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ROTARY TUBE SPRAY EQUIPMENT

by

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Final Report

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An advanced prototype rotary tube sprayer was designed, built and tested. Control settings were established to produce a majority of particles under 25 microns using No. 2 diesel oil. Spray characteristics with these settings using insecticides such as malathion differed from those observed with No. 2 diesel oil. Size, weight and noise level of the prototype machine were judged excessive, but other features, such as insecticide flow-rate control and provision for withdrawing insecticide directly from its shipping container, were

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BLOCK 20. ABSTRACT CON'T

considered superior. Overall, the prototype rotary tube sprayer compared favorably with several commercial sprayers.

PREFACE

Rotary tube sprayer development under LWL Tasks 09-BA-70, Rotary Tube Sprayer, and 06-B-72, Rotary Tube Spray Equipment, was initiated and directed by Dr. C. S. Barnhart, who had first applied the concept in an experimental sprayer at Ft Belvoir in 1962. Dr. Barnhart retired from Government service before the performance evaluation of his latest sprayer was completed, and he was not available to advise the evaluating personnel concerning adjustments that might have improved the spray characteristics of his machine. Nevertheless, it is encouraging to note that in the judgment of the evaluators (AEHA), Dr. Barnhart's sprayer overall compared favorably with several commercial sprayers.

Dr. Barnhart would be the first to acknowledge the patient and sustained contributions of Mr. C. K. Ramsdell, Chief, Design Branch, and of personnel both of that branch and of the Experimental Shop Branch of LWL whose combined efforts, with Dr. Barnhart's guidance, were responsible for the design and construction of the sprayers.

TABLE OF CONTENTS

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INTRODUCTION

A rotary tube sprayer was first described by Barnhart in 1962[1]. A liquid-containing tube is rotated at high speed; as the liquid is forced peripherally, droplets are sheared off at the tip. The size of the droplets depends on several variables, including tip speed and rate of throughput of the liquid. The principle of the rotary tube sprayer is essentially the same as a flit-gun; in the flit-gun, air is passed at high velocity over the tip of a stationary liquid-filled tube.

The original rotary tube sprayer described by Barnhart compared favorably with more conventional spinning disc and pressure nozzle sprayers with respect to particle size spectrum. It lacked, however, provision for directional control of the spray. This shortcoming was addressed in a later version of the rotary sprayer designed and built at the Land Warfare Laboratory[2]. In this version, a pair of 1/8 in. O. D. polypropylene tubes was mounted on a belt-driven spinner that, in turn, was axially mounted in the outlet air stream of a belt-driven vaneaxial fan with a capacity of 17,000 cu ft/min. Droplet size data were obtained with No. 2 diesel fuel. It was shown that at a constant fluid throughput rate of about 16 gph, droplet mass median diameter (mmd) ranged from 140μ at a tip speed of 90 mph to under 5μ at a tip speed of 400 mph.

In comparison with a rotary disc sprayer and a Tee-Jet nozzle sprayer under conditions in which the spray droplet mmd averaged about 21μ, a greater percentage of droplets under 50μ was produced by the rotary tube sprayer. Furthermore, a significantly greater percentage of the droplets produced by the rotary tube sprayer fell within a range of 5 to 25μ, suitable for ultra-low volume (ULV) spraying.

In an exploratory test with the early LWL sprayer, the Stored-Products Insects Research and Development Laboratory of the US Dept of Agriculture found that it could be used to apply technical dichlorvos in a large storage facility[3]. Dichlorvos vapor is an approved space treatment against stored-product insects in warehouses containing packaged, nonperishable food items. It was shown that the equivalent of a dichlorvos vapor application was achieved with the rotary tube sprayer at considerably less cost than the ususal vapor dispenser method.

Although the machine described in LWL Tech Report 71-05 had achieved the primary development objective of demonstrating the feasibility of the rotary tube concept, plus showing its adaptability for dichlorvos operation,

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[1]Barnhart, C. S. A Vehicle Mountable Rotary-Tube Sprayer. Jour. Econ. Entomol. 55:411-412, 1962.

[2]Barnhart, C. S. Rotary-Tube Sprayer. USA Land Warfare Laboratory Technical Report No. 71-05. April 1971.

