THE PRESENT STATUS OF LOW VOLUME (LV) AIR SPRAYS FOR CALIFORNIA MOSQUITO CONTROL

W. E. BURGOYNE, N. B. AKESSON, T. D. MULHERN, AND K. PHILLIPS [1]

Introduction. Liquid insecticides, widely used by aircraft since the late 1940's, have proved so advantageous over dry materials application that by 1949 more than half the crop acreage treated by air in the United States was with liquid pesticides. Liquid pesticides applications now account for 85 to 90 percent of the acreage treated and are commonly applied as dilute sprays, at rates of one to nine gallons per acre. Aerial sprays have revolutionized pest control over vast acreages of agricultural land.

Public health and vector control agencies entrusted with the task of controlling mosquitoes at minimum cost also use aircraft sprays extensively and have continued to seek control at lower dosage and application rates. Hocking, Yeo *et al.*, (1954) as early as 1953 experimentally controlled tsetse fly with DDT at rates of 0.25 gallon per acre (2 pints per acre). However, even this low rate was reported as ". . . too expensive. . . ." for use in East Africa (Hocking and Yeo, 1956).

By 1962 the Plant Pest and Entomology Division of the United States Department of Agriculture (USDA) in examining research reports from the U. S. and abroad found that certain insecticides controlled grasshoppers as well at 1 pint per acre as at the customary 1 gallon per acre rate (Messinger, 1964). Initial applications made by USDA groups with low volume concentrates (no diluting oil or water added) produced spectacular results and led to extensive tests over the United States against a variety of insects. In 1965 there have been reported successful experiments using low volume concentrate sprays against grasshoppers by F. E. Skoog (1965), cereal leaf beetle by M. C. Wilson (1965) and boll weevil by E. C. Burgess (1965). These few examples represent only a minute representation of the total interest in concentrate spray techniques through the country today.

In California, where public agencies are treating nearly one and one half million acres each year for mosquito control at rates around 1 gallon per acre of emulsifiable water-mixed spray, the abatement districts and the Bureau of Vector Control have been acutely aware of the effective control obtained by low volume airspray applications. Mulhern (1965), reported on experiments using undiluted malathion for control of mosquito larvae as early as October 1963. Results were so encouraging that experiments have continued among the 24 abatement districts in California using aircraft for mosquito larviciding.

The Department of Agricultural Engineering at the University of California, Davis, has for many years cooperated with the California Bureau of Vector Control on problems relating to application methods for dispensing insecticides by ground and air equipment. When contractual funds became available from the United States Department of Agriculture for investigating low volume techniques in mosquito control, the University in cooperation with the State Bureau of Public Health accepted responsibility for a research program in this area. The following, in brief, were the goals of the study:

(1) To test the effectiveness of one or more insecticides that would be adaptable to LV application techniques

[1] Respectively: Research Specialist; Professor, University of California, Davis; Technical Consultant, Bureau of Vector Control, California State Department of Health; and Technician, University of California, Davis.

(2) Design LV application equipment for both fixed-wing aircraft and helicopters.
(3) Evaluate the data obtained and the effectiveness of the LV technique in California mosquito control
(4) Develop guidelines and cost data for managers and pilots using low volume operationally

Methods and Materials. The majority of the aircraft used in California mosquito control are low wing monoplanes with 235 hp engines. Although conventional spray systems can be modified for LV (American Cyanamid, 1965) and several pressurized tank designs have been constructed (Glancy *et al.*, 1966), an electric motor-driven pump was chosen for its light weight and simplicity. In California, the Industrial Safety Commission must inspect and approve all pressure tank installations, sometimes involving delay. Although Federal Aviation Agency regulations permit considerable modifications of agricultural aircraft, the system developed for this experimental installation was certified by the FAA as a preliminary to recommending its use by mosquito abatement districts.

