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THE EFFECT OF DRY CHEMICAL EXTINGUISHING AGENTS ON THE EFFICIENCY OF MECHANICAL FOAM

by

D. Hird and M.J. Gregsten

#### Summary

A quantitative study has been made of the compatibility of dry chemical with fire-fighting foam, when applied to a petrol fire. It is shown that serious destruction of the foam can occur under some conditions, and that it is almost entirely due to the metallic stearate commonly added to dry chemical extinguishing agents to improve their flowing properties.

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# THE EFFECT OF DRY CHEMICAL EXTINGUISHING AGENTS ON THE EFFICIENCY OF MECHANICAL FOAM

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### D. Hird and M. J. Gregsten

# Introduction

The main use of dry chemical at the moment is for hand extinguishers intended for small spill fires, and the question of its compatibility with foam seldom arises in this application. However, because flammable liquid fires may be rapidly controlled with relatively small amounts of dry chemical without giving rise to toxic products this agent is at present employed in some aircraft crash fire-fighting vehicles (1) and its use in this way is likely to increase. In common with vaporising liquids, however, dry chemical does not protect the flammable liquid from re-ignition and it therefore seems probable that foam may always have to be used in conjunction with dry chemical.

Experience in this country and in America, however, has shown that mechanical foams may be broken down by contact with commercial grades of dry chemical. Tests (4) (5) carried out at the Maval Research Laboratories, Mashington, indicated that powders containing a metallic stearate as a flow additive had a serious effect on the stability of a foam layer when applied to its surface. They also showed that the presence of dry chemical in burning petrol could affect the subsequent formation of a foam blanket.

A quantitative measure of the compatability of foam and dry chemical is needed to help in deciding to what extent the two can be used together. It was thought that this could best be achieved by measuring (a) the effect of prior application of dry chemical to a fire on the critical rate of application of foam, and (b) the effect on the stability of a foam blanket of applying dry chemical to its surface.

### Test programme

The drainage of foam on hot petrol to which dry chemical had been added was measured in the "petrol resistance index" apparatus (2). The rate of drainage was affected by the degree of agitation of the petrol on application of the foam, and there was little evidence f the accelerated breakdown which practical experience has shown to be possible. Because of this it was decided to carry out tests which simulated operational conditions as closely as possible. Details of the experimental materials and procedure are given below.

# (a) Test fire

The test fire consisted of a  $1\frac{1}{2}$  in, depth of petrol burning in a 3 ft. square tray, 4 in. deep.

### (b) Dry chemical

Two readily-available dry chemical agents were tested - Powder A, a commercial dry chemical containing 95½ per cent sodium bicarbonate, 3 per cent tale, and 1½ per cent magnesium stearate, and Powder B, a sodium bicarbonate of coarser grade containing 1 per cent calcium hydroxyphosphate. The tale, being insoluble, could have no effect on the stability of protein foams. Powder B was the finest grade available which did not contain a metallic stearate but it was considered that the particle size of the powders would have little if any effect on foam stability. The main difference then between Powders A and B was that one contained the surface-active magnesium stearate as a flow additive and the other contained calcium hydroxyphosphate.

#### (c) Posm

Foam was supplied from a mechanical foam generator adjusted to give an expansion of 7 and a critical shear stress of 500 dynes/cm<sup>2</sup> + 10 per cent. The compound was a standard commercial type, in 3 per cent solution. Throughout this paper, the rate of application of foam, in gal/ft<sup>2</sup>/min, refers to the volume of solution contained in the foam, and not to the volume of foam. The foam was projected into the centre of the fire from a single jet 8 ft. from the centre of the fire and 4 ft. above the petrol surface.

### (d) Oriteria of control of fire and stability of foam layer

Three radiometers were placed around the fire, and the radiant intensity was continuously recorded during the tests. It was not possible completely to extinguish the fire with foam by the above method of application since the foam became contaminated with petrol.

The fire "control" time was taken as the point at which the intensity had fallen to 15 per cent of its initial value and it was considered that people clad in protective clothing could walk through the foam blanket at this stage.

On shutting off the foam, petrol contained in the foam layer continued burning at a low intensity. The criterion adopted to assess the stability of the layer was the time taken for the intensity of the fire to rise to one-third of its initial value.