[3]Technical dichlorvos applied as ULV into a tobacco warehouse with a rotary-tube sprayer. Letter report, Stored-Products Insects Research and Development Laboratory, US Dept of Agriculture. Aug 1971.

it had a variety of mechanical shortcomings. Not the least of these was the drive mechanism for the fan and the spinner. Further development effort was consequently directed toward the design and construction of a machine with improved mechanical features that would perform at least as well with respect to spray characteristics.

Two new prototypes were built at LWL. They are described in the ensuing sections of this report. Following limited in-house testing, one of the machines was evaluated by the Entomology Department of the US Army Medical Laboratory, Fort Meade, MD, in blackfly spraying operations at Camp Drum, NY[4]. The other machine was evaluated by the US Army Environmental Hygiene Agency, Aberdeen Proving Ground, MD[5].

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[4]Informal letter report, Field Evaluation of the Rotary Tube Spray Equipment, LWL Task 06-B-72, USA Medical Laboratory, Fort Meade, MD. Sep 1973.

[5]Evaluation of ultra-low volume spray equipment. Summer-autumn 1973. Entomological Special Study No. 44-032-73/74. US Army Environmental Hygiene Agency. Apr 1974.

DESCRIPTION OF EQUIPMENT

The advanced prototype rotary tube sprayer is skid-mounted so that it can be easily handled by a standard front-loading fork lift. Figure 1 is a front view and Figure 2 a rear view of the machine. It is 30 in. wide, 42 in. long, 42 in. high and it weighs 375 lb. The major components are a 4-cylinder 6HP standard military gasoline engine (FSN J058144), a 60-amp, 28v alternator (FSN 2920-909-2483), a metering pump shown in Figure 3, a spray head and fan assembly, shown in Figure 4, a control panel (Figure 5) and storage batteries.

The spray head (Figure 4) consists of 2 polypropylene tubes mounted on a metal bowl set on edge. Insecticide is pumped into the bowl directly from its shipping container by the metering pump, a stainless steel, positive displacement, self-priming pump adjustable to deliver from 0 gph to 3.8 gph. Rotation of the bowl, driven by the 6HP gasoline engine, forces insecticide into the polypropylene tubes. As the liquid leaves the end of the tubes, it is aerosolized by shearing action resulting from rapid rotation of the tubes. The axially mounted fan (Figure 4) is a 24 in. 4-bladed aluminum fan independently driven by a 28-volt, 1HP electric motor. The air stream generated by the fan carries aerosolized insecticide away from the sprayer.

The control panel shown in Figure 5 is located on the side of the sprayer. From left to right, it contains a tachometer to indicate spray head RPM, voltmeter, circuit breakers for the metering pump and fan, control switches for the pump and fan, ignition switch, hand throttle, engine magneto switch and a choke. Two 12v storage batteries connected in series supply engine starting power. Gasoline for the engine is supplied from a marine gasoline can. The fuel line is provided with a quick-connect device. Safety guards are located over the fan, the belt drive for the fan and over the belts on the engine.

