DISPERSAL OF INSECTICIDES FROM JET-PROPELLED AIRCRAFT [1]

DAVID L. HAYDEN [2]

Introduction

The Navy's vector control requirement for support of troops in military operations may be accomplished in a number of ways. One of the most useful methods, especially in the early stages of a campaign, is the dispensing of insecticides by aircraft. Dispersal equipment is now being furnished for helicopters, but often these aircraft are not available when needed or are highly vulnerable to attack and therefore their use is limited. Because of this, some other means of widely disseminating insecticides is needed. Jet-propelled aircraft are now provided in quantity in the Navy. A limited number of units capable of dispersing insecticides from jet aircraft are now available. The Disease Vector Control Center at Jacksonville, Florida was assigned the mission of evaluating this equipment.

In 1958 and 1959, tests were conducted by this Center to determine the effectiveness of a liquid insecticide dispersal tank, and in 1959, a dry insecticide disseminator was evaluated. This is apparently the first instance in aviation history of dispersing

---

[1] The opinions or assertions contained herein are the private ones of the writer and are not to be construed as official or reflecting the views of the Navy Department or the naval service at large.

[2] Testing and Development Entomologist, U. S. Navy Disease Vector Control Center, U. S. Naval Air Station, Jacksonville 12, Florida.

insecticide materials from jet-propelled aircraft.

DISPERSAL OF LIQUID INSECTICIDE

1. Equipment. a. The apparatus used for dispersing liquid insecticide materials was a tank fifteen feet long weighing about 1,500 pounds when fully loaded with insecticide. It has a capacity of 85 gallons. The tank can be easily mounted on and removed from an aircraft. High pressure nitrogen, supplied from a reservoir in the tank, provides power to propel the liquid from a central container out through a valve at the rear of the tank. The discharge valve can be adjusted to give flow rates of 100 to 400 gallons per minute. Breakup of the liquid is accomplished by impinging it upon a cone mounted one foot beyond the rear orifice. Electrically operated valves, controlled by the pilot, can govern the flow rate and discharge of the insecticide. A bank of cylinders mounted on a trailer cart is used to fill the nitrogen reservoir in the tank. The nitrogen charging and insecticide filling process can be accomplished in about twenty minutes by a crew of two men.

b. The type of jet aircraft used in these studies was a Navy A4D single engine "Skyhawk." It is a highly versatile single seat delta-winged aircraft with a wing span of 28 feet. Built by the Douglas Company, it is efficient at speeds ranging from 200 to 700 miles per hour. Figure 1 shows this aircraft with the spray tank in operation.

2. Operational tests. Operational tests were conducted to determine the effectiveness of the tank and aircraft in both upwind and crosswind flights. Test stations

FIG. 1.—Aerial Application of Insecticide by a Navy A4D"Skyhawk" Jet. Official Photograph, U.S. Navy

were set up at distances of 25 feet along a 500-foot line for the upwind tests, and along a 1,000-foot line for the crosswind tests.

The following materials were used to evaluate dispersal at designated distances along the test line:

a. Microscope slides coated with 10 percent General Electric "Dri-film SC–87," an oleophobic silicone solution. These slides were used for analysis of droplet size and distribution.

b. Cards impregnated with DuPont "oil-red" dye. "Printflex" cards were used in the initial tests, and were replaced in 1959 by "Kromekote" cards. "Kromekote" cards have superior qualities in retaining droplets below 100 microns. These were used to estimate the gallons deposit rate per acre.

c. House flies caged in screen cylinders; each cage containing 20 adult flies.

d. Standard petri dishes used for direct recovery of the droplets. Fourth instar mosquito larvae (*Culex quinquefasciatus*) were exposed in these dishes in the laboratory to evaluate effective swath width.

e. Accessory equipment consisted of weather measuring instruments, smoke bombs, and weather balloons. A large red arrow about 30 feet in length was used for marking the base or center of the flight line and indicated the flight direction. A radio trailer provided communication with the pilot during flight.

When the test line was established and the evaluation equipment was in place, radio contact was made with the pilot and several practice dry runs were performed over the test area to acquaint the pilot with the proper flight procedure. Meteorological conditions were recorded prior to the flight. The pilot was instructed by radio to commence spraying at an exact time. After each flight, the spray was allowed to settle for ten minutes, providing for maximum recovery of the droplets. Additional runs were repeated in a similar manner as above. Flow rates of 100 to 350 gpm, air speeds of 300 to 550 knots and altitudes of 75 to 200 feet were varied in experiments to determine the most favorable factors for dispersal. Flow rates below 150 gallons per minute were not heavy enough to produce a droplet spectrum which would give satisfactory insect kill. Therefore, the flow was increased to 300 gallons or more and gave a satisfactory deposit in all subsequent tests.

