feet. A similar treatment over open terrain and at higher wind velocities did not give effective control. With two treatments at a discharge rate of 0.26 pound of DDT per acre and a swath width of 600 feet, no reduction occurred in one of the plots and only temporary reduction in the other.

Two plots of 118 and 130 acres were treated with a ground-operated power sprayer at a dosage of 0.35 pound of DDT per acre. One treatment effectively reduced the number of both mosquitoes and blackflies for 24 hours, but reinfestation began within 48 hours. The results of the second test were questionable because a natural reduction occurred in untreated areas.

Small-plot tests with DDT sprays, pyrethrum and pyrethrum-DDT aerosols, and DDT-nicotine and benzene hexachloride smoke bombs gave temporary reduction of mosquitoes and blackflies, but the plots became reinfested within 15 minutes to an hour, an indication that such measures were of little practical use. The blackflies appeared to return into the treated areas sooner than the mosquitoes.

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HEAVY GROUND AEROSOL GENERATORS FOR THE CONTROL OF ADULT BITING INSECTS IN ALASKA[1]

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The usefulness of heavy ground equipment for generating aerosols for the control of adult *Culicoides,* mosquitoes, and blackflies was investigated under three types of Alaskan conditions during the summer of 1947. Tests were made in a small town with cross streets, in a small, wooded area encircled by roads, and in a third and more typical area traversed by a single road nearly 20 miles long. No unusual weather was encountered during the tests. Inversion or isothermic air temperatures occurred nearly every evening with few periods of strong breeze. Although little is known about the flight habits of these insects, there was probably little deviation from normal in the mild weather that prevailed during the tests.

The generators, a modified Besler (Chemical Corps designation E-15) and a large Hession, were mounted on a trailer towed by a ¾-ton truck. The Besler generator was operated at 600° F. and at a delivery rate of 40 gallons per hour. The Hession generator was a new machine of a type devised to produce a mist spray by throwing droplets from a set of rapidly revolving discs. The maximum flow rate was said to be 140 gallons per hour. The droplet size produced by both these generators was not determined.

[1] This work was conducted under funds allotted by the National Military Establishment to the Bureau of Entomology and Plant Quarantine.

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The solution used in the Besler was 25 gallons of Navy Fog Oil, 15 gallons of fuel oil, 8 gallons of Velsicol AR-60, (chiefly di- and trimethyl naphthalenes) and 25 pounds of DDT. The solution used in the Hession generator was 5 per cent of DDT dissolved in fuel oil.

CONTROL OF CULICOIDES IN A SMALL TOWN

Valdez, a town with a population of approximately 600, was used for the tests to control *Culicoides*. This town covers an area of about 1 square mile on a gravel flat between a mountain and a bay. At one side of the town a tidal marsh extends for several miles along the base of the mountain, and a river and flood plain lie on the other side. There are good roads around the landward sides of the town and adequate cross streets, almost to the high-tide line to allow swaths to be made 1 block apart. No roads are present along the base of the mountain or on the seaward side of the salt marsh. When the tests were made, the vegetation was dense and rank except in the thickly populated parts of the town.

The weather was "good" for Valdez between July 17 and 20, when the tests were made, as there was no rain or strong wind and the temperature did not become low enough to interfere with insect activity. The tests were made on two consecutive nights, during the temperature inversion of each evening, when a light breeze blew down the mountain, across the town, and out over the bay.

The first swath in each test was laid around the landward sides of the town with the Besler generator and then the generator was driven along the streets so that the coverage would be complete and fairly uniform. A lighter, second treatment was made by following essentially the same routes but at twice the speed. Much of the visible part of the cloud drifted across the town and out over the bay.

Estimates of population densities were based on the number of *Culicoides* resting on an observer's hat after a 3-minute wait at the counting station. Tests were made on 2 nights. Two stations were observed by the same persons both nights and two were not observed until the second night. A few blackflies and enough mosquitoes to be annoying were present at some of the stations, but the numbers were not sufficient to give significant counts. The mosquitoes appeared to be controlled effectively by the treatment.

In the first test a large initial population of sand flies was sharply reduced, but not eliminated, by the use of 50.5 gallons of 6.6-per cent (weight by volume) DDT solution (about 0.04 pound of DDT per acre). Counts at one station dropped from an average of 152 to 2.7 after a cloud of aerosol had passed. Counts at the other station went from 183 to 15 on passage of a light cloud, and down to 1.5 on passage of a dense cloud. Preliminary counts were low (average 13) at all stations on the second night, and only 27 gallons of solution were dispersed, about 0.022 pound of DDT per acre. Very thin clouds of aerosol passing over three of these stations had little effect, but passage of the main clouds brought the average of the combined counts down to 3.3, a level that would probably afford practical relief to the inhabitants of the town.

