residual effect is of sufficient duration to control first generation *Aedes*. However, further research should be conducted to determine more precisely the amount of residue and the duration of its effectiveness, resulting from application of 1.0 lb./acre and lower dosages, of methoxychlor.

EVALUATION OF A FUSELAGE-MOUNTED SPRAY BOOM FOR ULTRA-LOW VOLUME APPLICATION OF INSECTICIDES FOR MOSQUITO CONTROL [1]

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Ultra-low volume (ULV) application of insecticides, that is, the application of undiluted insecticide or highly concentrated formulations (>20%), has made possible the development and use of smaller and more compact aerial spray equipment. Examples are the compressed air systems described by Dearman *et al.* (1965) and Glancey *et al.* (1966) and the electric motor-driven pump system of Burgoyne *et al.* (1967). Also, we designed a system similar to that of Burgoyne *et al.* and operated it off a 12-volt battery so that a tie-in to the electrical system of the aircraft was not necessary. This system proved portable and adaptable and was used on a UH-ID helicopter by Lofgren *et al.* (1968) in Panama in tests for control of anopheline mosquitoes. The spray rigs just described depend on a conventional spray boom affixed to the wings of the aircraft which necessarily limits them to planes already equipped for aerial spraying (or requires the installation of a boom). Theoretically wing booms function primarily as a means of getting the insecticide spray into the vortices of air produced at the wing tips so wider swaths can be attained.

During our studies in mosquito control, we have concluded that wing booms, at least on larger aircraft, might be unnecessary with the ULV technique provided small droplets (<100 microns) are produced. This conclusion is based on the following reasoning. Control of adult mosquitoes is usually carried out in locations such as residential areas and marshland wildlife refuges where larger dosages of insecticide that give long residual control are objectionable. With the low doses that are required in these areas, control depends primarily on direct contact of the insecticide spray droplets with the mos-

[1] Mention of a proprietary product in this paper does not constitute an endorsement of this product by the U.S.D.A.

quitoes. Good examples of this approach are the thermal and pneumatic aerosol generators so commonly associated with mosquito control. These generators produce fine insecticide droplets [mass median diameters (mmd) <20 microns] that are carried by the wind through the infested area. Application rates as low as 0.01 lb./acre can be utilized. From these facts we concluded that wing booms carrying various configurations of nozzles would have little importance if the spray from aircraft was atomized finely enough so that it would drift in a similar way through an infested area. If this reasoning was correct, swaths as wide as, or wider than, those delivered with wing booms and coarse sprays could be obtained with a short boom stationed directly under the aircraft. In addition, the elimination of the wing booms would make both the aircraft and the spray equipment more versatile and adaptable.

We, therefore, designed a spray rig with a fuselage boom and began tests to evaluate its effectiveness. All tests of the rig were made with technical malathion delivered at a rate of 3 fl. oz./acre.

DESCRIPTION OF SPRAY RIG. Two slightly different spray rigs were designed. The primary rig was mounted in a DC-3 aircraft owned by the Lee County Mosquito Control District at Ft. Myers, Florida and consisted of a surplus military fuel transfer pump driven by an EEMCO D-378 electric motor (28 volt, d-c, 75 ampere) that pumped the insecticide from a tank (a used 9-gal. refrigerant can) to a boom consisting of a 1-in. galvanized pipe 20 in. long with fittings for 5 nozzles. The boom was connected to the pump by 6 feet of 1-in. galvanized pipe and a short piece of rubber pressure hose. A cutoff valve was placed in the line between the tank and the pump and the unit was placed in the rear of the aircraft forward of the cargo doors. The boom extended 30 in. below and about 6 in. to the left of the midline of the fuselage just aft of the cargo door. The pipe carrying the insecticide to the boom was clamped to the top of one of the frame girders and to the bottom of the adjacent girder and it extended through an inspection hole in the floor of the plane. TeeJet® nozzles with No. 6515 or 8008 tips were mounted on the boom facing forward at a 45-degree angle.

