\dults from vegetation or elsewhere in the ·icinity are captured with an insect net or ıspirator.

So far we have not attempted to carry ıdults great distances, but have done so uccessfully for more than 50 miles with ıo provision for moisture. On several ›ccasions these females have deposited ·iable eggs in the laboratory. It is thought ›robable that moistened cotton or filter ›aper in the vial would increase the per-entage of survival for greater distances.

Egg Rafts: A small amount of free vater is added to the vials used for egg afts. Each raft is lifted from the surface ›f the collecting site with a section lifter. Effort is made to have the raft near the nd, since it is removed from the section ifter by sticking the end into the free vater in the vial. After the raft has loated free, the excess water is removed rom the vial with a pipette. This allows the raft to rest on the surface of the moist filter paper.

By using these methods we have had egg rafts retain their viability for several days although sometimes they partially hatch while in the vials. In the laboratory the vials are partly filled with pond water. This usually floats the rafts off the filter paper and frees any larvae that may have hatched. The egg rafts and any larvae which may be present are then placed in larger containers for hatching and rearing.

Summary: Methods and equipment used for collecting and transporting living mosquitoes have been described. Larvae, pupae, and egg rafts have been kept alive for 72 hours and transported over 500 miles; pupae often emerge successfully as adults in the vials used for their transportation. No effort has been made to carry adults this far or for this length of time, but they have remained alive for shorter times and distances.

A REPORT ON TESTS OF THE PERFORMANCE OF ADULTICIDING MACHINES IN CALIFORNIA [1]

A. W. A. BROWN [2] AND THOMAS D. MULHERN [3]

INTRODUCTION. The fifty-three local ıgencies presently engaged in mosquito ontrol in California emphasize the con-rol of mosquitoes while in the aquatic tages, by elimination or reduction of the ources and by the application of larvi-idal measures. However, adulticiding is, ›n occasion, a necessary supplement to the ontrol of the preadult stages, and many of the agencies maintain adulticiding equipment on a standby basis, for use as need may arise. A survey by the Forms, Records and Statistics Committee of the California Mosquito Control Association showed that there are employed by 28 of the agencies within the state the following numbers of machines:

Venturi Exhaust Generators (on jeep exhausts)	23
California Exhaust Generators (on jeep exhausts)	21
California Fog Applicators	10
Holmes Insect-a-Fog Machines	10
Mist Blowers (various makes)	11
Husman Pneumatic Sprayers	1
TIFAs	20
Bes-Kil Aerosol Generators	8
Total	104

[1] The testing program, the results of which are eported herein, was conducted from July 1 to uly 15, 1954, as a joint study of the California Mosquito Control Association, Inc., and the Bureau of Vector Control of the California State Department of Public Health.

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[3] Associate Vector Control Specialist, Bureau of Vector Control, California State Department of Public Health.

Machines of this type were extensively used during the 1952 encephalitis outbreak in adulticiding populated areas where mosquitoes were present. In addition to their normal use for the reduction of mosquitoes which have invaded residential areas, they are frequently employed to adulticide irrigated pastures or other sources where the adult mosquitoes can be destroyed before leaving the breeding site.

The following machines, described elsewhere in this report, were assessed for physical and biological performance:

Alaska Aerosol Atomizer	(Fig. 1; Plate 2, "A" & "B")
Venturi Exhaust Generator	(Fig. 2)
California Exhaust Generator	(Fig. 3)
California Fog Generator	(Fig. 4)
Holmes Insect-a-Fog	(Fig. 5)
Small California Mist-Blower	(Fig. 6; Plate 2, "C")
Large California Mist Blower	(Fig. 7; Plate 2, "D")
TIFA	
Husman Pneumatic Sprayer	

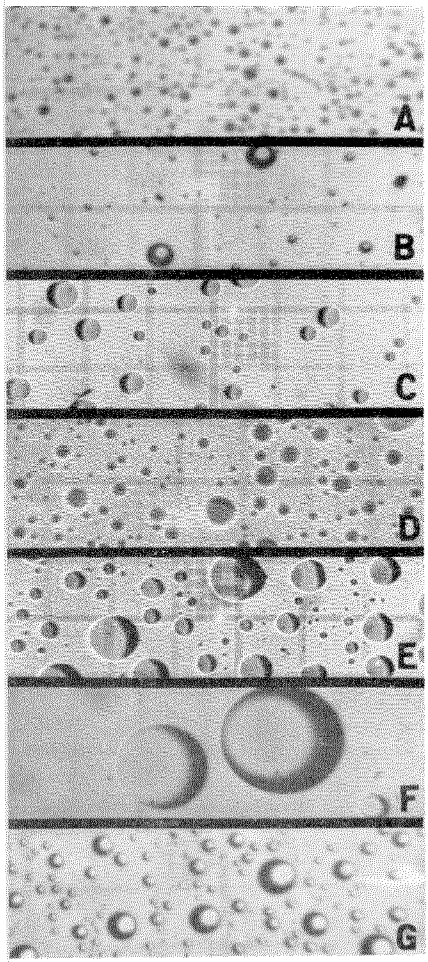
The study was an exploratory one, and the results should therefore be considered as indicative rather than conclusive. Due to exigencies of the time available, the droplet size assessments were based on a single sample for each setting of the various machines, chosen from a set of three samples which had been adjudged as satisfactorily representing the performance under these conditions.

