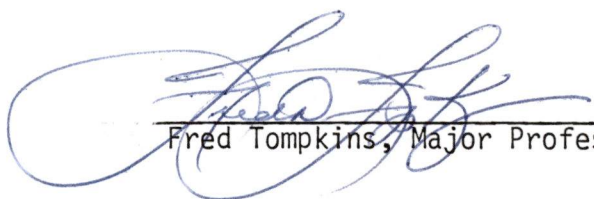
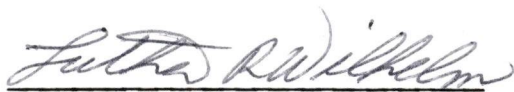


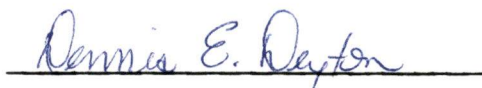
To the Graduate Council:

I am submitting herewith a thesis written by James Clifton McNeal entitled "Intermittent Chemical Applicator for Renovation of Strawberries." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Mechanization.

  
Fred Tompkins, Major Professor

We have read this thesis  
and recommend its acceptance:

  
Luther R. Wilhelm

  
Dennis E. Dayton

Accepted for the Council:

  
Vice Chancellor  
Graduate Studies and Research

INTERMITTENT CHEMICAL APPLICATOR FOR  
RENOVATION OF STRAWBERRIES

A Thesis  
Presented for the  
Master of Science  
Degree  
The University of Tennessee, Knoxville

James Clifton McNeal

June 1983

1482935

## DEDICATION

TO

My wife Susan and my children Sonny, Jason, and Jenny for their unbounded patience and support.

My parents, Mr. and Mrs. E. C. McNeal, for their understanding and support.

## ACKNOWLEDGEMENTS

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## ABSTRACT

A chemical applicator for renovation of strawberries was designed and constructed. Outputs of even spray nozzles spaced 8 inches apart were directed through ports alternately opened and closed by solenoid actuated gates for intervals corresponding to 16 inches of ground travel. Ports along the boom were alternately opened and closed, creating a grid pattern of sprayed and unsprayed matted-row vegetation. Formulation collected when a given port was closed was returned to the tank for recirculation.

In addition to design and construction of the applicator, the study objectives included evaluation of the precision of the grid pattern of sprayed areas produced by the machine. Colored water was applied on white crate paper at three operating speeds using the chemical applicator. Two series of tests were conducted on smooth operating surfaces, and one series was conducted on a bump track.

Data were collected by measuring the sprayed areas of each intermittent spray pattern track. There were approximately seven patterns created by each nozzle from each of these seven patterns. Variation of sprayed areas among treatments (speeds) and among nozzles was determined using these data.

Applicator modification was needed after the first smooth surface test, due to indicated excessive variation among nozzles. After completing modifications there was no significant variation

among treatments (speeds) or among nozzles with either the second smooth operating surface or the rough operating surface test.

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## CHAPTER I

### INTRODUCTION

#### I. Background and Statement of Problem

Maximum production with minimum cost in any area of agriculture requires constant research. Renovation of strawberries, as discussed by Bird (1960) of The University of Tennessee Experiment Station at Crossville, is a topic which has received little attention. In fact there have been few changes in methods since the early 1900's. Renovation is generally accomplished by tillage. Given favorable climatic and soil conditions, satisfactory results are obtained by these methods. But, favorable conditions do not always occur at the optimum period for renovation, which immediately followed berry harvest.

Fraser (1926) noted that strawberries allowed to grow stolons would form a matt, and that parts of this matt could be killed leaving space for rejuvenation the following year. At this early stage in production system evolution, tillage methods were the only apparent options. Unfortunately, these methods continue to be used almost exclusively today.

The United States produced approximately 544.2 million pounds in 1980 in the major strawberry production states. Even with this substantial level of production, annual imports into the United States averaged 32 million pounds from 1974 to 1980 (USDA, 1980).

This USDA report did not list Tennessee as a supplier of strawberries. However, the potential for increased production in Tennessee is considerable. In 1981 there were 28 certified strawberry plant producers in Tennessee, utilizing 260 acres for propagation of setting plants (USDA, 1981). There are about 1200 acres for fruit production in Tennessee, Rutledge (1983).

The need for the development of a renovation method, independent of climatic and soil conditions, should be emphasized. With such a method, strawberry production could be improved not only in Tennessee, but in other areas where climate dictates time of renovation.

## II. Objectives

The purpose of this study was to design, construct, and test a prototype chemical applicator for strawberry renovation following berry harvest. The applicator was to achieve a spot treatment ground coverage, resulting in a partial kill of strawberry vegetation within a matted row.

Specific objectives of this study were:

1. To design and construct the applicator.
2. To evaluate the applicator for effectiveness in achieving a uniform intermittend spray pattern.

## CHAPTER II

### REVIEW OF LITERATURE

#### I. Matted-Row Strawberries

The use of a matted-row culture for producing strawberries prolongs the productivity of an established patch (Boylan, 1974). Utilizing this system increases the longevity of a patch by 2 to 4 years, due to the ability of the strawberry plant to rejuvenate through stolonization.

With the matted-row system, plants are set out for the initial establishment in a level soil bed. The plants are usually spaced at 24 to 30 inch intervals in rows 48 inches apart. Each plant has the potential of producing 15 offsprings, which justifies the rather large spacing when transplanting. Early spring is the time best suited for planting.

Craig (1980) noted that the matt forming ability of strawberries is due to the production of genetically identical stolons from the parent plant. The first growing season is a period of establishment during which flowers are sometimes removed to allow vegetative growth. In the following seasons renovation is required for multi-year fruit production. Optimum stolonization is achieved when renovation is implemented soon after harvest. Excessive runners cause small fruit and lower quantity of production and are

considered strawberry weeds. The amount of runner removal during renovation depends upon the variety of strawberry plant involved.

## II. The Chemical for Application

This study was feasible only if a herbicide was available with characteristics favorable for strawberry renovation. According to Albregts and Howards (1975), a chemical for post-harvest thinning of strawberries must be a dessicant with no translocation from the original contact area.

### Herbicide for Renovation

The chemical used in this study is a herbicide in the Bipyridinum Family, commonly named paraquat and chemically named 1,1-dimethyl-4, 4-bipyridinum ion (Baldwin, 1963). Research was conducted by Frank and King (1979) for the USDA on the use of glyphosate and paraquat as weeding agents in strawberries. The experiment was conducted over a 2-year period. Due to the systemic action of glyphosate, severe damage was caused to non-contact vegetation resulting in poor production the following season. However, paraquat eliminated only vegetation contacted by spray material, and production was not affected. This was a confirmation of the conclusion reached by Albregts and Howard (1975) on the use of paraquat for weed control.

### Mode of Action

Ware (1978) of the University of Arizona described the mode of action of paraquat as disrupting the cell membrane integrity of

cells responsible for photosynthesis. The primary toxicants are OH-radicals of hydrogen peroxide ( $H_2O_2$ ), chemically formed after vegetative contact.

### Toxicity and Environmental Considerations

Paraquat is considered highly toxic to mammals, with an oral  $LD_{50}$  of 150 mg/kg. There is no known antidote after symptoms of poisoning are observed, thus warranting extreme caution with use. Due to rapid adsorption by soil colloids, paraquat has no herbicidal or toxic properties once in contact with the soil (Ware, 1978).

### III. Calibration Standards and Chemical Applicators

#### Calibration

The application rate of a given applicator is dependent on three variables, and each must be known before spray volume determination. The variables of consideration are nozzle flow rate, ground speed of the applicator, and width sprayed per nozzle. Calibration procedures vary with assorted applicators, since there is no single method suitable for all applicator types. Checking all sprayer parts is advisable before attempting calibration. Unless the spray mixture varies nozzle output by 5 percent or more, calibration should be accomplished by use of water, thus avoiding personal contact with the spray formulation or environmental contamination of the area used for calibration.

The calibration procedure followed by this study employed direct measurement of variables. Spray fluid (water) was collected

from the nozzles while operating over a known course length or over the time period for the course traveled. The following equation was used for application rate determination, after the above measurements were obtained (Agricultural Engineers Yearbook, 1980).

$$V = Q/A$$

where,

V = Spray Volume,

Q = Quantity Used,

A = Area Treated.

