Low Volume Chemical Application System

Hamid J. Farahani and Gerald W. Buchleiter
Agricultural Engineers
USDA-ARS Water Management Research Unit
Fort Collins, Colorado
Voice: 970-491-8511 Fax: 970-491-8247
Email: farahani@wmu.aerc.colostate.edu

INTRODUCTION

Control of pests and diseases are crucial for optimum crop production under irrigated conditions. For many years producers have successfully used chemigation where chemicals such as fertilizers and pesticides are injected in the irrigation water of self-propelled sprinkler systems. However where a foliar-applied spray is desired, even the typical minimum application depth of 6.4 mm (0.25 in) dilutes the chemical too much. In other cases, it may be critical that chemicals are applied in a timely manner even though there is ample soil water to meet crop needs. In some high value crops such as potatoes and onions, it may be necessary to apply chemicals in a timely manner multiple times throughout the growing season to control disease and insect problems. Sometimes crop and weather conditions limit the opportunities for applying the necessary chemicals with ground applicators or airplanes. There is increasing interest among producers to use self-propelled sprinkler systems to apply chemicals through a separate application system mounted on the sprinkler. The current interest in precision farming where areas within a field are managed separately is spurring interest in application systems which can variably apply water and chemicals across a field.

To address the need of the producers and to provide a more robust and flexible chemical application system, Valmont Industries recently introduced the Accu-Pulse system. It is designed to allow application of agricultural chemicals for controlling weeds, pests and crop diseases. The system may be used to apply crop nutrients as well. The Accu-Pulse is a low chemical application system and uses the concept of pulsing the chemical applicators to achieve the desired low rates. It is installed on self-propelled irrigation systems such as center pivots (as shown in Fig. 1) and linear moves. In contrast to chemigation and fertigation systems where chemicals are injected into the irrigation water during the irrigation operation, the Accu-Pulse system runs independent of the irrigation system and uses a separate water supply for chemical dilution. In practice, the irrigation system runs dry when chemicals are applied through the Accu-Pulse system. During the past few years, Valmont Industries has been continuously evaluating and enhancing the design of the Accu-Pulse chemical application system. Of particular importance is their newly designed spray heads or accumulators called "Phillips" which are the subject of few experimental tests reported in this paper.

Uniformity of application is very important in the efficacy of the chemicals especially when applied at very low rates. Usually a coefficient of variation (CV) of 0.15 is considered acceptable (Dr. Paul Ayers, Colorado State University, Fort Collins, personal communication). In the Accu-Pulse chemical application system, two separate tanks and pumps are utilized, where one tank contains the concentrated chemical and the other is filled with water. An injection pump is utilized to inject chemicals directly into the solution supply line that runs the entire irrigation system. This on-the-go mixing of chemical and water, however, could potentially create non-uniformity in chemical concentrations since the rate of chemical injection is kept constant but the rate of water flow may vary considerably depending on the different number of towers moving over time. It is noted that pulsing of a given lateral only occurs when the tower is moving. The effect of this potential source of varying concentration on the uniformity of the applied chemical concentration is not entirely known at this time and is the subject of ongoing research.

