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PRELIMINARY TRIALS WITH A LIGHT HOVERCRAFT FOR CDA SPRAYING

D.R.Johnstone, G.G.Pope, M.Andrews and G.R.Stacey[a]

Centre for Overseas Pest Research, College House, Wrights Lane, London W8 5SJ

Summary A light hovercraft (modified Pindair 'Skima 4') has been examined as a spray platform, with alternative equipment providing a) droplets large enough to minimise spray drift, b) small droplets for techniques utilising wind transport, for application of pesticide sprays to cereals at an early stage of growth and under soft soil conditions. The preliminary physical assessment of a trial against powdery mildew *Erysiphe graminis* on Autumn sown barley is reported.

INTRODUCTION

In mechanised agriculture, field work, including timely pest control operations, is sometimes impeded by damp weather conditions which can render the soil too soft to risk crop (and soil) damage by sending in wheeled equipment (Spoor, 1977). This is particularly the case in British agriculture in wet Autumn and Spring weather and the situation has been exacerbated by the widespread practice of Autumn planting of cereals.

As part of a research and development programme on the use of small hovercraft as all-terrain transport vehicles overseas, some thought has been given to the possibility of utilising such vehicles in the role of crop spraying platforms in suitable crop/terrain situations. The hovercraft possesses some of the advantages associated with the use of aircraft for the same tasks, but promises to be considerably less expensive to purchase and operate.

Following preliminary evaluation of a light hovercraft as a spraying platform and survey craft in the U.K. and Botswana in 1974 and 1975 (Pope, 1976), modification and development work was undertaken to provide the increased thrust required for an improvement in the overland capability (Pope and Stacey, 1977). The quite dramatic improvement in performance brought about by a 50% increase in thrust, together with interest in recent commercial developments of equipment for controlled droplet application of pesticides (CDA) (Bals, 1975; 1977) caused us to re-examine the hovercraft's potentialities as a crop spraying tool, and an opportunity to test the performance in the application of fungicides for control of powdery mildew *Erysiphe graminis* on barley, under damp December conditions, has provided the main data for this preliminary report.

MATERIALS AND METHOD

1. The hovercraft

The hovercraft used for the trials was basically a Pindair Skima 4[b], modified for crop spraying use by COPR. As the thrust of the standard Skima 4 was found to

[a]Authors' address: C.O.P.R., Division of Chemical Control, Porton Down, Salisbury, Wiltshire. SP4 0JQ

[b]Pindair Ltd., Quay Lane, Hardway, Gosport, Hants.

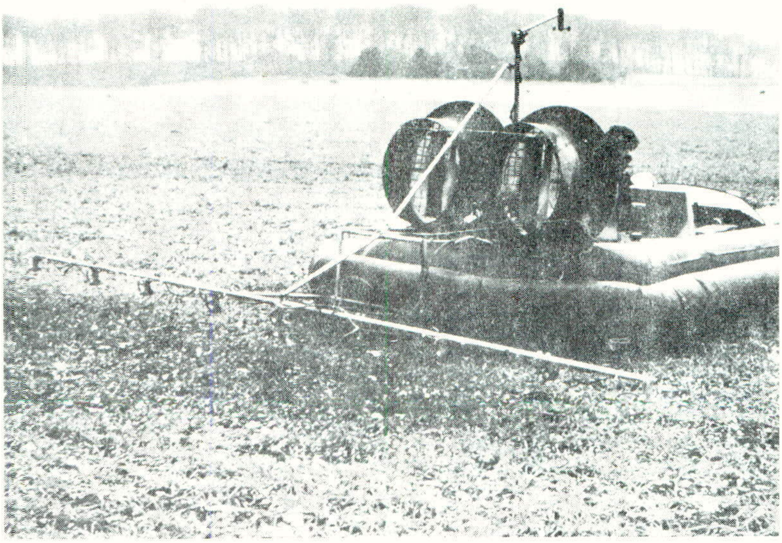
be barely adequate for the type of use envisaged, it was increased from 413 newtons (93 lb) to 622 newtons (140 lb) by fitting a single 42 h.p. Kohler engine in place of the two 11 h.p. Husqvarna engines, fitted as standard. The engine mountings, fans and pulleys were modified, as necessary, to accomodate the new installation. Mounting points for spraying equipment were fitted to the thrust frame and new chemical and petrol tanks were fabricated and installed in the craft. Power for the spraying system was provided by two 12 V accumulators mounted near the front of the craft, making both 12 and 24 V supplies available. The chemical was pumped through a filter to the sprayer by a 12 V vane pump[c] and a by-pass with restrictors was installed to allow the flow rate to the spraying system to be varied as necessary.