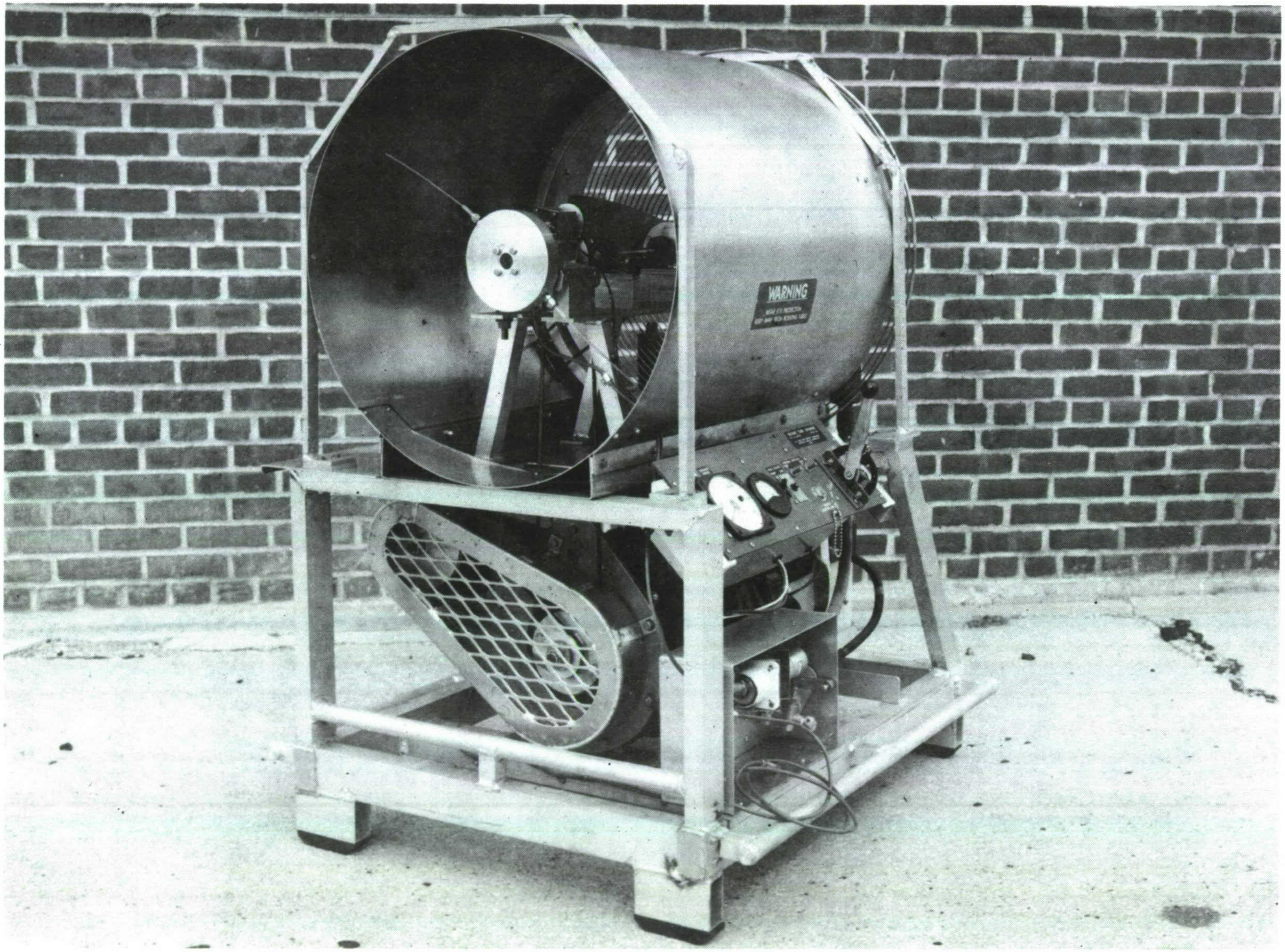

Figure 1. Prototype Rotary Tube Sprayer. Front View.
Note location of control panel and metering pump on left side.

