TECHNICAL REPORT NO. 71-05

ROTARY-TUBE SPRAYER

Final Report

By
Clyde S. Barnhart, Sr.
Biological Sciences Branch

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U. S. ARMY LAND WARFARE LABORATORY
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ABSTRACT

A sprayer of new design is described which utilizes a rotary-tube spraying principle. Droplets produced lie within more narrow size ranges compared to droplets produced by presently available rotary disc and pressure spray nozzles. The range of droplet sizes believed best for mosquito control was attained using diesel fuel as the test liquid. Droplet size of the spray is related to the tip speed of the rotary-tubes and rate of throughput of liquid.

This sprayer is easily maintained, is reasonably light-weight with efficient use of horsepower. The narrow spectrum of droplet sizes virtually eliminates waste and environmental pollution by spray droplets outside the desired size range.

FOREWORD

The writer first began the development of this sprayer while employed at the Engineer Research and Development Laboratories, Fort Belvoir, Virginia. At that time the work was funded by the Bureau of Yards and Docks, Department of the Navy.

This report covers work done at Fort Belvoir and under LWL tasks 03-CA-70, Population Control Disseminater; 04-CA-70, Ecological Control Technique Sprayer; 09-BA-70, Rotary Tube Sprayer; and 14-BA-70, Insecticide Sprayer Test/Evaluation.

The present sprayer was built by the Technical Support Division LWL. Mr. C. K. Ramsdell was especially helpful in the details of design and the selection and procurement of components.

Mr. Samuel B. Comer, Facilities and Engineering Directorate, Aberdeen Proving Ground, Maryland, arranged the practical tests fogging mosquitoes.

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cu ft/min	cubic feet per minute
g	grams
gph	gallons per hour
in.	inch
l	liter
lb.	pound
mmd	mass median diameter
mph	miles per hour
OD	outside diameter
rpm	revolutions per minute
μ	microns

INTRODUCTION

The state-of-the-art in spray atomization has been reviewed by recent authors. Frazer (1958) states that recognized inefficiencies in nozzle performance must lead to new inventive steps brought about by future research.

Mount (1970) reviewed present knowledge relating droplet size of insecticides to their ability to impinge on or to penetrate the target. He considers droplet size to be a principal factor in the efficiency of insecticide effectiveness. He concludes that for ground aerosol applications a droplet size range of 5 to 10 μ is optimum, and for aerial spraying the optimum droplet size is probably 10 to 25 μ.

Spinning disc and pressure nozzles currently being used do not achieve the particle size control now believed to be necessary. It is not likely that more than moderate improvement in their performance can be achieved by manipulation of formulation, flow rates and/or mechanical configuration.

If the problem of particle size control is to be resolved, new inventions and new engineering are required. From 1960 to 1962 at the U. S. Army Engineer Research and Development Laboratories, Fort Belvoir, Virginia, the writer invented and began the development of a new rotary-tube spraying principle. The principle of rotary-tube spraying is much the same as the flit gun. In the flit gun, air is passed at high velocity over the tip of a tube filled with liquid. In the rotary-tube sprayer, the liquid containing tube is rotated so that its tip moves at high velocity through the air. The effect is atomization in both cases. In the rotary-tube sprayer, the degree of atomization is shown to be related to both tip speed and rate of throughput of liquid.

The Fort Belvoir sprayer (Barnhart, 1962) is shown in Figures 1 and 2 mounted on a military vehicle. Although exhibiting improved droplet size performance, it fell short of satisfying the military requirement for such a sprayer because no means was provided by which the spray was blown clear of the vehicle. To overcome this shortcoming, an experimental sprayer has been built which provides a means for blowing the spray clear of the vehicle, as well as a means for experimentally narrowing the particle size spectrum by operating at the higher tip speeds.

This report includes data obtained by use of both the Fort Belvoir machine and the LWL machine.

FIGURE 1. Fort Belvoir rotary tube sprayer, jeep-mounted.

