Application and Precision Ag Technology

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with assistance and materials from:
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Bob Wolf, Retired Application Specialist, Dept. of Biological & Agricultural Engineering

Sprayer Components:

• Tanks – poly, stainless
• Pump, Strainers, Agitation
• Pressure gauge
• Hoses, Flow control assemblies
• Electronics: monitors-computers- controllers (GPS/GIS)
• Distribution system
• Nozzles – Not expensive but KEY!
## GPS Accuracy

<table>
<thead>
<tr>
<th>Receiver System</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autonomous</td>
<td>1 – 3 m</td>
</tr>
<tr>
<td>Differentially corrected</td>
<td>less than 1 m (sub meter)</td>
</tr>
<tr>
<td>Dual Frequency</td>
<td>~ 10 cm</td>
</tr>
<tr>
<td>RTK</td>
<td>~ 1 cm</td>
</tr>
</tbody>
</table>

**Differential Correction Sources**

- **Coast Guard Beacon**
  - Sub-meter
- **Single Frequency Satellite**
  - Wide Area Augmentation System (WAAS)
    - OmniStar VBS and StarFire1
      - Sub-meter
- **Dual Frequency Satellite Subscription**
  - OmniStar XP, HP, and StarFire2
    - Decimeter (2 - 6")
- **Real Time Kinematics (RTK)**
  - Centimeter (sub-inch)
What’s important, accuracy or precision?

GPS Accuracy... *by the numbers*

- Pass-to-pass accuracy is typically measured at a percentage and within a timeframe:
  - 4-6” within 15 minutes, 95% of the time

- Receiver accuracy – horizontal, vertical, and spherical, is measured as a distance, percentage, and over a given timeframe.

- Statistical Axioms: 1 standard deviation contains ~ 68% of the data, 2 standard deviations contain ~ 95% of the data, 3 standard deviations contain ~ 97% of the data.
GPS Accuracy... by the numbers

Make Sure Your Comparing Apples to Apples!
4" at 68% is NOT the same as 4" at 95%

- Receiver  68%  95%
- SF2      4.33  6.29
- 252 OmniStar 2.76  5.51

KANSAS STATE STARFIRE TEST
HORIZONTAL RADIAL ERROR: 68% = 0.19M, 95% = 0.36M, 99% = 0.61M

- MEAN = 0.019M  STDEV = 0.093M
- MEAN = 0.044M  STDEV = 0.159M
- MEAN = -0.016M  STDEV = 0.017M
GPS Accuracy... by the numbers

**KANSAS STATE HP TEST**

**HORIZONTAL RADIAL ERROR**

- 68% - 0.07M
- 95% - 0.14M
- 99% - 0.17M

**GPS Accuracy Tech Info**

- When buying GPS units, the accuracy is often given in several different ways. Typically it is a value.
- 1dRMS (or RMS) - Approximately 68 percent of the data points occur within this distance of truth.
- 2dRMS - Approximately 95 percent of the data points occur with this distance of truth.
- 3dRMS - Approximately 99.7 percent of the data points occur with this distance of truth.
Flow Control Systems

Controller with Automatic Section Control

- Boundary map
- GNSS Receiver (Location & speed)
- Controller + Software
- Closed-Loop Control
- ON-OFF Control Signal to Boom-Valves or Nozzle Solenoids
- Boom shut-off valves (Auto-Boom Control)
- Nozzles
- Tank
- Pump
- Regulating Valve
- Flow Meter
# Speed and Pressure Spraying

<table>
<thead>
<tr>
<th>Type of Spraying</th>
<th>Type of Sprayer</th>
<th>Tip Selection</th>
<th>What is Held</th>
<th>Speed Range</th>
<th>What Varies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed and Pressure</td>
<td>Tractor Mount or Pull-Type</td>
<td>One Tip per Speed</td>
<td>Pressure</td>
<td>Single Speed</td>
<td>Constant</td>
</tr>
<tr>
<td></td>
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</tr>
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<td></td>
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<td>Droplet Size</td>
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# Rate Controller Spraying

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<td>Constant</td>
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<td></td>
<td></td>
<td></td>
<td>Pressure</td>
<td>Constant</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Droplet Size</td>
<td>Constant</td>
</tr>
<tr>
<td>Rate Controller</td>
<td>Self-Propelled</td>
<td>One Tip per Rate</td>
<td>Rate</td>
<td>2:1 Range</td>
<td>(Chg of Speed)^2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(Chg of Pressure)^2</td>
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PWM Spraying
Rate Controller with Blended Pulse