#### Spot Treatment Sprayer

The purpose of most spot treatment sprayers is the conservation of spray material. Boving (1977) experimented with such a sprayer, which resulted in some significant conclusions. Implementing an infrared sensor along with a digital delay circuit, individual plant location was determined and discharge of spray material took place at that location.

Originally, the prototype sprayer consisted of a normal boom type sprayer with a solenoid valve included on the inlet side of each nozzle. The solenoid operated in response to the control circuit. Before actual field testing of the sprayer, the solenoid valve went through three 4-hour periods at 350 operations per minute. No indication of failure was apparent. However, when field tests were conducted the spray pattern was inadequate for proper coverage of seedlings.

Due to the poor operation of the hydraulic system an air-brush system was employed and gave satisfactory results. Drift must be tolerable with this system. An important aspect of this research was that the solenoids endured the continuous operation in pretest experimentation.

### Recirculating Sprayer

A recirculating sprayer was described by McWhorter (1970), who developed the sprayer at the Agricultural Experiment Station at Stoneville, Mississippi, as a chemical applicator with which spray material that does not contact target plants is recirculated back into the system via catch reservoirs. This prototype sprayer was designed to spray weeds which grew taller than the infested crop and utilized straight fluid streams directed horizontally over the drop with the streams crossing. Spray material which did not contact vegetation was captured in a reservoir and recirculated back into the supply tank. A venturi system was used to complete the recirculation process. This early recirculating sprayed displayed problems with contamination and foaming.

Supak and Abernathy (1977) reported that contamination and foaming were avoided by a modified version of the venturi system. With this system spray material accessing the nozzles was supplied directly from the catch reservoirs. The fluid level of the reservoirs was regulated by a gravity-fed float valve via the supply tank, isolating the tank from exterior contaminants.

Ewald (1978) noted that contamination in the venturi system was greatly reduced by repositioning the catch reservoirs from perpendicular to parallel with the crop rows. When using this arrangement along with shields to push foliage away from reservoir, little contamination occurred.

#### Boom Level Mechanism

Franklin (1981) of The University of Tennessee, Knoxville, Agricultural Engineering Department utilized a four-bar linkage which allowed vertical flotation of an attached applicator unit. Four pins held the applicator unit to the four-bar linkage and allowed easy removal. The bars were also hinged with four pins at the supporting framework, thus allowing constant contact of the attachment with the ground while the applicator unit remained level (Figure 1).

In this research two applicator units were used with various herbicides for weed control between rows of snap beans. The units included hooded and rope wick applicator attachments.

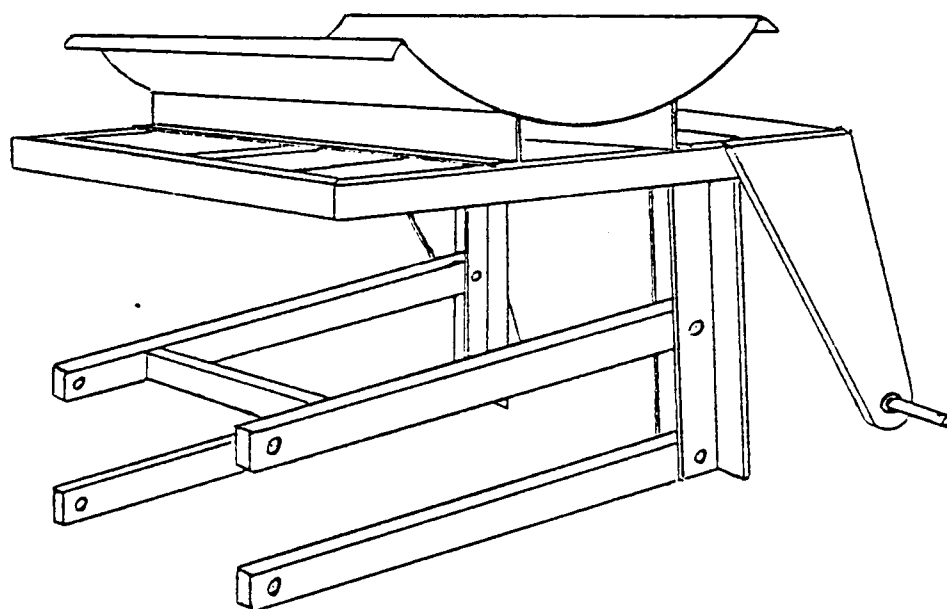


Figure 1. The framework of the four-bar linkage utilized by Franklin (1980) to allow a herbicide applicator to float on the ground surface independent of the prime mover.

## CHAPTER III

### APPLICATOR DESCRIPTION

A spot treatment applicator was designed and constructed at The University of Tennessee, Knoxville, Agricultural Engineering Department. The applicator combined features of a boom, a recirculating, and an intermittent sprayer (Figure 2).

#### I. Construction

The supporting frame for the applicator was an existing structure constructed by the Agricultural Engineering Research Shop at The University of Tennessee, Knoxville for work done by Franklin (1980). Due to the unique movement of the four-bar linkage, the chemical application was built utilizing this frame.

#### Delivery of Spray Material

Delivery of spray material to the nozzles was basically accomplished using a layout typical of a boom type sprayer. Manipulation of the spray pattern (on or off) took place after fluid exits the nozzles. Although the boom itself was modified to be compatible with the applicant unit, the plumbing system was that of a basic boom type sprayer (Figure 3).

The basic sprayer equipment consisted of a saddle mounted 25 gallon poly-vinyl supply tank (Century Spray Company) with a model N6500 PTO-driven Hypro roller pump. The pump was gravity fed from

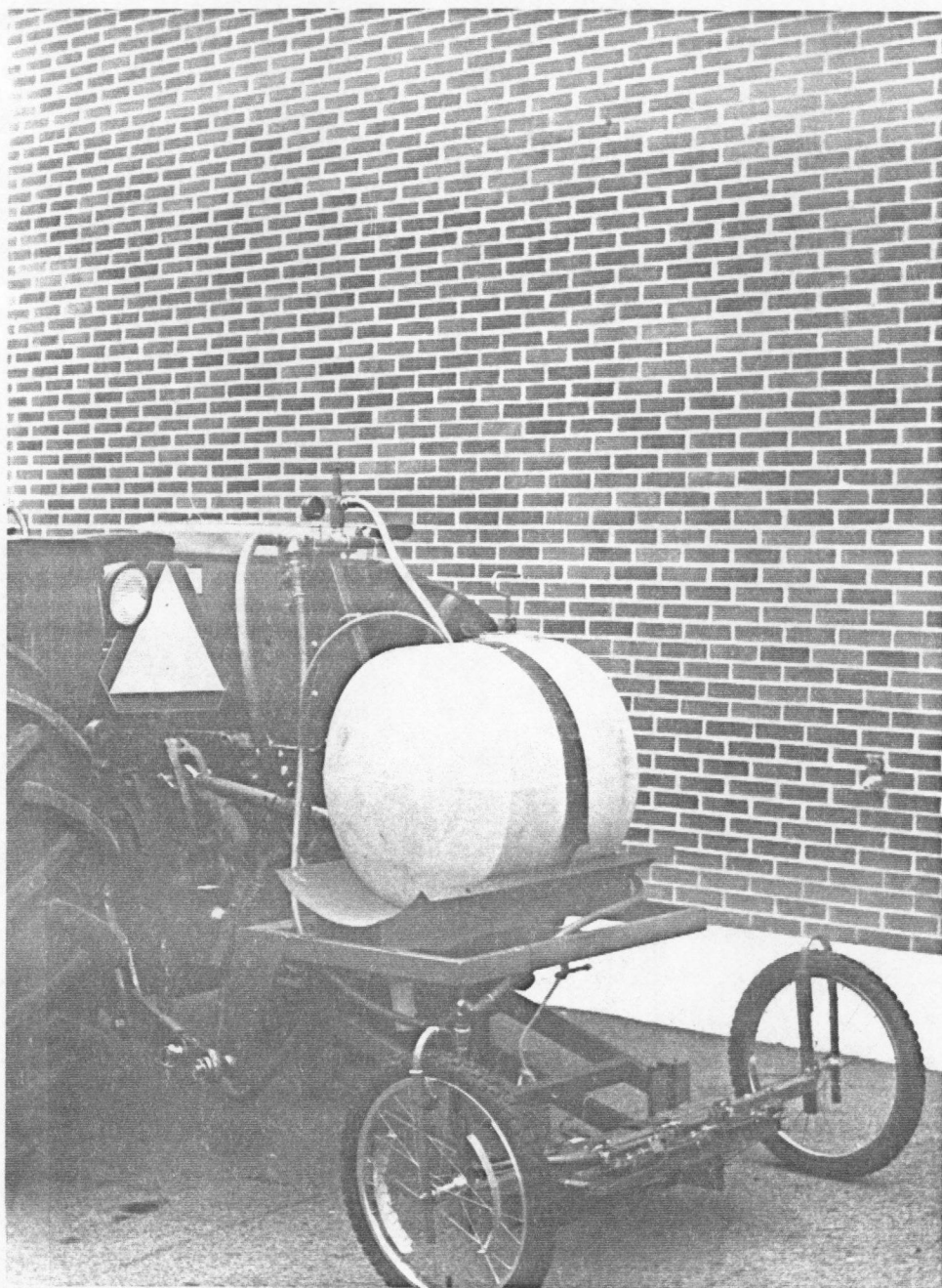


Figure 2. Experimental chemical applicator for renovation of matted-row strawberries.

