ARTICLES

AERIAL SPRAY OPERATIONS IN MERCED COUNTY, CALIFORNIA

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THE MOSQUITO PROBLEM IN MERCED COUNTY IN RELATION TO THE NEED FOR AERIAL SPRAYING—The Merced County Mosquito Abatement District includes nearly two thousand square miles of land. Approximately three fourths of this area presents a mosquito control problem. Although nineteen different kinds of mosquitoes are to be found in the district, most of the complaints about mosquitoes may be traced to only two species, namely *Aedes dorsalis* and *Aedes nigromaculis*. This is due not only to their extreme abundance, but also to their habits, for they are the most vicious biting mosquitoes in the valley, have the longest flight range and bite day or night. Because of their preferred habitat, probably 90 per cent of the necessary aerial spraying in the district is for control of these two mosquitoes. Both species have adapted themselves perfectly to the irrigation system of the San Joaquin Valley. Virtually every irrigated crop in the valley produces its share of *Aedes* mosquitoes on every irrigation from April to October. By far the greatest producer of all is permanent pastureland which is seeded with pasture grasses and irrigated regularly every 7 to 21 days all season. Unimproved land which is flooded and used as pasture also contributes a large share of the county's *Aedes* population. Ladino clover, alfalfa, barley, cotton, corn, beans etc. all produce *Aedes* mosquitoes in varying degrees.

According to the 1946 Agriculture Report, Merced County has 850,000 acres of pasture, a large part of it flooded 1–4 times a year, 37,600 acres of permanent pasture flooded every 7–10 days, 85,500 acres of alfalfa, and 73,000 acres of barley. Obviously even if only a small part of this land was producing mosquitoes at any one time it would present a problem of such magnitude that it could be handled only by aerial spraying. Actually, so much of this land is continually producing mosquitoes that it would be financially impossible to operate enough spray planes to keep the mosquitoes under control over the entire area throughout the season. However, it is possible to reduce substantially the mosquito population in the more populated areas for the greater part of the season by carefully selecting the areas to be sprayed and keeping abreast of current developments with a thorough system of inspection.

AIRPLANES AND EQUIPMENT USED BY THE MERCED COUNTY MOSQUITO ABATEMENT DISTRICT FOR AERIAL SPRAYING—The District has used two airplanes in its spray program, an Aeronca Champion owned by the District and a Stearman biplane under contract.

The Stearman spray plane was developed in the late summer of 1946 by the Inland Aviation Company of Los Banos, California. It is a PT-17 with a Pratt & Whitney 450 H.P. engine and was modified for liquid spray work by Lloyd Stearman, the designer of the original Stearman airplanes. The modified plane is known as an Inland Boeing 75-A. It is equipped with a 130 gallon tank, a spray boom and an exhaust aerosol apparatus.

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The spray boom is actually four separate booms equipped with a nozzle on each end. Each boom may be operated separately or in combination with one or more of the other three. This makes it possible to vary the output from 7 to 28 gallons per minute. In actual practice on mosquito work this makes possible dosages of from one-half gallon to ten gallons of liquid per acre.

The exhaust aerosol apparatus was constructed in accordance with the recommendations of the U.S.P.H.S. and T.V.A. in Public Health Report Volume 61, Number 32, August 9, 1946. It is capable of putting out from 1 to 14 gallons per minute or from 1 pint to 1 gallon per acre. The changeover from spray boom to exhaust aerosol can be made in the air or both can be operated together.

The Aeronca Champion was equipped with a metal propeller and the 65 H.P. engine was altered to increase the horse power to 75. The spray apparatus was designed by Lloyd Stearman and built by Inland Aviation Company. It consists of a spray boom with 10 nozzles, Spray system "whirljet" spray nozzle 1/8B5 and a 35 gallon tank. Liquid is supplied under pressure to the nozzles by an Oberdorfer pump No. 4, Type A, Form Y, 10 gallon per minute output. The pump is driven by a four blade aluminum alloy adjustable pitch propeller. Tank, boom, and all piping is aluminum alloy. Output is varied from one-half to one gallon per acre by means of a pressure regulating-valve.