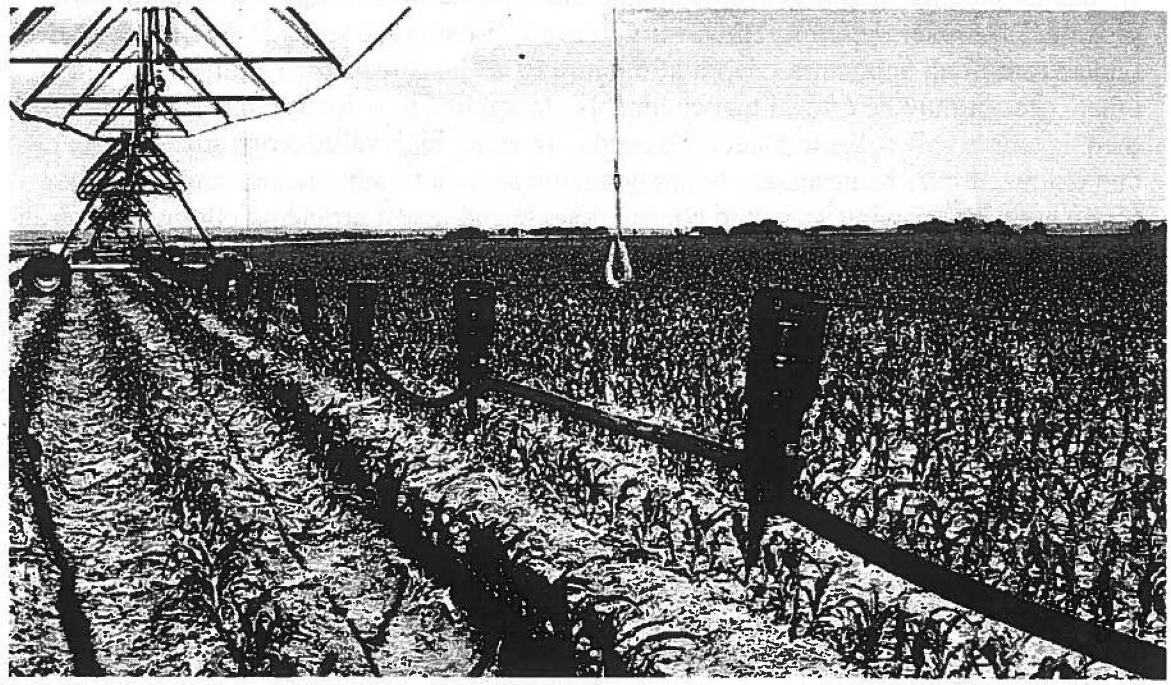

Figure 1: An Accu-Pulse chemical application system mounted on a center pivot.

Figures 2 presents a view of an older version of the Accu-Pulse spray head (or accumulator). The internal accumulator design for the Phillips accumulators (not shown herein) is slightly different than the design shown in Figure 2, but the mechanics of both designs are similar. As shown, the Accu-Pulse spray heads are individual units each molded to consist of a plastic nozzle with a spreader (not shown) at the lower end and an accumulator housing at the upper end. Each unit has an inlet and an outlet port at the sides. The Accu-Pulse spray heads are designed to hang on steel cables and are usually spaced 1.5 m (5ft) apart along the cable, which is strung underneath the irrigation mainline. The entire Accu-Pulse system is made up of individual laterals that feed off a supplyline that runs the length of the irrigation system. In center pivots and linear moves, all Accu-Pulse heads installed on a lateral line between adjacent towers are considered a unit and are pulsed by manipulating the liquid pressure inside that lateral. Each lateral is intended to pulse at pre-specified times (i.e., the last lateral is usually pulsed every 9 seconds). A lateral on a span pulses only when the span is moving. The sequence of discharge and filling of accumulators is unique because it applies the chemical solution in quick pulses.