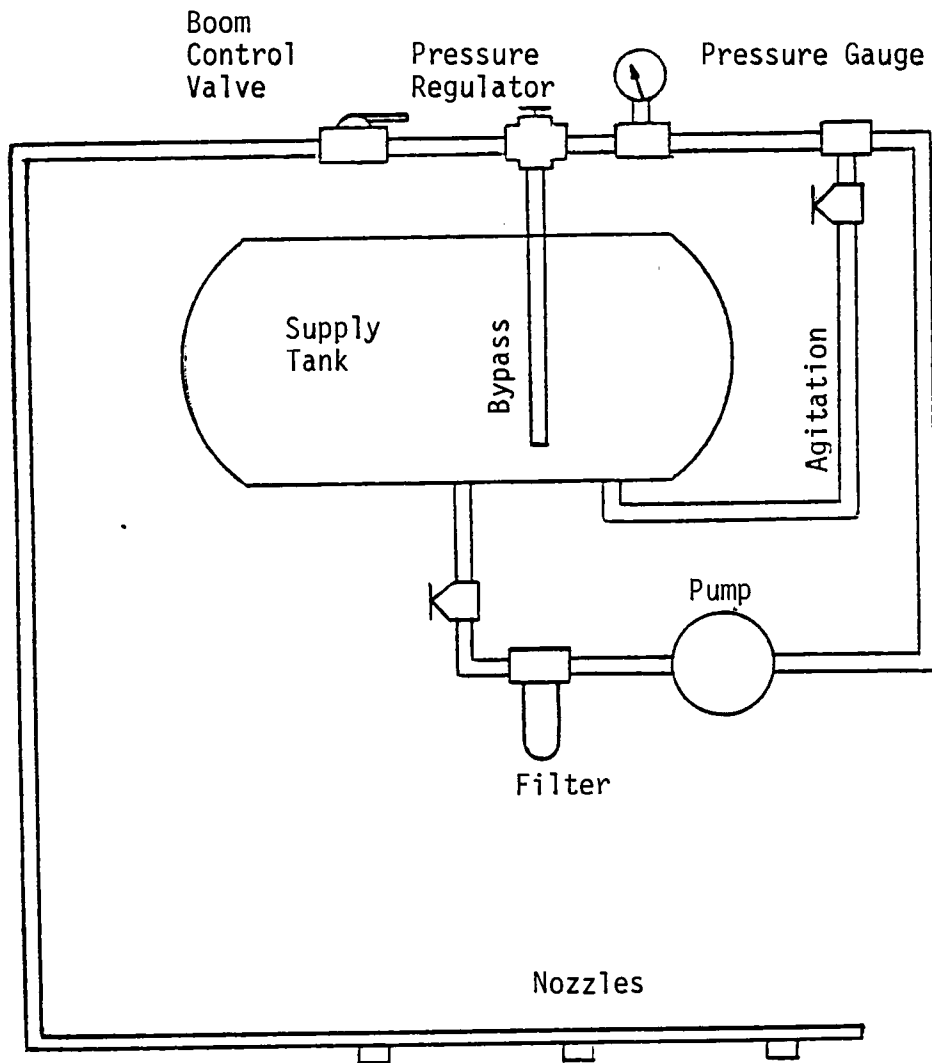


Figure 3. Schematic of the fluid delivery system for the experimental chemical applicator.

the supply tank through a 124A-3/4-I strainer (Spraying Systems Company). The pump supplies fluid to a 6290-SC agitator (Spraying Systems Company) in the bottom of the supply tank, controlled by a gate valve, three 8004E nozzles (Spraying Systems Company) with a ball valve between the nozzles and the pump. The pump also supplied a 6815-3/4-300 pressure regulator (Spraying Systems Company) which diverts excess spray material back to the supply tank.

Since the normal matt width of a strawberry row is 24-inch, three nozzles were employed on the boom to partition the matt into three bands. Using the equation below, the necessary nozzle height was computed to be approximately 5 inches from the targer surface. This height evenly divided the matt into three 8-inch bands.

$$\text{Tangent } 1/2 = a/b$$

where,

= The angle of spray pattern, degrees

a = Height of nozzle, inches

b = Base or band width/2, inches

Nozzle height was maintained by two ground wheels fixed to each end of the sprayer boom (Figure 4).

Spray material was delivered from the nozzles as with a normal boom type sprayer equipped with even spray nozzles for band application. The intermittent spray pattern was derived after the spray material exited the nozzles.



Figure 4. Ground wheel used to maintain proper nozzle height on the experimental chemical applicator.

### Mechanisms for Intermittent Spray Pattern

The intermittent pattern of spray material was accomplished with a reservoir equipped with three exiting ports, one under each nozzle, and ground wheel controlled gates which oscillated to cover and uncover the exiting ports. When a gate covered a port the spray material from the nozzle feeding that port was diverted into the collection reservoir (Figure 5). When a port was uncovered, spray material exited the reservoir and contacted the target area in the typical nozzle pattern.

The actual reservoir was constructed from 18 gauge galvanized sheet steel. Overall depth was 4 inches with a vertical front and the rear positioned at a 35 degree angle from horizontal. The bottom was only 1 inch from front to rear. The total length was 24 inches, and exiting ports were located on the angled rear member.

The sheet metal reservoir was rimmed at the top by 1 inch angle iron of 0.125 inch in thickness to provide rigidity and a surface for mounting of the unit to the main frame. The spray boom was bolted to this structure.

In order to achieve the cycle of target contact and diversion of spray material into the reservoir, a gate system was utilized. The gates were actually sliding sheets oscillating over and to the size of the exit ports. The gates were made of 18 gauge aluminum in order to minimize weight. Since the Massey Ferguson 265 Diesel Tractor used for operating the applicator had a 12 volt direct current (DC) electrical system, 28-12V Guardian continuous operation solenoids were utilized to actuate the gate oscillation. The

