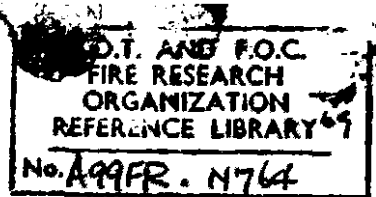


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Fire Research Note

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**BREAKDOWN OF HIGH EXPANSION FOAM USING
ANTIFOAMING AGENTS**

by

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BREAKDOWN OF HIGH EXPANSION FOAM USING ANTIFOAMING AGENTS

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SUMMARY

The use of antifoaming agents to break down high expansion foam was investigated in small scale tests, and three commercially available antifoaming agents were subsequently selected for large scale tests. In the latter tests about 2 l (0.4 gal) of a 5 per cent solution of the agents in water, when applied as a spray, broke down about 30 m³ (1000 ft³) of foam in 3 minutes; for these tests commercial garden spray equipment was used, with minor modifications.

The antifoaming agents were considerably more effective than plain water, and were also effective against various high expansion foam concentrates at present on the market. Other factors investigated included variation of rate of application and solution strength of the antifoaming agents on the breakdown of foam.

The spray technique was easy to acquire and economic to use.

KEY WORDS: High expansion, foam, antifoaming agents.

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INTRODUCTION

High expansion foam is becoming increasingly used as a fire-fighting medium, and this trend is likely to continue. The foam has the advantages that it can be applied from outside a building on fire, and it can penetrate into places that are inaccessible to other conventional fire-fighting techniques. Generators are available which can produce thousands of cubic feet of foam per minute. The expansion ratio of the foam is usually about 1000, that is a given volume of solution is expanded to 1000 times its volume of foam. A further advantage is that because of the small proportion of water in the foam, the amount of water damage caused to materials with which it comes into contact is minimal.

After a fire has been extinguished with high expansion foam, it is often desirable to begin salvage operations immediately, to prevent deterioration of stock which has not been affected by the flames. Alternatively, removal of the foam at a controlled rate may be required to ensure complete extinction of the fire. The foam is likely to take many hours to completely collapse if left undisturbed and, as visibility through the foam is low, means must be applied to remove it before effective salvaging can take place. The foam can be washed away with water spray, but the amount of spray required is such that water damage to stock may be unacceptably high. Alternatively, and especially if it flows readily, the foam may be sucked from the building by a fan. An appliance is on the market which withdraws foam by this method, providing that a suitable ducting passes into the building and that the foam has not drained sufficiently to have become too stiff to flow. Difficulties could arise in congested premises where removal of foam between stacks of goods would be required, and some manipulation of the ducting within the foam might be necessary.

An alternative method of removing the foam has therefore been investigated, in which commercial antifoaming agents have been sprayed onto the foam, causing it to collapse. For present purposes, commercial products called antifoaming agents or defoamers have been considered together. The advantages of the antifoam spray method are that access to the building is cleared from the outside, and that on moving inwards the spaces between stacks of goods etc. can be cleared quickly. Provided the quantity of antifoaming solution applied is kept well below the quantity of high expansion foam solution used, the additional water damage would be small. It would be advantageous if the antifoaming agents were easily available and cheap, and that their application could be made by readily supplied equipment. An additional requirement for successful antifoaming agents would be that they should not cause corrosion or have toxic effects. The object of the present work was to ascertain whether these requirements could be met.

The experiments were carried out in two series. In the first, small scale tests were made with a number of possible agents, and secondly the more promising agents were tested on a larger scale.

EXPERIMENTAL

MATERIALS

Antifoaming agents were obtained from a number of manufacturers. All agents were liquids and were diluted with water to 5 per cent by volume solution unless stated otherwise. The mixtures were in fact suspensions, rather than true solutions, and slow separation could occur unless they were occasionally agitated. This point is referred to again later.

The high expansion foam was generated from commercial materials available on the market, using the recommended dilutions of the concentrates in water.

Tap water was used for the solutions of both the foam concentrates and the antifoaming agents.