A secondary system (See Figs. 1 and 2)

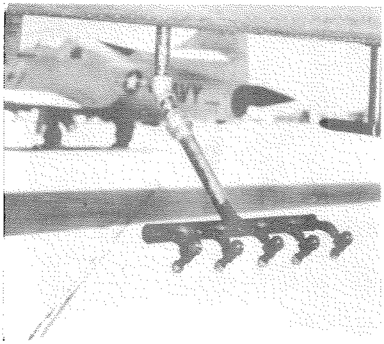

FIG. 1.—Fuselage-mounted boom on Navy C-117 aircraft. Pipe extends through inspection hole in rear of aircraft near cargo door.

was mounted in a Navy C-117 aircraft at Cecil Field, Jacksonville, Florida, and used in tests near Gainesville, Florida. This unit differed from the primary unit in that the section of pipe connecting the pump and the boom was altered so that it could be lowered in flight to a distance of 5 feet below the fuselage (Fig. 3). This change was made by welding 2 flanges (1 x 1 in.) 5 ft. apart to the section of pipe between the boom and the rubber pressure hose. Then a ½-in. hole was drilled through each flange, and the pipe was held in 2 steel plates bolted together, one above and one below two girders in the floor of the plane and directly over one of the inspection plates in the bottom of the fuselage. Also, a hole shaped like a keyhole was cut into the center of both plates; the pipe, including the flange, could be moved up and down through the plates and through the fuselage when

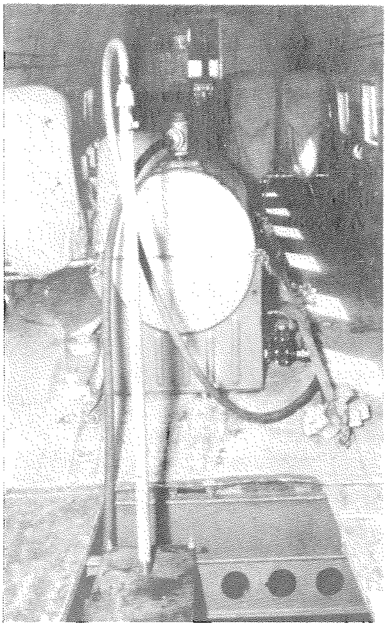

FIG. 2.—Fuselage-mounted spray system in Navy C-117 aircraft. Section of floor is removed, and pipe for insecticide is mounted in 2 steel plates affixed above and below the girders in the floor of the aircraft. Pump is located to the right and at the base of the cradle that holds the tank of insecticide.

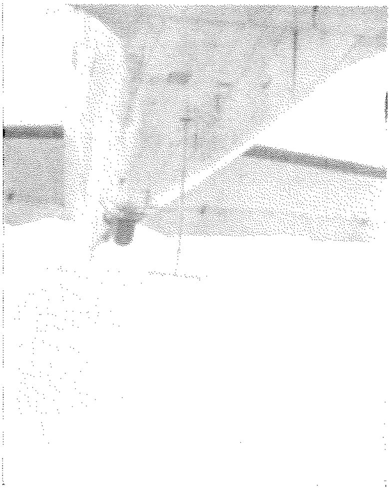

FIG. 3.—Fuselage-mounted spray system in operation with boom in lowered position.

the inspection plate was removed. In addition, two flanges were welded to the top steel plate on either side of the lateral section of the keyhole, and holes were drilled to line up with the holes in the pipe flanges. When all 3 flanges were aligned, a bolt was used to hold the pipe and boom in place. A safety bar was welded at a right angle to the top of the pipe to prevent it from being accidentally dropped through the holes in the plates during flight. Figure 3 shows the boom lowered beneath the plane during a test flight.

FT. MYERS TESTS. Swath width and rate of deposition of droplets were determined by using three different methods of assay: (1) oil-sensitive red-dye cards, (2) fluorescent dye (Patent Yellow C-4) was added to the malathion so the droplets could be collected on 3 x 5-in. blue file cards and counted under ultraviolet light, and (3) caged adult *Aedes taeniorhynchus* (Wiedemann) from our susceptible laboratory colony.

Both types of cards were fastened to 5 x 7-in. plywood panels with rubber bands. In the first tests at an airport near Ft. Myers, the panels were placed 27 feet apart on the ground in a line perpendicular to the line of flight and were picked up 2 hours after each flight. When mosquitoes were used in these tests, they were transported to the test area in large cylindrical screen cages. Then at the time of the test, about 20 to 30 were transferred to screen-wire cages, exposed to the sprays, and then transferred to clean cages that were held in a styrofoam box for 24 hours. Percentage mortality was then recorded. The flights at Ft. Myers were flown at a forward speed of 150 m.p.h. and the pump was operated at 40 psi.