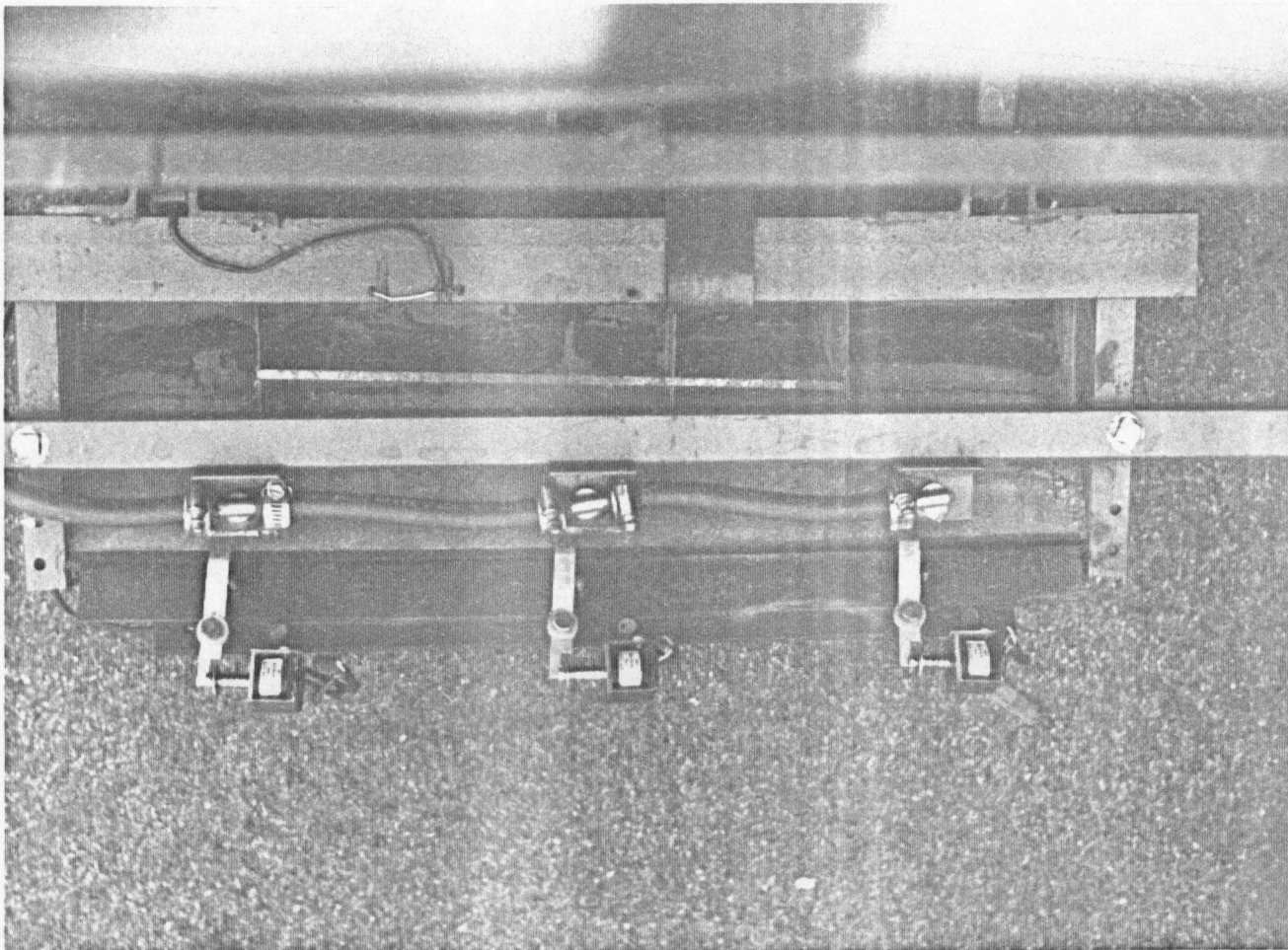


Figure 5. The reservoir and gate mechanisms used to achieve the intermittent sprayer pattern on the matted-row.

solenoids did not attain a plunger stroke of the magnitude required for the gate movement. The solenoid stroke maximum was 0.375-inch, while the gate needed greater than 1-inch displacement. Therefore, a 4:1 ratio lever arm was built in the gate-solenoid connection, delivering approximately a 1.25-inch movement of the gates. A low tension spring closed the gates, while exitation of the solenoids opened the gates. The two outside gates were synchronized for simultaneous operation, and the center gate functioned inversely.

Maintaining a constant spray coverage area independent of ground speed was desirable, and required a method of controlling the gates. The solenoids were operated by a microswitch located next to the boom level control wheels. Ribs on the ground wheels operated the microswitch lever, which opened and closed the circuit to the solenoids. In turn, the solenoids operated independently of ground speed. The ribs were constructed to deliver approximately 50 percent spray material coverage. Percent coverage could be alternated by raising the boom height or changing rib dimensions on the ground wheels.

As mentioned above, the ground wheels served two purposes. They provided height adjustment and controlled the intermittent spray pattern. The rims of the ground wheels were spoked and attached on each end of the boom. A 1-inch wide by 0.125-inch thick metal strip was welded to the 1-inch square tube boom. Height adjustment in increments of 1-inch was achieved by drilling 0.375-inch diameter holes in the metal strip. The ground wheel axles were bolted directly to the proper hole, according to the desired height of the

boom. Each wheel also had a forked brace, made from 0.5-inch wide by 0.25-inch thick metal strip, attached to each side of the axle. Flanges on the boom wheel braces prevented movement of the wheel forks. The microswitch that controlled the intermittent spray pattern was mounted on the left wheel fork (Figure 6).

#### Recirculating Spray Material

When the chemical applicator was in operation, spray material was continuously diverted into the reservoir from either the two outside nozzles or the center nozzle. Without some method of removing the spray material collected, the fluid level in the reservoir would rise above the exit ports and render the applicator unit inoperative. Therefore, a system for recirculating collected spray solution was fabricated. This system consisted of a rotary vane pump and a control circuit for monitoring the reservoir fluid level and turning the pump on and off.

The recirculating pump was powered by a 12-volt DC universal motor. The pump was located on a mount in the front of the reservoir (Figure 7). Spray material was gravity fed to the pump from a bulk-head fitting located near the bottom and center front side of the reservoir. This excess fluid was pumped back into the supply tank. The electrical current required to drive the pump motor was delivered through a 10-ampere relay. The relay was controlled directly by the logic circuit monitoring reservoir fluid level. Thus, the recirculating pump was indirectly operated by the logic circuit.

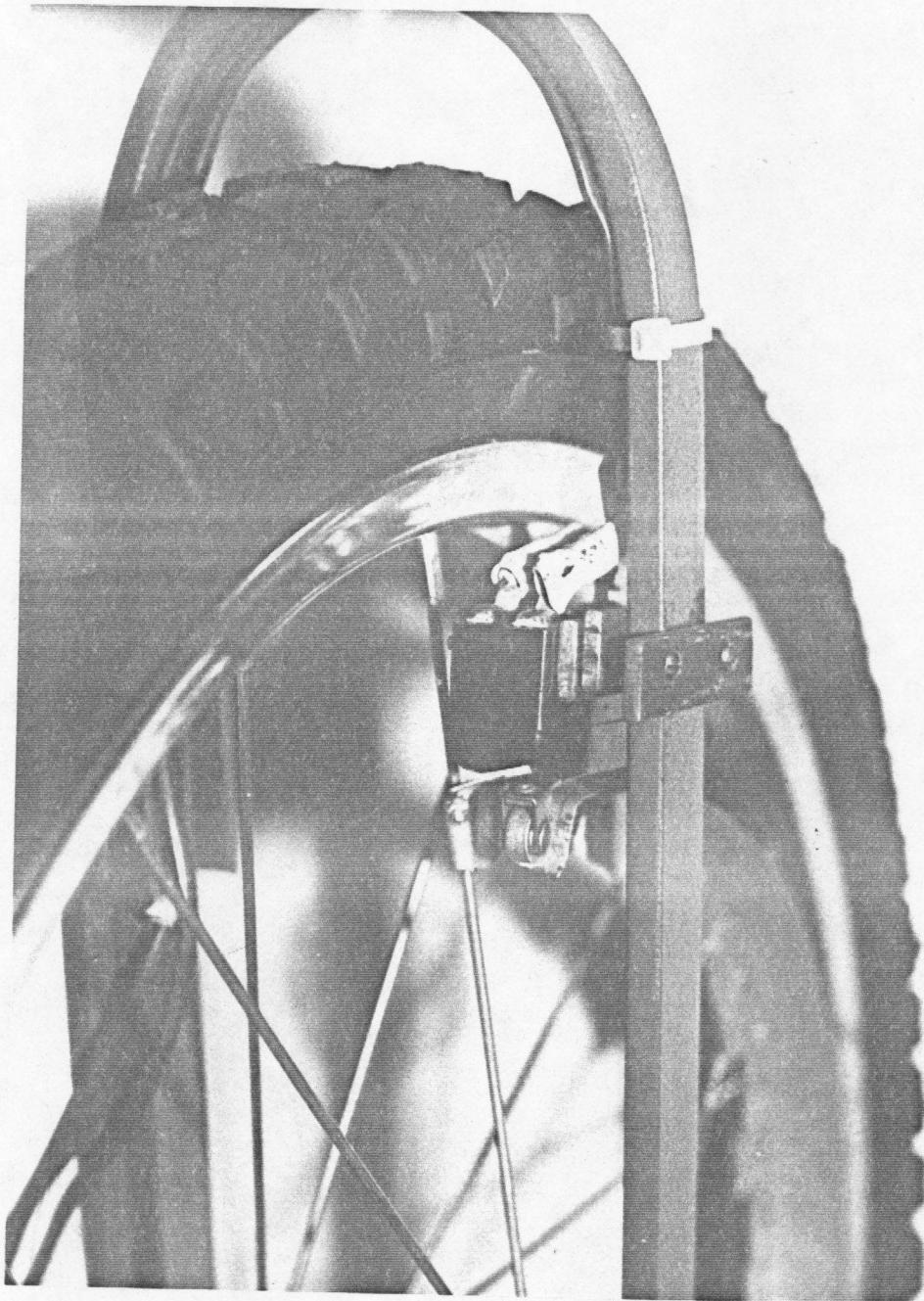


Figure 6. The microswitch that controls the intermittent spray pattern mounted on the fork of the left gauge wheel.

