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PYROTECHNIC AEROSOLIZATION OF IMBIBED LIQUIDS*

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Summary

In this study liquids were thermally disseminated as aerosol after incapsulation in loosely crosslinked polystyrene polymer. A stereochemical concept is proposed to explain this liquid imbibition phenomenon. Rate of liquid encapsulation, observed microscopically, is shown to be polymer particle size dependent. Total liquid volume imbibed by a polymer particle is calculated from polymer particle diameter measurements. The study emphasizes fog oil as a model liquid and demonstrates compatability and storage stability of the imbibed system with typical pyrotechnic compounds. Pyrotechnic dissemination efficiency results are also presented and discussed.

Introduction

The purpose of this study was to develop an intimate pyrotechnic composition which would disseminate a nontoxic, noncorrosive, visual screening smoke. It was also hoped that such an innocuous smoke might fulfill military training needs.

Currently available military visual smoke screens, whether disseminated pyrotechnically or by other means, yield hydrolized phosphorus acid(s), sulfuric acid, metallic oxychloride, metallic hydroxide, or oil aerosol. Based on recent medical guidance [1] and because of its noncorrosive characteristic, fog oil is the material of choice in the above inventory of smokes.

Results and discussion

Imbiber beads are commercially produced (under license from Dow Chemical by EMCO Inc.) for use in soaking up hydrocarbon spills [2] which pose an ecological hazard. We have exploited this solvation property and found it possible to thermally reverse the process thereby producing liquid aerosol smoke. In addition to this important solvation property, imbiber beads have been found to be hydrophobic and thermally stable to 300°C.

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These properties suggest storage stability and compatibility with a pyrotechnic mode of thermal dissemination.

The major focus of this investigation has been to study imbibition and dissemination of fog oil. However, other liquids have successfully been imbibed. Table 1 shows the liquids surveyed to date and indicates bead capacity for these liquids.

TABLE 1

Imbibition survey, TC bead

Liquid	Percent imbibed[a]
Titanium tetrachloride	>90[b]
Triethyl aluminum	>50
Eutectic white phosphorus	66
Fog oil	94
Diesel oil	90
Mineral oil	89
Rosin oil	>91
Cod liver oil	>86
Linseed oil	>85
Corn oil	>80

[a] Weight of oil × 100/(weight of oil) + (weight of bead)
[b] Unstable

Fog oil imbibition has also been followed by microscopic observation [3]. These observations indicate that bead volume increases appreciably during liquid uptake. The rate of imbibition for a given liquid is bead size dependent. Figure 1 depicts this relationship. Some data points are not included in the graphs, however, observations indicate maximum oil intake is eventually reached and that this yields a stable bead volume value.

Based on infrared spectral analysis, we have postulated that the imbiber bead utilized in this study, designated type TC by Dow Chemical Company, is composed of linear chains formed from tertiary butyl styrene copolymerized with monomeric styrene and a polymeric ester additive such as methyl methacrylate. Many such chains can be crosslinked with divinylbenzene as indicated in Fig. 2. The figure depicts the polymer to be made up of box-like units, the corners of which are phenyl groups whose origin is styrene monomer. These crosslinked sites are the likely sites in the linear chains that can be crosslinked since all other phenyl groups are blocked in the para position. The size of the open areas within these corners can be controlled by altering the amount of divinylbenzene and the amount of ester and tertiary butyl styrene utilized to build the polymer network. The polymer network is three dimensional. We postulate that the size of these "chemical holes", determined by crosslink density, specifies entrance of liquids into the polymer.

