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NOTES ON THE USE OF HIGH EXPANSION AIR FOAM IN FIRE FIGHTING

by

P.F. THORNE, D.M. TUCKER and D.J. RASBASH

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FIRE
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Fire Research Station,
Borehamwood,
Herts.
Tel. 01-953-6177

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SUMMARY

This note is intended as a guide on the use of High Expansion Air Foam (H.E.A.F.) for fire fighting. It contains recommendations on the generation and deployment of foam and suggests minimum application rates for various fire risks.

KEYWORDS: Extinguishing, foam, high-expansion.

MINISTRY OF TECHNOLOGY AND FIRE OFFICES' COMMITTEE
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1. INTRODUCTION

High expansion air foam (H.E.A.F.) is coming into increasing use in the fire service. The purpose of this note is to give guidance on the way it should be used, with particular reference to the flow rates of foam that are necessary to control and extinguish different fires. Table 2 gives minimum recommended application rates for particular risks.

2. GENERAL PRINCIPLES

H.E.A.F. is available at expansions in the range 50 to 1200. Foam of expansion less than 500 is normally generated in self-aspirating equipment, and that with higher expansion is normally generated in equipment using power-driven fans. H.E.A.F. of expansion 1000 has practically no 'throw' but it can be transported through ducts. As expansion decreases, 'throw' increases. Foam of expansion 150 has a typical throw of 3 to 6 feet, foam of expansion 75 has a typical throw of 20 feet.

H.E.A.F. of different expansions must not be confused and are not generally interchangeable in application. Foam of expansion 1000 is designed for filling enclosed areas and large volumes quickly. Foam of expansion 150 is not as suitable for this task since the generating rate of the equipment is much smaller. The time taken to fill an area or volume is much longer and nearly seven times as much water and foam liquid is required. Foam of expansion 150 should be reserved for the smaller risk and for fires at ground level, either indoors or in the open, which can be fought at close quarters.

Since most of the experimental work and practical experience has been with an expansion of 1000, reference to H.E.A.F. in this note implies an expansion of 1000, unless otherwise stated. The term 'medium expansion foam' refers to foam of expansion 150.

H.E.A.F. can work either by covering an area in which there is a fire or by filling a volume which contains a fire.

It is necessary to apply H.E.A.F. as directly as possible to the fire area. Although this should not be regarded as an inflexible rule, it is an advisable precaution since the foam is continually losing water through drainage and when used indoors, especially if moved along corridors, it may push open doors, close others and be lost through drains, ducts and apertures in walls. For these reasons a proportion of the H.E.A.F. may not reach the affected area. It is advisable to block up all openings other than those required for introducing foam or venting hot gases, as this will both restrict ventilation and prevent loss of foam.

When a compartment is being filled there should be a venting aperture for the air or combustion products displaced by the foam. This requirement can be met by providing an opening equal in area to the foam inlet at a point as high as possible in the compartment and remote from the foam inlet if at all possible.

As hot combustion gases will be forced from this and any other suitable apertures, there is a risk of fire spread from these gases, which should be guarded against. If the venting aperture is situated on the exterior of a building it should preferably not be upwind since a strong wind blowing into such an aperture may intensify the fire and would oppose the venting of displaced gases.

3. GENERATION OF H.E.A.F.

The air used for generating H.E.A.F. should be fresh. Air containing combustion products, especially if hot, produces poor foam and in extreme cases it may not be possible to generate foam at all. In particular, P.V.C. involved in fire will produce HCl gas which, if present in foam-forming air at concentrations greater than 5000 p.p.m. (parts per million) (0.5 per cent) will result in unstable foam. Air containing this concentration of HCl is also, of course, unbreathable and highly toxic. H.E.A.F. made with fresh air, however, can be used to displace combustion products including a certain amount of HCl gas since this contaminant is not so damaging when external to the foam as when contained within the bubbles themselves.

Difficulty in producing foam may be experienced during cold weather. The temperature of the foam liquid should not be less than 0°C and preferably be above + 5°C. Some foam liquids will precipitate some of the constituents below 0°C which results in poor foam. Foam inductors are designed for a liquid of a given viscosity. A viscosity higher than this, resulting from a low foam liquid temperature will result in a lower foam solution strength. Adjustable foam inductors may have to be reset if foam liquid temperatures are below + 5°C.