Since the tests to be carried out were planned as the basis for specific recommendations to operating agencies, several standards were adopted for the installation:

(1) There should be no tanks, lines, or pumps in the cockpit
(2) No pressurized tanks were to be used
(3) The aircraft electrical system should have sufficient capacity to drive the electric pump without overloading
(4) The boom operating pressure should be readily adjustable from 5 to 50 psi
(5) All parts should be readily available to facilitate service and replacement

A Piper Pawnee 235 aircraft was leased for the 1966 tests.[2] A short boom of ⅜ inch dia. brass tubing was fabricated and mounted on the trailing edge of the wing (Fig. 1). The mounting was designed so the boom and nozzles could be turned from straight back to 45 degrees forward and downward. A pressure hose connected the boom to an 8-gallon aluminum supply tank mounted inside the fuselage between the standard hopper and the firewall (Fig. 2). The pump used was an Oberdorfer bronze gear pump with a capacity of 2 gallons per minute, driven by a 1/10 horsepower 12 V D.C. motor, rated at 11.3 amperes. An Air Force surplus motor was used because a satisfactory new unit at a reasonable price could not be located. The pump and motor are located below the tank. The plane was rewired to accommodate a 50-amperes generator.[3]

This spray equipment is adaptable for helicopters. However, the rotor-craft used in these tests were available for short periods only, so the standard pump and boom were retained and modified by adding a boom-end fluid by-pass. Both Spraying Systems and Delavan 80 degree flat-fan nozzles were satisfactory. Most of the tests used nozzles equivalent to the SS 8001 to 8005 series. Twenty-four plots were sprayed: 13 in irrigated pastures, 7 in rice fields, and 4 over the lagoons of a sewer farm. The last four plots are not recorded in the tables.

The mode of operation in making these tests was as follows: A mosquito breeding area was selected in cooperation with the local mosquito abatement district. A technician employed on the project would survey the area the day before the arrival of the spray plane, selecting a representative 20-acre plot. Three replicated prespray larvae counts were made, each by dipping ten times at three-pace intervals along a line at right angles to the path of flight.

The pre-counts were made early in the morning of the day before spraying. On the afternoon of the same day the plane

[2] The "Pawnee" aircraft was leased on generous terms from Mr. Les Jones, Alaska Transportation Co., San Jose, California.

[3] We are grateful to Manager Oscar V. Lopp and aircraft mechanic George Allen of the Merced Mosquito Abatement District for making the LV conversion of the "Pawnee" aircraft.

FIG. 1.—Piper Pawnee 235 fitted with 25 foot, ⅜ inch trailing-edge low volume spray boom.

would be flown to an airport near the test area and there loaded and calibrated. The next morning the plot was sprayed, usually at dawn in conditions of minimum wind. Most swath runs were flagged. Twenty-four hours after spraying the field was again dipped and counted.

The plane was flown at 90 miles per hour with one notch of flap. Altitude was 12–14 feet and the dosage was calculated on the basis of a 70–80 foot swath. Graph 1 illustrates the patterns obtained with two modes of operation: with flaps up and with flaps down. Allowing for a difference in rate due to a clogged nozzle, there was little variance between the two patterns. The small boom and internal pump much improved the performance of the aircraft, and using one notch of flaps made it easier for the pilot to hold his speed.

Nine nozzles were located on the boom in an asymmetrical pattern of three to the left of the center line and six on the right side. However, better arrangements may be possible. The swaths produced by aircraft, even of the same make and model, should be individually evaluated to insure adequate distribution of the spray material.

Malathion was used on the first plots treated to obtain base-line data. However, because of resistance to malathion in the Central Valley, most of the spraying was done with fenthion (Baytex), using the California Mosquitocide seven pound formulation, and Dursban (o,o-diethyl o-3, 5, 6-trichlora-2 pyridyl phosphorothioate), a broad spectrum insecticide (Budwig and McNeil, 1966) not at present on the market.

RESULTS AND DISCUSSION. The first objective was to obtain base line data on LV techniques using malathion as recommended by the manufacturer. The aircraft available at the start of the investiga-