2. Spray equipment

i) Spraygear providing drops large enough to minimise spray drift

The spraygear consisted of nine electrically-driven CDA herbicide atomisers[d] (Bals, 1975) carried at 0.6 m centres on a 5 m boom. These atomisers provided a drop spectrum with v.m.d. of 240 µm and a ratio of v.m.d./n.m.d. = 1.4 at 0.160 l/min (Johnstone et al., 1977). For initial trials the boom was carried on a light supporting frame to the rear of the craft, with the plane of the atomiser discs horizontal and about 0.3 m above ground level (Fig. 1). Total throughput was 1.27 l/min (0.141 l/min/atomiser) giving a nominal volume application rate of 8.5 l/ha at 5 m/s on a 5 m swath. The expected coverage is about 10 drops/cm^2 at the nominal application rate (Johnstone, 1974). The anticipated short-period work rate is 9 ha/hr.

Figure 1.



Rear-mounted boom and supporting frame, carrying nine CDA atomisers

[c]Jabsco Model 14940. Cleghorn Warring and Co. Ltd., Baldock, Herts.

[d]Micron 'Herbi' atomiser heads. Micron Sprayers, Three Mills, Bromyard, Hereford.

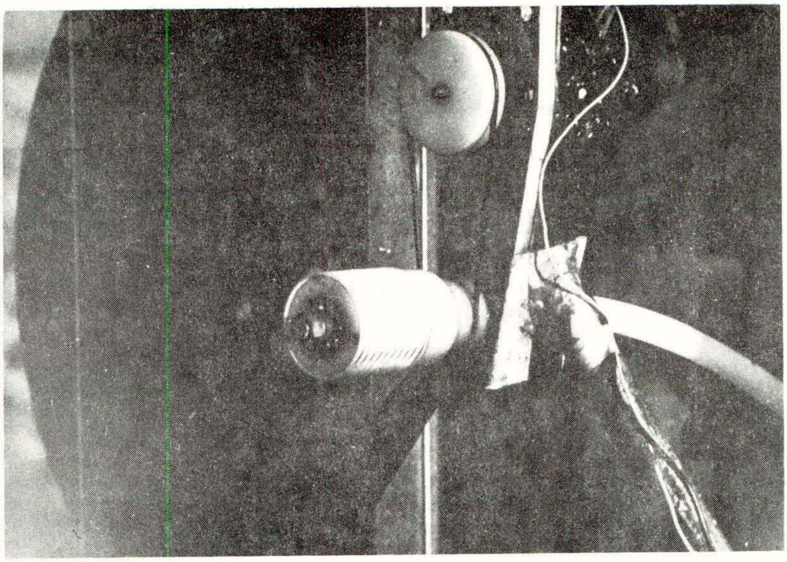
A functioning trial was performed over an Autumn sown barley crop at Allington Farm, Porton, on December 1st 1977, with soft, moist topsoil conditions. Samples of spray deposit were obtained on paper targets fastened around small wooden blocks (10 x 2.2 cm square section) placed on the ground across the swath.

ii) Spraygear providing small droplets for techniques utilising wind transport

For applications where less critical control of drift is acceptable smaller droplets (<100 μm) may be used with advantage to enable use of lower volume application and a wider swath interval. The accumulation of droplets on a broad overlap from several swaths builds up the level of deposit. Using a drift spray technique, 'weathercocking' or yawing, ceases to be a problem, and the handling of the hovercraft becomes technically easier.

The spraygear consisted of an electrically-driven, multi-cup, rotary atomiser (Bals, 1977) carried centrally to the rear, and level with the axes of the thrust fans (Fig. 2). The atomiser produces small droplets, the size of which can be varied by change in throughput and the voltage applied to the motor.

Figure 2.