FIGURE 2. Fort Belvoir rotary-tube sprayer, atomizing diesel fuel No. 2 to 20 µ. mmd at 16 gph.

CONCLUSIONS

For ground spraying applications against adult mosquitoes, a machine with a gasoline engine operating at 3400 rpm, belted to the rotary tubes operating at 300 mph (4200 rpm) spraying diesel fuel base insecticide at 16 gph should produce the optimum particle size range, 5 to 10 μ.

For aerial spraying the rotary tubes operated on aircraft at a tip speed of 230 mph with diesel fuel No. 2 base insecticide sprayed at 16 gph should produce the optimum particle size range, 10 to 25 μ.

The LWL sprayer configuration provides an effective means of blowing the spray clear of the truck and operator. There is no wetting of the vehicle when it is stopped. By observing the behavior of the fog as it leaves the rotating tubes, it is apparent that the spray is blown clear of the shroud. The air velocity is sufficient to keep the sprayer itself from being contaminated.

EQUIPMENT DESCRIPTION

This equipment utilizes a rotary-tube spraying principle first developed by the writer in 1960-61 at Fort Belvoir, Virginia. The principle of rotary tube spraying is somewhat similar to the flit gun. In the flit gun, air is passed at high velocity over the tip of a liquid-filled tube. In the rotary-tube sprayer, the tube of liquid is rotated so that its tip moves rapidly through the air. The effect is atomization in both cases.

The rotary-tube sprayer has two polypropylene plastic tubes, 1/8 in.OD, mounted on a metal bowl set on edge, which is belt-driven. The rotary-tubes are located in the outlet air stream of a 17,000 cu ft/min vanaxial fan, also belt-driven. The air stream serves to move the atomized liquid from the vicinity of the sprayer. A 12 horsepower gasoline engine powers both fan and rotary-tubes. The speed of rotation of the tubes can be varied between 3,000 to 6,000 rpm. An automotive type tachometer registers the speed of rotation of the rotary tubes.

Liquid to be sprayed is pumped to the rotating bowl by means of an electric fuel pump. The sprayer bowl is set on edge and has a constricted rim. Centrifugal force prevents overflowing and no packing gland or rotary seal is needed where the liquid enters the bowl. The liquid leaves the bowl through two oppositely mounted 1/8 in. OD polypropylene tubes, each of such length that the distance from the center of the bowl to the tip of the whip is 12 in.

Droplet size determinations were made using the technique described by Yeomans (1949). In this technique, droplets are impinged on oleophobic film-coated slides. The slides were hand held and waved through the fog or mist at a distance of about 20 ft. from the sprayer. For each determination, one hundred droplets on each of 2 slides are microscopically measured by ocular micrometer using a 10X ocular and a 10X objective. The spread-factor is taken into account and measured for each slide. The mass median diameter (mmd) is then calculated for each determination.

This waved slide technique has limitations for droplets smaller that 5 μ. Rothburn (1970) points out that the collection of droplets impinged on a 1 in. x 3 in. microscope slide waved at 20 mph is only .2 percent, 5 percent, and 20 percent efficient for 1, 5, and 10 μ droplets respectively. The waved slide technique was believed to be useful and was used in these tests.

Wind velocity measurements were made with a Dwyer hand held plastic wind meter. With a background wind velocity of 2 to 4 mph the wind velocity at the sprayer ranged from 40 to 60 mph maximum and from 15 to 20 mph at the sampling point 20 ft. from the sprayer.

PROCEDURES AND TEST RESULTS

A. Performance Tests.

Measurements of particle size of atomized diesel fuel No. 2 vs. tip speed vs. flow rates were made. The sprayer, mounted on a pick-up truck, was operated in a static position at the LWL Spesutie Island test site. The truck was parked so that the spray was blown with the wind. Flow rate of diesel fuel was measured using a 1 liter calibrated glass cylinder and a stop watch.