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<th>What is Held Constant</th>
<th>Speed Range</th>
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<td>One Tip per Speed</td>
<td>Pressure</td>
<td>Single Speed</td>
<td>Rate</td>
</tr>
<tr>
<td>Rate Controller</td>
<td>Pull-Type Self-Propelled</td>
<td>One Tip per Rate</td>
<td>Rate</td>
<td>2:1 Range</td>
<td>Constant</td>
</tr>
<tr>
<td>AIM Command</td>
<td>Self-Propelled</td>
<td>One Tip per Chemical Mode of Action</td>
<td>Rate and Pressure</td>
<td>8:1 Range</td>
<td>Constant</td>
</tr>
</tbody>
</table>

How it Works

- Uses high speed solenoid valves to regulate flow
- Varies application rate with duty cycle: independently of pressure
Pulse compared to conventional:

What is Pulse Width?

- Type of control system
- Modulates a DC square wave signal

![Diagram showing Pulse Width modulation with valve open and closed at different duty cycles.]
Synchro® Blended Pulse

Each Synchro® nozzle emits 10 pulses per second, with adjacent nozzles having alternating timing. The alternating pulses, combined with overlapping spray patterns and the natural dispersion of droplets traveling in air, blend together to provide consistent coverage.

Figure 2. Nozzle on-state time variation during 40% (left) and 80% (right) duty cycle with a 10 Hz (100 ms cycle) PWM system.
Spray pattern quality not sacrificed:

11008 Flat Fan Tip, 5gpa, 15mph, 50psi

Good Pulse Blending

Figure 1.
Conventional Application: Pressure varies with changing speeds
Procedures:

- **Treatment 1**
  - Conventional, 20 psi, 5 mph, tt11002, 8 GPA
- **Treatment 2**
  - Conventional, 75 psi, 10 mph, tt11002, 8 GPA
- **Treatment 3**
  - PWM, 40 psi, 5 mph, tt11004, 8 GPA
- **Treatment 4**
  - PWM, 40 psi, 10 mph, tt11004, 8 GPA

Drift

Horizontal Drift Deposition

<table>
<thead>
<tr>
<th>Card Position - Horizontal</th>
<th>% Coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Treatment 1
- Treatment 2
- Treatment 3
- Treatment 4
Benefits

• Operator dependent
• Application error
  – Skips (Red)
  – Overlap (Blue)
• Consistent
• Product savings
  – Reduced overlap
  – No skips

Turn Compensation

More accurate application when spraying contours or center pivots:
  Reduces weed resistance from non-lethal doses
  Prevents crop damage from chemical overdoes

Figure 6. The turn compensation feature for a PVM sprayer system modulates individual nozzles in order to maintain the target rate across the boom regardless of velocity between the inside and outside boom during curvilinear travel such as turning at field headlands or maneuvering around other obstacles. Off-rate application occurs without turn compensation technology (A), whereas uniform rate across the boom is maintained with the technology (B).
Individual Nozzle Swath Overlap Control

Minimize skips, over-spray, over-laps
Prevents over-application crop damage
Up to 15% Chemical Savings
Adjustable from 0% to 100% overlap.
Modifies the flow meter signal to satisfy the rate controller.

Follow Manufacturers’ Recommendations

• Low Duty Cycles Can Cause Differences in Effective Application Rate

• Typically wish to maintain duty cycles in the 50-100% range

Figure 9: Simulated application coverage of three complete pulses at a spray pace of 80%, 90 psi target pressure and 16 GPA target application rate (Manjus et al., 2013).
Market Players

- SharpShooter (Capstan/Case IH “Aim”)
- Pinpoint II (Capstan Ag/Case IH Aim Command PRO)
- ExactApply (Deere in MY18)
- Hawkeye (Raven/Case IH AIM Command FLEX)
- DynaJet (TeeJet)

K-State Extension Publication MF3314

Pulse Width Modulated (PWM) Technology for Liquid Application

Introduction

Liquid application systems are used for a variety of pesticide and liquid fertilizer applications. Self-propelled sprayers commonly use flow-based liquid control systems to implement application rates. Systems are also fitted with autonomous guidance and automation systems (ASC) ( phần tử) for individual fields and overall control.