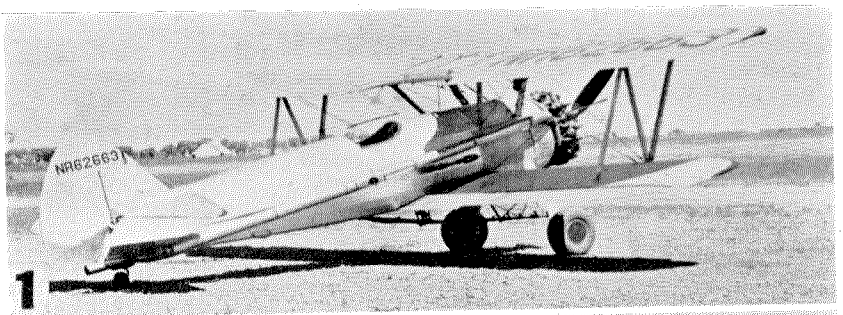
RATES AND METHODS OF AERIAL APPLICATION OF INSECTICIDES FOR MOSQUITO CONTROL IN MERCED COUNTY. The only insecticide used for aerial spraying has been DDT in its several different forms. Most of the work has been done with technical grade DDT in diesel oil, and xylene as an auxiliary solvent. In some cases the 25 per cent emulsible has been mixed with diesel oil and in a few cases the 25 per cent emulsible has been mixed with water. Five, ten and fifteen per cent solutions have been used, but in all cases the application rate of actual DDT was approximately the same. The first season a five per cent solution of DDT was used in the Stearman plane with the spray boom. It was applied at the rate of one gallon to the acre giving approximately .4 lb. to the acre. The second season a 10 per cent solution was applied at the rate of ½ gallon to the acre giving the same dosage of DDT. A fifteen per cent solution was used in the exhaust aerosol and applied at the rate of one quart to the acre giving approximately .3 lb. to the acre of actual DDT.

FIG. 1. The Inland Boeing 75-A showing the aerosol apparatus. The aerosol stack is fabricated from sheet stainless steel.

FIG. 2. Spraying an urban area. The entire city of Los Banos, California was sprayed to combat a serious infestation of *Aedes nigromaculis*. This treatment was only partly successful, but was given widespread credit by the local citizens for completely wiping out the mosquitoes for the remainder of the season as well as preventing the usual fall hordes of houseflies.

FIG. 3. During the 1946 season a total of 8,000 acres were sprayed by plane in the following areas: Merced, Planada, Le Grand, Los Banos, Gustine, Stevinsin and Hilmar, California. Nearly all of this spraying was of permanent pasture. Several drainage ditches and stream channels were sprayed as well as some forested river bottom lands and one urban area.

FIG. 4. Spraying pasture land. Most of the aerial spraying in the 1946 season was done in pasture situations such as this. This type of aerial spraying was 100 per cent effective against larvae with a residual effect through three irrigations and was 95 per cent effective against adult mosquitoes.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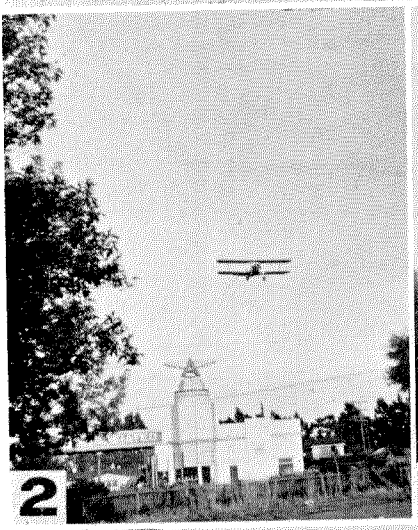
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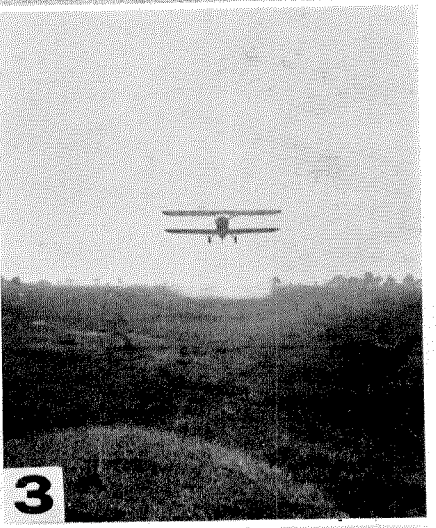
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The flight pattern used by all of the pilots is the same as was used by commercial dusting and spraying planes whenever possible. The plane was flown cross wind starting at the downwind edge of the field. Turns at the end of the flight line were made downwind so as to avoid going through the spray. When the wind velocity got up to 10 or 15 miles per hour, it was sometimes possible to continue spraying by flying into the wind. No spraying was done at a wind velocity of greater than 15 miles per hour. The Stearman plane flew at about an elevation of fifteen feet to give a swath width of about sixty feet with the spray boom and about 75 feet with the aerosol. The Aeronca flew at about an elevation of 12 feet to give a swath width of about 35 feet.