Multi-cup rotary atomiser, carried between thrust fans

Physical assessments

Preliminary tests were carried out at 12 and 24 V. Using water, the measured throughput was 1.2 l/min (equivalent application rate 3.8 l/ha on a 10 m swath at 5 m/s. Sampling was carried out over short grass and droplet samples were obtained for crosswind runs as described in 2(i) using paper samplers. Wind speed was recorded at about 3 m/s and the groundspeed of the hovercraft was 5 m/s.

Further assessments were carried out on 20th December 1977 (Fig. 3) when a 12 ha field of barley was treated with the fungicides triadimefon (0.5 kg a.i./ha) and ethirimol (0.44 kg a.i./ha), each treatment applied at 8.5 l/ha using a 5 m swath interval, average speed 5 m/s and delivery of 1.27 l/min. Both 12 and 24 V atomiser supply were tried. The temperature was 6°C, r.h. 98% falling to 85% minimum just after mid-day. Wind was light, 0.5 -2.0 m/s. A limited number of droplet samples were taken as described in 2(i).

Figure 3.

Fungicide application on barley with rotary atomiser, December 1977

RESULTS

i) Large droplets for minimising spray drift

The spraygear functioned satisfactorily and samples indicated an average of 8 drops/cm^2 on the upper faces of the blocks.

ii) Small droplets for techniques utilising wind transport

a) Preliminary tests

The measured droplet size parameters are shown in Table 1 and the distribution of deposit downwind in Table 2, in which the droplets (S) sedimented on the horizontal targets are distinguished from the droplets (I) impacted on the windward facing vertical targets.

Table 1.

Droplet size parameters (µm)

	N.m.d.	V.m.d.	V.m.d./N.m.d.
12V	80	103	1.29
24V	55	77	1.40

Table 2.

Spray distribution (Droplet no./cm^2)

		Distance downwind (m)						
		2	4	6	10	18	30	50
12V	S	24	24	17	5	2	0	0
	I	35	60	117	34	45	7	0.5
24V	S	42	62	49	8	2	1	0
	I	52	125	62	55	51	21	21

b) Fungicide application trial

Droplet size parameters obtained from 12 and 24 V treatments are shown in Table 3, and Table 4 records mean deposit levels and standard deviation σ from the n samples.

Table 3.

Droplet size parameters (µm)

	N.m.d.	V.m.d.	V.m.d./N.m.d.
12V	70	92	1.31
24V	53	77	1.45

Table 4.

Spray distribution (Droplet no./cm^2)

		Mean	σ	n
12V	S	22	10.7	4
	I	13	8.7	4
24V	S	31	8.8	10
	I	26	34	10

DISCUSSION

Tests over barley at Porton in early May 1977 indicated that it would be be possible to utilise the hovercraft in the crop at the post-tillering stage, but before pronounced stem extension (i.e., when standing about 0.25-0.30 m tall), without apparent damage. This would not be possible when the fruiting stem was further developed. Spraying opportunities available to the hovercraft are therefore restricted to weed and disease control operations in Autumn and early Spring.

i) Herbicide application and the need for large drops to avoid drift

The boom system utilising CDA herbicide atomisers was capable of providing a a narrow droplet spectrum with 240 µm v.m.d., and at 1.27 l/min was found to give 8 drops/cm^2 at 5 m/s on a 5 m swath, with elimination of drift. This type of application should be ideal for post-emergent herbicide application, particularly Spring applications against broad-leaved weeds using selective herbicides (Taylor, 1975).

Two practical difficulties remain to be overcome: firstly, it was noted that small, damp particles of soil blown rearwards from under the craft adhered to the boom and atomisers, and it appeared that a more satisfactory arrangement would be to carry the boom in a forward position,clear of the main airflow to the rear; secondly, the possibility of using a light tricycle 'undercarriage', with two wheels situated at the boom ends, and a third wheel to the rear of the craft, should be examined as a means towards counteracting the 'weathercocking' tendency of the craft in gusty conditions.

ii) Fungicide (and insecticide) application with technique employing dispersion of small droplets by the wind