Flow-based control systems regulate product flow rate in the pumping system to account for changes in ground speed (acceleration and deceleration) and spray nozzle width (ASC actuation) during field operation. These systems can direct-act to instantly adjust the nozzle flow rate to maintain the desired application rate. The sensors monitor the spray system, and the controller adjusts the flow rate accordingly to maintain the desired application rate. The controller is designed to achieve uniform coverage across the field.

Technology Basics

A Pulse Width Modulation (PWM) system uses minute modulated duty cycle to control the flow rate at each individual nozzle. The PWM signal is a ratio of the PWM signal to the peak output of the PWM signal. The PWM signal is then used to modulate the flow rate, ensuring that the output is consistent and uniform across the field.

Both droplet size distribution and spray fan angle consistency are critical to achieve desired overlap from adjacent nozzles and maintain uniform coverage.

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Electronics/Rate Controllers

• How does your system work when speed changes?
• Is it pressure based?
• What is the effect of going slower?
• What is the effect of going faster?

K-State Extension Publication MF3273

Understanding Controller Setup for Accurate Liquid Application

Introduction

Precision application technologies are increasingly being adopted by US producers and service providers to enhance seed, fertilizer, chemical and water use efficiency and increase field efficiency. Current precision technologies for agricultural sprayers include auto-guidance, rate controllers, automatic section control (ASC), and variable-rate controllers — all of which improve the application accuracy of crop protection products and nutrients. A critical component of sprayers is the application rate controller, which maintains the target application rate during changes of ground speed and swath width. Target application rate during speed and spray swath width changes are maintained by changing product flow rate (gallons per minute; typically using a flow control valve). These types of systems are referred to as flow-based systems because application rates are maintained by controlling the flow within the system. The controller of choice that controls the pump speed (Figure 1) or a hydraulic flow control valve is the boom (Figure 1) or a hydraulic flow control valve (Figure 2) to regulate the flow in the boom. The regulating valves used in the solution line are butterfly and ball valves, while hydraulic flow control valves are typically valve.
Flow oscillation and instability

Flow Rate (L min\(^{-1}\))

- Target Flow Rate
- Actual Flow - VCN 313
- Actual Flow - VCN 323
- Ground Speed

Speed (km h\(^{-1}\))

Boom-sections 1 through 3 turn Off
Boom-sections 1 through 3 turn On

Ground Speed

Target Flow Rate

Actual Flow - VCN 313

Actual Flow - VCN 323

Boom-sections 1 through 3 turn On

Boom-sections 1 through 3 turn Off
What does it mean on volume basis?

**SS3**

- Over-application
- Under-application

**SS5**

- Over-application
- Under-application

---

**Automatic Boom Height**

- Maintain uniform boom height
- Increase application uniformity and thereby effectiveness
- Reduces wear on sprayer boom
- Avoid contact between the boom or nozzles with the ground
- Increase field efficiency as the operator is not responsible for constant adjustment
- Potential to reduce drift and provide uniform droplet deposition
Automatic Boom Height

Options

- Sonar Based
- Physical Based (ground engaging wheel)
- Roll Sensors

Figure 2. Gauge wheels measure pressure between the wheel and the ground to determine boom height.

K-State Extension Publication MF3299

Automatic Boom Height Control Technology for Agricultural Sprayers

Ajay Sharda
Terry Griffin
Lucas Haug
John W. Slocombe

Introduction

Advancements in liquid application equipment make operation of large self-propelled machines easier. Current agricultural sprayers have boom widths of up to 120 feet. Because of a combination of increased machinery size, technology, and growing environmental concerns, more is being demanded from chemical applications.

One critical technology to meeting these demands is automatic boom height control (ABHC). This technology automatically maintains the boom at a target height from the top of the crop canopy, and is especially useful when operating in fields with varying terrace attributes or uneven crop canopy heights. In the case when the sprayer is traveling along uneven terrain, ABHC technology aligns left and right wings of the boom with respect to the terrain. During a typical field application, boom height of greater than the targeted plant top increases the potential for drift, loss of droplets to volatilization, and non-uniform spray coverage, whereas a boom down than intended to the actual...
Nozzles are important because:

- Control the **amount** – GPA.
- Determine **uniformity** of application.
- Affects the **coverage**.
- Influences the **drift** potential.