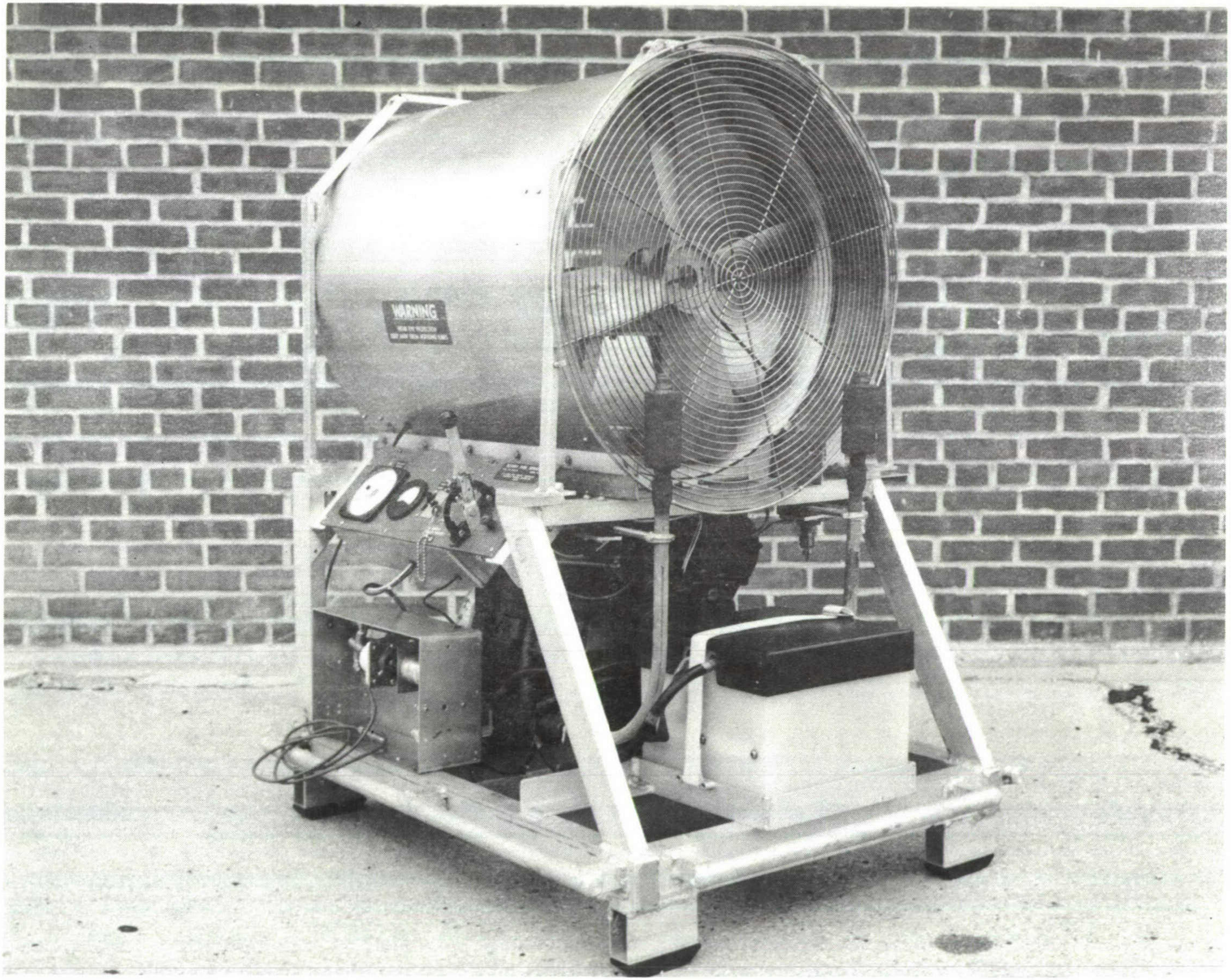

Figure 2. Prototype Rotary Tube Sprayer. Rear View.
Note battery case mounted on base.