CONTROL OF MOSQUITOES AND BLACKFLIES IN AN AREA SURROUNDED BY ROADS

Only one suitable area surrounded by roads but without adequate cross roads, was found before the tests made to control mosquitoes and blackflies were terminated by stormy weather. This area, near Slana, was a wooded triangle about ½ mile long and ¼ mile wide at the base. Good roads extended along each leg of the triangle and up a hill that formed the base. This hill was about 70 feet high and dropped abruptly to the level land below. There was a connecting road along the top of the hill and a passable track at the bottom of it.

With a 7-mile-per-hour wind blowing directly toward the apex of the triangle, the Hession generator was driven slowly

and with frequent stops along the connecting road at the top of the hill. Instead of the aerosol drifting over the flat, wooded area below, the wind swirled just beyond the brow of the hill and tended to carry the aerosol to one side of the triangular, wooded area.

The machine was then driven along the roads that formed each leg of the triangle, and an attempt was made to find some place from which at least a part of the plot could be treated. The drafts of air blew down each road, so that the aerosol did not reach beyond the edge of the cleared roadway. Even when the generator was driven along the track at the foot of the hill, the aerosol was drawn into the turbulence at the edge of the hill and toward the drafts blowing down the roads. Glass slides placed in two rows at right angles to the track showed deposits only to a distance of 100 feet. In these tests about 30 gallons of Diesel oil containing 5 per cent of DDT were dispersed in about 25 minutes. Cold rains prevented adequate checking of the insect population after treatment, but there was no evidence of reduction attributable to the aerosol.

CONTROL OF MOSQUITOES AND BLACKFLIES IN AN AREA TRAVERSED BY A SINGLE ROAD

The tests to determine the feasibility of controlling blackflies and mosquitoes under the third type of Alaskan condition were made on a series of selected plots on the road between Slana and Nabesna. Low but fairly uniform insect populations were found over a section of nearly 20 miles. The lower end of this road ran near the middle of a flat valley floor several miles wide. The valley narrowed at the upper end and the road ran close to the adjoining mountain. The vegetation consisted chiefly of scattered spruce interspersed with dwarf birch and the usual moss and small heath plants.

It was soon found that the air movements in the valley assumed fairly definite patterns. The prevailing wind movement during the tests was up the valley and therefore parallel to the road. In calm weather the air currents paralleled the lower part of the road during both lapse and inversion. They crossed the road only along the upper part. Practical treatment was therefore limited to about one-fourth the total roadside area—that is, to those areas reached by inversion currents moving across the road. Three attempts were made to reach plots on the opposite side by operating just at the time of the morning reversal of air movement, but all ended in failure due to thermal turbulence. Even with good inversion there was some difficulty due to turbulence of a different sort. The cool air draining down canyons and gullies tended to flow and eddy around obstructions so that a number of locations could not be reached. In a few cases this tendency could be used to advantage to fill a natural pocket.

A camp was established and maintained for 6 days at the upper end of the valley in what appeared to be an excellent site for demonstrating the protection to be obtained from aerosols. Two low hills about 1,000 feet apart and a small lake partially delimited this space of about 64 acres. The air movement during inversion was across the road and into the area. Treatments were applied with the Besler generator on 2 consecutive days.

In the first treatment 25.7 gallons of solution were dispersed on a 0.53 mile front, or about 0.21 pound of DDT per acre to be protected. The front was extended on the second day to 0.7 mile so that better coverage could be secured, and 28.2 gallons were delivered, or about 0.22 pound of DDT per acre to be protected. Inversion was good at the time of both treatments, and the drift into the trees was excellent.

Landing rates were too low and erratic to give satisfactory measures of the insect populations in the test area. The men had to wait 2 minutes at each counting station and then estimate the numbers of blackflies and mosquitoes around them. Although these estimates were not adequate for fine comparisons, it was evident that both blackflies and mosquitoes were present in distinctly annoying numbers 15 hours after

the first treatment. Immediately after the second treatment the number of mosquitoes was considerably reduced, but a great many blackflies were still present.

Blackfly and mosquito activity practically ceased during the middle of the day and late at night, so that counts after a treatment usually could not be made until the next active period. In 10 attempts to clear roadside areas, no satisfactory evidence of 24-hour protection was obtained. Even with fronts of a half mile, the depth of the area effectively reached was not sufficient to prevent reinvasion at the next period of activity. There is some reason to believe that the blackflies were not killed by the aerosols used. They were present in the camp area as soon as the men returned from making each treatment. It was thought possible that they had followed the men in from outside areas; so the camp was thoroughly smoked twice within a half hour, with a DDT insecticide candle (E-22) tied to a stick and carried around the camp. Each time the flies were back a few minutes after the smoke cleared.

