A NEW THERMAL-AEROSOL GENERATOR FOR DISPERSING INSECTICIDAL FOGS FROM A STEARMAN AIRPLANE

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The use of an exhaust-generated thermal aerosol apparatus on an airplane is not new. It has been utilized by the U. S. Department of Agriculture (Lindquist *et al.,* 1945), the Tennessee Valley Authority (Metcalf *et al.,* 1945), and other agencies. However, this equipment was never widely accepted for the control of adult mosquitoes in Florida.

The first attempt to control mosquitoes with thermal aerosols by the Brevard Mosquito Control District was made in 1951 with two Dynafog machines and DDT as the insecticide. However, because of the poor results probably due to mosquito resistance to DDT created by extensive spraying of the breeding areas by airplanes, no additional thermal aerosol ground units were purchased. The District turned to ground spray units instead.

When the Entomological Research Center, Florida State Board of Health, Vero Beach, reported excellent results with malathion as a thermal aerosol in ground equipment (Rogers *et al.,* 1957), the District again became interested in the use of fog in the control of adult mosquitoes.

To make ground control practical in an area as large as Brevard County, which is 72 miles long and has a population of slightly over 100,000, it was estimated that more than 15 units would be needed. Therefore, owing to the cost of machines on the market, it was decided that the District would manufacture its own ground foggers.

A surplus airplane engine was mounted in a large tube, and fog was produced by injecting the insecticide directly into the exhaust pipes. This apparatus was so successful (Rathburn and Rogers, 1959) that it was decided to install thermal-aerosol equipment on one of the six District-owned Stearman (PT-17) spray planes. This plane was equipped with an exhaust venturi constructed in accordance with the recommendations of the U. S. Public Health Service and the Tennessee Valley Authority (Krusé and Metcalf 1946).

This unit was used for a short time during the spring of 1958 and showed promising results. However, the back pressure on the engine created by the restriction in the venturi was intolerable. Therefore, since the ground unit worked so well with no restriction, it was decided to discard this unit and make one with no restriction.

A detailed drawing of the exhaust generator unit is shown in Figure 1. The original exhaust collector ring was completely removed from the airplane and left and right exhaust pipes of common soft iron exhaust-pipe material 3½ inches in diameter, were made to fit the engine. The left pipe collects the exhaust from four cylinders and the right one from the other three. The pipes are curved to conform to the shape of the radial engine, extend straight down approximately 30 inches below the bottom of the engine, and discharge between the landing gear. The insecticide is introduced at the top of the two pipes by a 1-inch air-driven centrifugal pump; a ⅛-inch restriction in the line controls the output at approximately 150 gallons per hour (Figure 2).

The advantages of this apparatus are as follows:

1. A fog plane provides a 200-foot swath, compared with the 100-foot swath furnished by the spray plane. A very large area can be treated with each load; thus time is saved in going to and from the area to be treated. One takeoff and