The multi-cup rotary atomiser has adequate throughput for very low volume application and the exhaust air from the thrust fans provides the initial dispersion of the droplet cloud to facilitate secondary spread by light to moderate crosswind. The small droplet spectra of 80 and 100 µm v.m.d. are satisfactory with aqueous spray under cool and humid conditions, the smaller droplet size providing better cover. In drier, warmer weather, the addition of an involatile carrier component to the spray mix may be considered desirable, or the application could utilise a suitable waterless ULV formulation at smaller droplet size with reduced throughput, possibly justifying extension of the operational bandwidth. Collection on vertical targets in the windspeed of 3 m/s suggests that a 20 m bandwidth should be effective in such conditions. With lighter winds experienced during the fungicide trial, the collection on vertical targets was reduced. Fewer droplets were collected on the artificial targets than anticipated, for if 8.5 l/ha at 240 µm provides 10 drops/cm^2, then the same volume should theoretically provide 80 droplets/cm^2 at 120 µm, or 640 droplets/cm^2 at 60 µm. We infer that the barley leaves (having a higher collection efficiency) filtered off a considerable proportion of the laterally moving droplets, reducing the numbers collected (with lower efficiency) on the blocks situated below the tillering leaf canopy.

No crop or soil damage is anticipated, even under the wettest Autumn conditions, but, whilst the hovercraft will tackle gradients up to about 1 in 6 and very stony ground, sharp flints can produce tears in the skirt, and it may be that a tougher skirt fabric will have to be specified for operation over flinty ground.

CONCLUSION

We conclude that the hovercraft has considerable potential for the roles described, and that further work is justified to improve the technique to the stage of commercial feasibility.

Acknowledgements

We are grateful to Mr Lester Chard, Regional Advisor, A.D.A.S. and Mr D.C. Gwynne, Plant Pathologist, A.D.A.S., Bristol, for their collaboration with trials organisation and preparation for biological assessment, also to Messrs. P. Chittenden, Allington Farm, Porton and W.J.Parsons, Church Farm, West Dean, for allowing us to operate over their barley fields.

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A NEW PETROL-ENGINED AIR ASSISTED SPINNING DISC SPRAYER

P. Fuller Lewis and N. K. Sylvester

Pan Britannica Industries Limited, Britannica House, Waltham Cross, Hertfordshire.

Summary The development and features of a new hand-held or shoulder carried petrol-engined spinning disc ULV sprayer are described, together with special methods for assessing its comparative performance on the bench, and in crops under glass and outdoors.

Relatively small differences in design, construction and available power produced marked improvements in spray performance including a 117% increase in droplets/cm^2 deposited on cordon apples by the new sprayer.

Vibration was reduced to a very low level by frame design and use of flexible mountings. A simple shoulder mounted carry-frame enabled operators to carry out the tests without fatigue, highlighting the potential value of this attachment for spraying large areas.

INTRODUCTION

In many parts of the world the use of tractor mounted or aerial sprayers is either not possible or uneconomic, so portable equipment is needed. The availability of a simple, battery powered spinning disc sprayer has increased the popularity of ULV spraying in developing countries, as it provides a relatively cheap and effective way of applying insecticides to crops such as cotton, providing the direction of the winds remain fairly constant and in the range 3 - 20 km/h (Matthews, 1973). In some circumstances an airstream must be provided hence the use of motorised knapsack mistblowers adapted to apply ultra low volumes of spray. A number of "ULV attachments" have been developed for mistblowers but these vary considerably in their effectiveness (Thornhill, 1974; Clayphon and Thornhill, 1974). The droplet spectrum of certain machines is relatively good but the units are heavy, noisy, relatively expensive and give a strongly directional air blast (Anon, 1976).

In 1968, Turbair Ltd announced the Turbair Tot for UK horticulture (Maas, 1971; Lewis and Sylvester, 1974). This ULV sprayer was specially designed for the application of oil-based formulations of insecticides and fungicides as solutions and suspensions. An un-ducted two-bladed axial flow fan produces a turbulent air blast to carry the droplets from a 3-disc rotary atomiser also driven by a small lightweight petrol-engine. Major advantages of this unit are its lightness, narrow droplet spectrum, typically with 84% in the range 50 - 100 microns VMD (Mboob, 1975), and relatively even distribution of droplets over the target plant.

The spraying performance of the Tot had been satisfactory during ten years of commercial use in the UK and overseas. It was decided therefore to develop this basic design for spraying larger areas of crops such as field vegetables, top fruit, cotton, tea and vines.

Four major problems inherent in the design of fan assisted ULV sprayers were studied.

