

# DROPLET GENERATOR SUITABLE FOR STUDYING DROPLETS OF WETTABLE POWDER SUSPENSIONS

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## INTRODUCTION

Effects of droplet size, deposit, and number of droplets per unit area on the behavior and mortality of some horticultural pests have been studied (4, 7, 9). This type of work has been limited, however, owing to the difficulty of producing large populations of droplets of uniform size at a rate sufficient for laboratory studies. The spinning disc is the most widely used of the several devices developed to produce droplets, but more sophisticated methods using magnetostrictive, piezoelectric, and sonic principles also produce droplets of uniform size (13, 14, 15, 18, 20). Most of these devices apply liquid pesticides only, preferably oil-based, and do not satisfactorily atomize aqueous suspensions of wettable powders. Because the pesticides used to control pests in horticultural crops are primarily wettable powders, there was a need for a laboratory droplet generator that would handle this sort of formulation. This paper describes such a generator.

## DESIGN LIMITATIONS

Literature, research, and personal experience indicated that, for application efficiency and deposit efficacy, the droplet diameters should be in the range from 100 to 500  $\mu\text{m}$ . Droplets below 100  $\mu\text{m}$  in diameter evaporate rapidly (8, 10) and tend to drift (1, 8, 16, 17, 19), so that only a small percentage impinge on the target (2, 12, 21). A second requirement was that, for any one setting, the generator should produce a narrow spectrum of droplet sizes. Finally, we decided that the generator should work satisfactorily with pesticide concentrations up to 16 times the dilute concentration recommended by the manufacturer for field applications. More concentrated sus-

pensions offer little economic advantage when applied by ground equipment (3).

## ATOMIZATION TECHNIQUE

The spinning disc was selected as the simplest and cheapest atomization method. Other workers (11) have encountered problems when using aqueous formulations with the spinning disc because the inability to wet the disc surface resulted in broad spectrum emissions. Neither surface treatment of the disc with silicones nor an hydrophylic surfactant (Tween 20) narrowed the width of droplet spectra from test suspensions.

Discs of various designs were constructed and tested; a walled disc of aluminum (Figure 1) was chosen. The design of this disc was based on the consideration that if peripheral flow was liquid to liquid, effects of non-wettability would be minimized. The inward sloping walls of the disc formed a circumferential reservoir that permitted liquid to liquid flow (Figure 2). Some sedimentation occurred at the base of the lip, owing to centrifugal forces, but was negligible during 5 min test periods with 16X suspensions.

The disc was mounted directly on the rotor shaft of a universal motor connected to a variable transformer. The disc speed could be varied from zero to 4,500 rpm and when operated above 1,000 rpm produced droplets below 500  $\mu\text{m}$ . Satellite droplets are usually produced when liquid is atomized at the circumference of a spinning disc, particularly if the main droplets are formed by streaming or strands of liquid. Equipment must be designed, therefore, to separate satellites from the main droplet population.

## SHROUD DESIGN

The design of the shroud and disc housing for separation of satellite drop-

lets is a modification of that of Smith et al. (18). In addition to the counter-flow airstream to retard and capture the satellite droplets, a cross-flow airstream is incorporated between the two separation slots to deflect the droplets downward according to size; a finer division of the main spectrum at the outer slot is thereby achieved. This design also provides a downward air velocity component to the counter-flow indicated at Figure 4. Small droplets, which are retarded by the counter-flow and droplets striking the interior walls of the shroud are carried down under the disc and away from the main droplet stream, thus reducing the chance for coalescence. The two sets of slots are adjustable and permit vertical positioning, as well as adjustment of slot widths. The motor-disc assembly is

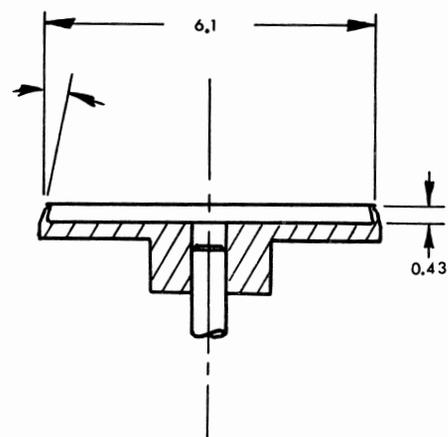


Figure 1. Cross-sectional diagram of disc with significant dimensions (cm).

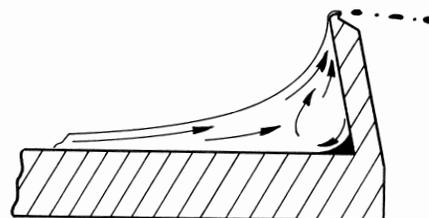


Figure 2. Flow characteristics of a walled spinning disc with corner sedimentation apparent.

