dosage, the ratio varying with the insecticide and being greater with the more toxic insecticides. The lower LC_{90} obtained in the laboratory is probably due to better coverage since all the aerosol produced must pass through the cage containing the mosquitoes.

SUMMARY. Against both mosquito species only fenthion, naled, and TH–3461 were appreciably more toxic than the malathion standard; and only Sevin, C–9491, SBP–1382, and EL–400 tested against *A. taeniorhynchus* were less toxic than malathion. SBP–1382, while extremely toxic to *C. nigripalpus*, was considerably less toxic than malathion to *A. taeniorhynchus*. Although not as pronounced as with SBP–1382, a difference in species susceptibility was also noticed with most of the other insecticides tested.

Almost a two-fold reduction in toxicity of naled solutions in kerosene was noted after 10 days. With the exception of dilutions of SBP–1382 which were only tested as freshly made solutions, none of the other insecticides tested showed any reduction in toxicity with increasing age.

Field to laboratory LC_{90} ratios vary with the insecticide, being greater with the more toxic insecticides. In the field, a 2 to 15 times higher concentration than that required in the laboratory is necessary for comparable kill.

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ULTRA LOW VOLUME TESTS OF MALATHION APPLIED BY GROUND EQUIPMENT FOR THE CONTROL OF ADULT MOSQUITOES

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Insecticides applied as thermal aerosols for the control of adult mosquitoes have been widely used for many years. Although this method has given excellent results, it has several inherent disadvantages, the main one being the hazard to automobile traffic caused by the dense fog.

Mount, *et al.* (1968) reported on a technique for dispersing ultra low volumes (ULV) of undiluted insecticides as nonthermal aerosols, and showed that technical grade malathion applied at 0.68 gallon per hour (gph) was as effective against caged adult mosquitoes as dilute formulations applied as thermal aerosols dispersed at 40 gph. These results coupled with the commercial development of ULV application have produced considerable interest in this new technique for adult mosquito control. As with any new technique, however, many questions arise which must be answered before it can be successfully used in routine control operations. This paper deals with some of the more important aspects of the use of this technique, including accurate control of discharge rates and effective dosage of malathion against caged adults of two species of mosquitoes, *Aedes taeniorhynchus* and *Culex nigripalpus*.

METHODS. All tests were conducted in the early evening hours after sunset. Temperatures at test time ranged from

75 to 85° F. and averaged 79.9° F.; wind velocities ranged from 1 to 11 miles per hour (mph) and averaged 5.8 mph. Three different test areas were used: Area A was a grassy field sparsely planted with pines 2 to 4 feet tall; Area B was a beach type residential area with sand dunes 5 to 10 feet high, and some scattered pines, grass and low plants; Area C was a new residential beach area that had been leveled, and had a few houses and a few scattered groups of large pines.

Four cages of mosquitoes, two of *Aedes taeniorhynchus* and two of *Culex nigripalpus* each containing 25 females, were attached to a metal pole at 6 feet and 2 feet above ground. The poles were placed 165 and 330 feet downwind and perpendicular to the line of travel of the first swath of the aerosol generator. In tests where three swaths were used, the second and third swaths were applied at one and two blocks (300 and 600 feet) upwind of the first swath. Each test or replicate consisted of the cages of mosquitoes from three sets of poles placed a block (approximately 600 feet) apart or a total of 12 cages of each species. The cages were 8 inches in diameter and 1 inch thick with 14 by 18 mesh galvanized screen on both circular surfaces. The cages were hung vertically on the poles, with the screened surfaces facing into the wind.

All mosquitoes used in the tests were from laboratory colonies and were between 2 and 8 days old. After exposure to the aerosol, the caged mosquitoes were anesthesized with CO_2, transferred to clean holding cages, and held with access to a sugar solution on a cotton pad for 12 to 15 hours at which time mortality counts were made.

The aerosol generator used in these tests was an early model Leco ULV cold aerosol generator mounted on a flat bed truck. The generator had a fixed nozzle position which discharged horizontally and rearward at a height of approximately 4 feet from the ground. An insecticide tank pressure of 3.0 psi. was used in all tests, and the flow rate was adjusted by means of a needle valve in the Fischer-Porter 37G flowmeter which was equipped with a stainless steel ball float. The fogging time was determined by use of a stopwatch and the actual amount of insecticide discharged in milliliters was measured for each test. Tests in which the output varied more than 10 percent from the desired volume were discarded.

It was determined early in the testing program that the discharge at a particular flowmeter setting varied according to the temperature of the insecticide; therefore, the temperature of the insecticide was taken before and after each test and the flowmeter was set for the desired discharge according to the insecticide temperature as obtained from previously calculated calibration curves.