SMALL SCALE TESTS

The apparatus in which the high expansion foam was generated consisted of a horizontal tube from the end of which the foam was delivered into a cylindrical container suspended from a strain bar to which strain gauges were attached. The tube was 2.1 m (7 ft) in length, 13.7 cm (0.545 ft) diameter, and the foam was formed on a nylon mesh, 1.5 mm (0.06 in) width stretched over the end of the tube. A small blower delivered air in at the other end of the tube. The foam concentrate solution was delivered from a nozzle on the axis of the tube, 14 cm (0.46 ft) upstream of the mesh. The foam fell under gravity into the container, which was an open topped plastic bin with internal metal reinforcing. The diameter of the container was about 73 cm (2.4 ft) the height 120 cm (4 ft) and the volume was 510 l (18 ft³). The quantity of foam in the container was weighed by the strain gauges and automatically recorded in every experiment.

The solution of antifoaming agent was delivered from a 250 ml conical flask by means of a narrow jet, usually under an air pressure of 0.07 kgf/cm² (1 lbf/in²). Application was by hand, the jet of solution being applied to the top surface of the foam in the container. The delivery rate from the jet varied with the antifoaming agent and ranged between 85 and 150 ml/min (0.02 and 0.03 gal/min) of solution, it could be further increased to 320 ml/min (0.07 gal/min) by raising the air pressure. The jet method was used for experimental convenience and was suitable for comparative tests. Alternative methods of application, e.g. sprays, might have been more effective but detailed investigations were not necessary for present purposes.

The experimental procedure was firstly to wash the foam container with water, and then to invert it and allow it to drain on the floor for 5 min. It was then attached to the strain bar and suspended for a further 5 min to permit excess water to drain away. The container was next filled with foam, levelled off at the top and extraneous foam on the sides removed, and suspended for 1 min during which time the rate of loss of weight due to drainage was recorded. If left undisturbed the foam lost half its weight in 16.5 min (half-drainage time). The antifoaming solution was applied to the top surface of the foam until complete collapse had occurred, or for a period of 70 s whichever was the shorter. The time for complete collapse, or the height of residual foam, was recorded in each test. In these tests repeatability was ± 10 per cent.

After each test the container was removed from the strain bar, washed with water, drained and the test procedure repeated. All the antifoaming solutions were shaken periodically during a series of tests to maintain good mixing.

LARGE SCALE TESTS

The more promising antifoaming agents shown by the small scale tests were selected for further tests on a large scale. The foam was produced from a commercial portable generator, designed to deliver 142 m^3 (5000 ft^3) of foam per minute with an expansion of about 1000. The generator delivered the foam into an enclosure consisting of portable screens, each 2.8 m (8.5 ft) high. The enclosed floor area was $3.1 \text{ m} \times 3.6 \text{ m}$ ($10 \text{ ft} \times 12 \text{ ft}$) and the volume enclosed was 29 m^3 (1020 ft^3). The enclosure had an open top. In the centre of one side of the enclosure, a wire mesh panel, length 1.4 m (4.5 ft) and width 69 cm (2.25 ft) was provided. Beneath the wire panel a smaller screen sealed the gap (see Plate 1). The purpose of the mesh was to allow application of the antifoaming agent to the foam in the enclosure, but to prevent the outward spillage of the foam. The lower panel was removed to allow access to the interior of the enclosure when the level of foam had been lowered by spraying.

The antifoaming solution was sprayed onto the foam using commercial garden spray equipment. The equipment used in the tests reported below consisted of a plastic container for the solution, volume about 8 l (1.75 gal), fitted with a hand pump, and an adjustable spray nozzle on a metal tube attached by a flexible tube to the container. For operational convenience, a pressure gauge ($0-7.0 \text{ kgf/cm}^2$ ($0-100 \text{ lbf/in}^2$)) was fitted to the container, so that a constant air pressure within it could be maintained throughout the tests (Plate 2). The most effective spray pattern was found to be a solid cone of diameter 40 cm (16 in) at a distance of 30 cm (1 ft) from the nozzle. The average delivery rate from the equipment was about 630 ml/min (0.14 gal/min) at a working pressure of 2.5 kgf/cm^2 (35 lbf/in^2). A shoulder sling was available for this equipment. A second set of equipment was obtained, which could be slung across the body, and which had a plastic container of volume 4.5 l (1 gal). The delivery rate from this equipment was slightly less, but the antifoaming spray was of similar effectiveness to that from the first set.

