PRECISION AGRICULTURE

Implementing Site-Specific Management:

Sprayer Technology – Controlling Application Rate and Droplet Size Distribution On The Go

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Introduction

Application rate control is a concept that is fundamental to site-specific management of crop production. The ability to vary application rates of crop chemicals based on control maps or sensor input holds the potential to improve both agronomic and environmental aspects of crop production. In the area of pest management, effective pest control has traditionally been the primary concern. With the recent increase in environmental awareness, regulatory scrutiny of crop production operations, and the appearance of genetically modified crops (e.g., Roundup Ready® soybeans), control of pesticide placement (i.e., hit the target, prevent drift) has gained increasing importance. Ideally, technologies that can produce site-specific application should help to improve pesticide placement. Unfortunately, some variable-rate technologies actually produce conditions that may make matters worse. Pressure-based variable-rate spraying systems that use standard nozzles can produce excessive spray drift when operated in conditions in which high system pressures are necessary. (See SSM-4-W "Implementing Site-Specific Management: Sprayer Technology – Controlling Application Rate On The Go" for a detailed discussion.)

There is now a chemical application system that addresses both application rate control and drift control with no reduction in overall system performance. That system, called modulated spraying nozzle control (MSNC), offers the potential to improve the performance of both new and existing spraying equipment significantly. Although based on a simple concept, the system merits close examination because of its potential to meet the agronomic and environmental challenges of chemical application today.

The Challenge of Spray Drift

The ability to control application rates on the go provides applicators and crop producers the opportunity to apply site-specific management to crop chemicals. However, varying application rates over wide ranges can lead to performance issues that are of increasing importance. Chief among those is drift. Drift occurs when the paths of spray droplets are altered to the extent that some or all of the chemical product does not reach its intended target. Methods of reducing drift have included:

Simple procedural methods

- Avoiding application in windy conditions.
- Lowering the boom (through the use of wider-angle tips) to reduce open-air travel distance and the opportunity for droplets to be carried away from intended targets.

Simple technologies

- Using hooded spray booms to reduce the effects of air movement on the transport of small droplets.
- Using drift-reducing nozzles.

Complex technologies

- Using electrostatically charged spray to induce travel to plant pest targets with opposite charge.

None of the technologies or techniques listed above has addressed the challenges of varying application rate over a wide range while controlling drift. Now, there is a method that incorporates drift reduction and variable-rate application capabilities.

Automating Control of Chemical Application Rate and Droplet Size Distribution

Modulated spraying nozzle control systems permit variable rate application with spray drift control under a wide range of operating conditions. MSNC systems do this by controlling the timing and duration of discharge from nozzles. High-speed valves are used to regulate the amount of time that spray is delivered from conventional nozzles. The systems offer the ability to change flowrate and droplet size distribution on the go. What follows is a brief description of the system.

MSNC-equipped sprayers use conventional sprayer nozzle assemblies that work in conjunction with direct-acting, in-line solenoid valves. Figure 1 illustrates such a solenoid valve-nozzle combination.

Figure 2 is a schematic of a spraying system that incorporates modulated spraying nozzle control. The system operates under the direction of a computer and an application controller that responds to signals from flow and pressure sensors.