1. Engine speed - Low speeds are unsuitable for direct drive to the atomiser and fan.

2. Noise - Continuous exposure of operator to high levels is not permitted or not acceptable.

3. Vibration - High levels cause severe operator fatigue and can affect low pressure chemical flow through jets, air bleed mechanisms of constant head systems and the droplet spectrum from a rotary atomiser.

4. Size and weight - Large and heavy units cause operator fatigue and prevent easy manoeuvrability.

The main parameters set for the new model were that it should be light enough to be hand carried but be provided with a harness to enable operators to spray for long periods without fatigue. The engine should be reliable and capable of continuous operation and vibration should be reduced to as low a level as possible.

DESCRIPTION

The Turbair Fox is similar in overall size and appearance to the Tot, but the engine and design of the frame with engine mountings are completely new. Features include:

- Engine* of heavy duty construction mounted to allow free airflow to the fan.
- Self-priming carburettor for easy starting, and a simple fine adjustment mixture control for peak engine performance.
- Modified silencer to reduce and direct noise away from the operator.
- Isolation of engine, fan, atomiser and guard from frame by three chemical resistant flexible mountings.
- Asymmetric frame to give strength, rigidity and easy access for maintenance.
- Modified stainless steel atomiser discs for more efficient atomisation of suspension formulations.
- Chemical bottle holder and air bleed isolated from engine vibration to give an even flow to the atomiser.
- Shoulder-mounted carry-frame on which the sprayer is freely suspended in front of the operator by a single coiled spring.

METHODS AND MATERIALS

<u>Sprayers</u> Two standard production Tots were compared with two final prototype Fox sprayers. Chemical output and engine rpm were adjusted for match before the series of tests and checked regularly throughout.

* F7 from Fox Motori, Italy.

Spray liquid A special oil-based suspension formulation containing 7.5% w/v of finely milled thiram was used. This showed up clearly on the target material surface when viewed under a microscope.

Targets Thin black cards, 2.5 x 7.5 cm, marked with a cm square outline with white ink, were positioned in the split ends of canes pushed into the ground to give various heights and locations as required.

Methods

1. Specification and static performance tests. Normal workshop equipment was used. Noise level tests were carried out in the field in a typical spraying situation. Flow tests were carried out on a test rig with the engine running and the sprayer held to simulate normal use.

2. Air blast velocity. Wind velocities were measured with a pith ball anemometer positioned in the centre of the air blast at distances from 2 to 9 m from the sprayer.

3. Air blast cone width. Tissue streamers 2.5 x 60 cm were fixed in the ends of 1 m canes. These were carried by an assistant into the air blast along a path at right angles to the spray direction. As soon as the streamer was flowing in a horizontal plane, the cane was placed in the ground to mark the periphery of the air blast cone.

4. Spray droplet distribution and deposition.

   No crop. A row of 1 m canes with targets in the tops was placed across the spray path 3 m from the sprayer each 0.6 m apart. A second row was placed 5 m away. The sprayers were held still 1 m above the ground and aimed horizontally.

   Tomato crop under glass. A dense crop 0.75 m high planted in close double rows was used. For each replicate nine targets on canes were placed in the crop foliage in shielded positions behind stems and large leaves, to show up any differences in spray cover. After each treatment the targets were replaced without altering the position of the canes. The operator walked at one pace per second holding the sprayer in a fixed position pointing obliquely into the crop 3.75 m ahead.

   Cordon apples. Seven canes of various heights with targets were put in the ground round a densely leaved tree about 2 m high. The operator walked at 1 m/s parallel to the line of trees and 2 m away, spraying at an acute angle and into the prevailing wind.

RESULTS

Specification and Static Performance

Table 1

Comparative data based on 2 units of each model selected at random

	Tot	Fox
Weight (kg) without bottle	4.5	4.75
Dimensions (cm) overall unpacked	35 x 30 x 23	34 x 31 x 24
Engine power, 1 bhp at	6,300 rev/min	6,800 rev/min
Engine/fan speed (rev/min)	6,700	6,900
Minimum noise level (dB) at operator hearing point	98	96
Discharge rate of spray liquid (ml/s)	77	79.5

The Carry-frame adds 1.5 kg and unpacked its dimensions are 42 x 28 x 49 cm.