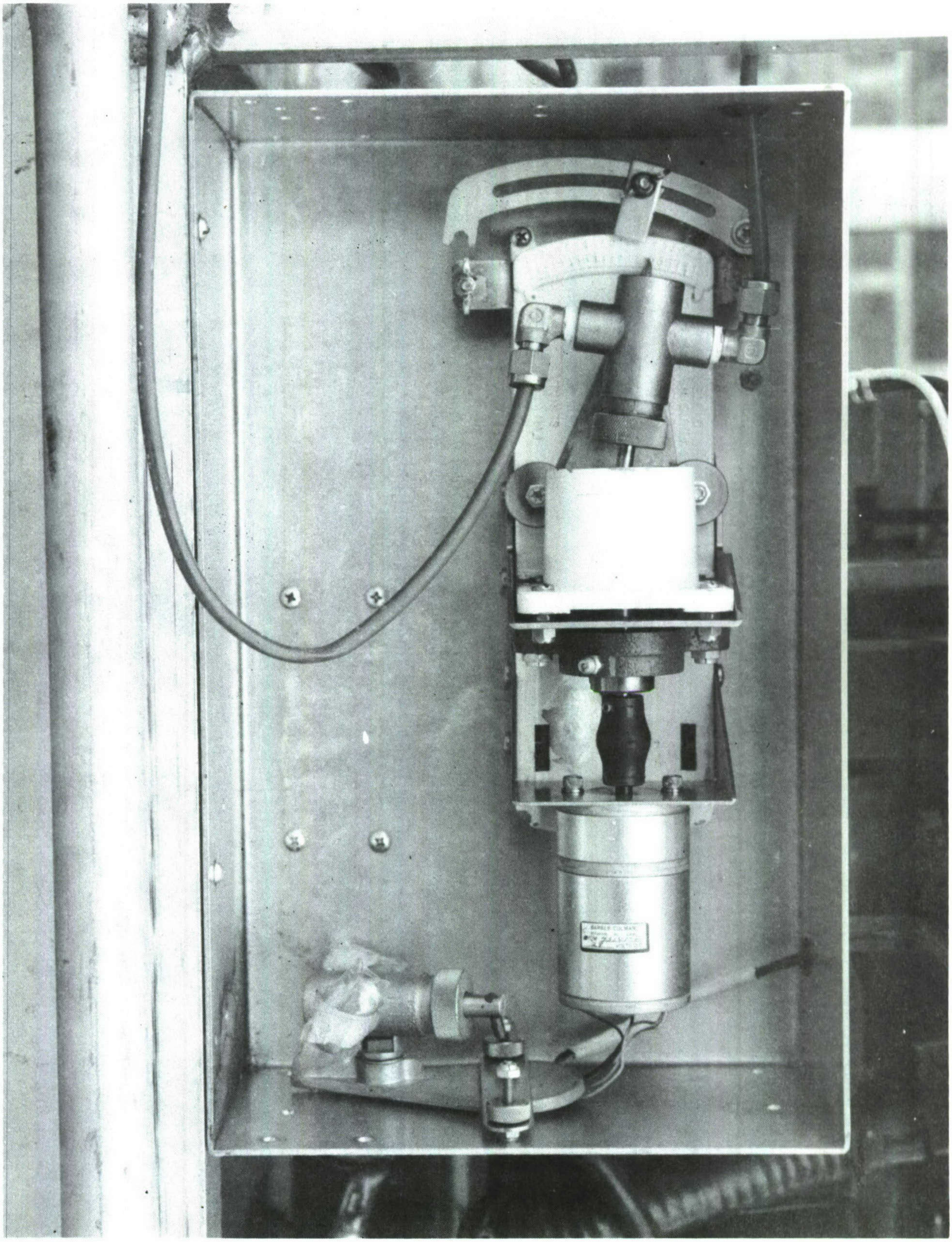

Figure 3. Metering Pump.

