STUDIES ON INSECTICIDAL FOG GENERATION FOR MILITARY USE

I. *Military Research on a Non-Thermal Aerosol Fog Generator*

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For several reasons, fog generation by the currently-used thermal means does not completely meet all military requirements. Thermal generation, however well controlled, entails the presumptive threat of creating a fire hazard or of being hazardous to personnel and the effect of the heat on certain insecticides and other agents is still not a matter of universal agreement. In tests at the Engineer Research and Development Laboratories we have found closely controlled spectra of particle sizes to be the exception rather than the rule with thermal generation. Where the equipment is capable of giving some control of particle size, it still is too heavy, too cumbersome or too complicated to be entirely acceptable for military operations. On the other hand, none of the alternative purely mechanical means has so far produced true fogs or produced them in a sufficient quantity to be satisfactory.

Military requirements are somewhat more exacting than civilian requirements because military equipment must be operated in rough or unimproved terrain, far from good repair and replacement facilities and often by personnel who are not completely trained or able to take all the care and precautions we might normally desire in the operation of equipment. While eye-appeal is important to military public relations, as it is to commercial, and while many of our situations are no different from those of non-military agencies, we must have the combat zone constantly in mind and must call for features of mobility, ruggedness, simplicity and dependability which would not always appeal to the average user.

With the military needs in mind, therefore, various non-thermal methods were tested and satisfactory modifications of them were attempted. Some of these, which seemed promising mechanically, developed unacceptable characteristics when variations in size, gallons per hour output or particle range were sought. At length it was decided to abandon the approach of remodeling existing equipment as units, and to work on the development of components which, while retaining the character of being compatible with commercial production, should each give the most satisfactory results as an individual mechanism. It was also realized that if each of these components could be an already standard item of manufacture, or so nearly standard that there would be no need for any difficult re-tooling by industry, we should gain both in cost economy and in ease of making replacements.

A commercial nozzle, first developed by Yeomans and commonly used on small equipment which is designed to be used in single rooms, was adapted for use in larger equipment for both indoor and outdoor use. Experimentation and engineering tests have shown that this nozzle can be used at low air pressures as a single unit to give a suitable fog at 5–10 g.p.h.; in multiple arrangement with an air source of larger output but still at low pressure, machines can be composed with increasingly greater capacities. A commercially-available air blower was selected which provided the required air output at low pressures and yet is small enough to leave the completed machine readily mobile and maneuverable. A new engine of very light weight but great power and higher than usual r.p.m., which is just completing developmental test at the Laboratories is used as the power source.

The oil used in the tests is Texaco #300 burning oil, a standard, almost completely non-volatile, oil having a density similar to Sovacide F, diesel #2, and other common fogging solvents. By supplying an appropriate volume of air at 5 p.s.i., a machine capable of creating a fog of any desired particle range from 10 microns to 40 microns or even larger, according to the quantity of liquid introduced, has been constructed. The spectrum produced is quite narrow, giving a rather symmetrical curve, and being normally within a range of about 20 microns on each side of the median; it can be reproduced whenever the appropriate settings of air volume and liquid are repeated. Insecticide output and particle size are controlled by liquid valve adjustment, air pressure regulation, or both.

So far this machine has been constructed only in the laboratory and difficulties of which we are not aware may well arise when we attempt to translate it into a field mechanism. However, on the basis of our military experience with field equipment and commercial equipment adapted to military field use, we do not anticipate any insurmountable difficulty. The nozzle is simple with no finely-machined orifice to be subject to plugging or erosion, the air source is a rugged, positive-displacement blower, the power source is a simple gasoline engine. Mounted in a ¼ ton trailer pulled by a jeep, the equipment can be carried into almost any terrain. A smaller size of about 10 g.p.h. output, which could be carried by two men or pushed on wheels, is also anticipated.