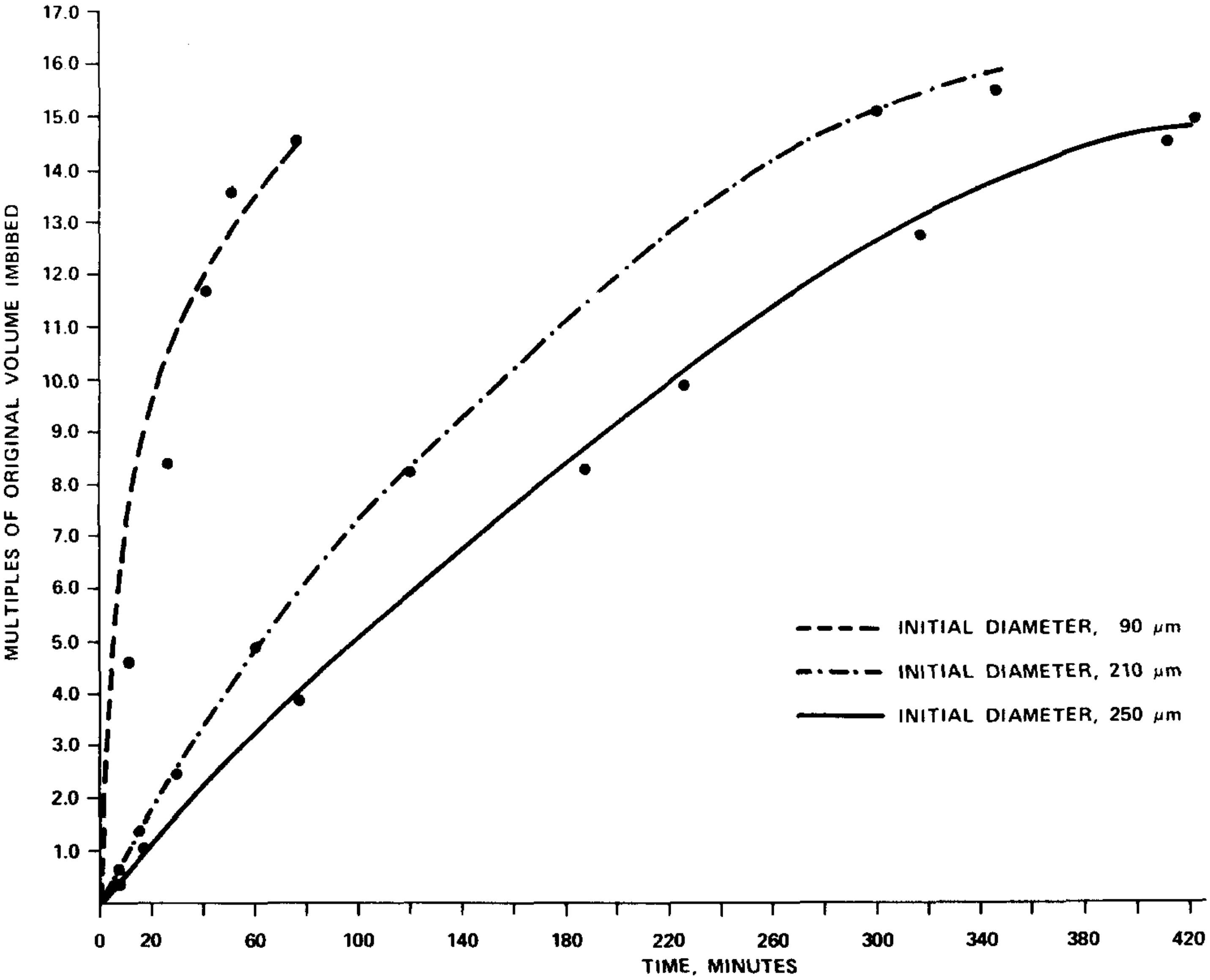

Fig. 1. Fog oil imbibition.