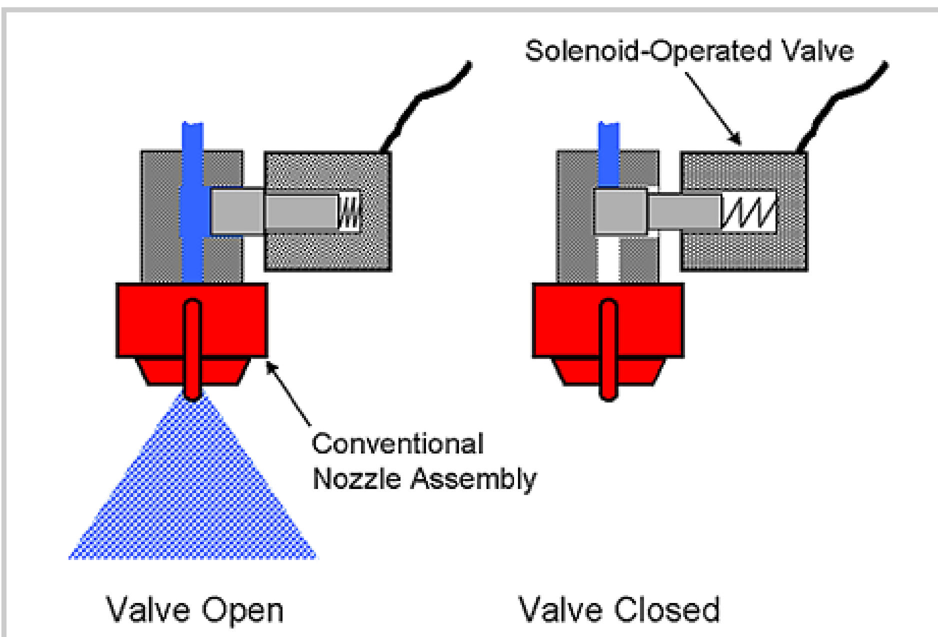

***Figure 1.** Illustration of a solenoid valve-sprayer nozzle assembly used for modulated spraying nozzle control.*

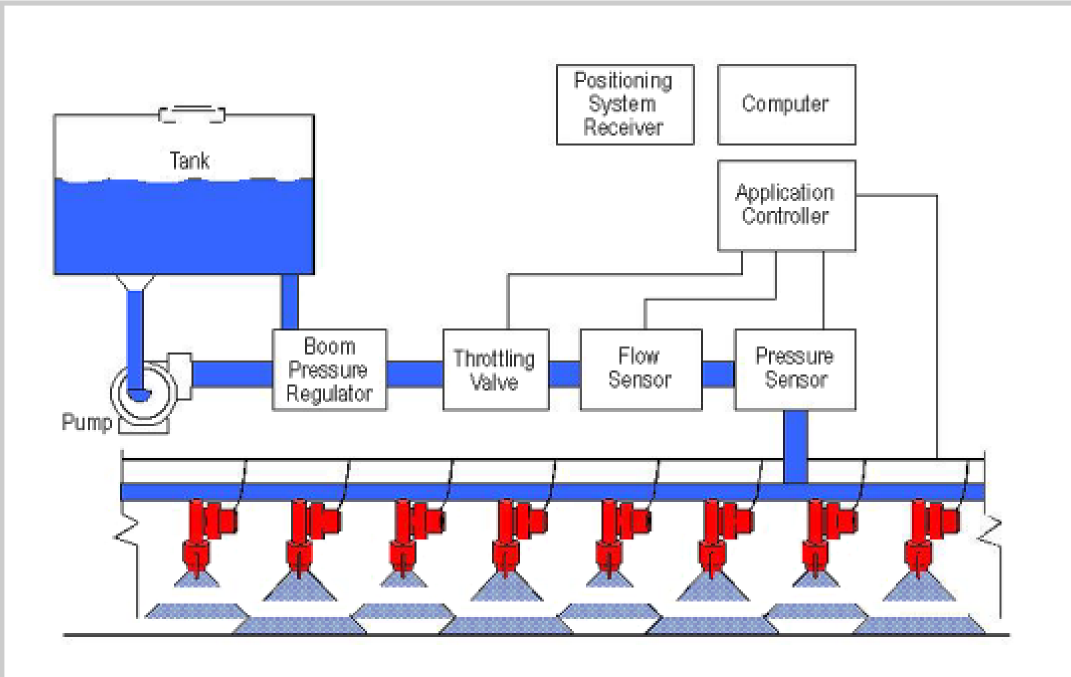

Figure 2. *Illustration of a spraying system that uses modulated spraying nozzle control technology.*

The basic concept behind MSNC spraying is to operate each nozzle at full design pressure and flow during periods when a flow control valve is open. The key is to vary the amount of time that the valve stays open to produce variation in the flow rate (thus application rate) without changing droplet size distribution or spray pattern. A fast-acting electrical solenoid-controlled nozzle assembly is depicted in Figure 3. A solenoid-operated valve is mounted directly to a conventional nozzle assembly.