The Ft. Myers tests were conducted primarily to evaluate the equipment and to determine whether the principle involved was sound. Therefore, since swath width should be dependent on wind, we released the insecticide at 300 ft. above ground in the first flight to allow time and space for considerable drift before the spray reached the ground; also, we used three TeeJet nozzles with No. 6515 flat-fan tips. The spray equipment proved adequate, and the release of the insecticide 18 in. below the plane did not deposit insecticide on the tail section of the fuselage. Also, the droplets deposited on the cards by these first flights (one swath) spread over distances of 450–1125 ft. However, the number of droplets collected was low (5.8 droplets/in.^{2} maximum on both types of cards). Moreover, though flights were made when there was little ground wind, the droplets did not fall directly beneath the plane as might be expected; instead they drifted in an apparently unpredictable manner; that is, they did not drift routinely in the same direction as the surface winds. Also, droplet size was not satisfactory because numerous large droplets were found; however, no evaluations of size were made in these tests. Therefore, in the other tests at Ft. Myers, No. 8008 tips were used.

To get a heavier deposition of droplets we decided to fly subsequent tests at an altitude of 100 feet. In one such flight (single swath) the droplets were collected over a distance of 648 ft. and averaged 9.1/in.^{2} (range of 1 to 100/in.^{2}). In another similar flight (5 swaths of insecticide at 500-ft. intervals), the droplets on the oil-red dye cards averaged 13/in.^{2} (range of 1 to 82/in.^{2}), and on the 3 x 5 file cards 19.1/in.^{2} (range of 1 to 121). The attempt to use mosquitoes for evaluation in these tests was hindered by excessive mortality due to factors other than insecticides, so interpretation of the results was difficult. However, the kill did not always correlate with the rate of deposition of droplets; that is, 100 percent kill sometimes occurred when a card adjacent to the cage had only 1 drop/in.^{2}

Gainesville Tests. The test flights at Gainesville were conducted over about 1 square mile of cutover forest land. The plane was flown at an altitude of 100 ft. in 500-ft. swaths at 150 m.p.h. No. 8008 flat-fan tips were used, and pump pressure was 30 psi. In these tests, 20–26 stakes were placed 100 feet apart along a road across the center of the plot. One oil-red dye card and a small cage of mosquitoes were placed at the base of each stake, and a second card and cage were hung on the stake, 2½ ft. above ground. The mosquitoes used in these tests were placed in the screen cages in the laboratory, transported to the field in styrofoam chests chilled with canned ice, and placed at each station about ½-hr. before treatment. In addition, a few cages of mosquitoes were placed in vegetation and bushes and in cardboard boxes (24 x 24 x 24 in.) that were laid on their sides with one-half the top left open. One-half hour after the application, the mosquitoes were transferred to clean cages, returned to the laboratory, and provided sugar-water for food. Mortality was determined after 6 and 18–24 hours.

Also, in the tests at Gainesville, the spectrum of droplet sizes produced by the system in flight was determined by exposing glass slides on stakes about 2½ ft. high; a cascade impactor was used to collect very fine droplets. When the plane was flown over these slides at an altitude of about 50 ft. (swaths 100 ft. apart), the area was flooded with droplets, and the slides collected a fairly representative sample of droplets. Tip Nos. 8004, 8008, and 6515 were evaluated. The mmd's were calculated by the method of Yeomans (1949) for impinged droplets.

The results of the tests are shown in Table 1. Good kill was obtained in the cages hung on the stakes in both tests (97 percent after 24 hr.), but kill at ground level was not as good in the second test (62 percent vs 97 percent after 24 hr.). This may have been because the *A. taeniorhynchus* were larger mosquitoes and perhaps not as susceptible to malathion. The kill of mosquitoes in the boxes and under vegetation or bushes averaged 40–59 percent. In both tests, the rate of deposition of droplets on cards at ground level (11.4 and 13.2/in.^{2}) and on

TABLE 1.—Results of delivering ULV aerial sprays of malathion with a short boom rig mounted on a Navy C-117 airplane based on droplets on cards and mortality of 2 species of mosquitoes.

