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A New Variable Flow Rate Nozzle for Aerial Application

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Abstract. *A new variable flow rate nozzle for aerial application –VeriRate Nozzle has been developed and marketed. The unique design of the nozzle provides for a wide range of flow rates with changes in spray pressure while maintaining droplet size and spray angle. The design is a combination of a flexible pre-orifice with a flexible spray orifice. Test have shown that as the spray pressure varies from 30 to 50 PSI, the flow rate of a VeriRate Nozzle varies from 0.3 to 3.0 GPM while the volume median diameter of the spray droplets vary from 250 to 350 microns and the spray angle from 20 to 40 degrees. The rate change response time is less than 0.25 seconds. The nozzle is adaptable to conventional spraying systems, and can be used with pressure regulators or automatic rate controllers. The nozzle improves chemical savings, boasts spray productivity, and environmental protection.*

Keywords. Atomizers, Spray Nozzles, Variable-rate Nozzle, Variable-rate application, aerial application.

Introduction

Agrochemicals are applied to agricultural fields to control pests or to enrich the soil with nutrients. The efficacy of an agrochemical spray depends on the performance of a nozzle including flow rate, droplet size, and spray distribution. The droplet spectrum for a nozzle on a high-speed aircraft is different from the one on a ground sprayer. The performance of a nozzle on a ground sprayer is dominated by hydraulic pressure and the one on a plane is dominated by aerodynamic shear that depends on the relative velocity of the spray to the airstream.

Spray nozzles are selected based on the needs of each field, the number of nozzles, and the travel speed. Flow rate of an individual nozzle depends on the size of the nozzle orifice and liquid pressure. For a fixed orifice, flow rate doubles as pressure increases by four times. The narrow range of pressure in aerial applications limits the flow rate range of a conventional nozzle. The normal pressure for most of aerial applications is in the range from 20 to 60 PSI. The lower pressure may cause poor boom dynamic and uneven flow among nozzle locations. Generally, higher pressures cause a decrease in relative velocity of spray to airstream velocity and an increase in droplet sizes. This may cause unevenness in droplet size within a spray. The optimum pressure for most of applications is 30 to 50 PSI.

The desired droplet sizes for a particular application is determined according to the applied chemical, target plant, and application conditions. Under optimal conditions, a spray of small droplet sizes provides even coverage over a given spray area. However, small droplets are more susceptible to spray drift, a condition whereby the droplets land outside of the intended spray area. Droplet sizes in the range from 300 to 400 µm for systemic pesticides and 175 to 250 µm for contact pesticides are reported to be efficient for spray coverage and effective for drift reduction. Droplet sizes generated by a spray nozzle depend on spray pattern, the deflection of the nozzle in the airstream, and application conditions including aircraft speed, wind speed, humidity, and ambient temperature. Generally, a solid straight stream spray provides droplet sizes larger than a fan pattern.

Spray distribution refers to the size of a spray area and the uniformity of the chemical along a spray boom. Spray distribution can affect the efficacy of a given application. For a given travel speed and spray height, spray distribution mainly depends on spray angle and nozzle spacing. Typically, wide fan angles produce large variation in spray velocity within a spray; resulting large variation in droplet size within a spray.

The importance of flow rate, droplets size, and spray distribution is well established. However, there is a limitation of current spray nozzles on controlling these variables. The flow rate for most conventional spraying systems is held constant or varied in a narrow range for a given application rate. The reason is that the conventional nozzle lacks the capabilities to control droplet size and spray distribution for various flow rates. The flow rate of a conventional nozzle is controlled by liquid pressure and doubled as liquid pressure increases by four times; resulting in large variation in droplets sizes and improper spray distribution.

This paper introduces a new commercially available nozzle-VeriRate Nozzle that is capable of controlling flow rate and maintaining proper spray pattern and optimum droplet size over the range of flow rate control. Specific topics were as follows:

1. VeriRate Nozzle
2. Nozzle performance
3. Field performance issues

VeriRate Nozzle

A VeriRate Nozzle (VRN) is a nozzle that is capable of controlling flow rate and maintaining proper spray pattern and droplet size over an extended range of flow rates. The nozzle comprises a flexible spray tip that is automatically and appropriately deformed by a metering assembly in response to changes in liquid pressure. The deformation of the spray tip maintains a desired droplet size and spray pattern.