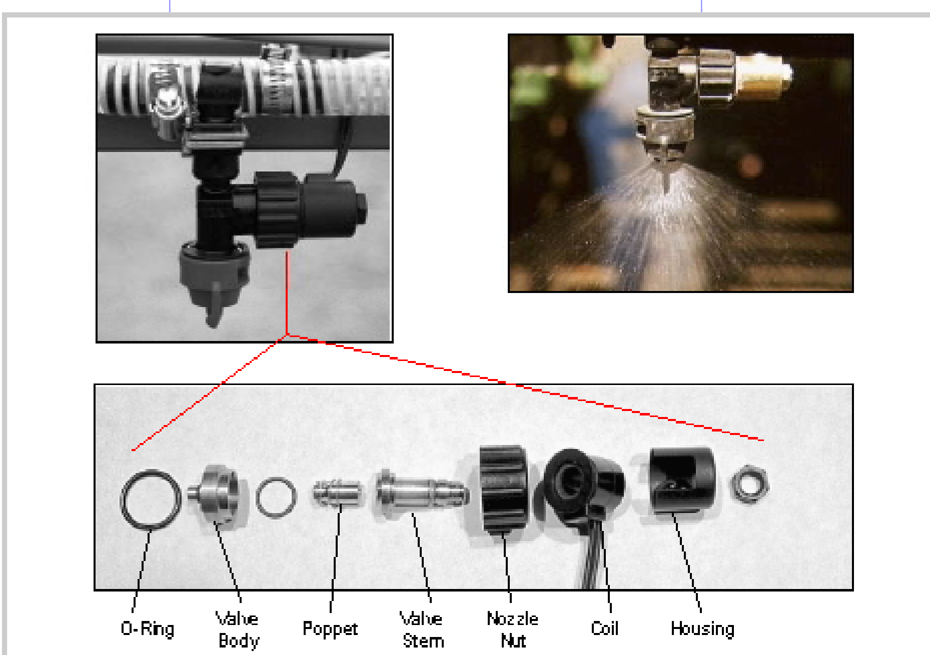

Figure 3. *Illustration of a nozzle assembly equipped for modulated spraying nozzle control. (Images courtesy of Capstan Ag Systems, Inc., Topeka, Kansas.)*

MSNC systems on the market today are equipped with solenoids that operate at a frequency of 10Hz. This means that solenoid position can be cycled between open and closed ten times per second as directed by a controller that responds to input from a computer and a set of sensors. A ***cycle*** of events (valve open/spray/valve close) takes place in one tenth of a second.

In order for MSNC systems to operate most effectively, valve response must be quite rapid. An electrical signal to each valve is used to produce one of two flow conditions – full flow (completely open valve) or zero flow (completely closed valve) (Fig. 4). The solenoid-operated valves take only about 4 milliseconds (0.004 second) to respond to an electrical signal. Changing valve position from open to closed and back (or vice versa) would take 8 milliseconds during any one-tenth-second cycle. In actual practice, this translates into a minimum ***duty cycle*** of about 10% and a maximum duty cycle of about 90% if the control system is changing valve position during each one-tenth-second time period. The MSNC system can also be operated at a full-open (100% duty cycle) setting as well. (See Glossary for additional information on duty cycles.)

Since flow rate from each nozzle is governed by the amount of time each flow control valve stays open, the percentage of full, rated nozzle flow would be equal to the duty cycle expressed as a percent. This results in a range of flow rates from each nozzle of approximately 9:1, although the MSNC systems have been advertised with a more conservative rating of flow control range at 8:1.

Example

Let's say that a standard nozzle has a rated capacity of 0.8 gpm at a pressure of 40 psi. The following table shows how varying duty cycle affects the output from the nozzle.

Duty Cycle (%)	Portion of Full Flow	Flow (gpm)
100	100% of 0.80	0.80
90	90% of 0.80	0.72
10	10% of 0.80	0.08

The MSNC system is very effective at reducing nozzle flow rates while maintaining droplet size distribution and spray pattern characteristics. Therefore, standard procedure/strategy is to install nozzles that will meet the greatest flow demand in a particular spraying situation. The MSNC system is then used to reduce rates as needed. A benefit of using larger nozzles is the reduced likelihood of plugging.