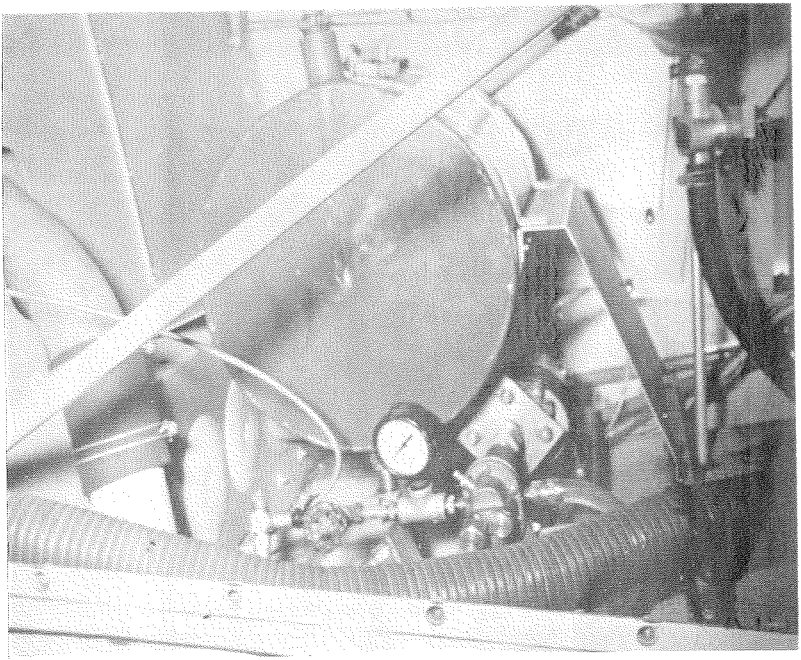


Fig. 2.—Low-volume spray tank, 1/10 hp. electric motor, and two gallon per minute gear pump mounted in Piper Pawnee 235 between firewall and hopper.

tions was a Hughes Ag 300 helicopter equipped with a 26-foot boom and two 60 gallon Agavenco spray tanks. Malathion at 10.2 fluid ounces per acre was applied to nine plots through six SS 8001 flat fan nozzles. Airspeed was 60 mph, altitude 10–12 feet, and the swath was measured at 72 feet. Table 1 gives the results.

At Tulare, where a tolerance for malathion has been previously demonstrated by the mosquitoes, larvae controls of 90, 88 and 34 percent were obtained. When malathion was applied in Merced, where no resistance has been reported, larvae kill was 100 percent on all plots, the differences being attributed to the degree of resistance in that area (Womeldorf). The malathion applications were made under conditions of almost no wind; however, it is of interest that Baytex applications were successful when made in a quartering wind of more than 5 miles per hour. Graph 2 illustrates the distorted "polliwog" shape that only a slight side wind can give to the LV swath. Although experimental flying in conditions of little or no wind is preferred, the fact that LV applications can be successful, disregarding the effects of drift, has been kept in mind for future investigation.

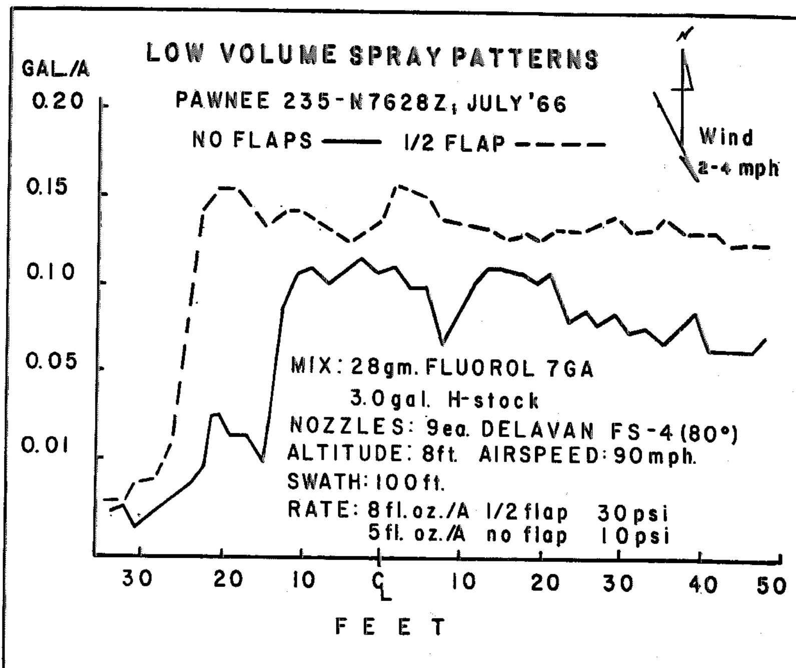
In 1966, several successful applications were made with the Merced Mosquito Abatement District's Bell Ag-5 helicopter at an application rate of ½ gallon per acre. The district reports that this rate and the spray boom and nozzle arrangement tested were used successfully for the entire season.

