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ENGINEERING EVALUATION OF COMMERCIAL BACKPACK SPRAYER/DUSTERS[1]

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ABSTRACT. Engineering evaluation of 9 commercial backpack sprayer/dusters was conducted by the U.S. Army in view of determining suitability to meet military needs. Important items included in the testing were reliability and ease of maintenance of the individual units, and determination of the pesticide dispersal rates. The most desirable characteristics of the sprayer/duster are also presented.

Disease vector control requires the use of a variety of liquid and solid insecticide formulations. These insecticides often must be dispersed effectively in small areas inaccessible to vehicle-mounted equipment. One means of accomplishing this is by small, motor-driven, backpack insecticide dispersal units. The U.S. Government emphasizes the use of available commercial units to meet the needs of the Army, rather than the development of unique items at Government laboratories. The selection of commercial units which meet the requirements of the Army is essential to this effort. An analytical tool for this determination is engineering evaluation of various commercial units to test relative suitability for military use.

Sixteen characteristics of 9 commercial backpack sprayer/dusters manufactured and/or distributed in the U.S. were evaluated. Units incapable of dispersal of both liquid and solid formulations were not included in this evaluation. Prior to testing units were weighed both with and without insecticides and fuel. Operating and storage dimensions were taken to determine the effect the addition of the item to the inventory would have on organizational mobility. After these pre-operative checks, units were operated and maintained in accordance with their instruction manuals for 250 hr. During this time, fuel consumption was determined. Insecticide tank capacity for liquid and solid formulations was measured. Flow rates and dispersal capabilities for each formulation were also determined. During the 250 hours of reliability testing, the number and type of failures were recorded. All maintenance time, both for routine services and malfunction repair, was recorded. At the end of testing a

[1] *Disclaimer*—The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents. Use of trademarked names does not imply endorsement by the US Army, but is used only to assist in identification of a specific product.

comparison was made of the 9 models based on a comparative assessment of the 16 characteristics. For proprietary reasons, the following analysis will not refer to specific manufacturers' names.

The first group of features to be considered included physical characteristics. (Table 1). These features impact on the user organization, its personnel, and its mobility. Weight was an obvious consideration because of back stress and fatigue. To the operator, the most important feature was weight when filled with liquid insecticide. According to current human use guidelines, the maximum backpack load for a male soldier who is required to walk is 55 lbs. Five models met this requirement (Table 1). The empty weight and volume of the machine affects the mobility of the user organization. Analysis of all equipment presently available and projected to become available to Army entomological control teams determined that an individual backpack sprayer/duster could not exceed 25 lbs in empty weight nor 4 cu ft in volume. Four and 5 models, respectively, met the empty weight and volume requirements (Table 1). The most desirable tank configurations were either with twin formulation tanks or with 2 interchangeable tanks. Unfortunately, this feature often was available only on models with weights and/or volumes which were greater than desired.

Operational features (Table 1) quantify a relationship between the physical impact of the machine on the organization and its personnel and the operational effectiveness of the machine as measured by mean time between refueling and formulation tank capacity. The first feature was the ratio of operating time (i.e. time between refueling) to empty weight, a constant independent of dispersal rate. The desired ratio was derived as follows. The operator and his assistant could each carry 55 lbs. This translated into approximately 5 gal of 91% malathion for the assistant and a backpack sprayer filled with fuel and malathion for the operator. Backpack sprayers normally were equipped with 3 gal insecticide tanks. McDonald and Teller (1969) reported that the mean time to disperse a 3 gal tank of a backpack was about 17 min. Thus, 8 gal of malathion would require about 45 min of operating time before extra fuel would be needed. Since the desired empty weight was 25 lbs, the desired operating time to weight ratio was 1.8. Ratios greater than 1.8 were acceptable. Five models met this requirement.

The ratio of weight to tank size was derived. In this calculation, a small ratio indicated that the machine would cause less human fatigue and had more dispersal capability before refilling with insecticide. Conversely, a large ratio such as 9.7 (Table 1) indicated a machine which was excessively heavy, even empty, and which had limited dispersal capabilities. Five models met this requirement. The ratio of storage volume to formulation tank size (Table 1) was similar to the weight to tank ratio. This latter ratio related impact on organizational mobility to the dispersal capabilities. A small ratio, such as 0.6, indicated a minor impact on equipment transportability and good dispersal capability. The final operating desideratum concerned safety and noise. No unit could be safely operated without hearing protection for the operator since all units exceeded 85dB (Table 1). For Army hearing conservation purposes, hazardous conditions exist with any exposure to steady state noise levels exceeding 85dB(A) (Nelson et al. 1975).

Dispersal characteristics (Table 1) were important since, in order to obtain effective control, the insecticides must be propelled properly and at the correct dosages. Almost all units met the minimum desirable air speed of 200 mph (Table 1). This air speed translated into an effective swath width of 50 feet or greater when the nozzle was held horizontally. Swath width could be increased with special extension nozzles and by holding the nozzle at an upward angle (McDonald and Teller 1969). Using malathion as the reference insecticide, five models were found capable of ULV

Table 1. Features considered in engineering evaluation of commercial backpack sprayer/duster.