Rotational speed of the spray head was measured by use of an automotive tachometer installed on the equipment.

B. Test Results.

Diesel fuel No. 2 was used as the test liquid. It has the advantages of being inexpensive, readily available, is a common base for insecticides and is relatively slow to evaporate, which allows sufficient time for microscopic examination of samples collected on glass slides.

Data are presented from both the Fort Belvoir sprayer (slower speeds) and the LWL machine at the higher tip speeds.

Figure 3 shows the degree of atomization in terms of mass median diameter (mmd) expressed in microns (μ). At a constant rate of spraying (about 16 gph) the mmd ranged from 140 μ for 90 mph tip speed to less than 5 μ for a 400 mph tip speed. The ends of the curve can be extrapolated to show that at higher speeds, finer sprays would probably be attainable, and at slower speeds coarser sprays could be expected to result.

C. Practical Tests.

The LWL configuration (Figure 4) was loaded on a pick-up truck (Figure 5) and used for approximately one week in the Engineer Entomology Services Mosquito Spraying Program at Aberdeen Proving Ground. The formulation used was 6 percent malathion in diesel fuel No. 2. It was applied at about 16 gph with the sprayer tubes running at approximately 4200 rpm (tip speed 300 mph). The spray produced was a dry fog. The particle sizes obtained were not measured but by referring to Figure 6, at the 300 mph tip speed, the particles probably ranged from 5 to 10 μ, the optimum size according to Mount (loc. cit.).

Operator personnel had no difficulty with the equipment. There was no report of spotting of cars. This sprayer was considered to be less noisy than the standard Army cold fogger routinely used. It was apparent that one operator (the driver) could operate this more simple sprayer while two people routinely operate the standard Army machine.