The procedure for the tests was to fill the enclosure with foam, after which the generator was stopped. Spraying of the antifoaming agent was then started immediately, unless stated otherwise, aiming it through the wire mesh panel near the upper part of the foam. As collapse proceeded, the top surface of the foam sloped towards the wire panel and when it had subsided sufficiently the operator entered the enclosure through the small panel below the wire mesh. Spraying continued until the foam had collapsed to within about 15 cm (6 in) of the floor (See Plate 3). The time of spraying and the quantity of antifoaming solution used were measured in each test. In the tests, repeatability was ± 10 per cent, and mean values were taken.

RESULTS

SMALL SCALE TESTS

Comparative tests were carried out on 5 per cent solutions of various antifoaming agents, and the results are summarised in Table 1. The effectiveness of the antifoaming solution was measured, in this and succeeding tables, as the ratio of the volume of foam collapsed to the volume of solution used. Some of the agents were noticeably superior, and all were vastly more effective than plain water. The expansion of the foam was $990 \pm 80^*$.

*Where the variation about a mean value is stated, the value given is that of one standard deviation.

Table 1

Comparative tests of antifoaming solutions against
high expansion foam

(Application rate 100 ± 14 ml/min)

| Antifoaming agent | Time of application of antifoaming solution (s) | Volume of foam collapsed (litres) | <u>Vol. foam collapsed</u> Vol. antifoaming solution |
|-------------------|---|-----------------------------------|---|
| N71D5 | 70 | 510 | 4620 |
| NXZ | 45 | 510 | 4870 |
| DNH 1 | 60 | 510 | 4870 |
| DD72 | 70 | 510 | 4660 |
| A | 70 | 171 | 1550 |
| B | 70 | 510 | 4120 |
| C | 70 | 363 | 3820 |
| D | 70 | 342 | 3230 |
| E | 70 | 235 | 2220 |
| Plain water | 70 | 21 | 210 |

The effect of variation in concentration of antifoaming agent was investigated using one of the agents (N71D5 for convenience) and the results are summarised in Table 2. The application rate was 128 ± 17 ml/min. Because increase in solution strength did not show a proportionate increase in performance, a 5 per cent solution of antifoaming agent was chosen as standard to ensure that adequate agent was present to give high effectiveness, but to avoid uneconomic excess.

Table 2

The effect of variation in concentration of
antifoaming agent on foam breakdown (expansion 980 ± 80)

| Concentration of antifoaming agent in water per cent by vol | Time for complete collapse of foam s | <u>Vol. foam collapsed</u> Vol. antifoaming solution |
|---|--------------------------------------|---|
| 2 | 36 | 6850 |
| 5 | 47 | 7140 |
| 10 | 30 | 7140 |
| 20 | 28 | 8860 |

The effectiveness of the antifoaming solution tended to increase with the rate of application (Table 3) but the effect was less than proportional. The results in Table 3 refer to agent N71D5, with a 5 per cent solution.

Table 3

The effect of variation in rate of application of antifoaming agent on foam breakdown (expansion 1070 \pm 70)

| Rate of application ml/min | Time for complete collapse of foam s | <u>Vol. foam collapsed</u> Vol. antifoaming solution |
|-------------------------------|---|---|
| 147 | 31 | 6720 |
| 175 | 24 | 7290 |
| 200 | 21 | 7290 |
| 249 | 14 | 8780 |
| 270 | 16 | 7080 |

Comparison was made of the effectiveness of agents N71D5, NXZ, DNH1 and DD72 against foams generated from a range of seven high expansion foam concentrates, manufactured by a total of five firms. The purpose of these tests was to show if the antifoaming agents were of general application or were specific to certain concentrates. The results for N71D5 are summarised in Table 4, and similar trends were observed for the other antifoaming agents. The high expansion foam concentrate F1 was that used in obtaining the results given in Tables 1-3.