The use of the aerosol was extremely dependent on the weather, and was restricted to the early morning hours. It was possible to use the aerosol from daybreak until the beginning of the thermal upcurrents which during the summer months usually meant from daybreak at about five A.M. until eight A.M. or only two to three hours a day.

The spray boom was more versatile and could be used until a strong wind came up or until it became quite warm. This meant about five or six hours of flying a day as it was usually possible to work until nearly noon with either plane. It was also possible to use the spray boom for an additional two to three hours in the evening and this was done regularly with the Aeronca. On one occasion the Stearman plane continued spraying from 6:00 A.M. until 4:00 in the afternoon, but such perfect weather conditions were rare.

Ordinarily spraying is continued until it becomes so warm that the spray no longer reaches the ground or until the wind becomes so strong or gusty that it is impossible to obtain an even distribution of the spray particles. That decision was normally left up to the man on the ground. The spray operations ordinarily required two men on the ground. One drove the truck with the spray material and operated the pump for loading the plane; the other man, usually the Division Foreman or Inspector, worked with the plane. In some cases it was necessary to measure off the swath width and signal the plane for each flight line. This was true in rice fields, duck clubs, etc. or any other large areas where there were no roads, fences or other markers for lining up the flight lines. Signaling was accomplished in the smaller fields simply by pacing off each swath and standing or waving a white flag at the end of the field. Where it was possible, a jeep or truck was driven ahead and parked for each swath. For long flight lines of one to two miles, it proved quite satisfactory for the jeep to shoot out a puff of the aerosol smoke as the plane approached each flight line. The smoke could be seen several miles away. Even when it was not necessary to signal the plane for swath width, the ground man stayed right with the plane in order to insure that an effective job was being done and to obtain a record of the area covered.

THE PLACE OF AERIAL SPRAYING IN THE OVERALL PROGRAM OF MOSQUITO CONTROL. Aerial spraying is only used when it has a definite advantage over ground spraying. Some areas are inaccessible from the ground, but may be reached easily from the air. In some situations where time is a factor, the mosquitoes might hatch out before they could be treated from the ground, but could be taken care of from the air. Spraying of large areas can be done more cheaply from the air than from the ground. With the Stearman plane it is not economical to spray individual fields smaller than 100 acres as so much time is lost in the turns that it raises the cost to more than it would be for ground treatment. With the Aeronca, it is not economical to spray fields smaller than 10 acres. With either plane, spraying of large areas brings the unit cost down to

a point where it is equal to or less than the cost of ground spraying.

Most of the aerial spraying in Merced County has been in the large areas of pasture land for control of both larvae and adults of *Aedes* mosquitoes, principally *dorsalis* and *nigromaculis*. No attempt was made to spray only that part of a pasture under water. When a pasture was partially flooded and developing mosquitoes, the entire field was sprayed. In a single large field or a series of smaller adjoining fields, a single spray job would be an adulticiding treatment at the end first flooded, a larviciding treatment of the actual water area, and a prehatching treatment of the end not yet flooded. Hence, it was necessary to arrive at a dosage which would effectively accomplish all three purposes. After much experimentation, a dosage of .4 lb. per acre was decided upon. This dosage gave 100 per cent larval kill, was a good prehatching treatment and gave a 95 per cent plus kill of the adults. In individual cases, this treatment has been effective through as many as three or four irrigations or a period of three to six weeks.

In addition to the spraying of the pasture land, the airplane has been used to advantage in otherwise inaccessible places such as: tule ponds, clogged drain ditches, sloughs, riverbottoms and gold dredger-pits. Entire cities have been sprayed as well as certain urban areas for fairs, celebrations, etc. Extensive rice fields which could be controlled in no other way were treated by aerial spraying.