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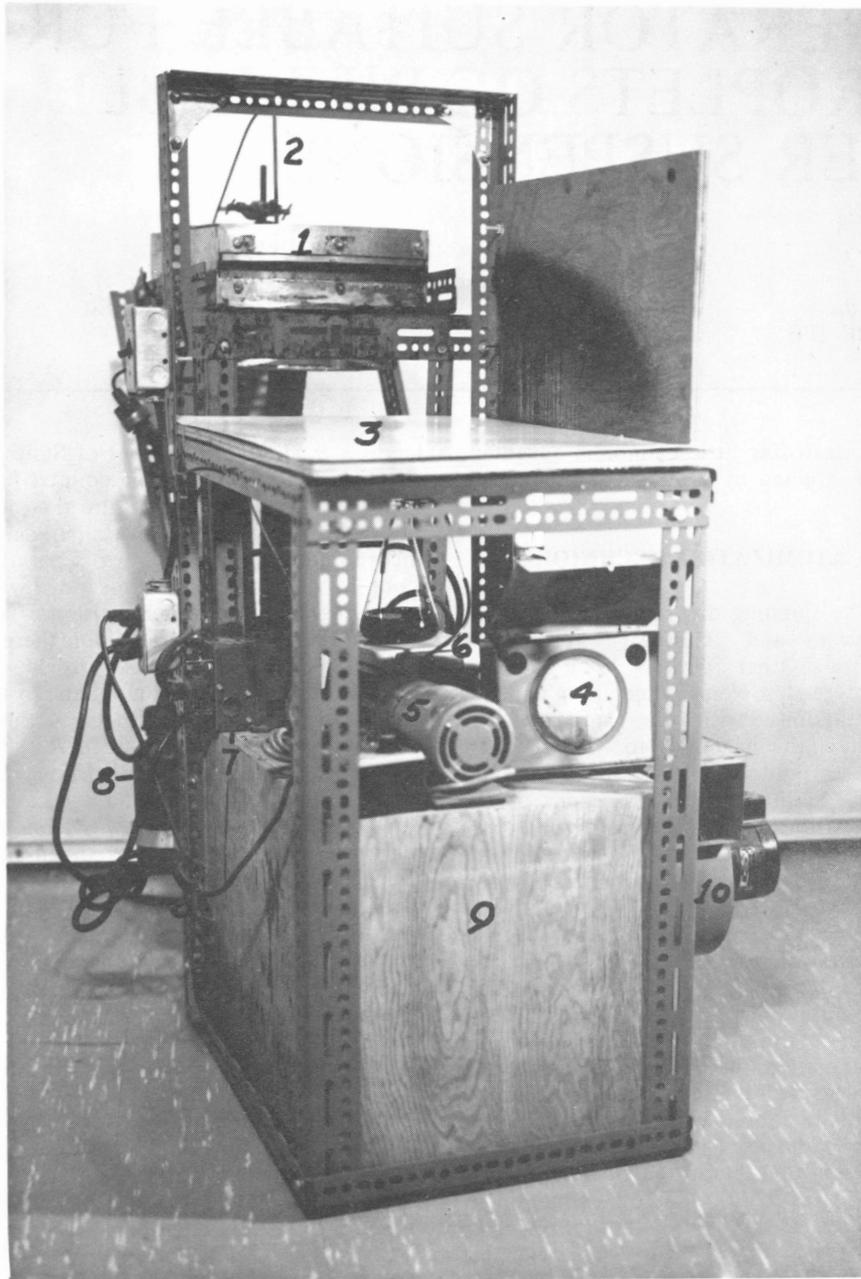


Figure 3. Droplet generator with ancillary equipment (1) shroud and outer emission slot; (2) pesticide injection tube; (3) collection table; (4) static pressure gauge; (5) pesticide pump; (6) magnetic stirrer and pesticide container; (7) disc rheostat; (8) drain holding tank; (9) plenum chamber; (10) exhaust fan.

mounted on a slotted bracket to facilitate both vertical and angular positioning with respect to the emission slots. Droplets are released through an angle of  $70^\circ$  about the disc axis. The spectrum of emitted droplets is further graduated according to size during the in-flight trajectory to the table surface. Droplets slightly larger than the selected size are thrown beyond the collection band whereas those slightly smaller fall short. The 4-cm collection band in an arc about the disc axis provides a satisfactory spectrum of droplet sizes at diameters below  $400 \mu\text{m}$ .