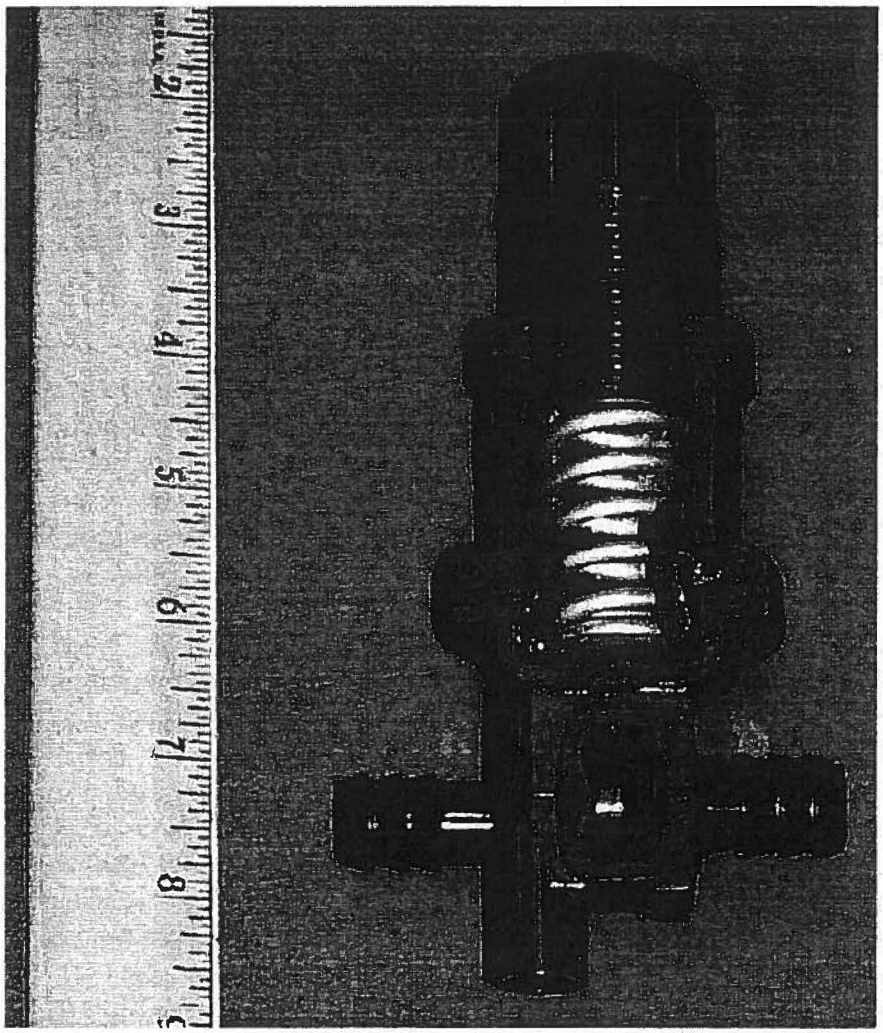

Figure 2. View of the internal components of an older version of the Accu-Pulse spray head (or accumulator).

An integral component of each accumulator is a 2-way valve that directs flow either into an accumulator chamber and the downstream tubing or else the spray nozzle for discharge. Figure 3 illustrates the two valve positions. When the lateral line is pressurized, the outlet to the spray nozzle is closed causing the chemical solution to flow into the accumulator chamber (compressing the spring). As the chamber is filling up, the chemical solution also flows through the lateral tubing to the next downstream spray head. This filling process continues until all of the accumulators on the lateral line are filled with the line pressurized. For safety purposes, a transducer constantly monitors the pressure at the end of each lateral line. In case of a line breakage or leak in any lateral, the entire system shuts off. Two two-way solenoid valves are installed at the upstream end of each lateral. These are called the FILL and FIRE valves and are controlled by relay switches and a programmable logic controller (PLC). Both of these valve are normally closed (when not energized) to guard against the loss of electricity. During operation, the FILL valve is energized (opened) to fill the lateral with the chemical solution to about 55-70 psi. Pulsing occurs by closing of the FILL valve and opening to the atmosphere of the FIRE valve. The FIRE valve is only opened to the atmosphere for a fraction of a second (0.25 sec). Opening of the FIRE valve suddenly reduces the pressure inside the lateral line and the accumulator thus causing the spring to expand forcing the cylinder downward with the solution discharging with a burst. A convex plate (spreader) below the nozzle produces a quick burst of spray about 4 - 4.5 m (13-15 ft) in diameter depending on the height above the soil surface. As the solution forces out, the upstream diaphragm is forced shut. When the FIRE valve is opened, the pulsing of accumulators occurs very rapidly. Our detailed laboratory tests showed that a lateral line with 30 accumulators spaced at 1.5 m intervals will take a fraction of a second to complete pulsing and about 3 to 4 seconds to complete the refilling process following the pulse. The nine-second pulsing interval currently recommended by Valmont Industries thus seems adequate, allowing enough time for the lateral to refill prior to next pulse. The amount of chemical solution applied can be varied by changing the frequency of the pulses, the volume of solution stored in the accumulator chamber, and the travel speed of the machine. The Phillips accumulators have an infinite setting for volume ranging from 0 to 20 setting that corresponds to about 10 to 30 ml per discharge, respectively.