Features	Desired	Number with desired feature	Commercial range
Physical			
Weight (empty)	25 lbs (max)	4	18–30 lbs
Weight (with liquid)	55 lbs (max)	5	47–69 lbs
Shipping volume	4.0 cu ft (max)	5	1.9–5.6 cu ft
Tank configuration	2 (twin or exchangeable)	2	1–2
Operational			
Operating time/weight	1.8 (min)	5	1.0–3.5
Weight/tank size	7.0 (max)	5	5.8–9.7
Storage volume/formulation tank size	1.0 (max)	4	0.6–1.9
Noise level (at operator's ear)	85 dB (max)	0	92–102
Dispersal			
Air speed	200 mph (min)	8	195–246 mph
Liquid	0.5 gals/acre (max)	5	0–6.9 gal/acre
ULV VMD (malathion)	17 u (max)	0	20–40 u
Dust	20 lbs/acre (max)	6	0.4–43 lbs/acre
Granules	2.5 lbs/acre (max)	6	0.5–43 lbs/acre
Maintenance			
Malfunction/250 hrs operation	0 (max)	2	0–10
Maintenance ratio	0.05 (max)	5	.016–0.25
% Carbon build-up in carburetor with 100 hrs	50 (max)	5	10–100
% Met	70%	2	19–81%

flow rates (i.e. 0.5 gal or less/acre). To determine potential acreage to be covered, it was assumed that an operating team could walk 2 mi in 1 hr. Acreage treated was calculated by multiplying 2 miles (in feet) by twice the horizontal throw distance (in feet) and dividing by the area of an acre (in square feet). Treatment rates for the various models ranged from 8.7 to 14.5 acres/hr. While 5 machines could disperse at ULV flow rates, no unit tested with malathion had a Volume Median Diameter (VMD) of less than 20 microns (Table 1). Two models qualified as ULV mist dispensers (particle sizes do not exceed 100 microns) while the rest dispense ULV mist/fine sprayers (particle sizes exceed 100 microns).

All backpack models had settings for dust dispersal which were capable of dispersals of 20 lbs/acre or less. This flow rate corresponded to the label instructions for Ortho 5% Selvin® Dust (carbaryl) when used for area flea control. While all models had rates of flow at or below 20 lbs/acre, 3 models, at maximum settings for dusts, dispensed much less than 20 lbs/acre. These units had unsatisfactory operational efficiency and were considered not to meet the requirement. A major problem with dust dispersal was clumping of the material in the tank and hoses. This clumping caused spurts of dust and resulted in nonuniformity of dispersal. This could be remedied by mixing small quantities of sand with the dust (McDonald and Teller 1969). The rates for granular formulations were similar to those for liquids. Six models had dispersal settings which were capable of dispersal rates of 2.5 lbs of granules/acre. This flow rate corresponded to the label instructions for Agrisect® 2% Abate (Gabriel Chemical Co., temephos) for larval mosquito control in clear woodland pools.

Maintenance characteristics were of prime importance to the Army (Table 1).

These were established by operating each machine according to manufacturer's instructions for a total of 250 hr. At the end of this time, the total number of malfunctions and total maintenance time, both for scheduled and unscheduled requirements, were calculated. Only 2 units operated during the entire 250 hr without malfunctions (Table 1). Other models had from 1 to 10 malfunctions during the same period. Some malfunctions were minor, such as a broken bracket, while others represented major safety and health hazards. Health hazards included leaks in the insecticide systems which could have contaminated the operator. Safety hazards included fuel leaks which created potential fire hazards. One model had a major safety hazard. The intake port of the air system was positioned so that foreign objects could be drawn into the turbine. In one incident, this occurred and caused the turbine blade to shatter throwing pieces of the blade outside the housing and injuring a technician. The ratio of maintenance time to operating time was related to malfunctions. A ratio of 0.05 or 3 min of maintenance for 1 hr of operations was desirable. Maintenance time included both routine maintenance and unscheduled repair time. Two units required 15 min of maintenance for each hr of dispersal. These 2 units were characterized by frequent breakdowns and major maintenance problems. Five models were found to have acceptable maintenance ratios (Table 1). The final maintenance characteristic was carbon build-up. Ideally, there should be no build-up in 100 hours of operation. Realistically, this was impossible due to the design of the noise suppression system. Actual ranges of build-up were from minor (10%) to nearly complete blockage (100%) of the exhaust port. While 5 models were satisfactory (Table 1), all models could have been satisfactory by cleaning out the carbon build-up in the exhaust ports after each 50 hr of operation. This has been suggested as a routine maintenance measure.

In all, 16 features were considered. No model met all features. The maximum number met was 13 of 16; the minimum met was 3 of 16 by two models. Dispersal and maintenance features were considered the most important for the units relative to military use.

Upon evaluation, the models were ranked by percent of desirable features met (Table 1). Only two models were highly rated, meeting greater than 70% of the characteristics with relatively minor flaws. The next 3 models were marginally satisfactory since they met 50% or more of the requirements. The last 4 models are considered unacceptable for military adoption. These models were generally characterized by high frequencies of mechanical and operational malfunctions, by being heavy and bulky, and in one case by having serious safety problems. While specific manufacturers names can not be disclosed here, an informal survey of commercial users has shown that those with the best potential for military use are those with the best market acceptability.

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