The pesticide suspension, constantly agitated in a supply container with a magnetic stirrer, is pumped with a variable speed roller pump at a rate of 35 ml/min and is injected into the disc's central reservoir. Air is extracted from the two baffle chambers and ducted via two flexible tubes (5 cm diam) to a plenum chamber which is exhausted with a squirrel cage blower. The plenum is equipped with an adjustable vent to permit variation in its static pressure. A negative pressure head of 174.6 Pa provides satisfactory airflow in the shroud

and slots. The surplus pesticide suspension from the baffle chambers is drained to a holding tank for disposal, and the air system can be exhausted to a fume hood or through filters. The shroud and ancillary equipment are illustrated in Figure 3.

### DROPLET MEASUREMENT

All collections of droplets were made by the method of Fisher (6) or on Kromekote paper. Initially, a Quantimet 720 image analyzing computer with a three power ocular and a microscope stage was used to measure the diameter of droplets captured in polybutene. The limit of resolution of the analyzer under these conditions was  $13.3 \mu\text{m}$  between picture points. To establish the stain ratio of dilute dicofol (Kelthane 18.5% wettable powder, 2 g/liter) on Kromekote paper the epidiascope attachment was used initially. When fewer numbers of droplets were collected in later tests, a stereoscopic microscope, fitted with a Vickers split-image eye-piece graduated to  $2.7 \mu\text{m}$  at a magnification of 25X was used. When it was observed that droplet collection in polybutene at ambient conditions of  $22^\circ\text{C}$  and 40% RH gave a misleading indication of the width of the droplet spectrum produced (Figure 5a), all subsequent tests were done at  $22^\circ\text{C}$  and 96% RH. This eliminated the differential degree of evaporation that had taken place following impingement. The narrower spectrum of droplet sizes collected at the higher RH (Figure 5b) indicated that the generator's performance met the design criteria.

### DROPLET DISTRIBUTION

Mortality of mites and insects is probably influenced by the spatial distribution of droplets on a test surface. It was desirable to determine, therefore, whether the generator distributed the droplets on the target in a random manner. Kromekote cards, 3 cm X 8 cm, were used as targets and the Quantimet 720 with microscope and reflected light was used to assess distribution. Fifty-four incremental areas were scanned and the number of stains per area counted. The data were divided in the middle to permit use of available tables of critical values for runs (5). Tests of randomness were conducted on each half. Nominal droplet sizes of 100, 150 and  $600 \mu\text{m}$  were each shown to be randomly distributed ( $P < 0.05$ ).

### STAIN RATIO TESTS

The ratio between stain diameter and droplet diameter for different sizes of

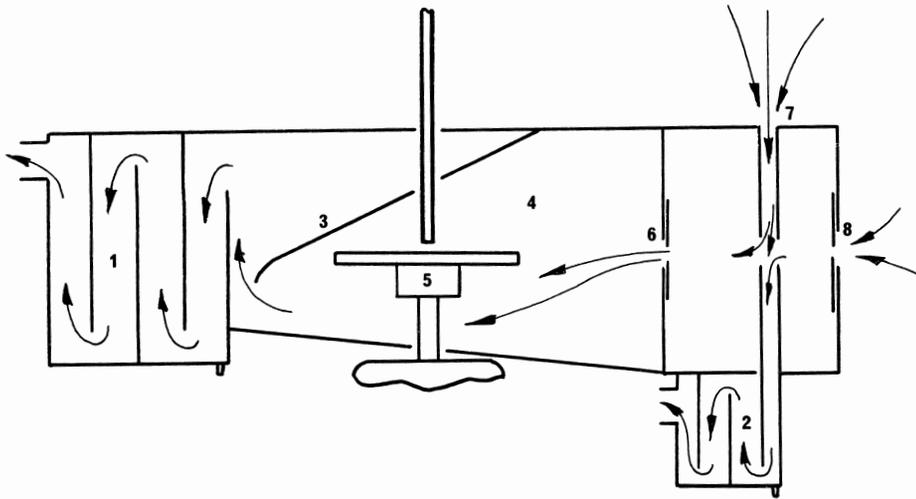


Figure 4. Schematic diagram of shroud and disc assembly indicating (1) rear baffle chamber; (2) cross-flow baffle chamber; (3) deflector; (4) disc chamber; (5) spinning disc; (6) inner variable emission slot; (7) cross-flow air intake and duct; (8) outer variable emission slot and counter-flow airstream.

droplets was calculated for dilute (2.0 g/liter) dicofol suspension which contained 1.1 g/liter nigrosine dye. A polybutene slide was placed beside Kromekote paper to collect droplets produced at a specific setting of disc rpm; the distance from the emission slot varied with disc speed. Twenty-four discrete disc speeds were tested which produced a range of droplets from 118 to 725  $\mu\text{m}$  in diameter. The data show a linear relationship between stain ratio and droplet diameter for droplet diameters up to 500  $\mu\text{m}$  (Figure 6). Reasons for the two widely divergent points at approximately 400  $\mu\text{m}$  are unknown. Presumably the spread of points for droplet diameters above 500  $\mu\text{m}$  was caused by flooding the disc or exceeding the design limitations of the generator.