Some of the pastures and duck clubs which remained flooded for long periods of time were sprayed for control of *Culex tarsalis* larvae. Sewer farms were sprayed for *Culex quinquefasciatus* and *Culex pipiens*. Ditches and sloughs were sprayed for *Anopheles freeborni, Culex stigmatosoma* and *Culex tarsalis*. The rice fields were sprayed for *Anopheles freeborni* and *Culex tarsalis*. The gold dredger-pit area along the Merced River produces all 19 kinds of mosquitoes found in the County, so was sprayed in an attempt to kill larvae and adults of as many kinds as possible. In some cases, the spray boom and aerosol were used together in order to get penetration through the trees and to get a high initial kill and a lasting effect.

THE RELATION OF THE MOSQUITO AERIAL SPRAY PROGRAM TO THE WILDLIFE OF MERCED COUNTY. Although no serious problem has yet arisen, there is always the possibility of deleterious effects of DDT on fish, birds and beneficial insects.

The dosage used, .4 lb. per acre, is sufficient to kill small fish in confined water areas such as shallow puddles left after flooding a field or ditches in which the water has been turned off. However, in these situations the fish would probably die anyway. It is doubtful that this dosage would be enough to kill any fish in the deep flowing canals, ditches, sloughs and rivers. Since most of the spraying is done on pasture and swamp land, the danger to fish does not present a very serious problem. A note of caution might be added in regard to the spraying of lakes, reservoirs or even slowly moving rivers. In one case in the upper Merced River area a number of bass were killed. The local fishermen blamed it on the mosquito spraying. Although the dosage applied would hardly be sufficient to kill such fish, in slowly moving water it is quite possible in this area that the pilot became confused and repeated the same swath several times. Such a heavy dosage would certainly be enough to kill fairly large fish.

There have been no ill effects on the bird population so far as is known. However, with nearly 300 duck clubs covering over 70 square miles, the possibility makes it essential that every precaution be taken. It seems very unlikely that there would be any direct effects of the DDT on the ducks, but since many of them eat a certain number of aquatic insects which are readily killed by DDT, it is possible that the ducks might be affected. The only place where this has come up is on the California State Game Refuge at

Los Banos, California. The manager of the game refuge was hesitant about allowing the district to spray his ponds. Instead of larviciding the ponds, the district waited until the mosquitoes had hatched and then adulticided the area with the exhaust aerosol.

Several thousand acres of duck clubs have been aerial sprayed with the same dosage used on pastures and swamps without a single complaint from the owners or the hunters.

The problem of killing beneficial insects has come up several times in regard to bees. Several complaints have come in to the effect that the aerial spraying was killing off bees in certain hives. Every case so far has eventually been traced to other spray materials, principally arsenicals. Although the pilots take every precaution to avoid spraying directly on bee hives, in one or two cases it has been done. In one case a truckload of beehives was in a back yard in town and was covered with the DDT spray. The owner observed the hives closely and reported no ill effects whatsoever.

There is also the possibility of materially reducing the populations of pollinating insects and insects in general. As yet so little research work has been done on such problems that it is difficult to determine how important the problem ac tually is. During the normal spray pro gram, the only other insect which was ob viously consistently killed off was th housefly. This was definitely an advantag as it resulted in much good will toward the district.

Just what the results of repeated spray ings in the same field will be is hard t predict. However, one incident involvin the application of a higher dosage thai normal showed some interesting results

In one particular field, 100 acres o permanent pasture, a dosage of .8 lb. t the acre was applied by mistake through faulty adjustment of the pressure relie valve. In this field no mosquito larva were found for nearly sixty days. How ever, at the time of the spraying many other insects in the area were also killed Within ten or fifteen minutes the surfac of the water was blackened with th bodies of insects such as bugs (notonec tids and corixids), beetles (hydrophilids and dytiscids, etc.), dragonflies, may flies, bees, wasps, etc. It almost seemed to be raining insects for a few minutes.

The danger of seriously upsetting the balance of nature is one which should be considered with due caution by those re sponsible for large scale aerial DDT spray programs.

COMPARATIVE TABLES — I.