In order to determine the effects of ULV aerosols of technical malathion on automobile paint, small sections of 4 by 12 inch painted panels of various colors supplied by courtesy of General Motors Corporation were exposed at discharge rates of 1 and 2 gph. The panels were hung vertically on stakes 3 to 4 feet above the ground facing into the wind and were placed at the side of the road about 10 feet downwind of the path of the vehicle on the first of three swaths applied along parallel streets. Therefore, the panels were exposed to three swaths, the first only 10 feet away and the second and third 300 and 600 feet upwind. After exposure, each panel was covered for protection and returned to the laboratory where it was examined visually and by means of a microscope at 80x magnification for any indication of paint damage.

RESULTS. Mosquito kills obtained in the three test areas are shown in Table 1. Percent kill shown is the average obtained at 165 and 330 feet from the first swath and were corrected by Abbott's formula for check mortality, which averaged 1.3 percent for each species. The poor kill of *C. nigripalpus* in Area A was probably due to insufficient coverage resulting from

TABLE 1.—Kill of caged adult *Aedes taeniorhynchus* (Wied.) and *Culex nigripalpus* Theob. obtained with ULV malathion applied by ground equipment.

Test Area	No. Swaths	Vehicle Speed mph	Discharge-gph		No. Tests	Percent Kill	
			Intended	Actual		*Aedes*	*Culex*
A	1	5	2.0	1.93	2	99	71
			1.5	1.47	5	90	56
			1.0	0.92	1	81	22
			40.0[a]	38.91	3	96	56
B	3	5	2.0	2.13	3	99	95
			1.5	1.56	5	98	87
			1.0	1.01	3	97	84
			0.5	0.52	3	96	72
			40.0[a]	39.81	6	100	88
		10	2.0	2.05	3	100	93
		15	1.5	1.59	5	97	71
C	3	5	2.0	1.99	3	100	100
			1.0	1.05	3	100	99
			0.5	0.49	3	100	85
		10	2.0	2.03	3	99	97
B & C	3	5	2.0	2.06	6	99	98
			1.0	1.03	6	98	92
			0.5	0.51	6	97	79
		10	2.0	2.04	6	100	95

[a] Thermal fog @ 8 wt. oz. malathion per gallon @ 40 gph (equals 2.04 gph actual malathion).

only a single swath treatment, since Clements and Rogers (1967) previously demonstrated a significantly higher kill of caged stable flies using three swaths than that obtained with only a single swath. From this series of tests, it is apparent that better kills of both species were obtained at a 2 gph discharge than with the thermal fog formulation of 8 wt. oz. of actual malathion per gallon at 40 gph (equal to 2.04 gph of actual malathion).

Although the caged mosquitoes in Areas B and C were both treated with three swaths, it is evident that better kills were obtained in Area C than Area B. This is probably due to the physical differences between the two areas, Area C being a more level area with fewer houses and vegetation, resulting in better coverage than in Area B. As an overall condition, the results obtained in both areas were averaged and shown in the last part of Table 1. From these averages, it is evident that satisfactory kill of caged *A. taeniorhynchus* was obtained with as little as 0.5 gph of technical malathion at a vehicle speed of 5 mph, while 1 gph at 5 mph was necessary for satisfactory kill of *C. nigripalpus*. Good kill of both species was obtained at 2 gph of malathion at a vehicle speed of 10 mph and it appears that 1 gph would probably give satisfactory kill of *A. taeniorhynchus* at this vehicle speed.

In Area B with three swaths, as in Area A with the single swath, somewhat less kill was obtained against *C. nigripalpus* with the thermal fog at 40 gph than with the ULV at 2 gph, although malathion dosages were the same. As in Area A, kills obtained at 1.5 gph with the ULV more nearly equaled those obtained with the thermal fog.

Comparing equal dosages in Table 1, such as 1 gph at a vehicle speed of 5 mph with 2 gph at 10 mph, and 0.5 gph at 5 mph with 1.5 gph at 15 mph, it is evident that increased vehicle speed did not result in reduced mosquito kill at these speeds when dosage remained constant.

The automobile paint panels were exposed in the tests at 1 and 2 gph. Five panels, two black, one yellow, one metallic light blue, and one metallic dark green, were used. The two black panels were each exposed in 14 tests, the yellow in 11 tests, the metallic light blue in 11 tests and the metallic dark green in 5 tests. When newly deposited, the droplets on all panels appeared as liquid hemispheres. After several weeks, the droplets deposited on the black panels were visible as white granular rings or spots only under magnification. These white rings or spots disappeared completely when polished with automobile polish leaving no evidence of paint damage, even under 80x magnification. After several weeks, the droplets deposited on the metallic paint panels were not visible probably because the white granular rings that were seen on the black panels were not distinguishable from the many small shiny metal flakes in the metallic paints. The larger droplets were visible on the yellow panels under magnification but were easily removed by polishing, leaving no visible damage to the paint.