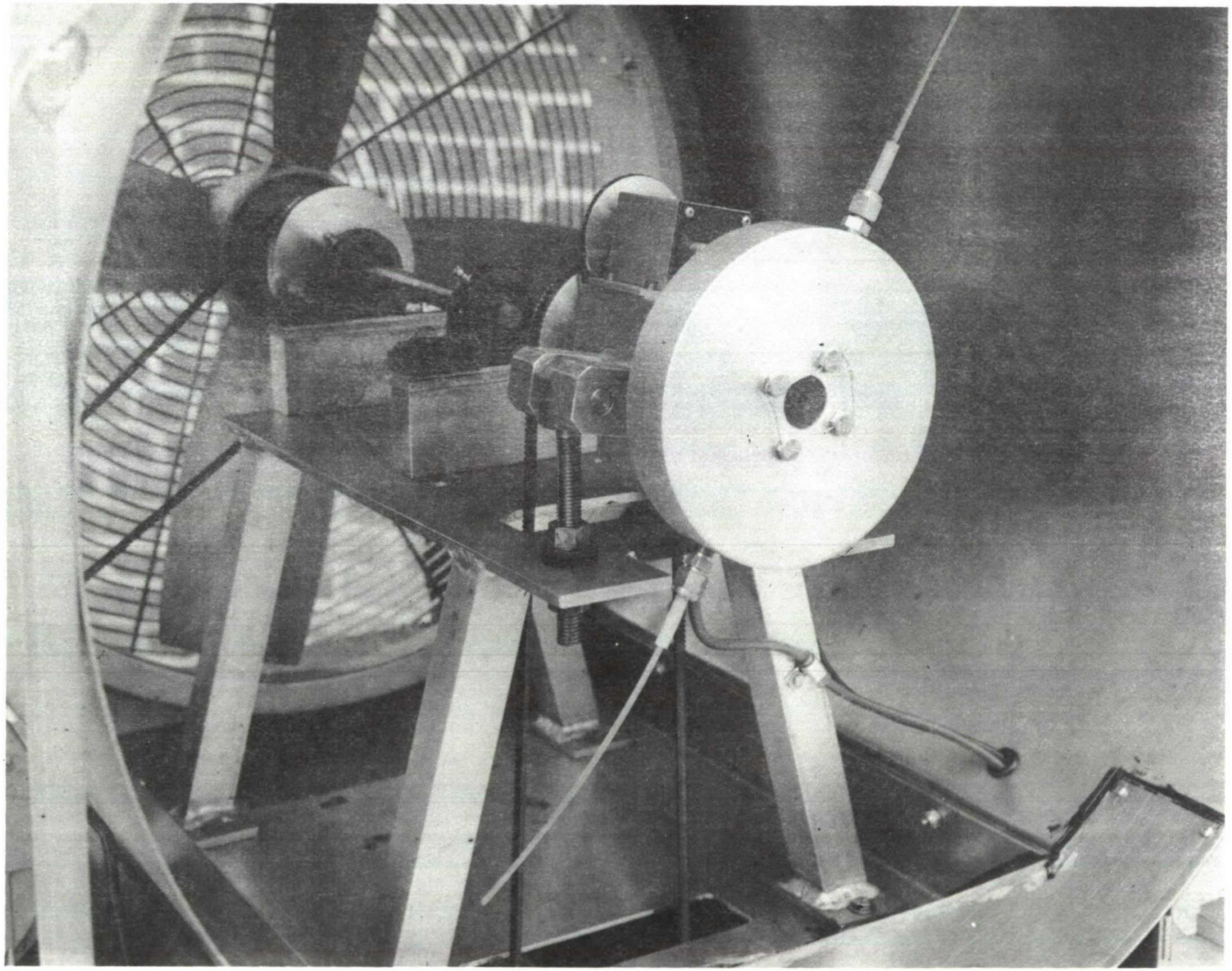

Figure 4. Spinner (Bowl and Tubes) and Fan Assembly. Note independent belt drives. The spinner is driven by the 6HP gasoline engine and the fan is driven by a 28-volt, 1 HP electric motor.