### SUMMARY

A droplet generator was designed to atomize aqueous suspensions of wettable powders. It employs counter and cross-flow airstreams and droplet trajectories to provide approximately isodiametral droplets. A relationship between stain ratios and droplet diameters was established for one concentration of dicofol. Droplets were deposited in a random pattern on the target and the performance of the generator is considered satisfactory.

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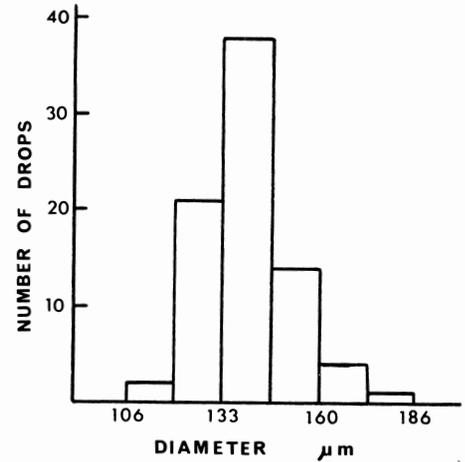


Figure 5a. Spectrum of droplet sizes with dilute formulation of dicofol plus nigrosine dye ((2 g 18.5% WP plus 1.1 g nigrosine)/liter). Droplets were collected in polybutene at 22°C and 40% RH. Rheostat voltage 104 Vac, disc speed 3,900 rpm.

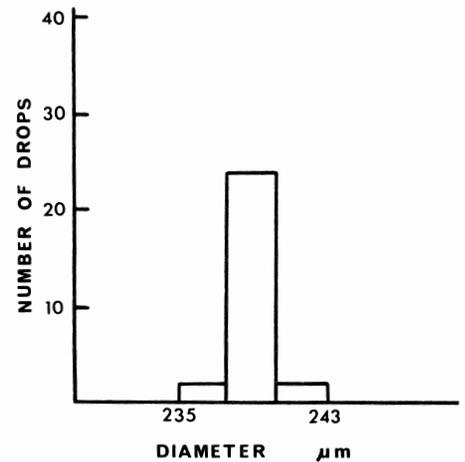


Figure 5b. Spectrum of droplet sizes of 8X dicofol (16 g/liter) suspension collected under controlled conditions of 22°C and 96% RH. Droplets were collected in polybutene and measured with a stereoscopic microscope fitted with a Vickers split-image eyepiece. Rheostat voltage 52 Vac, disc speed 2,000 rpm.

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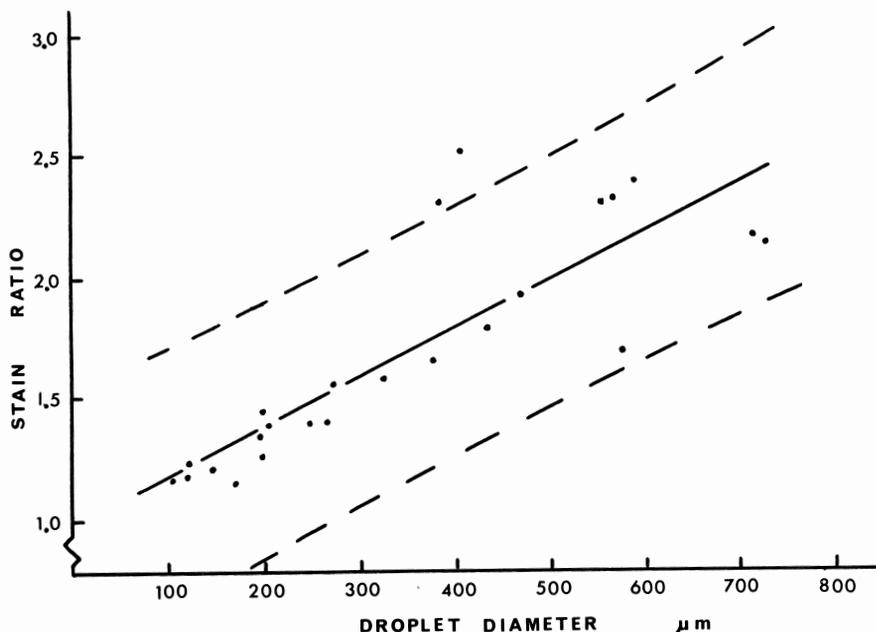


Figure 6. Relationship between stain ratio (diameter of stain/diameter of droplet) and droplet diameter with 95% fiducial limits indicated. Equation of the regression line is  $SR = 0.997 + 0.00198 D$  where  $SR$  is the stain ratio and  $D$  is the droplet diameter in micrometres. The standard error of the regression coefficient is 0.00027 and the correlation coefficient is 0.837.

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