Visual inspection of the foam is advisable at all times. Conversion of air into foam is highest when the foam is delivered from the generator as a solid 'plug'. The appearance of channels of free air in the foam indicates that the air flow rate needs to be reduced. This adjustment is most likely to be necessary in cold weather. Reduction of the air flow in these circumstances restores the fraction of air converted to foam.

4. APPLICATION OF H.E.A.F.

This section applies to H.E.A.F. of expansion 1000. Flow rates are expressed as the gross rate of increase in height of the foam layer over the whole protected area.

Thus

$$Q = R \times A$$

where Q = volumetric delivery rate of generator (ft^3/min)

R = gross application rate (ft/min)

A = protected area (ft^2)

4.1. Liquid Fuel Fires

4.1.1. Hydrocarbons (e.g. gasoline, kerosine)

Available information, based on tests carried out in U.K., U.S.A., France and Sweden[1-4], summarised in Table 1, suggests that in conditions of low wind speed, application rates for extinction in 8 to 10 minutes (critical rates) are between 0.5 and 2.0 ft/min. To obtain extinction in 2 to 3 minutes a gross application rate of not less than 3 ft/min is recommended. Very hot fires such as result from high boiling point fuels with a long preburn time may require two to three times this application rate.

Fire fighting with H.E.A.F. outdoors in windy conditions may not be successful since being of low density, H.E.A.F. is readily dispersed by wind. Liquid fuel fire outdoors can be successfully tackled by using H.E.A.F. of expansion 150 (see section 5).

The presence of hot metal surfaces in liquid fuel fires will accelerate foam breakdown but quantitative information on application rates required to deal with a fire in a liquid fuel flowing over a three-dimensional metal structure is not yet available.

4.1.2. Polar liquids (e.g. alcohol, acetone)

There is not, at present sufficient data to make a firm recommendation for application rates to water miscible liquids but rates of up to 25 ft/min may be necessary[2].

4.2. Solid Fuel Fires

Quantitative information on fully developed solid fuel fires is available from tests carried out in the U.S.S.R. using foam of expansion 500 on firewood and at the U.S. Bureau of Mines on coal. These tests indicate that the critical application rate is approximately 0.5 ft/min per lb/ft^2 fire load. This is equivalent to 0.025 lb water/lb fuel/minute and is very similar to the rate found necessary to extinguish room fires using sprays and jets and is independent of expansion. Although H.E.A.F. can quickly subdue flaming combustion in solid fuel fires, application of foam may have to be prolonged to counteract foam breakdown at the hot surfaces and to allow foam to penetrate into the mass of solid fuel. Water released onto the fire by this foam breakdown and by drainage from foam above the fire will eventually cool the solid fuel surfaces and extinguish the smouldering combustion. On average, a total quantity of 2 lb water/lb fuel applied over a period of 30 minutes was found to be necessary for complete extinction in the experimental fires. This is equivalent to 0.067 lb water/lb fuel/minute. The suggested minimum gross application rate is 1.0 ft/min per lb/ft^2 fire load applied for a period of 30 minutes.

There is no quantitative information available for fires past the 'flashover' stage in rooms with unrestricted ventilation.

Fires in rubber and plastics can also be tackled by high expansion foam. Again no direct quantitative information is available but the application rates quoted above should be adequate.

4.3. 'Ceiling' Fires

Where a ceiling is present, particularly with high stacked goods, flames may extend for a considerable distance under the ceiling, beyond the main fire area. These flames are a source of downward thermal radiation which will break down the foam as it rises towards the ceiling. A minimum (critical) rate is required for foam to reach ceiling level. At any rate lower than this, the foam will stabilise at some height below the ceiling where the rate of foam input is matched by the rate of foam breakdown caused by the foam movement and the radiant heat.

In a series of tests[1] in which flames were established under a ceiling 200 ft area and 8 ft high by burning gasoline in a 20 ft^2 tray placed 18 inches below the ceiling, the critical rate was found to vary between 4.0 ft/min and 6.5 ft/min according to the intensity of the fire. The minimum recommended rate for this fire situation is 8 ft/min.

