LOW VOLUME CONCENTRATE EQUIPMENT FOR FIXED WING AIRCRAFT[1]

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Introduction. The use of military aircraft for low volume insecticide dispersal has received its greatest emphasis since 1964. When this new technique was first attempted, the usual procedure was to modify existing high volume equipment for low volume use, with varying degrees of success. Eventually, equipment was built that was specifically adapted for this purpose. Preliminary research by the Navy with LVC dispersal equipment was accomplished with helicopters because of parallel development programs for dilute liquid and dry system requirements. Because the availability of helicopters and pilots was reduced due to war commitments, attention was directed toward the use of transport aircraft commonly available throughout the Navy.

In May 1967, the USDA Laboratory, Gainesville, Florida requested the Navy to assist them in a project for development and evaluation of equipment for a C-47 aircraft. The Commanding Officer, U. S. Naval Air Station, Cecil Field, Florida made the station C-117D (C-47) available for research and operational flights in the local area. The boom components and mounting hardware were provided by the USDA, and the tank, pump, and electrical system were provided by Disease Vector Control Center, Naval Air Station, Jacksonville, Florida.

The original equipment consisted of a 20-inch boom and a 6-foot vertical discharge tube constructed from 1-inch diameter galvanized pipe. Spraying Systems Company diaphragm Tee Jet® nozzles were used which had 8004, 8008, or 6515 tips. The discharge pipe was mounted vertically between two floorboard beams with two steel plates, along the center line of the aircraft, opposite the cargo doors. The vertical pipe extended through an existing inspection plate to the exterior of the aircraft. The spray boom was joined to the vertical pipe by a pipe union. The boom was fixed in a position so that the nozzles were at a forward 45° angle to the airflow to aid in atomization. The vertical pipe had two stops to secure it in a retracted position for landings and take-offs, and could be extended an additional 2 feet below the fuselage for spraying operations. It was thought that the boom needed to be at least 3 feet away from the fuselage to prevent contamination.

A 60-gallon fiberglass tank, mounted in an aluminum cradle, was used as an insecticide reservoir. An aircraft fuel pump-electric motor combination was used to deliver insecticide under pressures of 30–60 psi. An electric fuel valve was provided between the tank and pump to control insecticide flow and to serve as an emergency shut-off valve. For the prototype installation, the operator controlled spraying from the rear of the aircraft, with interphone communication provided to coordinate operations with the pilot.

Prototype Trials. Tests were conducted to determine droplet size produced by this equipment. Swath intervals of 50 feet at altitudes of 75–100 feet were flown using three different sizes of nozzle tips. The MMD was determined to be 34 microns with the 8004 tip, 50 microns with the 8008 tip, and 62 microns with the 6515 tip. Mortality determinations

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[1] The opinions and assertions contained herein are those of the authors and are not to be construed as official or reflecting the views of the Navy Department or the Naval Service at large.

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using caged *Aedes taeniorhynchus* adults were very encouraging.

Operational flights were made at naval installations in the Jacksonville area, and reduced light trap counts and complaint calls indicated excellent results. Most flights were made at altitudes from 100–200 feet at speeds of 150 mph with cross-wind swath spacing of 500 feet. The deposit rate of malathion was estimated to be 0.3 lb/acre. Mosquito species to be controlled were mainly floodwater *Psorophora* and *Aedes*. The unit was used throughout 1968, with several excellent operational flights. No major problems were encountered with equipment usage. However, it was felt that the quality of a number of components could be improved. The hose and boom system was difficult to drain prior to disassembly for removal from the aircraft, and spillage of concentrate always occurred.

While the work was being continued by the Navy, the USDA conducted tests with this equipment in Thailand. A large scale trial of the ultra low volume method was made to determine the effectiveness of ULV malathion applied at the rate of 6 ounces per acre for controlling *Aedes aegypti* with two applications made 4 days apart over an area of 7 square miles. Biting counts and oviposition rates were dramatically reduced. Although the kill of caged adults and larvae during the first treatment was only fair, the second test revealed almost complete kill of all adults placed inside and under houses; larval mortalities were also high. Reduction of other mosquito species and house flies was also noted.

NAVY MODIFICATIONS AND IMPROVEMENTS TO THE PROTOTYPE SYSTEM. After the completion of operations in 1968, inspection revealed serious deterioration of the pipe and hose system. The welded joints of the boom system showed visible evidence of cracking. As a result, several modifications and improvements were made in the equipment by the Agro Spray Development Corporation, with the addition of a new hose, vertical pipe, and boom system. The improvements to the new system were as follows:

1. Strengthened fiberglass tank with additional layers of fiberglass cloth and resin. The aluminum cradle was painted with insecticide resistant paint.
2. A safety return line was added to the pump system in case of pump seal failure. This prevents accidental discharge of the insecticide into the aircraft.
3. Armored Teflon® hose was used to replace the fuel hose line between the pump outlet and vertical discharge pipe.
4. The electrical controls were modified so that they could be operated from the cockpit of the aircraft. The entire electrical system has been overhauled and brought up to acceptable aircraft installation standards.
5. One-inch stainless steel tubing was used for the vertical pipe and boom assembly. In this model, the boom only needed to be lowered 7 inches for spray operations. Holes have been drilled in the boom pipe coupling nut, and the web of the 45° ell, so that the coupling nut can be safety-wired.
6. The new boom has provisions for 14 nozzles along its 4-foot length. A drain cock was installed in the center of the main boom. Both ends of the boom have pipe caps to facilitate draining and cleaning.
7. The metal plates that secure the vertical pipe between the floor board beams have been modified by the addition of an extra bolt in the center and jam nuts on the bottom of all bolts.
8. A modified floor board section was provided, and fits around the vertical pipe mounting plates.