A short track was found over which a vehicle could be moved at right angles to the road. This track was used one evening, when the wind was blowing parallel to the road at 6 to 10 miles per hour, to treat a short front with the Hession generator. Sixteen and a half gallons of Diesel oil containing 5 per cent of DDT were dispersed on a 425-foot front. Counts made the next day failed to show definite effects on the mosquito and blackfly populations of the small area reached.

DISCUSSION

Inability to reach the areas to be protected is the principal limitation to the use of aerosols generated by ground equipment. During the restricted weather conditions under which they can be used, i.e., inversion or isothermic conditions with low wind velocity, the air currents usually assume patterns that are fairly constant for each locality. Consequently, the only places available for treatment with heavy ground equipment are those with roads that are on the windward side under these particular conditions, and that have enough additional roads to allow sufficiently close swaths to be made and to take care of turbulence due to irregular terrain. Few places in Alaska have roads that satisfy all of these requirements.

Some towns, and probably some military posts and camps, could be treated cheaply and fairly effectively, but immediate reinfestation from surrounding areas should usually be expected. In Valdez, for example, the heavy populations of *Culicoides* just outside the town could not be reached from the single available road. Neither could the foothill area west of the town or the shore line to the east be reached with the equipment used.

SUMMARY

Tests were made in a number of areas to determine the suitability of using heavy ground equipment for generating aerosols for control of biting insects in Alaska. Inability to reach the areas to be protected was found to be the principal limitation to the use of such equipment.

In a small town encircled by roads and with adequate cross streets to allow close swathing, a high initial population of *Culicoides* was reduced to a low level by dispersion of about 0.04 pound of DDT per acre to be protected. The next evening a much smaller, but distinctly annoying, population was reduced to a similarly low level by dispersion of only 0.022 pound of DDT per acre.

In an area surrounded by roads but without adequate cross roads, a single attempt made in a 7-mile-per-hour wind failed to control mosquitoes and blackflies because of air turbulence caused by the terrain.

In a wide valley traversed by a single road, only about one-fourth of the roadside area could be treated. The prevailing winds and the convection air currents assumed fairly constant patterns, which were nearly parallel to approximately half of the road. The convection currents crossed

the remaining half of the road, but only one side was treated because the aerosol could be used only during inversion, and air movements toward the other side occurred only during lapse conditions.

In a series of 10 tests with fronts up to a half-mile, the effective penetration was not sufficient to prevent reinvasion of mosquitoes and blackflies within 24 hours.

There was some evidence that blackflies were not readily killed by the aerosols used.

STUDIES USING DDT APPLIED IN AIRPLANE THERMAL EXHAUST AEROSOLS FOR THE CONTROL OF ANOPHELINE LARVAE IN RICE FIELDS IN CALIFORNIA [1]

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I. INTRODUCTION

The control of *Anopheles freeborni* (Aitken) larvae in California rice fields has always been a difficult task. Mosquito control ground crews are limited in the extent to which they can treat rice fields with spray equipment. Dr. Basil G. Markos (1949) has shown that in California anopheline larvae breed throughout a rice field, in the center as well as along the edges. Spray crews can treat only the edges of rice field checks, and are unable to penetrate the center of the checks with larvicides. Therefore airplane treatment would be a very desirable method of applying larvicides to cover the extensive area of individual rice fields.

Krusé and Metcalf (1946) successfully controlled anopheline larvae in impounded water by the use of DDT applied in airplane thermal exhaust aerosols. The Sutter-Yuba Mosquito Abatement District during 1946 conducted airplane thermal exhaust aerosol operations using similar equipment and techniques with apparent control of *Anopheles* larvae in rice fields.[2] The studies reported herein were conducted in the Sutter and Yuba Counties during routine control operations in 1947.

In cooperation with the Sutter-Yuba Mosquito Abatement District, the State Department of Public Health, Bureau of Vector Control, conducted fourteen studies during September, 1947, which were part of a routine program to treat 18,000 acres of rice in the vicinity of Yuba City and Marysville.

II. OBJECTIVES

1. To determine if the thermal aerosol dispersal method was applicable for the control of anopheline larvae in rice fields in the Sutter-Yuba Mosquito Abatement District.
2. To determine the minimum dosage of DDT required to give 90% control of *A. freeborni* larvae in rice fields.
3. To determine the rapidity of recurrence of *A. freeborni* larvae after treatment in rice fields.

[1] This report is one of a series on continuing mosquito control operational and biological studies begun in 1946 by the Bureau of Vector Control, Division of Environmental Sanitation of the California State Department of Public Health in cooperation with various Mosquito Abatement Agencies.

[2] Unpublished records are in the permanent file of the Sutter-Yuba Mosquito Abatement District, Yuba, California.