PHYSICAL PERFORMANCE. The various machines to be appraised were operated at the settings normally employed by the operators in the field. The emission rates were determined at the same time that the aerosol samples were taken. The airborne material was sampled at a point 6 feet distant from the point of emission by drawing it through cascade impactors (Plate 2, "F") at 17.5 litres per minute (Brown & Watson, 1953). The slides, coated with Drifilm 9927, were then examined microscopically and the droplets sized by ocular micrometer, assuming a lens/droplet ratio (spread factor) of 2. From the cumulative total volume in the various size-classes, the mass median diameters were determined graphically, and the frequency distribution of sizes was derived. Plate 1 presents comparison photographs of som of the microscope slides which were ex posed in the cascade impactor. In eac case, only the second of the series of fou slides which were used in assessing th specific machine is presented here. Th squares which appear in the backgroun of the protographs measure 85 microns hence, a droplet lens which would ju fill a square would be 85 microns in d ameter, and would represent a droplet ha that diameter, or 42.5 microns.

Two formulations were used: (a) 5 pe cent DDT in fuel oil, made up by th Fresno Agricultural Chemical Compan ("Red-Top"), and (b) 5 per cent DDT i diesel oil, made up by diluting a 30% co centrate in xylene ("Red-Top") with parts of the diesel oil used by the Merce County Mosquito Abatement Distric The emission rates and mass media diameters are shown in Table 1, and th frequency distribution of droplet sizes i Figures 1 through 7.*

Laboratory work (by Latta *et al.*, an by Yeomans) has established that th optimum droplet size for killing adul *Aedes* mosquitoes is between 13 and 1 microns. It will be seen from Table that only two of the machines approx mated this condition, namely the Ventu exhaust generator with diesel oil and th Alaska aerosol atomizer with both kind of oil. A high content of droplet sizes to low to impinge upon mosquitoes (i. smoke) was produced by the Insect-a-Fo with the lower emission of diesel oil, an

* For graphs of the physical performance o the Microsol Generator, the Bes-Kil Generato the Husman Sprayer, the TIFA Machine, an the Dyna-Fog Generator, see Brown and Watso (1953).



LATE I.—Photographs of portions of the fields of microscope slides exposed in Cascade Impactor.

"A"—Alaska Aerosol Atomizer. Light fuel oil—10 gph.

"B"—Venturi Exhaust Generator on Jeep. Light fuel oil—20 gph.

"C"—California Exhaust Generator on Jeep. Diesel oil—9 gph.

"D"—California Fog Generator. Diesel oil—60 gph.

"E"—California Fog Generator. Light fuel oil—60 gph.

"F"—Holmes Insect-a-Fog. Diesel oil—48 gph.

"G"—Large California Mist Blower. Diesel oil —38 gph.

by the California exhaust generator with fuel oil. A high content of droplets too large to remain airborne for a sufficient length of time (or distance) was shown by the California fog generator, the Venturi exhaust generator with fuel oil, the California exhaust generator with diesel oil, and the Insect-a-Fog at the higher emission rates. An attempt to modify the entire droplet spectrum in a downward direction was met, in those machines, simply by an increase in smoke at the expense of a decrease in large droplets.

The droplet sizes produced by the mist-blowers were significantly larger, especially with the smaller model, which has the higher emission rate. The droplet spectrum for diesel oil in the latter is that of a typical spray. However, fine mist droplets occur in all the mist-blower spectra.