Aerial Spraying	*Ground Spraying*
Cost: Comparable to or cheaper than ground spraying where large areas are sprayed.	*Cost:* Cheaper than aerial spraying for small areas.
Time: Much faster. Possible to spray from 100 to 400 acres per hour.	*Time:* One truck with a spray boom can spray from 5 to 20 acres an hour.
Accessibility: Plane can spray many places which are inaccessible from the ground such as large swamps, tule ponds, duck ponds, rice fields etc.	*Accessibility:* Ground rig can sometimes get to spots with overhead obstructions which would prevent plane operation.

COMPARATIVE TABLES — II.

Small Plane (Aeronca Champion)	*Large Plane* (Inland Boeing 75A)
1. Can spray an average of 125 acres an hour.	1. Can spray an average of 270 acres an hour.
2. Economical for spraying areas of 10 acres or larger.	2. Economical for spraying areas of 100 acres or larger.
3. Can spray ½ gallon to 1 gallon per acre.	3. Can spray from 1 pt. to 10 gallon per acre.
4. No aerosol.	4. Equipped with exhaust aerosol apparatus.

COMPARATIVE TABLES — III.

District Owned Plane		*Rented Plane*	
Direct costs of operating the Aeronca Champion airplane from April 15, 1947 to Sept. 30, 1947. Not including the cost of insecticide.		Rental of 450 H.P. Inland Boeing 75A biplane. May and June, 1947.	
Gasoline and oil	$ 697.81		
Repairs & overhaul	649.63		
Hangar rental	180.00		
Fire & Theft Ins.	126.00		
Liability Ins.	180.00		
Compensation Ins.	371.68		
Pilot Salary	2,479.50	Plane rental	$2,939.83
Total direct cost for 1947 season	$4,684.62	Total	$2,939.83
Total acres sprayed	71,290		14,692
Cost per acre	$ 0.07		$ 0.20
Total Hours of flying	564		54
Cost per hour	$8.30		$55.00
Total gals. of spray	32,996		7,646
Cost per gal. sprayed	$ 0.14		$ 0.38
Gals per hour	58		141
Acres per hour	126		272

The above costs do not include the cost of 10 per cent DDT larvicide in diesel oil at 50¢ per gallon or the capital cost of the Aeronca aeroplane and the spray equipment.

COMPARATIVE TABLES — IV.

District Owned Plane	*Rented Plane*
1. Capital Investment Aeronca plane $2,777 65 Spray equip. 881.50 $3,659.15	1. Capital Investment None
2. Unit Operating Cost (does not include capitalized cost of airplane and equipment) $8.30 per hour $0.07 per acre covered $0.14 per gallon sprayed	2. Unit Operating Cost $55.00 per hour $ 0.20 per acre covered $ 0.38 per gallon sprayed
3. Convenience—always ready for immediate operation on short notice.	3. Require 24 hour notice and even then not always available.
4. No problem.	4. Minimum guarantee of 1 hour's flying time if called out.
5. Pilot is district employee, trained in mosquito control methods and is familiar with the terrain.	5. Same pilot is not always assigned to the job, hence is not familiar with the work or the terrain.

COMPARATIVE TABLES — V.

Aerial Spray — Boom	*Aerial Aeorosol*
1. Large droplet size. Mass median diameter of 150 microns	1. Small droplet size. Mass median diameter of 50–75 microns.
2. Fair penetration through foliage.	2. Excellent penetration through trees, bushes and tall grass.
3. Maximum kill in 24 hours.	3. Maximum kill in 3–6 hours.
4. One load of 130 gallons dispensed in 20 minutes at ½ gallon to the acre. 260 acres to the load. 10 per cent solution of DDT used to give .4 lb. per acre.	4. One load of 130 gallons dispensed in one hour at 1⅓ qt. to the acre. 390 acres to the load. 15 per cent solution of DDT used to give .4 lb. per acre.

CLASSIFICATION OF AREAS SPRAYED

	Acres	*Hours*
Pasture and Swamp	82,586	605:32
Ditches, Canals and Sloughs	1,986	5:25
Ponds	300	1:10
Rice Fields	320	2:19
Urban	210	1:03
Sewer Farms	580	2:31
Total	85,982	618:00

DATA ON AERIAL AEROSOL APPLICATIONS*

Plane rental	$1,743.64
Total acres fogged	9,222
Cost per acre	.17
Total gallons of aerosol	2,383
Cost per gallon aerosol	.73
Gallons per hour	74
Acres per hour	288

* The aerosol application was restricted largely to rice fields, heavily wooded river-bottom land and the gold dredger-pit area.