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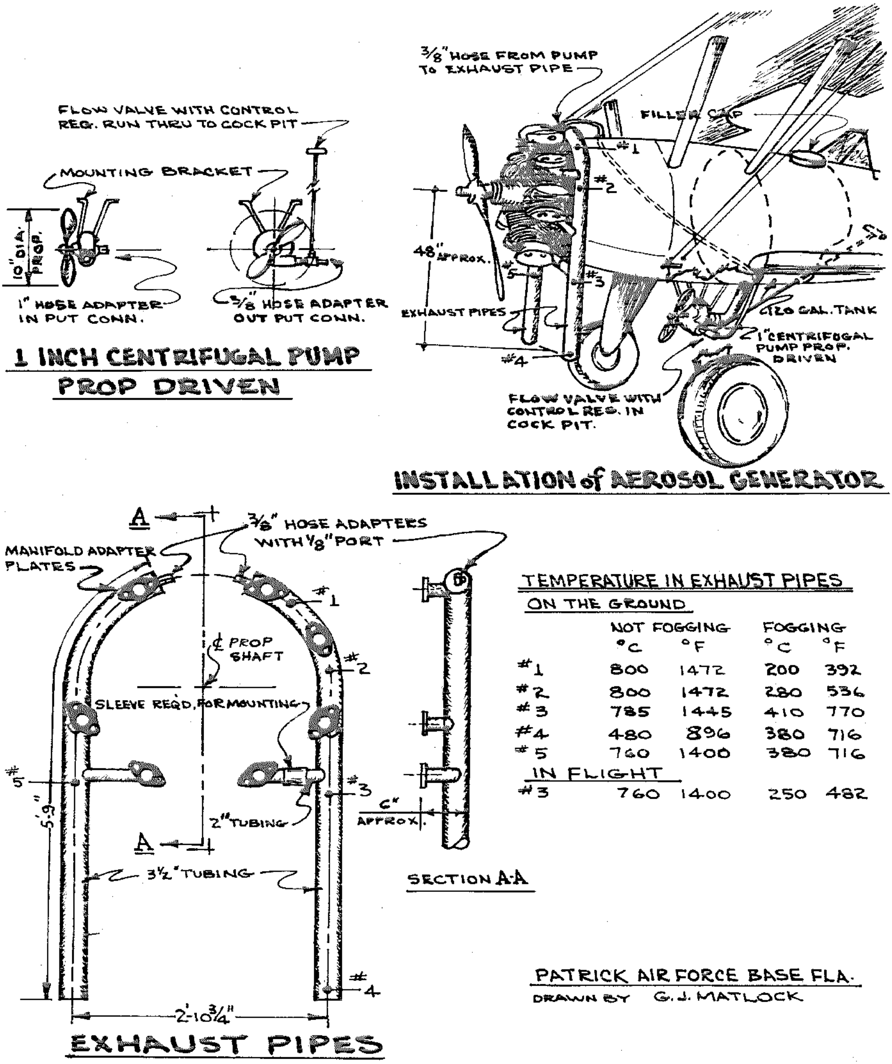

TEMPERATURE IN EXHAUST PIPES

	NOT FOGGING °C	NOT FOGGING °F	FOGGING °C	FOGGING °F
ON THE GROUND				
#1	800	1472	200	392
#2	800	1472	280	536
#3	785	1445	410	770
#4	480	896	380	716
#5	760	1400	380	716
IN FLIGHT				
#3	760	1400	250	482

Fig. 1.—Installation of exhaust aerosol generator on Stearman (PT—17), with details of the pump and exhaust pipes, and temperature data at selected sites in the pipes.

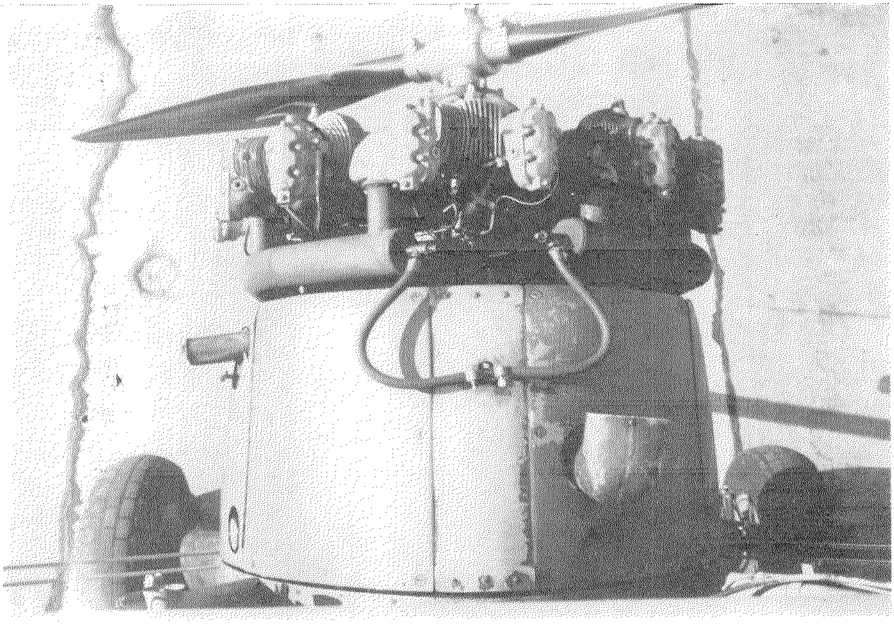

FIG. 2.—Point of introduction of insecticide solution into top of exhaust pipes.

landing are required, compared with at least six of each operation with a spray plane.