Concern that LV applications may increase the drift hazard prompted Yates and Akesson (1963) to include a comparison of low volume and normal application

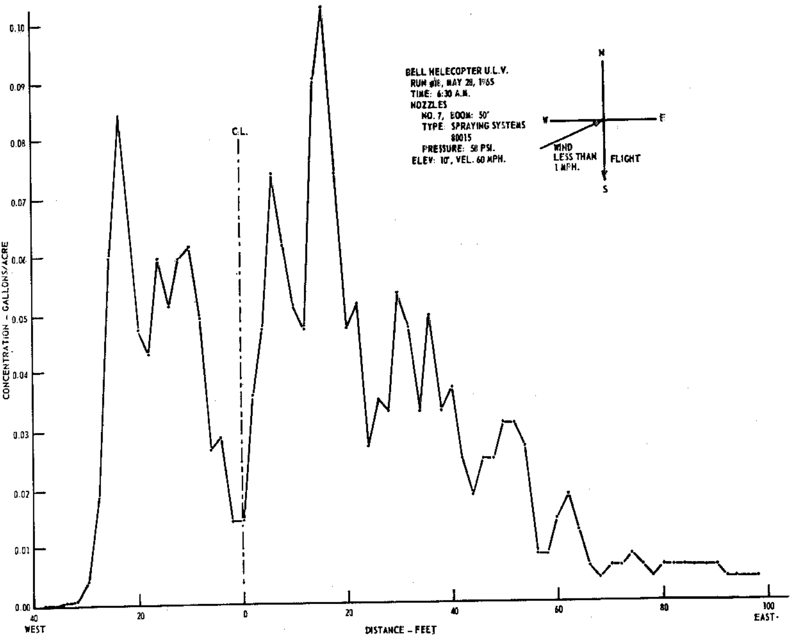
TABLE 1.—Low-volume plots made over irrigated pasture with Bell AG-5 and Hughes AG 300 helicopters.

Date	Aircraft	Location	Chem.	Dose (1)	Rate (2)	Swath	Larvae kill
		Irrigated pasture, helicopter · Hughes Ag 300/Bell A-5					
9/65	Hughes	Tulare	Mal (3)	0.1	10.2	60 ft.	98, 88, 34 %
9/65	"	Merced	"	"	"	"	100
9/65	"	Tulare	Bay (4)	"	"	"	100
5/66	Bell	Merced	Mal (5)	0.375	1/2 gal.	100	90
7/66	"	"	Dur (6)	0.05	"	80	100

(1) Pounds/acre (2) Fl. oz./acre
(3) Malathion 10 lb.
(4) Baytex 8 lb.
(5) Malathion 5 lb. emulsion
(6) Dursban 4 lb.



GRAPH 1.—Low-volume spray pattern obtained with Piper Pawnee 235 spray plane flown at 90 mph with no flaps and one notch of flap.



GRAPH. 2.—Low-volume helicopter spray test pattern, illustrating the downwind drift of spray under conditions of very low wind.

rates (8.9 gallons per acre) in their 1965 drift evaluations. Graph 3, plotted on log-paper, indicates that Ethion applied at 0.16 gallon per acre (1.3 pints per acre) resulted in drift residues at least five times greater at all downwind stations than methoxychlor applied at a rate of almost nine gallons per acre.

Irrigated pastures are probably the most prolific mosquito sources in the San Joaquin Valley, and rice fields are the most important sources in the Sacramento Valley. In 1966, after several unsuccessful early season starts using methyl parathion in areas where the mosquitoes were resistant, fenthion and Dursban were substituted. The Pawnee was flown at 90 mph with the boom at a height of 12–14 feet, producing a swath 70–80 feet wide. Later in the season a swath 125 feet wide was obtained when flying at an altitude of 25–30 feet; however, more work needs to be done under a variety of wind conditions before swaths over 100 feet can be recommended for "Pawnee" and similar aircraft. In all plots the rates applied were kept as near to 8 fluid ounces per acre as possible, and the dose applied was 0.1 pound per acre for fenthion and 0.05 lb. per acre for Dursban.

Table 2 shows that success against larvae in pastures with both fenthion and Dursban was almost complete using the 70–80 foot swath. When three applications were made over the same rice field during the month of August, a pattern of success and failure began to appear (Table 3). The first spraying was done on August 2, using the same procedures employed over the pastures: i.e., boom pressure of 25 psi., 80-foot swath, and FS-4 nozzles (equivalent SS 80015's, pointed straight down. The mortality recorded was only 50 percent. For the second spraying on August 15, the pressure was reduced and the nozzles were pointed back to obtain maximum

TABLE 2.—Low-volume test plots sprayed by Piper Pawnee 235 aircraft over 20-acre test plots in irrigated pasture.