The VRN includes a spray tip, metering assembly, diaphragm, a spring, and nozzle body (Fig. 1). The spray tip comprises a flexible spray orifice, the area of which is controlled by a pair of levers (Figs. 2 and 3). One end of the metering assembly, which is a wedge, controls the movement of the pair of levers. The wedge comprises two metering grooves of various depths. The other end of the metering assembly is coupled to a diaphragm, which is used to control the movement of the metering assembly through the balance of liquid pressure and spring force.

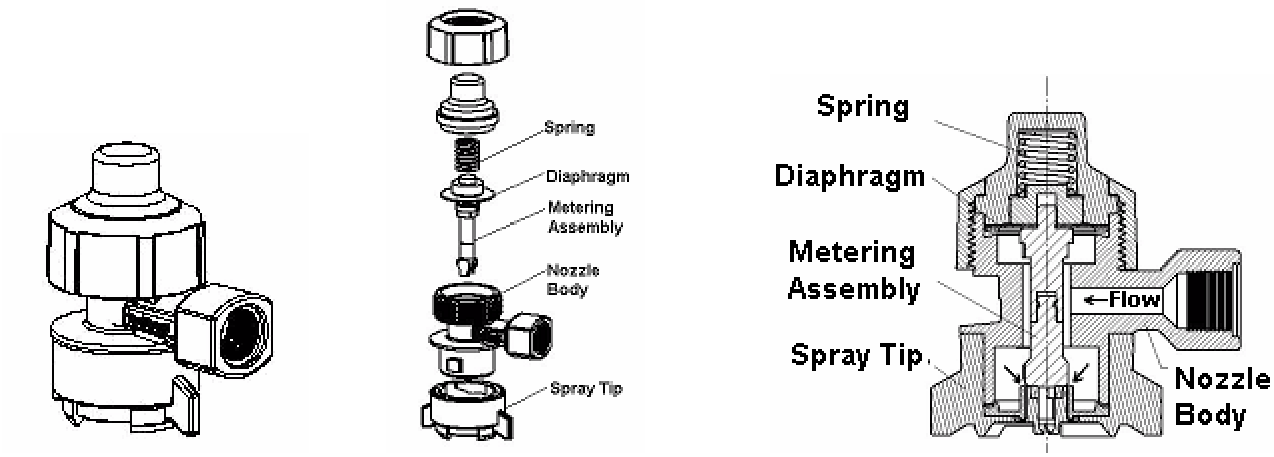

Fig. 1 VeriRate Nozzle

In operation, pressurized liquid enters the nozzle body, flows into the metering grooves of the metering assembly, and exits at the spray orifice of the spray tip. The flow is metered by the depth of the metering grooves and the area of the spray orifice. The movement of the metering assembly controls the flow rate. Liquid pressure and spring force controls the movement of the metering assembly. As liquid pressure is smaller than spring force, the metering assembly moves towards the spray orifice and flow rate decreases, and vice versa. Figure 2 and 3 show the position of the metering assembly at low flow rate and high flow rate.