2. The small droplets [3] do not spot automobiles. They also do not kill minnows and other wildlife.

3. The fog penetrates dense foliage more adequately than the spray.

4. The pilot can see the fog spread by the first pass and use it as a guide for succeeding ones. Thus flagmen can be eliminated.

5. Since there is no noticeable drag, the fog apparatus can be installed on the airplane in combination with that used for spraying or dusting.

6. Fog is easy to work with at night. Thus a large area can be treated while the mosquitoes are active.

7. The cost per acre is almost one quarter of that required for spraying.

The components and cost of a formulation used with excellent results in 1958 and 1959, are given in Table 1. Experimentation is not yet complete but preliminary studies indicate that an aerosol containing 10 percent v/v of 90 percent malathion and a fog oil cheaper than that used in 1959 can be recommended. This formulation, which reduces the cost from $0.15 to $0.114 per acre, will be used in 1960. The ingredients are also given in Table 1.

The average flight time, number of acres treated, and the cost of application of the malathion thermal aerosols and spray for each 120-gallon load are given in Table 2.

[3] On March 4, 1960, A. H. Yeomans, Agric. Res. Div., U.S.D.A., Beltsville, Md., collected droplets and found they had an average mass median diameter of less than 5 microns.

TABLE 1.—Cost of materials used in malathion aerosols and sprays per 100 gallons

	Aerosol				Spray	
	Percent (v/v)		Cost		Percent (v/v)	Cost
Material	1959	1960	1959	1960	1959	
Malathion (90%)	15	10	$123.60	$79.00	2	$16.48
Fog oil	15[a]	10[b]	6.15	2.40	—	—
HAN[c]	15	10	4.65	3.10	—	—
Diesel fuel	55	70	6.19	7.88	98	11.03
Total cost			$140.59	$92.38		$27.51

[a] Standard Oil No. 1.
[b] Standard Oil No. 345 (in 5,000-gallon lot).
[c] Heavy aromatic naphtha, auxiliary solvent.

TABLE 2.—Costs of operations

	1959		1960
	Aerosol	Spray	Aerosol
Flight time, minutes	99	27	99
Acres treated	1551	120	1551
Cost of material	$ 168.70	$ 33.01	$ 110.86
Cost of plane and pilot	$ 66.00	$ 18.00	$ 66.00
Total cost	$ 234.70	$ 51.01	$ 176.86
Cost per acre	$ 0.15	$ 0.425	$ 0.114

The costs were computed for a 220-hp. Stearman airplane and pilot at $40 per hour, flying at 80 m.p.h., dispersing 16 gallons of spray per minute in 100-foot swaths, or 2.5 gallons per minute as a fog in 200-foot swaths, each carrying 120 gallons per load.

While making routine treatments of large areas with fog, the pilot seldom finds it necessary to make a special effort to fly crosswind, as must be done with a spray. Even during periods of calm air the 200-foot swaths completely cover the area. Ordinarily the pilot prefers to select the longest runs to begin with in order to lighten the load as soon as possible, which in turn makes the airplane easier to maneuver; he then works out the shorter runs. However, in areas where a choice of runs is available and when the wind velocity is less than 10 m.p.h., crosswind flying beginning on the upwind side is preferred. With this method the body of fog drifts along as the airplane progresses and each pass increases the concentration (Figure 3).