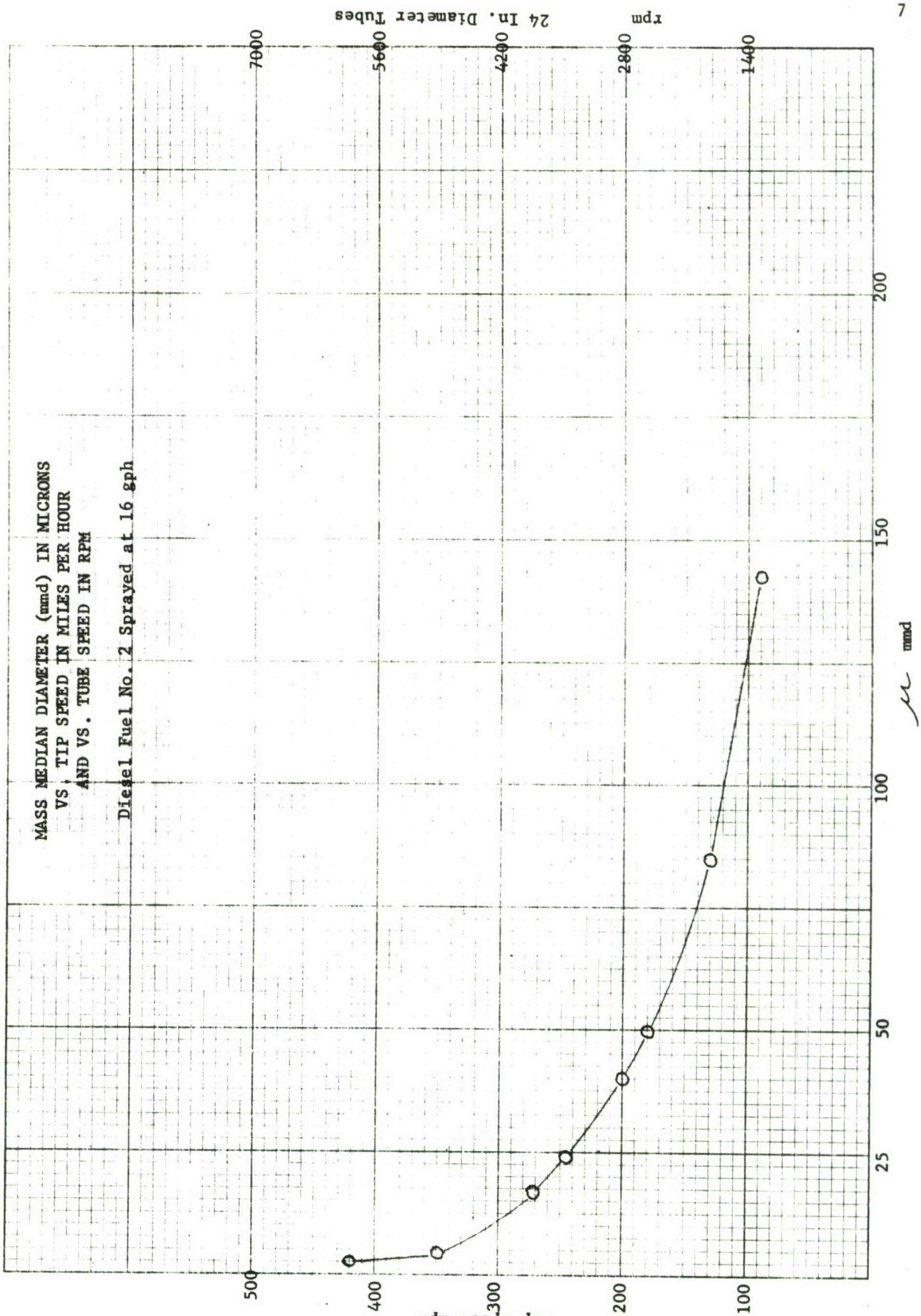

FIGURE 3. Mass Median Diameter (mmd) in Microns Vs. Tip Speed in Miles per Hour and Vs. Tube Speed in rpm. Diesel Fuel No. 2 Sprayed at 16 gph.