Tests materials were returned to the laboratory where droplet size and spectrum analyses were made. The dyed cards were evaluated for deposit rate. Mortality of house flies was recorded at 24 hours after exposure. Larval mosquito mortality rates were recorded at 24 and 48 hours.

3. Results and discussion. a. Crosswind flights. At flow rates of 300 to 350 gpm, an air speed of 450 knots and an altitude of 100 feet, effective kill was obtained up to 1,000 feet, and in some instances even beyond this distance. Droplet size on the test stations nearest the flight line approached that of a coarse spray (200 microns) and gradually decreased in size to that approximating a heavy mist (100 microns) at stations on the outer edges of the swath (1,000 feet from the flight line). This indicates a desirable droplet spectrum for aerial insecticide spray equipment. Table 1 gives data representative of a typical test flight where these conditions occurred.

b. Upwind flights. Recovery of the spray varied considerably even though flight tests were made in exactly the same manner on the same day at practically the same time. Similar wind conditions existed for all tests, i.e., a steady wind of at least five mph was recorded. The effective swath produced in these tests varied from a minimum of 100 feet to a maximum of 300 feet. Determination of the maximum swath in upwind flights is difficult to obtain even under the most ideal conditions. Sudden and/or small changes in the wind direction will often move the deposit to either side of the test line. Because of the high speed of jet aircraft, the problem is further compounded. It is extremely difficult to direct the aircraft over the center of the test line with accuracy. Data indi-

TABLE 1.—Representative crosswind performance data utilizing a liquid dispersal tank mounted on a Navy A4D jet-propelled aircraft. Air speed 450 knots, altitude 100 feet and flow rate 310 gpm. Temperature at six feet, 74° F. Relative humidity 86 percent, wind speed 1.5 mph.

Distance from flight line (ft.)	Deposit gallons per/acre (dyed cards)	Mass median diameter (microns)	Frequency median diameter (microns)	House fly mortality (24 hrs.) percent	Mosquito larva mortality (4th instar) *Culex quinquefasciatus* 24 hrs. percent	48 hrs. percent
50	0.3	208	199	100	100	100
75	—	—	—	—	—	—
100	0.2	—	—	100	95	100
125	0.2	—	—	—	—	—
150	0.08	133	125	50	100	100
175	0.08	—	—	—	—	—
200	0.2	—	—	55	100	100
225	0.2	—	—	—	—	—
250	0.2	136	128	100	100	100
275	0.2	—	—	—	—	—
300	0.08	—	—	100	95	95
325	0.14	—	—	—	—	—
350	0.1	113	105	95	95	95
375	0.1	—	—	—	—	—
400	0.15	119	97	80	—	—
425	0.15	—	—	—	—	—
450	0.1	—	—	100	85	95
475	0.02	—	—	—	—	—
500	0.03	—	—	100	85	100
525	0.03	—	—	—	—	—
550	0.03	101	94	90	90	95
575	0.025	—	—	—	—	—
600	0.01	—	—	95	90	95
625	0.01	—	—	—	—	—
650	0.01	—	—	—	70	70
675	—	—	—	—	—	—
700	0.01	—	—	65	85	95
725	0.01	—	—	—	—	—
750	0.01	98	90	—	85	100
775	0.03	—	—	—	—	—
800	0.02	—	—	95	95	95
825	0.01	—	—	—	—	—
850	0.01	102	87	—	85	90
875	0.01	—	—	—	—	—
900	0.01	—	—	80	80	90
925	0.01	—	—	—	—	—
950	0.01	—	—	—	70	80
975	0.01	—	—	—	—	—
1000	0.01	—	—	—	80	100
1100	0.01	—	—	—	—	—
Control	—	—	—	10	0.5	2.5

cate, however, that the maximum swath width to be expected approximates 200 feet. There is evidence of a deposit pattern resembling a typical bimodal curve. This condition is apparently caused by the wing tip vortices, a phenomenon already known to occur in propeller driven fixed wing and rotary wing type of aircraft. The blast from the jet engine does not appear to have any appreciable effect on the spray deposit pattern. This is because spray is emitted well below the exhaust of the aircraft. The effects of delta wing design and small wing span, which are characteristic of the A4D, may need further exploration. There is evidence indicating that an increase of air speed tends to decrease the swath width. Although inconclusive results were obtained in upwind tests, it does appear that adequate coverage can be obtained over a distance of 200 feet, even though there may be a tendency towards an overly heavy deposit in the center of the swath.

DISPERSAL OF GRANULAR INSECTICIDES

1. Equipment. The equipment used for granule dispersal was an experimental model developed by the Navy for dispensing dry materials from jet-propelled aircraft. In its original design, this device was of the same size and configuration as the liquid dispersal tank. An electric motor, activated by the pilot, operates a discharge value for release of the insecticide. Agitation is not used in this tank, because of the free flowing nature of the granules. Flow rate may be varied by interchanging different size openings on the discharge valve. No special deflection plates were provided to disperse the materials. The distribution of the granules is dependent mainly upon the aircraft turbulence.