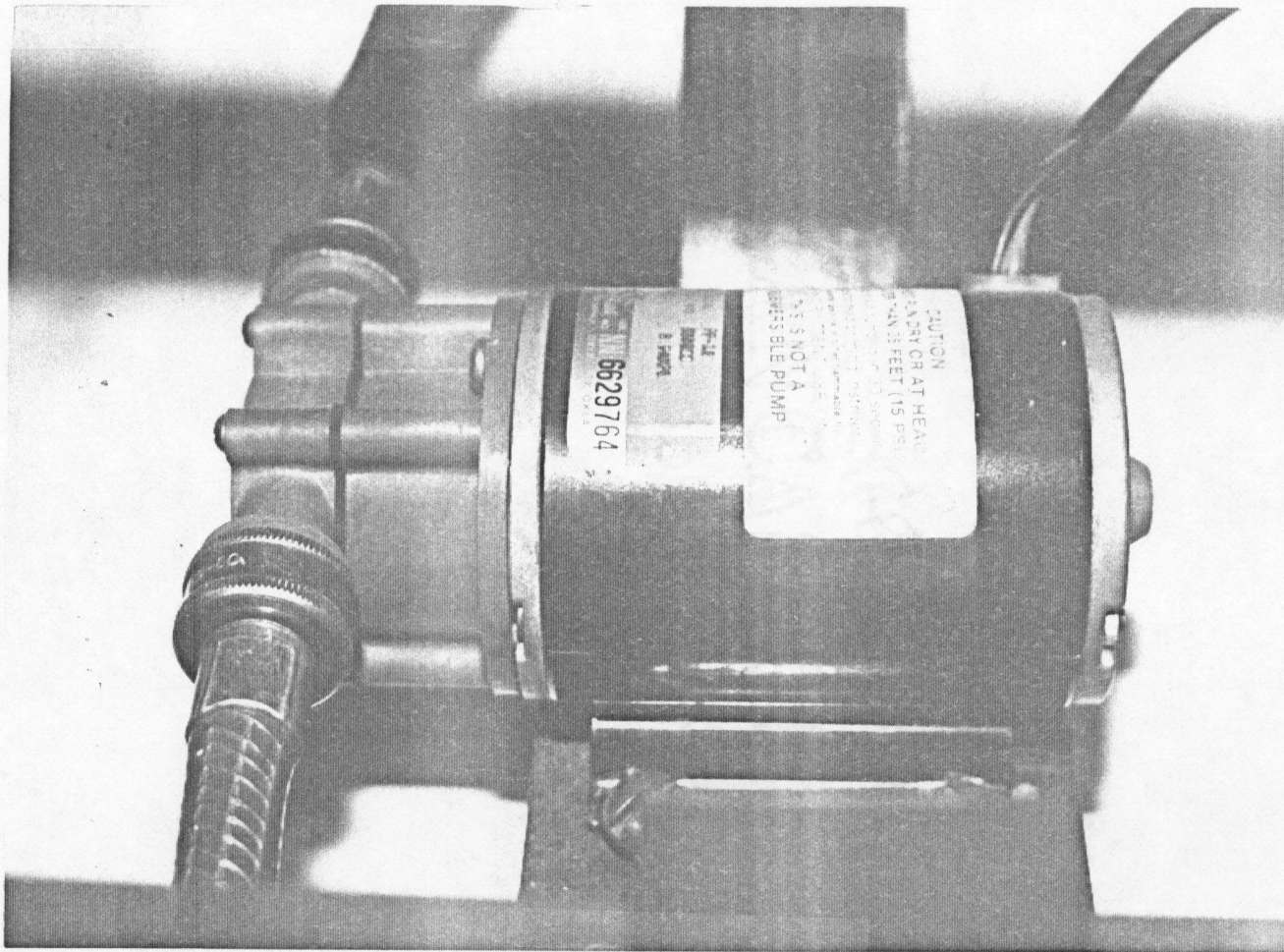


Figure 7. The recirculating pump located on the front of the reservoir to deliver collected fluid back to the sprayer tank.

The logic circuit, designed by Wilkerson (1982), consisted of three basic groups: the level sensor, latched output, and the power interface group. Components of the level sensor group included two sensor probes, which were simply 22-gauge solid copper wire, a 74LM339N comparator integrated circuit, and a 74LS22IN monovibrator integrated circuit, commonly named a one-shot. A DM7410N Nor-gate integrated circuit was implemented for the latched output groups. The power interface group was made-up of a T1L111 opto-couple transistor (Texas Instrument) and a TIP125 darlington transistor (Texas Instrument). A group flowchart can be seen in Figure 8. A schematic diagram of the logic circuit is shown in Figure 9.

The control circuit was initially operated by simulating the filling of the reservoir with a water filled beaker. A Heathkit ET3600 breadboard tester was used as the power source, and no problems were indicated by the test. However, when placed in the actual operating environment, false signals caused the control circuit to energize the coil relay sporadically. After consultation with Wilkerson (1982), the problem was alleviated by installing capacitors in parallel with all source voltage inputs and the sensor probes.

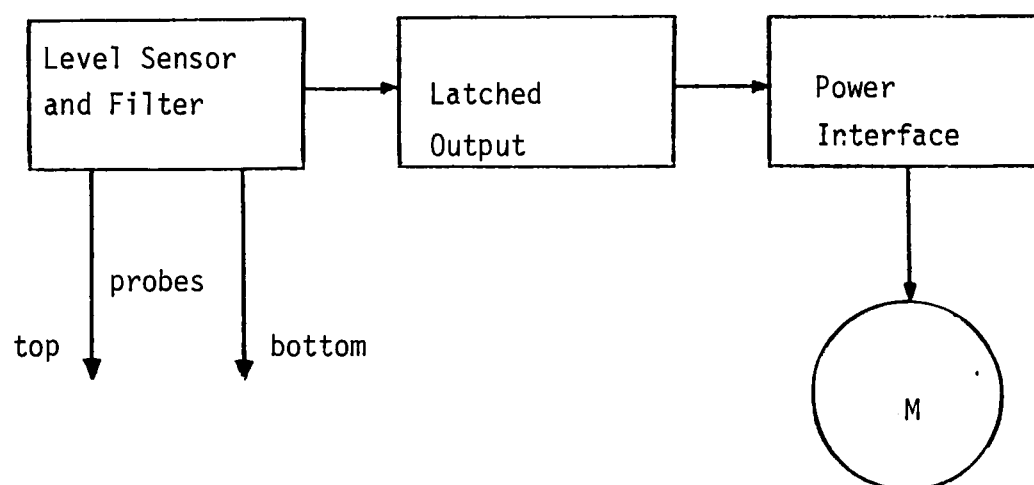


Figure 8. Flow chart diagram of reservoir fluid level control logic circuit.



## CHAPTER IV

### EXPERIMENTAL METHODS AND PROCEDURES

#### I. Experimental Design

The experimental design used for laboratory testing the experimental applicator was a split-block. These treatments were to be replicated four times. Each replication was also divided into three blocks, each block representing a spray nozzle on the applicator boom. Treatments consisted of three different operating speeds. An additional replication was included in the design, following analysis of an early laboratory test. Originally, two individual tests were to be conducted on the chemical applicator to determine spray pattern precision. The first test, mentioned above, was conducted on a smooth tractive surface. The second test was to be a repetition of the first except for use of a tough operational surface, simulating harsh field conditions. However, another complete smooth surface test was added with a fifth replication. Therefore, there were three series of tests, two on a smooth surface with the second test having an additional replication, and the third on a simulated rough field surface also with an extra replication (Table 1).