**Nozzle Controls**

**amount applied:**

**Nozzle Flow Rate** is affected by:

- Orifice size
- Pressure
- Solution characteristics

---

<table>
<thead>
<tr>
<th>Weight of Solution</th>
<th>Specific Gravity</th>
<th>Conversion Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.0 lbs/gal.</td>
<td>1.64</td>
<td>92</td>
</tr>
<tr>
<td>9.0 lbs/gal.</td>
<td>1.56</td>
<td>398</td>
</tr>
<tr>
<td>8.34 lbs/gal.</td>
<td>1.60</td>
<td>1.00</td>
</tr>
<tr>
<td>9.0 lbs/gal.</td>
<td>1.56</td>
<td>1.04</td>
</tr>
<tr>
<td>10.0 lbs/gal.</td>
<td>1.52</td>
<td>1.10</td>
</tr>
<tr>
<td>10.05 lbs/gal.</td>
<td>1.50</td>
<td>1.10</td>
</tr>
<tr>
<td>11.0 lbs/gal.</td>
<td>1.58</td>
<td>1.20</td>
</tr>
<tr>
<td>12.0 lbs/gal.</td>
<td>1.54</td>
<td>1.20</td>
</tr>
<tr>
<td>14.0 lbs/gal.</td>
<td>1.68</td>
<td>1.30</td>
</tr>
</tbody>
</table>
Calibration!!!!

Ensuring that the spray output is what it is supposed to be!

GPM Example Solution:

\[
GPM = \frac{GPA \times MPH \times W}{5940}
\]

\[
GPM = \frac{7.5 \times 12 \times 20}{5940}
\]

Answer: \(0.30\text{gpm}\)
Selecting the proper nozzle....

- Calculate GPM (formula)
- Look under GPM column
- Match to pressure-psi
- Choose the size needed
- Operate at given pressure and speed used in formula to achieve GPA

<table>
<thead>
<tr>
<th>Type No.</th>
<th>[1500kgs Force]</th>
<th>Linear Pressure</th>
<th>GPM</th>
<th>GPM Range</th>
<th>Pressure-psi</th>
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<tbody>
<tr>
<td>AOX110015</td>
<td>4 5/8&quot; (250kgs)</td>
<td>Yellow</td>
<td>29</td>
<td>0.11</td>
<td>24 to 35 psi</td>
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<tr>
<td>AOX110025</td>
<td>3 5/8&quot; (250kgs)</td>
<td>Yellow</td>
<td>30</td>
<td>0.15</td>
<td>17 to 25 psi</td>
</tr>
<tr>
<td>AOX110035</td>
<td>2 5/8&quot; (250kgs)</td>
<td>Yellow</td>
<td>31</td>
<td>0.19</td>
<td>13 to 20 psi</td>
</tr>
<tr>
<td>AOX110045</td>
<td>1 5/8&quot; (250kgs)</td>
<td>Yellow</td>
<td>32</td>
<td>0.23</td>
<td>9 to 15 psi</td>
</tr>
<tr>
<td>AOX110055</td>
<td>1 1/8&quot; (250kgs)</td>
<td>Yellow</td>
<td>33</td>
<td>0.26</td>
<td>6 to 10 psi</td>
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K-State Research and Extension

Selecting the proper nozzle....

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K-State Research and Extension
### ASABE Standard

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Category</th>
<th>Code</th>
<th>Relative Size</th>
<th>Comparative Size</th>
<th>Atomization</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>Fine</td>
<td>Orange</td>
<td></td>
<td>Human Hair (100 Microns)</td>
<td>Fine Mist</td>
</tr>
<tr>
<td>M</td>
<td>Medium</td>
<td>Yellow</td>
<td></td>
<td>Sewing Thread (150 Microns)</td>
<td>Fine Drizzle</td>
</tr>
<tr>
<td>C</td>
<td>Coarse</td>
<td>Blue</td>
<td></td>
<td>Staple (420 Microns)</td>
<td>Light Rain</td>
</tr>
<tr>
<td>VC</td>
<td>Very Coarse</td>
<td>Green</td>
<td></td>
<td>#2 Pencil Lead (2000 Microns)</td>
<td>Thunderstorm</td>
</tr>
<tr>
<td>EC</td>
<td>Extremely Coarse</td>
<td>White</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Fungicides / Insecticides**

**Herbicides**

*Source: Crop Life – July 2002*

### OLYMPUS™ FLEX Herbicide

For Post-emergence Control of Certain Grasses and Broadleaf Weeds in Fall-sown or Winter Wheat.