Test Location	Avg. Percentage Kill (and range) After Indicated No. of Hours: 6	24	Avg. No. (and Range) of Droplets/In.^{2} On Oil-Red Dye Cards
Test 1: against *A. aegypti* (23 locations)			
Ground	97 (48–100)	97 (76–100)	11.4 (0.25–58.0)
On stake	97 (36–100)	97 (44–100)	2.9 (0–15.5)
Inside box	40 (4–96)		
Under vegetation or bushes	56 (4–96)		
Test 2: against *A. taeniorhynchus* (20 locations)			
Ground	55 (8–100)	62 (16–100)	13.2 (1.25–54.75)
On stake	88 (48–100)	97 (76–100)	3.1 (0–15)
Under vegetation or bushes	48 (8–100)	59 (16–100)	

the stake (2.9 and 3.1/in.^{2}) was about the same. However, the number of droplets on the cards on the stakes was probably influenced by the winds which were variable (0–8 m.p.h.) and shifted about 90° during both tests.

Visual observations of the spray revealed that it held together in a narrow band for several seconds after emission from the boom; then it began to settle to the ground and to spread in a visible cloud (against a dark background) about 100–150 ft. wide. As the spray approached ground level, surface winds picked it up and drifted it across the plot.

Results of the tests to determine the spectrum of droplet sizes for the three sizes of flat-fan tips are shown in Table 2. The smallest tip (No. 8004) produced the greatest number of small droplets (mmd 33.6 μ); no droplets more than 100 μ were collected, and about 85 percent were less than 45 μ. The No. 8008 tips produced droplets with an mmd of 50 μ,

TABLE 2.—Spectra of droplets of malathion produced by nozzles with 3 flat-fan spray tips[a] (short boom on a Navy C-117 airplane flying at 150 m.p.h.).

Range of Droplet Size (μ)	Percentage of Droplets in Each Range of Size Delivered by Indicated Tip: 8004	8008	6515	Percentage of Volume of Spray Droplets[b] in Each Range of Size Delivered by Indicated Tip: 8004	8008	6515
5–15	17.1	1.3	17.5	5.2	0.3	3.7
16–30	42.9	32.9	14.1	31.9	16.9	11.8
31–45	24.7	31.8	19.8	31.2	27.0	17.0
46–60	7.8	9.8	11.8	13.6	11.5	13.6
61–75	5.4	12.3	8.0	12.1	18.6	11.8
76–90	2.0	6.3	10.0	5.4	11.6	18.5
91–105	0.2	3.5	3.4	0.6	7.7	7.3
106–120	0	0.8	2.4	0	1.8	5.9
121–135	0	1.3	1.6	0	3.6	4.5
136–150	0	0.3	0.8	0	0.8	2.5
151–165	0	0	1.0	0	0	3.4

[a] Tip size designations are those listed by Spraying Systems Co., Bellevie w, Ill. The first 2 digits indicate the angle encompassed by the spray in ground tests and the last 2 digits the discharge rate of the tips in gal/min of water at 40 psi when a decimal point is placed before the last number.

[b] Mmd's of sprays produced by each tip were as follows: 8004 (33.6 μ); 8008 (50 μ); 6515 (61.6 μ).

and 65 percent were less than 45 μ. The No. 6515 tips produced small droplets (51.4 percent below 45 μ); but they also produced the greatest numbers of large droplets (23.6 percent more than 90 μ). Although these spectra were produced with the boom located about 5 ft. below the plane, recent tests (unpublished data) have shown that similar spectra are produced when the boom is 22 in. below the fuselage.

DISCUSSION AND CONCLUSIONS. The emission of insecticide from equipment mounted under the fuselage is not new. A procedure known as the Porton method (Brown, 1951) depended entirely on crosswinds for swath width. The liquid spray was emitted from an open pipe into the relatively still air below the slipstream of the airplane where it was shattered by the forward velocity with which it hit the air. In tests forward speeds of 150 m.p.h. caused kerosene sprays to break up into droplets ranging from less than 10 μ to as much as 1 mm or more. In a crosswind, the larger droplets were deposited close to the line of flight of the plane but the smaller droplets drifted a sufficient distance to give an overall swath width of 600 ft. (airplane speed 210 m.p.h., height 120 ft.; wind 7.5 m.p.h.).