# Experimental procedure

# I. The effect of the prior application of dry chemical on the critical rate of application of foam to the test fire

It was first necessary to determine the effect of rate of application on "control" time for the method of application used in this investigation.

The petrol was allowed to burn freely for one minute. Foam was then applied and the "control" time was measured. The application of foam was continued until the quantity of foam applied after the fire had been "controlled" was as far as possible the same whatever the rate of application. The stability of the foam blanket was then measured by allowing the fire to burn back. Tests were made at different rates of application.

These tests showed that as the rate of application of foam was reduced the time taken to "control" the fire increased until a rate was reached at which "control" could not be achieved. This rate is defined as the "critical rate of application" and is a measure of the efficiency of fire-fighting foams. Any factor which affects this rate can be considered to have affected the efficiency of the foam.

Similar tests were made in which a known quantity of dry chemical was sprayed into the tray immediately after the preburn. The method and rate of application of the dry chemical were chosen so that the fire was reduced but not extinguished. When the intensity had again reached a maximum, foam was applied as before. It was found that at low rates of application of foam the fire could not be controlled. Tests were made, with a fixed quantity of the commercial dry chemical - Powder A - at increasing rates until the fire could be controlled twice in three attempts. Where control was achieved, the stability of the foam layer was measured as before. Firther tests were then made with a greater quantity of Powder A, and the whole series of tests was repeated with Powder B.

# If. The effect on the stability of a foam layer of the application of dry chemical to its surface

In this series of tests the fire was allowed to burn for one minute before foam was applied at four times the 'critical rate'. The application of the foam was continued after 'control' until a further  $l_4^1$  gallons of foaming liquid had been applied. A quantity of dry chemical varying from  $\frac{1}{4}$ lb. to  $10\frac{3}{4}$ lb. in different tests was then applied and extinguished the residual fire caused by the burning of the petrol in the foam. In order to measure the stability of the foam layer the fire was re-ignited by a taper as soon as application of the dry chemical was complete, and the 'burn-back' time was measured.

### III. The application of dry chemical and foam to sand soaked with petrol

An inch and a half of sand was laid in the bottom of the test tray and saturated with petrol. After the preburn time of 1 minute, 5 lb. of dry chemical containing magnesium stearate was applied to the fire. Foam was then applied at

just above the critical rate, as measured in I, to determine whether the critical rate had been increased by this condition.

### Remults

# Prior application of dry chemical

Table 1 shows the time taken to control the fire by foam alone, at rates of application from 0.028 gal/ft²/min to 0.5 gal/ft²/min, and also in conjunction with 5 lb. or 10 lb. of Powder A, or 11 lb. of Powder B. The solid curve in Figure 1 shows the dependence of control time on rate of application of foam alone. The detted curves show the effect of the prior application of dry chemical to the fire. This and earlier work (3) indicate that as well as increasing the critical rate of application of foam, the presence of dry chemical also increases the control time at rates above the critical rate.

Figure 2 shows more clearly the effect of the dry chemical containing magnesium stearate on the critical rate of application of foam.

### The application of dry chemical to the surface of a foam layer

The effect of this method of application on the stability of a foam layer is shown in Figure 3 for Powders A and B.

# The application of dry chemical and foam to petrol-soaked sand

The tests described above (Section I) show the critical rate of application of foam to the test fire containing 5 lb. of Powder A to be about 0.15 gal/ft2/min. On applying foam at a rate of 0.17 gal/ft2/min after 5 lb. of the chemical had been sprayed on to the petrol-soaked sand the control time was found to be about 60 seconds. This is lower than the mean time of 105 seconds found in the previous test for this rate of application, and shows that this condition is certainly no werse than that in the tests described in Section I.

### Discussion of results

It will be seen from Figure 1 that the critical rate of application of foam by itself to the test fire is about  $0.02~\rm gal/ft^2/min$ . The prior application of  $0.55~\rm lb./ft^2$  of Powder A increases the critical rate of application of foam to about  $0.15~\rm gal/ft^2/min$ , that is, by a factor of  $7\frac{1}{2}$ . The application of  $1.4~\rm lb/ft^2$  of the same chemical increases the critical rate by a factor of over 20, to about  $0.45~\rm gal/ft^2/min$ . However, the application of  $1.6~\rm lb/ft^2$  of Powder B, containing no metallic stearate, resulted in an increase of the critical rate of application of foam by a factor of only  $2\frac{1}{2}$ . This indicates that the increased rate of destruction of the foam is due to the metallic stearate, and that the effect of any change in the pH value of the solution is small in comparison.