While this equipment is not capable of being home-made, like the famous Plumber's Nightmare, it is not overly expensive and we hope to develop it into a piece of equipment which will require little manpower to operate and less to keep in repair. Extensive basic research is being continued on the entire subject, concentrating especially on the quality of the fog in terms of particle size control, and in addition, striving for low weight, small size and low cost. Commercial manufacturers, as has happened once or twice before, have also shown an awakened interest in the possibilities of such an arrangement and it may not be long before similar equipment makes its appearance outside military channels.

II. *Solvents for Insecticidal Fog Formulations*

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In connection with the studies on thermal and mechanical fog generation, research was conducted on the properties of various solvents and their suitability for fog formulations. Ten years ago, in some of the earliest investigations made in this country, Latta (4, 5) used an Army screening-fog oil having an S.A.E. rating of 50. Yeomans has also advocated the use of motor oils such as S.A.E. 10 and S.A.E. 50 and more recently stated (9) that about one-fourth of the formulation solvent should be such a non-volatile oil, particularly S.A.E. 50 motor oil, which might be added to mixtures of kerosene, xylene, carbon tetrachloride, cyclohexanone, tetrachlorethylene or other similar more volatile solvents. LaMer, Hochberg, Latta, *et al.,* in 1947 (3), found that oil solutions of this type did not decompose so readily with heat as did pure DDT, while Peterson (6), using fuel oil, S.A.E. 10 and S.A.E. 50 motor oils in 1952, found that a solution "based on fuel oil No. 2 has a much higher output for a droplet spectrum of 15 microns than one based on

S.A.E. 10 oil. . . ." He also found that a 5 per cent DDT formulation, applied by the thermal-generation technique was a satisfactory concentration and that the use of 20 per cent or higher was unnecessary and uneconomical.

Following these leads, operators generally have used diesel oil 5 per cent DDT formulations, with the addition of various proportions of fog oils, S.A.E. 50 motor oil, etc., for non-volatility and of carbon tetrachloride, tetrachlorethylene, xylene, etc. where volatility and small particle diameters are desired. Use of these latter materials has increased during recent years as fog machines have been modified to avoid taking the insecticide through the heating chambers because of the possibility of breaking down the DDT, which is still a moot problem. Operators have also turned to these materials with greater frequency as the use of fog has become more extensive in warehouse operations and less intensive out of doors, so that smaller particles have become more and more desirable.

In these military operations, the base oil has often been the mixture which is issued for use as an airplane spray. This has a base solvent with the character of a mixture of diesel oil No. 2 and heavier motor oils, which contains 20 per cent DDT: thus it is usually diluted with diesel oil No. 2, one part to three, resulting in an oil mixture approximating diesel oil in all major characteristics. Mixtures of the emulsion concentrate, in which the base solvent is xylene, with diesel oil No. 2 and S.A.E. 50 motor oil have also been used extensively in some areas overseas.

None of these mixtures has been entirely satisfactory, their use being a matter of expediency, rather than of considered choice. Laboratory-controlled field tests have shown that particle diameters tend to be distributed over a wide spectrum of sizes while field use has proved also that whenever materials are used which are capable of being readily volatilized into a screening smoke, control operators are under a heavy compulsion to use this smoke for its psychological value rather than to use the more effective particle sizes for their insecticidal worth.

More recently, "gap" oils have received wide attention because it has been claimed that they give a more uniform and narrow spectrum of particle sizes. These "gap" oils are a mixture of dissimilar oils, the fractional boiling points of which lie in ranges which do not overlap; they may be represented by a mixture of diesel oil No. 2 and S.A.E. 50 motor oil. While the results reported by various investigators have not always been entirely consistent, it has been generally agreed in unpublished discussion that these oils do seem to have a somewhat better characteristic than straight diesel oil or the diluted airplane spray. A 30 per cent DDT solution in xylene diluted by 5 parts of diesel oil to one of the original solution, was used by Brown and Mulhern (2) in 1954, and in 1953 Brown and Watson (1) reported using a No. 1 diesel oil, a gap oil and a methylated aromatic, although they did not note any significant differences in the results obtained from them.