Low volume spray plots, irrigated pasture—Pawnee 235 aircraft—1966

Date	Location	Chemical	Dose (1)	Rate (2)	Pressure	Swath	Altitude	Kill % (larva)
6/27	Kern Co.	M- para	0.1	1/2 gal.	40 psi	70 ft.	7–8 ft.	75%
6/29	"	Baytex 8 lb.	0.1	8.0	42	75	30	100
6/30	"	Mosq.	0.1	8.0	42	75	8	100
7/11	Tulare	"	0.15	12.2	50	80	12	100
7/13	"	"	0.1	8.0	25	80	12	100
7/21	Merced	DUR	0.05	8.0	25	80	12	100
8/21	Firebaugh	"	0.1	8.0	25	70	14	100
8/22	Tulare	Mosq.	0.1	5.0	10	70	14	100

(1) lb./acre (2) fl. oz./acre
M- para = methyl parathion
Mosq. = fenthion 7 lb.
DUR = Dursban 4 lb.

TABLE 3.—Low-volume test plots sprayed by Piper Pawnee 235 aircraft over 20-acre test plots in rice.

Low volume spray plots, rice—Pawnee 235 aircraft—1966

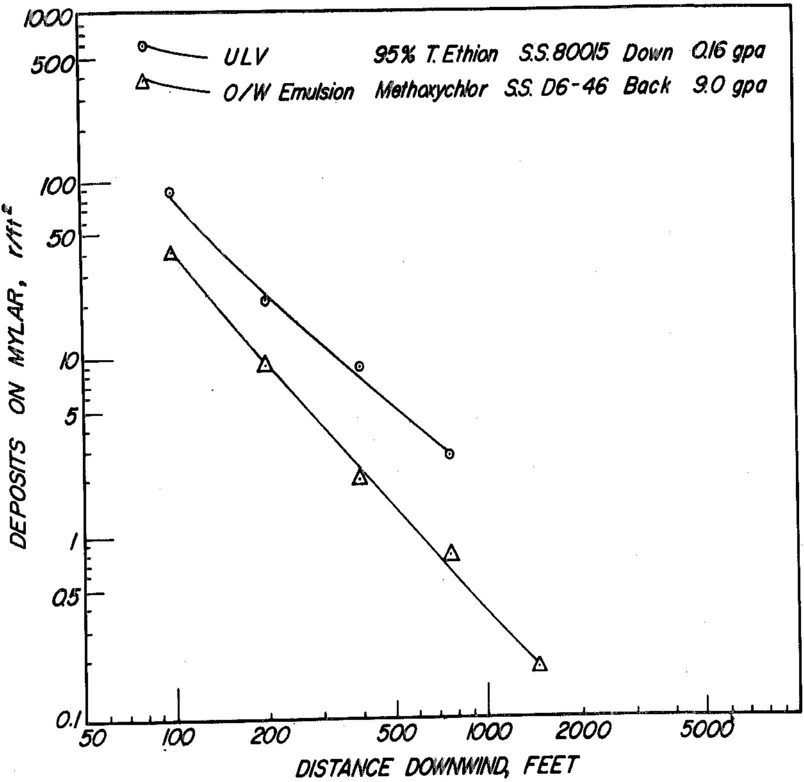
Date	Location	Chemical	Dose (1)	Rate (2)	Pressure	Swath	Nozzles	Kill %
8/2	Firebaugh	Mosq.	0.1	8.0	25 psi	80 ft.	down	50
8/15	"	"	"	6.6	20	"	back 45°	50
8/29	"	"	"	8.0	37	"	forward 45°	70
8/24	Colusa	"	"	8.5	30	"	back 45°	100
9/1	"	DUR	0.05	6.5	40	"	" "	100
9/9	"	"	"	9.2	38	"	down	100
9/9	"	"	"	"	"	"	"	100

(1) lb./acre (2) fl. oz./acre
Mosq. = fenthion 7 lb.
DUR = Dursban 4 lb.

sized droplets that we hoped might penetrate the now dense stand of rice to the larvae infested irrigation water. Again the kill obtained was only 50 percent. For the final application on August 29, the nozzles were turned forward and down, at forty-five degrees, and the boom pressure was increased for small droplets (Yates *et al.*, 1966). The resulting kill of 70 percent represented a decided improvement, for by this time the rice had "headed out" and the stand was very dense. A week before harvest a representative of the pesticide manufacturer cut samples of the rice for analysis. No residue of fenthion was found in the grain and only 0.03 parts per million on the straw (Denning).