By applying dry chemical through a flat spray nozzle the test fire could be extinguished repeatedly using only 0.2 lb. of chemical per square foot. However, under operational conditions, with large fires and with the apparatus and techniques at present in use, it is likely that much larger quantities of dry chemical would be used.

Aircraft crash fire-fighting equipment in use in this country at present isgrapable of delivering up to 300 gal/min, of water in the form of foam for about 2 minutes. Assuming that foam will be applied at not less than four times the appropriate critical rate, an indication of the maximum sizes of fire that could\_be\_controlled-by-successive-application\_of\_various amounts of dry chemical and foam, without rish of serious foam breakdown, can be deduced. These are given in table II.

Maximum fire area controllable by roam applied at 300 gal/min. after the application of dry chemical containing a metallic atearate.

POWDER	FO	1		
APPLIED	CRITICAL RATE	'TYPICAL'*RATE	MAXIMUM AREA	
LB/FT <sup>2</sup>	GAL/FT <sup>2</sup> /MIN	CONTROLLABLE SQ. FT.		
0	0.02	0.08	3750	
0.2	0.075	0.30	1000	
0.5	0.16	0.61	470	
1.0	0.30	1.20	250	
1.5	0.45	1.80	170	

\* Assumed to be four times the 'critical rate'.

Certain factors peculiar to the conditions of test, which may be modified under operational conditions, should be borne in mind when considering this table. In the tests, foam is applied from a single stationary jet and falls into the centre of the fire area, and the action of the dry chemical on the foam is almost certainly accelerated by the stirring taking place as the foam jet agitates the petrol. The depth of petrol, constant at lin. in the tests, would be expected to vary considerably in a crash fire, and this factor may have some influence on the degree of contact of chemical and foam. Despite these reservations, however, Table II gives a fair indication of the magnitude of the problem.

When 'control' was achieved the foam layer remained stable for a considerable time (Table 1). This is probably because there is no further agitation of the petrol by foam and consequently no further pick-up of the metallic stearate and free stearic acid present in the petrol. At this stage the surface active stearate will be present at the foam/petrol interface and at the petrol/water interface at the bottom of the tray. The presence of surface-active agents at the fram/petrol interface in the absence of agitation does not appear to cause rapid from breakdown. This is confirmed by one of the American Naval Research (5) Laboratories experiments where foam was applied gently after the application of dry chemical and little breakdown occurred.

Application of dry chemical to the surface of a foam blanket has a marked effect on its stability, dependent on the amount of chemical applied. Figure 3 shows the effect of sodium bicarbonate with and without magnesium stearate. If a foam layer which takes 5 minutes or longer to burn back is considered reasonably stable, then it is seen that the addition of only 0.15 lb. square foot dry chemical containing a metallic stearate renders the layer unstable. The stability is only slightly affected by the application of even large amounts of dry chemical not containing a metallic stearate.

### Conclusions

The use of dry chemical extinguishing agents containing a metallic stearate together with protein foam can lead to serious breakdown of the foam, and in some circumstances may even prevent the formation of a foam blanket. The effect is almost entirely due to the presence of the metallic stearate. The extent of their incompatibility depends very largely on the quantity of dry chemical involved, the rate of application of the foam, and the degree of agitation which is largely dependent on the method of foam application. It is considered that the conclusions from these small-scale tests should also be examined in full-scale operational tests.

A probable reason for the breakdown is that the very surface-active metallic stearate replaces, or partially replaces, the protein molecules conferring stability on the foam film at the gas/liquid interface. Since some additive is essential to improve the flow properties of dry chemical, an approach to the problem of commutability with foam might be made in several ways. Some suggestions for further investigations are given.

- (1) The effect of increasing the strength of the foam solution appreciably above 3 per cent.
- (2) If the agitation set up by foam entering the petrol containing dry chemical can be minimised, the degree of breakdown of the foam should be reduced. This could possibly be achieved by the use of a suitable sprayed foam.
- (3) The use of an additive in the dry chemical which is less surface active than the protein solution, without being appreciably more soluble than the present additive.
- (4) The use of an additive which is not surface-active. The calcium hydroxyphos-phate contained in Powder B is an example of such a material.