#### II. Materials Used

A technique was needed for quantitatively describing spray patterns produced by the applicator. For this study a coloring

Table I. The Split Block Experimental Design Used for the Analysis of the Chemical Applicator.

| Source of Variation           | Degrees of Freedom          |                                              |
|-------------------------------|-----------------------------|----------------------------------------------|
|                               | Initial Smooth Surface Test | Second Smooth Surface and Rough Surface Test |
| Replication (Reps)            | 3                           | 4                                            |
| Speeds                        | 2                           | 2                                            |
| Reps x Speeds                 | 6                           | 8                                            |
| Nozzles (Noz)                 | 2                           | 2                                            |
| Reps x Noz                    | 6                           | 8                                            |
| Reps x Speeds x Noz           | 16                          | 20                                           |
| Samples (Reps x Speeds x Noz) | 72                          | 90                                           |

agent was used to create a visually observable spray material, along with a target material that enhanced the staining contrast of the colored spray material and allowed physical measurement.

The coloring agent mixed with water as the spray material was a water color tempera. After investigating various colors, a blue tempera was chosen as the coloring agent. Using the tempera was advantageous in that it was easy to mix with water and convenient to clean up.

The material used as the target surface for the tests was 36-inch wide white crate paper. The paper allowed water to soak in where contacted, and the white color enhanced the tempera mix spray pattern making the stain conspicuous. Use of these materials also gave some indication of the amount of drift to be expected, since strap droplets showed up on the target paper outside the designated target area.

Materials used for fabricating the simulated rough field surface were 3 x 8 x 3/4 inch thick pine wood strips bolted to the test floor via special embedded anchors. Edges of the wooden strips were cut on a 45 degree angle, and the strips were placed 12 inches apart center to center. The 8-inch dimension was oriented transverse to the direction of machine travel. Each wheel of the applicator unit operated over a row of these strips. For replications one through three the strips were offset between the two rows and were aligned for replications four and five.

### III. Treatment Application

Each replication included three treatments, consisting of three different speeds. The purpose for the variation in speeds was to simulate speed variation which is possible in field operations. Although the range of test speeds exaggerated speed variations typical of actual field operation, an indication of the variation in spray pattern with changing speed was achieved.

The three test speeds were obtained by using three gear ranges on the Massey Ferguson 265 tractor used as the power source. The gear ranges used were second-low, third-low, and first-high. Engine speed per minute (rpm) was held constant at 1000 rpm. These combinations resulted in ground speeds of approximately 1.9, 3.1, and 4.2 miles per hour (mph).

Each treatment employed a 30.0 foot length of the white crate paper. The center 20.0 feet of the test paper was evaluated during data collection, with the remaining ends ignored with respect to the analysis.

### IV. The Split Block

Another source of variation in addition to the speed effects was possible with the chemical applicator. With three nozzles forming the band patterns, the potential for significant variation among the nozzles necessarily was investigated.

Each nozzle was designated as a single split block making a total of three splits within a replication. This approach yielded a

good indication of where variation was greatest, allowing separation of nozzles from the differing speeds.

#### V. Data Collection

Three samples were taken from each nozzle within each treatment (speed). A sample consisted of examining a single intermittent spray pattern track. There were approximately seven patterns within each nozzle treatment area (20 feet of travel), and the three samples were randomly chosen from these seven patterns.

The sprayed areas were rectangular in shape. Therefore, the length and width were measured, and the area was determined for each sample. This area was the numerical value used in the analysis of the chemical applicator.

Drift droplet stains were counted in 0.5-inch wide by 1.0-inch in length sample blocks placed 0.5-inch apart. There were three drift sample blocks with the first block located 0.5-inch from the center right side edge of each randomly chosen sprayed area used in the analysis of the chemical applicator.

## CHAPTER V

### RESULTS AND DISCUSSION

#### I. Initial Smooth Surface Test

Using area as the dependent variable for the analysis, variations among nozzles and among speeds were estimated with the split-block design. The first smooth surface test revealed significant differences of area among both speeds and nozzles. It was clear that some machine modification was essential for uniform spray material application among nozzles. Also, due to indicated variation with respect to a given speed, an additional replication was used in subsequent tests (Sanders, 1982).

Another problem indicated by this initial test was the occurrence of spray material drip in areas within the test matt which were to receive no spray material. Spray material escaped from the reservoir exit ports, flowed down the sloped rear portion, and dripped from the bottom of the reservoir. This problem was alleviated by the incorporating a catch tray under the reservoir which directed the excess to the exterior of the matt. Spray area data is tabulated in Tables II-VI. Separation of nozzle and speed treatment sprayed area means are tabulated in Table VI.

Table II. Effect of Speed Treatment and Nozzle Location on the Spray Pattern Area for Replication One, Initial Smooth Surface Test.

| Treatment | Nozzle | Sprayed Area (in <sup>2</sup> ) |       |       |
|-----------|--------|---------------------------------|-------|-------|
|           |        | Sample                          |       |       |
|           |        | 1                               | 2     | 3     |
| 1         | 1      | 85.0                            | 83.0  | 81.0  |
| 1         | 2      | 97.0                            | 100.0 | 104.0 |
| 1         | 3      | 110.0                           | 116.0 | 109.0 |
| 2         | 1      | 94.0                            | 91.0  | 94.0  |
| 2         | 2      | 112.0                           | 114.0 | 105.0 |
| 2         | 3      | 110.0                           | 117.0 | 111.0 |
| 3         | 1      | 99.0                            | 100.0 | 103.0 |
| 3         | 2      | 120.0                           | 117.0 | 112.0 |
| 3         | 3      | 124.0                           | 122.0 | 125.0 |

Table III. Effect of Speed Treatment and Nozzle Location on the Spray Pattern Area for Replication Two, Initial Smooth Surface Test.

| Treatment | Nozzle | Sprayed Area (in <sup>2</sup> ) |       |       |
|-----------|--------|---------------------------------|-------|-------|
|           |        | Sample                          |       |       |
|           |        | 1                               | 2     | 3     |
| 1         | 1      | 109.0                           | 85.0  | 93.0  |
| 1         | 2      | 118.0                           | 111.0 | 115.0 |
| 1         | 3      | 115.0                           | 113.0 | 110.0 |
| 2         | 1      | 93.0                            | 91.0  | 94.0  |
| 2         | 2      | 112.0                           | 114.0 | 100.0 |
| 2         | 3      | 110.0                           | 111.0 | 112.0 |
| 3         | 1      | 96.0                            | 99.0  | 97.0  |
| 3         | 2      | 114.0                           | 106.0 | 112.0 |
| 3         | 3      | 116.0                           | 127.0 | 122.0 |

Table IV. Effect of Speed Treatment and Nozzle Location on the Spray Pattern Area for Replication Three, Initial Smooth Surface Test.

| Treatment | Nozzle | Sprayed Area (in <sup>2</sup> )<br>Sample |       |       |
|-----------|--------|-------------------------------------------|-------|-------|
|           |        | 1                                         | 2     | 3     |
| 1         | 1      | 81.0                                      | 82.0  | 81.0  |
| 1         | 2      | 99.0                                      | 96.0  | 102.0 |
| 1         | 3      | 114.0                                     | 106.0 | 105.0 |
| 2         | 1      | 90.0                                      | 95.0  | 96.0  |
| 2         | 2      | 100.0                                     | 105.0 | 110.0 |
| 2         | 3      | 125.0                                     | 113.0 | 116.0 |
| 3         | 1      | 96.0                                      | 101.0 | 98.0  |
| 3         | 2      | 117.0                                     | 119.0 | 114.0 |
| 3         | 3      | 116.0                                     | 120.0 | 135.0 |

Table V. Effect of Speed Treatment and Nozzle Location on the Spray Pattern Area for Replication Four, Initial Smooth Surface Test.