Table 4

Performance of antifoaming agent N71D5 against foam from different concentrates

| Concentrate | Foam | | Time for complete collapse of foam s | <u>Vol. foam collapsed</u> Vol. antifoaming solution |
|-------------|------------------------------|-----------|--|---|
| | Half drainage time min | Expansion | | |
| F1 | 16.5 | 1130 | 24 | 9,490 |
| F2 | 7.0 | 1130 | 30 | 7,780 |
| F3 | 3.25 | 1010 | 15 | 12,190 |
| F4 | 9.25 | 780 | 18 | 11,780 |
| F5 | 10.5 | 860 | 24 | 8,980 |
| F6 | 8.75 | 1100 | 15 | 12,520 |
| F7 | 7.0 | 1110 | 16 | 12,810 |

Because the antifoaming solutions were suspensions, there was a tendency for them to separate into two layers on standing. The upper layer was a smaller volume in proportion, and where the antifoaming agent would be used in practice, the lower layer would be the more likely to be discharged by the spray. Some tests were carried out to estimate the loss in effectiveness of the antifoaming agent solution as separation of the two layers proceeded, using the lower layer only. In tests where the solutions were allowed to stand and were not shaken, no loss in effectiveness of the antifoaming solution was apparent after $\frac{1}{2}$ hour, but some reduction appeared after 2 hours. After a total standing period of 6 days the effectiveness was reduced to between three-quarters and half that of the fully mixed suspension. Even after 6 days standing the effectiveness could be fully restored by shaking well. The manufacturers of antifoaming agents recommend that solutions should be freshly prepared and used within a short time. The above behaviour was typical of all of the four antifoaming agents investigated.

LARGE SCALE TESTS

On the basis of the small scale tests, three antifoaming agents were selected for large scale evaluation. They were N71D5, NXZ and DNH1. In each case a 5 per cent solution was used, and the foam was generated using high expansion foam concentrate F1. Further tests in which plain water was sprayed onto the foam were carried out for comparison; a summary of the results is shown in Table 5. The operator had little difficulty in applying the antifoaming solution to the foam, and the foam collapsed rapidly whilst the spray impinged on the bubbles. When the spraying was stopped, the collapse of the foam due to the antifoaming agent also ceased.

Table 5

Results of large scale experiments

| Antifoaming agent | *Manufacturer | Application rate ml/min | Time for collapse of foam s | $\frac{\text{Vol. foam collapsed}}{\text{Vol. antifoaming solution}}$ |
|-------------------|--|----------------------------|--------------------------------|---|
| N71D5 | Messrs. Nalfloc Limited, P.O. Box No.11, Northwich, Cheshire | 700 | 168 | 14,000 |
| NXZ | Messrs. Nopco Hess Limited, 147 Kirkstall Road, Leeds 3 | 650 | 170 | 14,700 |
| DNH-1 | " " | 590 | 170 | 16,300 |
| Plain water | - | 560 | 568 | 5,200 |

*Note These names are given in alphabetical order for the guidance of the reader. No official authorisation is implied, and some products of other manufacturers may be at least as effective. Additional names may become available as a result of further testing.

Because the foam was attacked immediately after it had been generated, there had been little time for drainage and the foam was mobile and flowed easily towards the operator. Some further tests were carried out in which the foam was allowed to stand for approximately 1 hour after generation and before being sprayed with the antifoaming solution. The foam was much stiffer, and did not flow towards the operator on spraying (Plate 4). The volume of foam collapsed per unit volume of antifoaming solution increased noticeably; that is, the effectiveness of the antifoaming solution increased.

The values given in the last column of Table 5 represent a rate of breakdown of foam such that 2722 m^3 volume (960 ft^3) could be collapsed by one operator in under three minutes using a volume of about 2 litres (0.4 gallons) of antifoaming solution.