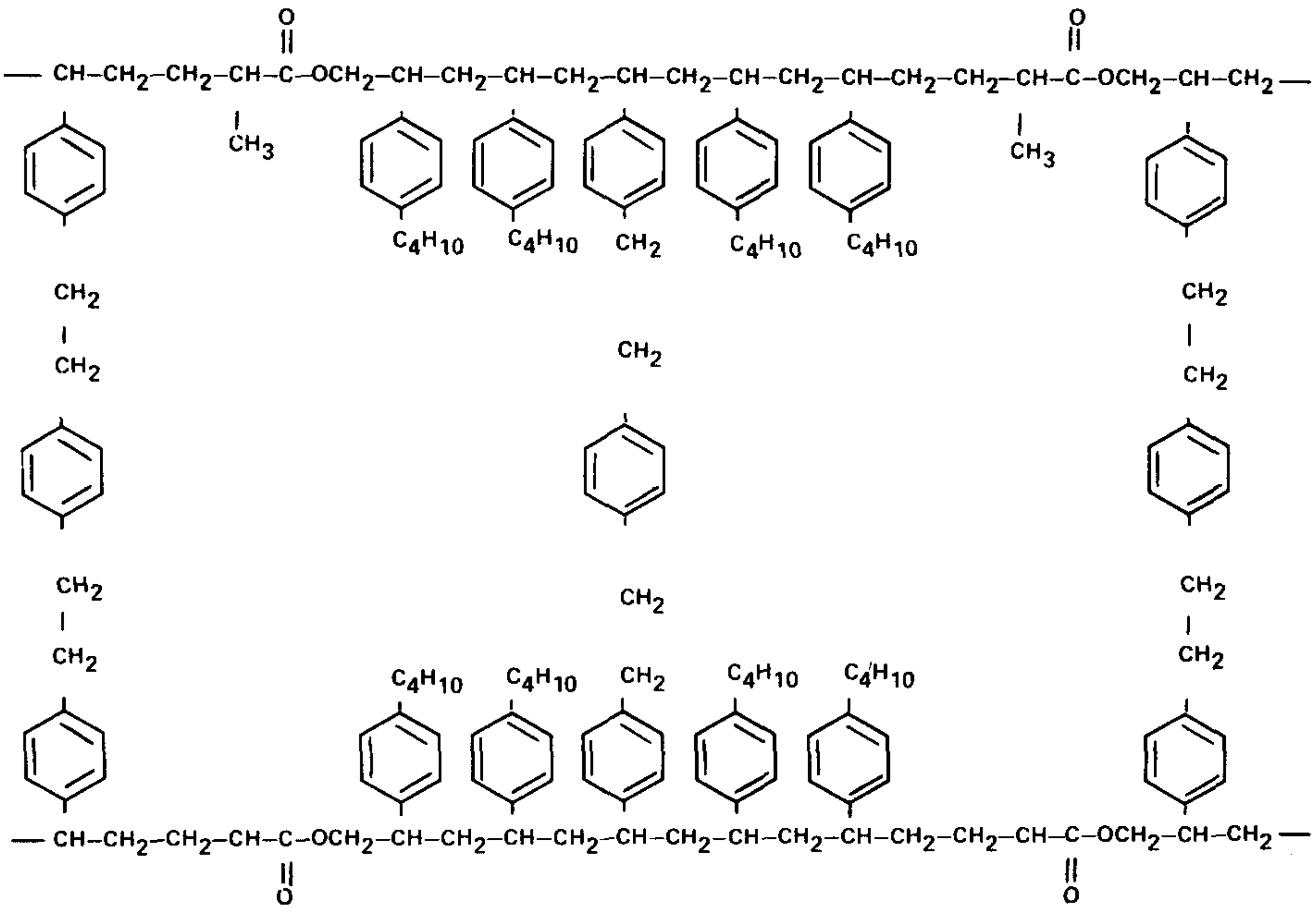

Fig. 2. A styrene based crosslinked copolymer.