| Treatment | Nozzle | Sprayed Area (in <sup>2</sup> ) |       |       |
|-----------|--------|---------------------------------|-------|-------|
|           |        | Sample                          |       |       |
|           |        | 1                               | 2     | 3     |
| 1         | 1      | 93.0                            | 98.0  | 96.0  |
| 1         | 2      | 116.0                           | 115.0 | 115.0 |
| 1         | 3      | 119.0                           | 121.0 | 118.0 |
| 2         | 1      | 84.0                            | 82.0  | 79.0  |
| 2         | 2      | 104.0                           | 102.0 | 99.0  |
| 2         | 3      | 106.0                           | 106.0 | 107.0 |
| 3         | 1      | 98.0                            | 94.0  | 95.0  |
| 3         | 2      | 115.0                           | 100.0 | 116.0 |
| 3         | 3      | 133.0                           | 132.0 | 133.0 |

Table VI. Mean Separation of Nozzle and Speed Treatment Sprayed Area Means of the Initial Smooth Surface Tests.

| Nozzle | Sprayed Area (in <sup>2</sup> ) |    | Speed (mph) | Sprayed Area (in <sup>2</sup> ) |    |
|--------|---------------------------------|----|-------------|---------------------------------|----|
|        | Mean Value                      |    |             | Mean Value                      |    |
| 3      | 116.8                           | A* | 3 (4.2)     | 112.3                           | A* |
| 2      | 111.8                           | B  | 2 (3.1)     | 102.9                           | B  |
| 1      | 92.3                            | C  | 1 (1.9)     | 100.3                           | B  |

\* Mean values in the same column followed by the same letter are not significantly different ( $P = 0.05$ ) as indicated by Duncan's Multiple Range Test.

## II. Second Smooth Surface Test

Upon completion of modifications to the applicator unit, the second test series was performed. Utilizing the same experimental design, no variation among nozzles was indicated. No significant difference ( $P = 0.05$ ) among speeds within the specified degrees of freedom was indicated, suggesting that a predictable target area was attainable using the chemical applicator. Spray area data are tabulated in Tables VII-XI.

Although speed variation was insignificant, treatment means suggest with increasing speed the spray pattern area also increases (Table XII). This is rationalized by the fact that the intermittent mechanism requires a finite amount of time to function and that time requirement remains constant as ground speed increases.

Drift and splatter of spray liquid into non-contact areas were of concern as droplet stains were counted in non-contact areas in specified locations (Table XIII). Contamination decreased as speed increased with no measurable drift occurring at the highest speed. This indicates that higher operating speeds are preferable with respect to drift and splatter control.

## III. Rough Surface Test

Variation in size of spray pattern area among nozzles during the rough surface test was insignificant ( $P = 0.05$ ). Therefore, the rugged course run had no effect on nozzles with respect to spray pattern area. However, size of the sprayed area varied significantly

Table VII. Effect of Speed Treatment and Nozzle Location on the Spray Pattern Area for Replication One, Second Smooth Surface Test.

| Treatment | Nozzle | Sprayed Area (in <sup>2</sup> ) |       |       |
|-----------|--------|---------------------------------|-------|-------|
|           |        | Sample                          |       |       |
|           |        | 1                               | 2     | 3     |
| 1         | 1      | 130.0                           | 134.0 | 134.0 |
| 1         | 2      | 135.0                           | 124.0 | 131.0 |
| 1         | 3      | 128.0                           | 131.0 | 129.0 |
| 2         | 1      | 134.0                           | 135.0 | 142.0 |
| 2         | 2      | 136.0                           | 136.0 | 142.0 |
| 2         | 3      | 142.0                           | 140.0 | 133.0 |
| 3         | 1      | 140.0                           | 145.0 | 141.0 |
| 3         | 2      | 134.0                           | 127.0 | 156.0 |
| 3         | 3      | 146.0                           | 144.0 | 128.0 |

Table VIII. Effect of Speed Treatment and Nozzle Location on the Spray Pattern Area for Replication Two, Second Smooth Surface Test.

| Treatment | Nozzle | Sprayed Area (in <sup>2</sup> ) |          |          |
|-----------|--------|---------------------------------|----------|----------|
|           |        | Sample 1                        | Sample 2 | Sample 3 |
| 1         | 1      | 133.0                           | 148.0    | 132.0    |
| 1         | 2      | 136.0                           | 138.0    | 119.0    |
| 1         | 3      | 144.0                           | 130.0    | 128.0    |
| 2         | 1      | 123.0                           | 131.0    | 128.0    |
| 2         | 2      | 136.0                           | 137.0    | 135.0    |
| 2         | 3      | 131.0                           | 122.0    | 137.0    |
| 3         | 1      | 131.0                           | 137.0    | 139.0    |
| 3         | 2      | 149.0                           | 127.0    | 135.0    |
| 3         | 3      | 131.0                           | 127.0    | 135.0    |

Table IX. Effect of Speed Treatment and Nozzle Location on the Spray Pattern Area for Replication Three, Second Smooth Surface Test.

| Treatment | Nozzle | Sprayed Area (in <sup>2</sup> ) |       |       |
|-----------|--------|---------------------------------|-------|-------|
|           |        | Sample                          |       |       |
|           |        | 1                               | 2     | 3     |
| 1         | 1      | 119.0                           | 121.0 | 128.0 |
| 1         | 2      | 127.0                           | 130.0 | 130.0 |
| 1         | 3      | 127.0                           | 124.0 | 131.0 |
| 2         | 1      | 138.0                           | 133.0 | 134.0 |
| 2         | 2      | 137.0                           | 131.0 | 142.0 |
| 2         | 3      | 136.0                           | 133.0 | 133.0 |
| 3         | 1      | 133.0                           | 132.0 | 134.0 |
| 3         | 2      | 130.0                           | 132.0 | 138.0 |
| 3         | 3      | 129.0                           | 132.0 | 128.0 |

Table X. Effect of Speed Treatment and Nozzle Location on the Spray Pattern Area for Replication Four, Second Smooth Surface Test.

| Treatment | Nozzle | Sprayed Area (in <sup>2</sup> )<br>Sample |       |       |
|-----------|--------|-------------------------------------------|-------|-------|
|           |        | 1                                         | 2     | 3     |
| 1         | 1      | 136.0                                     | 136.0 | 132.0 |
| 1         | 2      | 131.0                                     | 136.0 | 137.0 |
| 1         | 3      | 137.0                                     | 134.0 | 131.0 |
| 2         | 1      | 129.0                                     | 133.0 | 130.0 |
| 2         | 2      | 128.0                                     | 128.0 | 134.0 |
| 2         | 3      | 122.0                                     | 124.0 | 128.0 |
| 3         | 1      | 140.0                                     | 143.0 | 144.0 |
| 3         | 2      | 134.0                                     | 143.0 | 148.0 |
| 3         | 3      | 136.0                                     | 134.0 | 133.0 |

Table XI. Effect of Speed Treatment and Nozzle Location on the Spray Pattern Area for Replication Five, Second Smooth Surface Test.

| Treatment | Nozzle | Sprayed Area (in <sup>2</sup> )<br>Sample |       |       |
|-----------|--------|-------------------------------------------|-------|-------|
|           |        | 1                                         | 2     | 3     |
| 1         | 1      | 133.0                                     | 130.0 | 130.0 |
| 1         | 2      | 126.0                                     | 135.0 | 134.0 |
| 1         | 3      | 125.0                                     | 128.0 | 125.0 |
| 2         | 1      | 132.0                                     | 125.0 | 126.0 |
| 2         | 2      | 134.0                                     | 131.0 | 125.0 |
| 2         | 3      | 146.0                                     | 129.0 | 126.0 |
| 3         | 1      | 131.0                                     | 131.0 | 131.0 |
| 3         | 2      | 146.0                                     | 120.0 | 129.0 |
| 3         | 3      | 132.0                                     | 130.0 | 128.0 |

Table XII. Mean Separation of Speed Treatment Sprayed Area Means of the Second Smooth Surface Test.

| Speed | (mph) | Number of Observations | Sprayed Area<br>Mean Value (in <sup>2</sup> ) |    |
|-------|-------|------------------------|-----------------------------------------------|----|
| 3     | (4.2) | 45                     | 135.4                                         | A* |
| 2     | (3.1) | 45                     | 132.5                                         | B  |
| 1     | (1.9) | 45                     | 131.0                                         | B  |

\* Mean values in the same column followed by the same letter are not significantly different ( $P = 0.05$ ) as indicated by Duncan's Multiple Range Test.

