" capacity, to deal with the largest "first-aid" fires.

For larger fires, the diffuser nozzle or the jet is used in this country, while for very large fires the jet is mostly used. It is natural that this should be so, as the larger the fire, the more it has to be fought on a "perimeter" basis than on the "volume" basis appropriate to single room fires. The need to obtain greater flow, and greater throw in order to reach the heart of the fire, tends to single out the jet for this application. This is borne out by an analysis of American experimental measurements on a variety of spray nozzles, having cone angles between 30 and 90 degrees, and operating at pressures up to 150 Lb./sq.in. The analysis has shown that the throw of a spray increases only very slowly with increasing nozzle pressure, and that at least comparable increases may be obtained by reducing cone angle or increasing rate of flow. It is likely that for higher pressures, the proportional increase of throw would be even less. Despite this evidence in favour of the jet for larger fires, fire-fighters in America claim that their new "master deluge" sprays of up to 2,500 gallons per minute delivery for distances of 300 feet give remarkable results in subduing the largest of fires, such as blazing warehouses. There is clearly a need for a careful examination of all the factors involved to determine whether the spray can give better results than the jet, and whether or not its sphere of usefulness extends to the largest fires.

The use of foam against liquid fires is also receiving attention and a promising recent development concerns its application below the surface, in petrol storage tank fires. Hitherto, protection of this type of risk has been almost entirely by the top application of foam, but the fear that fixed apparatus of this type would be damaged before fire-fighting started, and that bund fires would make the tank unapproachable by portable apparatus, led to a study of the "sub-surface" or "base-injection" method. Petrol, unlike other oils of higher flash point, cannot be extinguished by the air stirring or air agitation method (2) first devised by Burgoyne and Katan of Imperial College, London, and later demonstrated in full-scale tanks by the Socony-Vacuum Oil Company Inc. of America. It is true that an appreciable if momentary reduction in the intensity of the flames may be obtained by the method, and that advantage may be taken of this, in very small tanks, to use other means to extinguish the fire. This is not, however, likely to be useful in full-zize tanks where the problem of accessibility exists. Work at the Joint Fire Research Organization has shown that it is possible to extinguish fires in petrol tanks by the base injection method, so long as the foam properties at the point of input to the tank are suitable. The foam, on rising to the surface of the petrol, collects petrol which is trapped as discrete "globules" in the foam layer. The fire above the petrol surface collapses onto the foam layer as the latter seals off the surface (3), and will ignite the petrol contained in the foam, if this exceeds 10 per cent by volume of the latter, resulting in the ultimate destruction of the layer and the reignition of the petrol beneath. For this reason it is essential that the expansion of the foam at input should be not more than about $3\frac{1}{2}$; it is also necessary that the foam should be very fluid so that it can readily seal off the petrol surface, and that its rate of drainage should be limited so that sufficient foam reaches and remains on the petrol surface to give an adequate protective layer. Given these conditions extinction by base injection can be almost as economical in foam compound and water as top application.

It might be thought that these special foam properties would produce a need for specialised equipment. The indications are that this is not so; suitable foam has been produced by passing the foam output from a normal in-line foam generator, operating at 150 Lb./sq.in. water pressure, through a centrifugal pump having about twice the nominal water capacity of the generator. This pump, in performing additional work on the foam, renders it more homogeneous and reduces its drainage rate to an acceptable value. The expansion of the foam is not affected by the pump. If the foam compound is a suitable one - and only certain of the protein foam compounds have proved suitable - the additional work done by the pump will not produce an undesirable increase in the stiffness of the foam. The centrifugal pump performs a secondary function also, in that it raises the output pressure of the foam sufficiently to overcome losses in the pipeline to the point of input. By this method, fires have been regularly extinguished in a 9 foot diameter tank, 30 feet high, containing 26 feet depth of burning petrol. The simplicity of the method, and of the apparatus required, do give considerable hopes of its success on larger scales. It would nevertheless be desirable to prove the method on larger tanks to see whether unexpected scale effects arise.

Finally may be mentioned a problem the solution of which is likely to be so complex and difficult that it deserves a separate article to do it justice - the problem of aircraft crash fire-fighting. Here everything is against the fireman. From one of the most intense types of fire he may be required to remove a large number of people, many of them injured in the crash. Even where the crash is on the runway of the airport, the task is a formidable one, and it seems likely that future equipment must be designed with a view to reducing the largest of this type of fire to negligible proportions in less than a minute. This may well call for the combined use of a "knocking-down" agent such as dry powder or a vaporizing liquid, and a "sealing agent", which is likely to be foam. It will not be possible to tolerate, in this problem, any adverse reaction between the agents tending to reduce their efficiency, and the sealing agent must be spread, in the first instance at least, only just thick enough to hold down the fire, so that the largest possible area may be covered. It follows that the properties of the agent, and its method of application, must be carefully chosen to meet this requirement.