These last two suggestions are intimately connected with those flow properties of powders which affect their behaviour during discharge from fire-fighting equipment, and any investigation would also have to take these flow properties into consideration.

### Acknowledgments

Mr. K. Sumi of the National Research Council of Canada carried out some of the preliminary laboratory work and also helped in some of the fire tests.
Mr. D. Barnes also assisted in much of the experimental work.

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<u>Table 1</u>

Fire control times under various test conditions

	FOAM		FIRE CONTROL TIME (SEC.)			(3) Total volume	(3) Volume applied	<b>S</b>	
Rate of application Critical Stress of	Critical shear stress dynes/cm <sup>2</sup>	ritical shear Total time of application min. sec.	No powder	5 1b. powder (1) <sub>A</sub>	10 lb. powder A	11 1b. powder (2) <sub>B</sub>	foam applied gal/ft <sup>2</sup>	after control gal/ft <sup>2</sup>	him-back time min.
0.028 0.056 0.11 0.14 0.17 0.22 0.28 0.33 0.35 0.42 0.50	465 510 515 465 440 580 325 485 500 475 475 475 430 430 430 430 430 430 475 565 5425 510 350 510 510 510 510	8 74 46 56 3 2 3 3 3 2 1 1 1 2 2 3 4 1 3 4 4 2 1 1 2 0 1 1 1 2 1 1 2 2 3 4 1 3 4 4 2 1 1 2 0 1 1 1 2 2 3 4 1 3 4 4 2 1 1 2 0 1 1 1 2 2 3 4 1 3 4 4 2 1 1 2 0 1 1 1 2 0 1 1 1 2 0 1 1 1 2 0 1 1 1 2 0 1 1 1 2 0 1 1 1 2 0 1 1 1 2 0 1 1 1 1	140 95 621 821 50 36	(0) <sub>N</sub> .C. N.C. N.C. 50 N.C. 1221 90	185 N.C. N.C. 200 N.C. N.C. N.C. (5) N.C. (5) 68 (5) 65	185 135 195	0.233 0.212 0.224 0.224 0.350 0.294 0.341 0.340 0.220 0.330 0.316	0.168 0.166 0.165 0.177 0.168 0.160 0.248 0.154 0.165 0.165 0.165 0.170 0.078 0.170 0.070 0.109 0.139 0.139 0.184 0.168 0.184 0.208	>55557 >55557 >555557 >555550113115115555555555555555555555555

Notes

<sup>(0)</sup> N.C. - No control.

<sup>(1)</sup> Powder A - 95½ per cent sodium bicarbonate, 3 per cent talc, 1½ per cent magnesium stearate.

<sup>(2)</sup> Powder B - 99 per cent sodium bicarbonate, 1 per cent calcium hydroxyphosphate.

<sup>(3)</sup> The volume of solution contained in the foam is given.

<sup>(4) 3</sup> ft.  $3\frac{1}{2}$  in. x 5 in. circular tray.

<sup>(5) 3</sup> ft. x 8 in. circular tray. The deeper circular trays were found necessary at the higher rates of application due to foam spillage from the normal test tray.