It is stressed that the figures reported are based on single samples, picked as the best of 3 taken simultaneously. Difficulty was encountered with emission rates with the home-made machines, where valve settings could not be calibrated, and a small change in setting could mean a large change in emission rate. These machines also tended to be either "smokers" or "spitters," producing droplets that are either too large or too small, since the large droplets are wasteful and fall out after travelling a short distance, and the smoke-size droplets are carried into the upper air. As an example of the latter class, the California fog generator was tested by emitting a known volume of material over a large area of paper toweling spread in front of it. From the gain in weight of the toweling, it was found that with 30 g.p.h. emission the fallout was 0.1% in the first 5 yds. (principally from muzzle drip), 1.6% in the second 5 yds., and 1.3% in the third 5 yds., with very little beyond. With 60 g.p.h. the

TABLE 1.—Delivery rates of 5% solutions of DDT in oil (in U. S. gallons per hour) and mass media diameters (m.m.d.) of their droplet spectra (in microns)

	Formulation	g.p.h.	m.m.d.
Venturi Exhaust Generator	Fuel Oil	20	137
	Diesel Oil	18	16
California Exhaust Generator	Fuel Oil	12	4
	Diesel Oil	9	46
California Fog Generator	Fuel Oil	60	55
	Diesel Oil	10	43
	Diesel Oil	60	91
Holmes Insect-a-Fog	Fuel Oil	45	74
	Diesel Oil	35	3
	Diesel Oil	48	50
Alaska Aerosol Atomizer	Fuel Oil	10	5
	Diesel Oil	15	30
Small California Mist Blower	Fuel Oil	48	191
	Diesel Oil	48	231
Large California Mist Blower	Fuel Oil	33	70
	Diesel Oil	38	128

fallout appeared visually to be 4 times as great.

Samples of the airborne cloud were obtained on 9-inch squares (Plate 2, "E") of 25-mesh copper screening exposed at 100 yds., 200 yds., 300 yds., and 400 yds. distance from the machines. In these tests, the cloud was created by emitting 1 gal. of 5% DDT in diesel oil per 200 yards of frontage. The samples were placed in individual large test tubes, and sent to the Food and Drug Laboratory of the State Department of Public Health at Berkeley for assessment of DDT by the Schechter-Haller method. One untreated screen was sent with each group as a check. The machines tested were the California fog generator, the Holmes Insect-a-Fog, and the Large California mist-blower. Results of the assessments are shown in Table 2.

BIOLOGICAL PERFORMANCE. Comparisons were made between pairs of machines, based on their reduction of landing rates at distances up to 400 yards. In all cases, 1 gallon of 5% DDT in diesel oil was emitted along a 200-yard line at right angles to the wind. Landing rates were assessed by counting the number of landings on a 36-inch square of red broadcloth during 3 minutes (or 1 min., in high populations). Four or five observers were used, and counts were taken every 100 yards downwind. Pre-assessment were made immediately before treatmen and post-assessments were commenced o. hour after treatment. Results were ex pressed as the reduction at post-assessmen in percent of the pre-assessment coun They are presented in Table 3.

The dosage employed, equivalent t 0.18 lb. DDT per 100 yards frontage, wa chosen as a sublethal one to give partial re duction in order to compare machines; thi is about two-fifths the level of 0.47 lb. pe 100 yards which Dickinson, Merritt an Hough had found in 1947 to give com plete mortality of *A. nigromaculis* for 44 yards downwind. The dosage of 0.18 lb per 100 yards did give the desired level c mortality in the flat fields at Merced, bu not in a highly leveed field at Planada this latter field was very heavily infeste despite repeated airspraying, and it i therefore probable that a degree of DD' resistance was present.

The results in Table 3 show tha machines with suitable droplet spectr i.e., the Venturi exhaust generator an the TIFA,* are superior in performanc

* The assumed superiority of the TIFA, whic was not clearly evidenced in these experimen due to a defect in the machine tested, is base upon a thorough investigation by Brown an Watson (1953).

TABLE 2.—Aerosol samples taken on 9″ squares of 25-mesh copper screen. Analyzed for DDT by Schechter-Haller method. Wind speed 4 m.p.h.

			DDT (milligrams) Recovered from Screens				
Date	Machine	g.p.h.	Untreated Screen	100 Yds.	200 Yds.	300 Yds.	400 Yds.
7/12/54	California Fog Generator	50	0	0.46	0	0	0
7/15/54	Holmes Insect-a-Fog	35	0	0.35	0	0	0
7/19/54	Large California Mist-Blower	38	0	0.35	0	0	0

TABLE 3.—Reductions of *Aedes nigromaculis* obtained with 1 gal. per 200 yds. frontage using 5% DDT in diesel oil, equivalent to 0.18 lb. per 100 yd.