The staff of the federal game refuge in Colusa, California, allowed us to apply a series of plots to rice fields cultivated for duck food. One hundred percent control was obtained with both fenthion and Dursban at pressures near 40 psi (Table 3).

The size of the drop produced by the nozzle or spinner device is of critical importance to the technique of low volume spraying. Work in the rice at Firebaugh indicated that spray droplets must be small enough to penetrate a dense crop without impinging on the plants, yet must not be so small as to drift indefinitely. Graph 4 illustrates the range of drop sizes that are produced when an oil solution is sprayed into a moving airstream. Curves for the flat fan nozzles USDA 8002 and UNIV



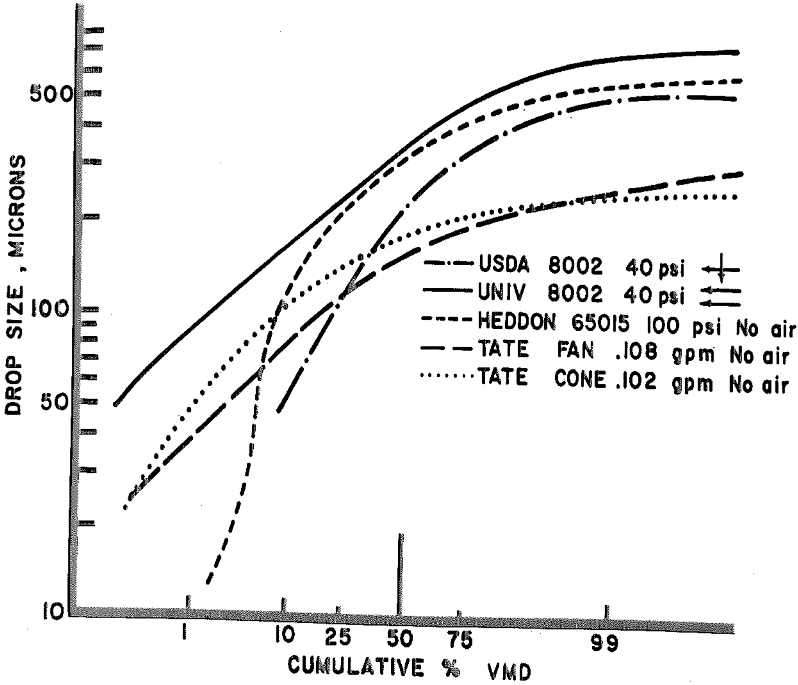
GRAPH 3.—Illustrating the increased downwind drift deposits recovered from Mylar after comparable aircraft spray applications at normal (9.0 gpa) and low volume applications (0.16 gpa).

8002 display the results of tests with orifice sizes and pressures close to those used in our 1966 field trials. On the cumulative percentage VMD scale, the 50 percent mark is equivalent to the mass median diameter (mmd). The mmd of nozzle UNIV 8002 was above 300 microns, when its flow was directed with the airstream. That of USDA 8002 was reduced to 200 microns when directed at 90 degrees to the airstream.

Spinning screen devices, either air or electric-driven, reduce the mmd of the drops produced to about 100 microns. It is worth noting that conventional flat spray nozzle and spinners produce substantial percentages of large drops that easily impinge on plane surfaces, as well as very fine droplets subject to excessive drift.

CONCLUSIONS. Tables 2 and 3 indicate that the key to successful spraying for mosquito larvae is penetration of the pesticides through the crop or weed canopy that covers the standing water. Results of tests on the rice plots at Firebaugh (Table 3) suggest that droplets too small to easily impinge on plant surfaces (drops under 100 microns mass median diameter) are best; however, the majority of the spray must be above the size of fog droplets (10 microns mmd) in order that swath and drift can be controlled.

The 1966 experiments appeared to confirm the view that the low volume tech-



GRAPH 4.—Illustrating the differences in the range of droplet sizes obtained with standard spray nozzles (USDA B 002, Univ. B 002) when the nozzle is placed with the airstream and at 180 degrees to the airstream.

nique is a valuable new tool for mosquito control. The test plots were small and it is not yet feasible to estimate accurately what the saving in time and money is for the operator switching to LV, but there is no doubt that it can be considerable. Mosquito abatement districts in California are beginning to order new aircraft with LV equipment installed in addition to the conventional spray gear, and it may be only a matter of a short time until this method of spraying comes into general use. However, operators who may employ this promising new technique must consider its limitations, and must take extraordinary care to avoid undue drift. It is important that the research and development of new pesticides and formulations keep pace with the techniques for application.