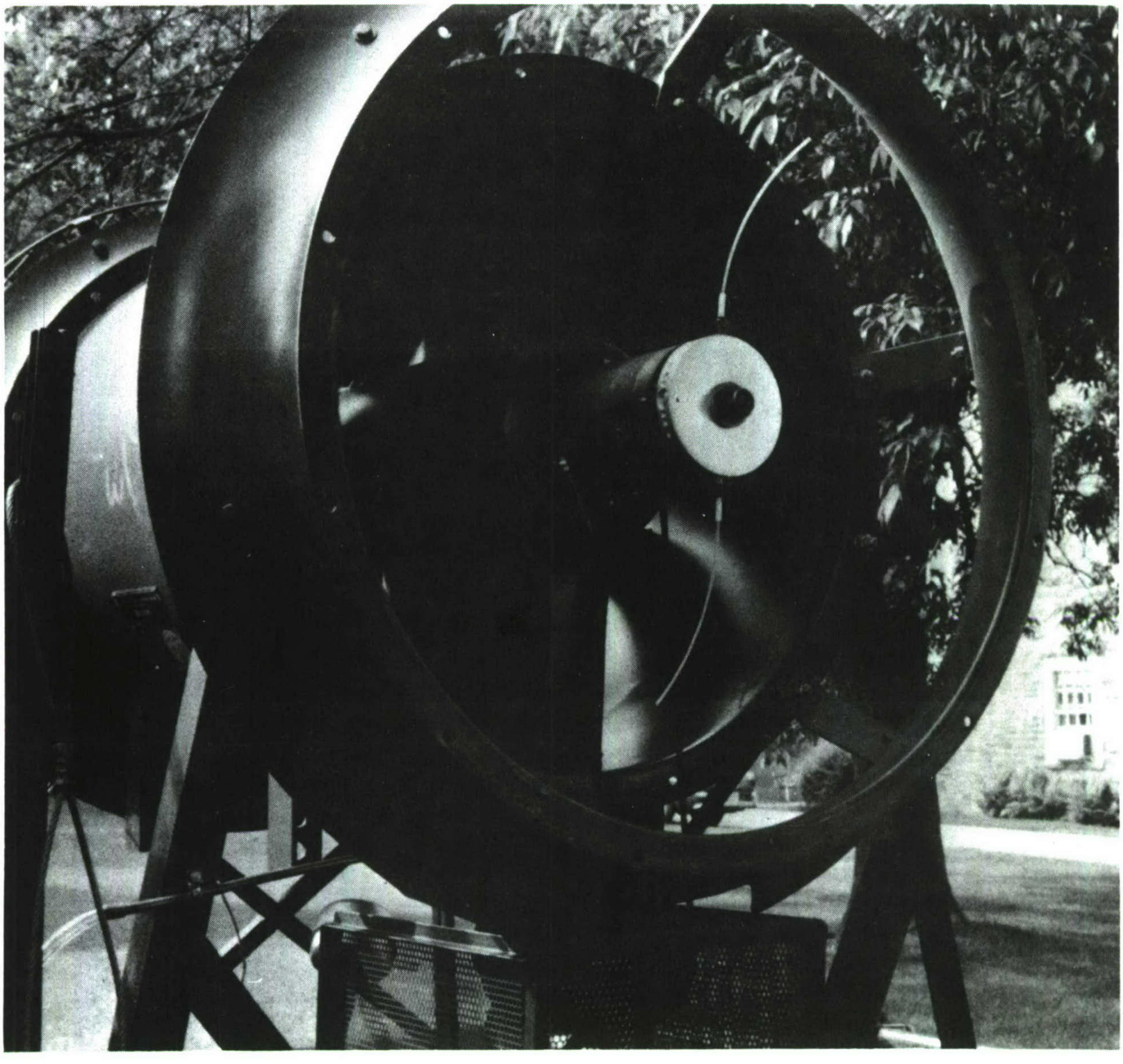

FIGURE 4. LWL Rotary-Tube Sprayer, Skid Mounted.