Machine	Vehicle m.p.h.	Wind m.p.h.	Time hrs.	Percentage Reduction in Landing Rate 100 yd.	200 yd.	300 yd.	400 yd.	Average
Flat Fields at Merced								
Venturi Exhaust Generator	5.0 *	4	0645	57	91	94	0	60
California Exhaust Gen.	6.0 *	4	0600	0	87	80	6	43
Husman Pneumatic Sprayer	2.3	5	2030	70	90	69	70	75
Small Calif. Mist Blower	5.4	5	2030	96	90	58	58	75
Leveed Fields at Planada								
Holmes Insect-a-Fog	4.0	4	0630	52	18	41	0	28
TIFA	2.3	4	0615	39	56	0	7	31 †
California Fog. Gen.	3.2	4	2000	0	27	13	14	14
Large Calif. Mist Blower	4.2	4	1930	50	12	4	0	17

* 3.5 and 7 traverses made respectively.
† Burner too hot, with probable destruction of DDT.

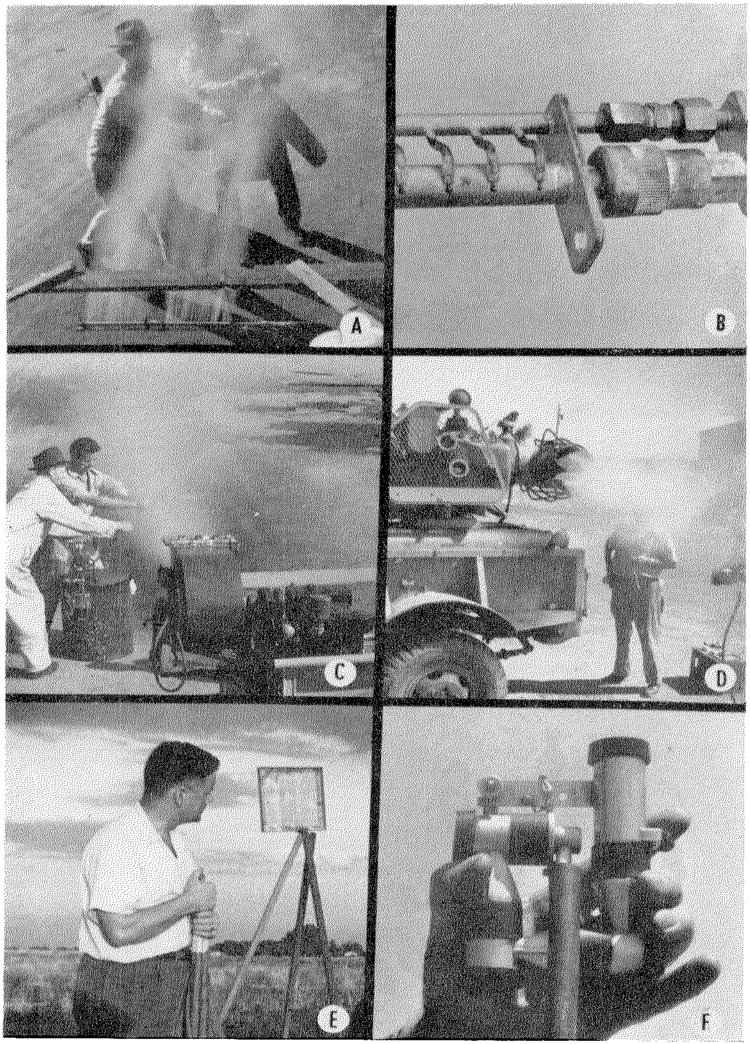
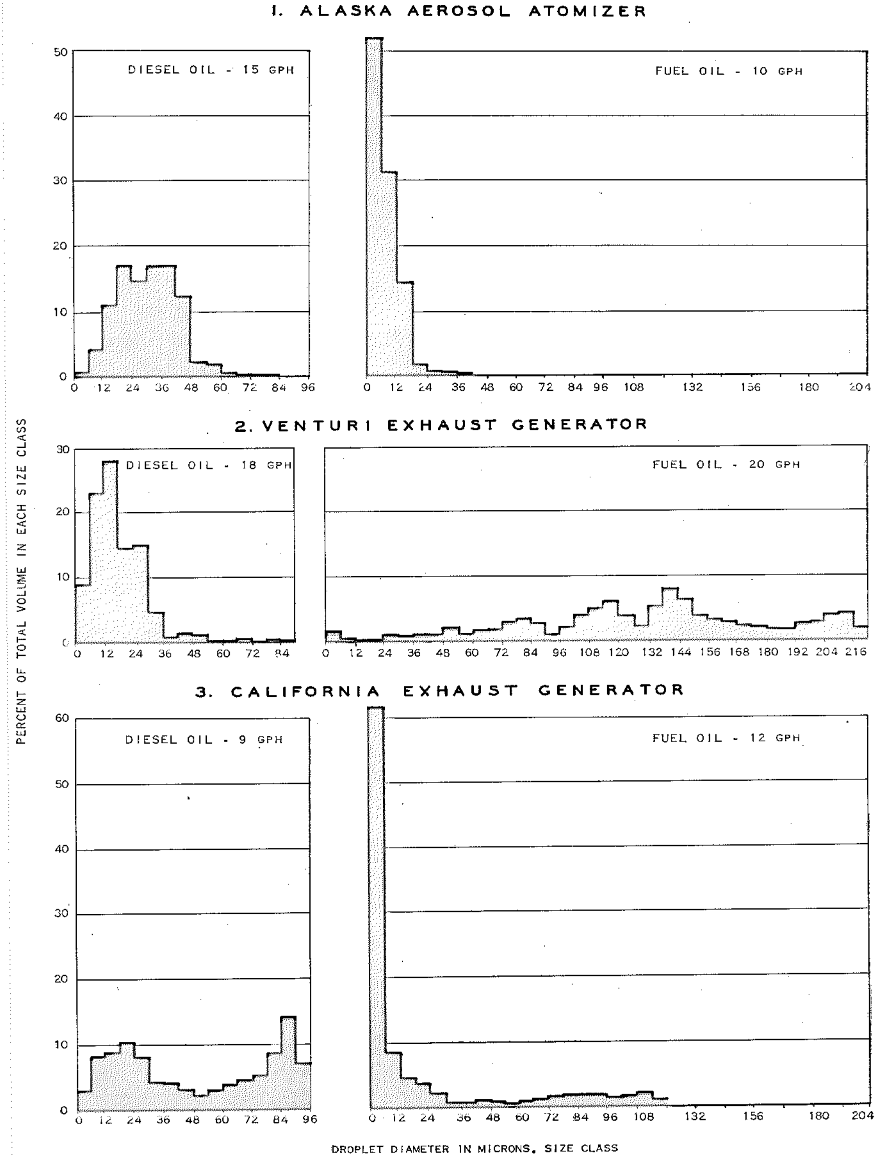
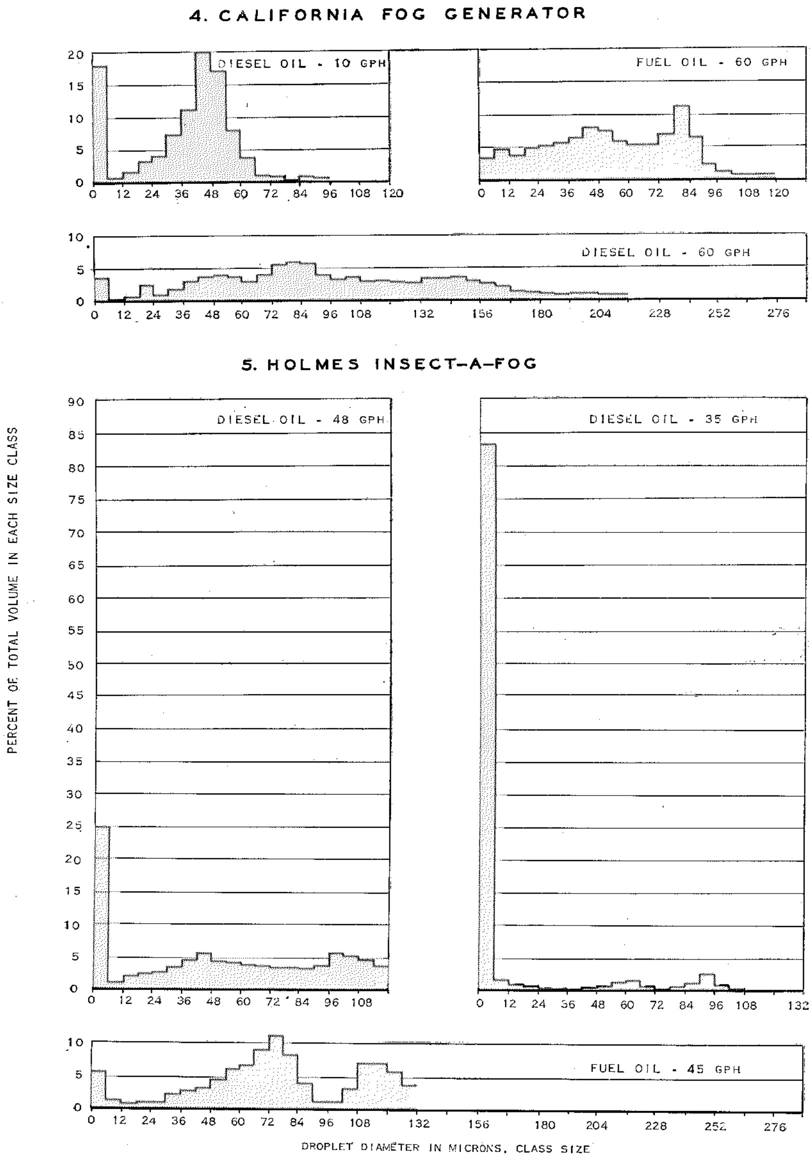