When plain water was used, (Table 5), the spray increased the mobility of the foam so that it flowed out of the enclosure and across the floor of the laboratory. With the antifoaming agents, it was noticeable that the bubbles were collapsing with very little flow of the high expansion foam from the enclosure; the mechanisms of dispersion of the foam were thus different in the two cases. This point is emphasized by the poor showing of plain water in the tests summarised in Table 1, where movement of the foam was prevented by the walls of the small container within which the foam was sprayed.

DISCUSSION

The results given in Table 1 showed that in the comparative small scale tests there were appreciable differences in the effectiveness of the nine antifoaming agents tested, as measured by the volume of foam collapsed by unit volume of antifoaming solutions. Furthermore, in this test, all agents were greatly superior to plain water applied in the same manner. The main purpose of these tests was to select the more effective of the agents, for further large scale trials, and agents N71D5, NXZ and DNH1 were chosen. Agent DD72 was made by the same manufacturer as NXZ and DNH1 and because it was marginally less effective for the present application was not considered further. The results of the small scale tests were sufficiently consistent to permit other antifoaming agents, which may be submitted, to be tested by the same method.

The ineffectiveness of plain water (Table 1) when the foam was restrained within a small container emphasized the observation that water causes little collapse of the bubbles but tends to cause the foam to flow under gravity if the situation permits. A conclusion of practical importance would be that where foam is in a situation where it cannot flow away under gravity, e.g. in a basement, the application of a plain water spray is not likely to lead to rapid dispersion of the foam. A spray of antifoaming solution, because it causes collapse of the foam bubbles, would be likely to be much more effective in a similar situation.

In selecting the optimum concentration of antifoaming agent in solution, two points need to be considered. Firstly, a 2 per cent solution was highly effective (Table 2) but, on the other hand, plain water was known to have low effectiveness (Table 1). There was thus a concentration region below the 2 per cent level at which performance would drop off very sharply. To ensure that this concentration region is avoided, a margin of safety is required. Secondly, at agent concentrations of 10 and 20 per cent the volume of foam collapsed per unit volume of antifoaming concentrate would decrease rapidly (Table 2) thus becoming less economic. On balance, a solution concentration of

5 per cent was taken for the subsequent tests as being a practicable compromise.

In the small scale tests the effectiveness of the antifoaming agent tended to increase with the rate of application of the solution (Table 3). The results in Table 1, although consistent within themselves, were obtained with a relatively low application rate (100 ± 14 ml/min) and should not be compared directly with the results in Table 2, 3 and 4, which were obtained with higher application rates. Since the application rate has an effect on the breakdown of the foam, the results for large scale tests, particularly as regards the volume of foam collapsed per unit volume of antifoaming solution, cannot be related directly to values obtained from small scale tests. In the large scale tests, other factors were also probably of importance particularly the high operating pressure of the spray equipment which would cause the antifoaming solution to impinge on the bubbles at a higher velocity.

The evidence obtained in the tests with different high expansion foam concentrates (Table 4) showed that the antifoaming agents were highly effective against all the concentrates tested. These concentrates represented the majority commercially available in this country at the present time. As new concentrates are introduced, check tests would then be necessary, but at present the antifoaming agents do not have to be matched to the concentrate.

The effectiveness of the antifoaming solutions was not reduced after allowing the solutions to stand undisturbed for $\frac{1}{2}$ hour, but some reduction was evident after 2 hours. With prolonged standing over a period of 6 days, substantial loss of effectiveness developed. However, in each case, the effectiveness could be restored by simply shaking the solution. It would not be good practice to allow the solutions to stand for long periods after production, because of possible deterioration of the constituents of the agent, but providing the solutions are used within hours they should be satisfactory. If the manufacturers instructions are correctly followed, the antifoaming agent concentrates can be stored without deterioration for many months. They are not flammable.