The changes to the overall system were considered necessary to improve its utility and flight safety. The quality of the equipment is superior to that of any of its predecessors, and because of its ruggedness and portability it lends itself well to military operations. It is equally adaptable to a variety of civilian aircraft.

NEW UNIT TRIALS. Initial flight testing

of the new system was accomplished in June 1969. Pilots, crew members, and mosquito control personnel have been enthusiastic in the acceptance of the new unit. Problems previously encountered with flight operations have been virtually eliminated. There is still some difficulty with drainage of the system after flights are completed. If a reasonable amount of care is taken in the removal process, however, very little liquid is spilled. The boom, in the extended position, projects far enough below the aircraft so that no contamination of the rear fuselage or tail surfaces occurs. The addition of a 30-foot electrical control cable to allow the spray operator to stand just behind the cockpit during operations is considered to be a very worthwhile modification of the equipment.

Preliminary droplet studies revealed that either flat fan or hollow cone nozzle tips produce particle sizes in a range for effective control of adult mosquitoes. Although additional work remains to determine optimum operating factors and droplet size, hollow cone nozzle tips will be used for the next series of flights. Table 1 gives essential data from the preliminary studies.

operating time on the new unit is about 25 hours. The pump and motor assembly on this unit have been in use for seven mosquito seasons, and have had about 300 hours of operating time. There have been no malfunctions to date. Installation requires approximately 30 minutes for a crew of two. Removal requires approximately the same amount of time.

Conclusions. This unit is still considered to be an operational prototype. Some factors concerning its employment remain to be investigated. These are: adaptability to other aircraft (including high performance types), feasibility of use under combat conditions, and dispersal of LVC insecticides other than malathion. Emphasis has been placed on the design and construction of high quality equipment built to aircraft standards.

Some of the variables concerning LVC dispersal with this equipment on any aircraft will require extensive evaluation. Observation over several control seasons undoubtedly will be required to assess factors such as optimum droplet size, swath width and aiming, and other flight procedures. The basic problems of equipment design appear to be solved. Attention now can be directed toward the determination and evaluation of operational techniques.

Table 1.—Representative performance data using a 14-nozzle boom with Tee Jet X-12 tips on a Navy C-117D aircraft. Aircraft air speed 150 m.p.h., Malathion (95%) flow rate 3.0 g.p.m. Temperature 72° F., relative humidity 81%, wind speed 5 m.p.h. Measurements were made directly under the line of flight.

Altitude (ft.)	Mass Median Diameter (Microns)	Frequency Median Diameter (Microns)	Range of Particle Sizes (Microns)
50 (No dye)	26	17	7–52
50 (Oil red dye added)	43	17	5–58
150 (No dye)	29	17	5–48

Operational flights were made during 1969 in the local area for control of both floodwater and salt-marsh mosquito species. Results were excellent based on decreased light trap counts and complaint calls. Operational altitudes ranged from 100 to 500 feet, and crosswind swath spacing was maintained at 500 feet. Total

Summary. A low volume concentrate insecticide dispersal unit for Navy C-117 (C-47) aircraft has been built with emphasis on construction of high quality equipment built to aircraft standards. The

unit described consists of a 60-gallon fiberglass tank, an electric motor and control system, a positive displacement pump, Teflon hose and a stainless steel boom with provisions for 14 nozzles. Installation or removal of all equipment requires approximately 30 minutes. No structural modification of the aircraft is required. Droplet mass median diameters range from 25 to 50 microns using flat fan or hollow cone nozzle tips. The unit has demonstrated excellent operational performance dispersing malathion at 0.3 pound per acre for adult mosquito control.

THE EFFECT OF TEST CAGE MATERIALS ON ULV MALATHION EVALUATIONS [1]

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INTRODUCTION. Ultra-low-volume (ULV) applications require a correlation between droplet distribution of insecticide and mosquito mortality. When malathion is used, malathion-sensitive dye cards and confined adults or larvae are positioned so the number of droplets appearing per card or per square inch can be compared with percent mortality. Thus, it should be possible to determine the droplet distribution necessary for a given mortality of an exposed species. Also, many workers use caged insects, without associated indicators of insecticide distribution, to bioassay the effectiveness of ULV treatments. Ultra-low-volume experiments conducted by the Central America Malaria Research Station (CAMRS) in coastal El Salvador during 1969 revealed that the type of screening material used in test cage construction was of considerable importance in making proper evaluations.

During the first of ten aerial ULV treatments programmed for the 1969 dry season, there was a discrepancy between mortalities of adult *Anopheles albimanus* confined to cages and larvae of the same species in open containers as related to droplet distribution on adjacent dye cards. The correlation between droplet distribution and mortality was much higher with larvae than with adults even though adults were the primary target. Since the larval containers were open at the top and adults were in screened cages, it was surmised that droplets were not penetrating the cages in numbers sufficient to result in consistent adult mortality. Therefore, experiments were designed to measure the effect of test cage screening materials and to develop cages to allow maximum penetration of insecticide droplets.

PROCEDURE AND RESULTS. C-47 aircraft flying 160 mph at 125 feet altitude made all applications, delivering 3.0 fluid ounces of malathion ULV concentrate per acre. On February 18, 1969, stations at 40 sites were used to evaluate the ULV treatment of a 3,000-acre area of coastal El Salvador east of the port city of La Libertad. The mosquito target was the local vector species of malaria, *Anopheles albimanus*. Each station (Figure 1) consisted of a wooden platform, 18 inches high, on

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