References

AMERICAN CYANAMID COMPANY. 1965. A new concept in aerial insecticide application.

BURGESS, E. C. 1965. The control of boll weevil with technical malathion applied by aircraft XI. Journal of Economic Entomology 58(3).

DENNING, D. G. Chemagro Corporation, Kansas City, Mo. Personal communication.

GLANCEY, B. M., WHITE, A. C., HUSMAN, C. N., and SALMELA, J. 1966. Low volume applications of insecticides for control of adult mosquitoes. Mosq. News 26(3):356–359.

HOCKING, K. S., and YEO, D. 1956. Aircraft applications of insecticides in East Africa VI. Bulletin of Entomological Research 47(4):631–644.

———, ———, and ANSTEY, D. G. 1954. Aircraft applications of insecticides in East Africa VI. Bulletin of Entomological Research 45(3):585–603.

LUDWIG, P. D., and MCNEIL, J. C. 1966. Results of laboratory and field tests with dursban insecticide for mosquito control. Mosq. News 26(3):344–351.

Messenger, K. 1964. Low volume aerial spraying. Agr. Chem. 19(9):61–64.

Mulhern, T. D., Gjullin, C. M., Lopp, O. V., Ramke, D., Frolli, R. F., Reed, D. E., and Murray, W. D. 1965. Low volume airplane sprays for the control of mosquito larvae. Mosq. News 25(4):442–447.

Skoog, F. E. 1965. Ultra low-volume aerial spraying of dieldrin and malathion for rangeland grasshopper control. Journal of Economic Economology 58(3).

Wilson, M. C. 1965. Low volume concentrate sprays applied by aircraft for the control of cereal leaf beetle. Journal of Economic Entomology 5B(1).

Womeldorf, D. J., and Gillies, P. California Bureau of Vector Control. Personal communication.

Yates, W. E., and Akesson, N. B. 1963. Fluorescent tracers for quantitative microresidue analysis. Transactions of the American Society of Agricultural Engineers 6(2).

———, ———, and Coutts, H. H. 1966. Drift hazards related to ultra low-volume and diluted sprays applied by aircraft. Transactions of the American Society of Agricultural Engineers (in press).

VEHICLE MOUNTED ASPIRATORS[1]

W. L. Bidlingmayer and J. D. Edman

Most mosquitoes are nocturnal and most sampling methods require mosquitoes to be in flight. Examination of collections made by different methods showed blood-engorged females, and those maturing eggs, were not taken in expected numbers. Presumably, these females had little need to fly. Many species rest in ground litter during daylight hours. A collection obtained here at this time should sample the whole population and reflect its actual composition more closely than methods which capture only flying mosquitoes. For this purpose, the use of large aspirators was investigated.

Power vacuum equipment has been used by entomologists to sample insects in the field for many years (Hills, 1933; Johnson *et al.*, 1957; Dietrick, 1961). Basically, each device consisted of an intake, a flexible suction hose, a mesh bag for holding the catch, a blower or fan, and a power source. Most models were carried manually, and collections made from vegetation, ground litter, and other habitats. Van den Bosch *et al.* (1959), used a large truck-mounted aspirator for collecting aphid parasites.

Mosquito numbers are often low, and when small aspirators are used, the desired numbers may not be obtained. In addition, the operator may bias the sample by his operating technique and also by serving as an attractant. Our program required a sampler that would provide large numbers daily with a minimum of human error. A large, vehicle-mounted aspirator would rapidly sample extensive areas and, since the operator's only function was to drive, the area would be sampled in a similar manner each time.

Most details will be omitted in the following description of two different models. In designing and construction, many decisions were made without preliminary tests and a number of variations of our designs would undoubtedly be satisfactory.

The vehicle aspirator consists of a rigid transparent intake, a screen cone with a net bag at the apex, a flexible rubber hose, and a blower powered by the vehicle. The larger model was mounted on a 4-wheel drive Willys Jeep (Fig. 1). The intake consists of two sections; one a heavy (2″ x 2″ x ¼″) angle iron frame 36″ wide and 30″ deep mounted beside the left front wheel (A). A forward extension along

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