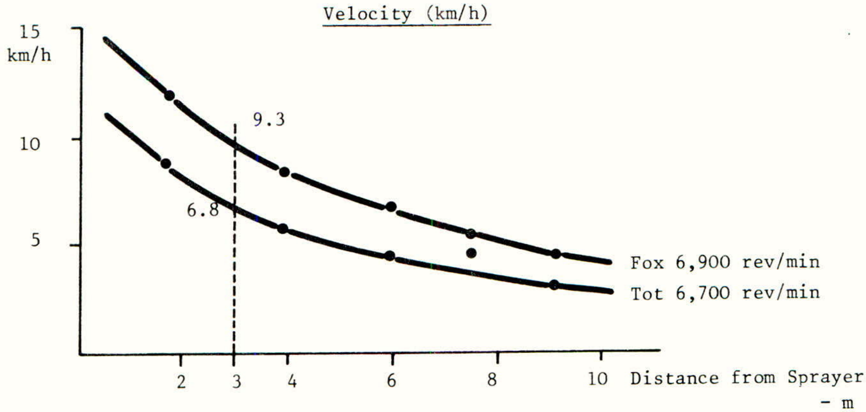
The Fox sprayers showed no fall off in performance after 12 periods of 8 hours continuous running and when stripped no detectable wear was found, except for the spark plugs which needed replacing.

The two sprayers (Table 1) are similar in most respects but the Fox engine runs faster and developed peak power at a higher speed. Theoretically the Fox should therefore produce a stronger air blast than the Tot and this was confirmed in the experiments.

Air Blast

Fig. 1

Velocity (km/h)



A 3% increase in fan speed gave a 37% increase in air blast velocity at 3 m.

Table 2

Cone width (cm)

Distance from Sprayer (m)	Turbair Tot	Turbair Fox
1	109	120
2	142	131
3	169	154
4	202	183
5	265	211
6	292	246
7	295	265

(Mean of 4 replicates per sprayer).

The air blast from the Fox was better controlled directionally with less "spillage" from the periphery. The edge of the air blast cone was very clearly defined up to 7 metres from the sprayers (Table 2). The furthest point at which streamers remained horizontal was 10.72 m for the Tot and 11.02 m for the Fox.

Spray Droplet Distribution and Deposition

When there was no crop the number of droplets deposited by the Fox compared with the Tot (Table 3) was greater at 5 m than at 3 m, indicating that the Fox has a greater effective range and should give superior performance in tall or densely foliaged crops. This was confirmed (Table 4) where the coverage achieved with the Fox was significantly better on the targets at Site 1 which were more difficult to spray due to masking by foliage.

Table 3

Total Droplets/cm^2 collected in 5 s - No crop

Distance from Sprayer	Swath Width	Tot	Fox	% Difference
3 m	5 m (5 targets)	175	205	+ 17
5 m	7.5 m (7 targets)	54	69	+ 28
Mean		115	137	+ 19

(Mean of 2 replicates per sprayer).

Table 4

Droplets/cm^2 in a tomato crop under glass

	(Mean of 9 targets) Tot	Fox	% Difference
Site 1	61	112	+ 84
Site 2	111	151	+ 36
Mean	86	131	+ 52

(Mean of 2 replicates per sprayer)

Similar results consistently in favour of the Fox were obtained when spraying cordon apples (Table 5). Variability between targets was probably due to a gusty wind of 6 - 10 km/h blowing obliquely across the plot against the direction of the spray.

Table 5

Droplets/cm^2 in Cordon Apples

	(Mean of 7 targets) Tot	Fox	% Difference
Replicate 1	92	200	+ 117
Replicate 2	58	89	+ 53
Mean	75	145	+ 93

DISCUSSION

Improvement in the engine mounting and the use of a lightweight shoulder harness has undoubtedly reduced the effect of vibration and made the sprayer far easier to use continuously for long periods. Throughout the tests the Fox was easy to start and completely reliable.

Methods devised to detect relatively small differences in physical performance showed that droplet density on sample targets was improved with the Fox by 36 - 117%.

This was probably due to the design of the Fox causing less disturbance of the air flowing over the engine to the fan and negligible vibration to interfere with chemical flow and drop formation.

The results also emphasise the importance of design detail in small fan-assisted ULV sprayers where spray distribution and deposit is the result of many interacting factors including fan and atomiser configuration, evenness of liquid feed to the atomiser, spatial relationships of key components, obstructions to air flow round the fan and air blast turbulence.