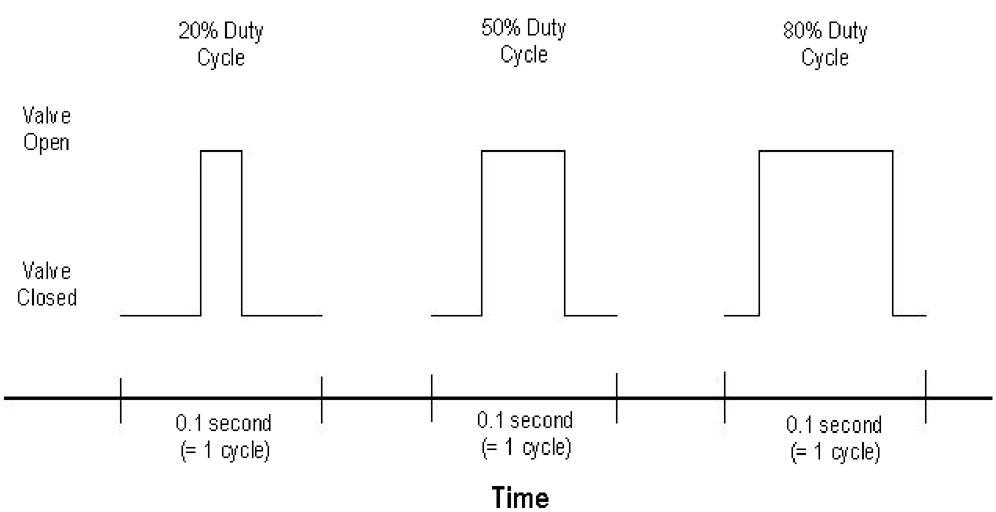

Figure 4. *Illustration of the electrical signal pattern used to control the operation of solenoid valves. (Note the varying duration of valve opening among the waves. This technique is referred to as **pulse width modulation**)*

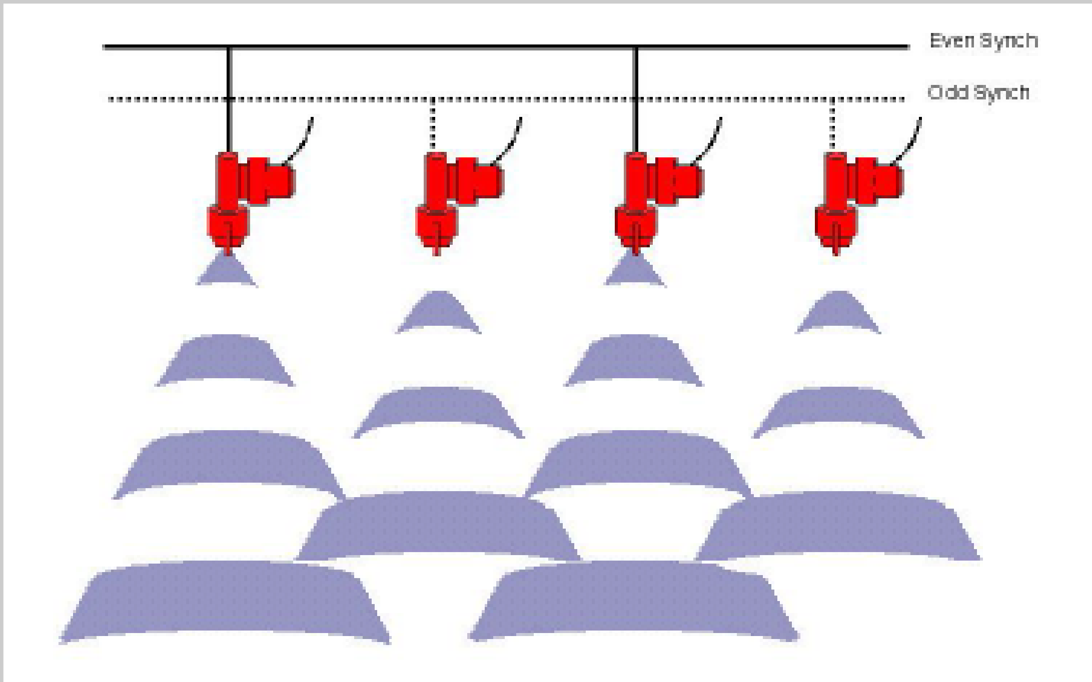

Figure 5. *Illustration of the alternating spray pattern from nozzles on a boom.*

In addition to controlling nozzle flow rates at a given system pressure, the MSNC system can be operated at reduced pressures to increase droplet size and reduce drift potential in locations and under atmospheric conditions in which drift would be likely to cause damage. Application rates could be maintained, even as system pressure is lowered, by increasing the duty cycle at which the solenoid valves operate.