As part of a Cooperative Research and Development Agreement (CRADA) between USDA-ARS Water Management Research Unit (Fort Collins, CO) and the Valmont Industries (Valley, NE), a series of laboratory tests were conducted during 2000 to study the performance of the newly designed Phillips accumulators. The main objective of the tests is to assess the uniformity of discharge volume and chemical concentration using Valmont's Accu-Pulse chemical application system. A combined approach involving both lab and field testing as well as development of a computer simulation model was envisioned to evaluate system performance under various conditions as well as to provide a useful tool for evaluating alternative designs and operating procedures. We felt that it was not physically and economically feasible to try to collect samples that could be analyzed for chemical concentration over an entire section of a field to assess the spatial uniformity of applied chemical. Since it is extremely difficult and costly (if not impossible) to evaluate the many possibilities of variations in mixing ratios due to variations in inflow water rates, simulation modeling will be utilized to evaluate the system. Chemical concentrations measured from laboratory tests will be used to validate and calibrate the model. Results from the simulation model can ultimately be used to produce a map showing the spatial variability of applied chemical.

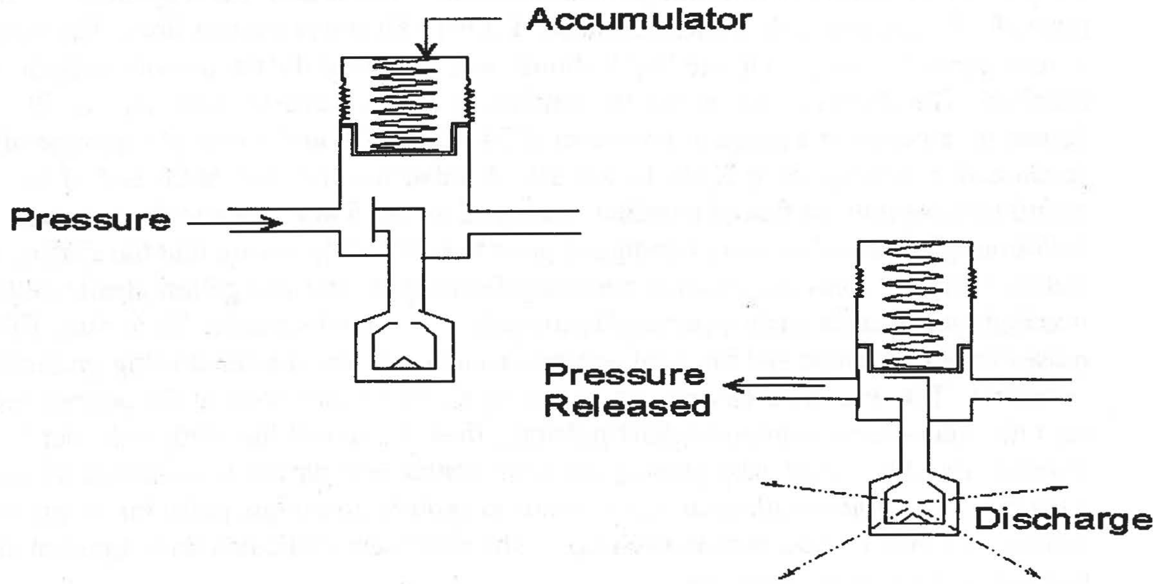

Figure 3. Schematic of the pulsing spray head (or accumulator).

In this report, we are presenting results from two different laboratory tests and briefly discuss key findings. The first test was a static distribution or spray pattern (using catch cans) for the Phillips accumulators. The other test was intended to quantify the discharge distribution for 30 Phillips accumulators installed on a single lateral line, operated using Valmont's recommendations and equipment.

Methods and Materials

Spray Pattern

A total of 167 catch cans (8 cm dia x 15 cm high) were placed in radial lines (covering a maximum of 7 feet in radius) under a Phillips accumulator to measure the depth of water application for 6000 pulses. Can spacing was 0.3 m (1 ft) in the radial direction and either 15 or 30 degree increments in angular direction. The bottom edge of the spreader was set at 5 ft above the top lip of the catch cans. Based on results from preliminary tests, 6000 pulses were found to be sufficient providing adequate volumes in most catch cans for graduated cylinder measurements. Tests were conducted at pressures of 55 and 70 psi with the accumulator at 5 and 15 settings (corresponding to about 14 and 26 ml of discharge per pulse).