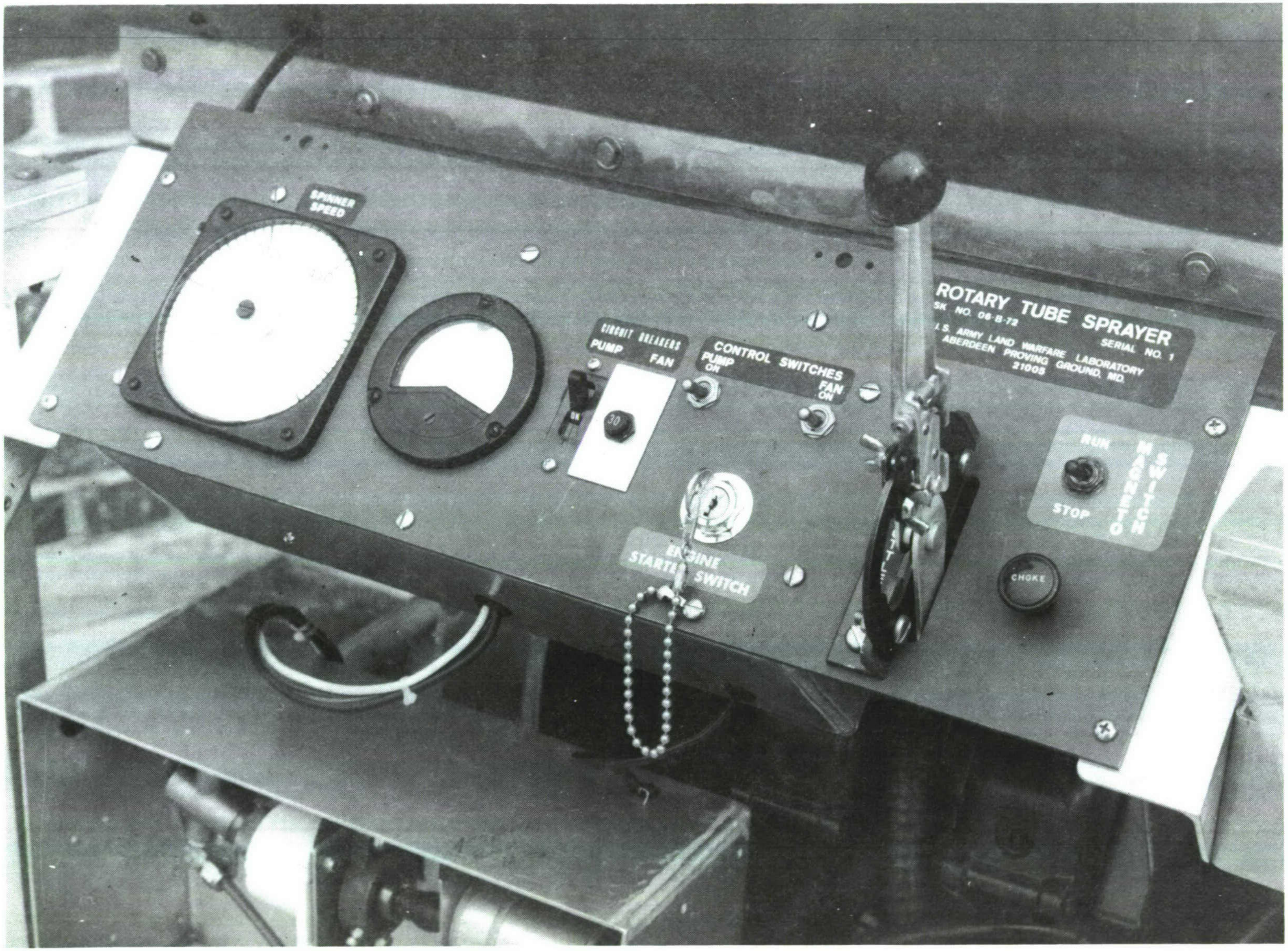

Figure 5. Control Panel. Note that the throttle handle can be secured by wing-nut clamps.

PARTICLE SIZE CONTROL

A primary criterion of sprayer performance is the particle size spectrum. Efficient dispersal of a spray, as well as its biological effectiveness, are dependent to a large degree on the particle size. The ULV ground dispersal technique, in particular, requires that 80% of the spray volume consist of droplets in the range of 0.1μ to 30μ.

Particle size control is achieved with the rotary tube sprayer by varying the rate of spinner rotation (tube tip speed) and/or the insecticide flow rate. Tube tip speed also is dependent on the length of the tubes, which can be varied as needed. Another important factor that affects the particle size spectrum is the viscosity of the insecticide.

With No. 2 diesel oil as a test fluid, it was found that a majority of the particles will be between 5μ and 25μ when the tube length is 11 in., spinner speed 5200 rpm and the flow rate indicator on the metering pump is set between 2 and 3 on the upper part of the scale. In terms of tip speed and fluid flow rate, these settings represent approximately 350 mph and 2 gph respectively. The relation between tube length, spinner speed and tip speed is shown in Table 1.

TABLE 1. RELATION OF TIP SPEED, TUBE LENGTH AND SPINNER SPEED

Spinner Speed rpm	Tip Speed, mph Tube Length, Inches 10	10½	11	11½	12
4000	237	249	261	273	285
4500	264	281	294	307	321
5000	297	312	327	342	356
5500	327	343	359	376	392
6000	356	374	392	410	428
6500	386	406	425	444	464

ROTARY TUBE SPRAYER PERFORMANCE

A. Blackfly Spraying Operation*

A test ULV spraying operation against blackflies at Camp Drum, New York, was conducted with the rotary tube sprayer during the period 1 May to 30 June 1973. An insecticide particle size range of 5 to 10μ was desired, but was not obtained with the insecticides used.** The sprayer was, however, operated at the calibration settings for No. 2 diesel oil; no attempt was made to recalibrate the machine. The average mmd for all the insecticides was about 26μ (range 21μ to 29μ); the observed particle sizes ranged from 8μ to 76μ.

Aside from the fact that the mmd's obtained with the insecticides used in the test did not correspond to calibration data relating to No. 2 diesel oil, the main performance shortcoming of the machine was that it did not propel the aerosols beyond 50 to 100 ft.

The size and weight of the machine were judged excessive, making it difficult to handle and maneuver. Overall, however, the machine was reported to be very easy to operate and the engine was considered outstanding.

B. AEHA Test Operation***

The LWL rotary tube sprayer and 5 commercial ULV sprayers were evaluated to determine their suitability for use in DOD pest management programs. All tests were conducted using 95% technical malathion.

Droplet Production Characteristics. The LWL unit produced a malathion droplet spectrum having 84.3 percent of the total droplets and 68.7 percent of the total insecticide volume in droplets less than 24μ in size. The droplet mmd was 12.3μ.