**ACTIVE INGREDIENTS:**
- Propoxycarbazone-sodium (CAS No. 181274-15-7) ................................................................. 6.75%
- Mesosulfuron-Methyl (CAS No. 208465-21-8) ........................................................................... 4.50%

**INERT INGREDIENTS** .................................................................................................................. 88.75%

Contains petroleum distillates.

Protected by U.S. Patent Nos. 5,648,315 and 5,688,745  
TOTAL: 100.00%

This product is a water dispersible granule containing 6.75% Propoxycarbazone-sodium and 4.50% Mesosulfuron-methyl, by weight.

EPA Reg. No. 264-833  
EPA Est.
Checking for accuracy

• Check several new nozzles
  – flow rate within 5-7% of desired output?

• Check flow rate frequently
  – adjust pressure to compensate for small changes output due to wear

• Replace nozzles & recalibrate when:
  – output > 7% change from new nozzle
  – when pattern becomes uneven
2. Set up for Uniformity:

Goal is to put the material on evenly from nozzle to nozzle, end of boom to end of boom, and across the entire field. A 20-inch spacing requires 17-19" above target for 50-60% overlap. **Nozzle mount angle?**

**NEW SPRAY TIPS**
Produce a uniform distribution when properly overlapped.

**WORN SPRAY TIPS**
Have a higher output with more spray concentrated under each tip.

**DAMAGED SPRAY TIPS**
Have a very erratic output – oversupplying and undersupplying.

---

**SpotOn Electronic Calibration Tool**

Sponsored by Successful Farming
Sponsored

Scott Bretthauer - U of I
Jim Wilson - SDSU
Randy Taylor - OSU
Bobby Grisso & Pat Hipkins - VTU
Mark Hanna – ISU
Bob Wolf – KSU

[Images of SpotOn tool and calibration process]
Accuracy of SpotOn Tester by Nozzle Type

### Average by Nozzle Type

<table>
<thead>
<tr>
<th>Nozzle Type</th>
<th>SpotOn gpm</th>
<th>Scale gpm</th>
<th>Visual gpm</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIXR</td>
<td>0.34</td>
<td>0.34</td>
<td>0.35</td>
</tr>
<tr>
<td>TT</td>
<td>0.34</td>
<td>0.34</td>
<td>0.35</td>
</tr>
<tr>
<td>TTJ60</td>
<td>0.34</td>
<td>0.35</td>
<td>0.36</td>
</tr>
<tr>
<td>ULD</td>
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<td>0.37</td>
<td>0.38</td>
</tr>
<tr>
<td>XR</td>
<td>0.34</td>
<td>0.34</td>
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</tbody>
</table>

*Nozzles tested included the TeeJet Air Induction XR (AIXR); the Turbo TeeJet VP nozzle (TT); TTJ60; the TeeJet Turbo Twist Jet (TTJ60); Mypro Ultra LoDrift (ULD); and the TeeJet XR (XR).*

Agricultural engineers tested readings in a comparison of the SpotOn calibrator, actual scale measurements, and a visual evaluation across five nozzle types. There was little difference between the three readings across all five nozzle types. The SpotOn calibrator provides an accurate and quick calibration reading, says Bob Wolf of Wolf Consulting & Research.

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Accuracy of SpotOn Tester by Nozzle Size and Pressure

### Calibration Comparison

<table>
<thead>
<tr>
<th>Orifice/pt</th>
<th>SpotOn gpm</th>
<th>Scale gpm</th>
<th>Visual gpm</th>
<th>Manu standard gpm</th>
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<tbody>
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<td>0.12</td>
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<td>0.21</td>
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<tr>
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<td>0.26</td>
<td>0.24</td>
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<tr>
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</table>

Testing by scientists at six universities compared SpotOn gpm readings with actual scale measurements taken of a given nozzle flow along with a visual evaluation and the manufacturer's standard gpm. It was tested under three nozzle orifice sizes: 1:1002, 1:1004, and 1:1006. The SpotOn readings compared favorably with all other measurements, says Bob Wolf of Wolf Consulting & Research.
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