Single Span Distribution of Discharge Volume

A single span (lateral) with 30 Phillips accumulators spaced at 1.5 m (5 ft) intervals was setup in the laboratory for discharge measurements. The lateral was suspended from 3 rows of 3/8 inch steel cables approximately 1.2 m (4 ft) above the test floor. The pump system currently being marketed by Valmont was used to make the tests as realistic as possible. The objective was to test the uniformity of discharge for three reps of 50 consecutive pulses at a range of pressures of 35, 45, 55, 70 and 90 psi and a range of accumulators settings of 0, 5, 10, 15 and 20. A valve was installed at the end of the lateral to flush the line free of possible entrapped air for 5 minutes prior to each test. Additionally, 200 pulses were conducted prior to each test to ensure that the system is stable. With the spray heads set at the desired setting, a clear one gallon plastic milk jug was hung underneath each spray nozzle to catch the entire discharge. Each time, fifty pulses were conducted and the total volume in each jug was measured using graduated cylinders. The tests were carried out by setting all 30 accumulators at the desired setting, start the Accu-Pulse system (without pulsing), flush the lateral line with water for 5 minutes, run 200 pulses, stop pulsing but keep system pressurized to minimize air entry, hang milk jugs underneath each accumulator to capture discharge, pulse for 50 times, and measure volume of discharge in each jug. The tests were replicated three times at all settings and operating pressures.

Results and Discussions

Figure 4 presents a 3-D view of the catch can volumes after 6000 pulses of the Phillips accumulator at the 15 setting (operating pressure of 55 psi). This pattern is very typical of all of our measurements, a shape that resembles a donut shape with distinct peaks. The outer peaks were the result of the side-arms in the convex spreader. At the lower setting of 5, the magnitudes of volumes in the catch cans were decreased, but the shape of the pattern remained similar to the one shown in Fig. 4. We intend to study the influence of overlapping on application uniformity and most importantly on ground coverage using simulation modeling.

A summary of results for the single span volumetric discharge measurements is presented in Table 1. The coefficient of variation (CV) is defined as standard deviation divided by mean, a normalized measure of the degree of variability used to aid comparison. Valmont recommends operating the Accu-Pulse system at 55 psi and higher pressures. Figure 5 presents a graph of the mean discharge per pulse at accumulator settings of 0, 10 and 20 all operated at the 55 psi pressure. At this pressure, mean discharge volumes per pulse were 9.8, 14.6, 20.6, 25 and 29.3 ml for the 0, 5, 10, 15 and 20 settings, respectively. That is roughly a ml per setting number plus 10. The settings zero and 20 are the lowest and highest settings for the Phillips accumulators. At 55 psi operating pressure, CV values of 15, 10 and 14% for the 10, 15, and 20 settings indicate very acceptable performance (see Table 1). Irrespective of the operating pressure, the most significant level of non-uniformity in discharge among the 30 accumulators was