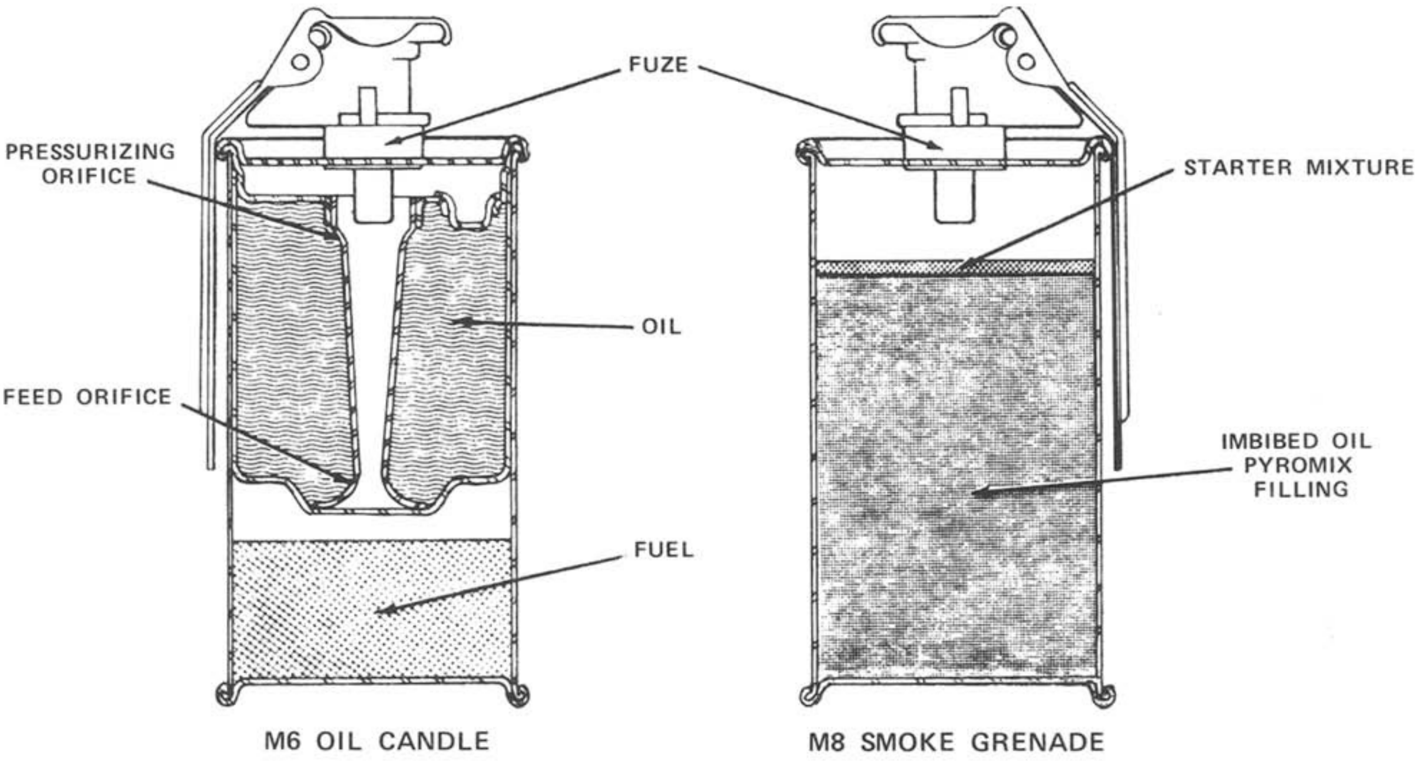

Fig. 3. Comparison of fuel block and intimate mix designs.

The oil smoke we are disseminating is new in the sense that it is emitted from a canister containing an intimate pyrotechnic mixture. This mixture is composed of pyromix granules blended with imbibed fog oil. Prior to these studies fog oil was pyrotechnically disseminated only by means of a more complicated two compartment generator design. Figure 3 indicates the relative complexity of the older design. This particular design efficiently vaporizes oil only when the smoke pot is in an upright position.

An imbibed fog oil mixture was prepared by synthesizing fuel pyromix composed of potassium chlorate, sugar, and magnesium carbonate granulated with nitrocellulose. The grains were then blended with fog oil and imbiber beads. The composition of this mixture is given in Table 2.

Two standard U.S. Army canisters which have been loaded and functioned with imbibed fog oil pyromix are the M8 and M48 canisters. Figure 4 shows smoke being emitted from an M8 grenade loaded with imbibed fog oil pyromix. Almost complete obscuration of a trailer is seen produced by the esti-

TABLE 2

Imbibed fog oil pyromix composition

Ingredient	Weight percent
Potassium chlorate	22.2
Magnesium carbonate	9.8
Sugar	14.7
Nitrocellulose	5.2
Fog oil	43.3
Imbiber beads	4.8