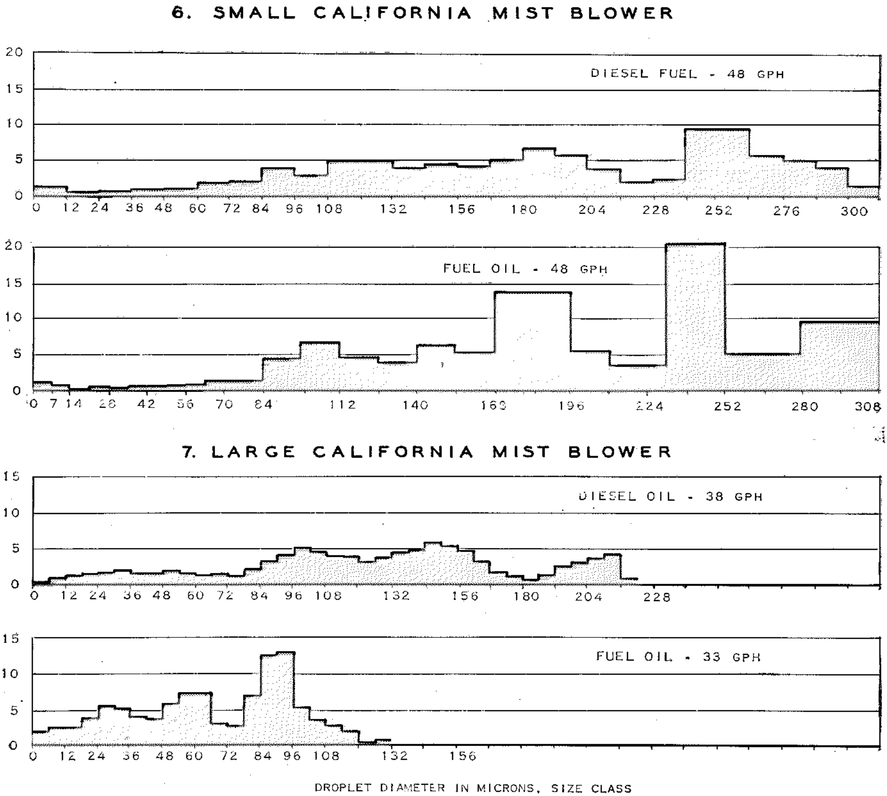
PLATE 2
"A"—Sampling fog from two sections of Alaska Aerosol Atomizer.
"B"—Close-up of atomizing tips of Alaska Aerosol Atomizer.
"C"—Sampling fog from the Small California Mist Blower.
"D"—The Large California Mist Blower.
"E"—Nine inch square of 24-mesh copper screen used to collect a sample of the air-borne DDT insec icide, for quantitative analysis by the Schechter-Haller method.
"F"—Cascade Impactor used to cause droplets to impinge on microscope slides.



Figs. 1, 2 and 3.—Droplet spectra from different machines, as noted.



FIGS. 4 and 5.—Droplet spectra from different machines as noted.



FIGS. 6 and 7. Droplet spectra from different machines as noted.

o those with unsuitable spectra, i.e., the California exhaust generator, the California fog generator, and the Insect-a-Fog. The fog from the latter three machines had its greatest optical density at the top of the cloud which remained visible for many minutes and several miles, as it gradually gained altitude at the rate of about 40 ft. per mile. The lower part of the visible portion of these clouds did not descend to the ground for at least 100 yards downwind, and it is noteworthy that with both the California exhaust and the California fog generators no reduction was obtained in the first 100 yards downwind. The fog from the TIFA and Venturi exhaust generators hugged the ground and became invisible after traveling 0.25 mile; it was a characteristic of both machines that the vegetation immediately in front of the muzzle appeared to "reek" as the droplets entered the vegetation and gradually left it again some time after the main cloud had passed.

The reduction obtained with the mist-blowers was high in the Merced field and low in the Planada field. Naturally the greater reduction is obtained at 100 yards;

in the last 200 yards the landing rate is reduced by half, since the spectra contain a certain proportion of fine aerosol droplets, but there is no reduction where the mosquitoes are presumably resistant.

OBSERVATIONS AND CONCLUSIONS. 1. The California exhaust generator, the California fog generator and the Holmes Insect-a-Fog produce droplet spectra which are less satisfactory than those produced by the Venturi exhaust generator, the Alaska aerosol atomizer, the TIFA, and the Husman pneumatic sprayer.