It has only been possible, in this article, to touch on a few of the interesting developments in the fire-fighting world to-day, but it is hoped that these will be sufficient to show that success in most problems can only be attained by the utmost co-operation of all concerned.

References.

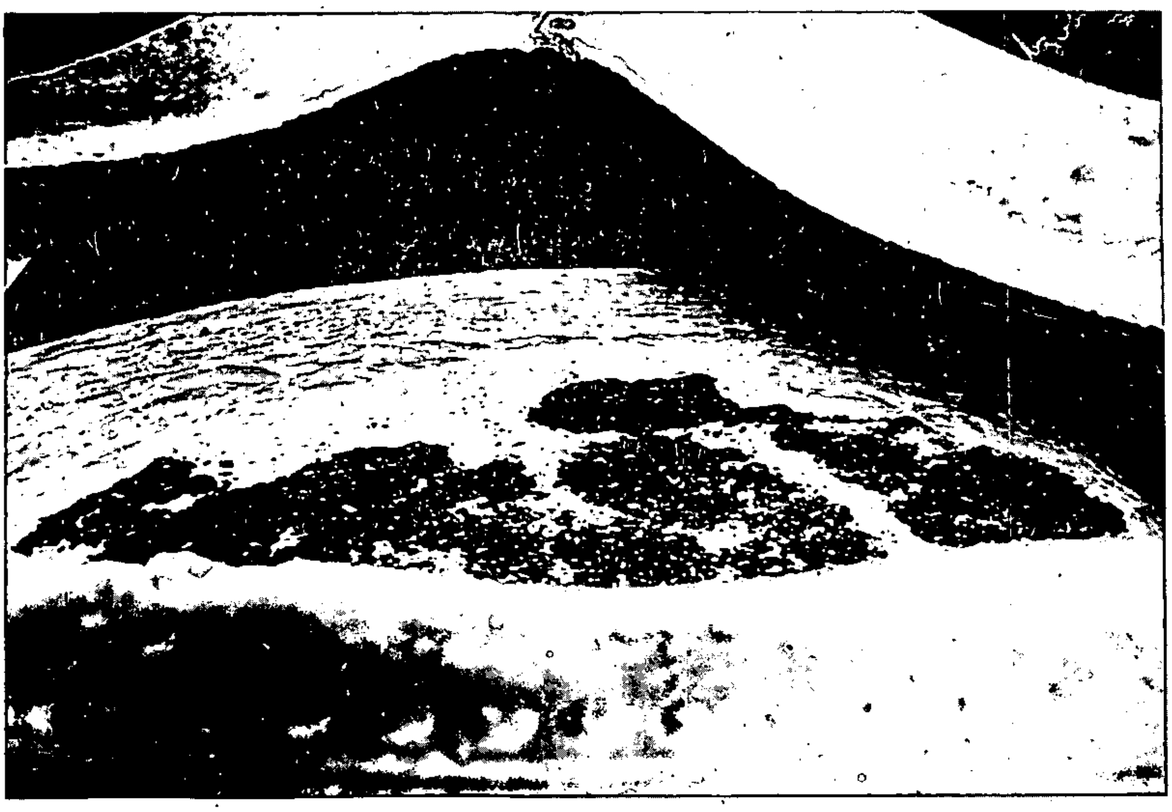
(1) Institution of Fire Engineers, Annual Report 1955.

(2) Fires in Open Tanks of Petroleum Products: Some Fundamental Aspects. J.H. Burgoyne and L.L. Katan. Journal of Institute of Petroleum Vol. 33 No. 279 March 1947.