Ceilings which have been heated by hot gases or which are only smouldering will have a similar, but smaller, effect.

4.4. Fires in Compartments

Foam application rates of 3 ft/min and upwards have been recommended for various fire conditions. These rates relate to the direct application of foam to the actual area of fire involvement itself. In a compartment in which there is fire, it is often difficult to judge the exact area of fire involvement. If the fire is very hot, then it may be best to assume that the whole of the fuel contained within the compartment is involved and the appropriate rate given in Table 2 should be applied. This would suggest very high flow rates indeed for large compartments containing high stacks of combustibles which have become appreciably involved in fire. However, it may be that flow rates less than those given in Table 2 could be usefully applied in situations where only a fraction of all the fuel in the compartment is involved in fire. For example, it is unlikely that the whole of the fuel can even be involved at any one time in compartments exceeding two or three thousand square feet in area unless substantial flames have been established under the ceiling. Experience in the field would be valuable in judging the minimum flow rate that would be required for practical situations.

Low rates can also be usefully applied to compartments adjacent to the fire area and which may be subject to heat from the fire but have not been seriously penetrated by fire. Fire spread can be reduced by filling these compartments and covering fuel not yet involved in fire. Also, restriction of ventilation will tend to reduce the size of the fire. It is suggested that a minimum of 1 ft/min be available for this duty.

If a large amount of combustible material has become involved in fire, then even after the compartment has been filled with foam substantial breakdown will continue to take place and it is necessary to prolong flow through the compartment, possibly at a reduced rate. It is important for compartments to remain filled so that adequate cooling can take place. If the quantity of foam is allowed to decrease before solid fuels are completely cooled, re-ignition can occur. This is especially important with high stacked storage. It is therefore suggested that foam injection continues for a period of 15 minutes after the compartment has been completely filled, before attempts are made to enter the foam and inspect the fire. The appearance of foam at a point remote from the point of injection, together with a considerable reduction in the amount of smoke, is a good indication that the compartment has been filled. If the compartment has not been filled at the end of the expected filling time, based on the recommended application rate, this is an indication of abnormal foam breakdown or loss and that a higher rate is required. If possible all sources of loss should be located and eliminated.

If it is not possible or desirable to fill the whole of a large compartment, the use of nets to sub-divide the area can be considered[8].

5. APPLICATION OF 'MEDIUM' EXPANSION FOAM

It was pointed out earlier that H.E.A.F. is not always suitable for use outdoors especially in very windy conditions. Medium expansion foam (typically of expansion 100 to 200) flows freely, especially over liquid fuel surfaces, and is often more useful for outdoor situations involving liquid or solid fuel fires at ground level. Since the throw is small, i.e. 3 to 6 feet, the branchpipe is most effective when used at the fire itself rather than remote from it. This requires either the use of protective clothing, e.g. aluminised fire suit or remote control by mounting the branchpipe on, for example, a small 'snorkel'. Both liquid and solid fuel fires can be successfully extinguished by this foam even in windy conditions. For example, a branchpipe producing 1000 ft^3/min can extinguish a 125 ft^2 petrol fire in 12 seconds. A pile of 15 motor car tyres given a preburn time of 5 minutes can be extinguished without the use of protective clothing in 10 seconds; a further 10 seconds application will prevent re-ignition. Any tyres found smouldering during turning of the pile can be extinguished by throwing them into the foam. This is normally a difficult fire to extinguish by traditional methods. Larger tyre fires can be successfully tackled by using appropriate protective clothing.

6. SAFETY OF PERSONNEL

H.E.A.F. can be entered by firemen and provided the foam is made from uncontaminated air. Although generally recommended breathing apparatus is not absolutely necessary if fresh air can be released from the foam by breaking the bubbles. A hand cupped over the mouth and use of a single mask, e.g. handkerchief, will avoid the inhalation of foam bubbles if the foam is not higher than a few feet above face level. If the foam is much deeper, this method may not prove effective and breathing apparatus may be essential. It is important that personnel do not remain stationary. The oxygen in a pocket of air around a stationary or unconscious person immersed in foam will soon become exhausted, and asphyxiation will follow[9]. H.E.A.F. is opaque and therefore visibility is nil. Hearing is also seriously impaired and thus immersion in H.E.A.F. gives a feeling of complete isolation which may prove to be an important psychological factor. It is essential therefore that lifelines and possibly 'intercom' are used. Care must be taken with the foam liquid as this can irritate the skin.