2. Wind conditions in the San Joaquin Valley are very suitable for applying aerosols, since the wind is almost constantly from the northwest, with a typical speed of 4 to 5 m.p.h. in the early morning and evening.

3. Convection conditions in the San Joaquin Valley are very unsuitable for applying aerosols, since a high lapse rate obtains throughout the day; it disappears only 30 minutes before sunset and reappears 30 minutes after sunrise.

4. Biological conditions in irrigated fields of the San Joaquin Valley appear unsuitable for aerosols. *Aedes nigromaculis* was observed to harbor in the grass and rice; true aerosols, and certainly smoke, would pass over this harborage, particularly when protected by levees.

5. At sublethal dosages of 0.18 lb. DDT per 100 yd. frontage, aerosols obtain an average of 50 per cent reduction of *A. nigromaculis* for 400 yards distance downwind of the generator. In a population of this species which was presumed to be resistant, a reduction of only 25 per cent was obtained.

6. For the above reasons, mist-blowers traversing at 200 yd. crosswind intervals, and discharging droplets into the herbage at a distance, would probably give better results than aerosol generators at 400 yd. intervals. On leveed fields it would appear that air-spray is the only sure method of reaching the target.

ACKNOWLEDGMENTS. This work was accomplished with the able and arduous cooperation of J. R. Holten, of the Bureau of Vector Control, J. L. Mallars, of the Contra Costa County Mosquito Abatement District, L. E. Myers, Jr., and J. O. Stivers, of the Merced County Mosquito Abatement District, and other personnel of the Merced and other Mosquito Abatement Districts. The authors are indebted to the Entomology Division, Science Service, Canada Department of Agriculture, through C. R. Twinn, Head, Veterinary and Medical Entomology Unit, Ottawa, Canada, for making possible the participation of the senior author in this work.

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APPENDIX

Descriptions of machines assessed for physical and biological performance.

Venturi Exhaust Generator: An attachment 20 inches long and 1.2″ diameter affixed to the exhaust of a Jeep travelling at 6 m.p.h. in low gear, low range with the engine operated at 2,000 r.p.m. The Venturi throat is 0.5 inches in diameter. Delivery is gravity-fed through a ¼″ pipe (.364″ I.D.) ending at the throat, controlled by a ¼″ gate valve. The delivery rate employed, sufficient to give an 0.1″ creep-back at the muzzle, is 18 g.p.h. with diesel oil. This unit has been described as the Jeep Exhaust Venturi Aerosol Generator by Jones and Holten (1949).

California Exhaust Generator: An attachment 25 inches long, consisting of a generating chamber of 1¼″ pipe (1.38″ I.D.), a constriction of ¼″ pipe (.364″ I.D.), and an expansion chamber o tandard 2″ pipe (2.067″ I.D.) is affixed o the Jeep as above. The insecticide is mitted from a ⅛″ pipe (.269 I.D.) open ng at the constriction, and is controlled as bove. The delivery rate, sufficient to allow drip of 1 drop per second from the muzzle, is 9 g.p.h. with diesel oil. This generator has been described, as the California Ground Thermal Aerosol Generator, by Raley (1947).

California Fog Generator: An assembly veighing 200 lbs. carried on a truck, consisting of a 3½ h.p. gasoline engine, an air blower, a combustion chamber, and 2 hermal fog units. Each fog unit is 30 nches long, and consists of a generating hamber 2.067 inches in diameter, a contriction 1.38 inches in diameter, and an xpansion chamber 2.067 inches in liameter; the insecticide is pumped hrough a .269 inch tube into the contriction. Both fog units arise from a combustion chamber in which gasoline is urned and into which it is pumped at o p.s.i. The blast of air to be heated is upplied from a 20 c.f.m. blower and attains a temperature of 1000° F. in the fog ead. The emission rate with diesel oil, djusted to a drip at the muzzle of 1 drop er second, is 30 g.p.h. This generator as been described as the Plumber's Nightmare King Size, by Raley (1952).

Holmes Insect-a-Fog: This thermal generator consists of a 7½ h.p. gasoline engine, 350 c.f.m. blower, a combustion hamber, and a special thermal fog head; t weighs 675 lbs. The fuel is propane as, supplied at 20 p.s.i., which heats the ir to 1000 degrees F. The insecticide is umped at 7 p.s.i. into the fog-head, and he fog then passes through an expansion hamber before being emitted in a fixed orizontal direction. The emission rate vith diesel oil with the metering valve a alf-turn opened, as employed in antimosquito fogging, is 35 g.p.h. The nachine is made by Liquified Gas Engineering, 2932 North Wilson Way, Stockon, California.