The large scale tests showed that the antifoaming agents had greater effectiveness than in the small scale tests, as measured by the volume of foam collapsed by unit volume of antifoaming solution (Table 5 last column). For practical purposes, there was little difference in the effectiveness of the three agents, and all were considerably more effective than plain water although the conditions of the test favoured the action of water in dispersing foam rather than collapsing it. The increased effectiveness of the agents, as compared with small scale tests, probably arose from the higher pressure at which the spray was delivered from the equipment, and consequently the higher velocity with which the droplets would impinge upon the foam. The rate at which the foam can be broken down is of practical importance, in the large scale tests a volume of 28 m^3 (960 ft^3) of foam was broken down by one operator in under 3 minutes using about 2 l (0.4 gal) of antifoaming solution. More rapid clearances could be obtained, if desired, by using several operators. The results in Table 5 were for foam which had been freshly generated; foam that was allowed to stand for an hour to drain collapsed more readily when sprayed. Thus the stiffer foams, which would be more difficult to remove by mechanical means, were easier to handle with the spray technique.

The spray equipment was easy to use, and the operator rapidly gained experience. No special protective clothing was needed, and the operator did not require a face mask. The antifoaming agents are standard products of the manufacturers, and in ready supply, and the spray equipment of the necessary capacity and delivery is available in a number of makes from gardening and similar stores. There should be no difficulty in obtaining supplies of agent

and equipment in any part of the country. The spray equipment is self-contained and portable, and can be fitted with shoulder straps to permit the operator one free hand.

The additional water damage likely to be caused by the antifoaming solution may be gauged from the values in Table 5, final column. Thus, taking a value of 1000 for the expansion of the foam the volume of foam solution present per unit volume of antifoaming solution is in the range 14-16. Thus, the additional water applied by the antifoaming spray is only 6 or 7 per cent of that present in the foam itself; additional water damage caused by the antifoaming solution is therefore not likely to be substantial.

As regards corrosion of metals by the antifoaming agents, the solutions are frequently used in industry where they can come into contact with metals, e.g. in paper making, and the manufacturers claim that the agents do not cause corrosion troubles. No evidence was obtained in the present tests of accelerated corrosion caused by antifoaming solutions; in addition the antifoaming concentrates can be stored satisfactorily for long periods in metal cans. The manufacturers also claim that there is no toxicity hazard in the use of the antifoaming solutions.

The cost of the materials and equipment is of interest, and the economics of the technique are favourable. The antifoaming agents N71D5, NXZ, DNH1 all cost between 2/6d and 4/- per lb, depending upon quantity purchased. Agent DNH1 is a few pence more expensive than agent NXZ. One gallon of the agents would thus cost about 30/- and would produce 20 gallons of a 5 per cent solution. If applied effectively this would cause the collapse of about 50,000 ft³ of foam. For comparison, the cost of the high expansion foam concentrates is a few shillings per lb so that the cost of antifoaming agent would be substantially less than the cost of the foam concentrate required to generate the foam that could be broken down. The spray equipment cost between £3 and £6 depending upon the size and make, and can of course be used repeatedly.

CONCLUSIONS

1. High expansion foam can be broken down after fire-fighting by using a spray of antifoaming agent solution.
2. Antifoaming agents were considerably more effective than plain water.
3. The antifoaming agents selected could break down about 30 m³ (1000 ft³) of foam in 3 minutes, using about 2 l (0.4 gal) of a 5 per cent solution in water.
4. Commercial garden spray equipment, with minor modifications, was suitable.
5. The spray technique was easy to acquire and economic to use.