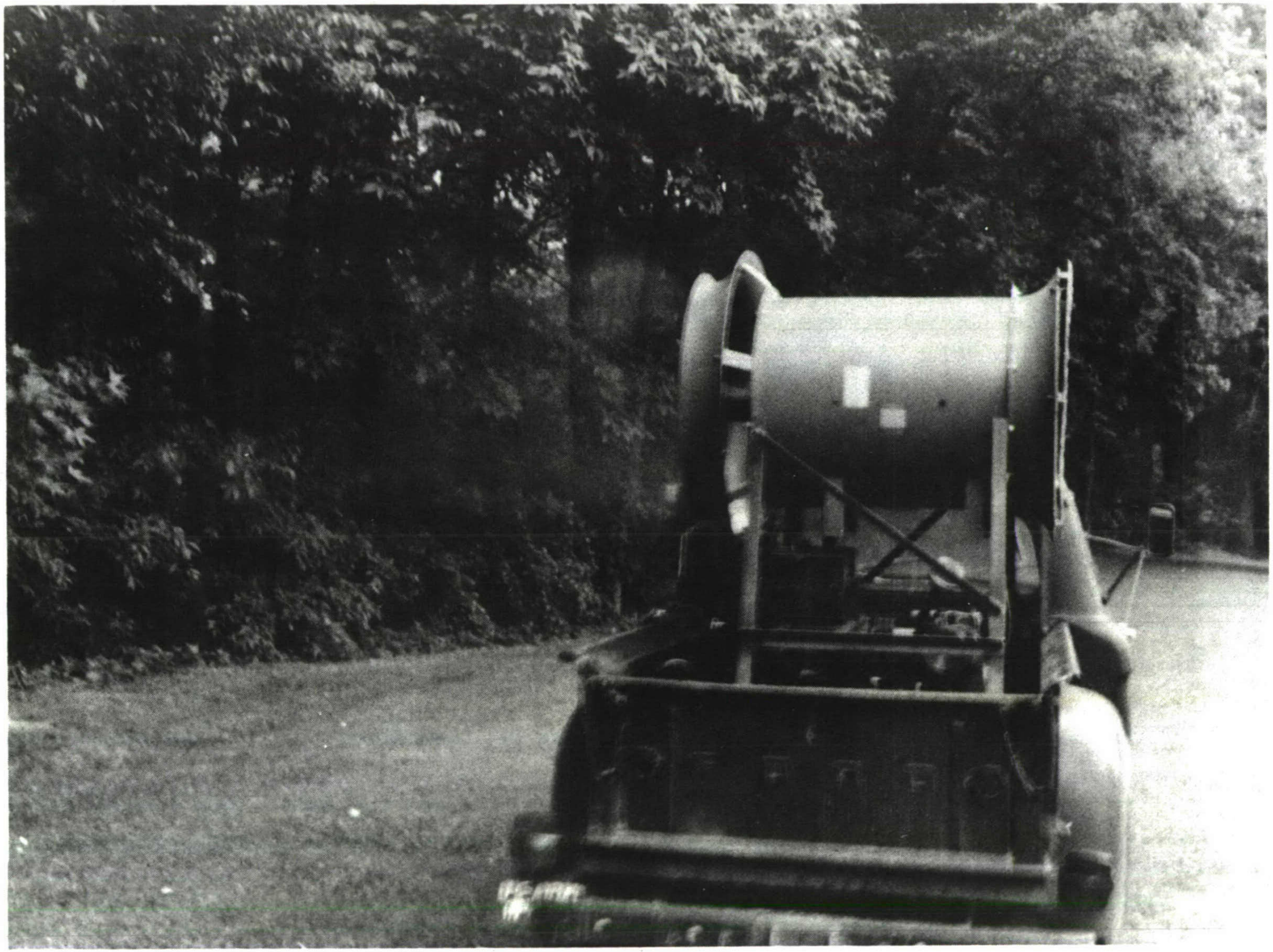

FIGURE 5. LWL Rotary-Tube Sprayer Atomizing Diesel Fuel No. 2 Base Insecticide at 12 gph to 10 μ mmd.