While research has continued to be extensive in many kinds of solvent mixtures, as may be seen, diesel oil has continued to be the solvent most commonly used in most commercial and community abatement work as well as in the military practice. In the course of searching for equipment which would be satisfactory when used in places far from repair and replacement supplies, it seemed of primary importance also to find a suitable solvent for use under these military conditions. It is the consensus of those who have suffered from supply problems overseas, that in military use there was a definite likelihood of fog operations having to be conducted in areas where the use of special formulations or solvents would be logistically undesirable. Studies were therefore commenced looking toward the discovery of a suitable solvent composed of those hydrocarbon oils which would be readily available at any motor pool and which therefore would be quickly obtained in

TABLE 1

Break-Up Characteristics of Various Insecticide Oil Formulations

Material	Method of Dispersal	Per cent particles in apparent micron diameter range of								Per cent within 10 microns below MMD	Calculated MMD[2]
		0–10	20	30	40	50	60	80	100[1]		
		5.0(5/u)								(%)	(/u)
Indoor fogging mixture (83% Tetrachlorethylene) (5% S.A.E. 50 Motor Oil)	Mech.[3]	43.0	35.5	15.0	1.5					78.5	11
	Therm.[4]	4.0	25.5	24.0	19.5	11.5	11.5	1.5	2.5	49.5	20
Kerosine[5]	Mech.	31.5	48.5	14.5	5.0	0.5				80.0	11
	Therm.	3.0	22.5	40.5	20.5	7.5	3.5	2.0	0.5	63.0	20
Kerosine (deodor.)	Mech.	15.5	61.0	18.5	5.0					76.5	11
	Therm.	—	—	—	—	—	—	—	—	—	—
No. 300 Burning Oil	Mech.	15.0	38.5	24.5	15.5	5.5	0.5		0.5	53.5	11
	Therm.	1.0	12.0	25.5	35.5	16.0	7.0	3.0		61.0	32
Airplane Spray-Diesel Mix. (75–25)	Mech.	11.5	40.5	29.0	16.5	2.5				51.5	11
	Therm.	—	—	—	—	—	—	—	—	32	32
Diesel Oil #2	Mech.	5.5	42.0	36.5	16.0					78.5	20
	Therm.	1.5	24.5	32.5	24.5	10.0	6.5	0.5		57.0	20
"Gap" Oil	Mech.	7.5	28.5	33.0	24.0	5.0	2.0			61.5	20
	Therm.	1.0	16.5	34.0	28.5	9.0	7.5	2.5	1.0	50.5	20
Diesel #2—S.A.E. 50 (80–20)	Mech.	1.5	29.5	45.0	18.5	5.5				74.5	20
	Therm.	2.5	16.5	16.5	33.5	14.0	12.5	3.5	1.0	50.0	32
Airplane Spray	Mech.	1.5	16.5	52.5	26.5	1.5	1.0	0.5		69.0	20
	Therm.	0.5	12.0	19.0	32.0	17.5	12.5	5.0	1.5	51.0	32

[1] Or over.

[2] Particles captured on magnesium oxide coated slides passed once for 1 sec. exposure at distance of 10 feet from outlet. By comparison with diameters calculated on dri-film coated slides, *f* at 20/u is .55; at 30/u it is .66 and at 40/u it is .80.

[3] 5 p.s.i. air pressure; 2.5 g.p.h. per nozzle—70° temp. air, liquid & ambient.

[4] Setting at mid-position for "wet" fog.

[5] Spelling preferred by the A.P.I.

quantity by a control unit operating in any theatre of combat operations, as well as in the communications zones to the rear.

The results of a series of fogging operations with the non-thermal generation method, and using various formulations, are shown in Table 1, together with the averages of several series conducted with thermal generators. The results are not strictly comparable because the number of particles which escaped as smoke and did not impinge on the magnesium oxide slides after thermal generation cannot be easily shown. However, considering only those particles which did impinge, it will be seen that the mechanical method is at least equivalent to and in some instances superior to the thermal method in compactness of spectrum and percentage of total particles falling closely below the mass median point.