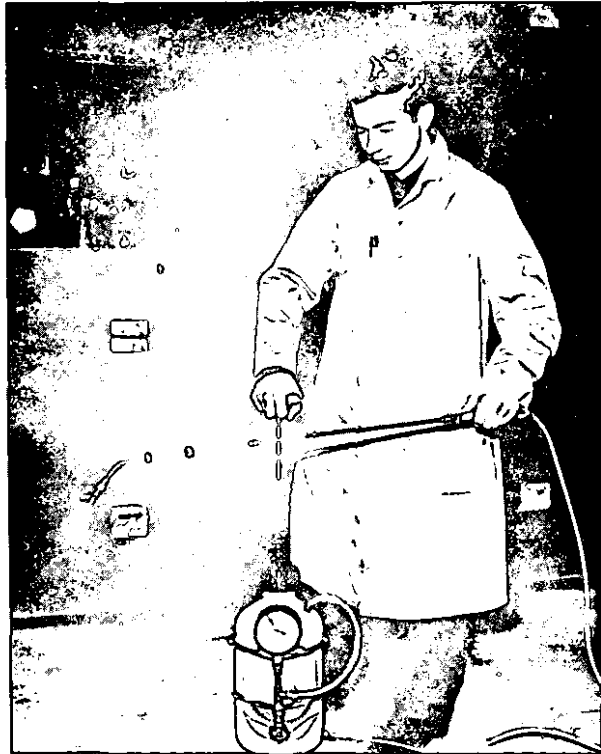
ACKNOWLEDGMENTS

Thanks are due to the various manufacturers of antifoaming agents, who generously contributed samples of their products.



WIRE MESH PANEL IN ONE
SIDE OF FOAM ENCLOSURE

PLATE 1

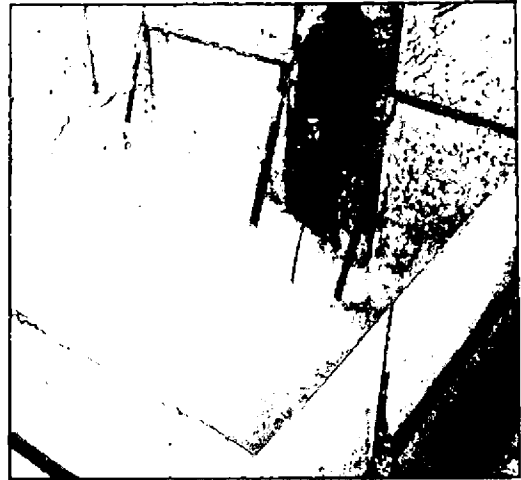


THE SPRAY EQUIPMENT

PLATE 2



(a) Anti-foaming agent applied
35 seconds

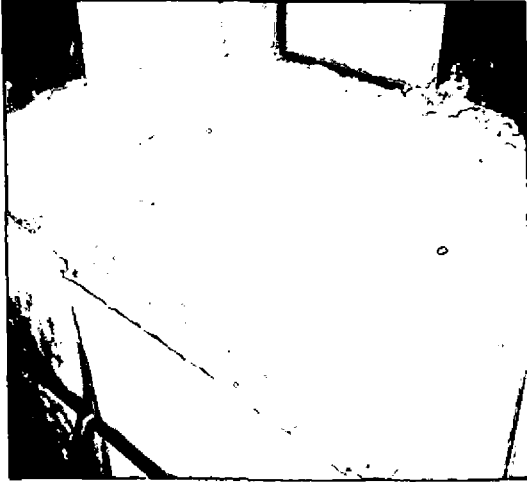


(b) Anti-foaming agent applied
93 seconds

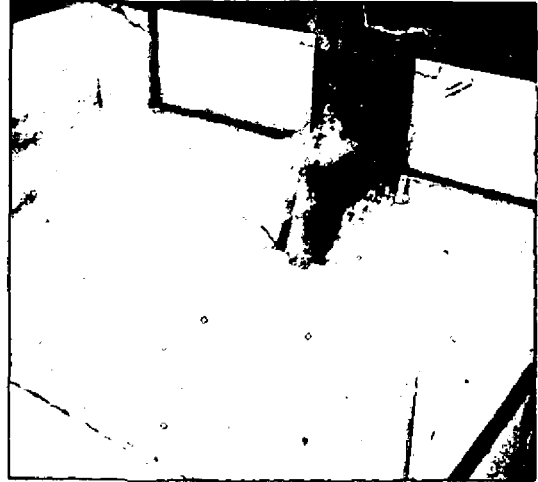


(c) Anti-foaming agent applied
155 seconds

BREAKDOWN OF FOAM IN LARGE SCALE TESTS



(a) Before application of anti-foaming agent.



(b) Anti-foaming agent applied 15 seconds



(c) Anti-foaming agent applied 30 seconds



(d) Anti-foaming agent applied 90 seconds

BREAKDOWN OF FOAM AFTER STANDING
FOR ONE HOUR

100

100

100