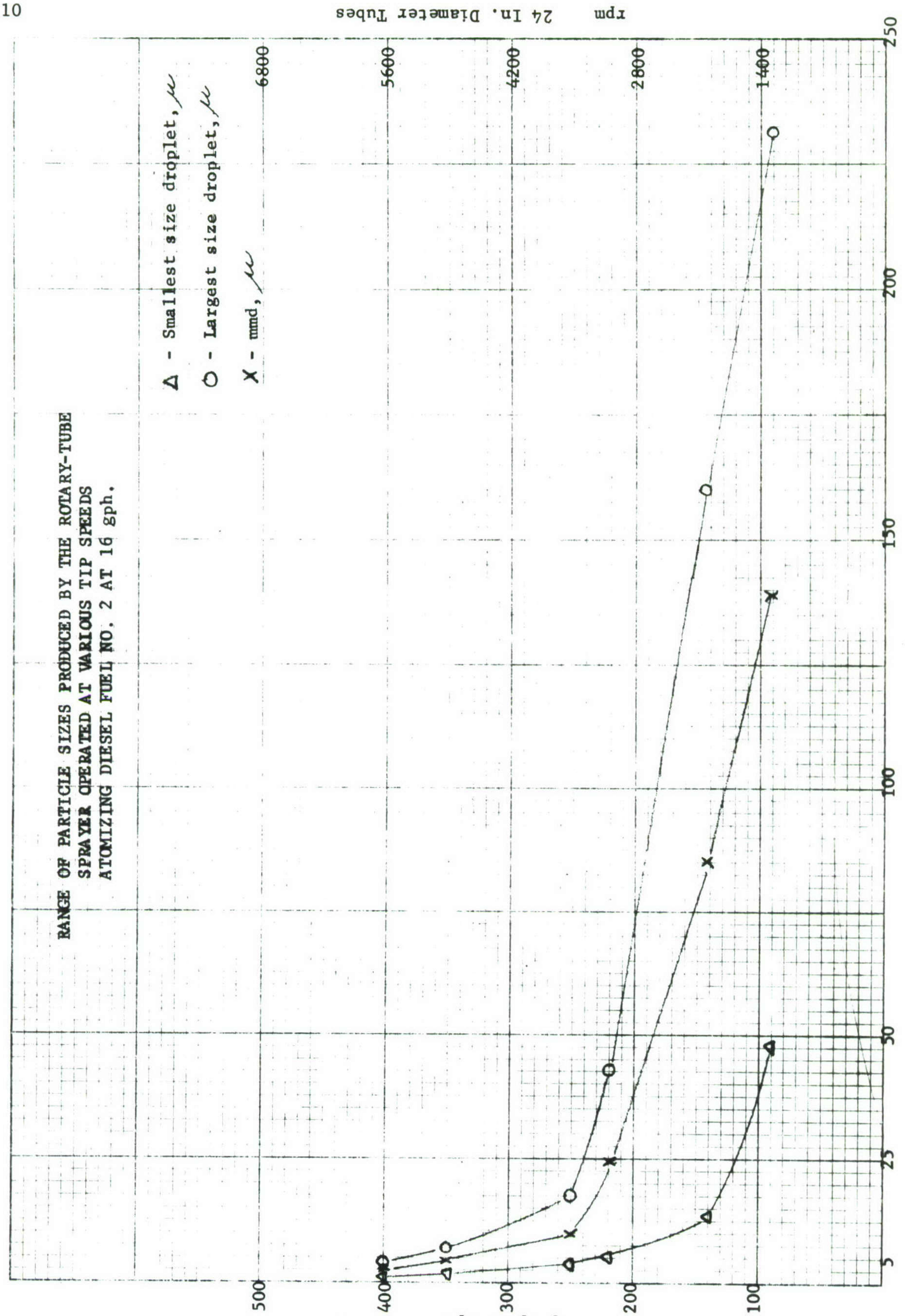

FIGURE 6. Range of Particle Sizes Produced by the Rotary-Tube Sprayer Operated at Various Tip Speeds Atomizing Diesel Fuel No. 2 at 16 gph.

DISCUSSION

A. Particle Size Distribution.

Mass median diameter (mmd) is a convenient measure for rule-of-thumb expression of sprayer performance. In comparing the atomization performance of different sprayers, however, mmd does not tell the whole story. Particle size distribution (particle size spectrum) of the spray with the percentage of the mass in each size range is a more meaningful criterion for comparison of sprayer performance. In practice, where only a narrow particle size range is effective in impinging the target insect, all particles larger or smaller than this range are lost and contribute to the contamination of the environment.

In Table 1 is shown the particle size spectrum produced by three different sprayers each utilizing a different spraying principle under conditions whereby the mmd produced was very near 20 microns. The sprayers compared are the rotary-tube, a rotary-disc and a tee-jet nozzle. Data for the rotary-tube sprayer are from Fort Belvoir tests by the writer; for the rotary-disc sprayer from Table 2, Mount, et. al., September 1970; and for the tee-jet sprayer, Table 6, Mount, et.al., December 1970.

TABLE I

Comparison of Droplet Size Spectrum for the Rotary-Tube Sprayer, the Rotary-Disc Sprayer and a Tee-Jet Nozzle Under Conditions in Which the mmd was Very Close (20, 22 and 23 Microns Respectively).