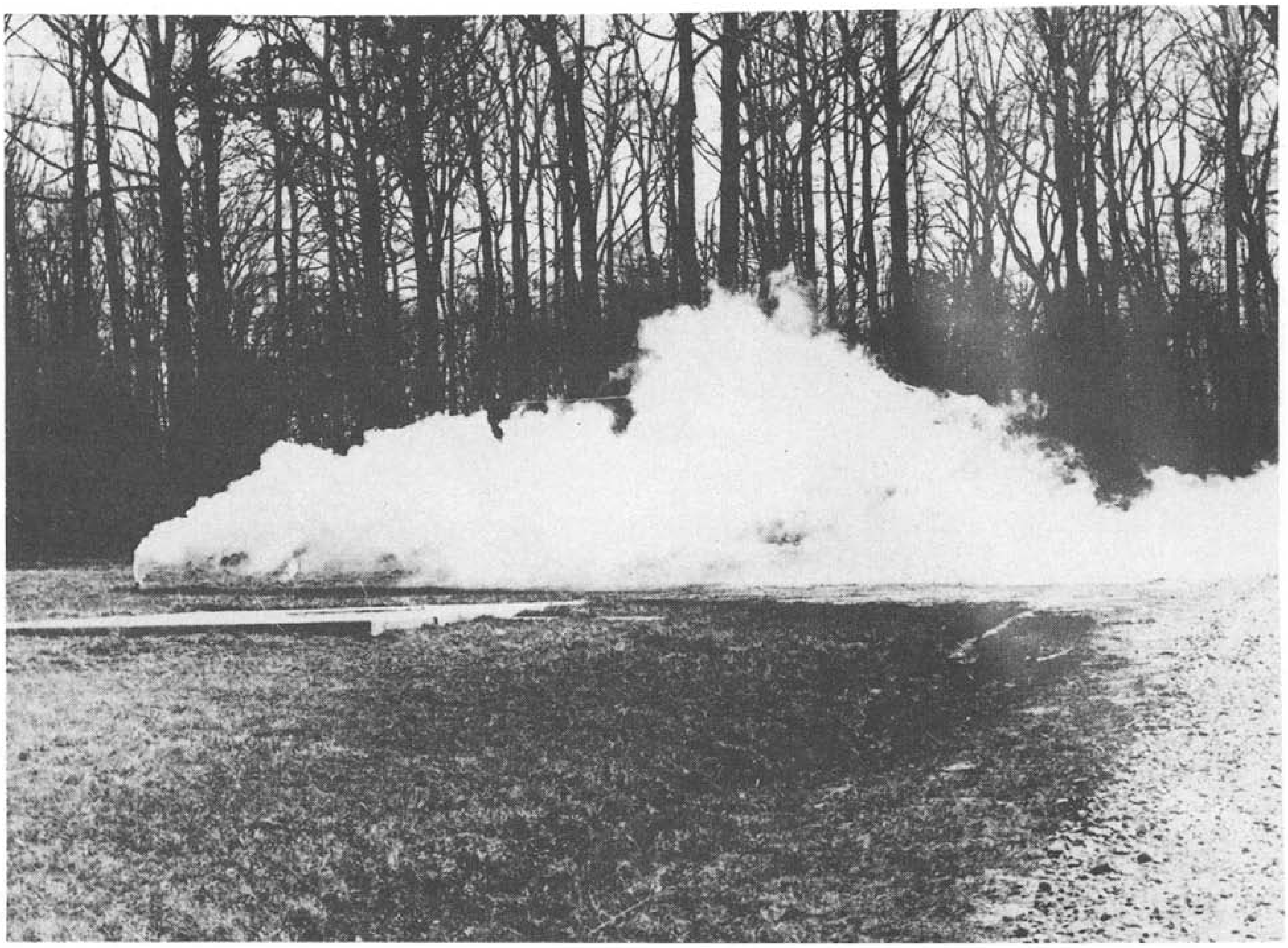

Fig. 4. M8 grenade generating fog oil smoke.

mated 122 grams of aerosolized fog oil disseminated over a 160 second period.

A batch of imbibed fog oil pyromix was prepared and loaded into small test canisters. Several of these were functioned in a test chamber to measure oil vaporization efficiency and several to determine the effect of storage on fog oil pyromix stability. The chamber data indicate that the formulation is 95% efficient in vaporizing fog oil. The burning time data obtained after storage was statistically compared to that obtained from control canisters. At a significance level of 0.1, we conclude there was no difference in mean burning time between control canisters and canisters stored either at ambient or at 160°F for 12 weeks. The β risks were calculated to be 0.299 for the ambient comparison and 0.166 for the elevated temperature comparison.

In summary this study demonstrated that near intimate mixtures of liquid disseminants and other pyrotechnic components are compatible. Furthermore, this study suggests that liquids are efficiently disseminated from such a pyrotechnic design.

Future studies should extend this concept to other liquid smoke agents which are still more innocuous to man and his environment. These studies should also explore dissemination of liquid obscurants useful in other regions of the electromagnetic spectrum.

References

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