2. Materials and procedure. A test line of 500 feet in length with stations spaced 25 feet apart was established. Five by six-inch plates, coated with a thin film of common heavy grease with the coated side up were employed at each station in all tests. The granules readily adhere to the greased surface on impaction. In some tests, 4 x 5 x 2 inch plastic containers were used to recover the granules.

The pilot was instructed by radio to fly in the same manner prescribed for the liquid dispersal flights. All test runs were made into the wind, with the exception of one crosswind flight. Attaclay granules, 20/40 mesh unimpregnated, were used in two of the tests. Vermiculite also was employed in two flights, and 30/60 mesh 10 percent DDT-impregnated Attaclay granules were used in one test.

Problems of aligning the aircraft over the target were also encountered in this test series. It appears that shifting winds influence the spread of granules in much the same manner as occurs with droplets.

The test materials were returned to the laboratory where the granules were tabulated on a special illuminated counting chamber. The average number of granules per square centimeter on the entire 5 x 6 glass plate was calculated. The number obtained was then converted into pounds of granules per acre. Vermiculite samples were evaluated in a similar manner.

RESULTS AND DISCUSSION

The results obtained in these tests using granular 20/40 mesh Attaclay show that the maximum swath width produced was 200 feet. This swath was effected at an altitude of 200 feet and an air speed of 200 knots. The mean deposit across this swath was 1.3 pounds of granules per acre. Representative data are shown in Table 2.

TABLE 2.—Representative upwind performance data obtained using a granular disseminator mounted on a Navy A4D jet-propelled aircraft. Air speed 200 knots, altitude 200 feet, flow rate 150 pounds per minute. Temperature 60° F., wind speed 10 mph. A last minute light crosswind shifted the deposit to the right of the flight line

Distance from center of flight line—feet	Deposit rate pounds of granules per acre
25	0.128
50	0.128
75	0.514
100	3.087
125	3.599
150	1.285
175	1.413
200	1.221
225	0.257
Mean Deposit	1.292

At altitudes below 200 feet, the swath width was reduced to less than 125 feet.

In one crosswind test, a swath width of 200 feet was obtained, with a mean deposit of 0.19 pound of granules per acre. This test was also made at an altitude of 200 feet and an air speed of 200 knots. Data recovered in this test series also indicated that increasing the speed of the aircraft tends to decrease the swath width. In trials using vermiculite, the data recovered were inconclusive. However, swaths of 200 feet were obtained.

CONCLUSIONS

Under present day considerations, it would seem that insecticide dispersal by jet aircraft is very costly and somewhat impractical at least for civilian usage. However, after the importance of military aircraft was established in World War I, many civilian uses for aircraft became apparent. It is therefore not unreasonable to assume that in the future, we may find that jets will be employed for mosquito control or agricultural purposes in place of or in competition with propeller driven craft. There is no question that jet aircraft have promising potentialities for insect control work. However, much research remains to be done in determining the type of jet and dispersal equipment most suitable for a wide range of control applications.

Certainly, for the present at least, jets will be invaluable for use where no propeller-driven craft are available. It is doubtful, however, that jet-carried equipment will be extensively used, except for aerial dispersal of insecticide in support of tactical military operations. There are some instances, however, where they could be usefully employed. Such conditions could exist where mass applications are required such as in disaster or other emergencies, and where spray drift or contamination outside of the target area would not be a hazard.

SUMMARY

Studies were conducted in 1958 and 1959 to determine the efficacy of dispersing liquid and granular insecticides from jet-propelled aircraft. The type of aircraft used in these studies was a Navy A4D single engine "Skyhawk." The tank for dispensing liquid insecticides uses high pressure nitrogen to propel the liquid through an opening at the rear of the tank. Breakup of the liquid is accomplished by impinging it upon a cone mounted beyond the rear orifice. Flow rates of 100 to 350 gpm, air speeds of 300 to 550 knots and altitudes of 75 to 200 feet were varied in experiments to determine the most favorable factors for dispersal. Crosswind swaths of up to 1,000 feet effective for mosquito larviciding were realized using flow rates of 310 to 350 gpm, an air speed of 450 knots and a spraying height of 100 feet. Dispersal of granular materials was accomplished by using a simple gravity flow system at a constant rate of 150 pounds per minute. Air speeds were varied from 200 to 560 knots and altitudes from 50 to 200 feet in upwind swath width determinations. The maximum upwind swath width obtained using 20/40 mesh Attaclay granules was 200 feet with a mean deposit across the swath of 1.3 pounds of granules per acre. This was accomplished at an altitude of 200 feet and an air speed of 200 knots. At altitudes below 200 feet, the swath width was reduced to less than 125 feet. Increasing the air speed showed a tendency to narrow the swath width. This is believed to be the first instance in aviation history of dispersing insecticide materials from jet-propelled aircraft.