In winds above 10 m.p.h. it seems to be necessary to fly almost parallel with the direction of the wind. When the line of flight is not exactly with the direction of the wind, it is advisable to start on the upwind side and work across; thus the body of fog is increased each time. Excellent results have been obtained over large areas using this method in winds up to 25 m.p.h. (Davis *et al.*, 1960). Above this wind velocity it is not safe to fly a loaded airplane at treetop level.

Since 1950 the District has had a waiver for low flying at night for the purpose of spraying. Because of the inversion of the temperature gradient, night flying increases the effectiveness of spraying as well as fogging. By utilizing moonlight, very

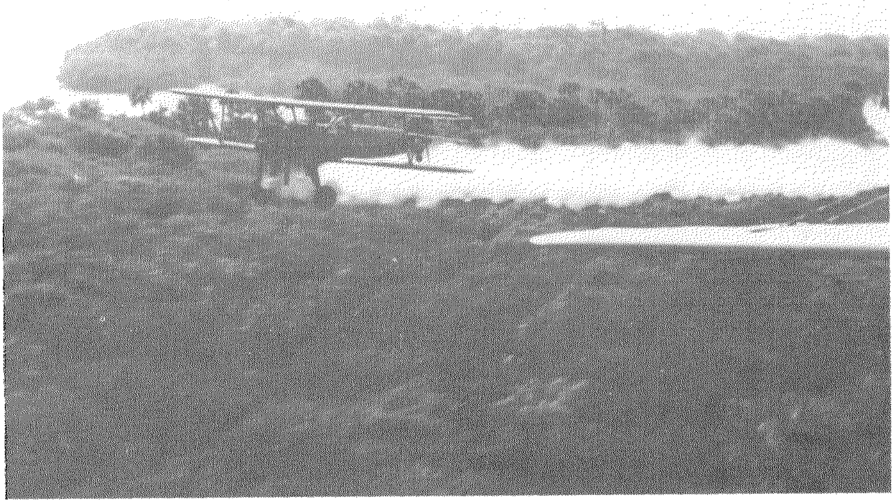

Fig. 3.—Aerial fogging with a Stearman (PT–17) airplane.

little flying has to be done in total darkness. Except on the rare occasions when the fog stratifies due to air currents and does not descend to the ground, aerial fogging works exceptionally well at night. Often the fog gets so dense that the swath width can be increased to as much as 400 feet and excellent coverage is still obtained.

A thermocouple was installed on the airplane at Patrick Air Force Base.[4] The temperature was taken at five different locations inside the exhaust while the engine was being run at 1,800 r.p.m. on the ground, before and after the fog was turned on, and at one location before and after the fog was turned on while in flight. The results are given in figure 1.

In conclusion, it should be mentioned that inasmuch as this apparatus makes it possible to treat entire broods of newly emerged adults over large areas, it would be reasonable to believe that a resistance problem could be created. The District has, on several occasions of extra heavy emergence near populated areas, used this method to apparently annihilate broods of

[4] This installation was made possible through the courtesy of H. J. Crawford, Entomologist, Patrick Air Force Base.

mosquitoes. If discretion were not used, and an effort made to treat all broods of mosquitoes upon emergence, resistance would undoubtedly occur.

Summary. A new thermal-aerosol generator has been developed for the aerial dispersal of insecticidal fogs. This unit consists of essentially left and right exhaust pipes constructed on common exhaust-pipe material 3½ inches in diameter. The insecticide solution is introduced at the top of the pipes by a 1-inch air-driven centrifugal pump at a rate of approximately 150 gallons per hour. The use of a thermal aerosol containing 15 percent of a commercial 90 percent-malathion solution, 15 percent of a heavy aromatic naphtha, 15 percent of a fog oil, and 55 percent of a No. 2 diesel fuel has resulted in excellent control of adult mosquitoes when the plane dispersed 200-foot swaths.

Preliminary droplet-size studies showed the fog to have a mass median diameter of less than 5 microns.

Temperatures inside the exhaust pipes were recorded at five locations. In flight the temperature at the hottest location was 1400° F.; during fogging it dropped to 482°.

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