Noise Production Characteristics. Noise levels produced by this unit as measured at driver positions of a 1/4-ton and a 3/4-ton truck were 106 and 90 dB respectively.

Overall Acceptability. During initial testing the LWL unit presented a potential operator hazard in that a thick coating of malathion was deposited inside the shroud which surrounds the nozzles (Figure 2) when a nozzle length of 11 inches and nozzle rotation of 5600 rpm were used. This operational shortcoming and potential hazard was corrected by shortening the nozzle length

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*As reported in informal letter report, Field Evaluation of the Rotary Tube Spray Equipment, LWL Task 06-B-72, USA Medical Laboratory, Ft Meade, MD. Sep 1973.

**Pyrocide 5%, Pyrocide X-2749, Malathion (38.8%)/Lethane (14.5%), Dibrom 14 (85%), Dibrom 14 (9.3%) and Baygon (6.5%).

***As reported in Entomological Special Study No. 44-032-73/74, USAEHA, April 1974.

to 10.5 inches. The nozzles present one additional potential hazard, for although they spin inside a shroud, an individual could inadvertently insert his arm into their path. Also, after several hours of operation the polypropylene nozzles tend to fatigue and bend, and should one break it could be thrown into an individual's eyes. Warning signs on the machine in accordance with AR 385-30, do indicate that eye protection be worn. All other moving parts are well shielded and present no significant hazard to the operator. The unit provides considerable flexibility in insecticide handling, for all that is required to effect insecticide transfer for operation is to drop a suction tube into the original insecticide container. Since this unit was a prototype, no consumer cost estimate was available.

In summary, the rotary tube sprayer was found to be satisfactory for dispersal of ULV sprays, though it produced the least acceptable atomization characteristics of the machines that were tested. It was the easiest to calibrate and regulate to maintain uniform insecticide flow with varying temperatures. The LWL unit also provided the greatest flexibility in insecticide handling and transfer in that the original insecticide container can be used as a storage tank. Over all, the rotary tube sprayer compared favorably with the commercial units.

DISCUSSION

It is not surprising that the spray characteristics of the LWL prototype rotary tube sprayer fell somewhat short of expectation in both the Camp Drum blackfly spraying operation and in the AEHA tests. Preliminary in-house testing and calibration had been limited to operation with No. 2 diesel oil. No data at all had been obtained relating to performance of the machines with insecticides such as 95% technical malathion, pyrocide, dibrom, etc., the viscosity of which may be quite different from that of No. 2 diesel oil. It was anticapted that appropriate adjustments of tube length, spinner speed and fluid throughput rate could be made in the course of the later tests to obtain more nearly optimal particle size generation with these other fluids. For various reasons, however, this was not done or, at best, was accomplished only to a very limited degree.

It seems entirely reasonable to assume that with a relatively small amount of additional effort, the rotary tube sprayer can be adjusted for optimal particle size spectra with at least the most commonly used insecticides.

Other features of the rotary tube sprayer prototype that have been criticized include failure to propel aerosols beyond 50 to 100 ft, and its bulk, weight and noise level. Design changes are undoubtedly possible within the present configuration that could effect considerable improvements in these areas. Also, it is possible that all-electric operation of the moving parts in a significantly less bulky, lighter and quieter configuration may be feasible.

Because the rotary tube concept is so elegantly simple in principle and because it is readily adaptable to the requirements of both ULV spraying and dichlorvos dissemination, it is to be hoped that the relatively small additional effort needed to make the rotary tube sprayer a practical machine for field operations will be forthcoming.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. The latest prototype version of the LWL rotary tube sprayer compares favorably with several commercial sprayers for ULV operation.

2. The atomization characteristics of the LWL rotary tube sprayer need to be improved by adjustment and calibration with a variety of insecticides.

3. The size, weight and noise level of the LWL rotary tube sprayer are excessive in the present configuration.

4. Superior features of the prototype rotary tube sprayer include overall ease of operation, reliability of the engine, the insecticide flow-rate control and provision for insecticide transfer directly from the original shipping container.

5. Rotary tube atomization can be used to disseminate technical dichlorvos for warehouse fumigation.

Recommendations

1. The present LWL prototype sprayer should be adjusted and calibrated with commonly used insecticides for optimal spray characteristics.

2. Additional development effort should be pursued to reduce the size, weight and noise level of the LWL sprayer.

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