Table XIII. Average Number of Droplets at Specified Locations Within Speed Treatments Along with Mean Separation of Speed Treatment Droplet Means Using Data from the Second Smooth Surface Tests.

| Speed | (mph) | Position (Droplets) |     |     | Droplet Mean |    |
|-------|-------|---------------------|-----|-----|--------------|----|
|       |       | 1                   | 2   | 3   |              |    |
| 1     | (1.9) | 9.2                 | 5.5 | 2.2 | 5.6          | A* |
| 2     | (3.1) | 3.6                 | 2.0 | 1.1 | 2.2          | B  |
| 3     | (4.2) | 0                   | 0   | 0   | 0            | C  |

\* Mean values in the same column followed by the same letter are not significantly different ( $P = 0.05$ ) as indicated by Duncan's Multiple Range Test.

( $P = 0.05$ ) with speed. Spray area data are tabulated in Tables XIV-XVIII. Mean separation using Duncan's Multiple Range Analysis indicated that the sprayed area mean for speed 3 was significantly greater ( $P = 0.05$ ) than the sprayed area mean for speed 1. Both were significantly greater ( $P = 0.05$ ) than the sprayed area mean for speed 2 (Table XIX).

Table XIV. Effect of Speed Treatment and Nozzle Location on the Spray Pattern Area for Replication One, Rough Surface Test.

| Treatment | Nozzle | Sprayed Area (in <sup>2</sup> ) |       |       |
|-----------|--------|---------------------------------|-------|-------|
|           |        | Sample                          |       |       |
|           |        | 1                               | 2     | 3     |
| 1         | 1      | 141.0                           | 143.0 | 137.0 |
| 1         | 2      | 137.0                           | 138.0 | 141.0 |
| 1         | 3      | 135.0                           | 138.0 | 134.0 |
| 2         | 1      | 133.0                           | 134.0 | 133.0 |
| 2         | 2      | 139.0                           | 134.0 | 128.0 |
| 2         | 3      | 132.0                           | 131.0 | 125.0 |
| 3         | 1      | 134.0                           | 135.0 | 138.0 |
| 3         | 2      | 145.0                           | 138.0 | 140.0 |
| 3         | 3      | 143.0                           | 131.0 | 137.0 |

Table XV. Effect of Speed Treatment and Nozzle Location on the Spray Pattern Area for Replication Two, Rough Surface Test.

| Treatment | Nozzle | Sprayed Area (in <sup>2</sup> ) |       |       |
|-----------|--------|---------------------------------|-------|-------|
|           |        | Sample                          |       |       |
|           |        | 1                               | 2     | 3     |
| 1         | 1      | 137.0                           | 132.0 | 139.0 |
| 1         | 2      | 134.0                           | 136.0 | 135.0 |
| 1         | 3      | 135.0                           | 138.0 | 135.0 |
| 2         | 1      | 133.0                           | 134.0 | 137.0 |
| 2         | 2      | 128.0                           | 136.0 | 144.0 |
| 2         | 3      | 130.0                           | 131.0 | 137.0 |
| 3         | 1      | 139.0                           | 130.0 | 136.0 |
| 3         | 2      | 132.0                           | 139.0 | 133.0 |
| 3         | 3      | 137.0                           | 133.0 | 137.0 |

Table XVI. Effect of Speed Treatment and Nozzle Location on the Spray Pattern Area for Replication Three, Rough Surface Test.

| Treatment | Nozzle | Sprayed Area (in <sup>2</sup> )<br>Sample |       |       |
|-----------|--------|-------------------------------------------|-------|-------|
|           |        | 1                                         | 2     | 3     |
| 1         | 1      | 139.0                                     | 139.0 | 137.0 |
| 1         | 2      | 139.0                                     | 141.0 | 134.0 |
| 1         | 3      | 134.0                                     | 134.0 | 134.0 |
| 2         | 1      | 132.0                                     | 138.0 | 132.0 |
| 2         | 2      | 138.0                                     | 128.0 | 128.0 |
| 2         | 3      | 138.0                                     | 131.0 | 132.0 |
| 3         | 1      | 132.0                                     | 138.0 | 142.0 |
| 3         | 2      | 138.0                                     | 137.0 | 136.0 |
| 3         | 3      | 137.0                                     | 135.0 | 137.0 |

Table XVII. Effect of Speed Treatment and Nozzle Location on the Spray Pattern Area for Replication Four, Rough Surface Test.

| Treatment | Nozzle | Sprayed Area (in <sup>2</sup> )<br>Sample |       |       |
|-----------|--------|-------------------------------------------|-------|-------|
|           |        | 1                                         | 2     | 3     |
| 1         | 1      | 141.0                                     | 137.0 | 140.0 |
| 1         | 2      | 137.0                                     | 135.0 | 138.0 |
| 1         | 3      | 142.0                                     | 140.0 | 138.0 |
| 2         | 1      | 135.0                                     | 139.0 | 134.0 |
| 2         | 2      | 139.0                                     | 138.0 | 139.0 |
| 2         | 3      | 137.0                                     | 137.0 | 137.0 |
| 3         | 1      | 138.0                                     | 141.0 | 131.0 |
| 3         | 2      | 139.0                                     | 148.0 | 144.0 |
| 3         | 3      | 142.0                                     | 150.0 | 154.0 |

Table XVIII. Effect of Speed Treatment and Nozzle Location on the Spray Pattern Area for Replication Five, Rough Surface Test.

| Treatment | Nozzle | Sprayed Area (in <sup>2</sup> ) |       |       |
|-----------|--------|---------------------------------|-------|-------|
|           |        | Sample                          |       |       |
|           |        | 1                               | 2     | 3     |
| 1         | 1      | 138.0                           | 139.0 | 141.0 |
| 1         | 2      | 131.0                           | 131.0 | 133.0 |
| 1         | 3      | 132.0                           | 133.0 | 134.0 |
| 2         | 1      | 143.0                           | 130.0 | 143.0 |
| 2         | 2      | 131.0                           | 131.0 | 128.0 |
| 2         | 3      | 142.0                           | 130.0 | 137.0 |
| 3         | 1      | 148.0                           | 146.0 | 139.0 |
| 3         | 2      | 134.0                           | 141.0 | 130.0 |
| 3         | 3      | 144.0                           | 145.0 | 137.0 |

Table XIX. Mean Separation of Speed Treatment Sprayed Area Means of the Rough Surface Tests.

| Speed | (mph) | Number of Observations | Sprayed Area                  |    |
|-------|-------|------------------------|-------------------------------|----|
|       |       |                        | Mean Value (in <sup>2</sup> ) |    |
| 3     | (4.2) | 45                     | 139.0                         | A* |
| 1     | (1.9) | 45                     | 137.0                         | B  |
| 2     | (3.1) | 45                     | 134.0                         | C  |

\*Mean values in the same column followed by the same letter are not significantly different ( $P = 0.05$ ) as indicated by Duncan's Multiple Range Test.

## CHAPTER VI

### SUMMARY AND CONCLUSIONS

#### I. Summary

A chemical applicator was designed and constructed for intermittent application of paraquat for renovating strawberries growing in a matted row. The objectives of the study were: (1) design and construct the applicator and, (2) evaluate the grid pattern for precision of sprayed areas.

The experimental analysis of the data for the study was a split-block design. Three operating speeds were used as treatments and the three nozzles on the boom were used as the split blocks. Three separate tests were performed. The first test consisted of four replications and the operating surface was smooth. The second test, also on a smooth operating surface, consisted of five replications. A fabricated rough surface was used for the third test, which included five replications.

The data used for the analysis of the applicator were the magnitudes of the sprayed areas of the intermittent pattern tracks. Three samples were randomly chosen within the path created by each nozzle within each treatment (speed). Drift was also considered by counting droplets in specified areas outside of the sample sprayed tracks.

## II. Conclusions

The conclusions of the study were:

1. A predictable spray pattern track is possible using the chemical applicator.
2. With increased speed of the applicator the spray pattern track size tended to increase, although not significantly ( $P = 0.05$ ).
3. Some drift was indicated at lower speeds, but there was no indication of drift at higher speeds.
4. Because of minimal leakage from the top cover of the applicator during the rough operating surface test, a sealed cover is needed for the recirculating reservoir.

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## LITERATURE CITED

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## VITA

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