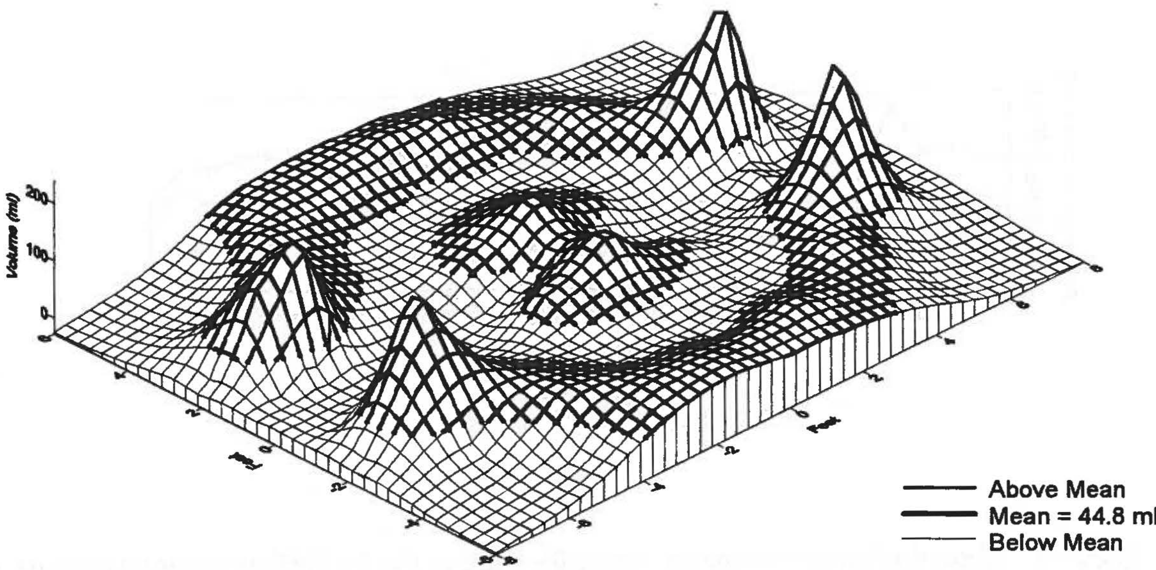

Figure 4. A 3-dimensional graph of the spray pattern for the Phillips accumulator (setting = 15, pressure = 55 psi) after 6000 pulses.

measured at the lower setting of zero with CVs mostly greater than 30%. As the operating pressure and accumulator setting increased, CV of discharge decreased. Our results reconfirms the recommendation by Valmont that best discharge uniformity is obtained at operating pressures of 55 psi and higher.

Conclusions

There is increasing interest, especially by producers of high value crops, in applying agrochemicals with independent systems that are mounted on self-propelled sprinkler systems. The Accu-Pulse chemical application system introduced by Valmont Industries appears to be a promising system that lends itself to precision agriculture and variable rate technology. In a laboratory setting and under a controlled environment, we found acceptable levels of uniformity for discharge volumes from a single lateral with 30 accumulators. We are very encouraged by our initial positive findings and the potential of the Accu-Pulse chemical application system. Additional detailed experiments are currently underway to further evaluate the performance of the Accu-Pulse system. In our opinion, the system requires comprehensive field and laboratory tests to quantify the spatial and temporal distribution of the applied chemical concentration and the effect of overlapping accumulator patterns on uniformity and the wetted coverage.

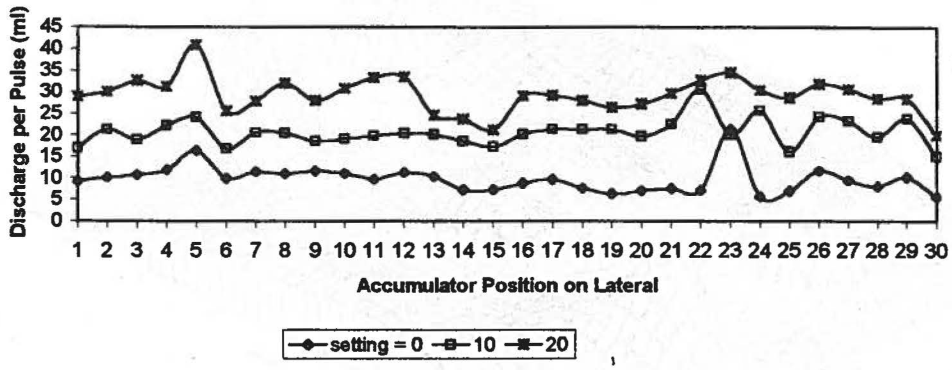

Figure 5. Mean discharge volume per pulse for each of the 30 Phillips accumulators on a single lateral line.

Table 1. Summary of discharge volume per pulse measurements for 30 Phillips accumulators on a single lateral line.

Operating					
Pressure	Accumulator setting				
psi	0	5	10	15	20
	Mean Discharge per Pulse (ml)				
35	5.9	17.0	19.9	24.7	26.1
45	12.9	16.0	21.0	26.6	25.8
55	9.8	14.6	20.6	25.0	29.3
70	9.2	14.1	19.9	26.1	27.0
90	9.2	14.2	21.3	26.8	29.5
	Standard Deviation (ml)				
35	1.8	4.5	6.4	2.1	3.7
45	8.7	5.0	4.3	3.3	4.1
55	3.1	3.3	3.1	2.6	4.0
70	4.9	2.6	2.4	2.1	2.7
90	2.9	1.9	1.9	1.6	2.4
	Coefficient of Variation (%)				
35	30%	27%	32%	8%	14%
45	68%	31%	20%	13%	16%
55	32%	23%	15%	10%	14%
70	53%	18%	12%	8%	10%
90	31%	13%	9%	6%	8%