Our preliminary tests with the fuselage-mounted boom definitely indicate that the system will distribute insecticides adequately enough to provide effective control of mosquitoes, but we cannot yet determine whether it will be as effective as a conventional wing-boom spray system. This information can be obtained only by making large-scale tests against natural populations. However, in the first such tests we have conducted (unpublished data) good control of *A. aegypti* was obtained in residential areas in Thailand with ULV malathion (6 fl. oz./acre) applied from a C-47 equipped with a fuselage-mounted boom. (The airplane in these tests was flown at 150 m.p.h., 150 ft. altitude and 500 ft. swath widths.) Further tests and more information are needed to determine the effect of position of the boom under the plane, tip size, and wind speeds on droplet size and the effect of droplet size on kill of insects.

We do not want to imply that the fuselage-mounted spray system should or can replace conventional aerial spray systems. However, we do feel that it can be exceptionally useful in emergencies when it would be necessary to obtain large numbers of planes to combat vector-borne disease epidemics and insect outbreaks. In such situations, a C-47 could be equipped to apply insecticides in a few hours.

SUMMARY. Tests were conducted with a C-47 aircraft (Navy C-117) equipped with a ULV aerial spray system that used a short boom mounted below the fuselage to dispense the insecticide. Distribution of the insecticide proved to be dependent on operation in crosswinds. Satisfactory distribution of insecticide was obtained over at least a 500-ft. swath. Kill of mosquitoes in cages hung on stakes 2½ ft. above ground averaged 97 percent in square-mile plots treated with malathion at the rate of 3 fl. oz./acre. The mass median diameter of sprays produced by TeeJet nozzle flat-fan tips Nos. 6515, 8008, and 8004 were, respectively, 61.6 μ, 50 μ, and 33.6 μ. The spray system is essentially portable and can be mounted on or taken off a C-47 aircraft in a few hours.

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PHLEBOTOMINE SAND FLIES IN LOUISIANA (DIPTERA:PSYCHODIDAE)[1]

RICARDO ROSABAL[2] AND ALBERT MILLER[3]

Nine species and one subspecies of *Lutzomyia* (split off from the original genus *Phlebotomus* by Theodor, 1932, 1965) are known to occur in the United States, namely, *L. anthophora* (Addis), *L. aquilonia* (Fairchild and Harwood), *L. californica* (Fairchild and Hertig), *L. cruciata* (Coquillett) (=*P. diabolicus* Hall), *L. oppidana* (Dampf), *L. shannoni* (Dyar), *L. stewarti* (Mangabeira and Galindo), *L. texana* (Dampf), *L. vexatrix vexatrix* (Coquillett) (=*P. vexator* Coq.), and *L. vexatrix occidentis* (Fairchild and Hertig).

The only previous report of the occurrence of phlebotomine sand flies in Louisiana is that of Hall (1936), based on two specimens collected on May 25, 1935, by the Civilian Conservation Corps (CCC) Mosquito Survey in a light trap at Ansley, Jackson Parish, in the northern part of the State. The species was identified by Dr. Alan Stone as *Phlebotomus vexator* Coquillett.

METHODS

A systematic search-and-survey was conducted in 1967 and 1968 to determine the presence, identity, distribution, and habits of phlebotomine sand flies in Louisiana. They were sought during daylight hours in natural cavities and hollow interiors of standing trees by inspection with a flashlight and injection of puffs of cigarette smoke or insect repellent spray (deet aerosol from a pressure can) to activate them. (While the spray penetrated hiding places more efficiently and was better for initial detection, it stimulated faster flight than smoke and was less suitable for disturbing the flies to facilitate capture. The flies are recognizable grossly by their small size, form, and characteristic erratic mode of flight.) They were collected by means of a simple aspirator consisting of a glass or transparent plastic tube, 0.5 inch in diameter and 10 to 12 inches long, to which a rubber tube 20 inches long was attached, with a screen barrier in the junction. The live insects were blown into a slightly moistened 4-oz. plaster-lined jar or earthenware pot that was provided with a cloth cover having a central aperture in a

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