Parenthetically, it might be noted that nomenclature of petroleum solvents in the insecticide literature shows so wide a diversity of use for the same terms that it appears that some standardization should be attempted. Discussions with leading oil companies and with the American Petroleum Institute have brought out the fact that viscosities and flash points often are either non-differentiating or inapplicable. For instance, fuel oil #2 and diesel oil #2 have similar viscosities, and the flash point of diesel is virtually the same as that of materials commercially known as deodorized kerosines. The two fuel materials are differentiated by cetane ratings but no such rating is usually given for kerosines. However, the American Petroleum Institute (API) gravities are widely recognized and are different for each material, as are the centipoise viscosities. It is suggested that, as a starting point for discussion, the classification in the accompanying table (Table 2) be considered:

Table 2.—Suggested classification of fog oils

Material	API Gravities	Specific Gravities	Centipoise Viscosities
Kerosine (stove oil, diesel fuel oil #1)	42.0	.81	1.7
Deodorized Kerosine	40.5	.82	1.7
Diesel Fuel Oil No. 2	38.3	.83	3.8
Fuel Oil No. 2	33.9	.85	3.8
No. 300 Burning Oil	35.0	.87	5.6

The wording "diesel fuel oil" is suggested by all oil companies and the institute to avoid confusion with diesel lubricating oils.

As Yeomans has stated in the previously cited references, it would be most desirable to have formulations consisting of highly volatile solvents with a high capacity to dissolve the insecticide and stabilized by the addition of a heavy and relatively nonvolatile motor oil. Nevertheless, such special formulations would be likely to be dependably available only in rear areas, and they are far more expensive than the materials hitherto used. It appears that the best second choice is an oil similar to the mixture of diesel oil No. 2 and motor oil, which may be purchased ready-mixed in the continental United States and formulated under emergency conditions overseas from commonly-used materials.

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REPORT OF A THREE YEAR LIGHT TRAP SURVEY FOR BITING DIPTERA IN PANAMA

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The purpose of this article is to report on light trap operations conducted by the 25th Medical Detachment (Preventive Medicine Survey), operating from the Surgeon's Office, U. S. Army Caribbean, Fort Clayton, Canal Zone.

Malaria control has been the important mission of this survey unit since its reactivation in Panama. Studies in jungle yellow fever have been next in importance and studies on pests or biting insects the third problem.

On all military installations horse-baited traps have been employed almost exclusively as a means of measuring population densities, thereby giving a constant check on the effectiveness of various control measures being used. Also, larval collections have been made routinely and systematically on and adjacent to all military installations. Horse traps cannot readily be transported to outlying districts and male mosquitoes, which are often needed for taxonomic purposes, very rarely enter such traps. These two factors contribute to the justification for the use of light traps.

This paper deals with light traps, a method of capturing insects which was not used extensively in Panama before the senior author initiated the present reported surveys. The purpose of these surveys was to establish the distribution of insects of medical importance which could be attracted to light. When the surveys were first initiated it was thought that it would be confined to studies on the genus *Anopheles,* the vectors of malaria, but the first surveys were so successful that they were soon expanded to include all biting Diptera, not only in the Canal Zone but also in the interior of Panama.

The present paper is the forerunner of a series of small papers which record the results of the surveys. A great many species taken in these surveys are being described by various workers. It is therefore felt that a short paper which establishes location and dates of surveys may stimulate subsequent workers to expand the survey area and fill in some of the gaps that we were not able to accomplish. In this paper only general remarks are made on the results obtained, since a series of short papers are being prepared to cover the details.

The Republic of Panama lies between Costa Rica and Colombia, at 7°39′ North latitude and between 77°15′ and 83°30′ W. longitude. It has an area of 34,169 square miles ranging in elevation from sea level to over 10,000 feet in the volcan section near Costa Rica. The Canal Zone is a strip of

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