Alaska Aerosol Atomizer: Attachments onsisting of 12-inch sections each containg 16 atomizing points. At each of these points a 2.7 mm. tip emits the insecticide opposite a 5.4 mm. air orifice. The insecticide is aspirated along a 0.375 inch supply pipe, off which the tips are tapped; the air is brought in through a 0.5 inch supply pipe, in which the orifices are bored. When two sections are supplied with air at 40 p.s.i. from a 33 c.f.m. compressor (1 c.f.m. per tip), diesel oil is emitted at 6 g.p.h.; thus 15 g.p.h. could be obtained with the 5 sections employed. The atomizer was supplied for testing by Mr. Charles Wilson, Public Health Research Center, Anchorage, Alaska. This device has not previously been described in "Mosquito News"; therefore, photographs are included.

Small California Mist-Blower: This unit consists of an 8 h.p. gasoline engine, an air-blower, a 17 c.f.m. compressor, and a set of nozzles. The insecticide is pushed at 15 p.s.i., and air at 20 p.s.i. atomizes it, at 6 air-mix nozzles (Spraying Systems 40100 fluid, 120–6–35–60 air). These nozzles are arranged in two opposed banks of 3 each along the long side of the 8 by 10 inch blower case. The case is elevated at an angle of 45 degrees with the horizontal, and the air-stream issues at 50 m.p.h. with the engine at 2400 r.p.m. This machine was made by the Merced County Mosquito Abatement District to be bolted on a truck, and emits diesel oil at 48 g.p.h. See photo herewith.

Large California Mist-Blower: The unit consists of a 13 h.p. gasoline motor, an air-blower, a 33 c.f.m. compressor, and a set of nozzles. The insecticide is pushed at 40 p.s.i., and air at 50 p.s.i. atomizes it, at 6 air-mix nozzles (as above) arranged regularly around the 14 inch muzzle of a circular blower pipe, baffled internally and adjustable to any angle from the vertical. The air blast issues at 80 m.p.h. This machine, mounted on a truck, has been adapted by the Merced County Mosquito Abatement District from a commercially made mist blower. See photo herewith.

In addition to these 7 machines, not previously tested by these methods, the following 2 machines were used. They had been previously tested by Brown and Watson (1953).

TIFA: The Todd Insecticidal Fog Generator was operated with the insecticide pressure at 25 p.s.i., the fuel pressure at 60 p.s.i., and the particle size selector at 11; the emission rate with diesel oil was 20 g.p.h.

Husman Pneumatic Sprayer: This machine is described in detail by Husman (1953). It was run with the insecticide at 17 p.s.i. and atomized at 25 p.s.i.: the emission rate with diesel oil was 20 g.p.h.

SOME NOTES ON THE BEHAVIOR OF FOURTH INSTAR *ANOPHELES QUADRIMACULATUS* SAY (DIPTERA, CULICIDAE)

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Information on the behavior and activities of normal insects is necessary for properly evaluating their responses to many physiological and toxicological stimuli, yet, so far as the writer is aware, no one has given a complete qualitative descriptive list of the larval activities for even a single species of the Culicidae. Hocking's paper (1953) on *Aedes communis* seems to come closest to giving such general information. Many isolated observations on different species of Culicidae are scattered in the literature, and much of this information has been reviewed by Bates (1949) and Hopkins (1952). Many activities of mosquito larvae do not seem to lend themselves to a quantitative approach. Others, e.g. reflex diving, are more readily subjected to experimental analysis. There are a number of excellent quantitative studies on larval responses to a variety of stimuli, notably those of Ivanova (1940), Thomson (1940), Folger (1946), and Thomas (1950).

The present notes are concerned with qualitative descriptions of the behavior and activities of normal fourth instar *Anopheles quadrimaculatus* Say under more or less uniform, and hence highly artificial, laboratory conditions. The data are assembled partly from detailed notes taken from controls in current experiments dealing with the effects of salts, drugs, and poisons on various organ systems in fourth instars. The information is also based on numerous observations made from time to time during the four-year period in which this species has been under study in this laboratory. However, no attempt has been made to elucidate any of the complex factors involved in the behavior observed. Quantitative data on some of the activities listed in these notes will be given in a subsequent series of papers that deal with physiological responses to abnormal stimuli.

Methods. The larvae of *Anopheles quadrimaculatus* were reared as described by Peffly *et al.*, (1946).

[1] The author is indebted to Mr. J. L. Scheltema for valuable suggestions in connection with this work.

[2] Laboratory of Tropical Diseases.