Opening and closing nozzles as a sprayer travels through the field might appear to be a risky proposition. If a nozzle is held closed, even for an instant, no liquid will be discharged. Surely there will be areas of a field missed during normal operation of the sprayer! How can this be addressed? By using a 1/20-second (1/2-cycle) “phase shift” of adjacent nozzles (Fig. 5). When one nozzle is “off,” the nozzles adjacent to it are “on.” To increase spray pattern overlap and minimize the effect of the “pulses and pauses” produced at the nozzles, these sprayers are equipped with wide spray angle nozzles (110° versus the more common 80°).

The potential benefits of using a chemical application system that permits the tailoring of both application rate and droplet size distribution throughout a field include the ability to:

- Produce a broader range in flowrates with much more consistent spray characteristics than “conventional” technologies;
- Vary nozzle flow rates and/or travel speeds over a wide range without affecting spray pattern or droplet size distribution; and
- Vary droplet size distribution without changing application rate to minimize drift potential near sensitive areas or to increase spray coverage needed for some contact-type products.

MSNC technology can also be used to apply fertilizer at variable rates. While drift control is not a major issue in fertilizer application, the implementation of variable-rate application of fertilizer has proceeded at a much faster pace than for pesticides. MSNC provides yet another option for applicators wishing to take advantage of site-specific management methods.

Summary

Conventional spraying systems have limitations that keep them from meeting the needs of today's chemical applicator. Today's nozzles produce better performance than ever before and electronic controllers can automate the process of maintaining precise application rates under varying conditions. However, it has taken technologies such as modulated spraying nozzle control to meet the simultaneous goals of controlling application rate and controlling drift. And, do these things on a site-specific basis without operator "intervention."

Glossary

Drop(let) size distribution - as all spray nozzles produce spray patterns composed of droplets of varying sizes, this term refers to the proportions of droplet sizes within a certain range; typically determined with sophisticated detection and measurement systems for a specific sprayer nozzle under controlled operating and environmental conditions; often expressed in terms of median droplet size (measured in micrometers (µm)).

[see Volume median diameter]

Duty cycle - for the solenoid-operated control valves discussed in this publication, the duty cycle is defined as the amount of ***time the valve is open*** divided by ***the total operation time*** (open and closed).

[To express as a percent, multiply the result by 100.]

Example: If a solenoid is used to permit flow to a nozzle for 0.1 sec during a 1 second period, the duty cycle is 10%

$$\left[\frac{0.1\ \text{sec}}{1\ \text{sec}} \times 100 = 10\%\right]$$

Flow control range - often expressed as a ratio (e.g., 8:1), is the range of output from a spray nozzle <u>at a given pressure</u> with the lowest effective output assigned a value of one, and the greatest output described as maximum flow rate divided by minimum flow rate.

Pulse width modulation (PWM) - a technique for controlling the operation of a device that responds to electrical signals (or pulses) by varying the amount of time that pulses last.

Rate controller - an electronic device used to adjust product application rates on the go, based on user directions or digital application rate maps.

Solenoid - a coil of insulated wire that can be energized electrically to produce a magnetic field within the coil. The coil of wire surrounds a moveable iron core that moves in response to the magnetic field.

Solenoid-operated valve (= solenoid valve) - a device that utilizes a solenoid to adjust the position of a flow-regulating member attached to the moveable core within the solenoid.

Volume median diameter (VMD; $D_{V0.5}$) - a measure of the droplet size distribution discharged by a nozzle; expressed as the droplet size (diameter) for which 50 percent of the total volume (or mass) of liquid sprayed is made up of droplets with diameters larger than the median value, and 50 percent smaller than the median value.

Related Publications

The following publications provide information about other aspects of chemical application and site-specific management:

A detailed discussion of variable-rate application equipment can be found in the following Purdue University Cooperative Extension publications:

SSM-2-W, "Implementing Site-Specific Management: Map- versus Sensor-Based Variable Rate Application"

SSM-4-W, "Implementing Site-Specific Management: Sprayer Technology - Controlling Application Rate On The Go"

An entry in the "Site-Specific Management Guidelines" series published by the Potash & Phosphate Institute (PPI) also contains valuable information about spraying systems:

SSMG-7, "Variable Rate Equipment - Technology for Weed Control," D. Humburg

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