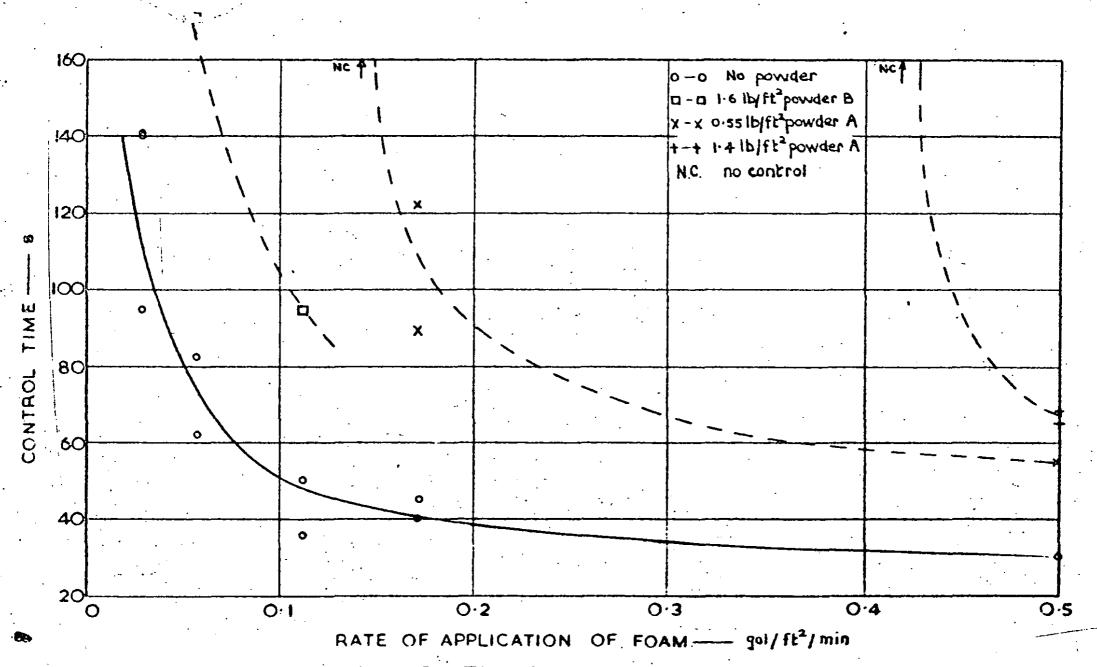


FIG.I. THE EFFECT OF DRY CHEMICAL ON THE CONTROL OF FIRE BY FOAM

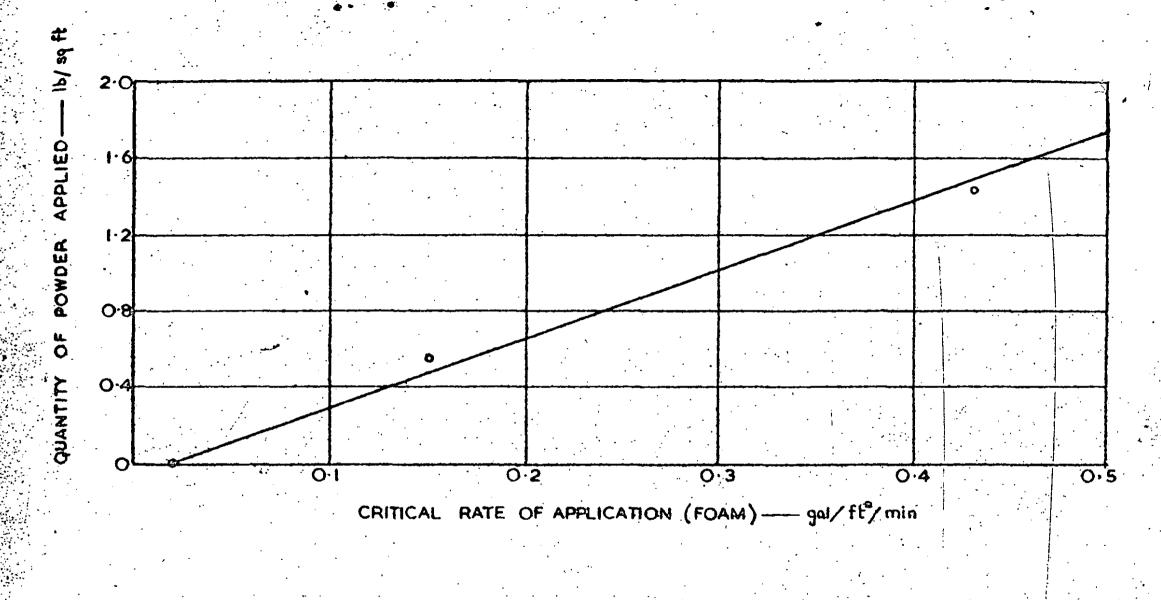


FIG. 2. EFFECT OF PRIOR APPLICATION OF DRY CHEMICAL CONTAINING A METALLIC STEARATE ON CRITICAL RATE OF APPLICATION OF

FIG 3 EFFECT ON THE STABILITY OF A FOAM LAYER OF APPLYING DRY CHEMICAL TO ITS SURFACE