	Percentage of Total Mass of Droplets in Indicated Size Range.					Mass Median Diameter (μ)
	5-10	11-25	26-50	51-125	126-200	
Rotary-Tube	20	58	22	0	0	20
Rotary-Disc	10	40	36	14	0	22
Tee-Jet	33	23	12	28	4	23

Performance of the rotary-tube sprayer is shown in Figure 6. The particle size spectrum is plotted for the entire range of tip speeds (90 to 400 mph) at which the sprayer was tested. This Figure includes the mmd data of Figure 3 and the data on largest and smallest particles produced. The data are for tests on both the Fort Belvoir machine and the LWL machine. Diesel fuel No. 2 was sprayed in all tests at about 16 gph, and the waved microscope slide technique was used for sampling.

B. Spraying Rate Vs. Particle Size Spectra.

In addition to particle size spectrum control by varying the tip speed, the rate of throughput of the liquid has an effect on droplet size spectra.

Data were not recorded throughout the whole range of tip speeds but two experiments show the effect of doubling the spraying rate. At tip speed of 218 mph throughputs for diesel fuel No. 2 of 16 and 32 gph were atomized to 26 and 56 μ mmd respectively. At a higher tip speed of 250 mph and reduced throughputs of 2 and 6 gph of diesel fuel No. 2, the measured atomization was 3 μ and 5 μ mmd respectively.

Regulating throughput, therefore, provides a means, in addition to tip speed, for control of particle size.

C. Particle Size Control.

Particle size control attainable by use of the rotary-tube spraying principle is superior when compared to rotary-disc or tee-jet sprayers. Mount, 1970, in his paper on Optimum Droplet Size for Adult Mosquito Control with Space Sprays or Aerosols of Insecticides, concludes that for ground application and for aerial application, droplet size ranges of 5 to 10 μ mmd and 10 to 25 μ mmd respectively are optimum. The LWL sprayer has the capability of doing much better in that it can produce all droplets within these ranges.

Referring to Figure 6, by running the sprayer at 350 and at 230 mph tip speeds, no particles are larger than 10 μ and 25 μ respectively. The use of this sprayer would thus entail no wasted droplets larger than the optimum size ranges. Such precise particle size control is not attainable by presently used military or commercial machines.

The LWL machine could well serve as a valuable research tool in further refining data on the biological effect of varying droplet size.

POSSIBLE APPLICATION IN DICHLORVOS WAREHOUSE TREATMENT

Dichlorvos (DDVP) is applied to warehouses for killing insects in subsistence items (flour, rice, dry pulses, etc.). Treatment consists of heat vaporization from 20 percent Dichlorvos in plastic granules at a dosage of 3 to 4 micrograms per liter of air, the concentration being maintained by operating the vaporizer for a 6-hour period. A total dosage of approximately 1 1/2 grams per thousand cubic feet in a 6-hour period is the standard treatment.

<u>The problem: Present procedure has shortcomings</u>. The present procedure is to vaporize DDVP with heat from a 20 percent DDVP, 80 percent plastic mix. This yields about 16, six-hour applications from 30 pounds of the mix, which is then replaced. The cost of the DDVP-plastic mix is currently $5.00 per pound.

The U. S. Department of Agriculture reports trials with atomizers for the dispersing of DDVP in warehouses. Their results showed that the larger droplets contaminated the packages.

<u>Sprayer potential for DDVP treatment of warehouses</u>. Due to the favorably narrow particle size spectrum of the spray droplets produced by the rotary-tube sprayer, it appears feasible to atomize DDVP liquid to less than 5 μ droplet size. This size droplet should evaporate long before it can settle out on the surface of subsistence packages. Indeed, the fan blast will keep the air in motion so that settling and impingement on surfaces probably will be minimal.

The air output of the LWL sprayer fan is 17,000 cubic feet per minute. A 1-million cubic foot warehouse will have 1 million cubic feet of air passing through the fan once each hour. In 6 hours the air will pass through the fan 6 times. This air movement appears to be 3 times more than adequate for a 1-million cubic foot warehouse since the output of a 500 cubic feet per minute fan is sufficient for a 100,000 foot warehouse (Gillenwater, 1971).

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13. ABSTRACT

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