H.E.A.F. is a weak conductor of electricity. The specific resistance of H.E.A.F. of expansion 1000 is one million ohm cms. This is about 1000 times greater than the value for water. The current passing (i) is

$$i = \frac{V.A.}{r\ l}$$

where V is the voltage

A is the cross-sectional area of the conducting path, at the contact area

r is the specific resistance

l is the distance to the source of voltage

Although the specific resistance is higher than water, the cross-sectional or contact area is also much higher and unknown in value in advance. Also, as drainage occurs, water will accumulate on the floor and in the lower parts of large depths of foam introducing the danger of conduction along the wet floors. It is wise, therefore, to take similar precautions to those taken when using bulk water.

7. DISPOSAL OF H.E.A.F.

The use of water spray to dispose of H.E.A.F. while effective, nullifies one of the advantages of H.E.A.F., that of minimum water damage. Work at the Fire Research Station has shown that a dilute solution of a silicone based foam breaking compound sprayed onto foam from a garden spray gun will effectively dispose of the foam. Full details of this will be published separately.

8. STORAGE AND CORROSION

H.E.A.F. liquid and 1.5 per cent solution can corrode steel and magnesium/aluminium alloy severely and aluminium and brass slightly. It is essential, therefore, to store the liquid in plastic containers and to wash thoroughly all apparatus and equipment after use.

Foam made from 1.5 per cent solution will cause steel immersed in it to rust. Work at the Fire Research Station has shown that this can be eliminated by the addition of a suitable corrosion inhibitor to the foam liquid. Full details of this will be published separately.

TABLE 1

Summary of Fire Extinction Results for H.E.A.F.

Source	Fuel	Preburn time (min)	Test area (ft²)	Percentage of area involved in fire	Critical rate (ft/min)	Extinction time at critical rate (min)	Minimum recommended rate (ft/min)	Extinction time at minimum recommended rate (min)
LIQUID FIRES								
J.F.R.O. (ref.1)	Petrol	0.5	200	10	0.5	2.0	2.5	0.3
U.S.A. (ref.2)	Petrol	-	10,000	100	1.2	8-10	3.0	2.0
France (ref.3)	Kerosine	5-10	455	55	2.0	8-10	3.0	2.5
Sweden (ref.4)	JP4/Petrol	3	10,000	100	2.0	10	-	-
Norway (ref.5)	Fuel oil	2	1,000	100			3.0	2.0
CEILING FIRES								
J.F.R.O. (ref.1)	Petrol	3	-	-	4-6.5	10	8.0	2.5
SOLID FUEL FIRES				Fire load				
U.S.A. (ref.6)	Coal	-	-	5 lb/ft²	0.5 per 1 lb/ft²	-	1.0 per 1.0 lb/ft²	20-30
U.S.S.R. (ref.7) (Expansion 250)	Fire wood	-	660	4-23 lb/ft²	Fire load (Exp = 1000)		Fire load (Exp = 1000)	

TABLE 2

Minimum Recommended Rates for H.E.A.F.

	Minimum rate (ft/min)	Maximum area for unit of 5000 ft^2/min capacity (ft^2/min)
Liquid hydrocarbon fuel fire at ground level	3.0	1650
Solid fuel fire at ground level	1.0 for each 1.0 lb/ft^2 fire load	1000 (5 lb/ft^2 fire load)
'Ceiling fire'	8.0	625
Filling of compartments not involved in fire	1.0	5000

Note : If the generating capacity of the equipment available is well below that needed to provide the above minimum recommended rates, it is advisable to deploy the equipment in protecting areas or risks not yet involved in fire or as part of a combined attack.

If sufficient generating capacity is available then it is beneficial to use higher application rates than those above.

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