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A SIMPLE VOLTAGE REGULATOR FOR SPINNING DISC CDA SPRAYERS

A.C. Arnold

Overseas Spraying Machinery Centre, Imperial College Field Station,

Silwood Park, Sunninghill, Ascot, Berkshire

Summary To maintain better control of droplet size with hand held spinning disc sprayers, a means of stabilising the voltage supply is required. A relatively simple system of voltage control is described in which the voltage can be set to provide the motor speed required for the appropriate droplet size for a given biological target.

INTRODUCTION

More efficient spraying can be achieved by using a narrow spectrum of droplet sizes such as that produced by a centrifugal energy nozzle. However, with the hand held spinning disc sprayers which are usually powered by heavy duty 'D' size dry batteries (zinc-carbon type), droplet size increases as the output voltage of the batteries decreases throughout their useful working life (Johnstone *et al.*, 1973; Matthews, 1971).

To overcome this problem, electro-mechanical speed regulation has been used on low speed motors (up to approx. 2,500 rev./min.) as on the Micron Herbi sprayer (Bals, 1975). This system cannot be used on high speed motors. Nickel Cadmium batteries require recharging and although zinc-air batteries (Matthews and Thornhi 1974) have an almost constant output voltage they are not commercially available i a suitable form. There is therefore, a need for a simple regulator which can be fitted inside the handle of the sprayer with little or no modification to the sprayer.

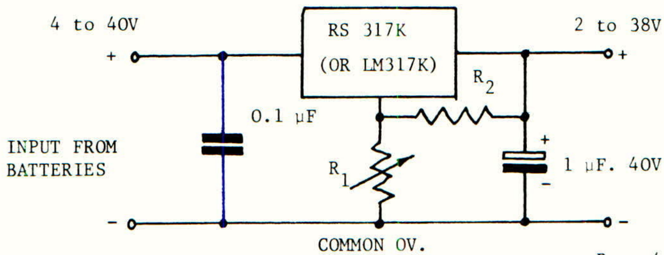
The regulator and associated components

An ideal regulator would consume little or no power and would regulate the output voltage without dissipating the excess power as waste heat. 'Switching' regulators fulfil these requirements most closely with efficiences of 60% and more, but they are not available in a suitable form to handle the power required. As a compromise a RS 317K three terminal monolithic voltage regulator was used as shown in fig. 1. This regulator with few additional components is of robust design incorporating internal thermal shut-down and short circuit protection. The two capacitors are optional in this application. The output voltage is adjusted by means of R_1 and may be calculated by the formula:

$$V_{OUT} = 1.25(1 + \frac{R_1}{R_2}) \text{ volts}$$

In practice this is true for output voltages up to about 2 volts below the input voltage level. This regulator with a suitable heat-sink will handle up to 1.5 amps.

Fig. 1.



R_1 = 4.7 kΩ Variable

Typical values

R_2 = 220Ω

RESULTS

The regulator may be fitted into one end of the battery holder by connecting its three terminals to their respective positions. The output voltage may be adjusted by means of the pre-set potentiometer.

In use the unit stabilised the voltage applied to the motor and dissipated a minimum of waste heat. In practice it can also economise on battery life despite dissipating excess voltage as heat, for example:

Assume battery input voltage to be 18 volts (nominal 12 volts motor)

Assume current drawn by motor to be 350 mA at 18 volts

Assume current drawn by motor to be 250 mA at 12 volts

Power consumed without regulator = W = IV watts

$$= \frac{350 \times 18}{1000} = \underline{6.3 \text{ watts}}$$

Power consumed with regulator set to 12 volts = power consumed by motor plus power dissipated in the regulator

$$= \frac{250 \times 12}{1000} + \frac{(18-12) \times 250}{1000} \text{ watts}$$

$$= 3.0 + 1.5 = \underline{4.5 \text{ watts}}$$

where W = power in watts
I = current in amperes
V = Voltage

Discussion

The example given shows that a constant disc speed and droplet size may be obtained by sacrificing a small amount of battery power (1.5 watts in this example) but still obtaining an extended period of use from the cells compared with the same cells running the disc from 18 down to 12 volts. Further work will be required with the regulator to see how it stands up to use in the field particularly in tropical countries where waste heat dissipation is more difficult.

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