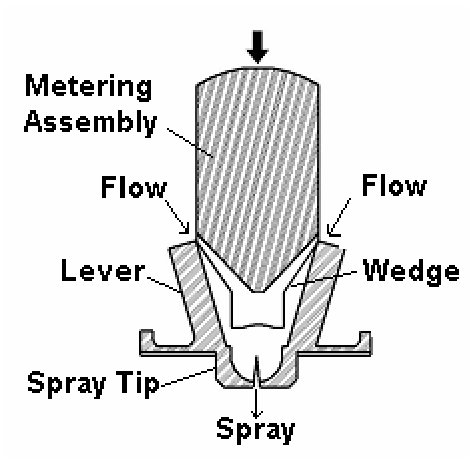

Fig. 2 Metering Position at 0.3 GPM

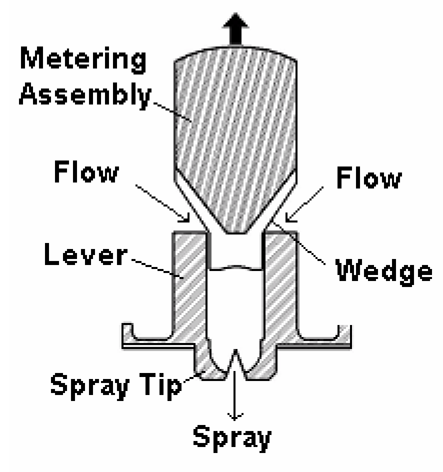

Fig. 3 Metering position at 3.0 GPM

Nozzle Performance

The relation between flow rate and pressure is shown in Table 1. Flow rate of a VR nozzle is variable from 0.3 to 3.0 gpm as spray pressure varies from 20 to 50 psi. Spray angle varies from 20 to 40 degrees as flow rate varies from 0.3 to 3.0 gpm. The response time to rate changes is less than 0.25 seconds. The nozzle can be used with a pressure regulator or with an automatic rate controller. When used with a pressure regulator, the nozzle flow rate can be controlled on the go to obtain a desired application rate and sprayer speed. When used with an automatic rate controller, the nozzle automatically adjusts flow rate according to the prescription maps.

Droplet sizes of a VR nozzle are shown in the table 2. The Data was collected in the USDA-ARS wind tunnel using the PMS probe positioned 30 inches behind the nozzle, which is the same configuration used in all of the USDA-ARS atomization nozzles.

For the airspeed of 120 mph, the droplet sizes have a volume median diameter ($D_{V0.5}$) from 356 to 426 µm and the $D_{V0.1}$ from 227 to 241 µm as the pressure varies from 20 – 40 psi. The $D_{V0.5}$ and $D_{V0.1}$ a pressure of 50 psi is 479 and 266 µm, respectively. The $D_{V0.5}$ at pressure higher than 50 psi or air speed lower than 120 mph is predicted larger than 479 µm due to significant reduction in relative velocity of the spray to the airstream. For applications with lower travel speeds, the nozzle deflection is recommended for optimum droplet sizes.

For the airspeed of 150 mph, the $D_{V0.5}$ is in the range of 279 - 332 µm and the $D_{V0.1}$ varies from 181 - 207 µm as flow rate varies from.3 – 3.0 gpm. The relative span of both airspeeds at various pressures is around 1 except for pressure of 50 psi. The high flow rate and low relative velocity is the main reason for large $D_{V0.9}$ and high relative span at pressure of 50 psi.

Table 1. Pressure and flow rate of VeriRate Nozzle.

Pressure (psi)	Flow Rate (gpm)
20	.30
25	.40
28	.50
30	.60
33	.90
36	1.4
39	1.9
42	2.3
45	2.7
50	3.0

Table 2. Droplet sizes of VeriRate Nozzle

Airspeed (mph)	Pressuse (psi)	$D_{V0.1}$ (µm)	$D_{V0.5}$ (µm)	$D_{V0.9}$ (µm)
120	20	234	371	604
120	25	263	426	735
120	30	227	356	600
120	40	241	397	834
120	50	266	479	1139
150	20	203	302	445
150	25	189	283	416
150	30	181	279	428
150	40	195	310	553
150	50	207	332	904

Field Performance Issues

The VeriRate nozzle was introduced this year and there were some performance issues with the nozzle in the field. The leakage at the diaphragm and the damage of the gasket seal at the spray tip occurred in the field. The damage of the gasket causes distortion in spray pattern. The problems were investigated and the gasket seal was redesigned. The new gasket seal and the diaphragm will be thicker and made out of Viton which provides better wear and chemical resistance. The droplet size category as a function of nozzle size and/or pressure, airspeed, and orientation will be provided in the next season.