The average diameter of 200 spots measured on the black panels was 113 microns; the minimum size observed was about 14 microns and the maximum about 286 microns. Since the droplets spread greatly after impinging, the actual size of the droplets which made the spots was considerably smaller. Also, only the larger droplets in the spray spectrum would readily deposit on the large stationary surface of the panels. Nevertheless, the spots should be representative of those that would deposit on automobiles.

During the initial testing of the ULV

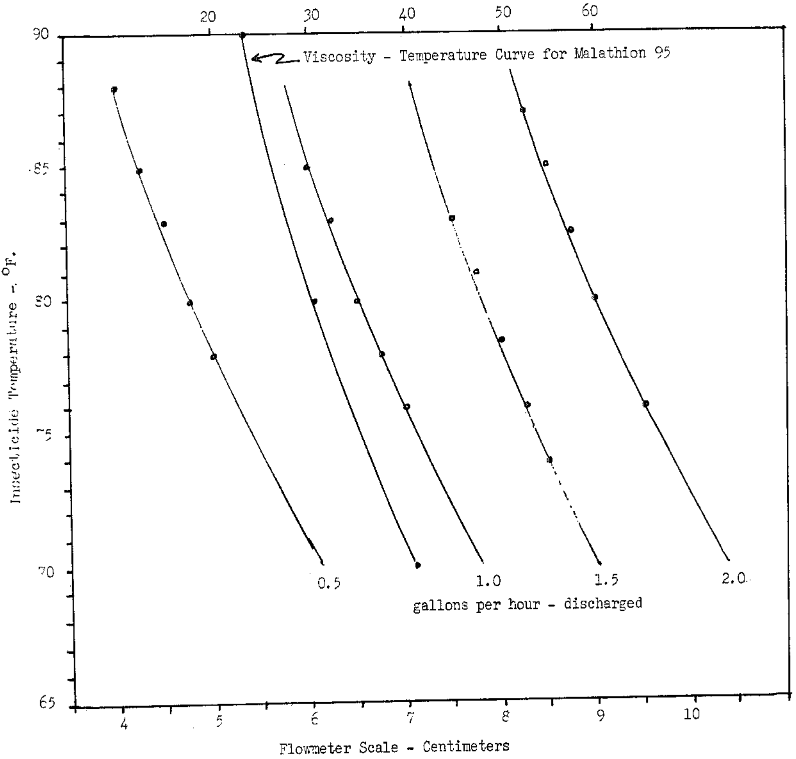

FIG. 1.—Calibration curves for malathion 95 at 3 psi using a Leco ULV sprayer equipped with a 37G flowmeter and stainless steel ball float.

technique, it became apparent that the temperature of the insecticide solution greatly affected the rate of discharge. Therefore, calibration curves were prepared, showing the flowmeter setting for the desired discharge rate at various insecticide temperatures. These calibration curves are shown in Figure 1. Shown in Table 2 are the effects of variations in insecticide temperature on the discharge rate of malathion. It is evident from this table that a difference of 2 to 3° F. in insecticide temperature results in a variation in discharge rate of 0.1 gph and a temperature difference of 2° will result in an error of 13 percent at a discharge of 0.5 gph and 5 percent at 2 gph. In order to maintain a minimum error in the discharge rate, the flowmeter must be adjusted for each 2° variation in insecticide temperature, and even then the error at low rates is considerably above that desired. Accurate control of the discharge rate is vital since rates lower than those recommended for a particular operation will result in reduced mosquito kill and larger volumes may produce large droplets which may spot automobile finishes.

TABLE 2.—Effect of insecticide temperature on the discharge rate of malathion 95 at 3.0 psi. with the Fischer-Porter aerosol generator using a Dwyer 37G flowmeter and stainless steel ball float.

Desired discharge in gph	Temperature difference in ° F. resulting in a variation in discharge of		Percent error of discharge for a 2° F. variation in insecticide temperature
	0.1 gph	10%	
0.5	3.00	1.5	13
1.0	2.50	2.5	8
1.5	2.25	3.4	6
2.0	2.00	4.0	5

CONCLUSIONS. ULV applications of malathion concentrate produce kills of caged adult mosquitoes equal to or better than thermal aerosols when applied at equal dosages. Satisfactory kills of *A. taeniorhynchus* were obtained with as little as 0.5 gph of malathion at a vehicle speed of 5 mph; however, 1 gph at 5 mph was necessary for adequate kill of *C. nigripalpus*. Satisfactory kill of both species was obtained at 2 gph of malathion at a vehicle speed of 10 mph, and it appears likely that 1 gph at 10 mph would be adequate for *A. taeniorhynchus*.

Under conditions of these tests, the droplets of technical malathion deposited on automotive paint panels did not result in damage to the paint.

The temperature of the insecticide solution was a critical factor in obtaining accurate discharge rates and the flowmeter must be adjusted for each 2° difference in temperature in order that errors in discharge be kept minimal.

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