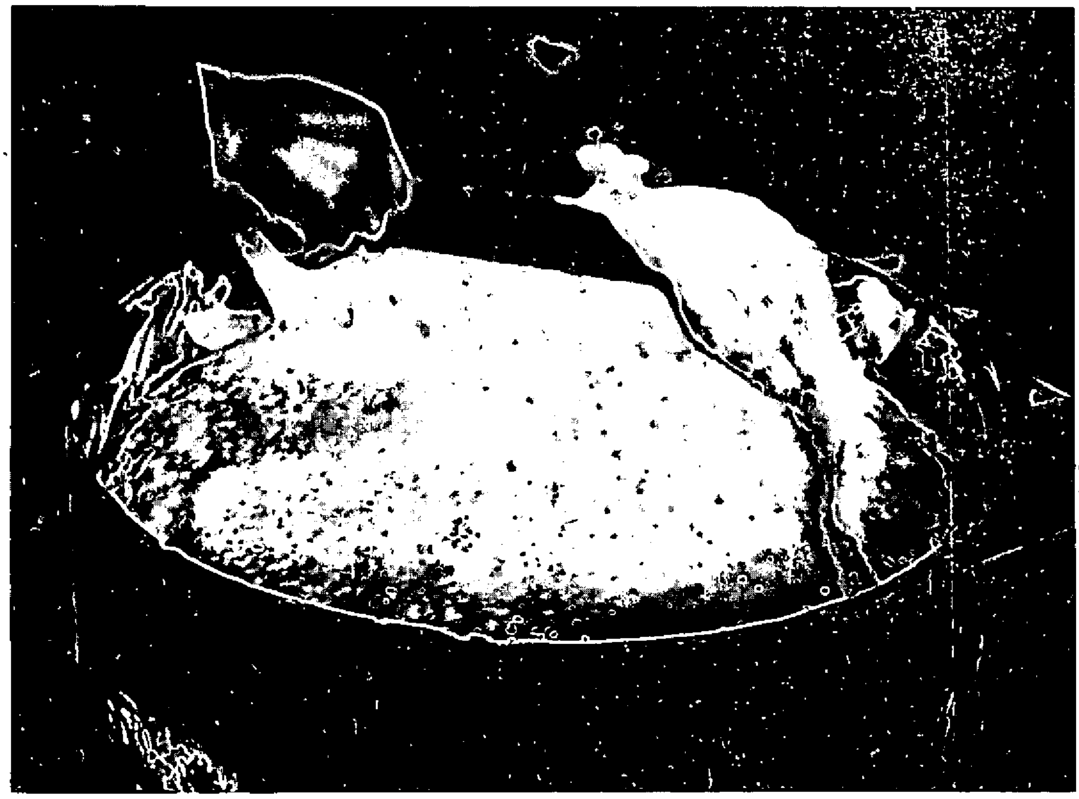
(3) Fire Research 1953 - H.M.S.O.

(4) Fire Research 1954 - H.M.S.O.

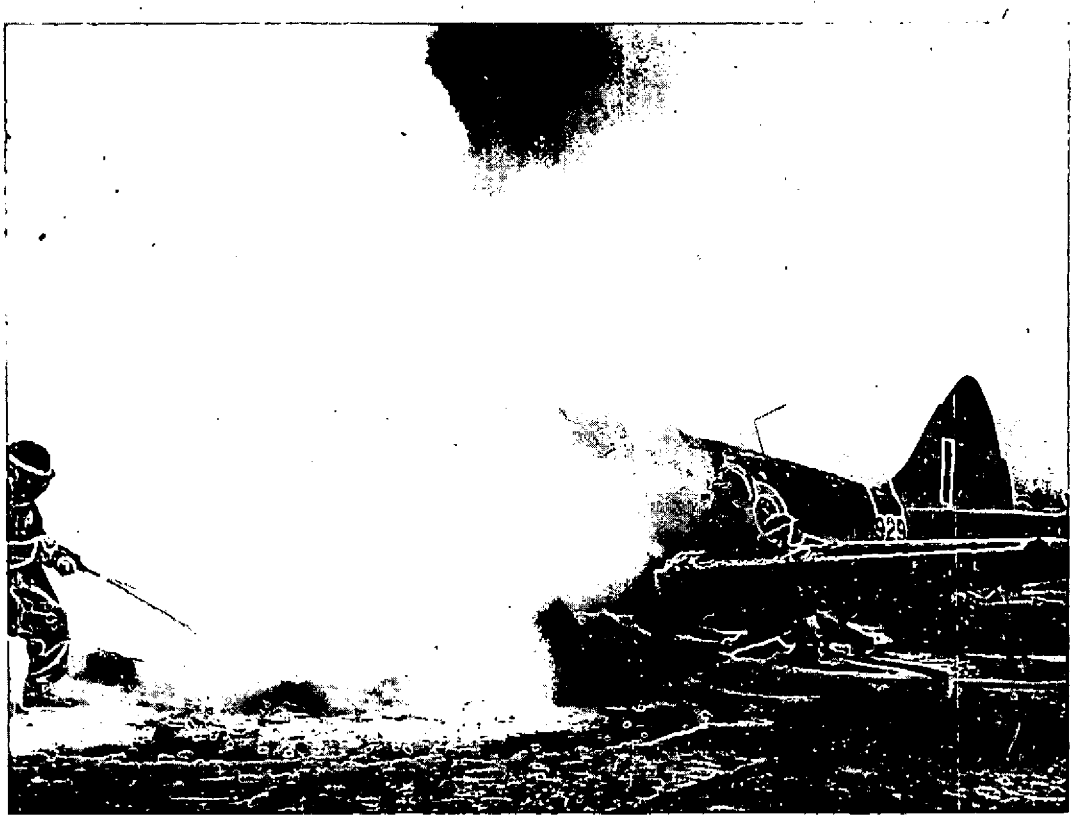
EXTINGUISHING A FULLY-DEVELOPED FIRE IN A ROOM WITH A DIFFUSER NOZZLE



BASE-INJECTED FOAM FORMING A LAYER ON THE SURFACE OF A 9ft DIAMETER PETROL TANK



SAMPLE OF BASE-INJECTED FOAM LAYER SHOWING PETROL GLOBULES



EXTINGUISHING AN AIRCRAFT FIRE WITH DRY POWDER